PLANNING AHEAD

Reducing Flood Losses in the 21st Century

Association of State Floodplain Managers

Proceedings of the 23rd Annual Conference
May 24–28, 1999 • Portland, Oregon
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Proceedings of the Twenty-third Annual Conference of the Association of State Floodplain Managers

May 24–28, 1999
Portland, Oregon
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The 23rd annual conference of the Association of State Floodplain Managers, which was attended by a record 600 people, took place in the city of Portland, Oregon. It was a setting highly appropriate for this year's theme, "Planning Ahead: Flood Loss Reduction in the 21st Century," because the Pacific Northwest is a region long known for its sensitivity to resource issues and dedication to wise land use management—crucial components in our preparation for managing floods in the future.

Inspiring opening addresses by James Lee Witt, Director of the Federal Emergency Management Agency and by Mark Van Putten, President of the National Wildlife Federation emphasized that we can and must find sustainable ways of coping with floods and of preserving floodplain and other resources for ourselves and future generations. Other plenary and small-group sessions throughout the week further explored the idea of looking ahead—from ways to improve state, local, and federal programs and policies in the future to the many techniques for actually planning and implementing flood loss reduction activities. As in previous years, we also held training workshops, committee meetings, our annual membership meeting, field trips, issue-oriented roundtable breakfasts, an awards luncheon, and social events. During this year's meeting we also administered our first-ever examination for professional Certification in Floodplain Management.

This volume compiles the technical papers presented at the meeting. They represent current thinking about the wide range of floodplain management topics that were examined and discussed during the week. Our hats are off with special thanks to our conference team: Clancy Philipsborn, Program Chair; Jerry Louthain, Conference Director; Dan Accurti, Exhibits Chair; and also to Jim Kennedy of the Oregon Department of Land Conservation and Development; Diane Watson and Debbie Pond of the Executive Office staff; and the many volunteers who helped to make the meeting a success. We look forward to another great gathering next year in Austin, Texas.

Lisa Holland
Chair, Association of State Floodplain Managers
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Acknowledgements

This 1999 annual conference of the Association of State Floodplain Managers, like those that preceded it, could not have been successful without the help of so many who contribute their time and talents. Many thanks to those shown below, and to any others we may have inadvertently omitted.

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Conference Director  Program Chair  Exhibits Chair

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Part 1

Local Projects & Programs for Planning, Mitigation, Acquisition, & Recovery
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Bucks County Flood Recovery and Mitigation Strategy

Benjamin J. Ginsberg
Delaware Valley Regional Planning Commission

The Bucks County Flood Recovery and Mitigation Strategy provides a comprehensive plan for Bucks County, Pennsylvania (Figure 1). As an element of a flood mitigation plan for eastern Pennsylvania, coordinated by the Economic Development Council of Northeastern Pennsylvania under a grant from the Economic Development Administration, the strategy describes both structural and nonstructural floodproofing alternatives. Additionally, an analysis of the impact of impervious development upon two local watersheds is provided.

Figure 1. Bucks County, Pennsylvania.
In both January and June of 1996, the residents of Bucks County experienced the devastating effect of floods. A January thaw coupled with excessive rain and melting snow caused the Delaware River and Neshaminy Creek to crest well above flood stage (Table 1). In June, a strong cluster of thunderstorms dumped more than nine inches of rain in less than five hours on lower Bucks County (National Weather Service, 1996). The resulting flash floods caused two deaths and damaged numerous structures, producing millions of dollars in damage.

Table 1. Delaware River Flood Stage Report: January 19-21, 1996.

<table>
<thead>
<tr>
<th>Location</th>
<th>Flood Stage</th>
<th>Crest</th>
<th>Date</th>
<th>Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riegelsville</td>
<td>22 ft.</td>
<td>29 ft.</td>
<td>1/20</td>
<td>6:15 p.m.</td>
</tr>
<tr>
<td>New Hope</td>
<td>13 ft.</td>
<td>15 ft.</td>
<td>1/20</td>
<td>11:00 p.m.</td>
</tr>
<tr>
<td>Wash. Cross.</td>
<td>18 ft.</td>
<td>18.5 ft.</td>
<td>1/21</td>
<td>12:00 a.m.</td>
</tr>
<tr>
<td>Trenton, NJ</td>
<td>20 ft.</td>
<td>22 ft.</td>
<td>1/21</td>
<td>1:30 a.m.</td>
</tr>
</tbody>
</table>

Although these floods were triggered by an abnormality in weather conditions, the floods were exacerbated by floodplain development and the growing amount of impervious coverage. These urbanized conditions prevent water from traveling its normal course and cause an increase in flood frequency and velocity (Center for Watershed Protection, 1997). As the central and lower portions of Bucks County continue to develop, the channelization of small creeks coupled with increased stormwater runoff and lack of adequate stormwater control will cause more frequent and severe flood events. In addition, past efforts to reduce flood losses by controlling flood waters rather than encouraging people to avoid flood hazard areas may have added to the damage totals (Center for Watershed Protection, 1997).

Once flood damage has occurred, a variety of federal, state, local, and nonprofit agencies and programs are set in motion to aid residents with the recovery effort. Assistance can range from covering insured losses under the National Flood Insurance Program to establishing Red Cross shelters and providing food and counseling. Due to the 1996 floods, more than 300 people used the Red Cross for assistance in Bucks County (American Red Cross, 1996). Moreover, the Small Business Administration provided 357 loans totaling more than $8.5 million in flood-related assistance (Small Business Administration, 1996).
Limiting flood damage may be accomplished through a variety of nonstructural and structural measures. Nonstructural measures are comprised of two components: those that modify floodprone property and those that persuade people not to build in floodprone areas. These include zoning and planning, tax incentives, flood insurance programs, stream corridor restoration, and acquisition and relocation.

Structural measures involve control of flood waters and include levees, floodwalls, dams, channels, stormwater drainage systems, and other public works that manage stormwater runoff. Structural approaches have been widely used throughout Bucks County by the U.S. Army Corps of Engineers, Pennsylvania Department of Environmental Protection, and Bucks County. Examples include a series of flood control dams along the Neshaminy Creek, a levee along the Delaware River in Morrisville Borough, and widespread stormwater control systems in the urbanized portion of the county.

The primary nonstructural means of limiting flood damage is to prohibit development within floodprone areas or to require development within the floodplain to adhere to certain guidelines. The Pennsylvania Flood Plain Management Act and the Delaware River Basin Commission Floodplain Regulations provide for limited control of floodplain development. In Pennsylvania, local governments make their own land use decisions and therefore have the direct responsibility for floodplain management. Within Bucks County, 94% of the communities have ordinance language that regulates development within the 100-year floodplain. However, only 36% of these municipalities regulate development in the flood fringe area, and only 46% provide floodplain mapping (Bucks County Planning Commission, 1993).

The Bucks County Flood Recovery and Mitigation Strategy identifies a variety of specific policies and recommended actions for improving floodplain management and limiting the potential damage caused by floods.

Major recommended actions include:

- Municipalities should seek to further reduce potential flood damage by adopting and enforcing more stringent regulations controlling development within the 100-year floodplain and flood fringe areas.

- The Federal Emergency Management Agency should provide updated Flood Insurance Rate Maps to communities in order to recognize recent flooding trends.
• Bucks County Emergency Management Agency and Pennsylvania Emergency Management Agency should conduct a public outreach campaign to better educate the public living in and around floodprone areas regarding the risks associated with purchasing homes in the floodplain and floodprone areas.

• The Pennsylvania Department of Community and Economic Development and Bucks County should promote the acquisition of floodprone land for community parks and recreational open space.

REFERENCES


Small Business Administration. 1996. SBA Disaster Loan Approvals by County. Dallas, Texas and Niagara Falls, New York: SBA.
Recent Initiatives in Long-term Recovery Planning

Pieter de Jong
URS Greiner Woodward Clyde Federal Services

INTRODUCTION

There is no single correct approach to facilitating a community's or region's long-term recovery from a major flood disaster. Each community's recovery has to be structured on the basis of the extent of damage, local or regional planning capabilities, and key interest groups in the community. This paper will briefly describe some recent initiatives, primarily through the vehicle of the President's Long-term Recovery Plans, but the major thrust will be on community-based recovery planning efforts.

THE PRESIDENT'S LONG-TERM RECOVERY TASK FORCE

President Clinton established a Presidential Long-Term Recovery Task Force after the extensive flooding in April 1977 that affected Minnesota and North and South Dakota. The interagency task force was chaired by Federal Emergency Management Agency (FEMA) director, James Lee Witt, and included representatives of all major federal departments and agencies with a role in disaster response and recovery. The most important role of the recent federal recovery task forces has been to coordinate federal activities in the recovery process to ensure that the most appropriate and beneficial form of assistance is provided and that duplication of efforts does not occur. As the draft task force report, published approximately a month after the declaration, indicates, another purpose of the report is to provide a compendium of federal programs clearly of value to affected states and affected local jurisdictions. What the draft of the final report of the Presidents Long-Term Recovery Task Force, prepared in December 1977, did not do is provide a clear framework for the long-term recovery planning process.

Two recent Long-term Recovery Task Forces dealt with the flooding in Georgia and Alabama (FEMA DR-1209-GA and 1208-AL). These action-forcing plans have more of a planning emphasis and do away with the compendium of federal assistance program descriptions. The repetitive
nature of this disaster (many of the affected communities were the same communities that were devastated by Tropical Storm Alberto in 1994) led the task force to focus on the critical role of hazard mitigation in the long-term recovery process. The report recommends that Elba and other Alabama communities affected by the recent flooding develop long-term recovery plans that incorporate a sound mitigation strategy and provide a vision for the community's future. The major benefit of this task force approach is that the final report is more of a working document, one that can guide federal agencies throughout the entire recovery process.

Hurricane Georges struck Puerto Rico on September 21, 1998, moving west across the island with winds gusting to 150 miles per hour and dumping up to 27 inches of rain in the central mountains. Hurricane Georges was the worst natural disaster to hit Puerto Rico in 70 years and the recovery needs are among the most extensive the federal government has ever faced (FEMA, 1998). FEMA's recovery assistance was estimated to exceed $2 billion and the total cost of federal government assistance will assuredly be much higher. President Clinton activated the Long-Term Recovery Task Force, composed of 15 federal departments, agencies and offices; their first joint meeting with the Government of Puerto Rico officials was held on October 14, 1998. Five long-term recovery priorities were identified at that meeting. They included mitigation, housing, economic revitalization and sustainability, energy, and transportation.

The President's Long-Term Recovery Action Plan, distributed about three months later, represents the most comprehensive recovery plan yet prepared. It includes 57 specific actions that federal departments and agencies are implementing to facilitate a well-coordinated and rapid recovery. The stated purpose of the Task Force was well-phrased, "to coordinate and target the diverse disaster programs of more than a dozen federal agencies to ensure the greatest level of effective federal support for a full recovery." For the first time, the term "sustainable redevelopment" emerged as a major thrust of this plan. The concept, as described in the plan, not only addresses the risks caused by natural hazards, but also takes into consideration the compatibility of development with the natural environment, the use of nonrenewable resources, and social and economic issues affected by improved community planning.

All of the recent federal long-term recovery task forces emphasize one important facet about the federal role in long-term recovery: that the federal role will be most successful if it supports and does not supplant efforts, resources, and decisionmaking at the state, region, and particularly at the local government level. Although FEMA does clearly have a role in coordinating federal agencies in the disaster response phase and it can
provide meaningful technical assistance, it has neither the resources nor the authority to actively participate throughout the lengthy process of a community's recovery. The logical next step for future task forces is to ensure better integration of Federal Recovery Task Forces with state long-term recovery efforts.

**LOCAL INITIATIVES**

One of the critical needs raised in the Hurricane Georges' Long-Term Action Plan is to provide technical assistance to develop land-use plans, comprehensive plans, and mitigation strategies that are community based and implemented. FEMA has addressed this need by tasking URS Greiner Woodward Clyde (UGWC) to create a community planning project team with Region II hazard mitigation staff and the Council for Information and Planning Alternatives (CIPA), a locally-based, non-profit organization. UGWC is currently developing hazard mitigation elements for seven rural municipalities. The communities include one coastal municipality, Maunabo, and six rural municipalities in the central mountains: Barranquitas, Orocovis, Corozal, Jayuya, Utuado, and Lares. The mitigation elements incorporate a GIS-driven hazard identification and risk assessment, and extensive community involvement through a series of working meetings with community planning boards and local government representatives. The hazards being investigated include flooding, seismic, high winds, and landslides. The public informational meetings held to date have been well-attended and have led to an emphasis on low-cost mitigation measures that can implemented at the local level.

There is only a very brief window of opportunity to build sustainable redevelopment concepts into the post-disaster recovery process. This is due primarily to an inherent tendency to rebuild to the pre-disaster conditions. The tendency is perfectly understandable: the disaster victims desire a return to normalcy; the FEMA Public Assistance and Disaster Housing programs are structured to expedite the reconstruction effort; and the political process reinforces these trends. To construct a more disaster-resistant community requires a community-wide decision and commitment to pause in the recovery process and evaluate how hazard mitigation elements can be best implemented to lead to a more sustainable long-term recovery. The best example of this commitment is Valmeyer, Illinois, a small river town along the Mississippi River that was devastated by a levee breach during the Midwest floods of 1994. The mayor of Valmeyer and residents came to a decision shortly after the flood to relocate the entire community to the limestone bluffs overlooking the river. With the assistance of FEMA and many other federal agencies a new community of
about 500 residents have relocated to the “New Valmeyer”. Temporary building permit moratoriums are not essential in this effort, but are a useful tool to provide that necessary window of opportunity.

It is the recovery planning process that is important to success not the preparation of the plan itself. As General Dwight Eisenhower said shortly after World War II, “A plan is useless but planning is essential.” Normally, comprehensive plans require an extensive amount of time to complete; a two-year time frame would not be unusual. The traditional comprehensive planning process must be compressed to a period of several months if it is to have an impact on the recovery process. This is a difficult objective but can be accomplished by use of a range of planning techniques that can be fitted to the communities’ specific situation.

The City of Arkadelphia, Arkansas, was devastated by a tornado in March 1997. UGWC conducted what is known in the architectural and urban design profession as a planning charrette, an intensive four-day land use and urban design effort, to initiate the recovery process. The planning team, comprising an architect, planner, engineer, economist, and GIS specialist, worked daily with a 15-member Disaster Recovery Plan Committee to develop a vision for the city’s recovery and a series of immediate, short- and long-term implementation recommendations. The recovery plan was completed within two months. Other planning techniques involve augmenting local planning resources, creation of a recovery task force, standing committees, or workshops on key recovery issues. Public involvement is essential and formal adoption of the plan by the local governing body is highly recommended.

Employ multi-objective planning when evaluating opportunities for disaster recovery. There are many opportunities for synergism in the post-disaster environment. Buying out floodprone homes may improve downstream conveyance of floodwaters, restore some natural and beneficial functions of the floodplain, and provide passive or active recreational opportunities. In Del Rio, Texas, where a Hispanic neighborhood was destroyed by a flash flood in 1998, the recovery planning process coupled a Section 404 acquisition program with a well-designed subdivision of mixed uses for affected low- and moderate-income residents. Housing and Urban Development and Texas Department of Housing and Community Affairs technical and financial assistance has been essential to this recovery effort. A conceptual plan to restore the San Felipe Creek floodplain and to expand a river walk and other passive recreational opportunities has been developed. The restoration plan also had to contend with an endangered species issue. The protection of the
Devil's River Minnow, a Candidate Federally Endangered Species, found in the reaches of San Felipe Creek, had to be incorporated into the floodplain restoration plan.

Maximize the use of non-traditional partners in the recovery process. In addition to the host of federal agencies that may fund disaster recovery efforts, non-profit organizations, national corporations, foundations, and civic associations should be actively encouraged to participate in the recovery process. Lessons learned from FEMA's Project Impact, a nationwide initiative to build more disaster-resistant communities, need to be carried to post-disaster recovery. For every single dollar spent by FEMA in Project Impact communities, over four dollars have been raised from non-governmental sources to promote or implement hazard mitigation initiatives.

In the post-disaster environment, many communities can take a more active role in the recovery process by identifying neighborhoods with low-income residents or disaster victims with special needs, such as the elderly or minorities. Many of the needs of these residents will be unmet by the traditional disaster response and recovery programs. These areas or special populations should be quickly identified through the use of census tract information and from interview data compiled by the Red Cross or other non-profit relief organizations. An excellent example of addressing unmet needs comes from Del Rio, Texas, where concerned citizens utilized an existing non-profit organization, expanded their mission to include disaster relief, and created "Del Rio Recovers." This organization is structured to provide one-on-one counseling by assigning a volunteer to shadow a displaced family throughout the recovery process. They will help the family understand the array of disaster assistance programs and work closely with family and relief agencies until their recovery needs are met.

In the recovery planning process, the most important dictum is to "stay out of the weeds." The brief window of opportunity for planning after a disaster necessitates that the recovery plan should be a framework for long-term recovery, not a comprehensive planning document. The reconstruction strategy should lay out actions that can be implemented through more detailed design and engineering conducted over a one- to two-year planning horizon. One of the important benefits of preparing a recovery plan is that the draft document provides a mechanism for community participation in the recovery effort. The document can be presented to residents through a public hearing and residents can be encouraged to comment on the plan's broad goals, objectives, and specific implementation actions. It is hoped that the reconstruction strategy can unify the community around the difficult process of recovery.
Reducing Flood Losses Through Floodprone Land Acquisition: Identifying Total Costs and Benefits

Gary G. Peterson, Thomas J. Helfrich, and Leo R. Smith
Pima County Flood Control District

INTRODUCTION

Most flood control agencies rely on a variety of structural and non-structural approaches to minimize flood losses in their communities. Flood control capital facilities, floodplain management regulations, and a host of other strategies all figure in this mix, as does the outright purchase of floodprone properties. Floodprone land acquisition has played an important role in minimizing flood losses in Pima County, Arizona. Initiated in 1984, the Pima County Flood Control District (District) has purchased more than 6,700 acres of floodprone land through its Floodprone Land Acquisition Program (FLAP). While land acquisition has proven to be an effective flood protection strategy, it also yields multiple community benefits. In planning to meet future regional flood control needs, the District has begun to identify and evaluate the various advantages and disadvantages associated with land acquisition. Although still preliminary, it is hoped that this evaluation procedure will have broader utility and perhaps generate similar kinds of assessments in other communities. Although each community’s list of advantages and disadvantages will vary, a process analogous to the one described in this paper should lead to a more balanced assessment of public acquisition of floodprone land as a means of meeting both public safety and other community needs.

PROGRAM OVERVIEW

The District’s FLAP program was developed in response to the October 1983 flood, one of the most extensive flood disasters in recent Pima County history. Initially the program focused on purchasing properties damaged in the 1983 event and providing relocation assistance to flooded property owners. The concept was to offer individuals who had either lost
their homes or sustained severe damage, the option of selling their property to the District rather than rebuilding at the same location. In later years, the program was expanded to include the acquisition of undeveloped properties and parcels in upper watershed areas. One major purchase has involved nearly 4,000 acres located along upper watershed areas on Cienega Creek.

An important issue that has recently affected District work is public and political interest in providing multiple benefits when constructing major capital improvements. We no longer simply build a new flood control facilities. Rather, capital projects almost invariably include recreation elements, environmental enhancement, and often, public art. These are desirable features, and there is clear indication that they will continue to be demanded by the residents and politicians alike.

Accomplishing these objectives in conjunction with structural flood control projects usually requires substantial additional costs. Conversely, many of these benefits are inherent with floodprone land acquisition. Less tangible community benefits such as open space protection, water quality enhancement, aquifer recharge, and wildlife habitat preservation are achieved in conjunction with acquisition efforts. Given an increasing interest in delivering multiple objectives along with flood control protection, purchasing floodprone land has strong appeal. To meet future flood control needs, the District has begun evaluating whether acquisition might offer greater overall advantage when compared to implementing other flood protection measures.

As part of this process, the District has developed a list of advantages and disadvantages that we believe have relevance to the political, social, and hydrologic conditions in Pima County, Arizona (Figure 1). It should be noted that some of these factors will have broader applicability, while others may have little or no relevance for other communities. At this point, we have chosen not to rank the factors in terms of their importance. Rather, as an initial step, they are simply ordered in terms of their overall tangibility, that is, how easy it is to quantify the economic value of each factor. In addition, the advantages and disadvantages are assigned to one of four main categories: (1) public safety, (2) natural resources, (3) administrative, and (4) other.

ADVANTAGES

On balance, there appear to be more advantages associated with acquisition than disadvantages. Most of the more tangible advantages (upper right quadrant of Figure 1) are public safety issues, which are factors likely to be common to most communities. One of the more
<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Eliminates flood insurance costs</td>
<td>- Requires funding source to purchase property</td>
</tr>
<tr>
<td>- Eliminates flood proofing costs</td>
<td>- Requires expenditure of funds that could be used for structural projects</td>
</tr>
<tr>
<td>- Provides income from leasing acquired property</td>
<td>- Removes property from tax rolls</td>
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<tr>
<td>- Often less expensive than a structural solution</td>
<td>- Requires ongoing administrative expenditures</td>
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<td>- Provides CRS benefits</td>
<td>- Requires funding for maintenance and property safeguarding</td>
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<tr>
<td>- Reduces emergency and disaster assistance costs</td>
<td>- Requires staff time to evaluate properties for acquisition</td>
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<td>- Avoids possible litigation costs on structural improvements</td>
<td>- Increases liability exposure on acquired properties</td>
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<tr>
<td>- Eliminates residual flood risks beyond the design of a structural improvement</td>
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<tr>
<td>- Maintains overbank storage and attenuates downstream flood peaks</td>
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<td>- Eliminates resident’s fear of living in a flood hazard zone</td>
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<td>- Provides passive and active recreational opportunities</td>
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<td>- Enhances water quality and promotes aquifer recharge</td>
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<td>- Preserves wildlife habitat and biodiversity</td>
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<td>- Provides open space benefits</td>
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<th>TANGIBLE</th>
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<td>- Public Safety/Hydrologic Factor</td>
<td>- Administrative Cost Factor</td>
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<td>- Natural Resource/Amenity Factor</td>
<td>- Other Factor</td>
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**Figure 1.** Some advantages and disadvantages of floodprone land acquisition.
compelling of the less-tangible advantages is the public safety concern of residual risk. Since flooding on acquired properties is expected, and since there is little development or infrastructure at risk, acquisition arguably eliminates nearly all of the flood hazards on the property, regardless of the magnitude of an event. Any residual risk from a flood that may exceed the design of a structural improvement is thus minimized.

Less easily quantified advantages appear in the lower left quadrant of Figure 1. Most of the factors grouped here are natural resource kinds of issues. These are recognized as important, but they are often difficult to evaluate in a direct benefit/cost analysis. For instance, deriving a concrete value for urban open space is, at best, challenging. We appreciate, and perhaps have general agreement, that open space is a desirable amenity; however, determining its absolute value is more difficult.

**DISADVANTAGES**

Accounting for possible disadvantages to flood-prone acquisition is an important task for any flood control agency that may be considering this type of non-structural program. The ability to gauge and acknowledge potential disadvantages, particularly in relation to other flood protection methods, will help foster both political and public support for acquisition.

Two dimensions in the tangible/disadvantage quadrant emerge from the categorization. First, the majority of the more concrete disadvantages appear to be administrative kinds of issues. General administration costs, expenditures for staff time needed to support acquisition work, and maintenance and property safeguarding are some of the administrative issues associated with an acquisition program. Perhaps the most obvious implication is that agencies that already have in place the administrative capacity to accomplish these kinds of tasks will be in a better position to establish an acquisition program, and in turn, make the case that the overall benefits of this strategy override the potential drawbacks.

Two other disadvantages, although less tangible, are nevertheless important considerations. Although grouped here in the other category, these two factors have a decidedly political dimension. Substantial political credit can accrue to elected officials (as well as accolades for local agencies) from attracting state and federal monies to construct local structural flood control improvements. Conversely, convincing a political leaders that government should acquire and own property, which also removes it from tax rolls, can be a challenging proposition. At a minimum, an evaluation of this nature allows decisionmakers to better gauge whether the advantages noted above—mainly public safety and
natural resource issues—ultimately outweigh these two less quantifiable, 
but still certainly very real, disadvantages.

**CONCLUSION**

The approach identified in this paper represents an initial step toward
developing a more thorough evaluation of the advantages and 
disadvantages associated with public acquisition of floodprone property.
The list of advantages and disadvantages presented here are factors we 
have found to be relevant to political, social, and hydrologic conditions in 
Pima County, Arizona. The list should be considered as a starting point, 
from which other communities can identify their own set of factors, 
tailored to meet specific community needs. Similarly, the categorization 
scheme is just one of many approaches, with various other configurations 
possible. A more comprehensive and balanced assessment of the 
advantages and disadvantages associated with floodprone land acquisition 
will ultimately result in greater community benefit and more cost-effective 
flood control solutions.
INTRODUCTION

The Harris County Flood Control District (HCFCD) was established by the Texas Legislature in 1937 for the purpose of "the control, storing, preservation, and distribution of storm and flood waters; and the waters of the rivers and streams in Harris county and their tributaries for domestic, municipal, flood control, irrigation, and other useful purposes; the reclamation and drainage of the overflow land of Harris County; the conservation of forests; and to aid in the protection of navigation on the navigable waters by regulating the flood and storm waters that flow into said navigable streams." The mission statement of the HCFCD is "to build urban flood control projects that work, with appropriate regard for community and natural values—ultimately, to get our citizens out of harm's way by: devising the flood control plan; implementing the plan; and maintaining the infrastructure."

The HCFCD has traditionally approached its mission via the implementation of structural flood control measures, primarily larger and straighter channels and detention basins. The HCFCD has recognized that floodplain buyouts are a viable and powerful flood control tool, and has determined that it could best be implemented with an ongoing, programmatic approach. Therefore, the HCFCD has embarked upon the development of a Pre-Disaster Flood Plain Buyout Program—a program that would result in the continued funding of and implementation of buyouts before, not after, the flood disaster strikes. They have enlisted a consulting firm, Turner Collie & Braden Incorporated (TC&B), to assist in the development and implementation of the program. The program is to be developed in three phases. Phase 1 will define and develop program guidelines. Phase 2 will perform a pilot study test on Cypress Creek, a
large watershed in north Harris County. Phase 3 is the county-wide program implementation. This paper presents the results of Phase 1.

**PROGRAM DEFINITION AND DEVELOPMENT**

A number of steps were utilized to develop the program. Initially, brainstorming sessions were held with members of HCFCD and TC&B staff, along with members of the Flood Plain Fringe Committee of the Harris County Task Force. From these, the following program goals were established: (1) provide a cost-effective approach to flood damage avoidance; (2) enhance public safety; (3) be responsive to the storm aftermath; and (4) be responsive to the citizens.

The goals were presented to a focus group comprising residents and community officials, and a number of issues were identified that are associated with the floodplain buyouts and the stated goals. The program was developed in such a way as to meet the goals while providing due consideration of the identified issues. Other communities were studied, and the successes found in those projects were incorporated into the program. Also, lessons learned by the HCFCD in the previous buyout projects were useful in addressing difficult issues.

The goals of the program, and the identified issues associated with the program, were presented at the 1998 Association of State Floodplain Managers conference in Milwaukee, Wisconsin. This paper presents the program policies, objectives, and procedures.

**PROGRAM POLICIES**

A number of policies were identified in the development of the program. Program policies define guidelines that establish the procedural framework for the buyout program. The program will be essentially voluntary. However, once an owner enters the program and commits his or her property to be purchased, termination of the acquisition will be allowed only at the sole discretion of the HCFCD. The program will incorporate Harris County Department of Public Infrastructure Right-of-Way Department procedures for property appraisals, relocation assistance, and other basic acquisition procedures that are currently followed and meet federal guidelines for relocation. The program will apply to all structures at risk, not just those with flood insurance. The program will not supersede Federal Emergency Management Agency (FEMA) post-disaster assistance, nor will it prohibit the acquisition of property under one of the other HCFCD projects or programs. The information available in the
program database will be available to assist these other activities, if appropriate.

The program will evaluate potential acquisition structures using a set of objective and consistent selection criteria. The program will address the issues of the surrounding community once a structure is identified for acquisition. The program will allow re-ranking of structures after a flood. The program will propose a formal procedure to coordinate with other regulatory agencies in response to and after a flood. The program will have a defined annual budget with which to implement its activities. The program will discourage resale of purchased land for rebuilding of a residential structure.

**PROGRAM OBJECTIVES**

To develop the program described above and to enable the HCFCD to objectively select and acquire structures located in flood-prone areas of Harris County, a process consisting of five primary objectives was identified:

1. Develop a floodplain inventory—to identify structures and determine their relative relationships to flood events and flood depths, an inventory of the structures and characteristics of the floodplain will be required. Initially, the inventory will include information from available sources.

2. Evaluate existing capital programs—major planned capital projects could impact the flood risk of a property. If a capital program is to be constructed in an area, it could reduce or eliminate at-risk, flood-prone areas that currently exist. In those cases, buyout may not be the preferred program.

3. Define eligibility and ranking criteria—criteria have been developed to determine which structures are eligible for buyout and to serve as a guide for ranking and prioritizing these structures. Issues to be considered in the determination of eligibility include risk assessment associated with various storm frequencies; recent flooding; financial limits of the program; availability of the data for a database; and standing relative to the capital program.

4. Address procedural matters—the program will include specific procedures for the implementation of the property acquisition, whether it is initiated by the homeowner or by the HCFCD.

5. Community issues—coordination with other agencies and groups, including the local community.
PROGRAM PROCEDURES

A comprehensive buyout program requires the implementation of numerous procedures. Procedures identify the basic responsibilities for the HCFCD and the homeowner within the program. Procedures also describe the activities that are performed by each party. Each procedure is described below.

Procedure for communication with the public and other agencies—Public education and communication were the primary concerns expressed in the focus group workshop. It is important to initially educate the public about the concept of buyout as an effective flood control tool, and about the program requirements and procedures. It is equally important to continue communication throughout the process. To achieve this, it is recommended that a single position of responsibility for this program be assigned, and that position should serve as a central point of contact for all inquiries, both from the public and other agencies, regarding the program. The HCFCD Communications Department has taken the lead in educating the public about the Buyout program. With their direction, the HCFCD cosponsored, along with the Bayou Preservation Association, a national conference entitled “The Buyout Conference: Building Partnerships in our Community” in April 1999. They have also published a brochure entitled “20 Questions About Buyouts”.

Procedure to identify, evaluate, and select eligible properties for acquisition—This procedure consists of eight tasks, some of which are procedures in their own right. However, the final product of these tasks together is a prioritized list of nominated buyout candidates. These eight tasks are: (1) select initial data set of structures to evaluate; (2) compile data into a geographic information system (GIS) database; (3) perform the initial screening of the initial data set of structures; (4) prioritize the initial data set of structures and select a subset of highest priority structures to be considered for further evaluation; (5) obtain refined data and additional data on the identified priority structures and perform second screening; (6) review selected structures to determine remaining community impacts; (7) determine final prioritized list of structures and coordinate with other agencies, as appropriate; and (8) notify selected candidates for inclusion in the program.

Procedure to designate final structures for buyout—Those candidates that agree to be acquired will begin the tract acquisition process. If nominated candidates do not respond, or they indicate an unwillingness to sell, the property may not be re-considered for
acquisition within the following three years, unless there is a change in the circumstances affecting the primary selection criteria for the property. This determination is at the discretion of the HCFCD.

Procedure to acquire designated structures—Once an owner enters the program and commits his or her property to be purchased, termination of the acquisition will be allowed only at the discretion of the HCFCD. The acquisition will be conducted by the Right-of-Way section of the Harris County Public Infrastructure Department. Some of the major steps in the acquisition are property appraisal, negotiation of purchase, relocation assistance for landowner or tenants, and disposition of the acquired property.

Procedure for potential funding opportunities—The program is designed to purchase homes using solely HCFCD program funds. However, this does not preclude the HCFCD from investigating and pursuing other methods or sources of funds. These may be FEMA funds in the form of Flood Mitigation Assistance (FMA) grants or Hazard Mitigation Grant Program (HMGP) grants, or others. In any case, the funding partner will likely impose requirements on the buyouts that in many cases will conflict with the procedures outlined in the program. In such a case, those requirements will supersede those set forth in the program.

PROGRAM STATUS

This paper provides a blueprint for the HCFCD's Pre-Disaster Flood Plain Buyout Program. The outline of the program, as described above, is Phase 1 of the program. The HCFCD is now working on Phase 2, which is a pilot to test the above procedures, and Phase 3, which is the work required to populate the initial data set. At the completion of Phases 2 and 3, the program procedures may be revised before final implementation. At this time, the program in its entirety has not been forwarded to Harris County Commissioner's Court for adoption. This will occur with the completion of all three phases of the program development.
Rehabilitation of Fawell Dam in DuPage County, Illinois

Anthony Charlton and Christine Klepp
DuPage County Department of Environmental Concerns

Hollis Ude and Donald Glondys
URS Greiner Woodward Clyde

INTRODUCTION

DuPage County Department of Environmental Concerns (DEC) is taking advantage of this era of hazard mitigation by utilizing existing infrastructure to reduce flood losses. In 1998, DEC acquired ownership of Fawell Dam and its associated saddle dike from the Illinois Department of Natural Resources/Office of Water Resources (State). DEC quickly realized that taking on such an endeavor would require a significant amount of public involvement, patience, and perseverance.

PROJECT CATALYST

Discussions of assuming operation and maintenance of these structures began in 1995, and were renewed again in 1996, after record rainfall that year. In July, areas in the southwestern part of DuPage County received between eight and ten inches of rain in 24 hours. In comparison, the 100-year rainfall is about 7.6 inches in 24 hours. One of the hardest hit areas included the downtown business district of Naperville, which lies along the West Branch DuPage River (West Branch) in DuPage County.

DEC has had flood control jurisdiction in DuPage County since 1987, when the State delegated this authority. Besides trying to assist Naperville with regional flood control efforts, DEC knew that the State was short-staffed and unable to keep this high hazard dam in operating condition. So DEC proactively pursued operation and maintenance and eventual ownership of the dam and its associated structures.

PROJECT SETTING

Naperville is about 35 miles west of Chicago. Fawell Dam is on the north side of Naperville and stretches across the West Branch. A 105.2-square-mile watershed drains into the West Branch, upstream of the dam. As
shown in Figure 1, Fawell Dam lies within McDowell Grove Forest Preserve, due west of the Cress Creek subdivision. As part of the original dam construction, the State purchased nearly 300 acres of property, which is now part of McDowell Grove. McDowell Grove consists of wetlands, tall grasses, bushes, and areas with well-established oak trees. In fact, three very old oak trees straddle the far side of dam's left abutment.

EXISTING DAM COMPONENTS

Fawell Dam is an intermediate-size Class I, high-hazard category dam (Illinois Department of Transportation, 1993). It was built between 1969 and 1971 by the state for flood control purposes. The dam consists of a 1100-foot-long main earthen embankment, a service spillway, a low-level outlet, and a 1900-foot-long saddle dike along the eastern side of McDowell Grove. The saddle dike is upstream of the main dam and protects the Cress Creek subdivision from flooding.

Figure 1. Location of Fawell Dam.
STATE OF AFFAIRS

During an inspection of the dam in September 1996, by URSGWC staff, the structure appeared to be in overall good condition. However, a 5- to 10-gpm seep on the right toe collection ditch was noted as well as a large amount of woody vegetation (scrub and trees) on both the upstream and downstream slopes. Also, the three inlet gates had been left in the completely open position by the State since September of 1989, due to vandalism. The reservoir upstream of the dam is dry under normal operating conditions.

A review of State records indicated that Fawell Dam had never received a dam safety permit from the State. A dam safety inspection report prepared by the U.S. Army Corps of Engineers in September 1981 indicated that no construction records or records of compaction of the earthen embankment were available and the dam lacked an emergency spillway.

DESIGN OBJECTIVES

DEC continued to pursue rehabilitation of the dam by funding the engineering design services necessary to develop the modifications to the dam and saddle dike. An agreement with the State was secured to provide the construction funding necessary to rehabilitate the dam in accordance with the State's dam safety regulations. Subsequently, the ownership, operation, and maintenance of the dam was transferred to DuPage County.

In order to bring the dam into compliance with dam safety standards and to safely pass 0.6 of the probable maximum flood (PMF), major rehabilitation work was identified. The height of the dam would be lowered and roller-compacted concrete (RCC) would be placed atop the existing earthen embankment. This would help protect the embankment and foundation of the dam during overtopping flows for the 0.6 PMF. Using RCC as overtopping protection for Fawell Dam has been identified as one of the first such uses in the State of Illinois. Installing erosion protection measures on the dam such as riprap, soil reinforcing mat, and Tri-Lock Block revetment were also identified. Raising the existing saddle dike, and extending it from its existing southern edge to the left abutment of the dam, and from its northern edge east along adjacent property, was another key component of the rehabilitation effort, and would prove to be one of the most controversial items.

An intergovernmental agreement between the Forest Preserve District of DuPage County and the DEC included new and improved recreational facilities. DEC and the Forest Preserve agreed on the addition of a canoe
portage facility on the right abutment of the dam, improved pedestrian bridges across the West Branch, and expansion of the regional trail system through the southern portion of McDowell Grove. These amenities provide an opportunity to enhance the quality of life for DuPage County residents by increasing recreational opportunities near the dam at a much lower total cost.

COMMUNITY AND AGENCY RELATIONS

DEC’s plan to reconstruct the dam, reinstate operation of the gates at the dam, and enhance recreational facilities, resulted in significant community and agency activism. Although 95% of the proposed work would be performed on public property, residents of Cress Creek subdivision were concerned about DEC removing significant amounts of vegetation within McDowell Grove, in particular three oak trees located on the left abutment of the dam. They were also concerned that raising and extending the saddle dike would obstruct their views of McDowell Grove. Lastly, they were concerned that introducing a trail behind their houses would change the rural character of the otherwise quiet preserve.

In response, DEC attended and initiated numerous public meetings, including field visits with smaller groups of residents closest to the proposed construction activity. DEC and URSGWC staff walked the entire length of the project with the neighboring residents and answered all questions about the proposed rehabilitation.

DEC and URSGWC, in coordination with the Forest Preserve, found a way to preserve the three existing oak trees, and to work with the contractors to save as much vegetation as technically justified. In addition to meetings, several detailed comment and response documents were prepared. All public information stressed that the dam rehabilitation was strictly for meeting current dam safety concerns.

Besides the residents of Cress Creek, the upstream community of Warrenville was concerned that the rehabilitation of the dam and saddle dike, along with resuming operation of the gates at the dam, would increase flooding in their community. As with Cress Creek, DEC had numerous meetings with Warrenville officials and residents to allay their concerns.

The Forest Preserve was concerned that construction of the saddle dike would limit its options for development of a trail system through McDowell Grove. To respond to the Forest Preserve’s and residents’ concerns, DEC sent URSGWC staff out with Forest Preserve staff to stake an alignment for the saddle dike, which would also serve as the trail system for the southern portion of the saddle dike. The intent of this field
work was to move the saddle dike and trail as far away as possible from the back property line of the residences without moving outside the limit of land originally purchased as part of the dam back in 1970. DEC also worked repeatedly with Forest Preserve staff on various issues pertaining to canoe portage and pedestrian bridge designs, assuring that the character of McDowell Grove was maintained.

CONCLUSION
Addressing community concerns has added several months to the schedule. However, DEC believes that it was well worth the investment to educate neighboring communities about the project and take this opportunity to build upon existing structures to help mitigate flood losses, in particular, loss of life.

REFERENCES
Part 2

Watershed Management
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Floodplain Management: Reaching Beyond the BFE and NFIP

Rod E. Emmer
Rodney E. Emmer and Associates, Inc.

INTRODUCTION

Floodplains and watersheds are married and cannot be divorced for management purposes. Precipitation falls throughout a drainage basin and generally does not result in a calamity unless circumstances concentrate runoff in floodplains at inopportune times. Creeks and rivers overtop banks, rush through canyons and onto alluvial fans, or spread behind ice jams. In some regions, lake levels fluctuate, inundating the adjacent low, flat landscape or rising groundwater fills basements. As a consequence, floods annually kill or seriously injure hundreds of individuals and emotionally stress survivors. Costs accrue to victims who must replace or rebuild property, to emergency workers who risk life and health, and to governments who spend millions of dollars for emergency response and rehabilitation. In addition, state and local economies suffer from lost time and disruption of commerce. Whether in or above the 100-year flood level, no one in a watershed escapes the direct or indirect adverse impacts of a disaster.

Many floods originate on the uplands surrounding valley floors, alluvial fans, playas, or lake margins. Achieving maximum flood damage reduction, therefore, entails considering opportunities outside the traditional institutional range in order to address the source of the problem. Local decisionmakers and elected officials must raise their vision and reach beyond the base flood elevation and the National Flood Insurance Program. This paper proposes that county (parish) and municipal governments more aggressively pursue flood damage reduction by expanding the scope and content of their floodplain management program to include greater coordination with associated federal, state, and local programs.

FLOODPLAIN MANAGEMENT

Earliest attempts at protecting people and property from floods emphasized physical control of water. Disaster costs and human suffering, however, continued to rise even after spending billions of dollars. Rather
than submit to catastrophic events as their preordained fate, state and local
governments practice floodplain management. As directed by the National
Flood Insurance Act of 1968 (P.L. 90-448, Section 1302(c)), the U.S.
Water Resources Council prepared its milestone report, A Unified
National Program for Floodplain Management, a document that sets the
framework for managing floodplains (Federal Interagency Floodplain
(NFIP) defines the 100-year flood as the base flood for participating
communities (L.R. Johnson, 1992). Floodplain management, as the overall
program of corrective and preventive measures for reducing flood damage
(L.R. Johnston Associates, 1992), focuses on the 100-year floodplain, the
area where the NFIP regulations apply (FEMA, 1997). The NFIP
approach protects existing and potential development on the 100-year
floodplain from anticipated events and prevents additional growth from
increasing flood threats.

Floodplain management is a continuous process used by state and
local decisionmakers when deciding whether and how to address
development in floodplains. Wise use of floodplains includes the full
range of public and private actions and policies: structural measures that
modify flooding; nonstructural measures that alter individual and
community susceptibility to floods; and preservation and restoration of the
floodplain's natural resources and functions. Regardless of state and local
politics and landscape characteristics, floodplain management remains
focused on the base flood elevation (the 100-year flood) and the NFIP.
Federal criteria for floodplain management (44 CFR 60) give minimal
recognition to watershed development by leaving regulation to the
discretion of the community.

BEYOND THE BFE AND THE NFIP
Communities feel the major impacts of flooding within the 100-year
floodplain while development and other activities throughout the entire
watershed contribute to the problem. When urban sprawl (subdivisions
and commercial centers), industries, or agricultural and forestry practices
modify the landscape, runoff dramatically increases. For example, runoff
from natural ground cover usually equals 10% of the precipitation. If
changing land uses modify 10 to 20% of the surface (impervious materials
and/or clearing vegetation), runoff increases to 20%. Extending
development to 75–100% more than doubles runoff to 55%
(Environmental Protection Agency, 1993). As a result, stream
characteristics change. Although flood stages may be of a shorter
duration, hydrographs show higher and more rapid peak discharges.
Construction, agriculture, and forestry practices may contribute to flooding problems in other ways. Land cleared for development, used for agriculture, or modified during forest harvests contributes sediment to channels, floodplains, and wetlands, decreasing their ability to store and/or convey floodwaters. Transportation networks encroach into floodways and floodway fringes and encourage growth in high risk areas. Communities and landowners drain or fill wetlands and potholes, again removing storage capacity from the entire watershed. Farmers clear riparian vegetation that helps reduce flood peaks by evapo-transpiration, detention, retarding erosion, or trapping sediment. As a result of more intense activities on uplands, homes and businesses now suffer that never historically flooded. Structures built above the BFE and in compliance with NFIP guidelines also flood because of new discharge peaks. Channels that once contained runoff now attain bankfull sooner and exceed capacity, causing expansion of flood prone areas.

Actions can be taken to eliminate or reduce these problems. If state and local floodplain managers reach beyond the minimum NFIP requirements, development can continue on the uplands without increasing the base flood elevation, avoiding additional damage and the necessity of revising the local flood hazard prevention ordinance. Several federal and state programs complement the traditional floodplain management practices.

First, as part of their comment opportunity on Section 404 permit applications (Clean Water Act, 33 USC 1251 et seq.) communities should advise the U.S. Army Corps of Engineers that continued filling of wetlands throughout the watershed will contribute to increased flooding and result in greater damage. The Corps should, therefore, cease issuing permits for converting wetlands because they serve as stormwater detention areas.

Similarly, state and local governments should work closely to protect critical habitat for threatened and endangered species (16 USC 1531 et seq.), especially those outside the 100-year floodplain. Many sites of critical habitat include upland wetlands that should also be retained for their stormwater storage capacity.

Third, through the Section 401 certification process (Clean Water Act, 33 USC 1251 et seq.) states have the authority to condition projects and address associated impacts, such as stream volumes and fluctuations or filling of habitat (Environmental Protection Agency, 1995). Preventing fill and capturing runoff reduces flood stages downstream.

Fourth, floodplain managers should encourage participation of neighboring farmers and ranchers in any of several U.S. Department of
Agriculture programs. The Conservation Reserve Program (Food Security Act, 16 USC 3821 et seq.), administered by the Consolidated Farm Service Agency, conserves and improves natural resources such as wetlands, waterfowl habitat, filter strips, and riparian buffers. The Water Bank program (16 USC 1301 et seq.) through the Natural Resources Conservation Service (NRCS) pays landowners to set aside wetlands for specified periods of time. The NRCS's Wetlands Reserve Program (16 USC 3837A et seq.) promotes restoration and protection of farmed wetlands, prior converted wetlands, wetlands farmed under natural conditions, riparian areas, and eligible buffer areas through permanent or long-term agreements. Each of these programs intercepts runoff, keeping sediment from waterbodies and water on the land to recharge groundwater and not rushing downstream to contribute to flood stages and volumes.

At the state level, water resource agencies use Environmental Protection Agency money (Section 319, Clean Water Act, 33 USC 1251 et seq.) to support demonstration projects and programs addressing nonpoint sources of pollution. Local governments working in cooperation with the state agency could select demonstration projects that reduce not only nonpoint source pollution but also downstream flooding. Along these same lines, the agricultural and forestry communities could allow greater capacity for storing runoff when implementing best management practices for nonpoint source pollution abatement. State park, recreation, and fish and wildlife agencies should incorporate stormwater detention projects, buffer strips, porous pavement, and vegetative plantings to reduce erosion in and runoff from refuges and management areas, parks, or recreation facilities.

Finally, local governments should mandate stormwater detention as a part of all new subdivisions, malls, hospitals, shopping centers, industries, and other land uses beyond the 100-year floodplain. Intensive development activities inevitably accelerate runoff as a result of parking lots, streets, and rooftops. In existing subdivisions, local governments could purchase or acquire easements on remaining wetlands for stormwater storage. Design and rehabilitation of recreation facilities should include a stormwater detention component and extensive use of porous pavement. Communities may reestablish vegetative buffer strips or other best management practices along creeks and streams to slow runoff, trap sediment, and detain stormwater. The Community Rating System encourages stormwater detention plans and gives credit for taking action.
CONCLUSIONS

Continually increasing runoff from uplands raises the base flood elevation and, as a result, adversely affects development in the NFIP mapped 100-year floodplain. Homes and business built to NFIP standards now flood in spite of the well-intentioned efforts of their owners. A comprehensive watershed plan or stormwater management plan may take years to prepare, cost millions of dollars, and, as a result, never be finalized and adopted. State and local decisionmakers need not wait for final plans, but can take action immediately. They can initiate greater cooperation with federal, state, and local agencies to aggressively incorporate existing programs and personnel into the county (parish) or municipal flood damage reduction efforts. Program constituents achieve their objectives, such as conservation of wetlands or abatement of nonpoint pollution, while floodplain managers reduce downstream floods.

In the evolution of all programs, periodic evaluation allows for refinement. A strategy of working more closely with related federal, state, and local programs raises the level of compliance of a county or municipal floodplain management program with two of the five general principals of floodplain management (Federal Interagency Floodplain Management Task Force, 1994):

Floodplains must be considered in the context of total community, regional, and national planning and management;

Resource management and protection typically focus on the specific resource, which may or may not occur entirely within the floodplain.

By reaching to include programs that affect upland activities, flood damage within the 100-year floodplain where NFIP regulations apply can be eliminated or significantly reduced.

REFERENCES


Achieving Consensus: Development of a Local Ordinance for Effective Floodplain Management

Mark A. Sites
ClasSickle, Inc.

Gordon R. Garner
Louisville and Jefferson County Metropolitan Sewer District

INTRODUCTION
Comprehensive watershed management in urbanizing areas is a complex and difficult task. Historically, floodplain management programs have typically focused on conveyance and minimizing property damage. Too often this approach has sacrificed the stream character and environment, particularly in urban areas, while not providing long-term solutions needed for floodplain management. When the Louisville and Jefferson County Metropolitan Sewer District (MSD) set out to update its floodplain ordinance, it desired to do so in a way that would protect the stream corridor while providing the necessary floodplain management for the future growth of the community.

PREVIOUS FLOODPLAIN REGULATION
Louisville and Jefferson County, Kentucky, have a lengthy history of development in floodplains and channelization to reduce flooding or provide additional land for development. With 96 incorporated cities in the county spread among nine upland watersheds and the Ohio River floodplain, floodplain management on a watershed basis was complicated politically and technically. As the county-wide drainage utility since 1987, MSD was addressing the demands to solve existing problems and at the same time develop planning solutions to prevent future problems. Like many communities, floodplain regulation in Jefferson County was based on its participation in the National Flood Insurance Program (NFIP). The local floodplain ordinance followed a Federal Emergency Management Agency (FEMA) model ordinance. Adoption of an ordinance to satisfy requirements of the NFIP was performed in 1978, with the perception created that by adopting that ordinance floodplain management had been
provided. No significant flood disaster had occurred in the 30 years prior to MSD beginning its effort to change the ordinance, and there was no community outcry for change. In general the community perceived flooding problems to be localized and the result of inadequate infrastructure.

BUILDING CONSENSUS FOR CHANGE

From its first day as the drainage utility MSD was deluged with demands by residents throughout the county to eliminate their flooding. The majority of requests were not related to structural flooding but basement, yard, and street flooding. With the use of its geographic information system (GIS) MSD determined that there were over 22,000 structures located in FEMA mapped flood zones and that over half of the capital drainage construction dollars were being committed to provide relief in areas constructed in floodplains, the majority of which were constructed within the last 30 years. In assessing the history of growth and the regulations governing it, the shortcomings of the NFIP-based ordinance, particularly for urbanizing areas, became apparent to floodplain managers. The primary problems that were observed included (1) future urbanization was not addressed; (2) filling in the flood fringe was not addressed; (3) only FEMA mapped floodplains were regulated; (4) site access was not addressed; and (5) no environmental considerations were made.

While the NFIP-based ordinance was sufficient for FEMA requirements, MSD concluded that new, more restrictive floodplain regulations were necessary for future management of the county’s watersheds. To develop public and political support for change MSD initiated preparation of a Multi-objective Stream Corridor/Greenways element for the county’s revised Comprehensive Plan in the spring of 1993. A Greenways Advisory Committee (GAC) was established to make recommendations for a multi-objective strategy of stream corridors, including new regulations.

GAC meetings were facilitated by Chuck Flink of Greenways, Inc., with explanations of technical issues facilitated by Ogden Environmental. All meetings were open to the public and opportunity for their input was provided at each meeting. The GAC consisted of representatives of elected officials, government agencies, the development community, the environmental community, and business leaders. The GAC was empowered to have the final decision on establishing the goals and objectives for future regulations with each member having an equal vote.

The GAC was presented background information on multi-objective planning, and the experiences of communities such as Denver, Colorado;
Tulsa, Oklahoma; Raleigh, North Carolina; and others were presented. In the presentation of the concept of multi-objective planning there were misperceptions that MSD was attempting to get into the trail business, taking private property, etc. In letters to elected officials, the Home Builders Association of Louisville (HBAL) asserted its opinion that MSD had authority only “to enforce the existing law,” and that its attempts at environmental regulation were being done “despite the lack of any lawful authority.” The local political mood toward regulation mirrored the national sentiment in 1993, that is, no more was wanted, and enacting environmental regulation without the benefit of state enabling legislation or federal mandate was not politically viable. It was MSD’s belief, however, that improved environmental protection for stream corridors would be a de facto product of appropriate regulations for floodplain development.

Key points were communicated to the GAC. First, the NFIP standards permitted construction of homes and businesses as long as the first floors were above the 100-year base flood elevation. Yards, driveways, parking, streets, and unfinished lower levels would flood. The frequency of this flooding could be less than a 100-year storm, even several times a year, and this was not acceptable to the community. Second, floodplain filling, especially when combined with no allowance for future development, guaranteed the expansion of floodplains. For urbanizing areas this dooms regulation to failure. Third, correcting this type of flooding would require structural controls to, in effect, make pre-existing floodplains go away, a public cost that would not have been considered had the homes not been constructed first. Fourth, in urbanized areas where stream corridors had been left natural no public money was needed for “improvements” and maintenance costs were almost non-existent.

In its plan the GAC called for a new ordinance to provide the following: a regulatory floodplain based on full watershed urbanization in accordance with land use plans; a conveyance zone (floodway) based on full urbanization; a requirement for 1:1 compensation for fill outside the conveyance zone; required access above the 100-year flood to and around new structures; a prohibition on channelization of streams and the preservation of stream side trees; and a minimum 25-foot vegetated buffer adjacent to streams. All of these goals were approved unanimously by the GAC members, and the final draft of the ordinance to codify these was endorsed by the Executive Board of the HBAL prior to its submittal for adoption.
RESULTS

By requiring consideration of future growth and floodplain storage, the new ordinance provided the needed regulatory framework upon which watershed planning could be based. As defined through the ordinance, floodplain limits are dynamic and may be modified through regional controls or overbank contouring in the flood fringe. In allowing these changes the ordinance did not prohibit development in the floodplain, rather it required that it be performed in a manner that would be cost-effective to the community in the long term. The ordinance permits more certainty for planning by developers, and provides a level of service for which the community had consensus. On March 1, 1997, Jefferson County experienced a greater-than-100-year flood event. Areas of recent developments where the new standards were applied did not have greater flooding, and in fact flooding appeared reduced as a result of overbank contouring performed in their construction.

The ordinance was monitored by opponents, who subsequently supported it, specifically to ensure it would not create additional environmental regulations. All proposed requirements were justified and supported on the basis of sound scientific principles, cost effectiveness, and public safety. In this way even opponents of new environmental regulations were able to support the standards in the new ordinance. These standards preserved stream channels and stream side vegetation, and promoted a fully vegetated floodplain. The ordinance does not provide specific means for environmental management of watersheds; however, the floodplain ordinance can provide the vital first step toward protecting the stream corridor, even for communities without progressive stream and water quality regulations.

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INTRODUCTION

Greensboro, North Carolina, is developing a "Dynamic Stormwater, Watershed, and Floodplain Management Program" to protect the resources of the community's watersheds. Components of the program include tools for proactive floodplain management built around existing public and private partnerships to eliminate existing problems and minimize future flooding. The City desires to create a Proactive Floodplain Management Program to meet today's needs while preparing for the challenges and opportunities of the 21st century.

Many of the tools may serve as models for other communities on the effective use of technology, particularly geographic information system (GIS)-based applications to automate hydrologic and hydraulic studies, floodplain and floodway identification, local government National Flood Insurance Program (NFIP) compliance requirements, and review of proposed modifications and encroachments in the regulatory 100-year floodplain. The Greensboro initiatives are thus envisioned to be a national model for potential Cooperating Technical and Project Impact Communities in effective, proactive, and comprehensive, watershed and floodplain management.
"DYNAMIC APPROACH" TO PROACTIVE WATERSHED AND FLOODPLAIN MANAGEMENT

The City of Greensboro is a growing community of 205,132 people located in the north central North Carolina. Over the next 15 years, the City and surrounding urbanized county area are expected to grow by 9%, resulting in a population of approximately 425,000 people.

Beginning in July 1994 with the creation of a stormwater utility, the City initiated development of a GIS-based Dynamic Stormwater and Watershed Management Program (DWM), which included monitoring of the local streams and watersheds; stormwater management planning and technological tool development; comprehensive watershed database development; extensive public outreach, awareness, and education programs; and related activities under implementation of the City's first NPDES municipal stormwater discharge permit.

This paper discusses the DWM GIS-based technical tools and applications, designed to facilitate the City's proactive efforts for watershed and floodplain management.

DWM PROGRAM

The DWM is based on scientifically and technically credible data, models, and policies that should result in improved water quality, enhanced aquatic habitat, and reduced flood damage. The foundation for the program is an innovative, open, and flexible GIS-based system that will allow users to identify the effects of proposed land use changes, management practices, and changes in conveyance systems on streamflow, flooding, water quality, aquatic habitat, and stream stability.

The DWM system provides a strong link between data, modeling results, and the technical basis for management decisions.

Phase I of the DWM program was the global positioning system (GPS) inventory of the drainage infrastructure and conveyance system in pilot watersheds and the creation of databases for use in later applications development. The City performed the inventory surveys of inlets, manholes, pipes, bridges, and culverts, as well as cross sections of the major open channel streams and drainageways. Condition assessments were made of drainage infrastructure features, while erosion areas and other natural features were identified along the open channel streams. All of the feature survey and attribute information was placed into a GIS, coupled with a robust relational database.

Phase II of the DWM, currently underway and scheduled for completion in early 2000, involves development of ESRI ARC/INFO®
GIS-based applications to utilize information from the GIS (digital orthophoto mapping and digital terrain models) and inventory databases to automate the hydrologic and hydraulic studies, to conduct water quality modeling to prepare watershed management studies, and to assist the City in the site plan review process. The watershed management studies will be digital, and all data can be accessed by a click on the screen, using simple graphical interfaces.

Phase III of the DWM, scheduled to start in 2000, includes detailed design and implementation of initial components of the stormwater, watershed, and floodplain management master plan on a prioritized basis.

The DWM System is modular in design and includes modules on (1) site development evaluation, (2) inventory, (3) hydrology and hydraulics, (4) digital master plan, (5) proactive floodplain management, (6) stream restoration, (7) benefit–cost analysis, and (8) water quality.

The DWM will allow the user to create hydrologic, hydraulic, and water quality models interactively using inventory and other GIS data. The user can evaluate effects of proposed new development on drainage, water quality, or flooding throughout the watershed. The DWM can be used to assist the City in reviewing proposed projects and to recommend site-specific mitigation measures, such as riparian buffers, and best management practices, including detention and flood control measures. Lastly, the DWM will be used to develop watershed mitigation measures, including stream restoration, flood control, regional stormwater management, property buyouts, elevation, and/or floodproofing of structures in the floodplain.

The Digital Master Plan Module will provide access to all recommended project data including calculations, cost estimates, and schedules, thereby replacing the hard copy technical addendums of the past. The Master Plan Module will be updated on a regular basis as components of the master plan change in scope or schedule or as new projects are added.
PROACTIVE FLOODPLAIN MANAGEMENT

Greensboro has participated in the NFIP since 1971 and is in good standing. The current Greensboro Flood Insurance Study (FIS) was primarily developed in 1985-1989 and is becoming outdated because of rapid urbanization. The FIS currently shows moderate risk at 100-year flooding, with approximately 800 structures in the floodplain, but a significant concern is development along unstudied streams and the potential for development occurring outside existing 100-year floodplains but within future-conditions 100-year floodplains. Being proactive today will better prepare Greensboro to handle future flooding hazards, thus moving a step closer to being a disaster-resistant community.

In the last several years, the City has experienced more frequent floods caused by rapid urbanization. Without a proactive floodplain management program that includes more stringent floodplain management requirements than FEMA's minimum standards, the City of Greensboro will likely become a repetitive flood-prone community.

Key components of the developing proactive floodplain management program include public and private partnerships involving stakeholder groups, consistent with the model for Project Impact, and enhanced risk assessment studies building upon the FIS and Flood Insurance Rate Map data. At the center of the enhanced risk assessment is the DWM System, which combines comprehensive relational databases that contain digital inventories of the drainage system (FEMA cross sections, GPS surveys of pipes and channels) with software applications that format the data for hydrologic and hydraulic (H&H) programs such as the U.S. Army Corps of Engineers' HEC-RAS and HEC-HMS models and the Environmental Protection Agency's SWMM software. The state-of-the-art software system includes both automated and semi-automated components. It includes interactive H&H modeling, automated digital floodplain mapping, a semi-automated floodway delineator, an automated benefit/cost analysis tool, and a semi-automated site development evaluation tool.

The software applications allow users to interactively evaluate the effects of development or encroachments on flood elevations throughout the watershed or evaluate alternative flood hazard mitigation measures. Combined with digital elevation certificates for all structures located in the 100-year floodplain and tied to georeferenced address fields, the risk assessment may be performed on a structure-by-structure basis.

Pre-disaster planning activities include development of future-conditions floodplains along all significant flooding sources, in addition to the development of associated stormwater and floodplain management ordinances that discourage development inside flood-prone areas.
Furthermore, by combining digital elevation certificates with the automated H&H modeling capabilities of the DWM, a flood hazard determination lookup function is planned for placement on the Internet to help homebuyers purchase properties with the best information on flood risk.

This same capability will be used as a component to improve the Community Rating System rating for the City and develop real-time flood warning information. Flood hazard mitigation planning before floods is to be evaluated on a watershed basis. By combining structure-by-structure risk assessment with automated H&H capabilities, the benefit-cost ratio of proposed mitigation measures can be evaluated. The mitigation measures to be evaluated include structural flood control measures; bridge and culvert crossing improvements; channel clearing; and elevation, relocation, acquisition, and floodproofing of structures.

By evaluating flood hazard mitigation measures on a watershed-wide basis, the City can develop a priority plan for improvements for local funding and can work with the state and FEMA to develop justified post-disaster projects to be funded under the Hazard Mitigation Grant Program. Post-disaster activities involve a collection of flood data to verify and recalibrate the H&H models and develop immediate damage assessments. This may be conducted by combining the automated H&H capabilities of the DWM with digital elevation certificates and the FEMA benefit-cost software.

Greensboro's proactive approach to watershed management is a model for local floodplain management in the 21st century.
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Part 3

Protecting & Restoring
Natural & Cultural Resources in Floodplains
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Multi-objective Management Criteria for Streambank Protection

Robbin B. Sotir
Robbin B. Sotir & Associates, Inc.

INTRODUCTION
Multi-objective management criteria are required to rebuild functions back into disturbed watersheds. It is a required step towards an effective long-term approach to solving problems and building sustainable, healthy systems. The broader context must be looked at to ensure that we understand the problem(s) and are treating the problems(s), not the symptoms. A number of integratable technologies, procedures, and measures are available to enable the watershed to recover its function and become self-sustaining. Obviously, this means that activities prone to causing damage at any level in the watershed are controlled or stopped altogether. These actions would be aimed at restoration to a sustainable system within the changed—reestablished—watershed, not the pristine pre-development stage.

RECLAMATION, RESTORATION, & REHABILITATION
These technologies broadly include the reconstruction of some or all of a watershed's natural structure and foundation and removing underlying causes of degradation. For sustainable streambank protection, these must include the upland slopes, streams, rivers, riverine corridors, and wetlands. In essence, restoration includes activities from single actions that solve local problems, such as vegetative plantings or rock toe protection, to comprehensive solutions aimed both at the site itself and at the sources of degradation throughout the watershed. The specific goals of any particular stream restoration and protection project should be defined within the context of the current conditions and disturbances, as well as understanding future changes in the watershed that will lead to rebuilding functionality in both the stream and the watershed system as a whole.

While some erosion is acceptable and beneficial as part of the natural system dynamics, much that has been created by human intervention is not. Human activities have contributed to changes in the dynamic equilibrium of stream and upland slopes. These activities center on
manipulating land and water systems for a wide variety of purposes, including domestic and industrial water supplies, irrigation, transportation, hydropower, waste disposal, mining, flood control, timber management, recreation, aesthetics, and more recently, fish and wildlife habitats. Increases in human population and industrial, commercial, and residential development also place heavy demands on the watershed. This has led to major losses in system functionality as a whole and specifically in stream channels. Various options are available to slow down, and often completely prevent, this degradation. While preventing damage and protecting healthy systems is paramount, after the damage has occurred, rebuilding functionality back into the watershed is the most effective long-term approach.

SOIL BIOENGINEERING

Various technologies from the engineering and environmental arenas have developed independently to develop solutions. Soil bioengineering represents one important entity and must be integrated with other technologies. It is based on sound engineering practice and integrated ecological principles. Soil bioengineering capitalizes on the benefits of vegetation for geotechnical, hydraulic and hydrologic slope stability aspects as well as erosion control. Environmental, water quality, and aesthetic values suggest opportunities for a more comprehensive approach, and less expensive from the life cycle perspective. It is a structural system that incorporates live plant materials and offers solutions that integrate with many engineering issues.

Numerous soil bioengineering methods have been adopted for a variety of multi-objective reclamation, restoration, and rehabilitation management applications in the watershed. This sound water management approach for rebuilding functionality back into systems aids in long-term stabilization, reduction of sediments that impact aquatic species and water quality, and creation of diverse upland, riparian, and aquatic habitat.

CASE STUDIES

The following case studies serve as examples of the use of soil bioengineering to assist in the reestablishment of function in stream and river channels where there has been local damage from over-recreational use, realignment, and major disturbance in the systems due to development in the watershed.

In conjunction with many other technologies, this procedure was used on several projects where environmental objectives were major concerns,
including Johnson Creek, a relocated stream in Portland, Oregon; and Longleaf Creek, a flood control project in Wilmington, North Carolina.

**Johnson Creek Relocation and Restoration**

Johnson Creek is located in the Portland, Oregon, metropolitan area. It is highly urbanized with land uses ranging from heavy industry to low-density residential. A survey of Johnson Creek revealed that, with few exceptions, stream banks are stable, heavily vegetated, and provide excellent riparian habitat and overhanging cover for the stream.

The Oregon Department of Transportation (ODOT) proposed relocating a section of Johnson Creek in the town of Milwaukee for bridge widening and new highway ramp construction. The relocated stream section would be about 20% shorter than the existing channel with a commensurate increase in gradient. A local committee, created because of concerns over water quality and aquatic habitat and an interest in restoring an anadromous fishery, was concerned about potential impacts of the stream relocation. This stream reach is in a highly visible location, and there was concern that the channel designed by ODOT would present a stark, sterile appearance and cause loss of habitat.

Robbin B. Sotir & Associates, Inc. (RBSA) was retained by ODOT to evaluate the proposed channel design for stability and for potential impacts to aquatic and riparian ecosystems, as well as to modify the design as needed to address the concerns voiced by the Johnson Creek Corridor Committee. The review determined that the proposed channel cross-section shape and gradient were too uniform and that the floodplain berms were too high. RSBA recommended changes to the channel to improve stability, water quality, and habitat value (Sotir and Nunnally, 1995). The channel cross-section was altered by lowering floodplain berms, incorporating a sub-channel sized to convey bankfull flows, and constructing a low flow channel to concentrate flows during the summer months. A pool-riffle sequence was created by widening the sub-channel and raising the invert by one foot in cross-over reaches and by lowering the invert by one foot in outside meander sections.

Streambanks were rocked to the ordinary high water elevation in the outside bends. Banks were installed with brushmattress, vegetated geogrids, live siltation constructions, and live fascines. The main stem and the adjacent sub-channel provide nesting and rearing opportunities for waterfowl and overhanging cover for fish.

The soil bioengineering systems were installed during the winter of 1993 and spring of 1994 with RBSA on-site. During the early spring and before the plants had established growth, the site experienced a 1,750 cfs
flood with mean velocities of 6–7 feet per second and maximum velocities estimated to be in excess of 10 feet per second. The soil bioengineering systems were secure, and by the end of the growing season they were providing excellent bank protection and habitat benefits. The project is now entering its fifth year and represents a recovering system.

**Long Leaf Hills Creek Stabilization**

This stretch of Long Leaf Creek is located in a well-forested residential neighborhood known as Long Leaf Hills Subdivision in Wilmington, North Carolina. The project is approximately 2,000 feet long. Streams in the Wilmington area, including Long Leaf Creek, have been altered by increased stormwater runoff due to development of the watershed. Increased flooding and high peak discharges have caused significant bank erosion and channel enlargement.

Compounding this and contributing to bank failure is seepage. In addition, the creek has been used as a dump site for organic garden debris, exacerbating erosional failures. These problems have caused degradation of the aesthetic and riparian corridor values in the creek. Public meetings illuminated the concerns about the existing conditions and the citizens’ interest in stabilization and restoration in terms of how they wanted to utilize and enjoy the creek.

Kimley-Horn & Associates, Inc., the prime consultant in Wilmington, and RBSA were commissioned by the City of Wilmington to develop a solution. The team prepared six conceptual alternatives, and matched these to the critical issues.

Soil bioengineering was selected because it fulfilled all the project goals. Long Leaf Hills/Hewletts Creek is presently under construction and is expected to be completed by the spring of 1999. Monitoring will be performed to evaluate the stabilization and restoration development.

**Summary**

This paper illustrates the useful integration of soil bioengineering in restoration, rehabilitation, and reclamation in a watershed and specifically for the incorporation of multi-objective management criteria to rebuild environmental function into stream channels.

**References**

When historic structures are located in high-risk flood-prone areas, and community leaders decide to take action to protect the historic character of their community, mitigation measures must be compatible with these desires. Such is the case in the City of Darlington, Wisconsin. Darlington is a small community in southwestern Wisconsin. The city was first settled in 1836 as a main commercial point along an early route between Galena, Illinois, and Mineral Point, Wisconsin. The region was one of the first European settlements in Wisconsin in the early to mid-1800s due to development of a lead and zinc mining industry.

This region of southwest Wisconsin, northeast Illinois, and eastern Iowa and Minnesota—which has been termed the “driftless area”—was never covered by glaciers during the period of glaciation in the Midwest. As a result, the landscape in this region comprises high, steep hills and narrow, steep tributary valleys flowing into a broad flat floodplain valley floor. Unfortunately, as the community of Darlington grew, downtown development occurred on one of these broad floodplains of the Pecatonica River. As a result, flood damage to the downtown businesses and homes along the river became a common occurrence. Repeated flooding over time led to deterioration in many downtown buildings. After experiencing severe flooding in the past 50 years, with four major floods in 1950, 1969, 1990, and 1993, the city officials, citizens, and business owners decided they could no longer sit by and let nature decide the future of their community.

The City developed a comprehensive flood mitigation plan that included a downtown rehabilitation and flood mitigation project. After the 1990 and 1993 floods, the City applied for and received funding through
the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program. Funding for the local match was provided by Wisconsin Division of Emergency Management (WEM) and the Wisconsin Department of Commerce. In 1994 the Wisconsin State Historical Society nominated Darlington's historic Main Street Central Business District to the National Register of Historic Places. The Main Street Historic District includes 51 buildings (11 non-contributing) within a six-block area. The buildings are narrow and deep, primarily two-story masonry on stone foundations or basements constructed between 1858 and 1940.

A study was completed to identify flood mitigation measures for 41 businesses the City identified for the downtown floodproofing program. The ongoing, multi-year project combines historic preservation with innovative floodproofing techniques. Instead of moving the downtown district, the project included in-place floodproo9ing and rehabilitation of buildings in the downtown historic business district.

The approach used for Darlington was to find a way for the government agencies, building and business owners, and the City to arrive at a consensus on how to accomplish four major objectives: (1) preserve the historic downtown business district; (2) restore the downtown economic base; (3) develop an urban river space park and recreation area; and (4) eliminate or substantially reduce flood disaster in the future. The flood mitigation effort was an integral part of the major objectives program to reduce future risk of flood loss to the greatest extent possible with the available federal and state funds, and to comply with state and local floodplain zoning regulations.

A second, and equally important indirect part of the flood mitigation program was to preserve the historic nature of Main Street and reestablish the economic base of the business district. Wisconsin floodplain regulations for historic structures/districts and the unique approach to the project to preserve downtown Darlington led to an agreement between the Wisconsin Department of Natural Resources (WDNR) and the Wisconsin State Historical Society (WSHS). The WDNR-WSHS agreement represented a compromise in relation to the normal floodplain regulations. State regulations normally require the first floor to be raised to a minimum of 2 feet above the base flood elevation (BFE), to what is referred to as the flood protection elevation (FPE). A federal rule change that was incorporated into the state program allowed historic buildings to receive variances from dimensional standards in order to maintain historic designation as a consequence.
The level of protection standard developed for the historic district required three actions: (1) fill the basement if applicable; (2) raise the first floor to the BFE; and (3) dry floodproof the first floor to the FPE (two feet above the BFE) by constructing a perimeter floodproof wall and raising the electrical and mechanics. The agreement represents a cooperative understanding between the two agencies to meet the intent of the state and local floodplain zoning regulations while preserving the historic nature of the buildings.

The agreement allowed existing building windows and doors, which are part of the exterior historic façade of the buildings, to remain intact or restored to historic detail. This created a dilemma of how to maintain the historic entrance to the building well below the flood level for historic purposes and raise the first floor several feet higher. To resolve this problem a vestibule or foyer was built just inside the front door at street level with an inside floodwall and floodshield separating the vestibule or foyer from the raised first floor with a stairs leading to it (Figure 1).

![Diagram](image_url)

**Figure 1. Vestibule flood shield.**
The vestibule was constructed with materials that would not sustain flood damage, i.e., ceramic tile, brick, cements, etc. The vestibule would be allowed to flood. After a flood, the area would be washed out and cleaned up with virtually no significant flood damage. A flood shield would be placed at the raised first floor entrance at the top of the stairs. The shield is a cast aluminum plate with pressure-locking handles that seal the plate tight against rubber gaskets in the opening frame. The height of the barrier would be at the FPE, which is the height of the floodproofed perimeter wall. A subfloor inside perimeter drain tile was installed as a secondary measure. The drain led to a common sump pump for a group of buildings. The WDNR and WSHS reviewed and approved specific designs for each building to verify compliance with the floodplain and historic preservation regulations. The flood mitigation recommendations were variations of the basic requirements and were reviewed and approved by the WDNR, WSHS, FEMA, and WEM during the development process.

Alternatives were developed for buildings where circumstances would not allow full compliance with the WDNR-WSHS agreement or the floodplain regulations. For example, some buildings could not comply due to building specific conditions, e.g., the first floor could not be raised to the BFE without raising the second floor. Lower floor elevations, based on a minimum ceiling height of 8 feet, were proposed and approved by the reviewing agencies. The other criteria of filling the basement and dry floodproofing to the FPE were maintained. Implementation of mitigation recommendations bringing the building into compliance with the WDNR-WSHS agreement would result in the building status being changed from a "non-conforming" to "conforming" for future zoning considerations.

The mitigation program paid for the code requirements on the first floor, with the property owner covering the code requirements for the second floors and above. Due to past flood damage, age, and deferred maintenance, many of the buildings were in need of considerable repair and even reconstruction. Before any mitigation funding would be provided on a structure, the basic structure had to be sound. The building owners had to make a commitment to correct certain maintenance items in order to be eligible for mitigation funding. Property owners covered the costs for rehabilitation and historic preservation of the buildings.

The historic structures were also brought into conformance with current building codes including the American Disabilities Act (ADA). How to meet the ADA requirements was a major issue. The building and business owners realized a commonly shared concrete handicap access ramp constructed in the back of the buildings with individual entrances to
the businesses was a viable solution to the ADA requirement. The handicap ramp also served a dual purpose in that it also provided a buffer from floating flood debris and it eliminated the need for an individual flood shield for each business's back entrance. A floodwall and shield was provided as part of the ramp. Some buildings did require individual ramps.

Based on the funds available, the City has floodproofed 14 buildings and work is in progress on five others. Remaining buildings have higher elevations and will require less extensive floodproofing methods. In addition to floodproofing commercial downtown businesses, mitigation measures were also completed on 52 residential structures. The City also acquired 12 commercial structures, several with environmental concerns, and developed an alternative site for business operations on a 33-acre parcel on higher ground. The acquired properties have been converted into recreational use.

The City of Darlington has worked continuously and aggressively to mitigate and reduce flood damage to businesses and residents. So often regulatory issues look good on paper, but in the real world do not accomplish what is intended. This project encountered its own challenges and flexibility was imperative to its success.

The Darlington mitigation project is a prime example of what can be achieved by long-term planning and the cooperation of city officials, local business owners, and concerned citizens. The project was a cooperative effort among many agencies including the Federal Emergency Management Agency; Wisconsin Division of Emergency Management; Wisconsin State Historical Society; Wisconsin Departments of Natural Resources, Administration, and Commerce; the Economic Development Administration; and the Southwest Wisconsin Regional Planning Commission. The City was honored with a State Historical Society of Wisconsin Historic Preservation Achievement Award on May 9, 1998. The architectural and engineering firm hired for the project received a state award for special categories through the Association of Building Contractors. "Darlington, The Pearl of the Pecatonica" . . . where the river flows and opportunity grows!
The Federal Emergency Management Agency, Region 10
Policy on Fish Enhancement Structures in the Floodway

Charles L. Steele, Carl L. Cook, Jr., Mark G. Eberlein
Federal Emergency Management Agency

The balance required between anadromous fish and the human environment is unique to the Northwest. Maintaining that balance often makes implementing regulations a challenge. Sometimes the local, state, and federal regulations contradict each other. This is the case with the National Flood Insurance Program (NFIP) and fish enhancement structures such as fish weirs, single log drops, root wads, and small rock deflectors.

FEMA’s regulations require communities to prohibit encroachments in regulated floodways unless accompanied by a no-rise analysis that demonstrates the project will cause no rise in the 100-year flood level. The current and proposed listing of certain anadromous fish species as Threatened or Endangered requires the restoration of their habitat to ensure their survivability. Restoring that habitat often entails encroaching in the floodway. A strict interpretation of this standard could require a relatively expensive analysis that might exceed the cost of the enhancement project.

FEMA recognizes this. While we believe the best course of action is to preserve the floodway encroachment standard as it exists, an informed judgment regarding fish enhancement structures can be made about exceptions for which less than the maximum hydraulic analyses are required. A community official often does not have the qualifications to make an informed judgment regarding the impacts of these structures on flood hazards. Therefore, FEMA will allow the community to defer to the “judgment” of a qualified professional regarding such impacts. Such qualified hydraulic or hydrology professionals would include staff of Rural Conservation and Development and the Natural Resources Conservation Service. It would also include similarly qualified staff of fisheries, natural resource, or water resources agencies. Though these professionals may advise a community, it is the community itself that will make the ultimate judgement.
The qualified professional should, at a minimum, provide a feasibility analysis and certification that the project was designed to keep any rise in 100-year flood levels as close to zero as practically possible and that no buildings would be negatively impacted by a potential rise. Additionally, routine maintenance of any project would be necessary to sustain conveyance over time and the community should commit to a long-term maintenance program in their acceptance of the project. FEMA also recommends a condition be placed on the projects emphasizing the dynamics of a river and, if the community deems necessary, further analysis be required.

We believe this is preferable to trying to specify in the community’s ordinance language all the different types of fish enhancement structures that may not need to comply with the “no rise” standard. Typically, any rise caused would require some offsetting action such as compensatory storage, channel alteration, or removal of existing encroachment. One of these alternatives would be appropriate to compensate for any rise and still preserve the integrity of the floodplain standards.

FEMA Region 10 feels this policy is in keeping with the concept of wise floodplain management. By implementing this process for approving fish enhancement projects, a community will satisfy the requirements of the NFIP.

**SUPPORTING DATA FOR FEMA, REGION 10’s POLICY**

FEMA’s regulation that governs development in the floodway says a community must prohibit encroachments, including fill, new construction, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses performed in accordance with standard engineering practice that the proposed encroachment would not result in any increase in flood levels within the community during the occurrence of the base flood discharge (44 CFR 60.3 (d)(3)).

The most conservative and safest way to accomplish this is to utilize a computer analysis of the hydraulic effects of the project. Lesser evaluations include hand calculations, comparisons to similar projects, and visual judgments. However, because the cost of a computer analysis ($5,000–$10,000) often far exceeds the cost of the project, all parties are reluctant to require one for these inexpensive projects. This analysis requirement may appear onerous, particularly for fish enhancement projects such as fish weirs, single log drops, root wads, and small rock deflectors.
FEMA is becoming more sensitive to the fact that these fish enhancement structures, while contributing to the protection and enhancement of the natural and beneficial functions of the floodplain, may be contrary to the letter of the floodway standard. FEMA is trying to walk the fine line of preserving floodwater conveyance while at the same time promoting actions that increase habitat, reduce erosion, and protect the floodplain values of recreation, water quality, and vegetative growth. In fact, a few years ago, FEMA responded to two Presidentially declared disasters in Oregon and Washington based on declining salmon harvests.

The community must remember that a "typical" enhancement project will have varying impacts on the floodway of different streams. Since most enhancement projects are on the smaller streams and in the upper watershed, the impacts are often indiscernible. However, with the listing of salmon as a threatened/endangered species, fish enhancement projects in urban areas may become more prevalent. These urban streams are often small and any encroachment into them may cause a discernible rise. The community must carefully evaluate the impacts of the fish enhancement project on neighboring properties, especially if a comprehensive no-rise analysis is not performed. If some type of negative impact may occur, the community would best be served to require a full analysis in order to ensure no such impact affects surrounding properties.

Managing its floodplain is a condition a community agrees to for participating in the National Flood Insurance Program. Floodplain management is a decision-making process that aims to achieve the wise use of the floodplains. Wise use of floodplains incorporates activities that are compatible with both the risks to human life and property from floods and the risks to the floodplain's natural functions posed by human activities. Often communities will weigh the risks against each other instead of with each other.

For example, after a flood, large woody debris is left strewn on the floodplain. This large woody debris could potentially damage structures during the next flood. However, it also could be providing natural bank protection and habitat for riparian-dependent species. The community must decide to either remove the debris or leave it in place. In seeking advice from other local, state, or federal agencies, the solutions provided sometimes conflict with each other. By removing the debris, the community reduces the risk to property but increases the risk to the floodplain's natural function. Sound floodplain management requires the community to balance the relative costs and benefits of each use and to decide how to best use the lands and waters.
The decision is not clear-cut, but is often situation dependent. The decision must be based upon a careful consideration of all impacts, including direct, indirect, short-, and long-term. Wise use would also require a solution that preserves and restores the natural resources of floodplains as much as possible while still minimizing the loss of life and damage from flooding. This means thoroughly understanding the intent of local, state, and federal floodplain or floodplain-related regulations.

A community’s floodplain ordinance empowers it to make a wise decision. For the situation mentioned above, a solution may be to move the large woody debris to another location where there is no potential to damage property, yet maintain the ecological value of the woody debris. Alternatively, it could be left in place and anchored with cables so that it floats as floodwaters rise and fall, and therefore is prevented from being propelled downstream against any structures.

FEMA regulations also require communities to ensure that the flood-carrying capacity of any altered or relocated portion of a watercourse be maintained (44 CFR 60.3 (b)(7)). However, FEMA recognizes that watercourses are either natural or human-made. The community’s program need not treat natural channels and human-made channels similarly. Natural channels have a wider area in which to flow. Trees and small log or debris jams can be accommodated by minor diversions of flow without causing any problems. Human-made channels are designed to use less area to carry more water and do not have the room to carry overflows caused by blockages. Too much vegetation is considered “debris” in human-made channels. Removal of such “debris” is required to ensure that the channel performs as designed. If a natural channel is altered in any way, that altered channel must be maintained based upon its new design. If a human-made channel is altered back to its natural state, then it must also be maintained as designed.

Finally, a community’s floodplain ordinance requires it to review proposed development to assure that all necessary permits have been received from those governmental agencies from which approval is required by federal or state law (44 CFR 60.3 (a)(3)). The State of Oregon has a joint permit application used by the Division of State Lands (DSL) and the U.S. Corps of Engineers (COE). Other states may have similar agreements. These applications often require comments from the local community on the consistency of fish enhancement projects with the local comprehensive plan. This includes compliance with the floodplain ordinance. Only the community reviews fish enhancement projects with regard to flood impacts. The COE and state agencies, such as DSL, do not
review these projects for their impacts on structures during a 1% chance flood.

FEMA embraces fish enhancement projects as being supportive of the natural and beneficial functions of the floodplain. FEMA also realizes that finding the best solution is often a murky business. While FEMA stands ready to provide advice to the community, the community itself must implement a decisionmaking process that chooses between competing uses, balances them against the various costs, and makes a wise decision based upon that particular floodplain's social, natural, physical, and economic condition. By implementing such a process for approving fish enhancement projects, a community will satisfy the requirements of the National Flood Insurance Program.
Heatherridge Stormwater Detention Basin: A Follow-up of Wetland Mitigation—Success or Failure?

Ruben W. Haye
City of Tulsa Department of Public Works, Engineering Services Division

INTRODUCTION
The Heatherridge Storm Water Detention Facility was constructed by the City of Tulsa as a joint multi-purpose project with Oklahoma Turnpike Authority (OTA) in 1995. The construction of the Creek Turnpike by the OTA created a southern loop road (toll road) around Tulsa, which damaged natural wetland areas (HNTB, 1988). Section 404 mandates required that any natural wetlands damaged during construction of the turnpike be replaced (HNTB, 1989). The Heatherridge project is a part of that mitigation effort. The wetland plantings, which were completed in May 1996, are now in their third year of growth. This paper describes which wetland plantings have thrived and those that have not, maintenance efforts, benefits of flood control from a recent 90-year storm event, and apparent water quality benefit.

BACKGROUND
During the design of the 6.9-mile Creek Turnpike, approximately 15 acres of impacted wetlands were identified. The identified wetlands had the following classifications: intermittent wetland, emergent wetland, riverine lower-perennial wetland, unconsolidated bottom system, open water wetland, and forested wetland. Approximately 7.8 acres of impacted wetlands were located on the west side of the Arkansas River, with 7.2 acres located east of the Arkansas River primarily within the Fry and Vensel Creek drainage basins.

In accordance with Section 404 permit requirements, OTA agreed to mitigate the loss of 15 acres of wetlands by creating 45 acres of new wetlands.
HEATHERRIDGE DETENTION BASIN

The Heatherridge Detention Basin is one of four facilities recommended for flood control in the Fry Ditch II Drainage Basin. It is situated on a 25-acre tract of land. The detention basin was designed for the 100-year frequency storm. The drainage area is 240 acres. Inflow is 1276 cubic feet per second (cfs), and outflow will be 38 cfs. The volume of flood storage is 115 acre-feet. The bottom is a small lake covering approximately 11 acres with a normal pool elevation of 679 ft mean sea level. Water levels will be maintained by an outlet control structure.

The detention facility will (1) reduce flooding to 21 homes, and (2) reduce runoff due to urbanization in the watershed, including the turnpike.

WETLAND MITIGATION

Approximately 15 acres of emergent marsh is created by this facility. A clay liner to minimize percolation and to keep water surface elevation stable has been added. An overburden of 1 ft of organic soil has been placed to support vegetative growth.

Four zones of wetland plants were planted. Zones 1 and 2 are the shallow depth wetland zones. Plantings in these zones are prairie cord grass and switch grass, soft rush, blue flag iris, common three square, and rice cut grass. Zones 3 and 4 are the mid-depth wetland zones. Plantings in these zones are arrow arum, lizards tail, smartweed and soft stem bulrush, pickerel weed, and sago pond weed. To provide diversity, plants in each zone were randomly mixed. All vegetation was supplied either bare-root or in 2½ pots planted on 2 ft centers.

A buffer zone of hardwood trees was planted. One-gallon container nursery stock, 20” to 30” in height, was planted on 10 ft centers in randomly shaped masses around the marsh. Fifteen different types of trees were planted: green ash, boxelder, black cherry, common mulberry, American elm, hackberry, honey locust, Chinquapin oak, northern red oak, Shumard oak, sweet pecan, sycamore, black walnut, black willow, and Eastern redbud.

A two-year vegetation maintenance program was implemented upon completion of the plantings to assure a successful mitigation effort. Maintenance included (1) watering weekly for the hot months, May through September, and watering as needed to keep plants moist in the other months; (2) removal of weeds as necessary; (3) removal of litter and debris as necessary; and (4) replacement of dead plant material annually. The goal of the maintenance program is to have at least 70% of the planted vegetation alive at the end of five years.
SUCCESS OR FAILURE

In mid-May 1999 we conducted a field review of the vegetative plantings. Plants in Zone 1 were planted around the perimeter of the highest elevations and consisted of prairie cord grass and switch grass. Only sporadic occurrences (3 or 4 clumps) of switch grass were observed and no occurrence of prairie cord grass was observed. Based on this review the stand would be considered a failure.

Planting in Zone 2 included soft rush, yellow iris, common three square, and rice cut grass. All species in this zone, except rice cut grass, were quite evident and are estimated to have a survival rate in excess of 80%.

Plantings in Zone 3 consist of arrow arrum, lizard tail, smartweed and soft stem bulrush. All species appear to be established enough to consider the stand to be successful.

Plantings in Zone 4 consist of pickerel weed and sago pond weed. Pickerel weed is prolific. However, sago pond weed is not growing as anticipated and would be considered a failure.

In the hardwood buffer Zone, 926 trees were planted. Originally the plan was to plant 50 black willow. However, during the time between construction of the detention basin and the plantings, black willows had begun to infill. Over 100 willows had begun to grow. These plantings were therefore deleted. During the first two years, 140 trees died. These were replaced with larger caliper trees.

It is our opinion that the one-gallon size trees were too small to complete with the prolific native grasses, i.e., Johnson grass. Our ongoing maintenance effort is to replace dead trees with 1” to 2” caliper trees. The trees that have had the best growth success are honey locust, box elder, common mulberry, green ash, and sycamore. The oak trees—Chinquapin, northern red, and Shumard—have not been successful. The Chinquapin oak has the worst survival rate of the three. The other trees are thriving as planned. We have done selective thinning of the willows to assure growth of the other trees.

In summary, the majority of vegetative planting and trees are in good condition and are present in sufficient quantities to insure an adequate stand.

The benefits of flood control have been observed several times over the last four years, the most recent being October 5, 1998. Over the Fry Ditch II drainage basin 6.1” of rain fell in six hours. This equates to about a 90-year frequency event. This facility, combined with the effects of the Bridle Trails detention basin, eliminated flooding to 20 homes. Overbank
flooding was generally less than one foot. The one home that experienced flooding has a floor slab less than 1 ft above the adjacent creek bank.

We are currently implementing plans to test the water quality of the effluent from our project. We have not done enough sampling to establish a trend, however, Table 1 does show some positive results. These results are from a ½" rainfall in February 1999. Other samplings will be made during the spring and summer growths of the vegetation to test the effects on filtering of various pollutants from the basin runoff.

The table shows significant reduction in suspended solids, phosphorous, cadmium, fecal coliform, nitrogen, BOD, and COD loadings. Therefore we believe we can conclude that over the long run, the wetlands planting will show a water quality benefit.

<table>
<thead>
<tr>
<th>Item</th>
<th>Influent</th>
<th>Effluent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia-N mg/l</td>
<td>0.27</td>
<td>0.29</td>
</tr>
<tr>
<td>Cadmium (T) microg/l</td>
<td>5.50</td>
<td>&lt;3.00</td>
</tr>
<tr>
<td>Fecal Coliform N/100ml</td>
<td>3100</td>
<td>2600</td>
</tr>
<tr>
<td>Lead (T) microg/l</td>
<td>5.1</td>
<td>1.7</td>
</tr>
<tr>
<td>Nitrate + Nitrite mg/l</td>
<td>0.81</td>
<td>0.681</td>
</tr>
<tr>
<td>Oil &amp; Grease mg/l</td>
<td>158</td>
<td>197</td>
</tr>
<tr>
<td>BOD mg/l</td>
<td>5.8</td>
<td>2.6</td>
</tr>
<tr>
<td>COD mg/l</td>
<td>66</td>
<td>39</td>
</tr>
<tr>
<td>Phosphorous (T) mg/l</td>
<td>0.408</td>
<td>0.128</td>
</tr>
<tr>
<td>Phosphorous (D) mg/l</td>
<td>0.184</td>
<td>0.08</td>
</tr>
<tr>
<td>Dissolved Solids (T) mg/l</td>
<td>147</td>
<td>229</td>
</tr>
<tr>
<td>Suspended Solids mg/l</td>
<td>310</td>
<td>56</td>
</tr>
<tr>
<td>Total Kjeldahl N mg/l</td>
<td>2.12</td>
<td>0.848</td>
</tr>
</tbody>
</table>

_table 1. Water quality data from February 1999 (VanLoo, 1999)._
CONCLUSION

We believe our efforts at wetland mitigation have been successful. Ducks and geese are raising their young on the islands provided by this project. Bullfrogs were observed in the water. White and blue cranes are frequenting the area. Redwing blackbirds are nesting nearby. Purple martins and other bird species have been observed flying over the lakes.

Ruppert Landscape Company, which planted the trees and wetland plantings, received an Award of Excellence in Landscape in the category of Ecological Planting from the Landscape Contractors Association.

The unique nature of the Heatherridge Storm Water Detention Basin and constructed wetlands is an example that dual-purpose projects can benefit our citizens and the natural environment.

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1989 "Creek Turnpike Designed Mitigation Plan." Tulsa, OK: HNTB.

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1999 Water Quality Data. City of Tulsa Environmental Services.
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Part 4

Community Assistance for
the National Flood Insurance Program
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Comprehensive Community Assessment Visit Pilot Project

Frank A. Pagano
Diane L. Calhoun
John P. Ivey
Timothy A. Hart

Since 1978 a total of 208,174 buildings have been paid flood insurance losses under the National Flood Insurance Program (NFIP) and 76,284 buildings have suffered repetitive losses. The states of Louisiana and Texas rank numbers 1 and 2 in the country for the number of flood insurance claims and the amount of claims paid. Approximately 1900 communities in the Federal Emergency Management Agency's (FEMA's) Region VI participate in the NFIP and all five states in the region have experienced recent flooding disasters. Historically, regular visits to local floodplain management officials have helped to prevent compliance problems from occurring and encourage good floodplain management practices.

A major goal of the federal/state disaster response effort after a flood is to evaluate the floodplain management program of each flooded community and provide guidance to flooded communities about substantial damage provisions and post-flood responsibilities. FEMA introduced a number of innovative disaster response techniques after the October 1994 east Texas Flood and in 1998 a comprehensive report entitled the "NFIP-Site Assessment Visit Report" was prepared in response to Tropical Storm Francis and the Del Rio and the south Texas flood events.

Galveston County and the upper Texas Gulf Coast have had 14 major flood events after the devastating 1900 storm that was responsible for the loss of over 6000 lives in Galveston. Ten major storms have impacted the upper Texas Gulf Coast since 1957 or the equivalent of one major storm every four years. The highest recorded 24-hour rainfall in North America was 43 inches measured at Alvin, Texas, during Tropical Storm Claudette in 1979 and 30 inches of rainfall occurred during the October 1994 flood at Magnolia, Texas, in Montgomery County. Both storm events resulted in federal disaster declarations in the Community Assessment Visit Pilot Study Area.
FEMA selected Halff Associates, Inc. to assist in implementing a Pilot Comprehensive Community Assessment Visit or CAV Project. The high flood loss areas of Galveston and Harris and Montgomery counties, Texas, and St. Tammany Parish, Louisiana, were selected for the CAV Pilot Project. The CAV Pilot Project scope of work includes FEMA Manual 7810.4 “Procedures for Conducting Community Assessment Visits” and procedures to meet the Region’s Strategic Mitigation Plan.

The Pilot CAV Project consists of 4 phases:

(1) Preparation
(2) Community Visit
(3) Documentation
(4) Summary Report.

The county/parish-wide CAV approach allowed the consultant to document the floodplain management procedures adopted by neighboring communities and share the success and failure principles from community to community. Analysis of repetitive loss structures was a major part of the CAV Pilot Project. Repetitive loss lists were field verified for each repetitive loss structure to:

- determine if the structure was in compliance with the communities’ ordinance;
- determine why the structure was flooded; and
- identify mitigation possibilities.

The repetitive loss lists for the CAV Pilot Study Areas were being revised by both FEMA and the Federal Insurance Administration during the study period. Several versions of the repetitive loss list were available in hard copy and electronic format. The problems with the lists were:

- mailing addresses in lieu of actual structure location;
- incomplete or incorrect addresses;
- duplicate addresses (i.e., the same street has two names);
- city address for structures located in the unincorporated areas of the county or parish; and
- addresses where the structure has been removed.

The CAV preparation included a start-up planning meeting in the FEMA Regional Office, review of documentation from previous CAVs, review of flood insurance studies and mapping, Letters of Map Amendment, Letters of Map Revision, submit-to-rate reports, repetitive loss lists, and community information data provided by FEMA. CAV
checklists were prepared for each step in the CAV process and a CAV handbook was prepared to assist the CAV field team.

A floodplain tour was conducted before the community CAV meeting to locate possible violations to the community's flood damage prevention ordinance and identify possible floodplain mapping problems. Digital photographs were taken of possible violations and included in the CAV report.

The community CAV meeting typically was from one to two hours long and was followed by review of permit files, mapping, and documentation. On several occasions the community officials invited the CAV team to tour the floodplain areas to point out problems and successes. The overall community response to a CAV was one of support and community officials welcomed the assistance and/or guidance on floodplain issues and permitting procedures.

Individual community CAV reports were prepared following FEMA's 81-68 "Community Visit Report" and submitted to the FEMA Regional Office for review and follow up action. A county/parish CAV summary report was prepared at the completion of the CAVs in each study area.

At the completion of the Galveston County CAVs, a meeting was held with Texas Natural Resource Conservation Commission and the Houston Galveston Area Council, and six county-wide flood mitigation recommendations were identified that should reduce repetitive losses:

1. Adoption of a Standard Flood Damage Prevention Ordinance that includes higher regulatory standards (for all 15 communities in Galveston County);
2. Adjustment for subsidence in coastal flooding areas;
3. Prohibition of development in identified coastal areas based on the projected erosion rates subject to legal authority from a pending modification of Texas state law;
4. Adoption of a community mitigation plan or repetitive loss plan by every community;
5. Adoption of county-wide detention requirements; and
6. Development and support of training opportunities for local floodplain administrators.

The FEMA Region VI Office follow up included notification of legislative offices within the area, personal visits to each community, and a series of news conferences and news releases. Each community was provided a copy of the CAV findings (see summary in Table 1) along with a compliance schedule to resolve the possible violations. FEMA
Table 1. Summary of the Galveston County CAV Pilot Project for 15 Communities.

<table>
<thead>
<tr>
<th>Category</th>
<th>Detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
<td>251,253</td>
</tr>
<tr>
<td>Flood Insurance Coverage</td>
<td>43,119 policies with $5,083M coverage</td>
</tr>
<tr>
<td>Total Structures</td>
<td>83,751</td>
</tr>
<tr>
<td>% Coverage</td>
<td>51.48%</td>
</tr>
<tr>
<td>Average Flood Insurance Policy</td>
<td>$117,899</td>
</tr>
<tr>
<td>Total Claims</td>
<td>22,641 claims for $202M (since 1978)</td>
</tr>
<tr>
<td>Average Claim</td>
<td>$8,949</td>
</tr>
<tr>
<td>Repetitive Loss Structures</td>
<td>1,853</td>
</tr>
<tr>
<td>Average claims per structure</td>
<td>2.8</td>
</tr>
<tr>
<td>Substantial Damage Structures</td>
<td>1,264 (claims since 1978)</td>
</tr>
<tr>
<td>Ratio Claims to Policies in Force</td>
<td>0.53</td>
</tr>
<tr>
<td>Possible Violations</td>
<td>861</td>
</tr>
<tr>
<td>1316 Declarations</td>
<td>124</td>
</tr>
<tr>
<td>HMGP Projects</td>
<td>0</td>
</tr>
<tr>
<td>FMA Projects</td>
<td>1</td>
</tr>
<tr>
<td>ICC Claims</td>
<td>1</td>
</tr>
</tbody>
</table>

Local Floodplain Administrator Experience for 15 Communities

<table>
<thead>
<tr>
<th>Time in position</th>
<th>3.8 years average</th>
</tr>
</thead>
<tbody>
<tr>
<td>Less than 12 months</td>
<td>5 of 15</td>
</tr>
<tr>
<td>Less than 3 years</td>
<td>11 of 15</td>
</tr>
<tr>
<td>Attended FPM training</td>
<td>12 of 15</td>
</tr>
</tbody>
</table>

Summary of Problems discovered by the CAV Pilot Project for 15 Communities

<table>
<thead>
<tr>
<th>Problem Type</th>
<th>Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>A-1 Problems with FPM Regulations</td>
<td>5 of 15</td>
</tr>
<tr>
<td>A-2 Problems with Administration or Enforcement</td>
<td>11 of 15</td>
</tr>
<tr>
<td>A-3 Problems with FIRM</td>
<td>14 of 15</td>
</tr>
<tr>
<td>A-4 Other FPM Problems</td>
<td>10 of 15</td>
</tr>
</tbody>
</table>
provided each community with a formal notice that NFIP compliance is mandatory and a schedule for:

- Communities' response and submission of Resolution of Intent to Comply;
- Plan of action to correct any violations; and
- Deadline to complete compliance actions.

The FEMA Regional Office immediately received two certified Resolutions of Intent to Comply and numerous telephone calls from communities requesting assistance. The open communications between the communities and the FEMA Regional Office in addition to the Regional Office and the Headquarters Mitigation Directorate will continue to be necessary to accomplish compliance, and stop the continuing cycle of loss of property and life.
INTRODUCTION

In late summer 1998, the Federal Emergency Management Agency's (FEMA's) Region VII called the state National Flood Insurance Program (NFIP) coordinating agencies together for the purpose of reassessing the methods by which community understanding of and compliance with NFIP regulations and standards are measured and assessed. The consensus decision was to refocus the efforts of both FEMA regional staff and state NFIP specialists toward a more customer-friendly approach. Community Assistance Visits and Contacts (CAVs and CACs), with their emphasis on documentation of shortcomings in community floodplain management programs, were set aside in favor of efforts to prepare guidance and instructional materials and conduct seminars and workshops on topics considered by community floodplain managers to be most in need of clarification and explanation. Just prior to launching this effort, two floods occurred in Kansas that resulted in separate Presidential disaster declarations. These events could have put the education and training efforts on hold or scrapped them entirely. Instead, they provided an opportunity to launch a concentrated series of Community Program Assistance Visits (CPAVs) with NFIP participating communities in the declared disaster areas.

DEMOGRAPHICS OF THE KANSAS DISASTER AREAS

Two distinct flood disasters occurred in Kansas in the fall of 1998. The first occurred principally in the Kansas City metropolitan area on Sunday night, October 4, 1998. The second occurred over the Halloween weekend in south-central Kansas. Flash flooding was vividly televised from Arrowhead stadium in Kansas City, Missouri, but essentially the same storm produced significant flood damage in several areas of Kansas. As is often the case when a significant disaster occurs, other less damaged, but still significantly affected, areas were included in the declared disaster. Areas affected were as dispersed as the southeast and southwest corners of the state, some 100 to 350 miles from Kansas City, located in extreme
eastern Kansas. In all, some 12 counties with a total population of 848,300 were eventually included in Presidential Disaster No. 1254.

The second flood took longer to develop but affected a far greater area and considerably more people. Some of the same areas were affected, with an additional 16 counties and 753,000 more people eventually included in Presidential Disaster No. 1258. Almost the entire length of the Walnut River and its major tributary, the Whitewater, flooded in south-central Kansas. Two cities protected by extensive levee systems, Augusta and Arkansas City, were heavily damaged when the levees were either overtopped or breached. It is estimated that the damage in Augusta was over $100 per capita. In Wichita, Kansas' largest city, local tributaries of the Arkansas River rampaged after heavy rains, damaging numerous homes and businesses. Table 1 summarizes the demographics of the disaster areas.

<table>
<thead>
<tr>
<th>Table 1. Kansas 1998 flood disaster area.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total population</td>
</tr>
<tr>
<td>No. of communities</td>
</tr>
<tr>
<td>Est. population in SFHA</td>
</tr>
<tr>
<td>Total NFIP policies</td>
</tr>
<tr>
<td>Est. no. damaged structures</td>
</tr>
<tr>
<td>Est. no. substantially damaged</td>
</tr>
</tbody>
</table>

**COMMUNITY PROGRAM ASSISTANCE VISITS**

**Desk Reference**

The recent experience of Region VII FEMA staff in Georgia and Iowa disaster field offices demonstrated the value of providing a collection of pertinent information and guidance on floodplain management and the NFIP to community officials in the midst of recovering from a disaster. Readily available materials were compiled into a loose leaf binder and organized under 12 headings. Among the headings or tabs were: (1) Community Floodplain Management Tools, (2) State Statutory Requirements, (3) National and Regional NFIP Guidance, (4) NFIP Map Information, (6) Procedure Models, (10) Fact Sheets, (11) NFIP Technical Bulletins, and (12) Forms and Publications. In addition to the tabbed material, copies of selected publications were also included. While the
Turning Disasters into Opportunities

contents of this desk reference were not explained during a CPAV, the outline and general nature of the contents were reviewed.

**Conduct of CPAVs**

For numerous reasons, logistical and otherwise, the work effort was divided between FEMA and Kansas NFIP staff. FEMA personnel conducted CPAVs in the cities and counties that were part of the flash flood disaster in the Kansas City, Kansas/Missouri metropolitan area, while Kansas NFIP personnel concentrated their efforts in south-central Kansas. This division of labor resulted in exposure of state floodplain management specialists to more complex floodplain problems and state and local administrative arrangements than they had previously encountered. Two flood disasters in quick succession reinforced the need to approach community floodplain administrators in a helpful and friendly manner rather than with an eye to scrutinizing their floodplain management programs for flaws, inconsistencies, or shortcomings. Most, if not all, of these were painfully obvious after the flood. For example, only a few weeks before the October 4, 1998 flash flood, an official in one Kansas community within the Kansas City metropolitan area remarked that they had their flood problems under control. The flood damaged numerous homes and washed out several roads and bridges in that community.

**CPAV Report**

Each CPAV was documented by completing a 3-page report form. The form was organized under six headings: (1) community data; (2) floodplain activities, both pre- and post-disaster; (3) floodplain management regulations and procedures; (4) mitigation activities, (5) narrative assessment; and (6) future needs. A collection of “talking points” was included under each heading to guide the discussion and questioning during the CPAV.

**Follow Up Letters**

After each CPAV a brief letter was sent to each community visited. These letters were addressed to the official with whom the visit was conducted. Copies of the letters were always sent to the community chief executive officer and the county emergency management coordinator, and often to the community’s attorney and other officials involved in the community’s floodplain management program. When the CPAV revealed that the city was considering or in the process of updating its floodplain management
regulations, a model ordinance was also sent to the addressee. No action was required of the community following the CPAV, but if further contact with the community was judged necessary, this was noted on the report form.

**MITIGATION PLANNING**

One of the opportunities presented by the follow up with communities affected by the flood disasters was an exploration of the level of understanding and interest on the part of NFIP communities in mitigation planning. Community floodplain managers were asked how they understood the term “mitigation” and whether their communities were interested in or already involved in flood mitigation or multi-hazard mitigation planning. It must be stated that confusion and misunderstanding was widespread, although not universal or pervasive. The most common misconception appeared to be that mitigation involved what we in the profession would call preparedness, response, and recovery. In other words, mitigation was not commonly understood as a pre-disaster program, activity, or project. It is safe to say that a great deal of education on the subject of mitigation needs to be done before community officials, at least in Kansas, are well versed on the subject.

**NEEDS UNCOVERED**

While the CPAV process was not intended to thoroughly scrutinize the level of NFIP compliance in the communities visited, a reasonably accurate picture of how well communities understand and implement the goals of the NFIP has emerged from the process. Following the outline of the CPAV report form produced the summary information shown in Table 2.

<table>
<thead>
<tr>
<th>Table 2. Generalized results of CPAV process.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ordinances needing revision</td>
</tr>
<tr>
<td>Maps needing correction or revision</td>
</tr>
<tr>
<td>Floodplain managers interested in training</td>
</tr>
<tr>
<td>Communities generally NFIP compliant</td>
</tr>
</tbody>
</table>
The CPAV process was originally intended to provide FEMA Region VII with something of a snapshot of the general condition of NFIP compliance within the region. Although many of Kansas’ NFIP communities remain to be visited, current plans are to continue the process for the remainder of the present fiscal year and through the year 2000. This should complete the snapshot of Kansas. Along with the CPAV process, Kansas NFIP specialists have begun a series of tiered floodplain management workshops. These workshops will be conducted essentially on a monthly basis and be targeted toward beginning floodplain administrators, those with some experience who need a greater depth of knowledge on a wide spectrum of NFIP related topics, and those who express a desire for more training on specific subjects such as ordinance adoption and amendment, mapping and map revision, enforcement and compliance issues, the Community Rating System, and other topics.

In addition to the CPAV process, the Federal-State Interagency Hazard Mitigation Team, convened under provisions of the Stafford Disaster Relief Act, and the parallel State Hazard Mitigation Team, were each composed of many new participants who had limited prior experience with disaster events. Thus, training opportunities were provided for state agency personnel to learn how their responsibilities are affected by floods and other disasters. In short, the recent flood disasters in Kansas have provided numerous opportunities to expand and enhance training of both community floodplain managers and associated local officials, but also fostered interaction and cross-training among state agency personnel and a newfound mutual interest in the mitigation of floods and other natural disasters.
INTRODUCTION

In a post-disaster situation, it is necessary to determine whether communities are in full compliance with the National Flood Insurance Program (NFIP) regulations. Determining full compliance can also help qualify communities for the Flood Mitigation Assistance Program, the Community Rating System, and other Federal Emergency Management Agency (FEMA) programs. The major method used to determine full compliance is a post-flood Community Assistance Visit (CAV) by FEMA or the NFIP State Coordinator. The CAV is used to review the community floodplain management capabilities and verify the correct application of the NFIP. The CAV has become a time consuming exercise because it has many uses and the person conducting the CAV reviews many types of activities within the community.

The objectives of this project were to develop and field test a Digital CAV (D-CAV) reporting process that involves a standardized data collection format. The D-CAV contains community information, location and type of potential violations, and digital images (or photographs) that have been integrated into a geographic information system (GIS). The digital product can be linked to a FEMA Digital Flood Insurance Rate Map (D-FIRM) or other evolving technology. The user will be able to print a summary of the visit and an attachment of identified violations for the CAV follow-up letter. The D-CAV data will then be loaded electronically into the FEMA Community Information System (CIS) database. These features will reduce the duplication of work in completing the CAV report, letter to the community, and follow-up coordination activities.
In addition to developing the software, URS Greiner Woodward Clyde (UGWC) Federal Services will prepare a Technical Guidance Manual regarding the functions and operations of the D-CAV software, an evaluation report of the data collection process, and a list of minimum computer hardware and software requirements for future D-CAV data collection efforts. The guidance manual will be prepared for training and field use by FEMA and NFIP State Coordinators.

This project was developed under the direction of the FEMA Mitigation Directorate and FEMA Region V and in cooperation with the State of Illinois. Although this version of the software was developed in accordance with current state regulations, which exceed the minimum requirements of the NFIP for the six counties of northeast Illinois, the methods and programming were prepared with the intent that these could be used by all FEMA regional offices or NFIP State Coordinators. The software and technical guidance manual are being developed under the assumption that all potential FEMA or state users are familiar with the NFIP regulations and the CAV process. FEMA has also expressed an interest in field testing the software in another region, preferably one with coastal flood hazard areas.

BACKGROUND ON SOFTWARE

Before departing for the field, the user will copy GIS files and D-FIRM maps for the communities to be visited onto a notebook computer. It is recommended that only the map data for the communities to be inspected be loaded onto the computer to conserve hard drive storage space.

INITIAL AND D-CAV SCREENS

Once in the field, the user will launch the D-CAV software and be able to select a community name from a statewide list of communities and corresponding NFIP Community Identification (CID) numbers. After the community is selected, the D-CAV screen appears and prompts the user to set the session constants for that community's data collection. The constants include the inspector's name; inspecting agency; and the names, addresses, and telephone numbers of the community's Chief Executive Officer (CEO) and Floodplain Administrator. The software adds the current date in a “mm/dd/yyyy” format that is Y2K compliant. The constants will remain in effect until revised by the user and thus reduce the amount of data entry for each site included in the community inventory.
STRUCTURE AND PICTURES DATA SCREENS

The general data for the building or site being added to the D-CAV inventory of potential violations is included on this screen. During the inspection phase of the CAV, all violations are considered to be “potential violations” until the community responds to the issues raised by the CAV follow-up letter to the community. The GIS map for the selected community appears along the left side of this screen. The toolbar along the top of the map allows the user to zoom-in, zoom-out, identify street names, add an icon to the map for new records, or re-position the map within the viewing area. Street names will appear as the user zooms in on the map. Just below the map, a BIN or building identification number will appear for the current record. The BIN is based on the CID, the current date, and a sequential building number determined by the software.

Upon completing a D-CAV, the community GIS map will contain icons (small dots or squares) representing the inventory locations that have D-CAV data. A user will be able to click on an icon to open the record and view the data and digital images for a particular location after the data is entered and saved.

Structure data involves the street address (in two fields to facilitate sorting), a pull down menu allowing selection of one of 10 pre-determined building types (1-story without basement, 2-story with basement, manufactured home, etc.), type and relationship (attached or detached) of accessory structures such as sheds or garages, square footage, building and trim colors, and up to five digital images of the site. This screen also includes navigation and function buttons for switching to other screens, opening the picture file, moving back and forth among completed records, editing existing records, adding new records, saving the data, and exiting the software. The Picture Screen carries over the site address and allows the user to view, add digital images or include comments on the contents of the images.

POTENTIAL VIOLATION DATA

This screen is partitioned into five different areas through two main tabs and four sub-tabs. Under the first main tab, the sub-tabs for Residential Categories 1 and 2 provide data fields for selecting the foundation type (slab, basement, etc.), site location with regard to the floodplain and floodway, type of construction (existing, addition, or new), whether construction should be considered as substantial improvement or substantial damage, and debris type and location (hazardous, non-hazardous, Zone AE), if present. The data fields under the sub-tabs for
Non-residential Categories 1 and 2 request similar data for non-residential buildings.

The second main tab on the Potential Violations screen allows the user to enter data for multiple violations at a site into a table containing three columns. The first two data entries are selected from two pull-down menus. The first column involves 21 items for Potential Violations and six location descriptions (floodway, Zone AO, etc.). The user highlighted data for these two fields appears in the first two columns of the table. The third column is titled Description and requests that the user enter data that further describes the potential violation, identifies items for further investigation, or recommends actions for resolution.

The data collected on the Potential Violations screen represents the information that the D-CAV and follow-up actions will be based upon. Therefore, it is critical that this data be filled in completely and accurately as it will be printed and provided as an attachment to the cover letter to the community’s CEO and Floodplain Administrator. The letter will request information, data, or provide comments on items identified as potential violations in the D-CAV report.

**SUPPORT DATA SCREEN**

The Support Data screen provides choices for the user to select data that is required from the community for its response to the list of potential violations presented by the inspector. The possible selections here include building plans; state or local floodplain management or development permits; copies of FEMA LOMAs, LOMR-Fs, or LOMRs; pre- or post-construction elevation data; substantial damage or substantial improvement determinations; plat of survey; subdivision plat map; site plan; compensatory storage computations (if applicable); floodproofing certificate; and calculations for the size of the openings in flow-through foundations.

**COMMUNITY VISIT REPORT—PARTS A AND B**

These screens replicate Sections A and B of the current FEMA Community Assistance Visit Report (FEMA Form 81-68, January 1992). The data entered in the software will be printed out in a completed, electronic version of this two-sided form for Sections I through IV. Sections I and II will be based on the data from the D-CAV screen while Section III will be derived from data entered into various check boxes or memo fields that are on these screens.
CONCLUSIONS

The D-CAV software developed for this project meets the intended objectives of collecting useful data in an electronic format and eliminating the redundancy of the current manual CAV format. The data collected during a D-CAV can be used to provide the inspected community with a list of potential violations, recommended actions, and requested support data. The D-CAV data can then be downloaded to the nationwide FEMA CIS database.
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Part 5

Techniques and Projects in Stormwater Management
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INTRODUCTION

Hilton Head Island is a barrier island off the southern coast of South Carolina; it occupies approximately 21,000 acres and supports a permanent population of approximately 28,000 people. The terrain is very flat, and the elevation low, causing stormwater management to be a critical issue. Flooding can occur because of the surge of the tide, rainfall, or a combination of both.

The majority of the island has been developed since the 1950s as planned communities with interconnected lagoon-type stormwater management systems. However, the unplanned areas were not developed under comprehensive stormwater plans. These areas now have a hodgepodge of ineffective or non-existent drainage systems. Additionally, many of the stormwater management systems in the areas outside of the planned communities have not been serviced since they were installed, resulting in heavily silted culverts and over-vegetated ditches.

PROJECT NEED

The Gum Tree Neighborhood is one area that does not currently have an adequate drainage infrastructure. The existing ditches and culverts were not planned but simply cut where the water flowed at least 30 years ago. As the area becomes more developed the need for a comprehensive drainage system becomes more critical.

On October 2, 1994 and October 12, 1994, respectively, storms were recorded having 8 and 14 inches of rainfall during a 24-hour period. These storms equate to the 25- and 145-year rainfall events. Additionally, on the Labor Day weekends of 1987 and 1988, Hilton Head Island experienced severe flooding. The isolated daily storm for both weekends exceeded the 100-year event.

In September of 1995, Thomas and Hutton Engineering Inc. completed The Town of Hilton Head Island, Island Wide Drainage Study. The study identified 17 public drainage projects to improve the stormwater management system to handle the 25-year, 24-hour storm
frequency, 8 inches. The projects were then prioritized on cost-benefit criteria. The Gum Tree Area drainage project was prioritized at fifth on the list with an approximate cost of $840,000 to improve the ditch and road-crossing network. In February of 1996 Thomas and Hutton contracted with the Town of Hilton Head Island to provide design services for the ditch improvements.

While improving drainage, the project will also include a recreational pathway and the restoration and preservation of wetlands to address the quality of the water that ultimately discharges to the Intra-coastal Waterway. The wetlands restoration and preservation portion of the project lends itself to including an educational component because it is adjacent to a new Boys and Girls Club and close to the island's public school campus.

**STORMWATER MANAGEMENT**

The main goal of the Gum Tree Neighborhood drainage improvement project is the improvement of the main line ditch and piping network to serve a watershed area of 520 acres of single-family stand-alone homes and subdivisions. The watershed characteristics are: approximately half of the watershed falls in the A-14 flood zone and half in a C zone; soils are mostly B and D types that are poorly draining; composite CN is 83 for the current development. The ditch will be improved from a straight side approximately 6-7 feet wide at the bottom section to a trapezoidal 10-foot-wide bottom section with a top width of 30 feet. Pipe improvements include upsizing from a single 36-inch diameter to double 42-inch pipes.

**WETLANDS RESTORATION/CREATION**

The wetland restoration/creation will act as a retention/detention pond near the end of the ditch improvement, contributing to improved surface water quality by providing a place for pollutants to settle.

Much of Hilton Head Island's isolated seasonally flooded freshwater wetlands have been lost to development. This project takes an area that historically has been used as a construction/landscape debris landfill, removes and safely disposes of the debris, then creates 0.72 acres of palustrine forested wetland. The Town of Hilton Head Island's Wetland Ordinance is a no net loss ordinance; the created/restored wetland will be mitigation for the wetlands disturbed by the ditch widening. The created wetland will be seasonally flooded, most likely in winter and spring. This will provide a resting and feeding area for winter migrants such as ring-
necked and black ducks, and resting/feeding/nesting habitat for wood ducks.

The Town of Hilton Head Island's Wetland Ordinance requires upland buffers to be placed around all created wetlands, which will be a minimum of 20 feet wide, as well as restrictive covenants that protect the project in perpetuity, and a mandatory 3-year monitoring program.

The wetlands restoration and preservation portion of the project lends itself to including an educational component because it is adjacent to a new Boys and Girls Club and close to the island school campus. The Town of Hilton Head Island will encourage these entities to take advantage of the area.

PATHWAY

The project will also include an 8-foot-wide paved recreational pathway that can also be used for maintenance access. This will provide an amenity to the community and allow people to enjoy the neighboring wetland habitat.

PROJECT BUDGET

The budget figures for the project are shown in Table 1.

<table>
<thead>
<tr>
<th>Stage</th>
<th>Budget</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey and Plat Preparation</td>
<td>$72,550</td>
</tr>
<tr>
<td>Design and Permitting</td>
<td>$50,000</td>
</tr>
<tr>
<td>Land Acquisition</td>
<td>$700,000</td>
</tr>
<tr>
<td>Construction (ditch and pathway)</td>
<td>$840,000</td>
</tr>
<tr>
<td>Wetlands Restoration (seeking a $50,000 grant)</td>
<td>$300,000</td>
</tr>
<tr>
<td>TOTAL</td>
<td>$1,962,550</td>
</tr>
</tbody>
</table>

PROGRESS AND FUTURE PLANS

As of April 1999, the status of the project is the following: the design is complete, permitting is underway, and land acquisition has begun. Three
of the six road crossings are constructed; construction of the remainder of the project is scheduled to commence in the late summer of 1999. The Town of Hilton Head will be responsible for the maintenance of the project.

The Gum Tree Neighborhood drainage project, as one of the first on the Town of Hilton Head's comprehensive drainage projects, has grown into a multi-objective project. Stormwater management, water quality protection, wetlands restoration and preservation, education, and recreation enhancement are all encompassed in this project.
Stormwater Utility: A Nonstructural Best Management Practice

Brant D. Keller
City of Griffin Public Works & Stormwater Department

INTRODUCTION

The U.S. Congress passed the Clean Water Act in 1972 with a stated objective to restore and maintain the chemical, physical, and biological integrity of the nation's waters through point source and non-point source controls. The method to achieve this restoration process is through the implementation of "best management practices" (BMPs). An effective tool to achieve compliance with the Proposed Stormwater National Pollution Discharge Elimination System (NPDES) Phase I and Phase II Regulations is implementation of a stormwater utility. The NPDES program was created to ensure that permitted discharges meet applicable water quality requirements.

The City of Griffin is required to comply with the requirements of the Phase II permitting process based on its size and population. Griffin decided to take a proactive approach to watershed management by addressing both stormwater quantity and quality. The City of Griffin established a stormwater utility (the Utility) as part of its overall Stormwater Management Program to manage its watersheds and to create a model for other cities to consider when evaluating possible funding sources to achieve compliance with the upcoming Phase II permitting process. The action plan created as part of the Utility consists of policy making, institutional planning, environmental review and planning, financial strategies, and public education and involvement. The Utility provides Griffin with a financial mechanism from which to address both water quality and water quantity control issues. It also will allow Griffin to develop BMPs to address non-point source pollution and flood control management (via infrastructure repairs) that, when implemented together, will ensure protection of the region's water resources. This paper

Thanks to Hector J. Cyre, Andrew J. Reese and Ronald A. Feldner for their help and knowledge.
summarizes the important aspects associated with Griffin’s successful effort to create and implement the first stormwater utility in Georgia.

A stormwater utility, like a sewer or water supply utility, is user oriented, with costs being allocated based on services received (Debo and Reese, 1995). Another way of saying this is, “you only pay for the demand you put on the system.” Traditional structural BMPs typically consist of detention ponds, grassed swales, sand filters/filter strips, infiltration basins, porous pavements, etc. Traditional nonstructural BMPs include special zoning requirements, ordinances (such as erosion and sediment control ordinances), maintenance activities (such as storm drain cleaning and street sweeping), and education/outreach activities (R.W. Beck, Inc. 1998). Griffin considers its Utility to be a viable nonstructural BMP that will enable the city to generate revenues for stormwater related improvements.

Stormwater utilities have been in existence since the 1970s and over 300 utilities are currently in operation across the nation. What makes Griffin’s Utility special? Griffin’s Utility will be the first in the nation to address the upcoming requirements associated with the Phase II permitting process, and the Utility will be generating revenues prior to issuance of the final permit in the year 2002. At this time, it is estimated that over 3,500 communities across the nation will have to comply with the Phase II permitting regulation. The City of Griffin has made the decision that implementation of the Utility now will ease the financial burden put onto the city as a result of the up-coming Phase II permitting requirements.

BACKGROUND

The experiences of hundreds of communities over the past 20 years suggest that a fairly consistent process involving at least five phases occurs from initial investigations and conceptual discussions through implementation of a stormwater utility, its service (user) charge, and achievement of an effective Stormwater Management Program (Cyre, 1997).

Phase I—Preparatory

This phase represents the basic idea that a change is needed in the way stormwater is managed and funded. The City of Griffin did not need a lot of investigative research to figure out what the needs of a 150-year-old city are: flood control, failed infrastructure, erosion and sediment control, and water quality issues with no program or funding source. A series of policy papers were assembled dealing with (1) program mission and
priorities; (2) extent, scope and level of service; (3) funding philosophy; (4) program/funding coordination; (5) funding methods; and (6) service charge rate structure.

**Phase II—Concept Development**

This phase includes the assembling of information needed to evaluate the basic feasibility of various options, followed by the selection of the most appropriate concepts. The City of Griffin, its staff, and elected body accepted the fact that stormwater problems were real and solving them was a priority.

**Phase III—Detailed Analysis**

In this phase the activities focused on policy and financial analysis required to establish a stormwater utility. Griffin’s elected officials were committed from the onset, allowing development of a conceptual rate structure as well as a secondary funding method. We were able to develop a detailed cost of service, rate base, and revenue/expenditure analysis for incorporation into the final rate ordinance.

**Phase IV—Data and Systems Implementation**

Griffin finalized the master account file, capability to bill service charges, receive and process payments, and properly account for the utility service.

**Phase V—Public Information & Education**

This phase is essential in successful implementing a stormwater utility. Successful implementation of the Utility was the result of educating the public as to the benefits of the overall program. Some of the tools that were used and continue to be used are brochures, films, television presentation, public meetings, and public presentations.

**RELATED DATA**

**Demographic Data**

Griffin’s population is around 24,000 people and its size is approximately 15.5 square miles. The city has approximately 150 miles of roads, six drainage basins and 39 sub-basins equaling a total of 16,403 acres. The city is 156 years old, and has an estimated 10,000 drainage structures. The city is responsible for the operation and maintenance of the entire drainage system. The size of this system requires a substantial operating
budget. After reviewing all the alternatives, Griffin decided to fund its Stormwater Management Program by creating a stormwater utility.

**Utility Data**

The user fee is calculated on impervious area only. The equivalent residential unit or equivalent runoff unit is 2,200 square feet. The charge per month is $2.95 per residence or per every 2,200 square feet of impervious area on non-residential properties. The user fee is estimated to generate $1.2 million dollars per year. This ERU break down is as follows: single family residence 6400, multi-family residence 1386, public/institutional 3074, light industrial/airport 2782, heavy industrial 2772, commercial 8143, undeveloped 396, roads 8732, totaling 33,685 ERUs.

**Results Data**

Over a period of five years, Griffin will add two five-person work crews, add an environmental science team to the staff, and establish a capital construction program. In addition to the items listed above, the city has contracted an engineering consultant to inventory the city’s stormwater drainage network into a geographic information system (GIS) database using state-of-the-art global positioning system equipment. The consultant will use the GIS database for its overall master planning effort.

**Keys to Success**

Developing and successfully implementing a stormwater utility is unique to each community because each and every community is different. Griffin’s approach is summarized as follows: (1) Griffin solicited support of important officials early in the process and discussed the city’s needs, the overall approach, as well as the expected results. (2) We retained a consultant with a proven record of accomplishment in stormwater utilities and management. (3) The city developed a truthful and direct approach with the general public and key stakeholders. (4) Griffin sold the utility as one key part of overall stormwater management program, but not the 100% solution to all stormwater related problems and issues. (5) Griffin developed a viable program and a solid sales strategy then we followed the prescription through the tough times and good. (6) The elected officials put one person in charge of all aspects of the work and became the focal point and major cheerleader for the Utility’s development and eventual success (Reese, 1998).
CONCLUSION

The City of Griffin is no different than any other community, or business, by trying to do more with less, downsizing in-house staff, out-sourcing certain tasks, while at the same time trying to provide the essential services to the citizens. Griffin believes that the "user charge system" concept is the most dependable and equitable approach available to local governments for financing stormwater management (APWA, 1991). The term stormwater management encompasses a broad range of related topics such as erosion control, floodplain management, wetlands mitigation, detention/retention, and drainage facility design (Pyzoha, 1994).

Griffin's successful implementation of the Utility has proven that a community can take a proactive approach to overall watershed management. Implementation of a stormwater utility (as a nonstructural BMP) can provide a community the financial mechanism to fund the design and construction of structural BMPs, to address both water quantity control and water quality issues. Design and implementation of effective BMPs can result in (1) decreased flooding, (2) improved water quality, (3) improved habitat for wildlife, (4) land preservation due to erosion control, (5) reduction of pollutant loadings in downstream receiving waters, (6) reduction in water treatment costs, and (7) protection of wetlands and other jurisdictional areas.

The Georgia EPD and the U.S. Environmental Protection Agency have stressed the importance of individual communities becoming stakeholders to protect our region's water resources. As additional communities develop and implement effective BMPs, the entire region will realize the benefits. The City of Griffin feels that successful implementation of a stormwater utility can be the first step towards better overall management of our watersheds.

RELATED BENEFITS

The City of Griffin used the momentum gained through the successful implementation of the Utility to secure additional funds to address stormwater-related issues. Specifically, Griffin secured a $750,000 Hazard Mitigation Grant from the Georgia Emergency Management Agency to address flooding along a major urban roadway in a commercial and retail area of the city; $1.0 million from Spalding County's Special Purpose Local Option Sales Tax Program to construct a regional stormwater detention facility in North Griffin; $158,000 Section 319 (h) Non-point Source Implementation Grant from the Georgia EPD and EPA; and a $2.6 million State Revolving Fund Loan from the Georgia Environmental
Facilities Authority for non-point source projects and equipment. The loan was the first granted in Georgia specifically to address non-point source issues. The city plans to go to the revenue bond market in 2001, backed by stormwater utility revenues.

RECOMMENDATIONS

The City of Griffin considers itself a leader and pioneer in the areas of stormwater management and water quality enhancement. The city hopes that its efforts associated with the successful implementation of the first stormwater utility in Georgia will encourage other community leaders to consider this unique BMP in the future. The city recommends that a statewide association be created to assist with the dissemination of stormwater management related information to interested parties. The city would encourage the various regulatory agencies to participate in the stormwater management association meetings. In this manner, they could provide the necessary guidance and advice to community leaders as they attempt to address the challenges of effective watershed management. Finally, it will be imperative that our state and federal government agencies develop programs to allocate up-front seed money to assist communities in the development of stormwater utilities around the state and region.

REFERENCES


Flood Compensation Banking

Kari Ann Mackenbach
Fuller, Mossbarger, Scott, and May Engineers, Inc.

Derek Guthrie
Metropolitan Sewer District

INTRODUCTION

Techniques to manage floodplains and stormwater runoff have evolved over a number of years in Jefferson County, Kentucky. Before 1987, floodplains and stormwater runoff were managed by a number of local government entities. Since January 1987, with the creation of a local stormwater management utility, the Louisville and Jefferson County Metropolitan Sewer District (MSD) has been responsible for ensuring that development plans contain responsible floodplain management and stormwater practices.

A new technique for proactive floodplain management is currently underway in Jefferson County. This public-private partnership is called Floodplain Compensation Banking. Flood Compensation Banks (FCBs) are very similar in concept to "wetland banking." In the case of FCBs, "storage," or "volume" is created to be sold to those that need it (developers) to satisfy floodplain and stormwater management requirements. The basins that are created under this concept will have a service area that is defined as the "zone of influence." The zone of influence is described as the effective hydraulic influence of any individual or group of basins. Some of the advantages of this floodplain management approach include: the use of private capital in building regional detention basins; the use of stormwater utility customers' funds to correct "stormwater problems of the past" and not subsidize new development; and the added benefit of preservation of greenspace in the floodplain in perpetuity.

BACKGROUND

The City of Louisville and Jefferson County, located in north central Kentucky, have a combined land area of approximately 300 square miles and a population of approximately 665,000 people. Most of this area's
stormwater eventually flows into Jefferson County streams, all of which ultimately flow into the Ohio River. There are approximately 700 miles of perennial streams within the county. Nearly 75 square miles are located within the Federal Emergency Management Agency’s (FEMA) defined flood hazard area, with about 22,000 structures located in the flood hazard zones.

From 1948 to 1987, MSD was a wastewater utility, with only a minor role in local stormwater management. In January 1987, by way of an inter-local agreement between Jefferson County, the City of Louisville and MSD, a stormwater utility was formed. This utility is responsible for performing all maintenance and capital improvement planning and construction within the service area, roughly two-thirds of Jefferson County. Additionally, MSD has the responsibility to review all development plans for adherence to stormwater design standards. This also includes management of floodplain activities and participation in FEMA’s National Flood Insurance Program Community Rating System. Currently, MSD is rated a Class 7, which translates to a 15% discount off the flood insurance premium rate. MSD hopes to attain a Class 5 next year, which would translate into a 25% discount for its residents with flood insurance.

Another MSD-sponsored program that sprang from their leadership was a new floodplain ordinance. This new floodplain ordinance, which was adopted in September 1997, represents a major change in the management of floodplains within MSD’s jurisdiction. Instead of using the standard FEMA approach, MSD, in conjunction with local officials and stakeholders, developed an ordinance that will manage floodplains through the study and implementation of fully developed land use conditions by computing the floodplains based on fully developed or built-out conditions. By studying these areas and the impacts that a fully developed watershed will have on their watershed, the community will better be able to plan for the future. The floodways have also been computed on the basis of a 0.1-foot rise as compared to the FEMA allowance of a 1.0-foot rise. There are essentially two flood hazard maps; one for planning and regulation purposes, and the official Flood Insurance Rate Map that the NFIP produces for insurance purposes.

**FLOOD COMPENSATION BANKING**

Another innovative technique that is currently being developed and tested is the concept of Flood Compensation Banking. A Flood Compensation Bank (FCB) is a detention basin that is used for floodplain encroachment or for flood storage in which a basin’s volume may be purchased to
mitigate the effects of new development. In general, developers may utilize off-site regional detention basins to meet floodplain encroachment and stormwater detention requirements, in lieu of or in conjunction with paying regional facility fees or providing on-site retention basins. In order for the basin to be designated as an FCB, it must have a total storage volume of no less than 50 acre-feet and be approved by MSD. When an FCB is established, it is assigned a number of FCB credits. A credit is equivalent to one acre-foot of floodplain encroachment compensation or stormwater detention storage. The total number of credits in an FCB is equal to the amount of usable storage volume in the basin. An FCB may not sell more credits than it is assigned by MSD. A credit may be used as compensation for floodplain encroachment or to satisfy stormwater detention requirements for a new development, but the same credit may not be used to satisfy both requirements. The purchase of FCB credits reflects a permanent transaction; credits may not be rented.

A development may purchase storage volume from a FCB to compensate for floodplain encroachment or to satisfy stormwater detention requirements provided the basin is within the appropriate "zone of influence." A zone of influence is defined by the hydraulic effectiveness of the basin at reducing the water surface level in the intercepting channel. Hydrologic and hydraulic modeling of the watershed and comparing the pre- and post-basin water surface profiles establish the zone of influence. It is the responsibility of the FCB owner to hire an engineering firm that is capable of computing the hydrologic and hydraulic components of the basin. This modeling will then be verified by MSD. The locations in the channel upstream and downstream of the basin where there is no longer an appreciable difference between computed water surface profile level for pre- and post-basin conditions denote the boundaries of the zone of influence. Prior to MSD's approval of a FCB to issue credits, the FCB sponsor must perform all modeling necessary to determine the FCB's flood storage zone of influence. The FCB sponsor is required to submit the computed flood storage zone of influence for the proposed FCB and a copy of the design calculations to MSD for approval.

In order for a basin to be designated as a Flood Compensation Bank, it must be approved by the MSD and have a minimum total storage volume of 50 acre-feet. Negotiation for the purchase of storage credits are between the FCB owner and a member of the development community. MSD will certify and approve each FCB transaction. Upon approval of FCB status for a basin, MSD will issue the FCB owner a document identifying the total number of credits in the FCB and its zone of influence, termed the bank instrument. FCB owners are required to keep a
ledger of credit transactions. The ledger must identify the total number of
credits sold, the purchaser of the credits, the development/property
assigned to each credit, and the credits remaining in the FCB. In addition,
FCB owners are responsible for summarizing their FCB transactions and
furnishing an annual report to MSD.

A private flood banking system provides MSD with an additional tool
to minimize the effects of new development in the watersheds of Jefferson
County. This public/private initiative has the following advantages over
the traditional smaller basin approach: it provides for larger regional
detention basins that are more effective in controlling storm flows; it
allows developers to have an alternative to the regional facility fee; it
potentially provides developers with better mitigation at a lower cost; it
creates a simpler stormwater review process, whereby a developer could
simply purchase credits from an FCB for stormwater and floodplain
compensation; it results in less maintenance because there will be fewer
basins to maintain; and it uses existing undeveloped lands for flood
compensation basins, therefore limiting impervious area, preserving green
space and providing a linkage to greenways. In addition, FCBs provide a
location for wetlands to be constructed; allow for flood protection of
existing development; use private dollars to fund public improvements;
and offer increased pollution removal than their smaller counterparts,
resulting in improved water quality in the watershed.

An FCB system provides a win-win strategy for stormwater
management of new development in Jefferson County. Commercial and
industrial entities benefit by a new business market, one in which they can
utilize pervious land with minimal capital investment. Watershed residents
benefit by the preservation of undeveloped areas in the watershed. Finally,
the utilization of undeveloped properties for Flood Compensation Banks
reduces the future burden on the existing drainage system, by ensuring
that some areas of the watershed remain undeveloped. Just like many
areas in the United States, the Pond Creek Watershed is susceptible to
flooding. By embracing this knowledge and looking for alternatives and
mitigation options, MSD is able to allow a community that would
otherwise be restricted, to grow.

Floodplain Compensation Banking offers a unique opportunity for
public-private partnerships. The concept has created much interest in a
very short period of time. In the last three months, there have been two
FCBs approved with a total capacity of 1,600 acre-feet. In Jefferson
County, Kentucky, FCBs are providing a useful tool for proactive
floodplain development, while at the same time satisfying rigorous
floodplain and stormwater management requirements.
The direction of recent research in the field of stormwater management reflects an interest in the broader area of sustainable urban systems (Ellis, 1995). Principles of sustainable resource management state that impacts to natural cycles (e.g., carbon, hydrologic, etc.) should be kept at small spatial and temporal scales. Traditional drainage design dictates that excess runoff be removed rapidly and efficiently, captured in a conveyance system, and possibly stored before being discharged. The design emphasis on removal may be valid for large events, but over the majority of smaller runoff-producing events these traditional drainage systems violate the precepts of sustainability.

The goal of current research in sustainable urban stormwater management systems is to reduce distortions in the hydrologic cycle that result from development (Ellis, 1995). Urbanization adversely affects the quantity, quality, and timing of all runoff producing events; not just the larger, design-magnitude events (Pitt, 1999). The vast majority of runoff-producing events result from smaller storms (Pitt 1999). These events have been termed "micro-storms" by Canderas et al. (1995). The challenge to stormwater managers is to design sustainable systems that reduce micro-storm impacts while maintaining drainage for larger events. In addition to micro-storm control, onsite control may have profound impacts on the quantity and timing of larger runoff events, possibly affecting the design of minor and major systems. An integrated design approach is needed to fully assess cost savings in minor and major design elements.

**OPTIMAL MIX OF FUNCTIONAL LANDSCAPES**

An integrated stormwater management system expands the traditional collection system concept to include the purposeful design of the urban land surface. Prince Georges County (1997) in Maryland has published design documents on methods of "Low-Impact Development" (LID) to
address this issue. The goal is to design a landscape that responds in a similar fashion as it would under undeveloped conditions, while maintaining urban land value and aesthetic appeal.

Constrained optimization techniques may be used to find least-cost designs. For example, the most well-known form of optimization is Linear Programming (LP) (Glover and Laguna, 1997), which may be used to design least-cost functional landscapes (Heaney et al., 1999). A 113-acre example design problem from Tchobanoglous (1981) was developed for an LP application of functional landscapes. An LP was used to optimally allocate hydrologically functional components for a set of urban parcels based on unit-area costs. The hydrologic function of each best management practice (BMP) was based on Natural Resources Conservation Service methods. Specifically, the objective of the LP was to find the least costly mix of stormwater BMPs that maintained the pre-development soil moisture storage condition for each land use parcel type (a generic low-density parcel, a generic commercial parcel, etc.). The soil moisture storage is equivalent to the initial rainfall abstraction using the NRCS Curve Number (CN) method (Heaney et al., 1999).

A set of 26 area-based BMPs was used to maintain the pre-development initial rainfall abstraction across five land use parcels (low, medium, and high density residential; commercial; and school); three transportation rights-of-way (ROW) (50-, 60-, and 70-foot ROW); and two hydrologic soil types. For example, the low density residential parcel had 14 options available (e.g., two roof types, two driveway types, two patios, etc.). The LP was constrained to select BMP options for the pre-specified roof area, patio area, etc., for each parcel in each soil type. Each BMP option had a higher unit cost for greater hydrologic control. For example, the first driveway selection had a low unit cost but a low initial rainfall abstraction (the impervious surface reduced the amount of available soil storage). The second driveway option had a higher unit area cost but a greater initial rainfall abstraction (coinciding with some degree of perviousness in the paved surface). The example layouts shown in Figure 1 demonstrate possible residential designs. The LP allocates the areas and materials shown on the right side of Figure 1.

The results of the BMP allocation analysis indicate that LPs show promise for distributing hydrologically functional controls. The analysis also shows that accurate costs are essential in determining economical designs. The results show that permeable patios, parking lots, streets, and driveways may be attractive alternatives to maintaining pre-development conditions, as are on-site wooded areas and healthy grassed areas.
STORM SEWER VERTICAL ALIGNMENT PROBLEM

Optimization techniques may also be used to develop least-cost solutions for more complex problems. Design constraints, discrete material costs, and nonlinear processes all work to make stormwater management design problems difficult to optimize. Fortunately, recent advances in operations research have opened heretofore inaccessible and intractable problems to optimization analysis. For example, meta-heuristic techniques may be used to intelligently search complex solution spaces to find quality design solutions (Glover and Laguna, 1997). Meta-heuristics are a means to efficiently select trial and error solutions while searching for the optimum. Genetic algorithms (GA) are the most commonly used meta-heuristic. GAs work by solving a problem many times, and improving on existing solutions by using a "survival of the fittest solution" routine (Glover and Laguna, 1997).

The runoff hydrographs from the functional parcel systems described above are the input hydrographs to the minor drainage system. The minor
system is typically a gravity storm sewer system. To assess the benefits of onsite stormwater management on design flows, a method was needed to obtain least-cost gravity sewers. A least-cost gravity sewer design must balance pipe diameter costs with excavation costs. To convey a design flow, a large (expensive) pipe may be used on a mild slope (lower excavation costs), or a smaller (cheaper) pipe may be used on a steeper (more expensive) slope. For one or several pipes, this problem is easy to solve with manual trial and error techniques. However, over a network of pipes, the cost-relationships between branches and trunks may be less obvious. Therefore a commercial GA was used as an add-in to MS Excel to search for a least-cost storm sewer design for a 63-pipe network serving the same example area as was used for the LP analysis described above.

The initial results of the storm sewer design using GA are encouraging. GA improves on manual designs and creates a more objective basis to estimate benefits realized with onsite stormwater management. Preliminary results of the example design based on a design example from Tchobonglous (1981) show cost savings in the storm sewer system attributable to the use of on-site stormwater management to maintain predevelopment hydrologic conditions.

**NEXT PHASE OF RESEARCH**

The NRCS methods underlying the example LP analyses are based on unit hydrograph theory (McCuen, 1989). A better understanding of onsite stormwater management may be possible through the use of process-oriented models such as SWMM RUNOFF. Of particular concern is the breakdown of the time of concentration ($t_c$) over small areas. Small values of $t_c$ will dominate system designs with unreasonably high design flows from small areas. The next phase of work, to be undertaken during the summer of 1999, will be to implement RUNOFF on a parcel scale to simulate runoff hydrographs.

An office in Boulder, Colorado, is being monitored for rainfall and runoff. The landscape of this site has also been drastically redesigned to reduce runoff. Directly connected impervious area has been reduced, infiltration has been enhanced, and vegetation has been planted to provide aesthetic and hydrologic benefits. This data will be used to verify the applicability of the SWMM RUNOFF model on small parcels.

The final phase of work will be to create RUNOFF models of urban land parcels for various land uses with and without site modification.
The LP solutions summarized above will be the basis for developing these models. Simulated runoff hydrographs will be used to compare the developed and pre-developed conditions, as well as the impact on the minor and major drainage system design.

REFERENCES


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Part 6

Hydrological Forecasting
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Advanced Hydrologic Forecasting Services: Experiences in the Des Moines River Basin

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INTRODUCTION

An ensemble streamflow prediction system that provides probabilistic hydrologic forecasts with lead times of a few days to several weeks is now operational for the Des Moines River basin in Minnesota and Iowa. These forecasts not only account for precipitation already on the ground but also account for estimates of future precipitation. This prediction system greatly improves the capability to take timely and effective actions that will significantly mitigate the impact of major floods and droughts. The system also provides better overall information for use in managing competing water demands for multiple water users, e.g., agriculture, ecosystems, hydro-power, and navigation. The system uses operational precipitation forecast products, including long-range probabilistic products that are produced by the National Weather Service (NWS), National Centers for Environmental Prediction. This paper presents an overview of the system, reviews recent forecast experience, and introduces advancements towards future ensemble forecasting trends.

ENSEMBLE FORECASTING DEFINED

The NWS River Forecast Centers (RFCs) typically issue deterministic stage forecasts for a few days into the future. These forecasts are primarily produced with only historical and real-time data; in some cases 24-hour quantitative precipitation forecasts (QPFs) are also used to increase lead times of real-time forecasts. For increased lead times from days to weeks, it is critical to include future temperature and precipitation forecasts at all time scales out to seasonal. Enhancements to river forecasting include the combined use of deterministic and probabilistic procedures through Monte Carlo type simulations, i.e., the Ensemble Streamflow Prediction (ESP) technique (Day, 1985) of the NWS.

ESP is one significant portion of the NWS River Forecast System (NWSRFS) as it produces an ensemble of possible streamflow hydrographs that can be analyzed using standard statistical techniques to generate forecasts. ESP is run to produce an ensemble of equally-likely-to-occur stages for each forecast point. ESP, in its basic form, assumes
historical meteorological data are representative of possible future conditions and uses these as input data to hydrologic models along with the current states of these models obtained from the forecast component of the NWSRFS. A separate streamflow time series is simulated for each year of historical data using the current conditions as the starting point for each simulation. The streamflow time series for each year's simulation can be analyzed statistically for peak flows, minimum flows, flow volumes, etc., for any future time period to produce a probabilistic forecast for the streamflow variable.

**DES MOINES RIVER BASIN—ESP FORECASTS**

The Des Moines River basin was selected as the first operational site for these long-range probabilistic forecast products after the devastating impacts of the "Great Flood of 1993" (NWS, 1994), which included severe flooding in and around Des Moines, Iowa, and along the Racoon River, a tributary to the Des Moines River.

Implementation of this advanced forecasting system for the Des Moines River basin began in 1995; it has been operational since March 1997. The functionality and associated implementation activities for the total system include (1) providing advanced hydrometeorologic/hydrologic modeling procedures that better account for the natural and human-made complexities of local river basins; (2) implementing the ESP procedure in order to provide probabilistic hydrologic forecasts into the future from days to months; (3) coupling meteorologic forecasts and climate predictions within the ESP procedure, including the effect of reservoir operations in both short-term and long-term forecasts; (4) implementing dynamic streamflow modeling in river reaches with significant dynamic effects caused by backwater, levee overtopping, or other transient phenomena; and (5) providing advanced visual display products (e.g., probability of occurrence information) for flood mitigation and water resources management activities to other federal, state, and local organizations.

**DESCRIPTION OF ESP FORECAST PRODUCTS**

In order to convey model output and information to users it was necessary to develop the ESP Analysis and Display Program (ESPADP). Two enhancements resulted from ESPADP: (1) a model analysis procedure and product generator leading to greater abilities to present probabilistic products for water resource managers, and (2) the provision of interactive graphical displays for both hydrologic forecasters and users to maximize
their ability to understand and interpret ESP output. Hydrologic products have typically been tabular in nature and limited to short time frames. These new graphical products are able to pass on greater amounts of data and information for longer periods of time, e.g., ESP probability interval and exceedence probability plots. The need for such products with more information has been voiced by water resource managers after all major flood disasters since 1993.

ESP FORECAST VERIFICATION
Since the beginning of these advanced operations for the Des Moines River basin, March 1997, only a few minor flood events have occurred. For those events, the 50% exceedence probability stage was as close or closer to the final observed crest than traditional outlook products (NWS, 1997). Keeping in mind, operational verification is not sufficient with limited data sets, additional data for future events will be gathered and examined.

THE NEXT STEP: NEAR-TERM PROBABILISTIC FORECASTS
The NWS is now enhancing the ESP technique to more directly include NWS meteorologic and climatologic forecasts in the near term. For this objective, different sources of meteorological forecasts are used as input to produce the future precipitation ensemble. NWS Weather Forecast Office (WFO) forecast information is emphasized for the near term (one- to three-day) time frame. At the present, this is a deterministic QPF forecast; probabilistic QPFs (PQPFs) are being developed and will be used in the future (Schaake and Larson, 1998; Adams et al., 1999). These PQPFs will control an ensemble precipitation processor that will generate ensemble members that account for hydrologically relevant space/time variability using historical precipitation to help limit extreme occurrences.

CONCLUSIONS
The Des Moines forecasting system has been very successful in that all major implementation goals were met. However, as an initial effort, there remain areas where improvements can be made. Some observations and recommendations follow.

- ESP spring flood outlook values, particularly at the 50% probability of exceedence level, compared well to traditional forecast techniques in areas where snowmelt flooding occurred. Furthermore, these
probabilistic products gave significantly more information to the users.

- Users of these new products, both external to and within the NWS, generally said the new product formats were very useful and contained additional information.

- The use of an Internet home page for outside user access has proven successful. The home page at WSFO Des Moines is still in use and can be accessed at http://www.crh.noaa.gov/dmx/ahps. ESP products appearing at this site are updated in conjunction with NWS climate forecast updates. The products would be updated more often as the hydrologic situation in the Des Moines basin dictates.

- The use of QPF and climate products are extremely useful. The ESPADP-generated forecast products (stage, flow, and volume) out to 60 days have been helpful to external users.

- It is recognized that additional operational verification data must be developed and analyzed.

- Additional training resources need to be developed for the interpretation and understanding of the statistical products and procedures.

- ESP is an important approach to river forecasting, because it can provide consistent probabilistic information about the joint occurrence of events at multiple locations in a river basin. This is an extremely important feature for decisions involving the operations of systems of reservoirs, downstream diversions, and downstream floodprone areas. These activities clearly show the benefits of probabilistic-type products.

- The use of PQPFs should be reviewed to further advance the ability to forecast river stages as accurately as possible, and at the same time quantify the uncertainty in the forecasts.
REFERENCES


The primary mission of the National Weather Service (NWS) is to issue weather and flood forecasts and warnings for the protection of life and property. The basis for this mission originates from Congressional actions dating to the late 1800s through various government departmental organizations. As different parent organizations directed these weather related services, they have evolved. In addition to governmental variations, knowledge of the science has greatly changed. Early days of forecasting took very low-resolution basic weather and river observations being reported from upstream areas and sent this information as a forecast of conditions to be expected at downstream locations. This timing aspect of the hydrology and meteorology events slowly increased in accuracy through statistical means and slowly evolved to the dynamic, physically based hydrometeorological forecasts of today. As the accuracy and the availability of these forecasts become more widespread, their use changed.

The NWS is in the final phases of a multi-billion dollar modernization, including state-of-the-art equipment installations using new scientific advancements. Doppler radar estimated rainfall gives the NWS and users a new data set of areal coverage of rainfall data. Higher resolution satellite data and higher speed communications systems that deliver this information to users and forecasters at ever greater speeds have enhanced many aspects of the forecast process. Satellite and radar data are used in various forms of computer models and observational systems for issuing forecasts and warnings. These new data sets, along with additional information communicated from various sources, including meteorological instrumentation of commercial aircraft, microwave sensor devices, and new surface-based observations systems, are being assembled for use in high-resolution computer models. These new data in the meteorological models increase the accuracy and forecasts of weather related data that can be used as input to hydrologic models.

Information provided from the meteorological models along with quantitative precipitation estimations using multiple sensors can now be
applied to the hydrologic models to improve the accuracy and lead time of hydrologic forecasts. The concept of multiple sensors has been theorized in the research community using various schemes to estimate rainfall amounts from radar and from satellite imagery. These processes have been combined and through additional research in the Office of Hydrology, Hydrologic Research Laboratory, helped provide proof of concept and tools for NWS River Forecast Centers to use this data for forecasting.

Computer workstations using specialized software help the integration of these data sets for use in providing flood warnings and forecasts. The Advanced Hydrologic Prediction System (AHPS) and Weather Forecast Office Hydrologic Forecasting System (WHFS) give forecasters new tools to prepare warnings and forecasts. These probabilistic hydrologic forecasts will provide warning of flash floods and long-term flood and water resource forecasts with a measure of uncertainty with increased lead time. Initial software builds of WHFS have been deployed to the forecast offices with planned enhancements to improve software utility and service. The main utility of the WHFS software is to improve the flow of information provided by the forecast office to the user community.

As the NWS makes use of scientific advancements in hydrology and meteorology, product enhancement efforts need to continue, so the information provided may be best used by various floodplain managers. AHPS and future enhancements to WHFS will use these advancements. Probabilistic information provided in meteorological quantitative precipitation forecasts by using the new data sets and meteorological models will be the first step. Hydrology advancements associated with AHPS and their utilization are discussed in another paper in this volume.

Scientific advancements and education on product use have increased their value to the user. Areas of expanding use of these products include watershed planning and management, land use management in floodplains, flood mitigation, stormwater, and specialized water management issues. This new information will be available to all users of NWS products. By communicating with our customers and partners through our local offices and national meetings and workshops, such as the Association of State Floodplain Managers, we hope to tailor these products for optimum utilization.

With this increase in data and information availability, not only do we want to work with existing users, but hope to expand our user base. One area is in planning as available land around cities becomes more expensive to develop and as citizens request more green space in planning issues, planners are being faced with requirements to utilize all available
space. A way to use floodplain space is development of flood warning and forecast information along with other mitigation efforts in the long-term plan. By working with the local NWS offices and seeing that appropriate data are collected and fully utilized in these new systems, they may provide advanced services to better meet the needs of a community.

Science and technology advancements, such as those found in AHPS, are great, but until a better understanding of the dangers associated with flood waters occurs, people will continue to lose their lives. To mitigate this fact, better preparedness through coordination with our partners and enhancements to NWS products with science must occur. Better preparedness, such as our current efforts with the Association of State Dam Safety Officials and the Federal Emergency Management Agency’s Dam Safety Office, in working to coordinate emergency action plans is one ongoing effort with the NWS. Current plans for enhancements to NWS products include such things as short time quantitative precipitation products with associated flash flood threat indices that will evolve to be displayed in graphical formats. With the expanding use of geographic information systems (GIS), the NWS hopes to tie radar and other related information with site-specific hydrologic model output to provide more information to the Project Impact type communities and to those 18,000 communities now in the National Flood Insurance Program to mitigate the threat to life and property.

Better understanding, training, and education will need to be coordinated in the use of these products. This will be calling for not only integration of weather and hydrology information, but other databases to complete a full suite of geographical information to be used to complete the tasks of various users. The only way this can be done is through continued expansion of outreach efforts of various federal, state, and local government agencies and decision support teams and organizations with the help of private sector to expand the use of these data sets to support saving lives and mitigation of property. You are urged to get to know people in your local NWS offices, including the Warning and Coordination Meteorologist, Service Hydrologist, or Hydrology Focal Points and the Meteorologist in Charge and see where you can work together to help make some of these projects come together to help your community.
Part 7

Flood Modelling, Geographic Information Systems, & Simulations
A GIS Interface to HEC-RAS

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INTRODUCTION
Since the 1997 release of the HEC River Analysis System (HEC-RAS, Version 2.0), the program has provided the option to import and utilize three-dimensional (3D) river reach and cross-sectional data from a data exchange file. Upon completing the hydraulic calculations, the computed profile and flow-width data can be written back to the data exchange file for floodplain mapping. With the release of Version 2.2, several additional features have been added to provide improved data transfer between the RAS geometry data and the terrain model. To facilitate geometric data development, a graphical user interface and macros have been developed to produce river-reach data in the exchange file format and to develop floodplain boundaries with the computed water surface elevations and flood boundary data from HEC-RAS. This paper describes the new package HEC-GeoRAS, an application for support of HEC-RAS using ARC/INFO.

HEC-RAS GEOMETRIC MODEL
HEC-RAS geometric data are defined by a set of River Reaches connected at Junctions. Through the program's graphical user interface, one can graphically define the river-reach system. River-floodplain cross sections are then input by coordinate points across the floodplain, along with associated Manning's $n$ values and reach lengths between cross sections. Since 1997, the program has an option of reading the river-reach and cross-section data from a data exchange file that could be produced by terrain modeling software.

DATA EXCHANGE FILE
HEC is developing a format standard for a general-purpose data exchange between GIS programs and its Next Generation computer programs (HEC, 1993). The goal is to facilitate data transfer between HEC models and the CADD and GIS software systems, without "adopting" any one system. Terrain data can include watershed boundaries, stream network definition,
catchment area, river cross-sections, and similar model data. The initial focus has been to provide an interface with the Hydrologic Modeling System, HEC-HMS (HEC, 1998a) and the River Analysis System, HEC-RAS (HEC, 1998b, c, d). Data records have been defined to provide basic terrain data to these two programs and new records will be added, as required. GeoRAS produces a data exchange file for HEC-RAS.

The data exchange file is a formatted ASCII text file. Standard records in the file are composed of keywords and values. The use of keywords and a text-file format provides a self documenting file that can be created or edited with a text editor, and is easily read and understood by reviewers. The components of a RAS exchange file are:

(1) Header—The header section can contain information like data units, digital terrain modelling type, map projection, datum, etc.

(2) Stream Network—A network section would contain records describing the river reaches. Additional reach data would include reach and stream identification, and centerline coordinates for each reach.

(3) Cross-Sections—Cross-section data define the river, reach, and station value; the cross-section Cut Line; and the Surface Line for the cross-section data. The bank stations and the reach lengths are optional data that can be included.

Appendix B of the HEC-RAS User's Manual (HEC, 1998b) provides a description of the exchange file format.

**HEC-GeoRAS**

HEC-GeoRAS, Version 1 (HEC, 1999) was developed to facilitate formation of an HEC-RAS geometric model and floodplain mapping using ARC/INFO. A GUI was developed to facilitate the application of ARC/INFO macros. It operates on NT or Unix computers with ARC/INFO Version 7.0, or higher, installed with the TIN extension. GeoRAS must be installed with ARC/INFO and it requires a digital terrain model as a triangulated irregular network (TIN) data set.

The steps to create a geometry file include: create a contour coverage; define the channel network; optionally define the main channel bank lines and overbank flow paths; define the cross-section cut lines; and then write the HEC-RAS Data Exchange File. The GeoRAS GUI provides convenient options to perform each step, which produces a data set that is saved in a separate file. The Project Manager GUI is shown in Figure 1.

First, a contour coverage is created from the TIN to facilitate defining stream lines and cross-section locations. The user specifies the contour
interval and file name. The procedure generates the coverage and displays the graphic representation.

The Main Channel Invert coverage is created to define the river network. River-reaches are defined by graphically constructing arcs from upstream to downstream nodes. A Data Editor provides the basic "tools" to define and edit the arcs. Downstream nodes can be connected to define river junctions. The user is prompted to define the river and reach name for each reach defined. The invert data are stored as a separate layer.

The Cross-section (XS) Cut Lines define the location for each cross section. The lines are drawn from left to right when looking downstream and perpendicular to the expected flow lines. The Cut-line coverage is stored as a separate layer.

Optionally, the Main Channel Banks can be defined by a set of arcs defining the bank lines. This coverage will be used to define the left and right bank stations for the cross sections. Also, the Overbank Flow Paths can be defined as arcs drawn along the expected center-of-mass flow line along the left- and right-overbank areas. These arcs and the Channel Invert line will be used to compute the left- and right-overbank and channel reach lengths. These coverages are saved as separate data sets.

After the required and optional coverages are completed, the geometric data can be extracted from the TIN and the results written to a data exchange file for input to HEC-RAS. Two options exist for

Figure 1. HEC-GeoRAS project manager screen.
computing cross-section data. Either the sections can be based on the intersection of the cut-line and the edge of each TIN triangle or they can be interpolated on an even horizontal interval. At this time, roughness coefficients, hydraulic structures, expansion and contraction coefficients, and flow data are not extracted by this procedure.

HEC-RAS MODEL APPLICATION

Developing a HEC-RAS model with imported data first requires starting a new project. Then the GIS data are imported by a File option in the Geometric Data editor. The program reads in the file and displays the river-reach graphic based on the imported data. The HEC-RAS program maintains the XYZ data for graphical displays and to provide output to the data exchange file. For hydraulic computations, the program translates the XYZ coordinates into two-dimensional cross sections. The translated data are shown in the program's cross-section editor.

The modeler will need to provide additional data such as Manning's $n$, contraction and expansion coefficients, plus bank stations and reach lengths if they are not included in the exchange file. The modeler will also have to add data defining all hydraulic structures in the reach to complete the geometric data model. Flow data and boundary conditions are required for the flow-data file. Then, the model should be ready to compute profiles. The program operation is the same as it is for user input data. However, the XYZ graphic displays the geometric data and water surface consistent with the 3D coordinate system.

When modeling is complete, HEC-RAS can write an output file in the data exchange file format. In the Main menu, under File, is an Export GIS Data option. In the file header section, the program writes the output date and time, the number of reaches, cross sections, and profiles. The computed water surface elevation for each profile is written with the cross-section data. A "bounding polygon" is written for each river-reach and profile. The polygon will be used in the GeoRAS inundation mapping procedure to limit the extent of flooding based on HEC-RAS flow-control features. Additionally, Version 2.2 can export user-defined cross sections and/or interpolated cross sections to the exchange file. The entire section or only the channel element can be output. This data can then be used to improve the channel portion of the terrain model (TIN).

MAPPING HEC-RAS RESULTS WITH GeoRAS

The data exchange file from HEC-RAS is read by GeoRAS. The Inundation Data menu shows the profile labels defined in HEC-RAS. The
user can select which profiles to process and define the grid resolution for processing. A water-surface TIN is developed, with each cross-section cut-line defining a water-surface break-line. A lattice (grid) is overlaid on the ground-surface and water-surface TINs. The program processes the ground and water-surface layers using an average elevation for each grid-cell. From this, the depth of water in each cell is computed and the inundated area is determined.

A flood map can be produced for one or more profiles. Depth grid displays are limited to one profile per map. The mapping options are performed in ARCPLOT. Options are provided for layers to display, color and fill, and background coverages. Standard zoom features are provided, along with options for printing the map results. Figure 2 shows an example depth map display. From the depth-grid map, the computed water depth can be found for any cell under the cross-hair location.

Figure 2. Example depth-grid map.
The map display of cross-section cut lines and flow paths, along with the inundated area mapping, should facilitate model-data review. The interface makes it easier to modify the cross-section locations and flow paths to develop a modified model. The modified geometric data can be imported without destroying the other data in the HEC-RAS model.

CONCLUSION

GeoRAS provides a convenient interface to ARC/INFO procedures to develop geometric data for river modeling and to display the computed results as inundation mapping. The interface makes it possible for people with limited ARC/INFO experience to define their river geometric model. However, GIS knowledge and skills are required to ensure that data collection and TIN model development are appropriate and sufficient for river-modeling purposes.

Mapping displays of inundated area along with cross-section cut-lines and river flow paths provide a graphical comparison of the expected flow-lines used for model development and the computed results. A review of this information should assist the modeler to determine whether the model results support the model assumptions.

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Near Real-time Flood-Simulation System for Salt Creek in Du Page County, Illinois

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INTRODUCTION

The Salt Creek watershed is in northeastern Illinois (Figure 1), primarily in Du Page and Cook counties. The drainage area is 115 square miles to the U.S. Geological Survey streamflow-gaging station (05531500). This gaging station is at the downstream boundary of the simulated reach. The Elmhurst Quarry Flood Control Facility, adjacent to Salt Creek at a point 12 river miles (drainage area is approximately 90 square miles) from the downstream boundary, is an off-line stormwater diversion reservoir containing 8,300 acre-feet of storage volume.

Hydrologic and hydraulic model simulations of Salt Creek have indicated that the timing of the flood wave in the lower watershed is highly sensitive to the temporal and spatial distribution of rainfall (Ishii et al., 1998). During short duration, high-intensity precipitation events, local runoff can produce the peak creek stages in the lower watershed. These peaks can occur before the flood wave from the upper watershed arrives. During long duration or multiple precipitation events, the local runoff can combine with the flood wave from the upper watershed, producing peak creek stages in the lower watershed. The capability to simulate the watershed response to precipitation events in near real time is a useful tool used by Du Page County to help evaluate and make effective decisions about diversion operations to reduce flood damage.
Near Real-time Flood Simulation System for Salt Creek

Figure 1. Salt Creek watershed in northeastern Illinois.

SALT CREEK FLOOD-SIMULATION SYSTEM DEVELOPMENT

Du Page County uses continuous rainfall-runoff simulation and unsteady-flow routing for watershed planning, hydraulic design and analysis, and floodplain delineation. The continuous-simulation rainfall-runoff model, Hydrologic Simulation Program Fortran, HSPF (Bicknell et al., 1997), and the unsteady-flow hydraulic routing model, Full Equations, FEQ (Franz and Melching, 1997), are used by the County. The HSPF model, as calibrated and verified by Price (1994), is used to determine the unit runoffs. The FEQ models of the Salt Creek Basin and tributaries developed by Du Page County for use in planning, design, and floodplain studies were unified and streamlined for use in the flood-simulation system.

Modifications were made to the HSPF and FEQ model codes to improve their utility for the unique requirements of near real-time simulation. HSPF was enhanced to save the state variables to a file at the end of a simulation. Subsequent model simulations read the state variable
file to obtain the initial conditions, thereby eliminating manual entry. An option to output a binary time-series file of unit runoffs suitable for direct input as lateral inflows to FEQ also was added. FEQ was modified to include additional output options for GENSCN post-processing.

The graphical user interface GENeration and analysis of model simulation SceNarios, GENSCN (Kittle et al., 1998), is an interactive software tool for plotting, listing, producing statistics, and animating the results of HSPF and FEQ simulations. The program runs on Microsoft Windows 9x/NT and functions as a model builder for HSPF, runs HSPF 12.0, and can be used to view and animate input data as well as HSPF and FEQ model-simulation outputs. The GENSCN interface, along with HSPF and FEQ, form the basis of the flood-simulation system. The GENSCN interface main window, for Salt Creek, is shown in Figure 2.

Figure 2. Salt Creek application of the GENSCN interface main window.

APPLICATION OF THE FLOOD-SIMULATION SYSTEM

The flood-simulation system will be operated by the Du Page County staff to assist in the evaluation of alternative diversion structure operations. The major function of the system is to simulate the Salt Creek mainstem
stages resulting from real-time or forecasted rainfall and snowmelt data, alternative operating strategies for the sluice gate at Elmhurst Quarry, and the timing of return flows pumped from the quarry. The diversion works for the Elmhurst Quarry Flood Control Facility consist of a 140-foot fixed-crest weir, an 80-foot variable-height weir, and a 7-foot by 7-foot sluice gate. Return flows are accomplished by pumping to a cascading aerating structure. The hydraulic features of these structures are simulated in the FEQ model.

Climatological data (air and dewpoint temperature, wind velocity, and solar radiation) needed to simulate rainfall-runoff and snowmelt are obtained by Internet access or from instruments at the Du Page County emergency management offices. The primary source of precipitation data is the radio-telemetered precipitation network consisting of 28 gages located throughout the county and surrounding area. After the data are retrieved, they are checked for errors or missing values and reformatted for input to the data base by a preprocessor program. Errors and missing data reports are reviewed and the automatic data revisions are either accepted or exchanged for data from other sources or estimates.

The GENSCN interface is used to write the data to the data base and run the hydrologic model (HSPF) input that produces the runoff time series to be routed. The unsteady-flow hydraulic routing model (FEQ) input uses data from the radio-telemetered stage gage as the upstream boundary condition for the simulated reach and the measured stage-discharge relation at the USGS gaging station (05531500) (see Figure 1) as the downstream boundary condition. The hydraulic model is run, and the routed results are reviewed for discharge, stage, and storage at critical locations. Additional forecast precipitation scenarios or structure operation scenarios then may be applied and the process repeated. The quicker visualization and analysis of each scenario generated with the flood simulation system permits better interpretation of the watershed hydraulics simulated with the complex HSPF and FEQ models, which will result in improved response by the County during precipitation events.

REFERENCES


An interactive flood modeling system that combines geographic information system- (GIS-) based terrain modeling and three-dimensional (3D) visualization tools has been funded by the National Aeronautics and Space Administration (NASA) as part of its Mission to Planet Earth program. It will be distributed through an Internet-capable client/server system able to disseminate imagery, GIS data, and remote sensing GIS applications, such as NASA's Regional Application Center.

As a case study the project used the Tillamook watershed and floodplain to demonstrate the feasibility of 3D visualization techniques, based on VRML standards. A virtual simulation of Tillamook County, Oregon, was developed building on three components: a terrain model, a GIS database, and 3D imaging. The case study tool moves through a variety of display scales for quick review of information on the basis of the upper watershed (which is fairly low-resolution data) and the floodplain, which necessitates relatively high resolution.

The Tillamook simulation utilizes three types of data: surface terrain, geospatially-referenced features (objects such as roads and terrain qualities that will exist in the virtual world), and quantitative and qualitative environmental data that will determine the states and conditions of these features (e.g., building and site data). Terrain and feature data were either acquired as, or developed into, ARC/INFO GIS data sets. The quantitative and qualitative environmental data generally required no additional processing with the exception of building elevation points in the floodplain. Image data was generated photographically. This simulation
method supports integration with flood modeling tools. The types of data sets are illustrated in Figure 1.

**OVERVIEW OF THE VEHICLE**

GIS and related geospatial data visualization tools have received widespread acceptance for planning and resource management for their ability to provide useful information and analysis in a timely and easily digestible manner. This application is being designed to import from and export to a variety of GIS systems. Features required from a geospatial database include: terrain (DEM or similar grid format, along with linear and point features that affect the surface); physical features (human-made and natural); and environmental features (environmental factors of consequence to the application, such as snow cover, ground saturation, and a real distribution of precipitation).

The three-dimensional display qualities further build on the strengths of this process by removing some of the abstraction commonly associated with mapping and computer visualization. The realistic three-dimensional display is particularly useful for quick review of information (e.g., in emergency settings); moving through a variety of display scales; and communicating with citizen groups and the general public who may not be familiar with standard two-dimensional, plan view maps.

A potential strength of the application will be the ability of users to develop scenarios based on specific flood event parameters and to test the impacts of those against various planning and mitigation efforts. This function is dependent upon advanced hydrologic modeling capabilities that will be integrated into the model as they are developed. The application will provide display and query of geospatial features, generation of the flood extent object, and manipulation of states and characteristics of existing objects. Interface functionality with other software is provided for additional GIS adaptability.

The database will accommodate the needs of traditional database functions, geospatially based queries, and the three-dimensional visualization process. Each object requires a two-dimensional array allowing for temporally based change. Attributes associated with each object will include location, the characteristics associated with that class of objects, and an inundation-state variable. Four superclasses of objects will exist: terrain (one object); physical objects (stationary human-made and natural features); environmental objects (conditions
Figure 1. ARCIINFO geographic information system data sets.
affecting the application, e.g., wells and ground saturation); and actor objects (mobile human-made and natural features that may affect other objects, e.g., major intersections, traffic generations, or emergency response facilities).

**IMPORT/EXPORT ENGINE**

This process translates geospatial features from the independent GIS into application objects. It will also be capable of exporting objects back into GIS features. This latter category will allow the user to take the object or subsets of cultural objects based on inundation state back into a full-featured GIS. Major GIS formats that should be considered include ARC/INFO export files, ArcView shape files, MapInfo interchange files, and possibly the export formats of Intergraph and a general ASCII standard (if identified).

**TERRAIN CREATION ENGINE**

This process will compile a composite terrain surface from the GIS terrain feature (e.g., a DEM) and other features that influence the surface such as stream channels, roadways, and significant structures.

**ACTOR CREATION MODEL**

This model produces appropriate actor objects based on the presence and state of other objects. For example, inundation of major roadways will trigger responding emergency personnel and persistent rain and high river levels could trigger logjams flowing in the river.

**OBJECT MANIPULATION ENGINE**

This process will modify object location, characteristics, and states based on user requests. This function will allow the user to control elements of the object model to experiment with new scenarios and alternative courses of action being considered.

**GRAPHICAL USER INTERFACE**

The graphical user interface (GUI) will serve as the direct interface between user and application. The GUI will use industry standard elements and design to give the application "out-of-the-box" functionality. Three individual sub-components will need to be smoothly integrated:
• Three-dimensional display of the objects and scenario with spatial and temporal viewer perspective control;
• Menu and window-based Model Manager interface; and
• Menu and window-based query and report function interface.

The nature of the three-dimensional display will control the visualization creation function (e.g., VRML or other three-dimensional object format). Ideally this display will allow direct interaction with point-and-click queries and Model Manager functions.

QUERY/REPORT ENGINE

This process will allow the user to perform database queries through either of two schemes:

1. Identify, and display attributes of, objects in spatial and temporal locations (through the specification of specific coordinates, a region of interest, or direct point-and-click choice on the screen).

2. Identify and display (or highlight) objects based on attributes. Identified objects will be highlighted on the three-dimensional display and display controls will allow for a "zoom" to the extent of the displayed items. The user will be able to display attributes on-screen and perform basic statistical analysis. The data results of queries will be exportable to database and spreadsheet applications for further analysis.

CONCLUSIONS AND APPLICABILITY

Once the ability for informed response is enhanced, the implications for mitigation become evident. It is anticipated that this tool will be useful to urban planners charged with integrating flood hazard reduction into the comprehensive planning process.

The tool described in this paper represents enhanced capability to visualize the implications of earth science data sets in relation to cultural features. It is an important vehicle for analyzing the interactions of the natural environment (e.g., flood parameters) with cultural features (building groupings, roadways, and regulatory boundaries). It is also potentially useful as a vehicle to simulate the implications of alternative planning strategies. For example alternative water detention concepts could demonstrate spatial and temporal implications of how actions taken in the upper watershed impact
terrestrial and aquatic habitat, residential and lifeline vulnerability, etc. Subsequently, types of trade-off decisions, e.g., vegetation management in riparian corridors, or property acquisition, can be explored.

Another potential use of this tool would be to illustrate alternative techniques to achieve more sustainable communities, e.g., of transferring densities from the undeveloped floodplain to a more urbanized area. Once the implications of such actions are understood, implementation strategies can be integrated into the comprehensive planning process. Such strategies can become a vehicle to implement such non-structural measures as wetland banking and conservation easements. They can also illustrate the efficacy of combination strategies, such as setback levees, which can also address habitat restoration and/or recreation needs.
Improved Methods of Floodplain Mapping and Risk Characterization: The Schoharie Pilot Project

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INTRODUCTION
The flood of January 19–20, 1996 was the most devastating natural occurrence in central New York since Hurricane Agnes in 1972. Based upon this record peak discharge, Schoharie County asked the Federal Emergency Management Agency (FEMA) and New York State Department of Environmental Conservation (NYSDEC) to help address its concerns. NYSDEC engaged PAR Government Systems Corporation (PAR) to deploy an advanced, semi-automated approach to hydrologic and hydraulics modeling and floodplain mapping. This innovative project may be a model for New York State’s Map Modernization Program.

OBJECTIVE
NYSDEC’s and FEMA’s objective is to demonstrate improved methods of floodplain mapping, risk characterization, and early warning, which can be conducted on a county-wide, watershed basis. To do this, PAR’s floodplain modeling and mapping software tool and method, Flood*Ware™, incorporates geographic information technologies—geographic information systems (GIS); imagery—remote sensing, global positioning systems (GPS); and advanced spatial analysis and visualization techniques.

STUDY AREA DESCRIPTION
The Schoharie Creek drainage basin consists of approximately 950 square miles, and approximately 100 impacted floodplain study miles. Within this area, there are 22 impacted communities that are identified in the National
Flood Insurance Program (NFIP). From its headwaters in the Catskills, Schoharie Creek extends approximately 80 miles to the Mohawk River, consisting of a 40-mile reach within Schoharie County.

GEOSPATIAL DATABASE

The digital GIS database was integrated using the following georeferenced coverages in the NAD 83 / NAVD 88 datums:

- New York State 1:24,000 (10-meter grid) regional digital elevation models (DEMNs);
- New York State 1:24,000 hydrography digital line graphs (DLGs);
- U.S. Environmental Protection Agency multi-resolution land cover (MRLC) classification and characteristics (from 30-meter LANDSAT-TM images) and Natural Resources Conservation Service digital soils coverages;
- U.S. Geological Survey 1-meter color-infrared digital orthophoto quarter quadrangles (DOQQs);
- LIDAR-collected (5-meter grid) floodplain digital elevation model (DEM);
- GPS field-surveyed wetted perimeter/cross-sections, hydraulic obstructions geometry; and
- New York State Office of Real Property Services (ORPS) digital real property data.

Also, the database incorporates the digital use and display of remotely-sensed data from the National Weather Service (NWS) WSR-88D weather radar. In particular, the use of the 88-D radar information addresses data gaps witnessed in historical NWS precipitation records. A multi-resolution DEM is created based upon NYSDEC 10m regional coverage, LIDAR-collected data, and NYSDEC GPS field survey collected data. This provides a high accuracy, 3-dimensional digital terrain model of the floodplain, which is necessary for improved floodplain characterization and risk assessment.

STREAM GEOMETRY ENHANCEMENT

As indicated in Figure 1, the stream geometry is enhanced through the digitization of the stream overbanks, based upon DOQQ imagery. These data are also used to determine a new stream thalweg, or channel centerline. This imagery provides a more current, accurate representation of the channel under 1-2 year return period flow conditions. The LIDAR data is then applied to support the determination of a bank definition, at a
Figure 1. Stream geometry definition process.

Figure 2. Runoff modeling process.
Figure 3. Flood modeling process.

Figure 4. Flood mapping process.
defined flood stage. This digital delineation is then used to support an eight-point, Muskingham-Cunge, cross-section definition of the channel. Moreover, using classification techniques, the LIDAR data are separated into land and water classes in order to generate a streambed elevation point matrix. High accuracy GPS field-surveyed data of the streambed and overbanks are then combined with the streambed elevation data to generate a floodplain matrix. Using the previously digitized overbanks as break lines, merged elevation data sets are interpolated into the terrain surface model. These differentially-corrected, high accuracy GPS survey data also provide a suitable supplement to any witnessed data voids in the LIDAR coverage, especially in the wetted perimeter region.

MODELING AND MAPPING METHODOLOGY

Using Arcview (GIS) and custom Flood*Ware™ software, the GIS database is interrogated for the determination of hydrologic model input data sets. As shown in Figure 2, runoff model data sets are generated in a semi-automated manner, and the HEC-1 model executed, with subsequent greater accuracy and speed. As described in Figure 3, the HEC-RAS hydraulics analysis, flood modeling, is enhanced through the generation of cross-section data from the merged, multi-resolution digital (terrain) elevation model. As represented in Figure 4, Flood*Ware™ then generates flood inundation extents for the ultimate preparation of a Digital Orthophoto Flood Insurance Rate Map. As another example, Figure 5A shows the elements used to generate the HEC-RAS flood model, using the DOQQ as the base map. Also, Figure 5B depicts those data items used to generate the HEC-RAS flood model, with a shaded relief of the LIDAR data in the background. In particular, the software generates cross sections every 250 feet, with the bank definitions shown.

SUMMARY

Semi-automated, GIS-based modeling and visualization techniques allow for the improved understanding of flood-related problems. This methodology allows for more rapid hydrologic and hydraulics model calibration, thus providing substantial accuracy improvements, and the potential elimination of uncertainty in the mapping process.
Figure 5A. Example of elements used to generate flood model over DOQQ.
Figure 5B. Example of elements used to generate flood model over LiDAR.
Part 8

Flood Hazard Mapping
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INTRODUCTION

The Stormwater Management Division within the Department of Development and Stormwater, DuPage County, Illinois, instituted a program that will remap all streams in the county. The process involves several phases and relies heavily upon geographic information system (GIS) tools and technology to meet its goals. The program is underway with the goal of having a countywide DFIRM (Digital Flood Insurance Rate Map) in 2000.

CONDITION OF THE CURRENT FLOODPLAIN MAPS

DuPage County is located west of Chicago and covers approximately 336 square miles. The county comprises 40 communities, including the unincorporated portions of the county. Each of the communities has its own Flood Insurance Study (FIS) and Flood Insurance Rate Maps (FIRMs). The effective map dates range from 1977 to 1999. Approximately 80% of the FISs and 85% of the FIRM panels are more than 15 years old. To complicate matters, the majority of the hydrologic/hydraulic models used to develop the FIRMs and FISs are in poor condition or do not exist.

DuPage County has gone through rapid urbanization over the past 45 years. In 1955, 58.5% of the county was in agricultural production compared to 5.3% in 1995. This conversion of agricultural land corresponds with the change in the county population from 154,599 in 1950 to 781,666 in 1990. Furthermore, from 1980 to 1995, the county population grew by more than 180,000 residents, residential land use increased from 27% to 35%, commercial land use increased from 24% to 34%, and undeveloped/agricultural land use declined from 35.5% to 12%. Continuing county urbanization has markedly altered the Federal
Emergency Management Agency (FEMA) floodplain maps developed for the county in the late 1970s and early 1980s. While many residential and commercial developments avoided the mapped floodplains, the changing land use has had a profound impact on the hydrology and hydraulics of the streams in DuPage County, ultimately affecting the usefulness of the floodplain maps.

There are several other limitations with the current maps. The current maps have discontinuities in flood zone boundaries and elevations from panel to panel. Many of these discontinuities are a result of adjacent communities having different study dates. A model that was used to develop a FIS and FIRM in one community may have been updated to develop a FIS and FIRM in an adjacent community without revising/updating the first community's study. In addition, the current maps do not reflect Letters of Map Revision (LOMRs). This has a significant impact in urban areas where development has occurred. Finally, many of the maps are simply cartographically incorrect and do not accurately represent the stream location.

COUNTY FLOODPLAIN MAPPING PROGRAM

The county has undertaken updating all the studies and maps within the county. The county will be using the HSPF/FEQ/PVSTATS approach to update the FISs and FIRMs. Updates will be performed on a tributary/watershed basis. The county has identified 59 tributaries/watersheds that will be updated. Since the FISs and FIRMs will be updated on a tributary/watershed rather than a community basis, the issue of discontinuities between corporate boundaries is eliminated. The new maps will rely heavily on GIS using a recent photogrammetrically derived map base. Given the number of tributaries/watersheds to be addressed, a complete remap of the county will take several years. It was deemed unacceptable to have a patchwork of maps with older maps based on community boundaries and newer maps based on tributary/watershed boundaries. In order to address this problem, the county decided to develop a countywide floodplain map using current FEMA flood profiles and the county's topographic data to create one consistent base map. The end goal is to use this countywide map to create a countywide DFIRM. As the county completes each tributary/watershed update, the new data could be "cookie cut" into the countywide DFIRM map.
COMPILATION OF CURRENT FLOODPLAIN DATA

Prior to development of the new countywide floodplain map, all current information needed to be collected from nearly 200 FIRM and Flood Boundary and Floodway Maps (FBFW). All FIRM and FBFW panels were scanned and rectified to State Plane Coordinates. GIS coverages of flood zones, floodways, base flood elevations, cross-sections, and elevation reference marks were developed from the scanned data. All LOMRs were obtained that resulted in a change in the flood profile. This was done to insure that the countywide map used the most current flood profile information in the development of the new floodplain limits.

COUNTYWIDE MAP DEVELOPMENT

Before the new floodplain boundaries could be developed, adjustments to the scanned GIS coverages were necessary. Each cross-section location is evaluated and adjusted to reflect the county's topographic map base. Many of the adjustments relied upon the profile sheets and any documentation that was available which referenced distances from identifiable structures (bridges, culverts, weirs, etc.). Once the location is fixed, the appropriate flood elevations are placed in the cross-section GIS attribute fields. These elevations are taken from the floodway data tables, flood profile sheets, and LOMRs. In situations where there are discontinuities at community boundaries, engineering judgement is used to estimate the appropriate flood profile. As this process is completed, the appropriate floodway tables and profile sheets are annotated to reflect changes.

Once all elevation information is compiled and adjusted, the floodplain limits are delineated by a GIS application using a GRID process. This includes creating a topographic grid and a flood surface grid. The topographic grid is subtracted from the flood grid to create a depth grid. At the transition from a positive to negative depth grid value, the floodplain limit is determined and a polygon coverage created and checked. Then the floodplain overage is created and the appropriate zone designations assigned. Next, the floodway limits are transposed onto the map. Since the hydraulic models used to create the floodway limits do not exist in most cases, the current floodway widths are transferred to the appropriate stream cross-sections. If the new floodplain is narrower than the current floodway, the floodway is made coincident with the new floodplain. The floodway is placed using topographic information and engineering judgement. Once the new boundaries are determined, they are sent to FEMA's Technical Evaluation Contractor for review and comment. Changes are addressed and the maps finalized.
PHYSICAL MAP REVISION DEVELOPMENT

Simultaneous with the development of these "interim" floodplain maps using current flood profiles, the county is developing new flood profiles using continuous hydrology, dynamic wave routing procedures, and the peak-to-volume statistical approach. The procedure uses the Hydrologic Simulation Program—FORTRAN (HSPF) to develop the hydrologic inputs for the hydraulic analysis. The hydraulic routing process uses the model Full Equations (FEQ) (Franz and Melching, 1997) to dynamically route the hydrologic inputs through the system. The determination of flood elevations is based on the peak-to-volume approach (PVSTATS) (Bradley and Potter, 1992). All cross-sections used in the FEQ model are developed using GIS application tools. Once the flood elevations have been developed, they are incorporated as attributes of the cross-sections and the flood limits are delineated using the same GRID process previously described (Brown and Steffen, 1998). Since floodway is a steady state concept, DuPage County determines floodway limits using the SCS FLDWY program with 100-year flood elevations and flows from the PVSTATS analysis. The physical map revision process will be done on a tributary/watershed basis. Once a tributary/watershed is developed and completes the public review process, it will be incorporated into the countywide map.

SUMMARY

DuPage County will finalize the countywide "interim" floodplain maps with FEMA, creating a countywide DFIRM. Previous physical map revisions as well as all future physical map revisions will be incorporated into the countywide DFIRM. DuPage County initiated this program in an effort to address their aging and obsolete floodplain maps and provide a base map that can be use as physical map revisions are required for the tributaries/watersheds within the county. The communities and residents of the county will benefit from maps that more accurately reflect the floodplain limits within the county.

REFERENCES


of the 22nd Annual Conference of the Association of State Floodplain Managers. Boulder, Colorado: Natural Hazards Research and Applications Information Center.

Flood Insurance Study
Aerial Mapping and Surveying Specifications
for GPS, DOQs, and LIDAR and IFSAR DEMs

David F. Maune
Dewberry & Davis

CHANGES TO FEMA 37

New Technologies
The Federal Emergency Management Agency (FEMA) is revising Appendix 4, "Aerial Mapping and Surveying Specifications," to FEMA 37, FIS Guidelines and Specifications for Study Contractors, to accommodate four new technologies relevant to the National Flood Insurance Program (NFIP): (1) global positioning system (GPS) surveys, (2) digital orthophoto quarter-quads (DOQs), (3) light detection and ranging (LIDAR), and (4) interferometric synthetic aperture radar (IFSAR). LIDAR and IFSAR are both used for the production of digital elevation models (DEMs) for hydrologic and hydraulic modeling.

New Standards
In addition, the revised Appendix 4 to FEMA 37 will tie all new Flood Insurance Study (FIS) surveys to the National Spatial Reference System (NSRS) and implement the new National Standard for Spatial Data Accuracy (NSSDA), which has officially replaced the National Map Accuracy Standard (NMAS) for digital spatial data that are used in production of Digital Flood Insurance Rate Maps (DFIRMs), DFIRM Digital Line Graphs (DFIRM-DLGs), and other digital products.

CHANGES AND RATIONALE

NSSDA
Digital spatial data used for the production of DFIRMs and DFIRM-DLGs are to be compiled, tested, and/or reported in accordance with the NSSDA published in 1998 by the Federal Geographic Data Committee (FGDC). These criteria are established to bring FEMA's digital spatial data into conformance with Executive Order 12906, which requires federal agencies
producing geospatial data to comply with FGDC standards (i.e., the NMAS published in 1947 by the Bureau of the Budget and/or the NSSDA published in 1998 by the FGDC).

The NMAS defines accuracy at the 90% confidence level, whereas the NSSDA defines accuracy at the 95% confidence level; but this is not the major distinction. The major distinction is that the NMAS remains relevant only to hardcopy maps where accuracy is defined by map scale or contour interval. The NSSDA replaces the NMAS for reporting the accuracy of digital geospatial data that are not constrained by scale or contour interval. The NSSDA also replaces the Accuracy Standards for Large-Scale Maps (ASPRS 90), published in 1990 by the American Society for Photogrammetry and Remote Sensing, the mapping standard previously endorsed by FEMA in FEMA 37. ASPRS 90 served as the basis for the FGDC's development of the new NSSDA.

**Network Control Points**

Each FIS should identify or establish a minimum of two network control points (NCPs) referenced to the NSRS. Using National Geodetic Survey (NGS) Data Sheets, NCPs should be identified or established and then used to further establish GPS base stations for differential GPS surveys (airborne, ground, and hydrographic surveys) and/or for conventional surveys of temporary bench marks, horizontal and vertical check points, etc. This criterion was established so that the entire FIS has good "network accuracy" relative to the horizontal and vertical datums and so that FIS data will register to geodigital data compiled by other agencies to FGDC standards.

The "network accuracy" of a control point is a value that represents the uncertainty in the coordinates of the control point with respect to the horizontal and/or vertical geodetic datum at the 95% confidence level, whereas "local accuracy" represents the uncertainty in the coordinates of the control point relative to the coordinates of other directly connected, adjacent control points at the 95% confidence level.

The revised Appendix 4 provides guidelines for establishing NCPs. Elevation reference marks will no longer be published on FIRM panels but will be included in the Technical Support Data Notebook as "temporary bench marks"—provided that they have been surveyed relative to an NCP.
Horizontal Accuracy

As a rule of thumb, FEMA prefers work maps compiled to NSSDA with Accuracy_r (radial accuracy) of 19 feet or better at the 95% confidence level. These work maps are equivalent to hardcopy maps compiled to NMAS at a 1:6,000 scale, although scales as small as 1:12,000 can be used if they are the best available. This criterion is established for FIS work maps, normally compiled at larger scales than the published FIRM, and so that DFIRMs, DFIRM-DLGs and derived geodigital products will correctly register to standard DOQs produced by the U.S. Geological Survey (USGS).

Under the NSSDA, where accuracy is determined at the 95% confidence level, the geodigital reporting standard in the horizontal component is the radius of a circle of uncertainty, such that the true or theoretical location of the point falls within that circle 95% of the time. Accuracy_r of 38 feet at the 95% confidence level is equivalent to RMSE_r (radial root mean square error) of 22 feet. This, in turn, is equivalent to the NMAS Circular Map Accuracy Standard of 33.3 feet, i.e., the horizontal error allowed by the NMAS at the 90% confidence level for DOQs and other maps compiled at a scale of 1:12,000.

FEMA study contractors are responsible for obtaining the best available community base map for use by FEMA in preparing and updating the base map for the DFIRM. Because digital submissions are now required, geodigital data are preferred over hardcopy maps, which would need to be digitized. Should accurate digital planimetric data be unavailable from the community or elsewhere, the default base map for the new DFIRM product is the USGS DOQ. DOQs are compiled to NMAS at a scale of 1:12,000 so that the horizontal accuracy is ±33.3 feet at the 90% confidence level. This is equivalent to DOQs compiled to the NSSDA so that Accuracy_r is ±38 feet at the 95% confidence level.

FIS work maps are normally compiled at larger scales than the published FIRM. This means that all work maps must be compiled to scales equal to or larger than 1:12,000. Hardcopy work maps compiled to NMAS at 1:6,000-scale may be used and subsequently digitized; their horizontal accuracy is ±16.7 feet at the 90% confidence level. The equivalent digital work map would be compiled to NSSDA with Accuracy_r of ±19 feet at the 95% confidence level. This guarantees that DFIRMs, DFIRM-DLGs, and derived geodigital products will correctly register to DOQs, whether or not DOQs are used by FEMA as the base map for the new DFIRM product.
Vertical Accuracy

FEMA prefers digital elevation data compiled to NSSDA with Accuracy\(_z\) (vertical accuracy) of 1.19 feet or better. This is equivalent to topographic maps compiled to NMAS with a 2-foot contour interval. This criterion was “tightened” from prior 4-foot contour interval requirements to improve the accuracy of base flood elevations (BFEs) and Special Flood Hazard Area (SFHA) boundaries.

Under the NSSDA, for the digital equivalent of 2-foot contours, the reporting standard in the vertical component is a linear uncertainty value such that the true or theoretical location of the point falls within ± of that linear uncertainty value 95% of the time. Accuracy\(_z\) of 1.19 feet at the 95% confidence level is equivalent to the NMAS Vertical Map Accuracy Standard of 1-foot, i.e., the vertical error (one-half contour interval) allowed by the NMAS at the 90% confidence level for maps compiled with 2-foot contours.

This vertical accuracy rule of thumb can be waived if the FEMA Regional Project Officer determines that the additional cost of 2-foot contour interval equivalent data is too expensive compared with 3- or 4-foot contour interval elevation data already available.

Digital Elevation Models for Automated Hydraulic Modeling

When used for automated hydraulic modeling, digital elevation models (DEMs) are to be tested so that Accuracy\(_z\) is 1 foot or better at the 95% confidence level, and this requirement cannot be waived. If such DEM accuracy is not achieved, other data (e.g., surveyed cross sections and break lines) must be used to augment the DEMs. This criterion was established so that DEMs will have the 3-D accuracy necessary to support the automated computation of BFEs and SFHA boundaries. This vertical accuracy criterion is strict, but FEMA believes it must proceed cautiously when using evolving techniques (e.g., LIDAR and/or IFSAR DEMs) for automated calculation of critical BFE values and SFHA boundaries.

Before such DEMs are accepted for automated hydraulic modeling, 60 or more elevation check points, surveyed with 5-cm accuracy, must be used to evaluate the accuracy of the DEM data, using 20 check points in each major vegetation category (e.g., trees/forests, scrub/crops/weeds, and grass/dirt). If there are other major categories, such as mangrove or sawgrass, they too should have 20 check points each to verify the accuracy of “bare earth” DEMs in such vegetation. Such DEMs should have uniform point spacing of 5 meters or less. Check points should be
selected on terrain with uniform slope within a 5-meter radius so that linear interpolation can be used from surrounding DEM points.

To provide Accuracy\(_z\) of 1 foot or better, the RMSE\(_z\) for the 60 or more check points must equal 6 inches or less. These numbers are rounded. The exact formula is:

\[
\text{Accuracy}_z = 1.9600 \times \text{RMSE}_z.
\]

**SUMMARY**

When republished in the next year, FEMA 37 will include examples of how to survey NCPs, how to verify the horizontal accuracy of planimetric data, how to verify the vertical accuracy of DEMs, and other procedural guidance. With the new FEMA 37, study contractors will have significantly better guidance on utilizing new technologies and applying new FGDC standards to NFIP products. As a result, the new DFIRM product will have both the horizontal and vertical accuracy necessary for accurate depiction of flood hazards, overcoming well-known limitations of past FIRM and DFIRM products.
Upgrading FEMA Maps with Master Drainage Plans

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INTRODUCTION
This paper will describe the process of using master drainage plans or feasibility studies to update Federal Emergency Management Agency (FEMA) flood maps. Usually these drainage studies will include updated or revised hydrology, hydraulics, and mapping. Issues that arise in this process will be discussed, including coordination with adjacent communities and affected citizens, technical differences due to better/more data or improved methodology, and differences between FEMA criteria and city criteria.

FEMA FLOOD INSURANCE STUDIES AND FLOOD INSURANCE RATE MAPS
Flood Insurance Studies (FISs) and Flood Insurance Rate Maps (FIRMs) are the documents that provide uniform floodplain management and flood insurance data and are the technical backbone of the National Flood Insurance Program (NFIP). The reports and maps issued by FEMA identify and define the areas of the 100-year and other frequency floodplains.

Flood insurance studies and the resulting maps have evolved since about 1968 into standardized products that include street and city boundary information with flood-related data superimposed upon the base maps. Many of the currently effective FIRMs are based on U.S. Geological Survey quadrangle maps. Often, hydraulic cross sections are widely spaced or are outdated. The technical quality of the mapping, surveying, hydrologic, and hydraulic data varies widely and is enhanced when updated from master drainage studies.

REASONS FOR UPGRADING FLOOD INSURANCE MAPS
Diverse Uses
The approximately 100,000 FEMA map panels produced through the NFIP were originally intended to support flood risk determinations, but
their uses have broadened significantly to include land use planning/regulation, mortgage transactions, title transfers, land development ordinances, disaster and emergency preparedness and response, risk assessment, drainage regulations, and permitting.

**Inadequate or Obsolete Base Data**

The basic mapping, surveying, and engineering data used in many of the existing FEMA maps are often obsolete, inaccurate, and grossly out of date.

**Aging of the Maps**

Unfortunately, the NFIP mapping is aging. About 45% of the maps are at least 10 years old.

**GENERAL PROCEDURES FOR CONVERTING DRAINAGE STUDIES TO FEMA MAPS**

There are no precise guidelines for converting more detailed drainage studies to the FEMA format, although there are specific procedures for the actual submittals and review process at the federal government level (FEMA, 1996). General procedures include:

1. Convert fully urbanized watershed hydrology to “existing conditions.”
2. Incorporate any intermediate Letters of Map Revision that affect the streams being analyzed.
3. Prepare flood profiles for the 10-, 50-, 100- and 500-year floods.
4. Prepare new floodway models (attempt to use the current widths).
5. Prepare revised floodplain and floodway maps.
6. Correlate the new mapped data with adjacent community maps, if applicable.
7. Coordinate map changes with the affected citizens and other impacted entities.
8. Prepare and submit FEMA application/certification forms.
9. Coordinate review process with FEMA technical contractors.

**ISSUES/PROBLEMS IN CONVERTING DRAINAGE STUDIES TO FEMA MAPS**

Some of the technical problem areas or issues that may be encountered when drainage studies are being converted to FEMA mapping are listed below.
• Fully Urbanized Versus Existing Conditions Hydrology—Most master drainage plans account for future urbanization within the watershed and reflect "fully-developed" conditions. FEMA hydrologic criteria is generally for "existing" conditions.

• Proposed Bridges, Culverts, Dams, and Channelization—FEMA requires that only existing structures and improvements be included in the hydraulic models.

• Engineering Methodology—Hydrologic or hydraulic software or methods used for a master drainage study versus those used for FEMA studies. Generally, FEMA accepts non-standard computer programs if they meet certain criteria and review.

• More Detailed Analysis—Generally, FEMA accepts and encourages more detailed analysis of watersheds and streams that have been previously mapped for an FIS.

• Additional Surveying or Topographic Data—Many master drainage studies include updated or very detailed topographic mapping or more field survey data than is normally available for FEMA-funded studies.

• Coordination—Since watersheds and streams do not always follow political boundaries, the conversion of drainage plans to FEMA maps often will require resolution of floodplain/floodway differences at corporate boundaries.

CASE STUDIES

Case I: Comprehensive Drainage Study for the City of Hurst, Texas

In 1983, a Comprehensive Drainage Study was prepared for the City of Hurst with fully urbanized watersheds and floodplains. Since 1983, two Corps of Engineers’ flood control projects, and three City projects have been constructed on Lorean Branch.

Conversion to FEMA Maps—In December 1992 the City submitted a request to FEMA for a LOMR and Physical Map Revision for Lorean Branch, including analysis of the "as-built" conditions. The 100-year base flood elevations (BFEs) were reduced by as much as 3.98 feet, and the floodplain and floodway maps were revised to reflect the improvements.
Technical issues included obtaining all "as-built" plans, field surveying to verify improved grades, revising the hydrology to reflect "existing conditions," and revisions to the floodways.

**Case II: Fish Creek Drainage Master Plan for Grand Prairie, Texas**

A May 1990 drainage master plan (DMP) study on the Fish Creek watershed was prepared by Halff Associates. Using fully urbanized discharges, flood profiles for the 5-, 10-, 25-, 50-, 100, and 500-year floods were determined and revised floodplains delineated.

**Conversion to FEMA Maps**—In July 1994 the City of Grand Prairie submitted a request to FEMA for a LOMR and Physical Map Revision for Fish Creek. This report, prepared by Halff Associates, included an update of the DMP Fish Creek HEC-2 model with additional cross sections and fill projects. Floodway encroachments were modified to conform to topographic maps, reflect fill projects, and maintain one-foot criteria.

Technical issues were correlating the various mapping and surveying datum, incorporating all previous LOMRs, and revisions to the floodways that were the "best fit" to the currently effective data.

**Case III: Storm Drainage Master Plan (Phase I) for City of Colleyville, Texas**

A February 1992 Comprehensive Storm Drainage Master Plan (Phase I), for the City of Colleyville was prepared by Halff Associates, Inc. SPOT® satellite imagery was used to analyze existing land cover over the 70 square mile watershed and detailed HEC-1 and HEC-2 computer models were prepared for existing and future development conditions. Comprehensive 100-year floodplain and floodway maps were based on future fully urbanized watershed conditions.

**Conversion to FEMA Maps**—In August 1997, the City of Colleyville submitted a request to FEMA for a LOMR and Physical Map Revision for Tributary LB-2 (Little Bear Creek tributary). This report included a HEC-RAS model using the master plan HEC-2 model as a base. The re-study was conducted because of channel and culvert improvements in the upper watershed.

Technical issues included incorporating the hydrologic effects of the railroad constriction into the models, correlating the "as-built" construction plans, and revising the hydrology models to reflect "existing conditions."
The City decided to eliminate floodways altogether on Tributary LB-2 because of the number of flooded properties in the lower end of the creek. Additional encroachment was viewed as a potential liability.

CONCLUSIONS

This paper illustrates the basic procedures and potential technical problems encountered when converting master drainage plans to FEMA maps. Three of the most significant tasks or issues, common to most of the studies are:

1. Preparation of the required FEMA forms and coordination during review.
2. Correlation of the current effective FIS and other engineering studies.
3. Reconciling the “new” floodway with the effective floodway.

Some of the benefits of these conversions include:

- Removing properties from the FEMA floodplain.
- Providing a more precise definition of the actual flood hazard.
- More accurate FEMA maps for flood insurance and other purposes.
- Reflecting the construction costs expended by the cities to reduce flooding.
- Consistency between the City’s planning/master plan maps and FEMA maps.

REFERENCES

GPS and Terrestrial Remote-Sensing Technologies to Support FEMA's Map Modernization Program

Arnold Lanckton
Synectics Corporation

Fred Howe
New York State Technology Enterprise Corporation

INTRODUCTION

Advances in terrestrial data and image collection complement the Federal Emergency Management Agency's (FEMA's) Map Modernization Program. Synectics Corporation and the New York State Technology Enterprise Corporation combined on a project to provide digital terrain and bridge data in support of the Schoharie Creek (New York) Flood Modeling and Digital Ortho-image Flood Insurance Rate Maps project. Synectics' TerrainMapper™ was used to collect data on centerline profiles, river cross sections, highway cross sections, elevation certificates, elevation reference marks, and bridge details consisting of railings, curbs, catch basins, and other bridge hydrology features. Synectics obtained the services of Harza Northeast, Inc., a New York corporation and professional engineering firm, to assist in the surveying and engineering phases of the project.

The successful completion of the project demonstrated cost-effective applications for global positioning system (GPS) and terrestrial remote-sensing technology. Sample Elevation Certificates, which are critical components for any community participating in the FEMA Community Rating System, were developed. The results of the project demonstrated that the TerrainMapper™ technology could deliver a product in days—versus weeks using conventional survey methods—and at a lower cost.

In addition to reducing the cost of producing terrestrial data, the TerrainMapper™ technology enables delivering surveying and mapping products rapidly. Base station establishment and field collection can be managed so that data for multiple bridges can be collected each day. Since the centerline product only requires one hour to produce, it can be delivered the day after the collection. The TerrainMapper™ client/server
post-processing architecture allows multiple operators on separate
monitors to work simultaneously on data from the same bridge,
facilitating rapid product delivery.

The project demonstrated the relatively low fixed costs associated
with base station establishment, data collection, and centerline production.
Variable costs were analyzed for feature extraction, sensor integration, and
product generation in compiling digital terrain models for cross sections,
highway centerlines, bridge details, and other features. It is estimated the
per-bridge costs documented on this project can be further reduced.

**TERRAINMAPPER™ PROCESS**

TerrainMapper™ is a real-time kinematic differential GPS surveying
device that provides control to digital images collected sequentially along
a route of travel. The TerrainMapper™ has digital cameras to capture
stereoscopic images of areas directly below and beside the trailer. A third
camera captures forward-looking views for reading highway signs and
identifying features. Immediately after collection, the highway centerline
and precise exterior orientation elements are calculated for each exposure,
and the controlled digital imagery is placed into a data base for data
extraction. This Point Position Data Base can be exploited on a Pentium-
class PC using TerrainMapper™ Software. The TerrainMapper™ Software
features a unique application of a client-server processing architecture that
permits data from a single field collection to be distributed to an
arbitrarily large number of processor stations for parallel data extraction.
This allows project turnaround time to be scaled simply by using more
personnel and more processor stations. Figure 1 summarizes the
TerrainMapper™ process.

**BRIDGE DATA**

The following three bridges in the Schoharie Creek watershed area were
selected to be mapped.

**Bridge #1**—The Cobleskill Park is on the Mill Creek and a dam has
been constructed to form a small pond within the park. This particular site
has stream channel conditions that require several stream cross-sections
above and below Route 7 and above the dam to develop accurate
hydrology. There are several commercial establishments in the area that
serve as excellent examples for elevation certificates.

**Bridge #2**—The Cobleskill Bridge site is located just south of the
village of Cobleskill on State Route 145, approximately 200 yards north
of the Interstate Route 88 crossing over State Route 145.
Bridge # 3—The Middleburg Bridge site crosses Schoharie Creek and is located on the west edge of the village of Middleburg on State Routes 145 and 30.

The products produced from this project are reflected in Table 1.

Table 1. Bridge products.

<table>
<thead>
<tr>
<th>Products Produced</th>
<th>Bridge #1</th>
<th>Bridge #2</th>
<th>Bridge #3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bridge details*</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Topography**</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Elevation Reference Mark</td>
<td>1</td>
<td>None</td>
<td>1</td>
</tr>
<tr>
<td>Elevation Certificate</td>
<td>4</td>
<td>1</td>
<td>None</td>
</tr>
<tr>
<td>Planimetry***</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

*Bridge details consist of bridge rails, bridge abutments, curbs, and catch basins.

**Topography consists of centerline, terrain breaks, and 5-meter-spacing DTMs.

***Planimetry consists of curbs, building outlines, trees, edge of pavement, etc.
COST ESTIMATES

The actual project costs in compiling DTM for cross sections, highway center lines, bridge details, and other features for this project averaged $1900 per bridge and are based upon the parameters listed in the Cost Parameter Table (Table 2). These costs are the sum of $800 for feature extraction, $100 for sensor integration, and $1000 for product generation. It is estimated that these costs can be reduced from $1900 to $500 per bridge with an experienced staff and a set of production procedures. This project was the first conducted by the TerrainMapper™ staff, and there are several production areas where costs can be significantly reduced. The costs for base station establishment, collection, and centerline are reasonably low, and it is not expected that they can be further reduced.

Table 2. Cost-parameter table.

<table>
<thead>
<tr>
<th>Item</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Labor Rate</td>
<td>$100/hr</td>
</tr>
<tr>
<td>Per Diem</td>
<td>Not included due to variability</td>
</tr>
<tr>
<td>Travel time to and from project</td>
<td>45 minutes each way</td>
</tr>
<tr>
<td>Travel time between bridges</td>
<td>30 minutes</td>
</tr>
<tr>
<td>Number of Base stations per day</td>
<td>7</td>
</tr>
<tr>
<td>Survey crew</td>
<td>2</td>
</tr>
<tr>
<td>Number of Bridges per day</td>
<td>6</td>
</tr>
<tr>
<td>TerrainMapper™ crew</td>
<td>3</td>
</tr>
</tbody>
</table>

In addition to reducing the cost of producing terrestrial data, the TerrainMapper™ technology enables delivering surveying and mapping products rapidly. The base station establishment and field collection can be managed so that data can be collected for six bridges each day.

The information required for Elevation Certificates is currently prepared on a structure-by-structure basis by land surveyors using conventional survey methods to extend vertical control from the nearest Elevation Reference Mark. The application of the TerrainMapper™ technology allows a community to significantly reduce the cost and time involved in producing Elevation Certificates (Table 3).

The optimum approach would be to collect data throughout the entire community. A less-extensive approach would be to collect data on structures in marginal areas. This latter approach would entail a collection process
similar to collecting data for six bridges a day except that six different adjacent areas would be collected.

*Table 3. Elevation Certificate cost.*

<table>
<thead>
<tr>
<th>Function</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost to establish one base station</td>
<td>$286.00</td>
</tr>
<tr>
<td>Cost to collect 12 miles on one side of the highway a day</td>
<td>$2,400.00</td>
</tr>
<tr>
<td>Total collection cost</td>
<td>$2,686.00</td>
</tr>
<tr>
<td>Number of structures imaged/day requiring certificates</td>
<td>760</td>
</tr>
<tr>
<td>Collection cost per certificate</td>
<td>$3.50</td>
</tr>
<tr>
<td>Feature extraction and product generation per certificate</td>
<td>$33.00</td>
</tr>
<tr>
<td>Total cost per certificate</td>
<td>$36.50</td>
</tr>
</tbody>
</table>

The above cost analysis involves only survey costs and is based upon a reasonable density of structures throughout the TerrainMapper™ data-collection area and a collection rate of about 3 to 4 miles per hour. The Cost per Elevation Certificate Chart (Figure 2) illustrates the cost per Elevation Certificate for a varied number of structures collected during a single day.

*Figure 2. Cost per elevation certificate.*
Special Flood Hazard Boundary: A "Line" or a "Fuzzy Band"

Theodore E. DeBaene
Owen and White, Inc.

Special Flood Hazard Areas (SFHAs) are targeted with a myriad of regulations. Location within the SFHA produces a significant cost to a property. To insure proper allocation of property, the boundary line defining the SFHA is frequently clarified through elaborate base map and geographic information system (GIS) procedures.

While the exercise in precision may appear to be noble, it totally misses the true problem of the SFHA boundary. Due to the inaccuracies of large scale topographic maps, the location of this line can easily be hundreds and even thousands of feet off its true position.

EXPLANATION OF THE PROBLEM

The boundary line is generally interpolated between contours of work maps. The most common map source is the U.S. Geological Survey (USGS) quad sheet. These maps are published with 5-foot or 10-foot contour intervals. Their accuracy is ½ of a contour interval, which is from 2½ to 5 feet from true elevation. Aerial photography can economically produce 2-foot contours supplemented by spot elevations. While this is a significant improvement, an interpolated line can still be improperly placed. In addition, tree cover can totally nullify the process. This is especially critical considering that the best time to establish a new SFHA is in a "soon to be developed" area, which is usually dominated by tree cover.

Black Bayou in Ascension Parish, Louisiana, exemplifies boundary line improvement with better topographic mapping. The SFHA boundary was originally plotted on a Flood Insurance Rate Map (FIRM) using a 5-foot contour quad sheet as a work map. A revised Flood Insurance Study (FIS) produced an identical profile. However, our topographic map utilized 2-foot aerial photomap contours that produced a boundary totally foreign to the original FIRM. In a 4-mile stream reach, 140 acres of the "C" area became "AE"; 190 acres of the "AE" area became "X." This analysis shows how vulnerable the boundary line is to map accuracy.
In another project, West Baton Rouge Parish retained us to revise its FIS. We could have interpolated the flood boundaries between the 5-foot contours of the quad sheet, but these contours are 10,000 feet apart. For an extra $23,000 we would provide aerial photomaps with 2-foot contours. They opted for the 2-foot contours, showing that more accuracy is a priority for communities.

In other cases, we have been unable to offer aerial photomaps due to a forest canopy. For the Tickfaw River in Livingston Parish, the highest 5-foot contour does not confine the flow throughout 15 miles of reach length. It is within the range of the next contour interval, so the flow could possibly be confined. The boundary is really indeterminate with available mapping, and mapping improvement is cost prohibitive. In DeSoto Parish, all of the detailed study streams have impenetrable forest canopy and the quad sheets provide 10-foot contours. The contours of the quad sheets are not only sparse but could easily be in error since the forest canopy existed during their preparation as well. These typical flood insurance study situations involve a risk of massive errors in the placement of the SFHA boundary line.

The Letter of Map Amendment (LOMA) process does provide a means of correcting an improper delegation of a property to an SFHA when its actual elevation exceeds the base flood elevation (BFE). However, there is no procedure to corral those properties who actually are below the BFE but are outside of the SFHA boundary.

Thus, I do not believe that it is possible to define a line that represents the SFHA boundary.

POTENTIAL SOLUTIONS

Since the boundary of an SFHA cannot be truly represented by "a line," a "band" should be used instead. Since this is an area of uncertainty, we refer to it as a "fuzzy band." The width of the band would depend on the accuracy of the topographic map. The determination of whether a property lies within the SFHA would require a ground survey. A certified engineer or surveyor would physically measure the actual elevation of the ground at the building site and record it with the BFE on an elevation certificate.

In this concept, FIRMs would contain three basic zones (Figure 1):
Figure 1. Proposed FIRM flood zones.
"For Sure" = That portion of the current AE zone having elevations on a topographical map that can be identified as being lower than the BFE less the contour tolerance. This entire area is in the SFHA.

"Rare and Local Flooding" = That portion of the current X Zone having elevation on a topographical map that can be identified as higher than the BFE plus the contour tolerance. None of this area is in the SFHA but it is recognized that flooding may occur from overland flow, unstudied streams, and infrequent events.

"Fuzzy Band" = Those portions of the current AE Zone and X Zone having elevation on a topographical map between the BPE minus the contour tolerance and the BFE plus the contour tolerance. Elevation certificates would compare the BFE with the ground elevation at the foundation to determine whether the property is within or outside the SFHA.

ADVANTAGES OF THE "FUZZY BAND"

Advantages of this system include:

(1) The potential of property below the BFE being located outside the SFHA is virtually eliminated.
(2) The "closeness" of a marginal property to being within the SFHA is emphasized.
(3) LOMAs would disappear.
(4) The decision on inclusion within an SFHA would be local and immediate.
(5) The cost of providing more accurate topographic maps would shift from FEMA to the local communities who use the maps.
(6) The survey expense would apply to the specific property being developed at the time that other planning functions are being provided.

CONCLUSION

Due to the inaccuracies of mapping large areas, the delineation of the SFHA by a boundary "line" is impractical. The questionable range can be described more accurately by a "band." The inclusion of a structure in the SFHA would be determined by an on-site survey.

While this may seem to be a drastic departure from the current process, it is only a slight modification. Although an additional zone, the
“band” can be delineated without any survey, hydrology, hydraulic, or profile changes.

Its principal advantage is the inclusion of all properties below the BFE into the regulatory portion of the program while relieving properties above the BFE from the time and expense of the LOMA process.
An Evaluation of Flood Frequency Relations for Jackson County, Oregon

Jerry B. Stonefield and Wilbert O. Thomas, Jr.
Michael Baker, Jr., Inc.
Larry Basich
Federal Emergency Management Agency

INTRODUCTION

Regional regression equations are often used to estimate flood discharges for ungaged streams for use in flood insurance studies (FISs). These regression equations relate the flood discharges, such as the 1% chance (base) flood discharge, determined at gaging stations, to watershed and climatic characteristics that are determined from topographic maps and rainfall atlases. Regional regression equations were used to estimate effective base flood discharges for ungaged streams in Jackson County, Oregon. Recently, the Federal Emergency Management Agency (FEMA) evaluated these equations in response to possible revisions to the Flood Insurance Rate Map (FIRM).

The effective base flood discharges were based on two sets of regression equations for watersheds greater than 100 square miles and for watersheds less than 100 square miles (Federal Emergency Management Agency, 1993). These equations were evaluated by comparison to (1) updated base flood estimates for 20 unregulated gaging stations in or near Jackson County, (2) regression equations previously developed by the U.S. Geological Survey (USGS) (Harris et al., 1979), and (3) regression equations developed as part of this evaluation.

EFFECTIVE FIS EQUATIONS

The effective FIS regression equations for estimating the base flood discharge ($Q_{1%}$) in cubic feet per second (cfs) as a function of drainage area ($A$) in square miles are:

$$Q_{1%} = 699 A^{0.354} \quad \text{for } A < 100 \text{ square miles} \quad (1)$$

$$Q_{1%} = 2,232 A^{0.491} \quad \text{for } A > 100 \text{ square miles} \quad (2)$$
Equations 1 and 2 provide very discontinuous estimates of the base flood discharge for watersheds with drainage areas from approximately 50 to 200 square miles. Equation 1 was based on data for six gaging stations ranging in size from 5.11 to 45.5 square miles, while Equation 2 was based on data for four gaging stations with drainage areas from 133 to 297 square miles.

EXISTING USGS EQUATIONS

Harris and others (1979) developed regression equations for estimating the magnitude and frequency of floods in western Oregon. They divided western Oregon in four hydrologic regions. Jackson County, which borders northern California, is in the southern portion of the study area and in both the Rogue-Umpqua and High Cascades regions.

The USGS equation for estimating the base flood discharge in the Rogue-Umpqua Region is:

\[ Q_{1%} = 77.3 \cdot A^{0.90} \cdot (ST+1)^{-1.34} \cdot I^{1.08} \]  

where \( ST \) is the area of lakes and ponds expressed as a percentage of the drainage area and \( I \) is the 24-hour rainfall with a recurrence interval of 2 years and expressed in inches. The USGS equation for estimating the base flood discharge in the High Cascades Region is:

\[ Q_{1%} = 22.6 \cdot A^{0.41} \cdot (ST+1)^{-1.17} \cdot (101-F)^{0.03} \cdot I^{1.57} \]  

where \( F \) is forest cover expressed as a percentage of the drainage area and all other variables are previously defined.

DEVELOPMENT OF NEW EQUATIONS

The first step in evaluating Equations 1 and 2 was to update flood frequency estimates for 20 gaging stations in or near Jackson County that are not effected by regulation, have a sufficient record length for flood frequency analysis, and have a drainage area less than 1,000 square miles. These stations are listed in Table 1. Base flood discharges were estimated using Bulletin 17B guidelines (Interagency Advisory Committee on Water Data, 1982) and annual peak flow data through 1993. Record lengths ranged from 12 to 72 years.

New regression equations were developed for estimating base flood discharges for Jackson County using data for the 20 gaging stations in Table 1. First, an equation was developed based only on drainage area to be consistent with Equations 1 and 2. This equation is:

\[ Q_{1%} = 317 \cdot A^{0.74}. \]
Table 1. Summary of the base flood discharges and watershed characteristics for 20 gaging stations in Jackson County, Oregon. (-- indicates data not available).

<table>
<thead>
<tr>
<th>USGS Station Number</th>
<th>Area (mi²)</th>
<th>Soils Index (inches)</th>
<th>Gaged Data (cfs)</th>
<th>FIS Eqs 1-2 (cfs)</th>
<th>USGS 79-533 (cfs)</th>
<th>Eqn 6 (cfs)</th>
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<tr>
<td>14327500</td>
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<td>4.1</td>
<td>5740</td>
<td>26600</td>
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<td>28100</td>
<td>36800</td>
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<td>46400</td>
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<td>14368500</td>
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<td>2140</td>
<td>1500</td>
<td>1690</td>
<td>1850</td>
</tr>
<tr>
<td>14371500</td>
<td>22.1</td>
<td>1.2</td>
<td>6640</td>
<td>2090</td>
<td>4400</td>
<td>7620</td>
</tr>
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</table>

The standard error of estimate of Equation 5 is 57.3% (0.2316 log units) and the R² value is 0.82 implying that drainage area alone is explaining 82% of the variation in the base flood discharge.

A significant difference was noted in base flood discharges for the Rogue-Umpqua and High Cascades regions. Of the watershed characteristics exclusive of drainage area given in Harris and others (1979), the soils index explains most of the variation in base flood discharges between the two regions. The following regression equation for estimating base flood discharges was computed based on data for 19 gaging stations (Si was not available for station 14354400):

\[
Q_{1%} = 941 \cdot A^{0.72} \cdot Si^{0.75}
\]  

(6)

where Si is the soils index in inches and all other variables are previously described. The standard error of estimate of Equation 6 is 47.9% (0.1974 log units) and the R² value is 0.86, implying that drainage area and soils
index explain 86% of the variation in the base flood discharges. Based on the standard error and $R^2$ values, Equation 6 provides only a marginal improvement over Equation 5.

The soils index is the maximum potential retention (infiltration) and is computed from hydrologic soil types and land cover as described by the Soil Conservation Service in the National Engineering Handbook, Section 4, dated March 1985. The soils index is related to the runoff curve number (RCN) and be estimated as $Si = (1000/RCN) - 10$.

**COMPARISON OF EQUATIONS**

The base flood discharges from the FIS equations (Equations 1 and 2) are compared to the updated gaging station estimates, to estimates from regression equations documented in Harris and others (1979) and to estimates from Equation 6 (regression on drainage area and soils index) (Figure 1). In Figure 1, the published FIS equations are estimates from Equations 1 and 2 and they are notably discontinuous around 100 square miles. The base flood estimates from Equation 1 tend to be too small for watersheds in the vicinity of 100 square miles and those from Equation 2 tend to be too large relative to the updated gaging station estimates. The FIS equations do not provide consistent estimates across all drainage areas in the county and should not be used for estimating base flood discharges in Jackson County.

Base flood estimates from regression equations (Harris et al., 1979) (Equations 3 and 4) are also shown in Figure 1. There is considerable scatter in the USGS regression estimates, but they seem to be unbiased and can be used for estimating base flood discharges in Jackson County.

Estimates from the FIS equations were also compared to estimates from Equation 5 (regression on drainage area). One approach for determining if the FIS equation estimates are significantly different from Equation 5 is through the use of prediction limits. The 67% prediction limits for Equation 5 were computed and are shown in Figure 2 along with estimates from the FIS equations. An interpretation of the 67% prediction limits is that the true base flood discharge should lie between the upper and lower limits 67% of the time. The 67% prediction limits are equivalent to plus or minus one standard error of prediction about the regression equation.

Base flood estimates from the FIS equations plot outside the 67% prediction limits of the new regression equation based on drainage area in the range of 50 to 200 square miles. On this basis, the FIS equations are considered significantly different from Equation 5.
Figure 1. Comparison of base flood discharges for gaging station in Jackson County, Oregon.

Drainage area (square miles)

Peak discharge (cfs)
Figure 2. Comparison of base flood estimates from published FIS equations to the regression equation based on only drainage area.
SUMMARY

The published FIS equations for Jackson County, Oregon, were shown to provide discontinuous estimates of base flood discharges in the range of drainage areas from 50 to 200 square miles and to be inconsistent with estimates based on updated frequency curves at selected gaging stations. The regression equations were discontinuous because the equations were based on two distinct sets of data. If stratified data sets are used, then the analyst must insure that the regression equations provide similar estimates at the breakpoint.

Regression equations developed by the USGS (Harris et al., 1979) were shown to be unbiased, but estimates of base flood discharges exhibited significant variability. Regression equations were developed as part of this evaluation based on drainage area alone (Equation 5) and drainage area and a soils index (Equation 6). These equations were based on the updated frequency curves and watershed characteristics at the 20 gaging stations. The regression equation based on drainage area and soils index is only a marginal improvement over using just drainage area as the explanatory variable.

Base flood estimates from the published FIS equations were compared to the 67% prediction limits of the new regression equation based on drainage area. In the range of drainage areas from 50 to 200 square miles, the FIS estimates plotted outside the 67% prediction limits. On this basis, the FIS equations are considered significantly different from the new regression equation.

The published FIS equations should not be used for future restudies or map revisions in Jackson County. Either the USGS equations (Harris et al., 1979) or Equations 5 and 6 developed in this paper should be used.

REFERENCES


Part 9

Special Flood-related Hazards
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Predicting Stream Reach Erosion Using HEC-RAS

Bill Norris
Inter-Fluve, Inc.

INTRODUCTION

Stream assessment surveys usually include characterizing erosion potential along stream reaches. In many cases, this is done by visual and quantitative assessment of current stream bed and bank erosion and overall condition. When assessing streams within modified watersheds, however, observations of current conditions may not be a reliable method of directing future restoration efforts within a stream reach.

The physical response of a stream lags behind changes in hydrologic regime caused by watershed modifications. The stream will eventually reach a new state of equilibrium with respect to watershed conditions after conditions stabilize and sufficient rainfall-runoff events of significant magnitude and duration occur. Thus, a channel that appears to be in good condition simply may not have experienced a sufficient number of erosive events since its watershed was altered. Alternatively, streambank erosion may appear to be a problem when the channel is beginning to reach a new state of equilibrium and erosion rates are declining.

Applying a hydraulic model such as HEC-RAS to the assessment of stream reach stability can provide additional insight as to whether the stream channel may be reaching an equilibrium state with respect to its watershed conditions. HEC-RAS is a one-dimensional steady state hydraulic model developed by the U.S. Army Corps of Engineers. This paper reviews a method for evaluating erosion potential using HEC-RAS. The evaluation of erosion potential will include comparing calculated channel bed and bank shear stress to an estimate of the channel bed and bank allowable shear stress.

CALCULATED SHEAR

A shear analysis of a stream reach provides a quantitative method of assessing erosion potential, and may be used to supplement observations of current channel conditions. Shear stress, or tractive force, is the force
imposed on a channel's boundary due to the movement of flowing water. The equation for calculating shear is shown below.

\[ \tau = \gamma Rs \]

where:
- \( \tau \) = shear stress, psf
- \( \gamma \) = specific weight of water, pcf
- \( R \) = hydraulic radius, ft
- \( s \) = energy slope, ft/ft

HEC-RAS uses the above equation for calculating shear, thus providing an average shear over the channel's wetted boundary. HEC-RAS will calculate shear along a cross section's left bank, right bank, and channel, each based on the hydraulic radius of that portion of the cross section. The practitioner should be aware that actual bed shear will exceed HEC-RAS values at depths exceeding the hydraulic radius. HEC-RAS bank shear may be overestimated or underestimated, depending on the depth of flow at the point of interest. It should be noted that tractive force is commonly calculated using flow depth at a point of interest (d) rather than hydraulic radius (R). By using depth (d), variations in shear along the channel's cross section may be calculated as well. The variation in shear along a channel bank is illustrated by a diagram of bank and bed shear offered by Lane et al. (1953), and shown in Figure 1. Figure 1 is a theoretical boundary shear diagram that suggests shear approaches zero at the corners of the channel. It is more appropriate to assume that shear may be determined as related to depth and energy slope using the above equation at the toe of the bank as the shear and erosion potential is the greatest. Bed and bank shear relations are further defined in Figure 2 as reported by Lane et. al. (1953). Figure 2 relates maximum unit shear versus aspect ratio, the ratio between bottom width, b, and depth, d.

![Figure 1. Bed and bank shear in a trapezoidal cross section.](image-url)
Because shear varies with flow depth and energy slope, a range of flows along the channel should be run through the model until the flow that produces the highest shear (based on hydraulic radius) value is determined. Energy slope and water surface elevation associated with the flow of maximum shear can then be used to perform a more detailed shear analysis. Using the water surface elevation and energy slope from the flow of maximum shear, the practitioner can calculate shear at any depth throughout a cross section. The return frequency of the flow of maximum shear may also provide the practitioner additional insights and provide a basis for evaluating risk.

It should be recognized that channel bends induce additional shear due to secondary currents produced as flow direction changes. Bend shear is not accounted for by HEC-RAS as it is a one-dimensional hydraulic model. Flow depth and energy slope at the flow of maximum shear should be used to obtain an initial calculation of scour at the outside of the bend. An appropriate multiplier can then be applied to the initial calculation of scour to obtain a bend scour value. Bend scour calculations are reviewed in Chen and Cotton (1988).

Figure 2. Maximum unit shear versus aspect ratio (b/d).
ALLOWABLE SHEAR

The geologic, vegetative conditions, and geometry of a channel provide an inherent level of erosion resistance. This condition defines the allowable shear above which erosion would be expected to occur. Although it is possible to estimate allowable shear, it is an uncertain process and undoubtedly an area that requires more study. There are several variables that influence allowable shear. Some of these variables include soils’ cohesiveness and/or particle size characteristics; vegetation rooting depth and rooting density; and vegetation stem length, density, and stiffness. A summary of literature evaluating allowable shear for natural channels is shown in Table 1.

Table 1. Some reported shear stress limits for vegetation/riprap (from Hoitsma and Payson, 1998).

<table>
<thead>
<tr>
<th>Lb/ft²</th>
<th>N/m²</th>
<th>Type of vegetation/materials with citation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.33</td>
<td>16</td>
<td>2.5 cm (1 in) gravel riprap (Chen and Cotton, 1988)</td>
</tr>
<tr>
<td>0.35</td>
<td>17</td>
<td>Dense sod; fair condition (class D/E); mod. Cohesive soil (Austin &amp; Theisen, 1994)</td>
</tr>
<tr>
<td>0.67</td>
<td>33</td>
<td>5.0 cm gravel riprap (Chen and Cotton, 1988)</td>
</tr>
<tr>
<td>0.90</td>
<td>44</td>
<td>Bermuda grass fair stand, &lt; 12 cm tall; dormant (Parsons, 1963)</td>
</tr>
<tr>
<td>1.00</td>
<td>49</td>
<td>12.5 cm of exc. Growth of grass/woody veg on outside bend failed (Parsons, 1963)</td>
</tr>
<tr>
<td>1.10</td>
<td>54</td>
<td>Bermuda grass good stand, &lt; 12 cm tall; dormant (Parsons, 1963)</td>
</tr>
<tr>
<td>1.40</td>
<td>68</td>
<td>Grass and legume plots withstood flood flow (Porter and Silberger, 1960)</td>
</tr>
<tr>
<td>2.00</td>
<td>98</td>
<td>15 cm rock riprap (Chen and Cotton, 1988)</td>
</tr>
<tr>
<td>2.10</td>
<td>103</td>
<td>Dense sod; ideal cond. (class B); non-erosive soils (1.9 m/s) (Austin &amp; Theisen, 1994)</td>
</tr>
<tr>
<td>2.70</td>
<td>132</td>
<td>Bermuda grass exc. Stand, 20 cm tall; dormant (Parsons, 1963)</td>
</tr>
<tr>
<td>2.80</td>
<td>137</td>
<td>Bermuda grass good stand, 20 cm tall; green (Parsons, 1963)</td>
</tr>
<tr>
<td>3.20</td>
<td>156</td>
<td>Bermuda grass good stand, &gt;20 cm tall; green (Parsons, 1963)</td>
</tr>
<tr>
<td>4.00</td>
<td>196</td>
<td>30 cm rock rip-rap (Chen and Cotton, 1988)</td>
</tr>
<tr>
<td>5.00</td>
<td>244</td>
<td>Flume trials; fabric reinforced veg failed after 50 hrs; (2.2 m/s) (Theisen, 1992)</td>
</tr>
<tr>
<td>7.00</td>
<td>342</td>
<td>Bermuda grass failed (7.5 cm soil erosion) after 2 hours (WCHL, 1979)</td>
</tr>
<tr>
<td>8.00</td>
<td>391</td>
<td>Flume trials; fabric reinforced veg failed after 8 hours (Theisen, 1992)</td>
</tr>
<tr>
<td>8.50</td>
<td>416</td>
<td>Fabric reinforced Bermuda grass failed (soil erosion) after 2 hours (WCHL, 1979)</td>
</tr>
</tbody>
</table>

Since there are several interacting variables influencing allowable shear, and failure may be defined differently from study to study, the reader should use caution when assigning values to allowable shear. A thorough review of the methodology used to determine any allowable shear value should be conducted before using these values.

In the publication HEC 15, graphs of permissible shear for cohesive and non-cohesive soils are also provided. These may be applicable in streambeds or where streambanks are composed of exposed soils. It
should be recognized that HEC 15 assumes that no deformation of channel boundaries should be allowed, which may conflict with natural channel restoration design criteria (Miller and Skidmore, 1998).

An alternative method of relating allowable shear to particle size is to perform an incipient motion particle size analysis using Shields (1936) equation. The incipient motion particle size is the size of particle that is just at the beginning of motion for the given hydraulic conditions. Particles larger than this size would be expected to be stable whereas smaller particles would be expected to be mobile and transported by flow.

\[
T_* = \frac{\gamma_s R_s}{(\gamma_s - \gamma_w) D}
\]

where: 
- \(T_*\) = dimensionless shear stress
- \(\gamma_w\) = specific weight of water, pcf
- \(\gamma_s\) = specific weight of particles, pcf
- \(R_s\) = hydraulic radius, ft
- \(s\) = energy slope, ft/ft
- \(D\) = particle diameter, ft

The dimensionless shear term is a constant that was originally set at 0.060 by Shields (1936). Subsequent work (Meyer-Peter, 1948 and Gessler, 1971) has suggested that dimensionless shear be set at 0.047 instead. It has been debated, however, that the value assigned to critical shear stress is closely tied to grain size distribution (Andrews, 1983). Relating the incipient motion particle size to grain size distribution is yet another area where further study could allow better determination of allowable shear. The use of Shields equation allows determination of incipient motion particle size or the particle diameter size that will remain immobile at certain flows. HEC-RAS can provide values for hydraulic radius and energy slope for any flow of interest.

**CONCLUSIONS**

A hydraulic model, such as HEC-RAS, can allow efficient determination of the flow that produces the maximum shear on a channel boundary. Using the energy slope and water surface elevation associated with that flow, a stream restoration practitioner can calculate maximum shear on the bed or bank of a channel. This may provide useful quantitative information to the practitioner when comparing calculated shear with literature citing allowable shear values.

The practitioner should use discretion when estimating allowable shear. Allowable shear depends on cohesiveness of soils and/or particle size and distribution, and vegetation characteristics. The practitioner must understand these relationships and perform a review of methodologies.
used to determine allowable shear before using values published in the literature.

Although it is possible to estimate allowable shear, it is a topic that requires further research. With further research, comparing calculated shear with estimations of allowable shear could become a more reliable quantitative approach for predicting erosion potential in streams and rivers.

REFERENCES

INTRODUCTION
The November 1996 storms in southwest Oregon triggered rapidly moving landslides from forest land that caused five fatalities. Here we describe rapidly moving landslides, assess the relative risk of these to homeowners, describe management activities that increase upslope hazard, identify sites at higher risk of rapidly moving landslides, and present steps taken to reduce risks from forest landslides to human life and property.

DEBRIS FLOWS AND TORRENTS
Debris flows generally occur when landslides move rapidly downslope as semi-fluid masses. Debris torrents are channelized debris flows that generally contain much large woody debris (Figures 1 and 2). Because debris torrents are rapid, scour steep tributaries, and deposit material in lower-gradient channels and floodplains, these mass failures can affect fish habitat and represent a serious threat to humans and structures in their path. Recent research suggests that debris torrents are commonly found in steep channels of forest watersheds. The Oregon Department of Forest survey of storm impacts and landslides of 1996 (hereinafter ODF Landslide Survey) found that 37% of 118 miles of channels surveyed in the “red zone” (highest landslide incidence areas) had high impacts, and 73% of channels were highly impacted in one area (Robison et al., 1999). Benda and Dunne (1997) reported that debris torrents are a natural and essential occurrence in steep forest watersheds, supporting earlier work by Everest and Meehan (1981) about their potential benefits to fisheries.
Identifying Areas of High Hazard and Risk for Landslides from Forests

Figure 1. Locations at high risk to debris flows and torrents.

RELATIVE RISK TO HUMANS FROM DEBRIS TORRENTS

Landslides represent a risk to humans and property. The November 1996 storm produced debris torrents that killed four people in or near a dwelling. Elsewhere, a motorist was also killed by a debris flow. Many other injuries and damaged structures occurred. During the February 1996 flood, 705 landslides occurred in the Portland area alone, and many homes were damaged. Yet, most of these failures were in an urban area, not associated with managed forests. A recent review of Oregon Department of Forestry (ODF) records for approximately 25 years found that the five November 1996 fatalities were the only ones in Oregon connected to rapid channel failures from forest lands (Lorensen and Bell, 1998). In 1999, however, two loggers working near the town of Mapleton were killed by a debris flow.
Similar findings are reported for Washington (Brunengo, personal communication). Five fatalities associated with rapid channel failures from forest land can be documented. These include four fatalities in November 1985 on the Cascade River resulting from failure of an orphaned road, and one fatality in January 1983 during multiple channel failures near Lake Watcom. Klock and Helvey also reported four people were killed in the Entiat River Valley after wildfires in 1972. These events were described as debris torrents, but were probably a complex combination of tremendously increased peakflow, channel scour and deposition, and torrents.

Lorensen and Bell (1998) calculated that the annual death rates for smoking and auto accidents in Oregon were 2.0 and 0.17 per thousand, respectively. This compares to an annual death rate from forest landslides of 0.00011 per thousand. One reason for the low incidence of landslide-related fatalities is the current very low population density in high risk locations.
MANAGEMENT ACTIVITIES INCREASING UPSLOPE HAZARD

Timber Harvesting

The role of timber harvesting in landslides is complex. Harvesting forests removes all or part of the forest canopy, which may affect water delivery to soils (especially during short, intense rainfall periods) as well as the characteristics of roots that may provide slope reinforcement. Timber harvesting may also increase debris loadings in channels. The recent ODF Landslide Survey indicates that there is a period of increased landslide occurrence for about a decade after clearcut harvesting (Robison et al., 1999). However, landslide density in forest stands between the ages of 10 and 100 years was typically lower than landslide density in mature forests. Other, non-logging-associated disturbances such as windthrow events and especially wildfire can also influence landslides. Regardless of timber harvesting activity, slopes steeper than 70 to 80% (depending on geology and landform characteristics) have the greatest hazard for landslides that can initiate debris flows (Robison et al., 1999).

Woody debris in steep channels creates a challenging dilemma. The Oregon Forest Practices Act has established goals for increasing large woody debris (LWD) in stream channels to improve fish habitat. Landslides are seen as an agent that can contribute LWD to fish-bearing streams. However, increased LWD loads may also increase the size and impact of debris torrents. Harvey and Squier (1998) found that "slash piles in the channel, or abundant slash, which can form temporary debris dams in the channel, can increase the severity of a debris flow. The temporary blockage and build-up, and eventual release, unleashes a greater level of destructive energy than would have otherwise existed." Figure 2 shows that debris torrents commonly transport many trees and other large pieces of wood.

Roads

Forest roads can more clearly cause landslides. Roads further steepen already steep slopes, alter drainage patterns, and can result in lower-strength slopes (fills). Robison et al. (1999) report that "although the number of road associated landslides was not great, the landslides that did occur often had great impacts on stream channels, and were at least partially responsible (through combining with non road associated debris torrents) for 74 percent of the heavily impacted channels in the Scottsburg study area." A December 28, 1998, landslide near Alsea, Oregon, that destroyed a house, resulted from a small road failure that accumulated over a long, continuous reach.
If roads represent a disproportionately higher risk for contributing to in-channel failures, they are also more manageable. Sidecast removal and end-hauling of spoils, diversion-proof road crossings, and proper drainage are among the methods that reduce failures. There is evidence that the proportion of road failures is declining with improved road construction, maintenance, and maturing of the road network.

**LOCATIONS AT HIGHER RISK OF DEBRIS TORRENT IMPACTS**

Locations for buildings and roads at higher risk of debris torrent impact include sites where watersheds contain a significant percentage of steep (>70%) hillslopes (NCASI, 1985), where adjacent stream channel gradients are steep (>6%), and where tributaries join at an angle greater than 70° (Benda and Cundy, 1990). There may be geomorphic indicators of susceptible areas as well, such as debris fans or channel scour marks. In the fatal Rock Creek slide, Harvey and Squier (1998) reported that “visual examination of the site reveals that the residence was constructed on a debris flow fan built-up over time by a series of debris flow events emanating out of the Rock Creek channel.” These debris flows have occurred over a geologic time period. Proximity to steep hillslopes and confined stream channels certainly increases risk. Typical volumes of debris flows in Oregon range from 1,000 to 50,000 yds³. Exceptionally large events of 500,000 yds³ have been documented. Debris flows caused by volcanic eruptions, though rare, can be several orders of magnitude larger still.

**OREGON RESPONSE**

After the 1996 floods, the Oregon State Department of Forestry requested a voluntary deferral by forest landowners on harvesting on steep slopes where landslides would pose a hazard to human health. This voluntary deferral was followed by passage of Senate Bill 1211, providing the state forester with the authority to “prohibit timber harvest or road construction operations to prevent risk to human life from landslides or debris torrents.” Features that must be present to prohibit harvest and road construction activities include high landslide risk; residences, other buildings, or paved county or state highways in close proximity to the potential path of a landslide or debris torrent such that there is significant risk to human life; and “the farthest expected extent of a potential landslide or debris torrent.”

The state has developed a debris-flow warning system as part of Governor Kitzhaber’s Debris Avalanche Action Plan (Cathcart, 1999). It
provides debris flow advisories when threshold rainfalls are expected for 6-, 12-, or 24-hour periods, and warnings when rainfall actually exceeds these thresholds. These announcements are broadcast over NOAA Weather Radio and the Office of Emergency Management's communication system. The state is also mapping debris flow hazard in western Oregon, using slope steepness, channel confinement, geology, and historical debris flow activity as principal criteria. Additional legislation that would protect the public more comprehensively from rapidly moving landslides (including improved home siting standards and disclosure of risk to home buyers) is also being considered.

REFERENCES


Mitigation of Local Tsunami Effects*

Jane Preuss
Urban Regional Research

OVERVIEW OF ISSUES

A tsunami is a potentially destructive wave that is generated by a local or distant source earthquake. Tsunamis can also be caused by landslides or volcanoes. Tsunamis occur infrequently, but when they do occur the impacts are devastating. Between 1995 and 1998 approximately 4,500 people were killed by tsunamis. In addition, thousands of homes and businesses have been damaged through the direct wave impacts and indirect effects such as fire.

Although all the recent major tsunamis have occurred outside of the United States, the conditions leading to life loss and destruction are comparable to conditions in this country. For example, it is reported that the immediate cause of the Papua New Guinea event that killed an estimated 2,200 people was an underwater landslide generated by a magnitude 7 earthquake. Such conditions were present in Alaska in 1964 and resulted in destruction of the Seward waterfront. Vulnerability to landslide-induced tsunamis from a Cascadia subduction earthquake also constitutes a significant source of risk for Washington, Oregon, and the northern California coastal regions.

Among the factors leading to their destructiveness is the interactive nature of tsunamis. Critical interactive issues include fire, access disruption, and debris (generation of debris and impacts of debris onto houses, tanks, electrical facilities, etc.). Debris is defined as floating objects such as vehicles, and dislodged structures. The 1994 tsunami that struck southwest Hokkaido and Okushiri Island, Japan, resulted in the destruction of approximately 500 homes and businesses from fire and debris as well as direct impacts of the waves. The impacts of these recent events are comparable to the causes of destruction in Seward, Valdez, and Whittier, Alaska, as well as Crescent City, California, after the tsunamis generated by the 1964 earthquake.

* The research upon which this paper is based was funded by the National Science Foundation CMS-9528054.
VULNERABILITY

It is well known that the tsunami hazard does not result in a single risk factor to all vulnerable communities. Furthermore, the effects for any tsunami event vary throughout the community. Responsive plans must, therefore, integrate a high level of uncertainty with regard to time and characteristics of the event and with a relatively high level of precision with regard to causes of damage. The first step in developing a mitigation strategy is to conduct an assessment defining direct and indirect vulnerabilities. Key vulnerability issues are based on three criteria that present the most significant risks: (1) potential for significant damage, (2) high disruption, and/or (3) potential for interactive and collateral damage (Figure 1).

Through a land use inventory communities can define the uses that constitute prime risks. They also identify uses and building conditions that can cause problems (become debris) for nearby structures.

Figure 1. Structures on piers have a high potential to become debris especially if liquefaction has occurred. Cars also are very likely to become debris. Power will be disrupted.

Source: URR, Local Effects of Tsunamis
SIMULATING MITIGATION ALTERNATIVES TO REDUCE TSUNAMI IMPACTS

Understanding local (shore-based) tsunami effects is an important aspect of a responsive mitigation strategy. The methodology used by the project upon which this paper is based focused on selected case studies that illustrate representative land use and building conditions located on a sloping beach. Initially a three-dimensional numerical simulation identified velocity and forces; to validate the simulation laboratory experiments were conducted using the same assumptions. The laboratory experiments yield results almost identical to the numerical simulation. Three strategies were then simulated as a basis for development of alternative strategies to reduce the effects of tsunamis (Figure 2).

The first mitigation alternative placed a low obstacle (dike or small building) in front of a structure. The simulation showed that the dike created a ski jump effect; the water basically went up and hit the face of the building at a higher elevation than it would have without the dike. In addition, the new moment arm is significant (25% higher moment than no dike), indicating a concentration of the force. A second moment is also created, which is of the same magnitude.

The second simulation placed five pilings or trees in front of a tall structure. Since the water was forced to come back off the front face of the pylons there was somewhat less water impacting the “obstacle.” The small structure thus diverts some of the water, but not much.

The third simulation was a long ditch or groove. In the simulation the water goes down into the depression, which disrupts the activity and reduces acceleration. This alternative was found to significantly reduce the moment and therefore is the most effective tool to reduce forces on coastal structures. Unfortunately its applicability from an environmental standpoint could be limited to tank drainage and other such uses.

LAND USE IMPLICATIONS

Buildings and structures rarely occur in an isolated setting; i.e., they are located in communities consisting of many structures where some face the waterfront, and others are located adjacent to but behind the first tier of buildings. In many communities newer buildings have been constructed to recent codes with relatively high levels of resistance to lateral forces, while adjacent sites are occupied by single-family and older structures.
Protection from property damage and loss of life depends to a significant degree upon land use planning and structure design that take local tsunami effects into consideration. Accordingly, when local effects on structures are better understood the resulting knowledge can constitute an important tool for planners and regulators. Once the dynamics and
relative magnitudes of such forces are understood it becomes feasible to define polices that decisionmakers should consider to minimize property damage and loss of life.

CONCLUSIONS

Mitigation efforts for flood hazard reduction have to an increasing degree focused on removing buildings "out of harm's way." Mitigation for other hazards (e.g., earthquakes and hurricanes) for which it is impossible to project the locational incidence has focused on design standards. Unfortunately, tsunamis fall into both and neither of these classifications. When tsunamis do occur damage is confined to a definite area. Because there is rarely data with respect to repeat events the precise location of events cannot be forecast.

To reduce exposure to the tsunami threat, communities must first approximate which portions of the community are potentially vulnerable. In 1997 Congress established the National Tsunami Hazard Mitigation Program, which is administered through the National Oceanic and Atmospheric Administration with precisely this mandate. The program fosters preparation of tsunami inundation maps through application of numerical modeling. Since it is neither practical nor desirable to abandon the potential inundation areas it is incumbent on planners to ensure that land use practices and building design are as safe as possible. Thus application of knowledge pertaining to forces of the waves as they impact the structure can serve as an important basis for responsive designs that reduce damage from future events.
Ponca Creek Floodplain Delineations for Ice Jam and Open-water Flow Conditions

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INTRODUCTION
Residents in the vicinity of Ponca Creek, Nebraska, concerned with a perceived increase in flooding, petitioned the U.S. Army Corps of Engineers (Omaha District) for action. The Corps commissioned WEST Consultants to examine current and historic floodplains for the lower 10 miles of the Creek, for both open-water and ice jam affected conditions. The most recent version of HEC-RAS at the time (version 2.1) was used to model open-water hydraulic conditions. However, that version does not support modeling of flow affected by ice jams or ice cover. The Corps provided a test version of HEC-RAS version 2.2, which does have these abilities, which WEST used for the ice-affected hydraulic modeling efforts.

This paper briefly describes the floodplain study with emphasis on the ice jam modeling methodology. Comments on the use of the ice jam option in the recently released version 2.2 of HEC-RAS are also presented.

BACKGROUND
Ponca Creek is a tributary to the Missouri River, located approximately 5 miles upstream of the Niobrara River confluence. It flows from the northwest to the southeast, draining more than 812 square miles in Nebraska. Ponca Creek is a flat, shallow meandering stream with bed material of fine sand and silt.

The Omaha District of the U.S. Army Corps of Engineers (the District) has reported frequent flooding of Ponca Creek in recent years, often exacerbated by ice jams in the springtime. In a 1997 Engineering Assessment (USACE, 1997a), the District concluded that the total channel average streambed elevation of the Missouri River in the vicinity of Ponca Creek had increased 2 feet between 1955 and 1995 as a direct result of the growth of the Niobrara River delta farther downstream. The report stated that this change on the Missouri River had likely induced aggradation of similar magnitude on Ponca Creek, causing it to lengthen.
more than 2000 feet in the downstream direction. Analysis by WEST Consultants (WEST, 1998) concluded that the sedimentation in the lower reach of Ponca Creek has decreased channel capacity, raised water surface elevations, and contributed to increased flooding. The purpose of this study was to determine the zones of increased flooding between historic and present conditions.

HYDRAULIC MODELING

Models were developed for existing and "historic" channel geometries, for ice jam and open water conditions, and for varying levels of the Missouri River at the downstream boundary. The end products of the modeling efforts were floodplain maps showing the extent of flooding for the 2-, 5-, 10-, 20-, 50-, and 100-year frequency discharges for the various scenarios. All models extend from the November 1997 confluence of Ponca Creek with the Missouri River upstream approximately 10 miles to a point roughly 4 miles west of the town of Verdel. The HEC-RAS modeling system (USACE, 1997b) was used for all the models. Eighteen models were produced for the various scenarios.

Base Model

This model, developed using 1997 surveyed cross sections, served as the "base" model from which all others were derived. Frequency flows were developed as part of the study, but will not be discussed here. Six bridges were included in the models.

Modeling Methodology and Assumptions—Throughout each of the models, ineffective flow areas were defined at cross sections to separate areas of active conveyance from areas where ponding occurs. Artificial levees were used at several sections where flow was believed to be confined to the channel. For each of the open water models, floating debris was imposed on piers due to heavy debris observed in the field and in historic photographs. A debris pile 5 feet wide by up to 5 feet deep was used at each pier. No floating debris was used for the ice jam models.

Calibration—Although no definite high water marks were available for calibration purposes, rating curves for a U.S. Geological Survey gage on one of the bridges were available. The best combination of roughness values was found to be 0.035 for the channel and 0.07 for the overbanks. These roughness values were used for the entire stream length and are identical to values used by the District in a model of another nearby tributary to Missouri (USACE, no date).
"Historic" Models

The calibrated base conditions model was altered to represent 1950 channel conditions. First, the 1950 invert profile was estimated by observing where 10-foot contour lines cross Ponca Creek on USGS topographic maps. Second, 1950 invert elevations at the location of the 1997 cross sections were produced by interpolation (or extrapolation at the downstream most end of the model) using the elevations from the first step. Third, cross section ground points between bank stations were lowered or raised by the difference between the 1997 and 1950 invert elevations. The historic conditions geometry was used for models with and without ice jams. The channel distance between cross sections was modified for cross sections where a different channel alignment existed in 1950 compared to the 1997 base model (a channel cutoff occurred between these two dates at one section of the creek).

Calibration—Computed water surface profiles were compared with USGS rating curves at the gage location. As roughness values from the calibrated base conditions model gave satisfactory results for the historic period, they were not changed.

Ice Jam Models

As ice jams cannot be modeled in version 2.1 of HEC-RAS, a pre-release copy of version 2.2 of HEC-RAS was obtained from the Cold Regions Laboratory of the Corps (CRREL) with the permission of the Hydrologic Engineering Center (HEC). Version 2.2 is able to model both stable ice cover and wide-river ice jam situations. In the solution procedure, an ice jam force balance equation is solved using an approach analogous to the standard step method (USACE, 1998). The thickness at each cross section is found, starting from a known ice thickness at the upstream end of the ice jam. After the ice thickness is calculated at a section, the following tests are made:

1. The ice thickness cannot completely block the river cross section. At least 1.0 foot must remain between the bottom of the ice and the minimum elevation in the channel available for flow.
2. The water velocity beneath the ice cover must be less than 5 fps (1.5 m/s) or a user-defined maximum velocity. If the flow velocity beneath the ice jam at a section is greater than this, the ice thickness is reduced to produce a flow velocity of approximately 5 fps or the user-defined maximum water velocity.
(3) The ice jam thickness cannot be less than the thickness supplied by the user. If the calculated ice thickness is less than this value, it is set equal to the user supplied thickness.

Five of the Ponca Creek models produced included ice jam effects. The maximum water velocity was left at the default value of 5 ft/s. A stable ice cover thickness of 1.5 feet was used at the upstream and downstream ends of the model and was also used for the minimum ice jam thickness. This thickness was based on oral accounts and photographs of ice jam flooding from local residents and input from the District and CRREL on reasonable thicknesses. A stable ice cover was used for the first three cross sections of the models, with the ice jam starting at the fourth cross section. The ice jam zone extended from this point upstream to a point where, based on accounts from local residents as to the extent of past jams, no jam was expected to occur. Default values were used for ice cover specific gravity (0.916), internal friction angle of the jam (45 degrees), ice jam porosity (0.4), coefficient K1 (longitudinal to lateral stress in jam, 0.33) and ice cohesion (zero). Manning’s “n” values for the ice cover were set to 0.015, while the roughness of the ice jam was allowed to vary according to the empirical relationships derived from the data of Nezhikovsky (USACE, 1998). Ice jam formation was limited to the channel only—the overbank areas were assumed free from ice obstruction (any floating ice in the overbank would have limited effect on flow).

MODEL PERFORMANCE WITH ICE JAMS

Several comments are in order regarding the ice jam option in the test version of HEC-RAS version 2.2. First, the execution time of a model with the ice jam option is much longer compared to an open water run. This is especially noticeable when computing several profiles in a single run. The longer run time is due to the number of iterations needed to determine the ice jam thickness. The default number of iterations is 2.5 times that specified for open water flows (using the default value of 20 iterations will result in 50 iterations for ice jams). In some instances, the model failed to converge and caused HEC-RAS to shut down. This was especially frustrating when it occurred at the end of a long multi-profile run as the results from the beginning profiles were not saved. However, a stable run could be achieved by changing the default number of iterations to less than 20. A sensitivity analysis of the ice jam results as a function of the number of iterations revealed that, as long as the solution is
converging, the majority of adjustments to ice jam thickness occurred within the first 10 iterations.

SUMMARY

This paper briefly describes the engineering analysis for the lower 10 miles of Ponca Creek, Nebraska. The analysis compared existing and historic flooding conditions, for ice-affected as well as open-water situations. Eighteen additional models were created from the base conditions model to simulate present, historic, and future conditions. Five of these models represent current and historic conditions with ice jam-affected flow.

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Part 10

International Approaches to Floodplain Management
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Floodplain Management in England and Wales: Data is the Key

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INTRODUCTION

Rivers, the coast, and their floodplains are widely regarded as attractive places to live, work, and find enjoyment. This fact, together with economic, transport, and other considerations, has led to extensive development in floodplain areas. Historically, although infrequent, floods were often an accepted risk. In more recent times, society at large will not accept the consequences of these events, and as the public becomes more detached from its natural environment, nature is forgotten. The legacy of development decisions that followed was often made by people who were unaware or ignorant of the flood risk. We now have the tools and data to make informed decisions on development proposals in a planned and integrated way.

THE ENVIRONMENT AGENCY

The Environment Agency was formed in 1996 to provide a comprehensive approach to the management of the environment by combining the regulation of land, air, and water with the aim of sustainable development. The management of flood risk, or floodplain management, is an important part of the Agency's work, spending some $430 million (£270 million) annually, over 40% of the Agency's budget. The principal activity areas are flood warning, regulation (floodplain mapping, floodplain policy), maintenance, and structural works. Floodplain mapping is the focus of this paper.

Government policy on flood and coastal defence is set by the Ministry of Agriculture, Fisheries and Food and the Welsh Office (MAFF/WO, 1993), and implemented primarily by the Environment Agency.

*I am grateful to Dr. Geoff Mance, Director of Water Management, for permission to publish this paper. Any opinions expressed are my own.
LAND USE PLANNING

Land use planning is the statutory process used to decide on the type and location of development. Changes were made to this system in 1991 that require planning decisions to be in accordance with the Development Plan, the primary purpose of which is to balance the competing pressures and allocate land for development. Government household projections forecast that during the period 1991-2016, the number of households in England will rise from 19.2 million to 23.6 million, an increase of 4.4 million, or 23%, placing floodplain areas under even greater development pressure. (This represents an extra 1.3% of urban land. Average population density in England and Wales is 339/km$^2$, and in the USA 27/km$^2$). There is widespread consultation on the plan with many organisations and the public. Insurers are taking an increasing interest in development and flood risk. It is worth noting that flood insurance (building and contents) is included in insurance policies in the UK. However, the industry has signalled that in the future the cost of insurance may be adjusted to reflect flood risk (Crichton & Mounsey, 1997), especially where development has proceeded against the advice of the Agency.

Floodplain management is dependent on an effective partnership between planning authorities (who decide) and the Environment Agency (who advise) on flood risk issues, including the management of runoff. This system depends on the Agency providing the necessary information on flood risk. An advantage of the plan-led approach is that all parties are aware of flood risks at an earlier stage, and if development in flood risk areas is promoted, any necessary flood risk infrastructure can be planned in as a fundamental part of development. It is crucial for the Agency to play a proactive part in this process, because if it does not, it could find itself having to provide and fund flood defences for development where flood risk issues were not given their proper weight in the decisionmaking process.

On some matters planning authorities have very little discretion, whilst on others, including flood risk, their discretion is very wide. (A review of the planning guidance on Development and Flood Risk is currently being considered). The whole ethos of sustainable development challenges us to approach floodplain management in a strategic way. Piecemeal and inefficient solutions should be eliminated, and problems viewed in the widest context, taking care to ensure that a problem solved in one place does not exacerbate things elsewhere.
USING FLOOD RISK DATA TO MAKE BETTER DECISIONS

The key flood risk issues affecting new development are that it should be intrinsically safe in its own right (1% annual exceedance probability for rivers, 0.5% for the coast) and it should not increase flood risk to others. This is the general framework, and these standards are not mandatory. They are guidelines. Often we forget that nature does not respect these targets, and we must continually reinforce the fact that the bigger flood will come one day, such as at Easter 1998, when over 4000 houses were flooded, in what has now become a national benchmark flooding event alongside 1947, and 1953 (Bye and Horner, 1998) and has stimulated much interest in flood issues (www.environment-agency.gov.uk/flood). Flooding in many locations was the most severe ever recorded.

Floodplain Mapping Programme

In 1992 the government indicated that it wanted the main Agency input to development plan preparation to be floodplain surveys. The flood risk data generally available at this time was last collected systematically in the late 1970s. However, it was recognised that the Agency could not produce extensive flood risk survey information immediately. A National programme of floodplain surveys, costing $38 million, was developed, with the aim of covering areas targeted for development by 2001.

Two key factors recognised in developing the mapping programme were that some areas were under much more development pressure than others, and there was not sufficient capacity in the survey and modelling industry to match the demand. A variety of mapping techniques were used and it was taking up to two years (including air survey) to produce flood risk maps. It became clear that there was a need to balance accuracy and cost when choosing a mapping method in order to deliver a realistic mapping programme. In a comparison of methods, typical costs of floodplain mapping for a 10-kilometre reach ranged from $6 to $60 (Ramsbottom et al., 1997). Accuracies for the most expensive method were on the order of +/- 100mm for the level, and 0-50m for the flood limits (full hydraulic model, calibrated flood hydrographs, full topographic survey). With other methods, flood levels were +/- 600mm, and flood envelopes 0-600m compared with the most expensive method. This work demonstrated the degree of uncertainty with different methods and showed that there is no absolutely correct flood envelope.

An exciting development in 1996 was the production of an automated national flood risk map. This map quantifies the areas of England and Wales at risk from river flooding under natural conditions. (The
expression "natural conditions" means disregarding any benefits of flood defences). This has been made possible by the recent completion of several major digital data sets for England and Wales, the development of methods of estimating flood depths from catchment characteristics, and the development of techniques and software for exploiting digital spatial data. (Morris and Flavin, 1996). The maps also identify the built-up areas that would be at risk. An estimated 6.8% of the built-up area in England and Wales is at risk from the 100-year fluvial flood. Previously there has been no consistent nationwide estimate of these quantities at this level of detail. The chosen return period was 100 years, but the methodology could be used to calculate flooding extent for any return period.

FLOODPLAIN MANAGEMENT IN THE FUTURE

The national flood risk map has tremendous value for strategic planning, especially at the regional or river-basin scale. These data have now been combined with floodplain estimates produced by other methods (where they exist), including historic records, and a composite data set of the best available information produced. The flood outlines for England and Wales fit on one CD, and are being provided to Planning Authorities. The information is comprehensive but not consistent in terms of the accuracy of the flood estimation or underlying topographic data. Great care has been taken in combining these datasets, so that the flood estimation method used for a given location can be quickly determined, and professional judgment applied to determine if this is appropriate for the intended purpose. These flood estimates can be improved through the addition of improved flood estimation, and height data.

Flood Estimation Improvements

A 5-year research project improving flood estimation methods is nearing completion. Parts of this will be original, presenting new generalisations of rainfall and flood frequency across the UK. Users can look forward to an important change in flood frequency estimation by statistical methods: catchments will be grouped according to the similarity of their flood regime, rather than in geographical regions as previously. Particular emphasis is also being given to methods that exploit catchment information in digital form, freeing the user from routine map work.

Advances in Digital Terrain Modelling

One of the most expensive pieces of work involved in defining the floodplain is in the topographical survey requirement. Land based or aerial
survey costs can be prohibitive, however new techniques such as airborne LIDAR (for height data) and CASI (for vegetation recognition) are reducing costs dramatically. LIDAR is now being used routinely, and together with GPS, enables accuracies of +/- 10 cm (vertical) to be achieved. Its principal advantages over aerial photography are that it requires very little user input, cost (approximately 1/10th) ($320/km²), quicker delivery of processed results (2 weeks), and the ability to directly import digital data into hydraulic models/GIS systems. This has been done with HEC-RAS, and is completely changing the way floodplain modelling is approached.

Whilst these methods are giving us first estimates of the area at risk, they are still relatively crude. For example, the presence of defences (levees) was ignored in the method. Defence details are now being added to the data set. Being in digital form it is possible to automatically combine areas of flood risk with other digital data sets. This is helping increase the value of floodplain maps for other parts of the flood defence service, including flood warning. The addition of socio-demographic data is informing exactly who is at risk (e.g., the elderly, ethnic groups) and what types of asset are at risk (e.g., hospitals, depots, police stations, schools, flood critical infrastructure), together with estimates of their value. It is currently estimated that the average annual damage avoided by the presence of existing defences is $3.2 billion. This work will help refine that estimate, and perhaps challenge our current approaches. The methods permit rapid sensitivity analysis, and scenario evaluation. This is particularly useful at the river basin level, and for considering uncertainties such as increased storminess for which agreed methodologies do not yet exist. Three dimensional visualization building on LIDAR, CASI, and flood extents is proving helpful in communicating with all stakeholders, especially the public.

CONCLUSIONS

Effective floodplain management depends on a successful partnership between the Agency who have the specialist data and skills, and the planning authorities who make decisions on land use planning. Flood risk mapping is probably the most crucial database necessary for the successful delivery of flood defence policy, and offers a new means for assisting in this planning. To fully realise the potential benefits for floodplain management, well organised data and skills need to be input to the decisionmaking processes at the appropriate time. More recently, there has been a trend to incorporate other data into this process, to help truly
quantify what our customers expect of us (e.g., Pelleymouuter, 1997; Tunstall, 1994; and Tapsell et al., 1999).

The keys to give "children" of sustainable floodplain management are "data" and "education." We need to invest in data, and know its value. Education needs continual updating, improving, and management to get across to each succeeding generation. And so does the data.

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The Role of Floodplain Management in Urban Developed Catchments in Portugal

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INTRODUCTION

Floods are one of the most devastating natural hazards, when rivers overflow their banks and affect human lives and activities in adjacent floodplains. Flood risk can be an increasingly major threat in expanding urban and suburban areas. The expansion of impervious areas, changes in land uses, and the encroachment of floodplains can lead to an increase of flood risks and significant losses in urban areas. At the same time, such developments also affect the integrity of fluvial ecosystems and runoff processes, within catchments areas and floodplains.

In Portugal, flood events are estimated to affect about 5% of the country’s area (approximately 4500 km²) but the total population at risk has not been quantified (Correia et al., 1993). The more densely populated coastal areas and large alluvial plains of major rivers are highly prone to flooding events, with potential damage. However, two main types of flood problems can be identified—extensive floodplains with slow, large floods, caused by fronts or succession of fronts coming from the Atlantic, or small floodplains in catchments prone to flash floods, caused by local thunderstorms and very intense rainfall. This is mainly the case of coastal catchments in highly populated areas, sometimes with poorly planned urban development.

This paper is concerned principally with the risks of flash floods in urban and coastal areas with high population densities, as seen in Portugal and other southern European countries. Flash floods in small catchments with torrential flow regimes can be more dangerous, especially where there are strong pressures for urban development, floodplain occupancy, and stream culverting, such as the Lisbon metropolitan area and in the southern coast of Algarve.

In the Lisbon metropolitan area there were 400 casualties during the 1967 catastrophic flash flood event, and, in the 1983 event, 10 casualties
and more than 600 buildings severely damaged. Recently, in the autumn of 1997, very heavy local rainfall caused almost 30 casualties in the Azores islands and southern Portugal and Spain (Alentejo and Extremadura). Flash floods can cause a severe threat due to the characteristics of Mediterranean climate and torrential flow conditions.

THE PORTUGUESE CONTRIBUTION TO THE EUROFLOOD RESEARCH PROJECT

Between 1992 and 1996, a European research project, named EUROflood, was undertaken in two phases. EUROflood I has been sponsored by the Commission of the European Communities under its EPOCH programme (European Programme on Climatology and Natural Hazards), aiming to undertake basic research on the causes, impacts, and response to flooding, and also developing policy instruments for Europe-wide application. It was coordinated by the Flood Hazard Research Centre, at the Middlesex University, UK, and the collaborators were Delft Hydraulics and University of Twente, Netherlands; Braschel+Schmitz, Germany; CERGRENE, France; and Instituto Superior Tecnico and Laboratorio Nacional de Engenharia Civil, both from Portugal. EUROflood II continued the research of an earlier phase, looking at the investigation of methods for better management of flood hazards, in order to reduce vulnerability. Funding was sponsored by the Commission of the European Union under its Environment Programme. The coordinator and the collaborators were the same, with the addition of the University of Cataluña, Spain, and the University of Catania, Italy.

In the context of this research, a book *Floods Across Europe* (Penning-Rowsell and Fordham, 1994) and several Technical Annexes outlining the main approaches and results of the conducted research have been published.

The Portuguese contribution to this project has focused on multi-disciplinary issues in urban developing areas regarding decision making in floodplain management. Using as a case study a small coastal catchment area prone to severe flood risk, and subject to strong development pressures, some approaches have been undertaken to analyse the complexity of floodplain management and its multiple social and environmental dimensions and requirements.

Among others, research has concentrated in the following issues:

• public perception of flood risks and potential public willingness to cope with flood threats;
• hydrologic and hydraulic modelling using both lumped and distributed models;
• modelling scenarios in a combination of urban growth dynamics and flood related impacts;
• social and economic characterisation of flood affected areas;
• land use control instruments and their effectiveness for floodplain management.

A geographic information system (GIS) has been set up to collect, store, and manage a variety of information sources required to analyse and assess the complex interactions between all critical research components. Such an approach was to provide the basis for a decision support system for floodplain management at a catchment level (Correia et al., 1996).

**BRIEF DESCRIPTION OF CONDUCTED RESEARCH**

A case study of a small catchment in central Portugal, the Livramento creek in Setubal, prone to flash floods and subject to fast-growing trends of urban development, was analysed from the viewpoint of the hydrological, biophysical, and planning processes, with special emphasis on public perception of flood hazards.

The research conducted allowed the development of several approaches to floodplain management, aiming to contribute to a multi-disciplinary assessment process and to improve local decision making for floodplain management. This process followed a conceptual model with five stages for floodplain policy, from data collection, analysis, synthesis, assessment, and decision making. The use of the GIS has been an effective and powerful tool to integrate and cross information relevant for the analysis pursued.

A detailed description of hydrologic and hydraulic modelling in the catchment and mapping of the flood affected areas for several return periods has been presented elsewhere (Correia et al., 1998a). Alternative scenarios for urban development and evaluation of consequences on flood regime have also been investigated, which results have been assessed and presented in Correia et al. (1997).

Public perception of flood hazards has been one of the key topics of the completed research. Surveys of population groups have been undertaken in order to analyse public perception of flood risks; the results were included in a wider study of land use planning for the Livramento creek catchment, in which an integrated approach was taken towards various elements of the land use planning process in flood-prone areas as

The survey assessment showed that residents of old neighbourhoods retained elements of a traditional flood culture, with the ability to make adjustments in order to minimise flood effects. On the other hand, new residents that live in the floodplain area but do not have an experience of flood events see this hazard as a dramatic situation causing them serious damage and tend to blame the authorities for the situation. Asked for their possible actions in the event of a flood, most think they couldn't do anything to avoid the situation, only complain to the authorities responsible. Other groups have been interviewed, such as shop owners, technical staff, and elected officials of the local authority. These groups showed different patterns in their perception of flood causes, actions to be taken, and levels of commitment regarding institutional and public roles, in the case of a flood event. Experience of a previous flood event has been shown to be an important aspect in mitigation behaviour.

This research pointed at the important role of involving the public in flood management. Research into public perception and attitudes with respect to flood hazard is essential in understanding how the public copes with these events, and for precautionary, emergency, and recovery planning measures.

**FINAL COMMENTS**

The definition of flood defense strategies assumes a multi-dimensional character in which interaction with the public is crucial for their understanding and acceptance of such strategies. This aspect has accordingly taken on increasing importance in recent analyses of decision processes involving perception and action in the face of natural risks, particularly floods. The need to understand how people evaluate and respond to flood hazards is thus very important for the adoption of appropriate and viable flood protection measures, in both structural and non-structural terms.

The importance of understanding the psychological and social-cultural aspects of flood risk perception should not be underestimated. Flood research showed the importance of experience in this process and in the effective adjustments developed to reduce or prevent the hazard impact. There are several examples in the literature of communities that have developed effective behavioural adjustments to flood risk situations, which can be called a “flood culture,” showing preventive adaptations and appropriate responses during or immediately after a flood, that can lead to alleviation of both tangible and intangible damage. Such adaptations are
seen in communities with long experience of flood events, passed down through the generations. One may refer to this as "institutional memory."

However, in urban communities where there are changing populations, the accumulation of flood experience is often lacking. Growing urbanisation in hazard areas can increase the number of risk-exposed people who have no perception or memories of such risks. Thus urban floodplain residents must often make decisions facing an event in relative ignorance and extreme uncertainty.

Spatial and land use planning should consider the aims of preventing, managing and/or reducing the effects of natural hazards such as floods. Strategies for floodplain management should be considered in a comprehensive approach, taking into account other sectoral policies, such as environment, water resources and emergency planning (Saraiva, 1998).

This research showed the relevance of the local and watershed context for floodplain management, and the necessary crossing with other approaches for flood mitigation strategies, such as land use planning and other non-structural measures, beyond the planning and design of structural works. This project was an opportunity of developing and linking some technologies, such as the use of GIS, with the general purpose of contributing to an integrated and comprehensive view of flood mitigation problems.

Experiences gained and lessons learned from a multidisciplinary, complex, and interactive approach on modern floodplain management can be particularly useful in river basin management plans in Portugal expected to be finished in the beginning of the millennium. Flood mitigation and floodplain management are issues expected to be seriously addressed in those river basin plans, aiming to a better integration between water resources and land use planning in the coming years.

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Flood Management on the
Grand River Basin

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INTRODUCTION

The Grand River forms one of the largest drainage basins in the southwestern portion of the Province of Ontario. The river drains an area of 6700 square kilometers to Lake Erie. Drawn by the availability of waterpower, early settlement of the basin during the 1800s by Europeans focused on the Grand River and its tributaries as the nucleus for both urban and rural development. This development of the floodplain land coupled with deforestation and drainage of wetlands inevitably led to periodic flooding of these communities.

The management of land and water resources, involving the consideration of many natural and human factors, is becoming unnecessarily complex. As a result, land and water management has often been a testing ground for attempts to coordinate various levels of government and different user groups. The Grand River Conservation Authority (GRCA) has worked in partnership with watershed municipalities and other government agencies to solve flood, low flow, and water quality problems. The formation of the GRCA meant that a comprehensive approach could be taken to reducing flood damage on a watershed basis considering both water- and land-based resources as well as urban and rural areas.

The GRCA's 44 local and regional governments are represented by 26 members appointed by the local governments. Spending for GRCA programs includes core programs such as flood control, water quality, and reforestation (48%) and non-core programs such as conservation parks and nature centres (52%). Currently, routine and preventative maintenance of the major flood control structures is shared 50% by the GRCA and local municipalities and 50% by the Government of Ontario.

FLOOD MANAGEMENT SYSTEM

The Grand River Flood Management System includes both structural and non-structural approaches to reduce damage and risk to life associated with floods. Flood control includes not only structural changes to
riverbanks but also recognition of the value of woodlots, wetlands, and natural stream channels in natural flood protection and water quality improvement. Structural measures include flood control reservoirs, dykes, and channelization works. Non-structural approaches include floodplain management, watershed planning, flood warning, and education. A combination of these approaches is used to address flooding problems.

**STRUCTURAL APPROACHES**

Reservoirs are used to regulate flood flows to reduce the risk of flooding in downstream areas. Seven reservoirs provide storage for both flood control and flow augmentation function. This dual function results in fluctuating amounts of flood control storage throughout the year. The level of flood reduction that can be provided by the reservoirs varies depending on the available flood storage and the magnitude of the flood.

Dykes and channelization works have been constructed to reduce the risk of flooding for specific flood damage areas. Cost-benefit analyses are used to assess the practicality of implementing structural measures. Often there are several different alternatives and conflicting demands to consider when defining a program of structural measures.

**NON-STRUCTURAL APPROACHES**

The term floodplain management should be viewed more from the perspective of wise planning than strictly regulation. Flood management implies managing the flood risk. There will always be pressure to place urban development, agriculture, or recreational uses such as golf courses in floodplains. Floodplain management balances the risk associated with the floodplain against the desire to make use of the floodplain lands.

Floodplain management can be viewed as having three important components: development of floodplain mapping, implementation of policies for floodplain areas, and maintenance of the mapping and policies supporting the program.

The regulatory floodplain design standard is based on Hurricane Hazel. This is an observed storm that occurred east of Grand River near Toronto in 1954 and dumped 285 mm (11.2 inches) of rain over a 48-hour period. This storm has an estimated return period of between once in 250 to once in 500 years. The current mapping standard being used is 1:2000 scale topographic mapping with a 1-meter contour interval. Once flood flows have been established, flood elevations are calculated by applying hydraulic models, typically HEC-2 and HEC-RAS models.
The Conservation Authorities Act allows Conservation Authorities the ability to regulate filling and construction activities in floodplain and wetland areas. Floodplain policies and implementation guidelines were also developed and passed to ensure consistency in approach to floodplain management. A key aspect of floodplain management policies must be flexibility and the ability to deal both with new uses as well as pre-existing uses of floodplain areas. There are three floodplain policy areas: one-zone policy areas, two-zone policy areas, and special policy areas that allow development with increased levels of risk dependent upon local need.

Geographic information system (GIS) tools are being developed and maintained to support these programs. Floodplain-related themes have been developed and include extent of floodplain areas, floodplain policy areas, and location of hydraulic cross-sections. These are referenced to indexes and files containing flood elevations and metadata of source information. Current development work on the GIS system includes preparation of specifications for detailed topographic mapping and imagery, database linkages with observed and computed flood elevations, and flood damage areas. Implementation of these tools allows for ready access of organized information for the entire Grand River system.

Watershed planning also plays an important role in floodplain management. Watershed planning is undertaken on the basis of the physical system it addresses, and does not contain itself to political boundaries and jurisdictions. The role of the GRCA is required to achieve this interjurisdictional form of planning. Good watershed planning helps avoid changing the flow response of a watershed changing from rural to urban land use to help avoid new flooding problems.

The GRCA operates a flood operations system to provide effective operations of reservoirs to reduce downstream flood damage and to provide flood warning to municipal officials in the watershed. The main components of the system include: flow monitoring and data collection, streamflow forecasting, and flood warning.

The GRCA operates a hydrologic monitoring network to collect the necessary information needed to provide flood forecasts. The network operated by the GRCA monitors air temperature, precipitation, reservoir information, stream level and stream flow, and totals some 80 real time and periodic stations. Weather warnings and forecasts are obtained from other providers including federal, provincial, and commercial sources. The system is based on a design philosophy that if all else fails manual readings could be taken at gauge sites and communicated by radio or
Flood Management on the Grand River Basin

A telephone to the respective reservoir or Flood Control Centre. River watch personnel supplement the system during periods of high flow.

A variety of flood forecasting techniques are used by the GRCA ranging from simple empirical models to complex deterministic models. No one technique is relied upon to produce flood forecasts; backups are a necessity. The Grand River Integrated Flood Forecasting System (GRIFFS) is a real-time streamflow forecasting model. Major features of this model include its hydrologic routines, method of distributing meteorological inputs, and data editor. The hydrologic routines in GRIFFS are based on the Guelph All Weather Sequential Event Runoff model (GAWSER). This model is capable of modeling single or multiple events and has provisions for recovery between events.

Dissemination of the flood warning message is a vital component of any flood warning system. In the Grand River watershed a combination of police and media is used to get the message out. The fan-out system is designed to spread the message quickly and delegate the warning responsibility. The flood warning system is tested annually to verify it is working properly. An annual meeting of the municipal Flood Coordinators is held to present the results of the test and listen to any suggestions or concerns about the system. Typically a guest speaker is invited to make a presentation related to flooding. The annual test and meeting of flood co-ordinators is an important function to maintain a state of alertness and readiness.

PAST, PRESENT, AND FUTURE

The current organizational structure and operations of the GRCA have evolved based on institutional arrangements, current needs, and past experiences. Efforts to refocus the operations of the GRCA have occurred periodically and have been driven both by internal forces such as strategic basin planning exercises, and also by external influences such as major flooding events and senior government support. The Grand River Watershed Plan is currently being developed to again reestablish strategic focus and partnerships for the current planning horizon. Much of the current work of the GRCA has focused on maintenance and organization of its information base.

Basic principles maintained through past and current evolution include management of water resources on watershed basis, maintenance of partnerships and accountability with local municipal governments, and facilitation among all stakeholders.
Floodplain Management and Flood Warning in Europe

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INTRODUCTION

A devastating flood hit Eastern Europe in July 1997. In the Czech Republic, the Morava River breached its embankments at several locations to inundate large rural and urban areas, causing damage estimated at $2 billion (US). In Poland, severe flooding occurred along the Vistula and Odra River, 140,000 people were evacuated, and the damage amounted to about $3 billion (US).

The flood highlighted a need for improved flood management technology in both countries. For operational purposes there is a demand for timely and accurate forecasts of river flows and water levels in flood prone areas. For planning and development there is a need for a flood management system that can be used for flood control studies, flood mapping, risk analysis, selection of a strategy for flood protection, etc.

Based on requests from the authorities in the two countries, the Danish Environmental Protection Agency (DEPA) is now financing a transfer of flood management technology from DHI. A core element in this is the MIKE 11 modeling system, which is applied for flood forecasting and flood control planning throughout the world.

This paper describes briefly the applied MIKE 11 technology, gives the current status of the model applications in the two countries, and describes two new development applications underway related to generic flood management.

FLOOD MANAGEMENT MODELING

Combining advanced flood modeling with a GIS enables users and decisionmakers at various levels to investigate and assess proposed flood mitigation options and prepare environmental impact assessments.

Implementation of a real time data network and operation naturally succeeds project implementation. Supervision, control, and the ability to
Floodplain Management and Flood Warning in Europe

initiate emergency relief requires that the developed flood model application be linked to a real-time reporting telemetry system. With the real-time linkage established, the flood model can be applied on an operational basis for real-time flood forecasting, flood inundation mapping, and eventually as an emergency response tool.

MIKE 11

MIKE 11 is a professional engineering software package for the simulation of flows, water quality, and sediment transport in estuaries, rivers, irrigation systems, channels and other water bodies.

The applied implicit numerical methods yield unconditionally stable solutions and provide a complete and effective design environment for engineering, water resources, water quality management, and planning applications. MIKE 11 includes basic modules for modeling and integrating rainfall runoff processes, transport-dispersion, cohesive/non-cohesive sediment transport, and water quality.

MIKE 11 GIS merges the technologies of numerical river modeling and geographic information systems (GIS). It is developed as a fully integrated interface in ArcView GIS.

Linking results from a MIKE 11 model simulation file with a DEM MIKE 11 GIS produces three types of flood maps: depth/area inundation, duration, and comparison/impact maps (Figure 1).

MIKE 11 FLOOD FORECASTING

The MIKE 11 FF system, is designed to perform the procedures required to simulate the future variation in discharge and water level in a river system as a result of catchment rainfall and inflow/outflow through boundaries in the river system. The MIKE 11 FF module includes the following components:

- Calculation of mean areal rainfall from point rainfall,
- The rainfall-runoff module for simulating sub-catchment inflow to the river system,
- The hydrodynamic module for routing the river flow and predicting water levels,
- An automatic updating procedure that utilizes the measured and/or calculated discharge or water levels to minimize differences between observations and simulation at the time of forecast,
Flood Control Studies

Figure 1. Flood mapping using MIKE 11 GIS.

- Specification of quantitative precipitation forecasts (QPF) and predictions of boundary inflows, and
- The MIKE 11 GIS interface for mapping depth/area inundation.

MIKE 11 FLOOD WATCH

Flood Watch is a framework for MIKE 11 Flood Forecast applications. The Flood Watch interface is an ArcView GIS application and serves as the central manager for acquisition of real time data, data pre-post processing. It consists of three main modules.

The modeling module includes tools to set up and execute hydrological and hydrodynamic models and to perform post-processing of the results. The setup tools provide facilities for fast data entry, receiving
of telemetry data, and options for data processing, e.g., calculation of discharges from water levels and rating curves. Further, the setup tools include pre-designed menus for specification of quantitative precipitation forecasts and prediction of boundary inflow in the forecast periods. The post-processing module allows the user to present results in tables, as graphs, or as flood inundation maps.

FLOOD WARNING IN EUROPE

The Czech Republic

The Morava River, in the eastern part of the Czech Republic, breached its embankments at several locations during the 1997 flood. Large rural and urban areas were inundated, with damage estimated at $2 billion (US).

All flood mitigation proposals are being assessed using the MIKE 11 modules for modeling rainfall-runoff, hydrodynamics, and sediment transport, and for mapping simulated inundation, using ArcView. After the 1997 flood, most of the dikes and embankments were rebuilt to ensure that minor floods could not cause more damage. To limit damage from future major floods, a number of proposals have been put forward:

- construction of flood retention areas,
- changes in the land use of the catchment area,
- establishment of wetland areas along the river,
- construction of navigation channels parallel to the natural rivers, and
- improved dike protection of towns and villages.

A proposed land use change scenario has already been analyzed using the rainfall-runoff model of MIKE 11. In this scenario, 15% of the agricultural land is changed to meadow and pasture (10%) and forest (5%). The results showed a significant local reduction of runoff, whereas the impact on catchment scale was limited.

The hydrodynamic model, describing the flow and water level variation in the rivers and on the floodplains, is the core of most of the analyses. The model has been calibrated for average flow conditions, and the calibration including floodplain flow is well under way.

The preliminary model calibration shows that the simulated flood extent matches well with the observed maximum flood extent (Figure 2).

Poland

Several floods have occurred in Poland over the years, mainly along the Odra River and the Vistula River. The flood that hit Poland of July 1997 was particularly severe along the Odra. More than 140,000 people were
evacuated as 86 cities and 845 villages were inundated. It is estimated that the damage amounted to about $3 billion (US).

Based on a request from the Ministry of Environmental Protection, Natural Resources and Forestry in Warsaw, the Danish Environmental Protection Agency (DEPA) has decided to finance the transfer of Danish flood management technology to Poland. The costs of software, training, and know-how to be transferred total 6.4 mill. Danish Kroner (about $950,000 US). The project will last about 30 months.

DEPA also is supporting a similar project in the Czech Republic. By this dedicated effort in the two countries DEPA has been aiming both to provide the authorities with state-of-the-art flood management technology but also to put emphasis on the need for coordinating flood prevention activities in the two countries with their trans-boundary river system.
After the devastating floods in 1997 the World Bank launched a 3-year, $200 million (US) Emergency Flood Recovery Project in Poland. The Danish technology transfer project is complementary to the World Bank project and efforts have been put into a smooth coordination between the two projects.

The project will comprise the following main activities:

- Strengthening of flood modeling capabilities. This will be achieved through training courses in river modeling in Denmark at DHI, workshops in Poland, and on-the-job-training at the local institutions;
- Development and implementation of MIKE 11 flood forecasting and management systems for the Upper Vistula River basin and for the Upper/Middle Odra River basin.

FUTURE DEVELOPMENTS

EUROTAS

The European River Flood Occurrence and Total Risk Assessment System (EUROTAS) project is directed at the development of integrated catchment models and procedures for the assessment and mitigation of flood risk. Project partners come from across Europe including Denmark, France, Germany, Greece, Italy, The Netherlands, Spain, and the United Kingdom. The project has three main objectives.

- The development of an integrated framework for whole catchment modeling based upon and "open system" approach;
- The demonstration of the feasibility and benefits of integrated modeling to answer real scientific and practical issues on the changing nature of flood risk in five river catchments; and
- The development of procedures to determine the impact of river engineering works and environmental change on flooding and the assessment of flood risk.

The project includes application of the technology to five river catchment studies. The studies will address issues at the heart of sustainable development in river basins such as flood mitigation measures and the impact on flood risk from past and future climatic and land use changes. The catchments selected for the EUROTAS demonstration include:

- Elbe River (Czech Republic and Germany),
- Liri-Garigliano River (Italy),
- Pinios River (Greece),
- Saar/Rhein rivers (France & Germany), and
• River Thames (United Kingdom).

The principal output of the research will be a prototype-integrated catchment modeling system, which will include decision support for the developed procedures.

WAMM

The tool being developed under this project is a Water Management Model (WAMM) founded on the application of Synthetic Aperture Radar (SAR) images for improved mathematical modeling of floods.

WAMM will be able to provide accurate answers to questions such as: When will flood water reach a given location? How long will the inundation last or be more than a given depth? How much could the flooding be reduced by alternative measures including reservoir regulation or controlled flooding of selected polders?

To this end, the MIKE 11 system will be extended with facilities to utilize the SAR data for model calibration/validation and additional facilities for presentation of the results in selected points as well as spatial overviews for result analysis and warning dissemination. These will be fully integrated as a decision support system (DSS), providing the user with the required information, overviews, and model simulations to decide on the best possible line of actions in flood situations.

The system components should also be applicable separately to enable their use as part of other, existing flood management systems. This is important for the dissemination and widespread application of WAMM.

REFERENCES


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Part 11

Flood Insurance
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The Effectiveness of the National Flood Insurance Program in Two Communities: Syracuse, New York, and Tampa, Florida

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INTRODUCTION

The National Flood Insurance Program (NFIP) has been in effect for 30 years, but there has never been a detailed analysis of its consequences. While annual dollar losses (inflation adjusted) from floods in the United States have increased between 1906 and 1993, damage as a percentage of the Gross National Product has decreased (Yen and Yen, 1996). This trend suggests that flood mitigation measures have been effective, although the annual toll remains high and is still increasing. What is not known is to what extent these trends have been influenced by the NFIP.

This study is based on a research design developed by Newton et al., (1996), which posed three questions related to floodplain activities over the last 30 years: (1) What has been the effect of the NFIP on human occupation of floodplains? (2) What has been the effect of the NFIP on the net economic value of floodplain occupancy? and (3) What has been the effect of the NFIP on the natural functions of watersheds? This pilot project, then, was aimed at obtaining a preliminary view of the impacts of the NFIP and at refining a method for a broader national assessment. The results reported here focus on the first two questions.

THE STUDY AREAS AND METHODOLOGY

Two cities were included in the pilot study: Syracuse, New York, and Tampa, Florida. These were selected because they both joined the regular program of the NFIP in the early 1980s, which provided an important

The authors would like to thank the Compton Foundation for financial support to carry out this research.
common denominator for evaluation of the effectiveness of the program. Furthermore, they represent examples of different types of flood hazard, sizes of communities, and growth trends—differences that were expected to be important factors in explaining variations in effectiveness of the NFIP. For instance, the counties in which these cities are located had similar populations in 1970, but changed significantly since then. Hillsborough County, which includes Tampa, had a 1970 population of 490,244 and increased by 3% between 1980 and 1990. In contrast, Onondaga County, New York, had a 1970 population of 472,678, which declined by 3.7% per year during the same period (Gibson, 1998).

The flood situations of each community differ as well. Syracuse has several small streams, which are mostly engineered in the city. Local topography leads to rather small scale but rapid flooding because of quick runoff from hillsides. On the other hand, Tampa has little topographic variation, larger rivers and tributaries, and slow-rise riverine flooding.

Within each city, particular areas were selected for in-depth analysis. Various strategies were used to choose these areas, and different sampling methods were employed to determine how many and which properties to include. Again, these techniques were intended to test the feasibility of different methodological approaches. In Syracuse, wards were used to define the research area (only one of which is reported here) because they provide contiguous land areas, some in the floodplain and some not, and incorporate several neighborhoods. All floodplain properties and a random sample of non-floodplain properties were included in the analysis. In Tampa, spatial delimitation of the study site was based on township and range, and two neighborhoods were chosen with similar socio-economic and demographic characteristics, one in the floodplain, and one not. All properties in these areas were included.

Data were collected from official tax assessment records on address, property size, land use, characteristics of buildings, and valuation (adjusted to 1984 dollar values) for each land parcel. Different years were used in each community because of data constraints. In Syracuse, 1979, 1989, and 1999 are the study years; in Tampa, 1980, 1992, and 1996 records were used.

RESULTS

The results presented here represent the first stage of analysis, comparing changes in numbers of structures and value of property in and out of the floodplain over time. Table 1 traces numbers of structures in and out of the floodplain in Syracuse, by land use type. There were only two land uses in this ward: residential and commercial. Vacant land decreased
Table 1. Syracuse: changes in occupancy and economic value in and out of the floodplain.

<table>
<thead>
<tr>
<th>Land Use</th>
<th>1979</th>
<th>1989</th>
<th>1999</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Flood-plain</td>
<td>Non-flood</td>
<td>Flood-plain</td>
</tr>
<tr>
<td>Vacant</td>
<td>18</td>
<td>13</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-6%</td>
</tr>
<tr>
<td>Comm.</td>
<td>7</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>-80%</td>
</tr>
<tr>
<td>Resid.-Single</td>
<td>302</td>
<td>331</td>
<td>287</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Resid.-Multi</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| Single-Family Residence | 16707 | 29334 | 18865 | 13% | 31178 | 6% | 28282 | 69% | 43804 | 49% |

*Percentage change from pre-NFIP numbers and values.

slightly in the floodplain, suggesting infilling, but this accounted for only two properties; a different trend was seen in non-floodplain areas. Single-family residences decreased in number throughout the ward over the 20-year period, with different experiences evident between floodplain and non-floodplain areas. Between 1979 and 1989, during which Syracuse joined the NFIP, the number of single-family residences in the floodplain decreased, but increased in non-floodplain areas. In the ensuing decade, both areas decreased, although it was greater in the floodplain. At the same time, the number of multiple-family dwellings increased significantly in both areas, particularly between 1989 and 1999. In some cases, properties were converted from single-family to two family residences; in others new structures were constructed. Nonetheless, the intensity of use in both areas has increased, but much more so in non-floodplain areas.

Property values for single-family residences increased throughout the ward, with a greater proportional increase in the floodplain than non-floodplain. However, the adjusted 1999 median value for single-family
housing in the floodplain is lower than the adjusted 1979 median value for non-floodplain houses. Thus, while values have increased, the economic value of property at risk remains low.

In Tampa, changes in occupancy varied significantly by land use type (Table 2). Commercial land uses in the floodplain showed huge proportional increases, but the number of such properties remained low compared to the non-floodplain area. Similarly, increases in institutional

| Table 2. Tampa: changes in occupancy and economic value in and out of the floodplain. |
|-------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| **Land Use** | **Flood-plain** | **Non-flood** | **Flood-plain** | **Non-flood** | **Flood-plain** | **Non-flood** |
| *Vacant* | N.A. | 94 | 45 | 104 | 11% | 42 | 84 | -11%* |
| *Comm.* | 5 | 167 | 22 | 192 | 15% | 27 | 440% | 205 | 23% |
| *Indus.* | - | 17 | 1 | 18 | 6% | - | 15 | -12% |
| *Institut.* | 3 | 27 | 8 | 34 | 25.9% | 10 | 233% | 36 | 33% |
| *Gov.* | 11 | 31 | 13 | 34 | 10% | 13 | 18% | 33 | 6% |
| *Resid.- Single* | 1054 | 1296 | 1065 | 1343 | 1% | 1343 | 4% | 1070 | 2% |
| *Resid.- Multi.* | 7 | 159 | 483 | 676 | 6800% | 483 | 6800% | 676 | 325% |
| **Single-Family Residence** | **Med. Value $** | 35097 | 32499 | 36378 | 31586 | 36849 | 29485 |
| *Percentage change from pre-NFIP numbers and values.* | 4% | -3% | 5% | -9% |
uses were proportionally greater in the floodplain, but the absolute number of properties was still lower than non-floodplain. Both areas exhibited small increases (2%) in the number of single-family residences by the end of the study period, whereas the increase in multiple-family residences was considerable between 1980 and 1992. This suggests infilling and a huge increase in investment in both floodplain and non-floodplain areas.

The median assessed value of single-family residences in the floodplain area in Tampa increased during the study period, while the median value of non-floodplain residences decreased. In addition, floodplain residences started out at a higher level than non-floodplain residences, and they remained that way throughout the study period. This was probably due to the desirability of the floodplain area, which is located on the bay, compared to properties that are inland.

**CONCLUSIONS AND IMPLICATIONS**

The results from this pilot study suggest that there are differences in occupancy and economic value of floodplain and non-floodplain areas since communities joined the NFIP. Some differences can be attributed to economic and demographic characteristics, but others cannot. With all but multiple-family residences, there is a tendency toward decreased investment in floodplains, but patterns differ between the two cities. In Syracuse, a decrease in the number of structures was evident, except with multiple-family residences. In Tampa, there were increases in all floodplain land uses, but the absolute change in number of structures was higher in the non-floodplain area. Thus, even with growth, there is a tendency toward less economic activity in the floodplain. The timing of this differs between cities. In Syracuse, joining the NFIP coincided with a decrease in the number of structures, whereas in Tampa, the greatest increase in number of structures in the floodplain occurred at this time. Of course, these changes could have come about before entrance into the NFIP. However, the pace of investment decreased in the floodplain as community experience with the NFIP increased, and this differs from non-floodplain areas.

It is clear, therefore, that these results are not removed from other forces that affect investment in development. In Syracuse, for instance, the study period includes times of economic downturn, and the decreases in numbers of structures could be attributable to that. However, if that were the case, the differences between floodplain and non-floodplain areas would probably not exist. As a result, it appears that the NFIP is making a difference, irrespective of the socio-economic characteristics of communities.
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INTRODUCTION

The federal government is currently expending significant effort and money to discover methods that will reduce or mitigate flood losses on existing and new structures in flood zones. At the same time, a federal program, established more than 30 years ago to enable those who built in flood zones to relocate when flooded, has become a subsidy encouraging more development in flood zones. After 30 years of existence, it would be appropriate to evaluate the program’s effectiveness at achieving its stated objectives, and make reforms in light of historic events. As basic as it may seem, the best method to reduce flood losses is to prevent structures from being built in known flood-prone areas. The best mechanism for achieving no new building in flood zones may well be to use the federal policy that is already in place, the National Flood Insurance Act.

NATIONAL FLOOD INSURANCE PROGRAM

The National Flood Insurance Program (NFIP), the programmatic arm of the National Flood Insurance Act of 1968 (NFIA) (P.L. 90-448), has been in effect for nearly 31 years. The program made federally subsidized insurance available to homeowners, but was contingent upon a community’s commitment to reduce flood losses through non-structural floodplain management. The original bill received heavy lobbyist support from the real estate, banking, and construction industries, yet President Johnson received the following warning from then Secretary of Housing and Urban Development, Robert C. Weaver: “Some continuing subsidy will also be necessary to a comparatively small number of present occupants of high flood-risk areas. Otherwise the costs of their flood insurance will be more than they can bear; but such a subsidy should not be extended to persons who propose to build new homes in such areas,
for this would lead to increased total flood hazard" [emphasis added] (Lindley, 1986).

The purpose of the NFIA can been seen in two of its objectives: 
“(1) encourage state and local governments to make appropriate land use adjustments to constrict the development of land that is exposed to flood damage caused by flood losses, and (2) guide the development of proposed further construction, where practicable, away from locations that are threatened by flood hazards. . .” The success that the NFIP has achieved for those objectives over the past 31 years is questionable, at best.

MISSED REFORM OPPORTUNITIES

There have been several missed opportunities for reform that could have made significant progress toward the stated objectives, most notably the reauthorization of the National Flood Insurance Program, which was Title V of the Reigle Community Development Act of 1994 (P.L. 103-325). In the 1994 reauthorization sequence, the coastal zone was receiving considerable attention. Senator John Kerry had proposed changes that addressed, in an intelligent way, many of the shortcomings in the NFIP. Those shortcomings included the funding for relocation of damaged structures, insurance eligibility for buildings in known high hazard areas, and the notion of movability of structures in coastal erosion zones (NFIRA, 1994). Unfortunately, none of the proposals was included in the final version of the reauthorization bill.

One area related to the required participation in the NFIP that has seen reform is the requirement of lending institutions to force-place insurance. Mortgage institutions have been required to comply with mandatory flood insurance purchases for mortgages since 1974. But given the fact that, at most, 19% of properties requiring insurance are insured, it is clear that the mortgage institutions are not complying with the requirement (Spann, 1994). The 1994 final reauthorization bill contained a provision for fines on institutions that have a pattern of non-compliance. However, some believe that lending institutions have no real incentive to force compliance, since they have virtually never been penalized in the past for non-compliance (Coughlin, 1996).

Finally, the 1994 reauthorization process provides an example of a flaw in our policymaking. Special interest groups that are well funded, organized, and vocal can wield significant clout with our policymakers. Some of the same special interest groups that supported the NFIA’s creation were able to change Senator D’Amato from a proponent of
Senator Kerry's policy changes to an opponent, leading the attack to defeat the reforms (*Congressional Quarterly*, 1993). Those groups which changed the course of taxpayer liabilities included the National Association of Homebuilders, the Fire Island Homeowners Association, and the Long Island Coastal Alliance, who collectively number fewer than 2 million (Spann, 1994; Fischer and Schwartz, 1995).

**IMPARTS**

The impacts of the NFIP on our natural systems and economic resources have been significant and are only likely to continue or increase. Until the mechanisms within the NFIA that perpetuate the activities that cause the impacts are changed, there is little hope for halting or reversing these trends.

The natural systems impacts include the large amount of the 100-year floodplain that has been, and continues to be, developed; the increased building of levees; the channelization of floodways; and large tracts of coastal floodplains being built upon, often with second or vacation homes by the wealthy. Because the NFIP has become a subsidy, it has become the mechanism that allows developers to sell developments in areas in which people would not buy without the protective umbrella of the federal government.

Added to the impacts on the natural systems, there is a significant and growing economic strain on the NFIP, as well as the U.S. Treasury and taxpayers. The NFIP has been, and will undoubtably continue to be, in the red, due to the combination of inadequate premiums and increased claim events. Additionally, the exposure of the NFIP has grown as a result of more development in areas that require insurance as well as policy changes that raise insurance coverage limits and repetitive losses, which all contribute to the economic drain. Repetitive losses, in both coastal and floodplain areas, accounted for 37% of all NFIP claim dollars (ASFPM, 1998).

**PROPOSED POLICY REFORMS**

In order to alleviate some of the problems related to the NFIP, there will need to be significant modifications to the NFIA. As has been seen in the past, many of the needed changes will be unpopular to those who are benefiting from the NFIP in its current form.

To begin, decisions about changes should be made based on current knowledge and past experience. For instance, we know that coastal beaches are eroding through natural processes. We also know, based on
empirical study, that this erosion occurs at a measurable rate. Therefore, insurance eligibility and surcharges on existing policies should be tied to this known information, not deferred until another study can be completed.

Additionally, actuarial premiums should be charged on all new policies and development, and should be phased in on all existing policies. Until the true cost of living in hazardous areas is placed on those who live in such areas, there will be little motivation to move to safer ground or not buy properties developed in such areas.

Finally, where known flooding occurs, flood insurance for new construction should not be available. This type of policy reform could explicitly remove flood insurance eligibility for new construction in 100-year floodplains and V zones on the coast, as well as accomplish the NFIA's founding objective to get development out of harm's way.

RELATED PENDING LEGISLATION

In looking at the past 30 years of the NFIP's activities and resulting effects, it is troubling, to this author, to see new legislation introduced that applies similar techniques to other types of catastrophic events. The National Earthquake, Volcanic Eruption, and Hurricane Excess Loss Reinsurance Program bill (H.R. 481) was introduced into the first session of the 106th Congress. This bill would have made even more federally subsidized insurance available to those who lived or built in known hurricane impact zones. Not only would this add more federal liability on top of the flood insurance policies in this zone, but also it would potentially promote even greater populations to live in high hazard zones. This bill did not make it out of committee, but is likely to be reintroduced in the current session of Congress.

The scientific and professional communities must join together in a collective team to guide policymakers in wise policy development and reforms. Only together can the self-serving mechanisms of one or two groups be eliminated and ensure help for those who really need federal intervention.

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Flood Risk Assessment and Mitigation—
An Insurance Company's Approach

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INTRODUCTION

The insurance industry has long used engineering procedures to assist its policyholders in the prevention of losses due to perils such as fire. These engineering procedures are part of an overall process commonly referred to as loss prevention. Recently the industry has started to reassess the loss prevention process as it has been applied to natural catastrophes such as floods, wind, and earthquake.

This process evaluates risk, mitigation measures, and the cost/benefit of mitigation. With the information obtained from this process the insurance company can assist its policyholders in risk management. This paper describes a first-order flood risk assessment methodology used to aid in implementing the loss prevention concept.

BACKGROUND

Mutual insurance companies fund policies through the collection of premiums from their policyholders. Unlike capital-stock insurance companies, which sell stock, mutual insurance companies are owned by their policyholders. These premiums are invested and managed by the insurance company to provide coverage for insurance losses. Earnings in excess of losses and expenses plus reserves are the property of the policyholders. Consequently it is in the economic interest of the policyholders to minimize losses.

Insurance companies issue insurance via the process of underwriting. Underwriting consists of hazard recognition and evaluation, selection of insured, pricing, determination of insurance policy terms and conditions, and monitoring of risk. In order for underwriting to occur, the risk due to various perils including floods needs to be recognized and evaluated in a manner which is of use to the underwriting process.

This process permits mutual insurance companies to spread their risk to provide for adequate funds for claims. When issuing a policy, these companies endeavor to select highly protected risk clients (HPR). These
clients typically have the following characteristics: substantial construction, protected special hazards, fixed protection adequate water supply, exposure protection, and concerned management. In general, most if not all, successful industries possess these characteristics. HPR clients as a rule support the loss prevention concept.

Mutual insurance companies serve a very specialized market referred to as the highly protected risk. The overall property insurance market is $33 billion, of which $2.7 billion is devoted to mutual insurance company policies.

**Loss Prevention**

Loss prevention is the process by which overall risk is reduced or mitigated. In order to implement this process insurance companies have a staff of specially trained loss control engineers. These engineers inspect the facility to make an assessment and identification of risk. As part of this inspection the loss control engineer will:

- Assess/Identify Risk—site inspection and review of flood maps;
- Quantify Exposure—prepare loss vs. flood elevation curves; and
- Treat Exposure—flood barriers, etc.

With these methodologies the insurance company can better advise its policyholders on how to mitigate or eliminate the risk and thereby reduce losses due to various perils. The organization, which implements these tasks, can serve to assist local floodplain managers in assuring that prudent floodplain policies are practiced by local industry.

**FLOOD PROBLEM**

The insurance industry has experienced unexpected losses due to the occurrence of floods. Many of these losses could have been mitigated or prevented by a better understanding of the flood risk exposure. Currently the insurance industry utilizes Federal Emergency Management Agency flood insurance maps and profiles to derive the flood elevation at a particular location. Since the flood map results are “average” values the risk around this average value is unknown.

The FEMA analysis generally involves the following steps:

1. Derivation of flood flows for the 10-year, 50-year, 100-year, and 500-year events;
2. Acquisition of cross section data and other hydraulic related information;
(3) Preparation of backwater profiles with HEC-2 or another accepted methodology;
(4) Preparation of encroachment determination with HEC-2; and
(5) Completion of flood insurance study and flood mapping.

The flood discharges derived under item 1 are at the 50% percentile level. This means the discharge will be equaled or exceeded 50% of the time for the 10-year, 50-year, 100-year, and 500-year flood events.

**IMPLICATIONS**

The use of an average flood elevation has physical and cost implications for the insurance industry. Since the insurance industry uses an average value it is possible that the upper value can occur and cause an "unexpected" loss. This loss is in actuality not "unexpected" and through statistical methods the level of risk can be defined.

**Physical Implications**

The upper flood elevation causes deeper flood depths. The deeper flood depth can trigger bridge and culvert overtopping, and widen floodplains. Both of these effects increase flood depths for locations in the average floodplain and cause properties outside of the average floodplain to flood.

**Cost Implications**

Damage vs. elevation curves provides the insurance company with a method to compute potential loss exposure. From these curves the level of total risk to the insurance company can be determined. In order to successfully underwrite policies the insurance company needs an estimate of losses due to typically the 100-year event. If this value is underestimated the underwriting process cannot successfully work.

**SUGGESTED SOLUTION**

The determination of flood losses requires the use of hydrologic and hydraulic techniques. Inherent in these techniques is uncertainty in estimating various coefficients and parameters. Recently the Corps of Engineers (U.S. Army Corps of Engineers, 1996) prepared a monograph that quantifies the uncertainty of flood determinations into several categories. This elevation is subject to a statistical uncertainty due to (1) frequency analysis, (2) stage discharge function, (3) stage damage function, and (4) mitigation plans.
A risk assessment approach has been formulated with the goal of identifying the upper flood elevation utilizing category 1. This upper flood elevation is used by the underwriters to set policy rates and by the loss control engineers to assist the insured in forming mitigation plans. A greater level of detail would need to be pursued only on a case by case basis where categories 2 through 4 would be invoked.

Flood frequency analysis for FEMA applications traditionally uses a Log Pearson Type III distribution. With this analysis it is possible to determine the 95% and 5% discharge probability levels for a given chance event; low flood discharge is equaled or exceeded 95% of the time and the upper flood discharge is equaled or exceeded 5% of the time. This range is commonly referred to as a confidence ban. The ban reflects the uncertainty of the data set used in the analysis; as such it provides a range of risk.

The solution has two main components:

**Component 1**—Use the Log Pearson Type III method to determine the lower, average, and upper flood discharges.

**Component 2**—At a given site an increase in discharge yields a unique increase in flood elevation; use the stage discharge relationship to define the upper flood stage.

Here is a list of the steps needed to complete the first-order flood risk assessment:

**Step 1**—Gather data from various sources: such as the U.S. Geological Survey and FEMA.

**Step 2**—Determine nearest USGS stream gauging station and obtain peak flood flows.

**Step 3**—Operate USGS Log Pearson Type III PC program (U.S. Geological Survey, no date).

**Step 4**—Use discharge rating to determine upper flood stages.

**Step 5**—Prepare summary memorandum summarizing flood risk.

**CONCLUSIONS**

The original data sets used in the FEMA flood hydrology and hydraulics need to be readily accessible to floodplain managers and the public. Supplying this information will allow insurance companies the opportunity to help their clients mitigate flood losses.

There have been cutbacks on funding for the USGS stream gage program. It is extremely important that the floodplain management community expresses its support for this program. Our ability to identify
flood risk and quantify it is coupled with both the quality and duration of stream flow data.

FEMA will provide communities with flood insurance study backup information at no cost during the statutory 90-day appeal period for an initial or revised flood insurance study for that community. It would be beneficial for communities to routinely take advantage of this offer.

The flood management community should establish a liaison with the insurance industry to promote inter-organizational cooperation. The insurance industry has a large network of loss control engineers in the field. This represents a resource for managing the floodplain.

Floodplain managers need to contact loss control engineers to keep them current on local flood protection activities.

REFERENCES


Part 12

Federal Programs, Policies, & Initiatives
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Opportunities for Use of RiverWare to Assist Floodplain Managers in the West

Donald Frevert, Terrance Fulp, and Shannon Cunniff
U.S. Bureau of Reclamation

INTRODUCTION

Accurate and timely information is crucial to the planning, scheduling, and operation of water and power resources. These data include the distribution of precipitation and inflow into the watershed, stream flows, reservoir levels, and water and power demands. Historical and predicted data are needed to evaluate the relative benefits and risks associated with alternative operational strategies. Furthermore, these data must be readily available to model the effects of these alternative operational strategies on partners, stakeholders, and the general public.

Historically, throughout the Bureau of Reclamation, these data have not been readily accessible. Older water resources models such as the Colorado River Simulation System (CRSS—a long-term policy and planning model) gained a good level of acceptance among Reclamation stakeholders, but were cumbersome to modify and it became difficult to reflect continually changing priorities, mandates, and constraints. By the early 1990s it was clear that a new and more flexible modeling framework would be required to meet the needs of Reclamation decision makers in the future. RiverWare has the flexibility to route both historically observed and hypothetical flood events and has become a useful tool in this regard.

OPERATION OF LARGE COMPLEX RIVER SYSTEMS

Reclamation managers are presently confronted with a number of competing demands as they operate multiple reservoir systems. These competing demands include, among others:

- water supply for agricultural, municipal, and industrial purposes as determined by state-administered prior appropriation water rights systems,
- flood damage control as mandated by project authorizations,
- hydroelectric power generation,
• in-stream flow as determined by state water quality or fishery requirements or biological opinions pursuant to the Endangered Species Act,
• environmental restoration,
• interstate compacts and international treaties, and
• recreational uses by small businesses and the general public.

Prioritization of these demands is a function of many factors including legal requirements, contractual agreements with stakeholders, and public values. Accordingly, prioritization of these demands can and does vary significantly from basin to basin throughout the western United States. In addition, the prioritization can change over a period of time, further reinforcing the manager's need for flexible modeling tools.

DEVELOPMENT OF RIVERWARE THROUGH THE WATERSHED AND RIVER SYSTEMS MANAGEMENT PROGRAM

Recognizing this need for more flexible and effective modeling tools, and under the direction of the Assistant Secretary of the Interior for Water and Science, Reclamation began discussions with the U.S. Geological Survey in January 1992. These discussions led to an agreement to proceed with development of more efficient and mutually compatible modeling tools for both agencies. Key pieces of the improved modeling system include:

• the Modular Modeling System (MMS) of USGS, which models hydrologic and ecosystem processes at the watershed level;
• a Hydrologic Data Base (HDB), which includes streamflow, reservoir operations, snowpack and weather data; and
• the RiverWare modeling framework, which would be developed for Reclamation and used for short-term operations and scheduling of deliveries, mid-term operations and planning as well as long-term policy and planning.

RiverWare is being developed through a cooperative effort with the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado. The interactions between the MMS, HDB, and RiverWare are illustrated in Figure 1.

Beginning in October 1995, funding to support the RiverWare and HDB development was made available by the Bureau of Reclamation's Research and Technology Transfer Program, the Tennessee Valley Authority (where RiverWare is also extensively used), and several of Reclamation's Regional and Area Offices.
The technical capabilities of the program have been developed on an "as needed" basis focusing on river basins where managers have the most urgent need for these tools. In the initial 1992 meeting, the San Juan River basin and the Lower Colorado River basin below Hoover Dam were identified as the primary study areas. Subsequently, upon completion of work in those river basins, the effort has incorporated the Colorado River basin, the Pecos and Rio Grande basins of New Mexico, and the Yakima River basin of Washington. Beginning in the fall of 1999, the program will be expanded to include the Truckee and Carson River basins of Nevada and California.

Technical capabilities are reviewed periodically by an independent panel of water resources experts from leading universities and other
agencies. This panel reports their findings to Reclamation both in the context of a review of recently developed capabilities and a set of recommendations for future priorities.

PRESENT CAPABILITIES OF RIVERWARE

RiverWare presently has the capability to do simple simulation, rule based simulation, and optimization on multiple reservoir systems utilizing time steps ranging from one hour to one year. Duration of the simulation and optimization runs is not limited. As shown in Figure 1, the model interacts with the HDB and can use historically observed, forecasted, or stochastically generated data. Several recent publications (Zagana et al., 1998; Leavesley et al., 1998; Fulp and Frevert, 1998; Lins and Frevert, 1998; and Frevert et al., 1997) provide additional detail on the capabilities of RiverWare and the interaction between RiverWare, the HDB data base, and the MMS modeling framework. Additional information about the present capabilities of these tools can be found at the websites:

http://www.usbr.gov/rsmg/warsmp
http://wwwbrr.cr.usgs.gov/mms
http://cadswes.colorado.edu/riverware/riverware_info.html.

Because it can work with hourly data, RiverWare has substantial capabilities to route both historically observed and hypothetical flood events and is very useful in formulating reservoir operations strategies to help water resource managers better cope with flood events. The recently developed capability to perform multiple run analyses further enhances these capabilities and has greatly facilitated its use.

At present, capabilities for computation of inundation levels within RiverWare are limited and interaction is required with separate hydraulic models for this purpose.

POTENTIAL IMPROVEMENTS TO RIVERWARE TO FACILITATE FLOODPLAIN MANAGEMENT APPLICATIONS

Beginning in Fiscal Year 2000, the project budget is being programmed with flexibility to add new capabilities to the RiverWare framework. These capabilities would build on the present capability in RiverWare to simulate reservoir releases on an hourly basis and could include improved hydraulic routing and backwater capabilities to better estimate the water surface elevation associated with a given release. Development of these capabilities would be technically challenging and would involve a substantial effort, so financial assistance of funding partners would be critical to insuring success.
USE OF RIVERWARE TO FACILITATE FLOODPLAIN MANAGEMENT APPLICATIONS

In its present form, RiverWare can be a key part of the solution in estimating water surface elevations associated with a given release strategy. This presently would require use of a compatible hydraulic routing model, but in the event that these capabilities can be incorporated into the RiverWare framework at a future date, it would then become possible to do this in a single step. The multiple scenario management capabilities described previously allow managers to compare water surface elevations that might be expected during flood events under different management strategies.

One example of how these capabilities could be used in floodplain management would be to simulate how various releases from Lake Havasu might impact water surface elevations along the Colorado River Channel in Yuma, Arizona. Such information would enhance Yuma's efforts to plan appropriate, sustainable development of its floodplain.

CONCLUSION

State, local, and tribal entities interested in expanding RiverWare to facilitate their land use planning should contact the Bureau of Reclamation or the CADSWES group at the University of Colorado through the websites previously noted. By partnering with Reclamation and CADSWES, capabilities can be enhanced.

REFERENCES


INTRODUCTION

President Clinton proposed the American Heritage Rivers Initiative in order to support communities in their efforts to protect and restore America's rivers. In July 1998, the President designated 14 American Heritage Rivers (AHR) (Table 1), stating that the Initiative embodies the vision and essence of the National Environmental Policy Act as it promotes the paradigm that people and nature can exist in "productive harmony." The Initiative has three major objectives: natural resource and environmental protection, waterfront revitalization, and historic and cultural preservation (E.O. 13061). The AHR designation will assist communities by focusing support for, and simplifying access to, existing federal programs through a "Good Neighbor" policy in a manner designed by the community and espoused in its action plan. Considerable opportunities to restore floodplain, riparian, and wetland areas along thousands of miles of "heritage" rivers will therefore be available. Most designated river communities have experienced flood disasters and have addressed floodplain management issues in their AHR community plan in order to both protect their rivers and to reduce the loss of life and property caused by floods.

Table 1. American Heritage Rivers.

<table>
<thead>
<tr>
<th>Blackstone/Woonasquatucket rivers</th>
<th>New River</th>
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<tr>
<td>Connecticut River</td>
<td>Rio Grande River</td>
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<td>Cuyahoga River</td>
<td>Potomac River</td>
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<tr>
<td>Detroit River</td>
<td>St. John's River</td>
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<tr>
<td>Hanalei River</td>
<td>Lower Mississippi River</td>
</tr>
<tr>
<td>Hudson River</td>
<td>Upper Mississippi River</td>
</tr>
<tr>
<td>Upper Susquehanna/Lackawanna rivers</td>
<td>Willamette River</td>
</tr>
</tbody>
</table>
FLOODPLAIN MANAGEMENT

Floods have caused a greater loss of life and property and have devastated more families and communities in the United States than all other natural hazards combined. For many years it was the policy of the federal government to encourage and fund major "flood control" projects, such as dams and levees, in an attempt to prevent flood losses and so, in no small way, contributed to the loss and degradation of the natural resources and functions of floodplains. Although representing a diversity of federal agencies with varying missions and goals, the Federal Interagency Floodplain Management Task Force agreed that the document they prepared for the President, *A Unified National Program for Floodplain Management*, needed to explicitly state that floodplain management encompasses two co-equal goals—reducing the loss of life and property caused by floods and protecting and restoring the natural resources and functions of floodplains. The Task Force concluded that an effective means to achieve these goals was to promote a more comprehensive "watershed approach" to floodplain management.

Recent research has shown that significant flood events (e.g., the "100-year" flood) have large-scale, but positive impacts on the ecological riverine/floodplain system. These changes caused by floods are ecologically analogous to disturbances in terrestrial environments caused by forest fires, such as those in Yellowstone National Park in 1988. These changes may at first glance appear devastating to the environment. However, floodplains are dynamic systems in which floods effectively "reset succession" to earlier stages, providing a multitude of ecological benefits such as maintaining a diversity of habitats and biological communities, providing spawning areas for fish and other wildlife, and significantly increasing productivity within the floodplain environment (Michener, 1998). Conversely, channelizing rivers for navigation, draining wetlands for agriculture, and constructing levees for "flood control" cuts off the river from its floodplain, altering the hydro-regime, eliminating spawning and nesting areas for fish and wildlife, and at times aggravating flood losses. Protecting and restoring floodplain lands will not only prevent flood losses, but will also contribute to maintaining surface water quality, enhancing groundwater recharge, preserving wildlife habitats, and generally promoting the quality of life or "livability" of communities.
WILLAMETTE AMERICAN HERITAGE RIVER

The Willamette River is located in northwestern Oregon between the Coast Range and the Cascade Mountains. Its watershed comprises some 11,500 square miles. Nearly 70% of Oregon's population lives within 20 miles of the river, and 75% of its economy is based there. The vision for the Willamette River watershed is to "attain a dynamic balance between diverse human and ecological needs. Basin residents should live in healthy watersheds with functioning floodplains and habitats supporting a diversity of native species" (E.O. No. 98-18).

The native Americans referred to the Willamette as the "river of no sides" indicating the abundance of meandering side channels, wetlands, sloughs, and meadows that make up its floodplain. Salmon once thrived in the Willamette River watershed with the proliferation of suitable spawning habitats, clear water, and abundant food production in the naturally functioning riverine/floodplain ecosystem. In this century, however, the
Willamette and its tributaries have been channelized, dammed, leveed, polluted, its wetlands drained, floodplains cleared and developed, and forests cut, all contributing to significantly altering the hydro-regime and water quality of the Willamette River. These changes in the river/floodplain system have severely impacted the viability of salmon, as well as other fish and wildlife populations, and have aggravated flood losses. To address these problems Governor Kitzhaber of Oregon established the Willamette River Basin Task Force to study the causes of the Willamette's degradation and to recommend solutions. The Task Force in its report recommended a more systematic, watershed approach to water resources management so that the Willamette can function "more like a river than a ditch" (Miller, 1997). The Task Force also recommended that federal and state policies and programs that encourage floodplain development should be evaluated and a broad range of tools, such as economic incentives, tax credits, easements, acquisitions, etc., should be utilized to protect the river and its floodplain.

In March 1999, the Administration announced that it was listing nine species of salmon under the Endangered Species Act. This listing means that local and state governments will need to closely examine the causes of the degradation of their rivers, wetlands, and floodplains and adopt appropriate land use measures that would protect and restore them. The White House has made it clear, however, that the American Heritage Rivers Initiative does not create any new regulatory authority nor will it interfere with the internal matters of state, local, and tribal governments. In addition, the AHR Task Force will develop ways to inform federal agencies and river communities about the goals and objectives of AHR to ensure that federal actions are complementary to, and supportive of, these goals. Federal agencies will also be required to consult with the communities and states of the designated rivers early in the planning phase of proposed actions to be consistent with their plans.

The AHR designation for the Willamette River will bring federal agencies together to help protect the river, restore the salmon, and reduce flood losses. For example, the U.S. Environmental Protection Agency might contribute to achieving the Willamette AHR's goals by helping to improve water quality and protect wetlands; the Federal Emergency Management Agency could relocate homes out of flood hazard areas; the U.S. Army Corps of Engineers might restore the river's original meanders and remove levees; the Natural Resources Conservation Service could promote the establishment of riparian buffers zones through incentive programs; the Federal Energy Regulatory Commission might consider promoting the dismantling of some dams; the National Park Service could
Figure 2. Sculling on the Willamette River in Portland. Much progress has been made in improving the environmental quality and ecological integrity of the river, but much more needs to be accomplished. The AHR designation will help in that regard.

design a river greenway; and the U.S. Forest Service might accelerate reforestation of clearcut and riparian areas.

In these and other ways, the American Heritage Rivers Initiative will provide numerous opportunities to implement innovative and effective plans and programs to achieve the goals of floodplain management. The coordinated, cooperative efforts underway in AHR communities could be used as successful models of "reinventing government" for other river communities nationwide into the 21st century, and beyond.
REFERENCES


INTRODUCTION

The Federal Emergency Management Agency's (FEMA) Public Assistance Program provides supplemental aid for disaster recovery to state and local governments and certain private non-profit organizations under the authority of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, Public Law 93-288, as amended (Stafford Act) and Title 44 of the Code of Federal Regulations (44 CFR). Specifically, Section 406 of the Stafford Act authorizes supplemental aid for the repair, restoration, and replacement of facilities damaged by a major disaster. In approving grant assistance for restoration of facilities, FEMA also has the discretionary authority to provide funding for cost effective hazard mitigation measures (44 CFR Section 206.226(c)). FEMA recently developed a new hazard mitigation policy titled "Hazard Mitigation Funding Under Section 406 (Stafford Act)." This policy, which was approved on August 13, 1998, clarifies and simplifies eligibility criteria for funding hazard mitigation projects under Section 406. The policy reflects Director James L. Witt's emphasis on mitigation and is part of FEMA's overall effort to improve the delivery of its programs to customers. The policy does not apply to grants approved under the Hazard Mitigation Grant Program, which is authorized under Section 404 of the Stafford Act.
ELIGIBILITY CRITERIA FOR HAZARD MITIGATION UNDER SECTION 406

FEMA, the state, or the applicant for grant assistance may propose a hazard mitigation measure as part of a project to restore a facility damaged by a major disaster. The hazard mitigation proposal (HMP) is analyzed for a variety of eligibility criteria and, if approved, funding for the HMP is included in the grant for the restoration of the facility. To be approved, an HMP must meet certain criteria. First, the repair or restoration project itself has to be determined eligible for funding under the Stafford Act and FEMA regulations. The HMP must be directly related to the disaster-damaged elements of the facility; be technically feasible; directly reduce the potential of similar damage from a future disaster event; and comply with statutory, regulatory, and executive order requirements, including those regarding the protection of the environment (Federal Emergency Management Agency, 1998). Additionally, the HMP must be determined to be cost effective.

DETERMINING THE COST EFFECTIVENESS OF HMPs

The cost effectiveness of an HMP typically is determined by comparing the cost of the mitigation measure to the cost of potential future damage repair avoided by performing the hazard mitigation project. Before the establishment of the 1998 policy, the cost effectiveness of an HMP was determined by performing a benefit-cost analysis (BCA) with a FEMA-approved computer model. This model includes many variables that are based on a wide variety of assumptions. The consistency of the BCA results is a function of the number of assumptions that have to be made. While the assumptions are reduced when site-specific, historical data are available, these data are not always available for Public Assistance projects. Time consuming research is often required to obtain the accurate input parameters needed to develop a model that would produce valid results. This process was not always consistent with FEMA's goal of providing assistance to state and local governments as quickly as possible.

Further, the use of many assumptions often makes it difficult to ensure accurate BCA results. If reliable input parameters are not obtained, the use of the FEMA-approved computer model may result in an unreliable analysis that can be misinterpreted. Analyzing the cost effectiveness of HMPs in this manner presents a challenge to a consistent approach to providing funding for hazard mitigation measures.
THE 1998 SECTION 406 HAZARD MITIGATION POLICY

Recently, FEMA redesigned the Public Assistance Program to meet the needs of its customers. In redesigning the program, FEMA focused on providing better training for its people, providing better and more consistent information on FEMA's policies, streamlining the process of delivering assistance, and improving the overall performance of the program. The redesign resulted in a program that provides more effective, efficient, consistent delivery of assistance.

As part of the initiative, FEMA looked at simplifying procedures for approving hazard mitigation projects. The new hazard mitigation policy was developed as part of this initiative. This policy provides clear, concise guidelines for the approval of HMPs. The 1998 policy describes the eligibility criteria already discussed and reiterates that hazard mitigation funding under Section 406 is approved at FEMA's discretion. In addition, the policy simplifies the procedure for determining cost effectiveness.

Under the new policy, cost effectiveness will now be determined in one of three ways. First, an HMP is considered cost effective if the cost to perform the hazard mitigation measure is no greater than 15% of the total eligible cost of the repair work on a particular project. Second, there are certain pre-identified mitigation measures that are considered to be cost effective as long as the cost of the measure does not exceed 100% of the cost of eligible repair work. These measures are identified in an appendix that is attached to the new policy. Some examples of pre-identified hazard mitigation measures include: replacing a drainage structure with multiple structures or a larger structure; installing headwalls and wingwalls to control erosion; installing gabion baskets or riprap to control erosion; and elevating electrical panels and equipment above flood elevations. The list of pre-identified hazard mitigation measures will be evaluated and updated as needed. Finally, if the HMP is not cost effective under the first two criteria, the state or the applicant may provide data demonstrating cost effectiveness using an acceptable analysis (FEMA, 1998).

The new policy is available on the FEMA website at www.fema.gov/r-n-r/9526_1.htm.

CONCLUSION

The simplified criteria to determine cost effectiveness, by eliminating the requirement for time-consuming technical analyses, will encourage applicants and FEMA and state field personnel to seek mitigation opportunities. The simplified criteria will also strengthen the ability of field personnel to prepare sound recommendations for cost effective
mitigation projects and allow for an expedited review of HMPs by FEMA staff. Further, if an applicant proposes an HMP that is complex and does not meet the simplified criteria for cost effectiveness, the applicant has the opportunity to provide valid input parameters when performing his or her own BCA.

In summary, the new policy streamlines the process of making funds for hazard mitigation measures available during the disaster recovery process. The streamlined process furthers FEMA's goal of administering its programs with a focus on customer satisfaction.

REFERENCES
An Initiative for a U.S. Geological Survey National Streamflow Information Program

John E. Costa, Jerad Bales, David Holtschlag, Kenneth Lanfear, Stephen Lipscomb, Paul C.D. Milly, Roland Viger, and David Wolock
U.S. Geological Survey

INTRODUCTION

In recent years, the demand for and value of streamflow information has grown, and information users have developed increased expectations for the reliability and timeliness of the information stream. During the same period, the overall size of the U.S. Geological Survey (USGS) stream gaging program first leveled off and has since begun to decline. Furthermore, the share of the gaging program supported by federal funding has dropped disproportionately, with consequent loss of representation of federal interests in the siting of gages. In 1998, the USGS provided less than one-third of the funds to operate the current streamgaging network, while other federal, state, and local partners provided the remainder. This decline is especially evident in the loss of long-term gaging stations (Figure 1).

![Figure 1. Number of stream gaging stations with 30 or more years of record discontinued each year, 1921-1995.](image)
THE PROGRAM OUTLINE

The USGS has completed a preliminary analysis of the current streamgaging network. The responsible committee has made the following recommendations to ensure the effective collection, processing, and dissemination of streamflow information for federal needs into the future through a comprehensive National Streamflow Information Program (NSIP). NSIP will consist of the following components:

(1) A nationwide system of gages for measuring streamflow and related environmental variables reliably and continuously in time;
(2) A program for intensive data collection in response to major floods and droughts;
(3) A system for data processing, quality assurance, archiving, and access;
(4) A program for periodic regional and national assessments of streamflow characteristics;
(5) A program for streamflow information delivery to customers; and
(6) A program of techniques development and research.

Two levels of streamgage network are considered. "Base" information needs are those that should be met by the USGS stream gaging program even in the absence of support from funding partners. The "base" network includes sites associated with existing compacts and decrees, existing National Weather Service (NWS) flood-forecast sites, water-budget accounting units, Hydro-Climatic Data Network stations, regionalization, and federal lands. "Full" information needs are those that should be met by the program when funding partners are willing to provide substantial support. The "full" network provides information on cross-border flows, high-population floodplains, additional regionalization sites, federal reservoirs, quality-impaired cataloging units, National Stream Quality Accounting Network, and Wild and Scenic Rivers (Table 1). New funding to support approximately 5,000 stations would be sufficient either to meet the "full" set of federal information needs (in conjunction with USGS funding-partner supported gages), or to meet the "base" federal requirements in the absence of any USGS funding-partner supported gages.

The Committee recommended that the funding of gaging stations be based on a model of federal support for the fixed costs of all gaging stations. Stations operated for other federal agencies, or state and local cooperators, would be priced at the marginal cost to operate the gage, and this amount could be cost-shared, resulting in significant savings to partners.
Table 1. Base and full stream gaging needs, with level of satisfaction in 1996.

<table>
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<tr>
<th>Characteristic</th>
<th>Base</th>
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Features of gaging stations in this new network would include real-time stage-measurement capability, two-way communications, a surveyed cross-section, a rating curve extended to the 500-year flood level, flood-hardening to the 500-year level, global positioning system location, and additional equipment including a rain gage and sensors to measure water temperature continuously. The NSIP would explore new technology to make stream gaging safer, faster, and less expensive. Among the possibilities are non-contact stage sensors, and the option of completely non-contact discharge measurements using radar technology. A proof-of-concept experiment using totally non-contact methods was completed in April 1999.

A systematic approach for response to floods and droughts is envisioned, that includes teams of hydrologists, geologists, and biologists to respond to major floods and droughts using a systematic set of hydraulic, hydrologic, water-quality, geomorphic, and biologic measurements. The response would shift focus away from very-high
quality data collection at a few sites to collection of more data at more sites, and emphasis on the collection of time-series water-quality data.

The database and software systems for receiving and processing streamflow data would move from a distributed computer network system to a centralized multi-server system. Collection and review of the data would take place at locations remote from the locations used for storage and access. The database system would contain separate components, one each for data collection, review, routing, archiving, and access. Statistical methods of uncertainty analysis would be used to perform quality control, to construct rating curves, to determine when to apply rating-curve shifts, and to quantify confidence limits on stage and streamflow data. Individual database sites would be as fault tolerant as possible using technologies such as redundant arrays of inexpensive disks, cluster servers, and uninterrupted power supplies. Redundant processing databases would be housed in physically separate locations with independent data feeds.

The USGS will establish a permanent, national program of regional streamflow assessments to address at-site streamflow characterization, trend analysis, and regionalization. The basic study units for the regional assessments will coincide with the major physiographic provinces of the nation. Regional assessments will be repeated on a 10-year cycle, and the assessments will be staggered in time across regions. Assessments will include analyses of numerous streamflow characteristics, including mean and median flows, flood and low-flow characteristics, normal seasonal cycles, and measures of streamflow variability, such as baseflow/runoff ratios. The assessment program will include an ongoing national-scale assessment that integrates information from the regional assessments. NSIP streamflow assessments will be increasingly cognizant of nonstationarity and deterministic controls on temporal variations of streamflow.

Under NSIP, streamflow information will be delivered through a variety of interfaces tailored to the needs of interactive users, batch users, push customers, and USGS hydrographers. All available stage and streamflow data will be served at the time interval on which data are collected (unit values), or as user-requested time averages (daily, monthly, and annual) through an interface that unifies "historical" and "real-time" databases. USGS streamflow information products will be linked to the maximum extent possible with other USGS products and with the relevant products of other federal agencies. Where USGS gage sites and NWS forecast service locations coincide, the USGS will provide unified graphical presentations of NWS forecasts in the context of USGS measurements and streamflow characteristics. Interactive users of USGS
databases will have WorldWideWeb access to numerous user-customized map, graphs, data tables, and miscellaneous information reports. The USGS will seek to build a partnership with the Federal Emergency Management Agency (FEMA), NWS, and other relevant agencies to design an integrated program that will modernize techniques for the generation of flood-risk maps, develop a process for routine revision of flood maps, provide near-real-time maps of flood inundation areas, and provide forecast maps of flood-inundation areas.

RESEARCH NEEDS FOR STREAM GAGING

Research needs for a National Streamflow Information Program include the following:

- Techniques to improve regional regressions of flow characteristics,
- Methods of non-contact stage and discharge measurement,
- Techniques to estimate stream-gaging error,
- New methods for flood-frequency and trend analysis,
- Investigations of variations in streamflow characteristics,
- New methods of indirect discharge measurement,
- Investigations of processes in open channels during high flows,
- New debris flow models, and
- Investigations of velocity profiles across a range of geomorphic settings.

This plan for a National Streamflow Information Program will be refined over the next several months, sent to other federal and non-federal partners for review, and re-evaluated. Streamflow information is essential for the physical and economic well-being of the nation, and widespread support for this new program will be essential for success.
INTRODUCTION

In an ongoing effort to streamline the implementation of the Hazard Mitigation Grant Program (HMGP), the concept of "Managing States" was developed by Federal Emergency Managing Agency (FEMA) to allow states increased involvement in the determination of project eligibility and cost-effectiveness. While the HMGP Managing State pilots of Florida, Ohio, and North Dakota undertake significantly increased responsibility in the mitigation program decision-making process, National Environmental Policy Act (NEPA) and related environmental review requirements present a continued need for close local, state, and federal coordination. This paper describes some of the basic concepts which, while at the pilot stages of implementation, will be important to Managing State environmental review as it evolves into practice.

The Hazard Mitigation Grant Program has been in existence since the passage of the Robert T. Stafford Disaster Relief and Assistance Act of 1988. Since that time, FEMA offices and state offices have developed a great deal of experience and capability in mitigation and environmental compliance associated with mitigation grants. Further, the HMGP is heavily oriented toward state involvement in decisionmaking and management of the grant program with an increasing emphasis on building state capability in this regard. Consequently, the natural evolution of environmental review at FEMA is that states will take a greater role in ensuring that accurate environmental information is obtained in a timely manner meaningful to decisionmaking and that issues are identified and resolved at the lowest level to the maximum extent legally possible. This paper provides a strategy for states to promote increased involvement and responsibility in the review process.
THE PROCESS

As part of the environmental review process for Managing States, states agree to a level of responsibility for environmental review through Managing State Memorandums of Understanding. The state's participation in the process will vary in responsibility. In some instances, the state, in agreement with FEMA, may lead the environmental review on virtually all levels, and in others, FEMA could continue as the primary action agency for all environmental reviews. If a state takes on the fullest extent of responsibility, they may ultimately do all work required for a NEPA document and, if coordinated properly with FEMA, provide the Regional Environmental Officer with a document ready for final review and approval. The reality of where most states will be over the next several years lies somewhere between the two extremes. It is here, through development of procedures for consultation, evaluation, and documentation of environmental review, where there exists the best opportunity since the inception of the HMGP to focus both the scope and timing of environmental reviews towards an appropriate and effective level of effort. For the purpose of discussion, the state's participation level in the Managing State Environmental Review Process would be described as one of three general levels:

A. Minimal Support. The state would:
   • Ensure that all relevant project information and environmental data, resource and background information is collected and verified as accurate.
   • Maintain project reviewers qualified to verify accuracy of project information and environmental information collected.

B. Full Support. In addition to activities under the minimal level of support, above, the state would:
   • Take project and environmental information and apply environmental screening criteria.
   • Act on this information and initiate resource identification efforts or field studies, initiate informal consultation and, where permissible, formal consultation on FEMA's behalf.
   • Evaluate the data, analysis, and consultation and provide an evaluation of the recommended level of NEPA documentation.
   • Provide support to FEMA's preparation of NEPA environmental assessments and environmental impact statements.
• Maintain environmental specialists qualified to evaluate the potential environmental impacts and conduct consultation.

C. **High-level Support.** In addition to activities under the full level of support, the state would:

- Enter into formal agreements with FEMA and relevant federal resource agencies, accepting formal delegation of certain aspects of federal environmental compliance.
- Lead the production of NEPA environmental assessments and environmental impact statements, providing draft and final documents to FEMA for release to the public. The state will operate independently to produce these documents for FEMA final review and signature. These documents will be fully compliant with FEMA standards.

An important component of this effort is staff training and related guidance for states. As part of this effort, FEMA is developing a Managing State Environmental Review Guide. It is anticipated that the guide will provide environmental screening guidance for the cadre of project types that are typically proposed as mitigation projects, as well as environmental law summaries; details of the review process; and recommended qualifications for environmental specialists.

Managing States will have to coordinate with FEMA in developing policies and procedures to ensure technical assistance is available to manage and implement the review function within the state grantee office, and accomplish detailed or project specific studies, field work, or consultation. There are various ways states can obtain the necessary staff and technical studies. First, FEMA can provide staff or FEMA technical assistance contractors to work with the state on an as-needed basis to aid the state in carrying out its documentation requirements. Second, a state may develop a broad agreement or request assistance on a case-by-case basis from another state or federal agency. Most often however, states will hire one or more environmental specialists or coordinators to ensure completion of the agreed upon review activities of the state. Advice from the FEMA regional environmental staff or Regional Environmental Officer can be helpful in determining appropriate staffing levels.

**BENEFITS OF BECOMING A MANAGING STATE**

The benefits of becoming a Managing State relative to environmental review are related to the level of effort the state invests in undertaking the
review functions. Fundamentally, the implementation of the HMGP under the Managing State Concept is improved in the following ways.

- A streamlined grant approval timeline: rather than a large part of the environmental review beginning late in the application review process, a Managing State begins the review process early and resolves a significant number of environmental issues before projects arrive at FEMA. This results in faster processing at FEMA.
- States are better able to manage the entire project review process and integrate environmental considerations into their decisionmaking.
- Cost savings are achieved. In some cases an economy of scale can be realized because the state is working a large number of projects that are geographically accessible to state, other agency, and contractor staff.
- Better projects are developed. Early identification of environmental impacts and alternatives results in early modification of project scope and budget to account for necessary environmental mitigation actions.
- Enhanced communication with subgrantees early in the grant process regarding environmental concerns and data needs. This results in heightened awareness of these issues and faster resolution of potential problems.

DEVELOPING THE PROCESS—MAKING IT A SUCCESS

There are a number of activities that should be implemented to ensure successful Managing State environmental review. These include:

- Ensuring a knowledgeable staff is in place for environmental review. Staff should be qualified in environmental review and familiar with FEMA’s review process. The key to this is training and credentialing.
- Provision of clear FEMA guidance on the environmental review process. This is a combination of existing FEMA NEPA compliance and the proposed Managing State Guide.
- Development of State Standard Operation Procedures (SOP). The SOP is the identification of the process the state will follow, referencing existing documentation. The process of developing the SOP is important in bringing together FEMA, state, and resource agencies to develop informal or formal agreements and
understanding about responsibilities, communication, reporting requirements, and review processes.

The environmental component of the Managing State Concept attempts to create a path for states to take on this responsibility. If these efforts are successful, Managing States will have the environmental tools to expedite project approval while effectively directing evaluation resources to those projects with real environmental concerns.
Should the *Guidelines for Determining Flood Flow Frequency* (Bulletin 17B) be Revised?

Gary W. Estes
Citizen Activist

**SUMMARY**

The short answer is, Yes! To answer the questions of Why and How, read on. The economic justification for flood control projects throughout the United States is based upon the statistical tools and guidelines contained in the *Guidelines for Determining Flood Flow Frequency*, Bulletin 17B (IACWD, 1982). It establishes a uniform technique used by all federal agencies in estimating flood flow frequencies for gaged watersheds. The experience of using Bulletin 17B to justify flood control projects on the American River at Sacramento, California, suggests these projects might be oversized by overstating the flood risks. If true, the result is wasted government money by building projects larger than needed. Revising Bulletin 17B was proposed by Thomas (1985). More recently the National Research Council (NRC) recommended establishing a new interagency research effort focused on flood risk assessment and management, including revising Bulletin 17B (NRC, 1999). The Association of State Floodplain Managers (ASFPM) should re-activate its Research Committee to promote and to assist a new interagency research effort.

**HISTORICAL PERSPECTIVE**

Thomas (1985) described the historical development of the *Guidelines for Determining Flood Flow Frequency*, Bulletin 17B. Table 1 shows the timeline of the work beginning with Bulletin 15. Bulletin 17 was a major revision over Bulletin 15. Technical changes and editorial corrections were made to Bulletin 17 and designated as versions 17A and 17B. No major revision has occurred since 1976, some 23 years ago. Of the 43 references in Bulletin 17B, 7 are pre-1960, 18 cover 1960–1969, and 17 cover 1970–1978. The science is old. A major revision is past due.

Consider that personal computers did not exist and the Internet was not available when Bulletin 17 was being researched and written. Also, supercomputers, global positioning satellites, and the Microsoft Company
did not exist. The technological and informational resources available today compared to then are enormous.

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**Table 1. Timeline for revisions to flood flow frequency analysis publications (based upon Thomas, 1985).**

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<th>Work Initiated</th>
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<tr>
<td>1966</td>
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</tr>
<tr>
<td>1972</td>
<td>Mar. 1976</td>
</tr>
<tr>
<td>Jun. 1977</td>
<td>17A</td>
</tr>
<tr>
<td>Sep. 1981</td>
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<td>Major revision</td>
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<tr>
<td>17</td>
<td>Major revision based upon additional research</td>
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<tr>
<td>17A</td>
<td>Three technical changes and editorial corrections in 17</td>
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<tr>
<td>17B</td>
<td>Four technical changes to correct problems in 17A</td>
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<td></td>
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**THOMAS CALLED FOR REVISION**

Wil Thomas was a member of the work group that revised Bulletin 17 and resulted in versions A and B. In 1985 he already saw the need to revise Bulletin 17B. Fourteen years ago Thomas wrote,

As evidenced by the list of recent publications, there has been considerable research conducted and published since the original Bulletin 17 was written. The writers of the original bulletin did not have this recent information available for evaluation. The scope of the Bulletin 17A and 17B work groups was to improve Bulletin 17 within the framework of the log-Pearson Type III-methods of moments-generalized skew methodology described in the original bulletin. Therefore, no major deviations from the Bulletin 17 methodology was investigated. It is the writer's opinion that a new federal interagency work group should be established to evaluate recent research relative to its impact on new flood frequency guidelines (Thomas, 1985, pp. 334-335).
The U.S. Army Corps of Engineers asked the National Research Council (NRC) to create the Committee on American River Flood Frequencies to look at flood flow frequency issues specific to the American River because of controversy over the flood flow frequency analysis developed by the Corps. In addition to the work asked of the Committee's ten members, they saw a national need "to begin to seriously reassess policy and strategies for flood risk assessment and management not only for the Sacramento case but for the nation as a whole" (NRC, 1999, p. 105). The Committee took two of the five pages of its final chapter, "Summary and Recommendations" to include a section on "Research Needs." The Committee has made the case for why and how a new research effort is needed. The Committee's recommendations are presented below to increase their distribution.

The committee recommends the establishment of a new interagency research effort focused on flood risk assessment and management. The impetus for such action is clear: rising property damages and loss of life; 30 years experience with the National Flood Insurance Program; aging federal policy and technical guidance; improvements in scientific methods of computing and modeling; emergence of understanding of paleohydrologic and climate variability issues; and a growing data base and availability of information. Virtually all of these issues have arisen in the Sacramento case, and can be expected to arise in others as well.

It is envisioned that this recommended interagency effort will emphasize research programs oriented towards coordinated flood risk reduction, including meteorologic, hydrologic and hydraulic, and policy and socioeconomic aspects of flood management. Participating agencies should include such entities as the U.S. Geological Survey, the National Weather Service, the Federal Emergency Management Agency, the U.S. Army Corps of Engineers, the U.S. Bureau of Reclamation, the Tennessee Valley Authority, the Federal Energy Regulatory Commission, the National Science Foundation, and appropriate state, regional, and local agencies. Participation, in perhaps an ex-officio role, might also be considered for the academic community through a periodic rotation system.
In their deliberations, committee members identified a number of specific issues that should be addressed by the recommended interagency effort. These issues are summarized below:

(1) Enormous progress has been made in the analysis of flood data since the last major revisions were made to Bulletin 17-B. This progress has largely involved regionalization and the collection and use of historical and paleoflood data. In addition, a number of methods have been developed to handle mixed distributions, including aggressive censoring. These and other innovations in flood frequency analysis should be considered in a revision of Bulletin 17-B.

(2) A very strong research need is to better understand interannual to century scale climate variability as it relates to the potential for winter/spring floods in the American River basin and surrounding areas. This of course is a major undertaking by the earth science community. As indicated in Chapter 4, a framework for formally conducting such analyses to better estimate potentially changing flood frequency distributions and their uncertainty is needed. Historical and paleoclimate and hydrologic data as well as future model predictions would need to be integrated in this framework. Efforts should be continued to develop more detailed, comprehensive and systematic documentation of all major and significant floods, as part of a national database on floods. These efforts need to tie in information on ocean and atmosphere circulation conditions to the information on floods.

(3) A decision analytic framework that uses information as to the uncertainty of the flood frequency estimates explicitly in the analysis of the design level of flood protection is also needed. Dynamic and static risk analyses as discussed in Chapter 4 may be needed. Such a framework would consider the length of the record, climatic factors, the length of the planning period, an implicit long range climate forecast associated with this period, considerations of risk and estimate uncertainty, and a prescription of how the decisions could be periodically re-evaluated (NRC, 1999, pp. 105-106).

CONCLUSION

In 1999 the NRC's Committee on American River Flood Frequencies made the case for "why and how" a new interagency research effort focused on flood risk assessment and management should be established. Thomas suggested evaluating new research impacts upon flood flow frequency analysis in 1985. The Association of State Floodplain Managers (ASFPM) should re-activate its Research Committee to promote and to assist such a
new interagency research effort as proposed by the NRC Committee. The controversy over the flood flow frequency analysis computed for the American River near Sacramento using Bulletin 17B suggests that using outdated technology might be wasting tax dollars by overstating the flood risk and causing more expensive flood control projects to be built than are necessary.

REFERENCES

IACWD (Interagency Advisory Committee on Water Data)

NRC (National Research Council)

Thomas, Wilbert O., Jr.
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Related Publications of Interest from the Natural Hazards Center

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**QR82**  **Early Response to Hurricane Marilyn in the U.S. Virgin Islands.** Betty Hearn Morrow and A. Kathleen Ragsdale. 1996. 11 pp.

**QR84**  **Impact of Hurricane Opal on the Florida/Alabama Coast.** David M. Bush et al. 1996. 13 pp.


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Disaster Research

*Disaster Research* (DR), published about every two weeks, is an electronic newsletter that delivers some of the news items that appear in the *Observer* as well as other timely articles. In addition, it contains queries and messages from the DR network's many users. DR is distributed worldwide via the Internet to more than 2,000 subscribers. To subscribe to Disaster Research, send an e-mail message to listproc@lists.colorado.edu with the single command in the body of the message: *Subscribe Hazards [your name]*. Back issues are also posted on our Web site at the above address.

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