NANIA
"ALL TOGETHER"

Comprehensive Watershed Management

Proceedings of the Eighteenth Annual Conference of the Association of State Floodplain Managers

May 8-13, 1994
Tulsa, Oklahoma
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These proceedings record the technical presentations made at the eighteenth annual meeting of the Association of State Floodplain Managers, held in Tulsa, Oklahoma, May 8–13, 1994. The Tulsa conference will long be remembered as an historic meeting for floodplain management: it was the first time floodplain managers from all parts of the country gathered following the 1993 Midwest floods.

The meeting was opened by Native Americans, who, through a traditional dance, delivered a respectful address about values for Mother Earth. Top Washington officials discussed the importance of floodplain management and the need for their agencies to learn from the Midwest floods. The executive director for the White House Review Committee on Floodplain Management described a vision of future floodplain management that was strongly supportive of and in line with the lessons learned and directional changes promoted by floodplain management professionals. Clear credit was given by many speakers to the Association for its participation in shaping current policy debates.

James E. Goddard, who died in March 1994, was remembered, along with his contributions to national flood policy. Gilbert White offered a perspective on the historical significance of this period for national floodplain management policy. We came to terms with the fact that, although Gilbert, Jim, and other pioneers have provided a vision and direction, it is time for younger floodplain managers to become leaders, visionaries, and mentors in their own right.

A sense of energy grew rather than diminished during the week; even this report does not capture the mood and energy of Tulsa. For those in attendance, perhaps these proceedings will bring back memories. For those not in attendance, be assured this was an important gathering for the nation's floodplain managers, and its technical essence, at least, is reflected in this volume.

The Association is indebted to the conference team, our host city Tulsa, the record number of exhibitors, the enthusiasm of the participants, and a conference theme that—with great foresight—expressed the spirit of future floodplain management: "Nania—All Together."

Doug Plasencia
Chair
Association of State Floodplain Managers
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ACKNOWLEDGMENTS

The great Mississippi flood of 1993 set the stage for the eighteenth annual Association of State Floodplain Managers conference in Tulsa, Oklahoma. The cast prepared their lines, and opening night began. Three of the biggest concerns of all conference directors played upon our minds. Will they come? Will they have a good time? and How will we ever thank all those people? We now know that, yes, they did come; most had a good time; and there is no way to truly thank all those who gave of themselves and their time.

The Tulsa conference was unique in several respects. Tulsa was the first site to be chosen by the Association of State Floodplain Managers board and affirmed by the membership, rather than through a selection process. It was the first to be hosted by a local government agency. It was the first to be videotaped in its entirety. Finally, it was the first to have all the conference signs taken as souvenirs. All these "firsts" were made possible by the efforts of many sincere people.

Among those who should be thanked are the board members who supported these changes. Chair Doug Plasencia and Executive Director Larry Larson provided us with support and leadership, despite excessive demands on their time due to the great Mississippi flood. Both Doug and Larry supported new ideas while maintaining the time-tested agenda of past conferences. Tim Keptner, past Standing Conference Committee chair, deserves special thanks for his support and encouragement during the development phase of the conference; Tim's encouragement was instrumental in allowing us to take the risk. Then there was the person who is the Association—Diane Watson. She was always there—from start to finish—giving us her talents, advice, knowledge, and heart. Without Diane, the show would not have gone on.

On the home front, personal thanks go out from Jack Page to three very special people. "I thank Frank Spring, my assistant, for his many talents and support. Frank was always willing and capable. No job was too big or too small. The other two people who deserve special thanks are Becky Giangreco, my secretary, and MaryCarol, my wife. They became friends and neither actually tried to kill me, although I'm sure they both had that idea. Becky guided my work and MaryCarol guided my heart. I owe a great deal to you both."

Then there are those who took leadership roles in the conference committee. Pat Hoggard took on the monumental task of providing audio/visual equipment and videotaping the conference. (Poor Pat will never be the same.) Pat was assisted by a small army of people, mostly members of the Oklahoma Floodplain Management Association. They included Bob Bigham, Donetta Blanlot, Gavin Brady, Hank Elling, Tyler Gammon, Ken Morris, Allison Nicholson, Carolyn Schultz, and Harold Springer. Kim Meloy did all the
desktop publishing. Dale Reynolds and his crew—Ruben Haye, Dave Spear, John Herbert, and Cheryl Cheadle—organized the technical tours. Sharlet Ball coordinated the Thursday dinner. Becky Giangreco oversaw the conference notebook and registration while taking care of her newborn son. Frank Spring coordinated security and ground transportation, Ruben Haye arranged the golf tournament, and Maggie Mathis and crew at Dewberry & Davis developed the conference signage. They all managed to see that the show went on.

What is a show without a script? Karen Kabbes' Program Committee, Dave Carlton and Ann Patton, did an excellent job of planning and pulling together an exciting program. Thanks go to Carl Cook who provided the "Floodplain Management 101" training. Carl, you were the right man for the job! Thanks also go to Michael Baker and Associates and Dewberry & Davis for coordinating the post-conference training on "How to Get a FEMA Map Revision." Both were excellent courses that we hope become standard.

Finally, a big thanks goes to the multitude of speakers, moderators, corporate sponsors, and attendees who were the conference itself. You are the "Nania" of floodplain management; for you truly bring it "All Together." Thank you all.

Jack L. Page, Conference Director
Karen Kabbes, Program Chair
Dante C. Accurti, Exhibits Chair
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PART ONE

LOCAL AND REGIONAL APPROACHES TO FLOODPLAIN MANAGEMENT
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Introduction

The Village of Northbrook is a community of 34,000 located north of Chicago. We have two forks of the North Branch of the Chicago River running through the village and two tributaries within our boundaries. For many years, Northbrook was in the Catch-22 mode of having a heavy rain occur that created flooding, which then led to a study for possible solutions, followed by intense public discussion and the determination that the funds were lacking and the rain had stopped. The resulting studies were placed "on the shelf" until the next big rain. Then they were dusted off, reworked, and reconsidered in the same circle of events. The 1989-90 Federal Emergency Management Agency (FEMA) requirements for the village's floodplain ordinance opened the door for the Village of Northbrook to break this cycle and begin the path to a comprehensive stormwater management plan.

Identifying the Need for a Comprehensive Plan

During neighborhood floodplain information meetings prior to consideration of the changes in the village's floodplain ordinance, it became very apparent that the village's 500 floodplain residents had little or no idea what the Special Flood Hazard Area was and what the floodplain designation meant to them. Many of these homes had been built before the village joined the flood insurance program in 1973. The owners of these pre-FIRM homes were seeing an adverse impact on their salability due to the new flood insurance mandate and a state rule that banned construction, or even reconstruction, of an existing home if it was located in the designated floodway. Key village staff, including the Village Manager, John M. Novinson, made presentations at these information meetings. We were also very fortunate to have the voluntary assistance of the Illinois Department of Transportation Division of Water Resources personnel, in our case Karen Kabbes, assist in these presentations. One of the issues that emerged was the village's lack of tight controls on development in nonfloodplain areas. It was also clear that there were a number of major flood control projects that had been studied, sometimes more than once, but had never been constructed. The number of individual studies had increased to a point where there was a real concern that this piecemeal approach could create new flooding problems if any individual project was constructed.
In addition, the inaccuracy of the FEMA floodplain maps for Northbrook was a constant issue. Many residents in mapped areas reported that they did not have flooding or they knew of properties that had flooding but were not shown as being in the floodplain. The inability to show accurately who was and was not actually in the floodplain and subject to a 100-year flood also created many hard feelings.

Developing a Plan of Attack

The village staff developed a two phase plan of attack that was then presented to the Village Board. The first phase of the proposal to develop a village-wide comprehensive stormwater management plan was to develop a geographic information system (GIS) using aerial photography. This yielded topographic maps with contours accurate to plus or minus six inches. Flyover data were then digitized and used not only for more accurate floodplain maps but also for infrastructure management and planning. Detailed specifications for this project were developed jointly with an adjacent community.

At the same time the aerial photography and GIS work was being pursued, a detailed request for proposal was developed to select a consulting engineer to review the village's records, previous studies, and floodplain issues and develop a strategy for completing a stormwater management plan. We took extra time in developing our scope of services in an effort to identify as many of the areas of concern as possible. We also determined that a village-wide survey would be done to solicit additional public input from residents and businesses on flooding problems. Review and tabulation of these surveys became a part of the scope of services.

While a great amount of time and effort went into developing the scope of services, we did ask that the proposals provide a written approach to the project and what additional steps or studies should be added to the scope of services. This was done to provide the most comprehensive stormwater management plan possible and to ensure that both the village and the consultant had a firm handle on project costs. Following review of the written proposals by a team consisting of the Village Engineer, Village Planner, and Director of Public Works, the proposals were narrowed down to two firms that were, in our judgement, far above the others. These two firms were then invited to a final interview with the committee and Village Manager. The final interview was based on a revised scope of services and each firm was asked to bring a detailed cost break-down with a not-to-exceed dollar amount for the project.

While the selection process was underway, the Village Board continued to receive a great number of phone calls from upset floodplain residents. The Plan Commission had also begun public hearings on floodplain ordinance amendments that would continue for 12 months. This created the atmosphere for
the Village Board to take the major step to budget and award contracts for the aerial photography/GIS work as well as for the consulting engineer. Both these projects were budgeted for initiation in our 1991/92 budget year with carry-over into 1992/93. This approach allowed the $400,000 cost to be spread out. Aerial photography was awarded to Ayres Associates of Madison, Wisconsin. The GIS system is by GDS of St. Louis, Missouri. Our engineering consultant is T.Y. Lin International BASCOR of Chicago.

Community Involvement

Although the Village Board was enthusiastic in its support of this effort, the complexity of the issues and the demands of other village business resulted in delegation of project oversight to an ad hoc stormwater management committee. This was a nine-member group with two people appointed from each quarter of the village and one at-large representative of the business community. The Village President issued the call for resident volunteers. From the group, Edward Need was selected Chairman. Mr. Need has a master's degree in geology and water resources management along with 11 years of environmental engineering consulting. Although he was not the only member with engineering background, the understanding he brought to the chairmanship, along with his patient ability to handle untrained lay people, was a great benefit.

The lead engineer for BASCOR was their Executive Vice President Richard L. Thompson, a professional engineer, who also has a degree in psychology, which was evident in his people skills. The ultimate success of the project was largely due to these two people. In addition to the ad hoc committee, the village used its monthly newsletter to provide progress reports and educational information on stormwater or floodplain issues. Our agreement with the consultant had anticipated plan development within 12 months. The process actually took 18 months (30 meetings) with much of the time in the beginning devoted to educating the committee members on the complexities of stormwater and floodplain management.

The Village Board received regular status reports. When the committee could not agree on exactly how to prioritize projects within the stormwater management plan, the board was presented with alternatives. The board narrowed the discussion to two alternatives and then sent the matter back to the committee for a firm recommendation. Final project ranking became a hybrid of these two approaches with half of the priority score based on the rank a project had on a strict benefit-cost approach. That score was then combined with the ranking the project had based on the number of structures (not properties) benefitted. Once the draft plan was developed and unanimously accepted by the stormwater management committee, it was presented to the Village Board.
The Village Board scheduled a public hearing and the committee, with staff, initiated additional public educational efforts. We used brief commercial ads about the public hearing on our local cable television station. The committee and staff also worked a booth at the village's annual Northbrook Days festival in August. Information packets on floodproofing homes, maps of the floodplains, handouts on the public hearing, and general information on stormwater issues were made available during Saturday of the four-day event. Notices of the public hearing were also sent to each property in the floodplain and to all the homeowners association groups throughout the village. Following the overwhelming community endorsement of the plan at the public hearing, the Village Board adopted the stormwater management plan with some modification in October 1993, and issued bonds for the first $1.5 million in projects in March.

The Plan

The Village of Northbrook Stormwater Management Plan is intended to be a benchmark for measuring progress on stormwater issues. However, it is not just a plan of capital improvement projects, but also a guide for managing a dynamic process. It includes programs for residents to help themselves and it establishes a group to advise, administer, and revise the plan. The ad hoc committee is now a permanent Stormwater Management Commission. As the document indicates, the plan is just the initial step; it represents the "framework and road map" for stormwater management planning activities within the village. The plan contains both prioritized and non-prioritized but always specific projects. Lack of prioritization does not mean less important status, but rather acknowledges our inability to quantify the costs and benefits of certain specific improvements. Programs for residents to help themselves actually help the largest number of residents at the least cost. The controversy on these programs was, "Should the village tax base as a whole help residents to do things such as install reserve power for sump pumps, upgrade sump pumps, put in overhead sewers, or floodproof their homes? Or should property owners do those things on their own to protect themselves?"

The "Key"

Working with an ad hoc committee of residents added some time to the process. Basic education on stormwater issues for them and the public was time consuming, yet vital to the ultimate success of the plan. One can hire the best consulting firm that does a fabulous study and provides a document filled with the best engineering solutions. Yet if residents cannot understand it and more importantly do not buy in, it will be in trouble. Frequent meetings between the
committee, village staff, and the consulting firm work to educate the members of the committee and establish a strong foundation for the acceptance of the overall plan. Frequent communication with the public builds support and community-wide ownership.

The plan is only the beginning. It is a document to guide future decisions as the village seeks better stormwater and floodplain management. It provides a Stormwater Management Commission to monitor, review, amend, and develop the various aspects of the plan. As a result, my job will be easier.

Still, on the night of the public hearing, the realization hit that we were not reaching a conclusion, but only about to embark on the first step of a long journey. It was only the end of the beginning. That journey will be taken knowing we are all together—the Board, residents, and staff—and heading in the right direction.
Background

In 1989, the City of Boulder adopted revised floodplain regulations that established the High Hazard Flood Zone (HHZ). The HHZ is defined as that area within the 100-year floodplain where the product of the depth and velocity exceeds the number four (4). In the HHZ, construction of new structures intended for human occupancy is prohibited. As a condition of adoption of these regulations, the City Council directed its staff and consultant to develop and implement mitigation plans that would reduce the HHZ. Additionally, the Comprehensive Drainage Utility Master Plan was adopted by the City in 1989 and although monies were provided to study high hazard reduction along Boulder Creek, the plan did not address the funding needed to implement improvements along Boulder Creek.

Before adoption of the HHZ, the Boulder Valley School District (BVSD) held a successful bond election to fund school improvements to Boulder High School, among other activities. BVSD’s plans included the addition of a new west wing and improved parking for staff and students. Cooperation between the City and the BVSD was essential for the overall success of the project. If the Boulder Creek improvement plan was implemented, the high school would ultimately be removed from the HHZ, along with 227 additional residential units.

Alternative Project Approaches

Master planning efforts that were undertaken for the Boulder Creek hazard reduction improvements indicated that this reach of the creek (between 6th and 17th Streets) constituted the most promising area for HHZ reduction, where greater than 95% of the residential units could be removed from the HHZ. Improvements along other reaches of Boulder Creek would have minimal benefits and may have actually increased the hazard.
Alternative approaches were evaluated for this reach of Boulder Creek, considering the benefits and predicted costs associated with each approach. The following alternatives were considered.

No Action

This approach maintained the status quo. Financially, this approach would be the most attractive but would shift the focus to post-flood land acquisition and mitigation. The no-action alternative would not reduce the HHZ. This reach of Boulder Creek is critical and represented the City's greatest exposure to life-threatening floods. This approach offered the high school no help in removing the HHZ at a time when the school needed to expand.

Creek Channelization

This approach would contain floodwaters by modifying or channelizing Boulder Creek. Flood water containment through channelization would effectively reduce the HHZ by creating a structured corridor for containing high hazard flows. Boulder Creek channelization would violate the Boulder Valley Comprehensive Plan and City Council's direction for a non-containment approach to Boulder Creek floodplain improvements. The benefits and costs for channelization could be shown to be very high from a financial perspective. However, the adverse environmental impacts and destruction of the naturalized creek corridor rendered this alternative unacceptable.

HHZ Recontouring

This approach proposed overbank sculpting to allow for greater flow capacities and to force water flowing in a broad front across the land to move back into the creek bed. Naturalized creek characteristics would be preserved, and the overbank grading would create naturalized conditions without drastically altering the creek's appearance. Given available land for improvements, the benefit and cost for this alternative could be greater than that for channelization. Additionally, there would be no adverse impact on the existing creek watercourse since the actual stream bank and stream, as well as the trees along the stream, would not be impacted.

HHZ Property Acquisition

This approach proposed to acquire HHZ properties, remove existing structures, and retain the existing conditions of the creek corridor. The HHZ and creek environment would remain unchanged, but the elimination of buildings and occupied uses would reduce the flood hazard. The remaining open corridor would then be preserved for the passage of hazardous waters. Property acquisition is often a key component in flood mitigation projects, especially
when right-of-way for improvements is required. The HHZ for this reach of Boulder Creek is extensive, and the expense of acquisition of all the HHZ properties would prevent the realization of all of the benefits. Additionally, Boulder High School would not be removed from the HHZ unless the school were moved to another location, which was not an option for the BVSD. Benefits and costs for this alternative were unattractive based on financial expenditures. However, the reduced flood hazard improved the benefits.

**Combined Property Acquisition and HHZ Recontouring**

A final approach to HHZ reduction along this reach of Boulder Creek was to combine property acquisition with structure removal and HHZ recontouring improvements. This would effectively reduce the HHZ by providing the right-of-way necessary for HHZ recontouring, and by creating a preserved corridor for directing hazardous flood waters. The costs for extensive property acquisition would be minimized because only those properties needed to provide for improvements to reduce the HHZ would be acquired. Benefits and costs for this alternative were very attractive. The combined property acquisition and HHZ recontouring approach was the most effective and beneficial alternative from a benefit-cost analysis, preserving Boulder Creek by maintaining a non-containment approach.

**Boulder Creek Hazard Reduction Improvements**

The Boulder Creek Project proposed an acquisition program for properties located north of Boulder Creek and south of Arapahoe Avenue, from 13th Street to Boulder High School, and along the north side of Arapahoe Avenue from 13th Street to 14th Street. Acquired structures would be removed to eliminate hazardous uses, and to provide available lands for HHZ recontouring to increase flood water conveyance through an area with no structures. The HHZ recontouring was to be performed primarily from Arapahoe Avenue to 17th Street along the north side of Boulder Creek, but the creek itself would not be affected. This could remove from the HHZ nearly 31 acres of land north of Arapahoe Avenue, Boulder High School, and all City buildings but the original library. Property acquisition was required to perform recommended improvements, and resulted in property available for recreation space for Boulder High School and the community.

Block 1 improvements for HHZ reduction included the purchase and removal of all block 1 structures to allow for improvements associated with the Boulder High School west campus project. This allowed HHZ recontouring along the creek to pass high hazard flood flows back to the main channel of the creek. Block 1 also provided for the relocation of the parking lot away from the creek. Additional improvements included the elimination of a large 18-foot-wide
concrete bridge over Boulder Creek, which had served the high school's football field and track facilities and reusing an existing "breakaway" path bridge. Block 1 improvements also provided for the removal of Boulder High School and a major portion of a residential and commercial area north of Arapahoe Avenue from the HHZ. City costs associated with block 1 were $1.6 million and included the $1,255,000 cost of acquisition, $55,000 for demolition, and $295,000 for Boulder High School and Central Park HHZ recontouring improvements.

Block 2 improvements included the purchase and removal of all block 2 structures, which allowed for HHZ recontouring south of Arapahoe Avenue to Boulder Creek. This purchase and recontouring allowed for elimination of 44 existing residential units that were subject to the most extreme hazard. Block 2 combined with block 1 improvements provided for additional HHZ reduction benefits north and east of Boulder High School near 17th Street and would remove the Municipal and Park Central buildings from the HHZ. Total City costs associated with block 2 were estimated at $2.4 million and included the $2,175,000 cost of acquisition, $225,000 for demolition and HHZ recontouring improvements. Additionally, implementation of the Boulder Creek project will include preparation of new delineations of the Boulder Creek floodplain through this reach.

**Boulder High School West Campus Improvements**

BVSD concerns for life safety during flooding at Boulder High School were a major factor in the design of the west campus improvement project. The recently constructed west wing at the northwest corner of the school was sited away from Boulder Creek and was floodproofed to minimize flood hazard and damage since it will remain in the floodplain. HHZ recontouring south of the high school, along with erosion protection and berming around the school building, were performed to provide increased conveyance of floodwaters, which removed the school from the HHZ. The existing school building would then be in the floodplain and would be retrofitted with flood protection measures to reduce hazard and damages. The west campus improvement project provided for increased space at Boulder High, where site acreage is a problem. (The high school previously had 17 acres of campus whereas 40 acres is the normal BVSD standard.) The campus was increased by two additional acres of playing fields by the inclusion of the joint use area.

The Boulder Creek Joint Use Project has provided the City of Boulder with a unique opportunity for realizing multiple benefits under one major project. It provided the opportunity for multiple City departments to work towards a common goal as well as the opportunity for the City to work cooper-
Table 1. Boulder Creek project property benefits.

<table>
<thead>
<tr>
<th></th>
<th>Alternative 1</th>
<th>Alternative 2</th>
<th>Alternative 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Currently in HHZ</td>
<td>63</td>
<td>45</td>
<td>31</td>
</tr>
<tr>
<td>Remaining in HHZ</td>
<td>45</td>
<td>31</td>
<td>31</td>
</tr>
<tr>
<td>Area in HHZ (acres)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structures in HHZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>93</td>
<td>40</td>
<td>12</td>
</tr>
<tr>
<td>Residential</td>
<td>61</td>
<td>27</td>
<td>5</td>
</tr>
<tr>
<td>Non-residential</td>
<td>21</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>City</td>
<td>8</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>School</td>
<td>3</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Units in HHZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>289</td>
<td>197</td>
<td>14</td>
</tr>
<tr>
<td>Residential</td>
<td>230</td>
<td>183</td>
<td>6</td>
</tr>
<tr>
<td>Non-residential</td>
<td>48</td>
<td>8</td>
<td>5</td>
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<td>City</td>
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<td>School</td>
<td>3</td>
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</table>

A project of this nature represents a milestone in community development, resulting in improved life safety through the reduction of the HHZ, providing for future safe use of Boulder High School, and an open greenway in the heart of the city.
Conclusion

The City of Boulder's residents, visitors, students, and businesses greatly benefitted from the expenditures of funds for the completion of the Boulder Joint Use Multi-Objective Corridor Project. Some of the resultant benefits were:

- Reduction of the HHZ along Boulder Creek;
- Elimination of residential use in the HHZ;
- Elimination of structures for human occupancy from the HHZ;
- Removal of Boulder High School from the HHZ;
- Long-term safe use of Boulder High School;
- Reduction in flood damage potential along Boulder Creek;
- Naturalized creek corridor;
- Recreational space for Boulder High and the community;
- Enhancement of the Boulder Creek environment;
- Complementarity of the Municipal Campus and Boulder High;
- Opportunity for private property revitalization;
- Educational opportunities for flood safety and the impacts of floods on the environment.
THE HISTORIC ARKANSAS RIVER PROJECT

Donald H. Brandes, Jr.
Design Studios West, Inc.

Introduction

The City of Pueblo is located in southern Colorado along Interstate 25 at the confluence of the Arkansas River and Fountain Creek, approximately 100 miles south of Denver. Historically, Pueblo was home to six native American communities and served as the major trading center between the Spanish, French, and the new American Rocky Mountain West. The El Pueblo trading post, established in 1842, marked an early beginning of agricultural and industrial development that characterizes Pueblo today. Throughout the 1800s Pueblo attracted major industrial and transportation enterprises, boasting in 1890 the construction of the Pueblo Union Depot, which served five railroads, including the Denver and Rio Grande Railroad; the Atchison, Topeka and Santa Fe; the Denver, Texas and Fort Worth; the Chicago, Rock Island and Pacific; and the Missouri Pacific. By the early 1900s Pueblo was second only to Denver in overall population and claimed a significant percentage of overall state employment based on its strong industrial and agricultural base.

Central to Pueblo's growing economic vitality was the historic use and development of the Arkansas River. The Arkansas River was the primary corridor and regional landmark for settlement in the early exploration of Colorado and more importantly for the establishment of the Pueblo regional economy. Like many midwest and western communities, Pueblo thrived because of its rail and transportation linkage, industrial development, and utilization of natural resources. The key to all these sectors was the use and availability of the Arkansas River.

The Flood of 1921

As Pueblo developed from a small settlement into a city, the commercial center of the city and the region further established itself along the banks of the Arkansas River. In fact, prior to 1921, the Arkansas River flowed through the heart of Pueblo's central business district and was crossed by several bridges. In 1921, Pueblo realized a devastating 500-year flood on the mighty Arkansas. While the City of Pueblo had experienced many minor floods, the flood of 1921 leveled the downtown central business district, taking over 100 lives and costing an estimated $19 million (1921) in damage. Over 60% of the businesses were destroyed. In 1922, the Arkansas River was diverted into a flood-proof levy on the outer boundary of downtown. The historic water
channel, which once flowed through the center of downtown Pueblo, was then covered and replaced by parking.

On August 17, 1962, President Kennedy came to Pueblo to dedicate the Pueblo Reservoir, which further protected the city from periodic flooding. The effect of providing the channel levy and constructing the Pueblo Reservoir for flood protection was subtle. Over the years various businesses and industries fronted along the historic Arkansas River without fully realizing the historical significance of how the river once flowed through its center and created the city’s historic beginning.

The Citizen Initiative

In 1991, a small group of citizens organized and formed the Historic Arkansas River Project (HARP) Committee. The goal of the HARP Committee was to examine the possibility of bringing back the Arkansas River to its original river channel. To a great extent the HARP Committee understood the historical and potential economic benefits associated with waterfront development. Their stated goal was to educate and inform the community on how the historic Arkansas once served as the economic generator for trade, commerce, and industry, as well as to test the community’s desire to re-establish the river to its original stature and significance. It is important to note that the actual historic location of the Arkansas River channel today is unrecognizable. A small diversion from the Arkansas River still provides a small flow of approximately 38 cubic feet per second through the project area. This flow is used for cooling a power plant adjacent to the vacated Arkansas River channel.

The water from the power plant is then released underground for over two city blocks through a 96" concrete pipe. The pass-through water is not visible as it passes through the most active and urbanized area of downtown. As mentioned earlier, the river channel has been filled in and now serves as a public parking lot. When the water re-emerges, it flows into a natural drainage channel before leaving the project site to enter Runyon Lake before reaching the confluence of the Arkansas River and Fountain Creek.

During the past several years the HARP Committee, in cooperation with local, state, and federal entities, has prepared detailed urban planning, hydrologic, drainage, preliminary civil engineering, and landscape architectural studies that confirm that it is both suitable and feasible to vacate the surface parking that covers the old river channel and construct a downtown waterfront project. The HARP project will restore the river to its historic course near City Hall with below street-grade retail plazas overlooking the waterway, a lake with residential development, and a natural historic park. The HARP project will, once again, connect and link several civic and private-sector landmarks to the river and serve as a catalyst for future urban revitalization.
For planning purposes, there are three areas within the HARP. Each is briefly described below.

**Lake Elizabeth**

The water currently being stored by the power plant will be increased to create a unique lake-front setting for new in-city residential development. A waterfront park and lakeside promenade will provide a natural area for waterfowl, fish, and other water wildlife. The original Arkansas River wall is also incorporated into the Lake Elizabeth segment, marking the first segment of the HARP project.

**Urban Core**

Front Victoria Street to Main Street urban waterfront uses are planned for, including private sector entertainment, commercial and retail mixes, public art, plazas and fountains, urban pedestrian walks, commuter bicycle trails, river-taxi boats linked to the downtown hotel/convention complex, outdoor public amphitheater for festivals and special events, and other urban waterfront amenities. The urban core area will truly represent an urban waterfront linkage that is complementary to the adjacent downtown civic and shopping districts and is also unique as a regional destination.

**Natural Interpretive Park**

From Main Street to Santa Fe the historic Arkansas once served as the border between French and Spanish territories and later between the U.S. and Mexico. The enormous historical importance of this area provides tremendous opportunities to explain the native American and Hispanic influences unique to southern Colorado. Residents and visitors alike will enjoy interpretive displays for Pike's Stockade, a display of natural/native plant communities, wildlife habitat areas, a diversity of walkways and rest areas, and a unique combination of both contemporary and historical public art.

**Summary**

Throughout much of the Midwest, communities across American have been devastated by floods and water damage. While many communities will re-engineer and re-evaluate flood management systems by constructing flood channels and flood control structures, others may explore more creative, yet technically sound alternatives. Flood management and control is not simply single purpose, nor is flood management simply forensic hydraulic engineering.

Communities must be given appropriate urban or rural waterfront solutions that both protect the public’s health and safety and also demonstrate ingenuity, enterprise, and the potential for economic revitalization. Adversity
caused by natural hazards holds the promise that from loss of life and property can come more predictable paradigms of flood prevention and more community-based economic incentives that balance the risk of periodic flood events with exceptional waterfront planning and design.

HARP represents a three-year community-supported commitment to revitalize its historic waterfront. In many respects, the HARP planning and design process was far more important than the actual physical attributes of the project. The community embraced and championed the project because the project goals were well defined and modified to represent their local and regional issues and community values.

As we prepare ourselves for certain and massive flood control projects in the stricken Midwest, I would suggest that greater thought and consideration be given in further defining not only the hydrologic and flood control implications of future projects but also that perhaps greater consideration be given to including the community's unique values and closely held principles.

Project Data

Project Length: 3,000 linear feet
Project Land Area: 34 acres
Urban Water Flow: 30 cfs to 100 cfs (800 cfs storm water flow)
Potential New Development: 45,000 to 60,000 sq. ft.
    (commercial/retail/residential)
Estimated Construction Cost: $11 million (1994)
Proposed Construction Phasing:
    Phase One: 1994-1995 - $4.5 Million
    Phase Two: 1995-1997 - $3.5 Million
    Phase Three: 1997-1999 - $3 Million
Start of Construction: Fall of 1995
Source of Funding: Local, state, and federal

For more information, contact:

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Introduction

Mecklenburg County is a rapidly developing area containing the City of Charlotte, North Carolina. As with many high growth areas, the county is experiencing growing pains, not least of which are the problems associated with stormwater runoff. Since 1988 the Mecklenburg County Engineering Department and Ogden Environmental and Engineering Services, Inc. (Ogden) have been systematically studying and developing basin-wide master plans for each of the major creeks within the county where significant future development is expected. The basins have ranged in size from 10 to 38 square miles. The studies have taken a holistic and proactive approach to watershed management. Elements of these studies include identifying known and future flooding, erosion, and stream water quality problems; existing and proposed parks and greenways; wetlands; critical flora and fauna; planned transportation projects; and future development. The initial studies focused on solutions to flooding and erosion problems. Later studies increasingly focused on solutions to existing and/or potential stream water quality degradation from non-point source pollution.

The most recently completed basin master plan was for the McDowell and Gar Creek watersheds. These watersheds are part of the Watershed Protection Area established by the State of North Carolina for Mountain Island Lake, the primary drinking water source for Mecklenburg County. This basin study included the use of a geographic information system (GIS) to estimate the pollutant loadings expected from stormwater runoff for existing and future land use scenarios. An overview of the master planning process and the use of GIS to perform pollutant load estimates follows.
Master Planning Process

The watershed studies in Mecklenburg County have all followed a three step process. These steps are listed below:

- Identify existing and potential future problems or needs (such as flooding, erosion, and/or water quality degradation) and opportunities for multi-objective land use.

- Consider variables that affect placement of potential improvements, such as regional or on-site best management practices (BMPs).

- Evaluate the effectiveness of potential BMPs and system improvements to reduce flood peaks, erosion, or pollution.

Existing flooding, erosion, and water quality problems were identified by field inspection, research of previous studies, review of a citizen complaint database, and through stormwater modeling. Potential future problems were identified by modeling the watershed based on future land development. Projecting the type and amount of future development required research of available land use plans. By developing existing and future land use coverages in a GIS, future problem areas could be intuitively identified based on expected high development areas before performing detailed hydrologic modeling. Additionally, Ogden developed applications using a GIS that allow many of the hydrologic model parameters to be easily determined.

After identifying existing or potential problem areas, the variables that may affect placement of possible regional solutions were identified. Factors that may inhibit or enhance the use of a potential regional BMP site include proposed roadway projects, critical flora and fauna, historical and cultural locations, and wetlands. Other factors that were considered, and may even contribute to a regional site selection, included existing and planned greenways and parks, existing lakes and ponds, and undersized stream crossings with significant upstream floodplain storage. By incorporating each of these variables as coverages in a GIS system, regional BMP and improvement site selection was more easily accomplished. Other contributors to the cost effectiveness of potential sites were land availability and cost, physical suitability, soil suitability, regulatory requirements, environmental concerns, and existing or potential utility conflicts.

Evaluating the effectiveness of regional BMPs at reducing flooding and erosion involves traditional hydrologic and hydraulic modeling techniques, and can be performed in a cost-effective manner using traditional engineering models such as HEC-1, HEC-2, and HY8. Detailed water quality modeling may involve
extensive effort and cost to develop and maintain an accurate model of the watershed. Another approach that gives an approximate yet quantitative evaluation of non-point source pollution involves the use of GIS. This process is described in the next section.

GIS Application to Estimate Pollutant Loads and Assess BMP Effectiveness

As part of a pilot study performed for Mecklenburg County, Ogden developed a GIS program that uses existing and future land use coverages to estimate existing and future pollutant loads. The program, written in ARC/INFO Macro Language (AML), was also used to assess the ability of regional and on-site BMPs to reduce pollutant loadings to the receiving waters. For pollutant load estimates, the AML uses the Simple Method as developed by the Metropolitan Washington Council of Governments. The Simple Method was developed using the results of the National Urban Runoff Program (NURP) and is proposed for use by municipal stormwater discharge permit applicants in the U.S. Environmental Protection Agency’s (EPA) guidance document for municipal NPDES permit applicants. Approximate pollutant removal rates for various BMPs (such as wet ponds, extended detention basins, filter strips, etc.) for the 12 target pollutants listed in the guidance document have been established for use by the AML. The program allows the user to specify any of the BMPs listed for either regional or on-site controls, or both. This allows multiple analyses of various improvement scenarios.

Specific Application of the AML to the McDowell & Gar Creek Watersheds

The State of North Carolina has begun a comprehensive program of basin-wide watershed management. One of the first steps taken by the North Carolina Division of Environmental Management (NCDEM) involved the implementation of watershed protection regulations for water supply reservoirs. These regulations require local communities, including Mecklenburg County, to adopt local ordinances that restrict development within the contributing watershed of a community’s water supply intake. These development restrictions impose limits on the density of development and also impose on-site BMP requirements for "high-density" development, typically commercial, industrial, and multi-family development. One of the watersheds protected by the NCDEM’s requirements is the Mountain Island Lake watershed, which provides the drinking water for the majority of Mecklenburg County.

The McDowell and Gar Creek watersheds are within Mecklenburg County’s portion of the Mountain Island Lake Watershed Protection Area. As
a result, the main focus of the McDowell and Gar Creek Basins Master Plan was the analysis and enhancement of water quality. The AML was used extensively as a planning tool for determining potential regional BMP sites and predicting the effectiveness of the proposed BMPs. In addition, the AML was used to analyze the effects of on-site BMPs required for new development. This analysis may be performed independently or in conjunction with the regional BMP analysis. Pollutant loadings were estimated at each BMP site for existing conditions, future conditions, existing conditions with regional BMPs, future conditions with regional BMPs, future conditions with on-site BMPs, and future conditions with on-site and regional BMPs. A similar analysis was performed at the mouth of McDowell Creek and the mouth of Gar Creek.

Application of the AML required applying on-site BMPs in accordance with the Watershed Protection Overlay District (WPOD). The WPOD requires on-site BMPs for all newly developed high-density land uses in Protected Areas 1 and 2 of the McDowell Creek watersheds. Using the AML, the appropriate land use polygons were manually selected and the selection of the appropriate BMP was performed. This allowed the AML to apply the pollutant removal rates of the specified BMP to the pollutant loadings from the selected polygons.

The on-site BMP is based on the standard design developed by the NCDEM. As part of this project, pollutant removal rates were assigned for this BMP based on the NCDEM stated performance standard of 85% removal of total suspended solids (TSS).

Another aspect of the WPOD was the limit imposed on development density. The future land use coverage for both the McDowell and Gar Creek watersheds was "adjusted" to limit the intensity of future development in accordance with the WPOD restrictions. In order to provide a relative comparison of the benefits to water quality provided by the density limits and BMP requirements of the WPOD, the AML was used to estimate pollutant loadings for the following scenarios:

- Existing conditions (existing loads).
- Future development that would be expected without any land use restrictions imposed by the WPOD (unadjusted future loads).
- Future development in accordance with the land use restrictions imposed by the WPOD but without on-site BMPs (future loads).
- Future development in accordance with the WPOD including on-site BMPs (future loads with on-site BMPs).

By having existing and future land use coverages in the GIS, the AML allows the evaluation of different development scenarios very easily. This
enables county decision makers to carefully evaluate potential water quality impacts of proposed developments or land use plans.

Summary

Mecklenburg County and Ogden have jointly prepared master plans for much of Mecklenburg County. By use of a comprehensive process for evaluating existing and potential future flooding, erosion, and water quality problems, and siting regional BMPs, cost effective plans for the future can be developed. Innovative techniques involving the use of GIS improve the efficiency of the stormwater model development and the adaptability of the models to changing conditions.

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UPPER SLOAN LAKE BASIN:
A SMALL COMMUNITY EXPERIENCE
IN IMPLEMENTING
A MULTI-OBJECTIVE FLOOD CONTROL PROJECT

Robert Martin
City of Edgewater, Colorado

David Lloyd
Urban Drainage and Flood Control District

Introduction

Sloan Lake Basin is located in the west-central portion of the Denver metropolitan area. Generally, it drains in an easterly direction, directly into the South Platte River, which flows northward through the center of the City of Denver.

The basin is approximately 4.7 miles long and 1.4 miles wide and contains 5.5 square miles. The average slope of the basin is about 1.6%, with ground elevations ranging from 5,585 at the western edge of the basin to 5,190 at the bank of the South Platte River.

The most prominent geographic feature within the basin is Sloan Lake. History relates that the lake was formed in about 1866 when homesteader Thomas M. Sloan, while drilling a well to obtain irrigation water, struck an underground spring that in a period of three or four days flooded the valley on his farm and formed two large lakes, Sloan and Cooper. Later the two lakes were joined by canals, and over a period of years both lakes became known as just Sloan Lake.

Since that time, Sloan Lake, which now occupies 176.5 acres of a 290-acre Denver Park, has been a valuable recreational resource for the metropolitan area. In addition to its scenic and recreational significance, the lake provides the valuable function of controlling downstream flows that otherwise would run uninhibited through west Denver.

The upper basin, which contains 2.8 square miles, discharges directly into Sloan Lake in two tributaries flowing through the City of Edgewater, a small city of approximately 4,700 residents. The upper basin includes portions of the two larger cities of Lakewood and Wheat Ridge.
Project Formulation

Urbanization within the Sloan Lake Basin occurred primarily and almost totally during the 1950s. During this process of development, most reaches of the historic channels were obliterated. Not long after the basin's development, it became very apparent that mistakes had been made and that drainage considerations should have received more attention during development. Thunderstorms, which create most of the Denver area’s more serious flooding, began to expose several areas of continuing flooding problems.

In 1974, the Federal Insurance Administration published a Flood Hazard Boundary Map for the City of Edgewater. The floodplain mapping showed that many of the city’s residents and almost the entire commercial area along the city’s eastern edge were in the 100-year floodplain. The impact of the 100-year floodplain began to have serious consequences for the city’s economic future because a good deal of Edgewater’s revenue was generated from sales taxes and most of its tax base was now in the 100-year floodplain. Frequent flooding of the commercial area was very common, often resulting in the complete closure of Sheridan Boulevard, the major north-south arterial along the east boundary of Edgewater where most of the city’s commercial establishments were located.

Adding to the woes of the economic impacts caused by the floodplain problems was the issue of health and safety. Flooding was becoming more and more frequent as the basin fully developed. In July, 1972, during a summer rainstorm, two children lost their lives along the South Branch after being knocked off their feet by fast-moving floodwaters and pulled into a closed conduit.

In 1975, the cities of Edgewater, Denver, Lakewood, and Wheat Ridge, and the Urban Drainage and Flood Control District (UDFCD) entered into an agreement to fund a drainage master plan for the Sloan Lake Basin (Figure 1). This effort resulted in the completion of the "Major Drainageway Planning Phase B Sloans Lake Basin" report dated December 1977. The master plan recommended, in the upper basin, storm drainage improvements consisting of open channels, storm sewers, and detention storage with an estimated price tag of $4,167,000 (1977 dollars). Of this amount, $2,278,000 was for the Edgewater portion.

A Phased Solution

It became obvious early in the project that the implementation of the recommended improvements would have to be accomplished over a period of several years as monies became available.
Figure 7. Drainage project for Edgewater, Colorado.
In 1978, Edgewater, Denver, Lakewood and the UDFCD entered into an intergovernmental agreement for the design of the first phase of improvements for the South Branch Tributary, which was to consist of 100-year capacity crossings and channel improvements that would remove a large portion of Edgewater's commercial area from the floodplain. In 1981 the four parties entered into a second agreement committing a total of $2.1 million for right-of-way acquisition and construction. The first phase construction contract was completed in 1982.

With the completion of the first phase of improvements, the Edgewater Redevelopment Authority quickly began working on the redevelopment of the commercial area removed from the floodplain. The result of their efforts was completion of the $17.5-million Edgewater Market Place, which contains two large retail anchors plus numerous smaller businesses. With the influx of new businesses, Edgewater had begun to assure itself of a much-needed tax base for its continued solvency.

In 1985, a second phase of construction on the South Branch was initiated by Edgewater, Lakewood, and the UDFCD. Included in this work was the construction of a detention pond in the upper basin, capable of detaining the 100-year event, which allowed for a 5-year storm sewer capacity to be installed in the downstream reaches.

A third phase of construction, initiated in 1987, included a detention pond located on the athletic fields of the local high school. The pond was designed as an off-channel detention pond that will begin to detain storm flows for events greater than the 5-year frequency. Completion of this phase in 1988 was the last link in solving the drainage and flood control problems on the South Branch tributary to Sloan Lake through Edgewater.

Edgewater's attention was now turned to the North Branch, whose floodplain encompassed a large residential area as well as the remainder of the commercial area along Sheridan Boulevard. The master plan had called for large diameter storm sewer facilities only along this tributary. In an effort to reduce pipe sizes and to eliminate as much of the 100-year floodplain as possible, it was decided to look at the idea of an off-channel detention pond at an existing city park known as Citizens Park.

Turning Citizens Park into a detention pond capable of detaining the 100-year flow required the complete regrading of the existing facility. Edgewater saw this as an opportunity to upgrade existing park facilities, which had been neglected in the past, as well as to add new facilities that had never been considered because of the poorly drained park.

Construction of first phase improvements began in 1990 and were completed in 1991 at a total cost of $1.2 million. Storm drainage facilities were designed to carry the 5-year event before flows in excess of that would discharge into the detention pond. Construction of the second phase, which consisted primarily of storm sewer improvements extending through Edgewater
into Wheat Ridge, was completed in 1993 at a cost of $1.7 million. With completion of these improvements, the entire commercial area along Sheridan Boulevard and much of Edgewater's residential area were now out of the 100-year floodplain.

Over this 12-year period of phased construction, total project costs came to approximately $9.5 million. Of this amount, the City of Edgewater contributed in excess of $3,150,000. Much of this was possible for a city of this size due to its ability to obtain funding from other sources such as Community Development Block Grant Funds ($885,000 in the form of three separate grants from the State of Colorado), Jefferson County Open Space Funds ($120,000), and funding from the Edgewater Redevelopment Authority ($250,000). Lakewood contributed $1,334,000, Wheat Ridge $752,000, Denver $17,000 and UDFCD $4,243,000.

Summary

The City of Edgewater, faced with a seemingly insurmountable task of solving a flooding problem that caused health and safety problems for many of its residents and severely restricted its potential for growth, kept up an effort to solve this problem on a phased basis over several years that has paid dividends to date and will continue to do so long into the future. For a city of this size to have tackled such a problem is a tribute to its staff and elected officials.
Introduction

The Range Wash, located in the Las Vegas, Nevada, area, is one of seven major tributaries to the Las Vegas Wash. The Las Vegas Wash is the only outlet of the Las Vegas valley and drains southeasterly towards the Colorado River. The Las Vegas valley comprises approximately 600 square miles and is almost entirely surrounded by mountains. At the base of the mountains are alluvial fans, which extend to cover the majority of the valley floor. The desert environment has been susceptible to flash flooding produced by localized, short-duration, and high-intensity late summer thunderstorms.

The Range Wash has a 150-square-mile watershed with two major tributaries emanating from the Las Vegas Range Mountains on the northeast side of the valley. The two tributaries join at the upper end of the Sloan Channel, which runs parallel to the base of a steep alluvial apron from the smaller Frenchman and Sunrise mountains on the east side of the valley.

The Range Wash contributed to extensive flood damage in Las Vegas during the summer of 1984 when flows exceeded the capacity of the Sloan Channel and an embankment levee was breached. The Range Wash Confluence Detention Basin is an important component of a flood control facility plan. Located near the confluence of the east and west tributaries of the Range Wash, it provides immediate benefits to the area with the highest degree of residential development along the Sloan Channel. Its benefits can be achieved without implementation of other components of the facility plan.

Master Planning

The Clark County Regional Flood Control District (the District) had adopted a general Flood Control Master Plan for Clark County in 1986. In 1991 a Flood Control Facility Plan for the Range Wash was developed. The new plan incorporated updated land planning information, more site-specific information, and revised hydrologic design criteria adopted by the District. The facility plan included an evaluation of the previous Master Plan, plus three additional alternatives.

Alternatives were evaluated based on estimated construction cost and less quantifiable considerations, such as flood hazard reduction, ease of
implementation, and compatibility with future development plans within the community.

The effects of high intensity storms over different portions of the whole watershed were a key factor in evaluating effectiveness of various alternatives. Another factor was the incorporation of existing facilities. The existing Sloan Channel has varying levels of improvements, with unlined and lined portions all below the design criteria of the District. The alternative evaluation concluded that cost savings would result from the construction of a detention basin near the confluence of the east and west tributaries of the Range Wash versus the construction of the necessary channel improvements along the Sloan Channel.

Hydrologic analysis indicated that detention near the confluence had a considerable flood reduction benefit. A thunderstorm centered below proposed Master Plan detention basins on the upper alluvial fans would result in peak discharges exceeding the capacity of the Sloan Channel. Detention at the confluence can reduce flows to less than the capacity of existing improved portions of the channel.

The alternative evaluation resulted in the acceptance of a $42 million facility plan for the Range Wash watershed. The accepted plan best utilized existing facilities, with cost savings of approximately $20 million over the other three alternatives.

Design Phase Hydrologic and Hydraulic Optimization

During the design phase for the Confluence Detention Basin, additional optimization of the facility was incorporated. Design flows were optimized through use of a diversion control structure diverting only high flows to the detention basin from the west tributary channel. The design was further optimized by a two-level outlet system on the detention basin. An analysis of downstream hydrographs and the hydrograph for the bypassed flow was used to generate an optimum outflow hydrograph. Existing facilities were kept at near capacity for a longer period of time, greatly reducing the storage requirements of the detention basin.

An intense 100-year storm centered over the tributary area below the detention basin produced a peak flow of short duration of approximately 3,600 cfs at the downstream end of the Sloan Channel. This area includes the urbanized portion of the watershed and drainage from Sunrise and Frenchman mountains on the east. The unimproved portions of Sloan Channel, at the downstream end, would require improvements to handle this flow regardless of the upstream detention basin. This flow became the target discharge for setting the detention basin outflow when considering a larger, less intense storm over the entire watershed.
Flow from the west tributary of the Range Wash was conveyed by an existing under-capacity soil cement channel. Diversion is required to direct the flow to the detention basin site. The existing channel had an original design capacity of 2,600 cfs, but to meet current freeboard criteria and to limit flow velocity to 10 fps the proposed capacity was limited to 1,400 cfs. A diversion structure will cause flow to begin to spill into a diversion channel when the flow exceeds 800 cfs. A constriction in the channel will produce increased backwater depth and diverted flows will spill over a control weir 200 feet long and 6 feet above the invert of the channel. At the 100-year peak flow, 1,400 cfs are conveyed in the existing channel and 2,500 cfs are diverted toward the detention basin. This diversion reduces the volume of flow into the detention basin and maximizes the use of the existing channel.

Improved portions of Sloan Channel just downstream of the confluence of the east and west tributaries have a capacity of approximately 2,800 cfs. When a relatively high flow is bypassing the detention basin and a high peak is occurring from the downstream area, the flow released from the detention basin must be kept relatively low (360 cfs). The combined flow of the bypass, outflow, and downstream flows does not produce a peak greater than the target discharge of 3,600 cfs. After the peak flow from the downstream area passes, the flow released from the detention basin may be increased. Thus the hydrograph generated from the downstream area is dropping, while the detention basin outflow is rising, and the net discharge remains below 3,600 cfs.

The release rate from the detention basin outflow is increased by means of a secondary outlet, which begins to operate after the detention basin has filled to a higher level within three feet of the 100-year water surface. The initial low-level outlet has an orifice control. The high-level outlet has a large box structure into which the low-level outlet also enters. The top of the box forms a weir and increases detention basin outflow to approximately 1,800 cfs. The detention basin inflow and outflow hydrographs are shown in Figure 1.

Utilizing the existing channel to bypass flows and increasing the outflow reduced the storage requirements by one-third, approximately 400 acre-feet (645,000 CY of required excavation) over the initially estimated storage requirements.

**Location and Land Value Optimization**

The size and location were optimized based on topography and land value assessments. The basin is located adjacent to Nellis Air Force Base, where land values are low due to high noise levels that preclude normal development. The basin will serve as a buffer area between the Air Force Base on the west and proposed residential development on the east.
Figure 1. Inflow/outflow hydrographs.
The disposal of excavated materials was used to raise the grade of the adjacent lands to the east above a flood hazard level. Construction easements were obtained to place fill to raise adjacent properties above the top of dam elevation instead of directly purchasing these more expensive private lands. This increased their value and development potential. It also provided a place within a minimal haul distance to dispose of excavated materials from the detention basin excavation.

The design also incorporated a cost saving spillway concept. The concept of handling the probable maximum flood (PMF) flows reduced either the amount of land acquisition required and/or the amount of excavation to achieve the necessary storage requirements. The spillway costs were reduced by using a near grade soil cement overflow section and allowing flows to back up into the Nellis Air Force Base golf course. This allowed the 100-year water surface to be raised to the approximate grade of the adjacent golf course. It provided an increase in storage without increasing excavation. A portion of the PMF flows are allowed to flow around the basin though the golf course. The golf course area was utilized in satisfying PMF freeboard criteria. The flood hazard to the golf course was not increased since the golf course was already susceptible to Range Wash flooding. The detention basin and inflow channel through the golf course provided 100-year flood control protection to the golf course, which it previously did not have. The golf course area would be susceptible to PMF flooding with or without the detention basin.

Conclusion

The Confluence Detention Basin is a major component to a flood control facility plan for the Range Wash watershed. It is an excellent example of a community flood control mitigation project that utilized planning and evaluation studies and several optimization techniques to reduce the costs.

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DEVELOPMENT OF A
P.L. 566 NONSTRUCTURAL PLAN
TO REDUCE FLOOD DAMAGES IN THE
UPPER FRENCH BROAD RIVER, NORTH CAROLINA

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The French Broad River, a part of the Tennessee River drainage basin, originates in Transylvania County, North Carolina. The Upper French Broad River watershed has a history of flooding dating from 1791. Average annual rainfall in the headwaters is 80 inches, the highest in the United States. Twelve major floods have occurred, with the most recent in 1964. Numerous smaller floods have occurred throughout the period. Flooding damages agricultural lands, roads, utilities, businesses, and residences. Flooding on the Upper French Broad River has also resulted in the loss of life.

Elevations in the watershed range from more than 6,000 feet to 2,100 feet. The headwaters of the main stream and tributaries account for most of the elevation differential. The French Broad River downstream of Rosman follows a meandering path through a broad floodplain. The gradient is typically less than most mountain rivers, averaging 3.5 feet per mile.

Approximately 85% of the watershed is forested. Most of the floodplain is cleared and is devoted to agricultural, commercial, industrial, and residential uses. The Town of Rosman, near the confluence of the East, West, North and Middle Forks of the French Broad River, has a population of approximately 500. The City of Brevard lies 21 miles downstream and has a population of approximately 11,500.

Tourism plays an important role in the local economy. Much of the tourism is related to outdoor recreation provided by the lakes, streams, rivers, mountains, and forests of the area. Transylvania County bills itself as the "Land of Waterfalls." Canoeing, rafting, and trout fishing are important recreational activities that take place on the streams and rivers of the watershed.

Average annual flood damages exceed $1 million on agricultural properties and over $300,000 on commercial, industrial, and residential property. Hydraulic and hydrologic studies indicate that over 100 homes, four
commercial buildings, and one church would be flooded above the first floor level by a 100-year storm.

Local residents and government have sought assistance to reduce flood damages over the past 30 years. A number of structural plans have been developed, but none has been implemented. A draft work plan was developed in 1963 through Public Law 83-566 by local sponsors, assisted by the Soil Conservation Service. The plan called for land treatment and a number of floodwater-retarding structures. The plan was not approved for installation.

In 1965, local leadership accepted a proposal developed by the Tennessee Valley Authority which would have resulted in the installation of five dams. In 1970, local leaders adopted a resolution supporting an alternative plan developed by TVA. Neither of the TVA proposals was implemented.

In 1988, SCS completed a floodplain management study which identified several flood control alternatives, and in 1990 formally began the P.L. 566 planning process to develop a watershed plan/environmental assessment.

Throughout the planning process, interagency and public involvement was encouraged. In January 1991, the sponsors, with assistance from SCS, conducted an interagency scoping meeting. Potential floodwater-retarding structure sites were visited, as well as areas of the floodplain that had experienced repeated flood damage. Most agency comments expressed concerns about the environmental impacts associated with the construction and operation of floodwater-retarding structures. Impacts to trout waters, loss of aquatic habitat, loss of riparian terrestrial wildlife habitat, potential impacts to threatened and endangered species, and impacts to archaeological and historic resources were primary concerns. Non-agency personnel representing local environmental interest groups were also invited to and attended the scoping meeting.

A public meeting was also conducted in January 1991. The sponsors and SCS personnel discussed the alternatives being considered, and for the benefit of the public showed a video featuring aerial photography and simulated views of the potential floodwater-retarding structures. It was stressed that structures would be only one of the measures considered. Channel improvement, dikes, nonstructural measures, and various combinations would also be evaluated. The public was urged to give both oral and written comments on potential flood prevention measures. A wide variety of comments was received, including some opposed to any flood control measures, some opposed to structural measures, some favoring any means to reduce flood damages, and some suggesting development of additional alternatives. There were also concerns about the loss of stream-based recreation, such as canoeing, rafting, and trout fishing that could be associated with some measures.

In January 1992, the sponsors and SCS held another public meeting to update citizens on the planning process and to discuss both structural and nonstructural measures being considered. Again, a wide range of concerns was
expressed. Most concerns were related to potential impacts of floodwater-retarding structures.

In April of 1992, the sponsors and SCS conducted a tour of a nearby operational P.L. 566 watershed project so that local government leaders, local press, and citizens representing a coalition of environmental groups could see several floodwater-retarding structures of varying age and size. The sponsors of the operational project discussed their experiences and answered many questions.

A third public meeting was held in February 1993 to present 12 alternatives that had been evaluated by the SCS planning staff. Only two of the alternatives proved to be cost effective. The nonstructural alternative and the nonstructural with one "dry" dam alternative had positive benefit-to-cost ratios. The structural alternatives that had any significant effect on flooding had less than a 0.75:1.0 benefit-to-cost ratio. The sponsors, with input from the public, chose to pursue the nonstructural plan.

In order to calculate flood damages, over 323 individual properties were surveyed to establish ground level and first floor elevations. They were divided into groups based on the depth of first-floor flooding from the 100-year storm. Groups were: (1) less than 1 foot; (2) 1 to 3 feet; and (3) more than 3 feet. The depth of flooding at the natural ground elevation surrounding the building was determined to evaluate the potential of using floodwalls or levees, and to evaluate the threat of loss of life. A number of road and bridge crossings were also surveyed.

Cost estimates for floodproofing measures were based on a number of factors, including site location; flood depth, velocity, and duration; building foundation type; and building construction. Data from the U.S. Army Corps of Engineers and the Federal Emergency Management Agency were also used to develop cost estimates. Costs of floodproofing were compared to the market value of individual properties and average annual costs for the project were compared to the average annual benefits. Approximately 70 properties will be eligible for floodproofing at an estimated total cost of $618,000. The benefit-to-cost ratio is estimated at 1.8:1.

The existing flood warning system, Integrated Flood Observing and Warning System (IFLOWS), provides adequate flood warning for residents. The system is scheduled for improvement by the addition of additional gauges in the watershed. The North Carolina Division of Emergency Management is in the process of upgrading the Emergency Management Plan for Transylvania County, which will address emergency response to flooding. Because the state has a long-range plan for improved flood warning, it was decided not to include a flood warning system as part of the P.L. 566 plan.

The nonstructural measures will be implemented on a voluntary basis. Measures will be installed through long-term contracts with the owner. The owner will make application through the sponsors, and the contract will be between the owner and the sponsors. The SCS will enter into a project
agreement with the sponsors. The P.L. 566 share for the installation of nonstructural measures will be 75% of the total installation costs.

For measures such as elevating properties and others where SCS generally lacks expertise, the applicant will be required to obtain the services of a licensed architect/engineer to develop the plans and specifications. The applicant will submit them to SCS for review and approval. It will be the applicant's responsibility to be sure that the planned modifications meet applicable building codes, are consistent with the floodplain management requirements, and are structurally sound. The applicant will obtain the approval of the plans from local permitting officials. The SCS will check to be sure that they meet the requirements of the plan, such as being elevated above the level of the 100-year flood. The applicant will be responsible for inspecting the installation and assuring that the improvements are structurally sound. The sponsors will provide a certification to SCS that the measure has been implemented. SCS will limit inspection to that necessary to assure that the measure has been installed in accordance with the contract and the plan.

Besides the direct benefits associated with floodproofing, other data developed in the course of the study will also benefit the area. Road and bridge elevation and flood frequency information can be used by local planners to formulate emergency response plans and routes for emergency vehicles. Ground and building elevation information can be used by property owners to be more prepared and knowledgeable about what to expect in times of flooding.

Although the nonstructural plan does not address all of the concerns identified by the sponsors, it does address the damage to commercial and residential buildings and, most importantly, may reduce the threat to loss of life. The innovative approach used and the persistence of the sponsors and other local leaders will result in a plan to improve the quality of life of those affected by flooding in the Upper French Broad River Watershed.
Introduction

This paper describes the programs that the City of Tallahassee has implemented to manage the complex problems associated with stormwater management in the State of Florida. Tallahassee has implemented several comprehensive efforts to manage the water quantity and quality aspects of stormwater runoff within the city. These programs include the Stormwater Regulatory Program, Stormwater Planning Program, Capital Improvements Program, Surface Water Management Program, and Drainage System Maintenance Program. They are managed cooperatively among several departments within the city: the Stormwater Management Division, Streets and Drainage Division, and Growth Management Department. Funding for the implementation of these programs comes from the Tallahassee Stormwater Utility, permit review fees, and city taxes. The primary source of funding is the Tallahassee Stormwater Utility, which generates in excess of $7 million annually.

Stormwater Regulatory Program

Stormwater runoff within Tallahassee is regulated by the use of three devices: the Environmental Management Ordinance (EMO), the Concurrency Management System, and the Building and Construction Regulations. The Growth Management Department and the Stormwater Management Division are responsible for the enforcement of these regulations.

The EMO (City of Tallahassee, 1993a) is a comprehensive development ordinance that regulates new construction within the city. It includes requirements for rate and volume control, sedimentation and erosion control, wetland construction, floodplain construction, water quality treatment, and open space. Some of the pertinent stormwater regulations include the requirement that peak post-development discharges not exceed pre-development peaks for all durations up to and including the 25-year event, stormwater retention for the difference in peak and post-development volumes in closed basins, soil erosion...
and sediment control measures for all new development, restriction of development in undisturbed 100-year floodplains, and stormwater treatment measures in compliance with the Florida regulations. The open space requirements of the EMO specify that 25% of the site be landscaped (15% of an industrial site), and an additional 25% of the site be preserved in a natural condition.

The Concurrency Management System (City of Tallahassee, 1993b) is a program implemented within the city to assure that the capacity of public services such as traffic, water, sewer, public facilities, and stormwater are not exceeded when development occurs. To meet stormwater concurrency, it must be shown that the total post-development stream flows downstream of the development are less than the existing downstream capacity of the drainage system; or if an existing drainage problem exists downstream, that there is no increase in this problem. Capacity of streams is defined as bank full conditions. If the downstream drainage system capacity is inadequate, or if downstream drainage problems exist, the development must be designed such that the existing downstream deficiency is corrected or the known problem is not worsened. This analysis must be performed for the 25-year critical duration event. In order to assure that concurrency for a new development is satisfied, a detailed hydrologic and hydraulic model of the downstream drainage system is required for both pre- and post-development conditions. The Environmental Protection Agency’s Stormwater Management Model is required for the analysis. If an applicant decides to restrict post-development flows to 2-year pre-development flows, then a concurrency analysis as described above is not required unless there is a downstream drainage problem.

The Flood Hazard Protection section of the Buildings and Construction Regulations (City of Tallahassee, no date) sets forth the minimum building requirements as required for city participation in the National Flood Insurance Program (NFIP). The regulations in this section generally follow the minimum requirements set forth in the NFIP regulations.

**Stormwater Planning Program**

The purpose of the city’s stormwater planning program is to develop a comprehensive plan for the development of stormwater projects to address the existing and future stormwater needs within the city. The Stormwater Management Division is responsible for the development of the short- and long-term stormwater planning needs. To do this, the City is working on two major projects. These include the development of stormwater management plans for the major streams within the city, and the collection of stream and rainfall data throughout the region in order to better define and document the runoff
characteristics of the drainage systems. A more detailed explanation of these two projects follows.

The City of Tallahassee, Leon County, and the Northwest Florida Water Management District have recently completed a five-year study of the four major basins that encompass the city. The *City of Tallahassee-Leon County Stormwater Management Plan* (Northwest Florida Management District, 1992) identified numerous problem areas related to flood damages, street flooding, and degraded water quality on the major watersheds that encompass the city. The problem areas were identified by the use of hydraulic, hydrologic, water quality, and economic computer models. These models were developed for the major streams in the four basins. The analysis was completed for approximately 65 miles of stream for a total drainage area of nearly 200 square miles. As a result of this analysis areas of flood damage, street flooding, and water quality problems were identified for the major streams. Approximately 45 structural and non-structural solutions were evaluated to provide both flood control and water quality enhancement. The alternatives included regional stormwater storage facilities, culvert enlargements, wetland restoration, lake preservation, and floodplain preservation. The recommended alternatives amounted to approximately $33 million in design and construction costs. The city is using the results of the plan to prioritize future capital improvement projects.

The city is developing detailed basin plans for many of the problem areas that were identified in the Stormwater Management Plan. These detailed plans will better isolate the problem areas and develop designs for the proposed improvements.

The second major stormwater planning project being implemented by the city of Tallahassee and Leon County is an aggressive monitoring program to develop long-term discharge and rainfall records. This work is being performed by the Northwest Florida Water Management District and was initiated under the Stormwater Management Plan. As part of this effort, 19 stream gages and 12 rainfall gages are located throughout the four basins. The city has an additional 14 stream and 5 rainfall gages being used for specific capital improvement projects. These gages are considered temporary and are relocated as the need arises for specific projects. The gage data collected by these two efforts are used to calibrate and verify the hydraulic and hydraulic models being developed for the detailed basin plans and the capital improvement projects, and to verify existing drainage problems.

**Capital Improvement Program**

The purpose of the Capital Improvement Program (CIP) is to reduce or eliminate life threatening and damaging flooding throughout Tallahassee. The CIP is implemented through the Stormwater Management Division (SMD).
Tallahassee’s CIP has more than 10 stormwater projects in various stages of development, which equates to a design and construction cost of approximately $14 million. The five-year capital budget identifies an additional $25 million needed during the planning period. The highest priority projects from the Stormwater Management Plan are included in the five-year capital budget. Other sources of projects include citizens, city staff, city commissioners, and consultants. Using the various sources, SMD staff will prioritize and select projects for neighborhood, subdivision, and regional levels.

The process followed for the implementation of stormwater improvement projects has three phases; concept design, preliminary design, and final design and permitting. SMD begins projects by developing a conceptual design. The project team typically consists of city staff and consultants. During the concept design phase, the project team attempts to define the extent and location of the problems and then develops multiple solutions to the defined problems. With input from citizens, consultants, and staff a final solution is developed and recommended to the City Commission. A detailed basin plan has been developed at this stage and will be used in the preliminary engineering and final design phases. Preliminary engineering work, which is the next phase, involves further refinement and detailed engineering of the adopted conceptual design. Essentially, all engineering is completed during preliminary engineering. The project team (typically the consultant) provides the sizes, shapes, and sketches for all recommended facilities. They contact the permitting agencies and provide environmental assessments for sites where ponds or lakes are being proposed. The final phase of engineering is the preparation of final construction plans and permitting. Final plans are modified through an iterative permitting process that may take years to complete. Even as the permitting process changes the plans, it is the policy of the staff to inform the public of changes, thus additional community meetings are held to maintain the consensus that was forged in the early phases of the work.

Public involvement is a key part of successfully implementing a project in Tallahassee. To have a successful public process, citizens must be involved from the beginning when the problems are defined. At each step citizens express their views regarding the consultants’ work and what the next step should be. The city staff incorporates public comments and ideas into the project solution. There typically is not total agreement among all interested parties with the solutions proposed by the staff, but all ideas are brought to the table during the community meetings. The staff presents its recommendations, along with community meeting summaries, to the City Commission. If there are major disagreements between the staff and residents, the issues will be presented to the City Commission, which will resolve the differences and finalize the direction of the project.

The city has recently completed several stormwater improvement projects: the John Knox Pond, Frenchtown Pond, and the Jim Lee Pond.
provide approximately 150 acre-feet of volume for the storage and treatment of stormwater runoff. The total cost of these facilities was approximately $4.8 million. Some projects in the development stage include the East Branch, Cline Chamberlin, Killearn Lakes, and Trimble Mission projects. They will incorporate various solutions, including regional stormwater detention facilities, stream channelization, bridge and culvert improvement, and home acquisitions.

**Surface Water Management Program**

The Surface Water Management Program is implemented through the city’s Stormwater Management Division (SMD) and has two areas of responsibility: compliance monitoring and surface water body management. Compliance monitoring of surface water quality is a regulatory requirement of the state Department of Environmental Protection (FDEP) that may be required when significantly sized stormwater facilities are constructed. This monitoring is conducted for a specified period of time unless state water quality standards are exceeded. Monitoring may be extended if state water quality standards are violated. Monitoring has begun at three newly constructed facilities and the results will be reported to FDEP. Information obtained from monitoring will also be used to provide insight for future facility designs and for long-term planning of regional stormwater facilities in Tallahassee.

Vegetative monitoring is another aspect of compliance monitoring. When a pond is constructed, aquatic vegetation is planted to enhance water quality, support ecological diversity, and provide environmental aesthetics. Vegetative monitoring is conducted to insure that planted wetlands are successful and invasive species are held to a minimum.

Surface water body management entails the management of water bodies that were originally built or retrofitted for stormwater management. One example of this in Tallahassee is Lake Ella, a small urban lake (12 acres surface area) that was retrofitted to manage stormwater runoff. The pollutants that enter the lake at a high rate are trapped with the use of alum, which is injected in the stormwater runoff entering the lake. Monitoring also promotes good lake operations and management. The management objective is to achieve a balance between a clear pool of water (what the public believes is good water quality) and a healthy aquatic environment (necessary to support fish and some wildlife).

**Drainage System Maintenance Program**

The Streets and Drainage Division is responsible for the maintenance of stormwater facilities and drainage conveyance systems throughout the city. The drainage maintenance program is driven by routine inspections and requests generated from residents of the city. The city has recently implemented a
Tallahassee Stormwater Management Program

program in which the major ditches and stormwater facilities are inspected at least twice a year and maintained on the average every two years. In addition to this, known problem areas are inspected after heavy rains. The stormwater facilities maintenance program involves retrofitting facilities to design conditions, slope stabilization, filter cleanup and reconstruction, and removal of accumulated silt. The drainage conveyance system maintenance program includes the removal of weed and brush overgrowth, fallen trees, excessive silt accumulation and other debris.

Conclusion

Through the implementation of these programs the quantity and quality of stormwater runoff are being addressed within the city of Tallahassee. These programs address stormwater needs for both existing and future conditions. The city will continue to develop and modify these programs as future needs require.

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THE MC DONALD CREEK FLOOD CONTROL PROJECT, ARLINGTON HEIGHTS, ILLINOIS: A MODEL COMMUNITY FLOOD MITIGATION PROJECT

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Village of Arlington Heights, Illinois

Introduction

The McDonald Creek Flood Control Project is located in Arlington Heights, Illinois, a suburban community approximately 23 miles northwest of downtown Chicago. The project consists of the following components:

- Lake Arlington, a 50-acre recreational lake, which, when fully surcharged, provides 540 acre-feet of flood control storage (Figure 1). A 60-inch gravity outlet sewer provides drainage. Inflow is from two drop-inlet structures connecting the north and south branches of the creek to the lake. A 54-inch bypass sewer (100 cubic-feet-per-second capacity) connects the drop inlets to the original creek. The project also contains a grass-lined emergency spillway.

- 1.5 miles of upstream channel improvements, including channel widening, gabion lining, high-flow channels, and five culvert replacements (Figure 2).

Background

McDonald Creek is a tributary to the Des Plaines River. It drains about 6,800 acres of residential areas, commercial properties, and rapidly disappearing farmland. Since the late 1960s overbank flooding has been a problem along the creek. Like many urbanizing watersheds in this area, flooding seemed to worsen in the 1970s despite introduction of stormwater control ordinances in some of the communities in the watershed.
Several early flood control studies were made by Arlington Heights, U.S. Soil Conservation Service, Illinois Department of Transportation, Division of Water Resources, and the U.S. Army Corps of Engineers. In 1984, Stanley Consultants of Muscatine, Iowa, conducted a study of flood control alternatives that identified a 50-acre lake with 570 acre-feet of storage as the preferred alternative (Harza, 1987). Harza Environmental Services of Chicago, Illinois, was retained by the village of Arlington Heights in 1986 to proceed with preliminary and final design. The selected project included a 540-acre-feet reservoir. A gravity outlet was recommended over a pump station because of lower operation and maintenance costs. Ground breaking took place in September 1988. Construction was completed in the fall of 1990.

Figure 1. Lake Arlington.
Funding

A detailed benefit/cost analysis was undertaken to determine the dollar value of annualized savings provided by the project. The analysis involved estimating flood damages for every significant structure in the floodplain for a variety of storm events. Analyses were made of scenarios without and with project conditions. Annual flood damages were estimated to be reduced from $198,740 to $1,373 as a result of this project. The equivalent capital cost savings is $2.3 million.

These analyses provided the basis for funding negotiations with the state of Illinois, the Village of Prospect Heights, and the Metropolitan Water Reclamation District of Greater Chicago. These groups contributed a total of $1.25 million out of a total project cost of $13.75 million (ASCE, 1990). These economic analyses showed that reservoir storage of 370 acre-feet would benefit only Arlington Heights, but a 540 acre-feet project would also benefit other downstream communities (Harza, 1990).

Figure 2. A typical widened channel.
Project Construction

Excess materials from the excavation of the reservoir were used for construction of final closure of a municipal sanitary landfill that has been converted to the municipal golf course. The cost savings of this innovative use of excavated fill were estimated to be $5.0 million.

A large number of trees (exact number unknown) were saved through careful selection of reservoir shape and channel widening alternatives. The high-flow channels were designed to save trees along banks of existing channels.

Drop Structures

Cast-in-place drop structures were selected as inlets for the reservoir. The structures are buried for aesthetic reasons and allow limited access for safety reasons. The size and shape of the drop structures promote energy dissipation of flow entering the reservoir.

Normal Flow Diversion

Normal creek flow is diverted from entering the reservoir by a diversion structure. This diversion was designed to maintain a minimum creek flow, maintain high water quality within the reservoir, and limit the sediment load to the reservoir.

Box Culvert Construction

Since construction of portions of the north and south branches of McDonald Creek would be in areas with limited right-of-way, concrete box culverts were specified for portions of the channel improvements. Precast, reinforced-concrete box culverts allowed for quick construction across a busy traffic route. The box culverts also provided adequate flow capacity in areas where right-of-way restrictions limit the use of trapezoidal channels and safety concerns preclude the use of deep concrete-lined rectangular channels. Project construction was completed by Plote, Inc., Elgin, Illinois (reservoir) and La Verde Construction Company, Inc., Wheeling, Illinois (channel improvements and outfall sewer).

Lake Arlington

The lake has proven to be a very beneficial community resource. Recreational uses include sailing, fishing, and paddle boating. A jogging/bicycle path was constructed around the perimeter of the reservoir. Wetland areas were created for bird and animal habitat. Real estate values of homes near the lake
have increased. After construction was completed the lake and surrounding areas were turned over to the village’s Park District.

**Floodplain Remapping**

Floodplain re-mapping was complicated by the following factors:

- Illinois adopted a new rainfall-frequency standard after the project was permitted;

- A myriad of prior modelling efforts existed (Stanley study, Flood Insurance Studies, permitting analyses, economic analysis);

- Obtaining Illinois approval prior to submittal to FEMA;

- Certification of with-project discharges;

- Floodplain/floodway analyses to meet Illinois definitions; and

- Outdated topographic mapping.

Approximately 50 homes in three communities were removed from the regulatory floodplain as a result of this project.

**Conclusions**

- Flood control projects can provide many recreational benefits.

- Quantifying benefits can be helpful in obtaining financing assistance.

- The planning process must involve federal, state, and local agencies.

- Previous studies provide valuable insight into project development.

- Innovation in project layout can save trees.

- Innovative use of excavated material can cut construction costs.

- Floodplain remapping of a major flood control project in Illinois involves considerable effort.
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Harza Environmental Services, Inc.
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A NEW APPROACH TO FLOOD CONTROL
IN THE CYPRESS CREEK WATERSHED,
HARRIS COUNTY, TEXAS

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Introduction

In May of 1989, 8.0 to 12.5 inches of rain fell over a 24-hour period in the lower portion of the Cypress Creek watershed in Harris County, Texas. About 545 homes were inundated by the flood that resulted from this storm. Based on 20 years of record (1970 to 1989) at a local U.S. Geological Survey gage at Interstate 45, the flood was estimated to have a recurrence interval greater than a 100-year event (Lichliter/Jameson, 1991).

Five weeks later in June of 1989, another storm dumped 6.0 to 11.0 inches of rain in the lower reaches of this basin. Some 263 homes were re-inundated by this event. Based on the same period of record at the I-45 gage, this flood was estimated to be a 25-year event (Lichliter/Jameson, 1991).

Since May 1929 (the flood of record for Cypress Creek), 21 major flooding events have been recorded along the stream. The May and June storms of 1989 were two of the most recent significant storms (U.S. Army Corps of Engineers, 1988; U.S. Army Corps of Engineers, 1986; Turner Collie & Braden, 1984).

The Cypress Creek Watershed

The Cypress Creek watershed is located in northern Harris County and eastern Waller County, Texas (see Figure 1). It has a drainage area of approximately 320 square miles, making it one of the largest watersheds affecting Harris County. The basin is long and narrow with an average length of about 40 miles and an average width of eight miles. The length of the main stem from its headwaters to its confluence with Spring Creek is approximately 58.9 miles. Due to its proximity to the growing city of Houston, a tremendous amount of development has occurred in the lower (eastern) half of the watershed while the upper (western) half of the basin has remained largely undeveloped agricultural land.

Because of Cypress Creek’s wide floodplain and the fact that development occurred in the floodplain before implementation of the National
A New Approach to Flood Control in the Cypress Creek Watershed

CYPRESS CREEK WATERSHED

HARRIS COUNTY

CITY OF HOUSTON

Figure 1. Location of the Cypress Creek watershed.

Flood Insurance Program, many developed areas have been affected by 10-year and higher frequency events. In addition, many acres of undeveloped land in the upper half of the watershed along the main stem of Cypress Creek and its largest tributary, Little Cypress Creek, are inundated by such events.

Due to the stated trends in development (i.e., the lower part of the basin being developed while the upper portion remains undeveloped) and the shape of the basin, the watershed produces a unique response to basin-wide storm events. During these types of storms, the basin tends to react as two separate basins with the runoff from the lower half of the watershed reaching Cypress Creek quickly and peaking high, followed by a second peak from the upper portion of the basin occurring on the falling limb of the first peak (see Figure 2). Both peaks are capable of flooding many homes. The duration of a flooding event from a 24-hour basin-wide storm would be three to four days (this would include both peaks).
The problem associated with basin-wide storm events is that flood control by means of on-line detention ("on-line" meaning that the entire flood hydrograph must pass through the facility) becomes an obstacle due to the large drainage area and volume of water draining to such a facility. This is true of side-weir facilities as well ("side-weir" meaning a weir structure capable of diverting part of the hydrograph into an off-line facility). With this type of facility, the first peak fills the detention volume but cannot drain before the arrival of the second peak.

**Past and Future Projects**

In the past, several projects have been constructed to reduce impacts from flooding adjacent to Cypress Creek. In the 1950s, Cypress Creek was channelized by the Harris County Flood Control District (HCFCSD) from its
confluence with Spring Creek to U.S. 290 (about halfway up the main stem of Cypress; approximately 4.5 miles upstream of the confluence of Little Cypress Creek). The work consisted of enlarging, straightening, and clearing the main channel. However, the channel cross section was not maintained, which resulted in the channel taking back some of the characteristics of a natural stream.

More recently, developers have constructed a number of channelization projects along the main stem to provide for mitigation efforts primarily associated with the construction of bridges across Cypress Creek. One regional detention facility has also been constructed within the watershed. It was constructed as part of a developer project and currently has a storage capacity of 737 acre-feet.

Some recent public projects associated with flood reduction have been undertaken since the storms of 1989. These include the construction of the $5.0-million Inverness Forest Levee by the Federal Emergency Management Agency (FEMA) and HCFCD (providing protection for 136 homes), a $2.0-million channel maintenance program by HCFCD, and a $2.4-million buyout program by HCFCD and FEMA.

Future small projects to increase capacity along the main stem of Cypress Creek include selective clearing projects (the goal of this program is to preserve the capacity of the channel while minimizing environmental impact) and desnagging projects along the main stem.

Current Project Plan

A number of plans which would reduce flooding along Cypress Creek have been identified in the past by both HCFCD and the U.S. Army Corps of Engineers. These plans have included channelization projects (U.S. Army Corps of Engineers, 1986) and combinations of channelization and detention projects (Turner Collie & Braden, 1984). However, due to economic constraints, detrimental environmental impacts, and difficulty of phased implementation, these plans have never been constructed. Traditional methods of reducing flooding impacts along Cypress Creek have also tended toward large-scale projects with minimal benefit/cost ratios. This is due to the fact that mitigation efforts associated with these types of projects have caused an increase in costs.

In December 1992, HCFCD met with the Corps to mutually decide on a new approach to solving some of the flooding problems along Cypress Creek. The idea is one of local solutions to local problems as opposed to a single regional project to solve several localized flooding situations. Otherwise stated, rather than using one large project, several smaller projects would be used together to reduce existing flooding potential.

The process began by identifying areas of high damage adjacent to Cypress Creek along the main stem of the waterway. Ten reaches were
identified. It was then decided that five environmentally compatible plans would be developed that will provide significant reduction or protection from flooding for existing development.

Each of the five alternatives will individually address the problems in all 10 reaches. All available flood control options (i.e., channelization, detention, levees or floodwalls, and buyouts) will be investigated for each damage reach. As an example, Reach B may be addressed by channelization and Reach C by detention in Alternative Plan #1; in Alternative Plan #2, Reach B may be addressed by a levee and Reach C by detention. Impacts to a given reach resulting from a particular solution for an upstream or downstream reach will also be considered (e.g., it will be necessary to consider how the solutions for each reach will work together with the solutions for other reaches).

Upon completion of these five alternatives, HCFCD (as the public’s representative) will work with the Corps to determine the plan for final design that produces the most benefit for the community.

The current estimated cost of developing this plan is $1.9 million. This cost will be shared by HCFCD and the Corps on a 50/50 basis (dollar amounts and services). The cost of implementing the resulting plan will be determined through the course of the project.

During the course of this study, HCFCD will be fully involved in every aspect of this project to ensure a high degree of public involvement in the decision process culminating in the final plan.

The current status of the study is that the agreement between the Corps and the local sponsor (HCFCD) for the generation of this study was finalized and signed in February 1994. An update of the existing conditions hydrologic and hydraulic analyses is underway. The current schedule indicates that preliminary results on the selected plan will be available around the middle of 1995. Preliminary results on the five plans for consideration may be ready as early as late 1994.

Conclusion

Previous solutions to flooding problems along Cypress Creek in Harris County have called for massive construction along the main stem of the stream to lower flood levels in the local problem areas. This new approach developed by HCFCD and the Corps will provide a plan that will be supportable by the public at large and will yield the most benefit for the cost associated with it.

Traditional measures also required very large and expensive mitigation measures that reduced benefit/cost ratios to less than unity. The hope is that with this new approach, the required mitigation efforts will be minimal, thereby increasing benefit/cost ratios to acceptable levels.
This study will provide a unique opportunity for developing local solutions to local problems, as opposed to a single large-scale project to solve all local problems at once. This type of approach is the first of its kind in Harris County for a Corps project of this magnitude. It will also provide an occasion for the local sponsor of a federal project to work closely with the federal government in developing a plan that is in the best interest of the public.

References


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U.S. Army Corps of Engineers, Galveston District

U.S. Army Corps of Engineers, Galveston District
Introduction

The residents and businesses of the Clear Creek watershed residing near the main stem and its tributaries have experienced frequent and devastating flooding. The Clear Creek watershed is located in southeast Harris County, Texas. The creek forms most of the political boundary between Harris County to the north and Galveston, Brazoria, and Fort Bend counties to the south. The watershed has several hydrologic, hydraulic, and political features that complicate the implementation of flood reduction measures. Federal and local initiatives are currently underway attempting to provide flood relief and protection for the existing and future residents in the watershed.

The Harris County Flood Control District and the Texas Water Development Board funded a study in 1989 to develop a Regional Flood Control Plan to alleviate flooding in the watershed and to provide a master plan to guide development in the future.

Before describing local and federal flood control efforts, the general makeup of the area, components of the hydrologic cycle, historical storms, and floods will be discussed.

Watershed Characteristics

The Clear Creek watershed captures the runoff from 260 square miles encompassing portions of four counties. The main stem traverses a distance of roughly 47 miles before outfalling into Galveston Bay. Fifty-four percent of the basin is located in southern Harris County, Texas (see Figure 1). Portions of Fort Bend, Brazoria, and Galveston counties make up the remainder of the basin. The basin is home to 16 incorporated cities and five drainage districts, which are responsible for drainage facilities and flood control for the watershed area within their boundaries.

Due to its proximity to Galveston Bay, environmental sensitivity is even more pronounced in the Clear Creek watershed. The lower extreme end of the basin is influenced by the daily ebb and flow of tidal waters, enabling the area to serve as a nursery area for aquatic species (Corps, 1982).

Watershed terrain and soil are primarily made up of level to nearly level clayey soils, which aggravate the flooding problems encountered within the
watershed. Overland slopes average 2 feet per mile and vary from an elevation near sea level at the bay to 70 feet above mean sea level near the headwaters. The main stem has a slope of slightly more than 1 foot per mile, making for a very slow-moving stream. The combination of a large drainage area, flat topography, low permeability, and limited channel carrying capacity makes stormwater runoff rise out of channel banks frequently, causing overbank flooding.

Floodprone Areas

Hurricanes, tropical storms, and thunderstorms are major rainfall producers, and unfortunately, all are frequent visitors to the watershed. Average annual rainfall in Harris County is 48 inches.

In July of 1979, what is regarded as the worst flood-producing storm in the history of Harris County and the surrounding area wreaked havoc on the Clear Creek watershed. Tropical storm Claudette produced between 10 and 25
inches of rainfall over the entire watershed in one 24-hour period. An estimated 5000 commercial and residential structures were damaged in the Clear Creek basin totalling $90 million. Total damage in the Houston metropolitan area exceeded $227 million from the rains (Corps, 1982).

As with most storms, the rainfall was not uniform over the entire watershed. Some areas only recorded six inches in the same 24-hour period. The highest observed rainfall in the nation occurred just south of the watershed during Claudette near Alvin, Texas, a very wet 42 inches in 24 hours (Corps, 1982). Two months later another storm produced up to 14 inches of rain, and again caused significant damage (Dannenbaum Engineering Corporation, 1992).

The 100-year riverine flood plain in the Clear Creek watershed inundates 12,800 acres of which 1,310 acres are developed. Hurricane surges in the lower reaches and the area’s subsidence increase the amount of land subject to flooding. The 100-year floodplain from a fully developed watershed will contain roughly 23,000 acres of floodplain land (Dannenbaum Engineering Corporation, 1992) if flood control measures and watershed management regulations are not undertaken and enforced.

### Flood Control Efforts

It has long been recognized that flood reduction measures must be pursued in the Clear Creek watershed. Numerous studies and master drainage plans have been developed by the individual watershed entities to solve localized flooding problems.

The federal government through the U.S. Army Corps of Engineers has been an active participant in the pursuit of flood reduction in the Clear Creek watershed. The Flood Control Act of 1962 authorized the Corps to investigate flood control measures. The Corps produced a survey report on Clear Creek in 1967 recommending flood control measures along the main stem. Congress authorized the first Clear Creek project, which replaced 41 miles of existing channel with 31 miles of grass-lined channel extending from the upper end of Clear Lake to a point near the headwaters. The recommended trapezoidal channel section contained the 100-year fully developed condition storm flows with a 220-foot bottom width in the lower reaches, which narrows through the 31 miles to a bottom width of 80 feet at the upper end of the project. Average channel depth would be 20 feet (Corps, 1967).

The original channel design authorized by Congress in 1967 was found to lack public support. Additional flood reduction alternatives were investigated by the Corps, including possible north and south by-pass channels. The results of the analysis are documented in the Corps’ 1982 Clear Creek Project Preconstruction Authorization Report. The Corps recommended 22 miles of
channel enlargement and rectification. The modifications in Brazoria County were removed from the plan at the request of the county.

The current authorized Clear Creek Federal Flood Control Project covers a distance of 15.3 miles. According to the Corps, the proposed modifications will provide protection from the 10-year flood flow for ultimate development conditions. The trapezoidal channel section is proposed to be grass-lined with bottom widths varying from 130 feet in the lower reach to 50 feet at the upstream end of the project. Average depth of the proposed channel is 20 feet (Corps, 1982).

An integral component of the federal project along with the channel enlargement and rectification is an additional outlet to Galveston Bay. The existing channel’s outfall to Galveston Bay is constricted, inhibiting flood flows from discharging to Galveston Bay quickly. The proposed upstream channel modifications will increase discharges in the Clear Lake area. The design intent of the second outlet is to insure that the proposed channel modifications do not aggravate flooding in that area.

The ecosystem of Clear Lake will be protected by control gates in the proposed outlet channel, which will only be used during floods. Limited tidal surge protection is also provided by the control gates.

The control gates have been constructed but the channel linking Galveston Bay and Clear Lake has not. The project is currently on hold until issues surrounding the construction of a railroad bridge can be resolved.

The Clear Creek Federal Flood Control Project total cost is estimated at $116 million. The local sponsors, Harris and Galveston counties, are required to provide all lands, easements, rights-of-way, and disposal areas, and all relocations or alterations of buildings, utilities, bridges, roads, sewers, pipelines, and other alterations of existing improvements. The local sponsors will bear the cost of operating and maintaining the project. In addition, the local sponsors are to provide cash payments of not less than 5% of the total project cost.

Local Efforts

Harris County Flood Control District recognized that a regional flood control plan for the watershed was needed to reduce and eliminate existing flood prone areas. In addition, a flood control plan using the 100-year fully developed watershed design storm was essential to define the facilities necessary to allow full development of the watershed without creating adverse effects. A regional flood control plan was also necessary to manage development within the watershed so that the benefits realized with the Corps project were not lost. Therefore, with matching funds from the Texas Water Development Board, Dannenbaum Engineering Corporation was selected to prepare a regional flood control plan incorporating all existing studies as of 1989. Over 35 studies were
reviewed and incorporated into the analysis. A common methodology for computing flood discharges and profiles was established throughout the watershed.

With 16 incorporated cities and numerous other entities, a guiding force was needed to coordinate the study effort to address specific needs and concerns of the entities. The Clear Creek Watershed Steering Committee was formed during the initial phase of the study. It consists of elected or appointed representatives from the watershed entities. An interlocal agreement was signed and endorsed by the involved entities agreeing to cooperate in the pursuit of common objectives, namely: reduce flood risks by coordinating and participating in flood protection planning studies; provide an administration structure to obtain cost-sharing funds; provide a means to negotiate local cooperation agreements; pursue common goals for the watershed including flood protection, drainage, greenway establishment and protection, conservation, and planned development; and participate in the management of the watershed.

The steering committee was instrumental in developing a common flood protection criteria; a common methodology for computing flood discharges and profiles; and a mechanism to implement the flood reduction measures proposed in the regional flood control plan. Numerous mechanisms were investigated including master districts, non-profit corporations, and interlocal agreements. A steering committee with implementation by interlocal agreements was chosen to implement the Clear Creek Regional Flood Control Plan recommendations.

A Technical Advisory Committee was also formed to oversee and guide the study from a technical viewpoint. The committee was composed of appointed representatives of the steering committee entities. Those representatives reported the findings and recommendations to the steering committee members as well as provided input regarding particular aspects of their entity with which they were more familiar.

The recommended plan of improvements consists of 21 regional detention sites serving areas between seven and ten square miles encompassing 2200 acres and detaining 32,000 acre-feet of stormwater runoff (Dannenbaum Engineering Corporation, 1992). The federal Clear Creek Flood Control Project channel enlargement and rectification is included in the regional flood control plan. The main stem is proposed to be enlarged and rectified upstream of the federal project for a distance of approximately seven miles. Several tributaries are proposed to be enlarged with bottom widths varying from 20 to 80 feet. Additional outlet capacity is proposed to link Galveston Bay and Clear Lake.

In general, the proposed Clear Creek Regional Flood Control Plan reduces the 100-year fully developed floodplain to the Corps' proposed 10-year profile with the use of channel enlargements and regional detention basins.
Summary

With numerous watershed entities, the development of effective and implementable flood control measures in the Clear Creek watershed was complicated. The Corps of Engineers proposed channel modifications to provide protection from the 10-year ultimate developed watershed flood flow. Harris County Flood Control District along with the Texas Water Development Board funded a study to define flood control improvements in the Clear Creek Watershed and to develop a watershed-wide management plan. A steering committee and technical advisory committee were formed during the initial phase of the analysis and consisted of elected and appointed representatives from the entities to guide the study effort. The Clear Creek Regional Flood Control Plan has been completed and when fully implemented should reduce the future 10-year floodplain along the main stem to the proposed 10-year profile.

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FLOOD CONTROL DESIGN IN A
PIEDMONT WATERSHED:
HENDERSON, NEVADA

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Introduction

Implementation of flood control master planning in the urbanized areas of the Southwest desert presents a series of challenging problems. In this case study, we discuss several unique problems associated with flood control on a common landform in the Las Vegas Valley: the piedmont. Unique design challenges include the development of water control structures capable of handling flash floods and high sediment yield conditions, and integration of these facilities with existing and future land development. The design of the C-1 Channel flood control facilities in Henderson, Nevada, provides an excellent example of a successful implementation given these complex conditions.

The C-1 Channel controls some 40 square miles of drainage area from the River Range and McCullough Range mountains and piedmont areas, located in the southern and eastern limits of Henderson, Nevada. Land development in these areas has encountered serious problems with flash flooding and sediment deposition. In 1991, the Clark County Regional Flood Control District updated their Master Plan, which identified the flood hydrology and flood control facilities required for the C-1 watershed. The C-1 channel system includes five detention basins: the Mission Hills, the Black Mountain, the Equestrian, the Northeast, and the East basins. In addition to these detention basins, there are also approximately 18 miles of open channel, storm drains, and dike/levee systems. To implement the master plan, the VTN Nevada (VTN) team accomplished the following tasks: prioritizing the construction of facilities, completion of construction documents for the chosen facilities, and public involvement in the preliminary and final design process.

Piedmont Hydraulics

The piedmont landform occurs at the base of a mountain range as a depositional surface formed by erosion of upland mountain slopes. Hydraulic characteristics of piedmont areas are steep channels with high sediment loads.
Unlike in humid regions, where vegetation stabilizes soil surfaces, sediment supply from arid piedmont areas remains high, and erosion processes are continuously active. A wide variety of channel conditions can occur as a result. These range from active deposition at the mountain front (referred to as an alluvial fan) to incised arroyos. In a mature piedmont, such as the C-1 basin, the entire range of channel conditions is found.

Additional analytical tools are necessary to plan and design flood control works for piedmont areas. These tools must address the complex relationships between sediment supply and transport in the natural and human-made channel system. The tools for piedmont hydraulic analysis include quantitative geomorphic analysis, sediment yield computation, and alluvial hydraulic simulation.

Quantitative geomorphic analysis was used to assess the stability of the natural channel system and to identify the general causes of instability. For example, channel bed slope was found to be a critical variable for sediment transport capacity, and a distinct threshold slope for the McCullough Range piedmont was identified. By mathematical modeling later in the project, the same threshold was also identified. This early analysis established general relationships for stable channel design on the piedmont landform.

Sediment yield computation was used to estimate sediment volume requirements for detention basin facilities and for sediment supply to interceptor channels. A unique requirement of arid region hydrology is the analysis of a series of individual floods to determine an expected sediment yield, rather than the computation of an average annual sediment yield. The computation determines sediment supply from each potential surface (mountain slopes, inter-channel terraces, and channels) in a tributary basin. The computation uses sediment transport formulas that are consistent with later detailed hydraulic analysis.

Hydraulic modeling was used to determine the capacity of the flood control system. Requirements for the hydraulic model are stringent for the following reasons:

1) The steep channel slopes (typically about 2 or 3% gradient) result in upper regime flow, with flows accelerating in and out of critical depth. Short reaches of supercritical flow are common.

2) Sediment load is high (typically 10 to 20% of the flow volume) and the transport process will include reaches with deposition or scour, as the sediment wave propagates.

3) Flow resistance is dominated by alluvial roughness factors, and will vary with state and discharge in the channel.
The first model requirement means that the computational routine must be able to shift from subcritical flow to supercritical flow automatically. The second requirement, sediment transport, is common to a number of models, but the third requirement, alluvial flow resistance, is often lacking. The GSTARS model (General Stream Tube model for Alluvial River Simulation) by Hydraul-Tech Engineering & Software fits all three of the basic requirements. The model was calibrated based on data gathered from transects across the piedmont study area using relationships developed from the geomorphic assessment. The model simulations verified geomorphic thresholds, and allowed designers to determine channel section and profile capable of conveying both water and sediment discharges with a prudent factor of safety.

Prioritization

In order to compare the effect of each major detention basin facility in the C-1 system, VTN and Carter & Burgess developed a ranking scheme that addressed special piedmont flood conditions. The categories used to rank system facilities were water control, sedimentation, flooded area, affected population, and affected dwelling units. The methodology weighted each of these categories equally to determine overall relative ranking of each facility.

We developed a system baseline for each of the criteria using existing flooding conditions. Next, we estimated the ultimate build-out flooding conditions by assuming that all master plan facilities were constructed. VTN developed inundation areas for the existing flood hazard boundaries from the Federal Emergency Management Agency’s Flood Insurance Rate Maps. From the existing mapping we found that the inundation width decreased in the upstream direction approximately proportional to the decrease in discharge. We calculated inundation widths for the various design scenarios using this basic relationship. We based the inundation widths for the ultimate build-out flood conditions on the master plan update hydrology. We gathered information on the existing populations and dwelling units from City of Henderson, July 1, 1992, Housing Units and Population Estimates. The analysis then determined affected population and dwelling units for the various phasing scenarios.

Finally, we determined the cost of the facilities, and compared to the benefits provided. We ranked facilities and partial system configurations, to determine the best construction phasing. The final ranking was:

Phase 1 - Mission Hills Detention Basin
Phase 2 - Equestrian Detention Basin
Phase 3 - Black Mountain Detention Basin
Phase 4 - East Detention Basin
Phase 5 - North-East Detention Basin.
We found the combination of Phases 1, 2, and 3 (Mission Hills, Equestrian, and Black Mountain) to have the best partial system configuration cost-to-benefit relationship. These three facilities have a total estimated cost of $21.1 million that is only 45% of the total estimated cost for all master plan facilities, yet provides nearly 75% of the estimated benefits of the ultimate C-1 Channel system.

**Phase I - Mission Hills Detention Basin Design and Construction**

The Mission Hills Detention Basin ($5.1 million) is currently under construction and is to be completed by June 6, 1994. It contains 445 acre-feet of volume, which includes 57 acre-feet of additional storage for sediment. The basin is 25 feet high, 2500 feet long, and has 6200 feet of diversion dike. The 100-year peak inflow is 4000 cfs with a peak outflow of 300 cfs. The peak outflow discharges into a 84" RCP that is approximately 3100 linear feet and ties into the existing C-1 Channel. The detention basin will drain in approximately 36 hours. Three spillway configurations and materials were evaluated for this project: a roller compacted concrete (RCC), a labyrinth, and a concrete ogee weir. The labyrinth spillway was selected due to a cost savings of $200,000 over the RCC and $700,000 over the concrete ogee weir. The labyrinth spillway crest length is 536 feet with a width length of only 135 feet. The spillway is designed to convey the probable maximum flood of 20,000 cfs with 1 foot of freeboard.

**Public Involvement**

To adequately address the concerns of the residents, VTN and Carter & Burgess conducted a comprehensive public involvement program. VTN developed a series of workshops to solicit the opinions and ideas of the local residents regarding the design of the Mission Hills Detention Basin. VTN prepared a newsletter following each workshop to summarize progress on the project and to inform residents on current issues and upcoming activities. VTN and Carter & Burgess structured the workshops to provide up-to-date facts about the project design, and to participate interactively with residents. Workshop participants were encouraged to feel a sense of ownership in the project, and to actively participate in design issues.

The workshop sessions followed a standard format, hosted by a facilitator. The workshops commenced with the City of Henderson and key members of the design team presenting the status and objectives of the project. The facilitator then opened a discussion period that encouraged questions, statements, and an exchange of information. An assistant to the facilitator promptly recorded this public input on "analysis" cards and immediately posted
these on a wall of the meeting room. This interactive exchange of information effectively extends the design team to include the workshop participants.

The public involvement process provided a forum to address difficult issues such as alternatives for basin location, emergency spillway type, dam embankment slope, and many other concerns. The process provided residents with information that helped them understand many of the difficult tradeoffs between cost and design made by the design team. At the completion of the project design, residents, along with the City of Henderson and the design team, felt a sense of accomplishment in making certain that the project design had achieved its goals. Now that the project is under construction, residents understand and look forward to the many benefits of the flood control project.

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VTN NEVADA in Association with CRSS Civil Engineers, Inc.
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City of Henderson
There are many ways to modify a floodplain and to develop projects within a floodplain. These all require different local, state, and federal approvals. This paper deals with Federal Emergency Management Agency (FEMA) approvals only. It is often difficult to determine which FEMA approvals apply to specific projects, when hydrologic and hydraulic studies are required, and how long the process will take. This paper presents case studies that illustrate various methods and approvals. Each case study includes a brief description of the project, methods used, approvals obtained, and length of time required.

Case Study No. 1:
Floodplain and Floodway CLOMR and LOMR with Hydrologic and Hydraulics Study

In May 1991 a FEMA Conditional Letter of Map Revision (CLOMR) Study for the River Forest Subdivision in Bedford, Texas, was completed. This project determined the existing condition floodplain and floodway for an area along the East Fork of Hurricane Creek in the City of Bedford, Texas, and a proposed concrete channel sized to convey the 100-year flood. This would allow the area to be developed as a residential subdivision. The general procedures followed for the CLOMR were as follows.

Hydrologic Analysis

The hydrology developed in the FEMA Flood Insurance Study (FIS) for the area represented current conditions and was not changed. However, the city required discharges for a fully developed watershed. The watershed was sufficiently small that the Rational Method was used to determine peak discharges.

Hydraulic Analysis

A hydraulic analysis of the creek was completed using the HEC-2 computer model to determine existing conditions and the effect of the proposed changes in the floodplain. The procedures used are described below.
1. Encode the FEMA FIS HEC-2 computer model for the stream and run the model to assure duplication of the FIS.

2. Develop an existing condition HEC-2 model for the floodplain and floodway by adding surveyed cross sections through the project area.

3. Develop a proposed condition HEC-2 model for the floodplain and floodway by modifying the cross sections in the existing condition model to reflect proposed changes. Verify that this model results in equal or lower flood levels and creates no adverse erosive conditions.

Approvals

The CLOMR was sent to FEMA on July 3, 1991, and approval was obtained in October 24, 1991 (four months). The final Letter of Map Revision (LOMR) obtained after construction was verified by "as-built" plans including compaction certification. The LOMR study was submitted on April 23, 1993, and the FEMA approval letter received on August 11, 1993 (four months).

Case Study No. 2:
Floodplain/Floodway CLOMR followed by Completely Modified LOMR with Hydrologic and Hydraulic Studies

In October of 1986, a CLOMR was completed and submitted to FEMA for a floodplain reclamation project along an approximate one-half mile reach of Walker Branch and Tributary WF4 in the City of North Richland Hills, Texas. This proposed concrete channel confined a wide floodplain and floodway into a much smaller one allowing development of the former floodplain into a residential subdivision. The FEMA CLOMR approval letter was received on February 18, 1987 (approximately 4 months), and construction began.

By the summer of 1989, after most of the construction was done, financial difficulties prevented completion. By the summer of 1993 the project had sat idle for four years without any action when it was purchased by another developer and the construction work completed. During the time since the original CLOMR was approved a new FEMA study was completed for the city and several additional projects were completed on Walker Branch. This meant that a completely new study was necessary for the final LOMR approval. This new study bore little resemblance to the original CLOMR approved some six and a half years earlier.

The final LOMR required a new hydrologic study based on the HEC-1 computer model and new hydraulic studies using the HEC-2 computer model.
These hydraulic studies not only included the construction changes required by the city to complete the project according to current criteria, but also included new models based on the latest FEMA FIS for the city.

The LOMR was submitted to FEMA on July 9, 1993, and the FEMA approval letter was received on November 19, 1993 (about four months).

Case Study No. 3:
Floodplain Reclamation CLOMR and Intermediate LOMR-F before a Final LOMR

A residential subdivision was proposed in the Calloway Branch floodplain in the City of Hurst, Texas. This subdivision was to be constructed along Billy Creek Drive outside of the floodway, but within the floodplain. The study completed in support of a CLOMR more accurately defines the floodplain and floodway of Calloway Branch by adding improved survey and topographic data. The following describes the procedures used in the study.

**Hydrologic Analysis**

It was determined that the FEMA FIS hydrology was current so the existing discharge values were not modified. The city requires design conditions based on a fully developed watershed. This value was obtained from the City Master Drainage Plan.

**Hydraulic Analysis**

The following steps describe the hydraulic analysis of this project.

1. Encode the FIS effective HEC-2 model to obtain a duplicate model.

2. Correct technical errors discovered in the effective FIS HEC-2 model.

3. An existing conditional HEC-2 model was completed by adding survey and topographic data to the corrected effective model.

4. A proposed condition HEC-2 model was developed by modifying cross sections in the existing condition model to reflect the proposed changes at the project.

Since this project was completed outside the floodway an increase in the 100-year flood elevation was allowed under FEMA regulations. However, this is not advisable since increases in the floodplain can precipitate litigation from affected landowners. This project caused no increases.
On January 6, 1993, the CLOMR request was submitted to FEMA and an approval letter was received on May 4, 1993 (four months). Construction was started on the project in May 1993. Since this was a residential subdivision, lots were sold in phases and the developer wanted to finalize construction of several houses before the final grading of the subdivision was completed. The problem with this was that the city would not issue a Certificate of Occupancy for these houses without FEMA approvals.

The solution to this problem was to request a multi-lot Letter of Map Revision based on fill (LOMR-F) to eliminate the requirement to purchase flood insurance. This LOMR-F was based on the effective FIS and did not require hydrologic or hydraulic studies. The LOMR-F was submitted to FEMA upon completion of the residence slabs on September 30, 1993, and the approval letter was received on February 1, 1994 (four months). This allowed the residences to be occupied and construction of the subdivision continued.

**Case Study No. 4: Single Lot Letter of Map Revision based on Fill (LOMR-F) with No Hydrologic or Hydraulic Studies**

A homeowner in the City of Keller, Texas, was paying flood insurance premiums on a residence based on the residence's being located in a studied 100-year floodplain. Field surveys showed that the lowest adjacent grade to the house was at a higher elevation than the 100-year floodplain, so a LOMR-F request was sent to FEMA to remove the flood insurance purchase requirement at the residence. This submittal required the following FEMA forms:

- Form 81-87 Property Information
- Form 81-87A Elevation Acknowledgement
- Form 81-87C Community Acknowledgement

The basic information needed for these forms is shown below:

1. Copy of plat map with recordation data and recorder's seal,

2. Location of map showing exact location of property on the FEMA FIRM (certified),

3. Map showing any structures on the property (certified),

4. Legal description of the property,

5. Lowest adjacent grade to the slab (certified), and
6. Elevation of lowest floor (certified).

The submittal was sent to FEMA on February 28, 1994, and an approval letter was received on March 2, 1994 (one week).

Summary

Our experience has shown that a CLOMR and LOMR with hydrologic and hydraulics studies is required in the following situations:

1. Whenever work is proposed in the floodway,

2. Whenever floodplain work might cause significant increases in the base flood elevation,

3. Whenever required by the local authority,

4. Whenever a FEMA map change is desired,

5. Whenever FEMA information is incorrect, and

6. When the floodplain is undefined or not studied by detailed methods.

FEMA approvals not requiring hydrologic or hydraulic study are appropriate in the following situations:

1. Homeowners or developers requiring single or multiple lot residence flood insurance purchase waivers or premium reductions in FEMA detailed study areas, and

2. When survey information substantiates a change in the floodplain that would not affect flood elevations, velocities, or have other adverse effects (very rare).

This paper has only discussed FEMA requirements. There are a number of local, state, and federal requirements not covered here. Two important areas in this category are the Corps of Engineers regulated Section 404 permits and the State Water Impoundment and Dam Safety Requirements. Most projects involving fill or other modifications in the floodplain areas will require a 404 permit. Whenever detention ponds or other water impoundment areas are to be created or modified, the state should be notified as well.
PART TWO

FLOODPLAIN MANAGEMENT
IN
TULSA AND OKLAHOMA
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ROOFTOP TO RIVER:
TULSA’S UNIFIED LOCAL PROGRAM FOR
FLOODPLAIN AND STORMWATER MANAGEMENT

Charles L. Hardt
City of Tulsa Public Works

Introduction

This paper gives an overview of Tulsa’s floodplain and stormwater program, including our strengths, weakness, and some of the lessons we have learned. Additional papers in this volume describe specific elements of the City’s program. This is not a perfect program, and I want to discuss our weak points and what we are trying to do about them, with a glimpse of what we think the future may hold.

From Worst to Best

Tulsa’s floodplain and stormwater program has come a long way. We have learned some hard lessons. Our program is not perfect, and we are still learning. We have survived some stormy times. The remarkable thing about Tulsa’s program, as a local editorial writer once wrote, is that it exists at all.

Less than 20 years ago, we had virtually no program to manage floodplains or stormwater. We were racking up arguably the worst flood record in the nation. From 1970 to 1984, Tulsa County was declared a federal flood disaster area nine times—more than any other community in the nation. Houses could be flooded with no more than 2" of rain.

Twenty years later, our citizens are enjoying the nation’s lowest flood insurance rates, because the federal government has ranked our program tops in the nation. The Association of State Floodplain Managers has twice given us its coveted local program award. Most importantly, our community has survived nearly a decade without serious flooding—an unprecedented period of relief that shows our system can now handle many small-to-moderate rains without flooding. When the next major rain hits, we will still have flooding—make no mistake about it. Our program is still being built, and even our completed projects have a finite level of protection. But we have made significant progress.

Tulsa’s improvements did not occur accidentally. With the Federal Emergency Management Agency’s (FEMA) help we have produced both a video and booklet (Rooftop to River) that describe the evolution of our program. A
second booklet, *From Harm’s Way: Flood Hazard Mitigation in Tulsa, Oklahoma*, goes into more detail about our floodplain acquisition projects.

We are told that nothing about Tulsa’s program is particularly unique, but that few other communities have been able to sustain the political support to put these pieces together into a comprehensive whole. It is fitting, then, that the program this week is called "Nania—All Together." We have learned the hard way that piecemeal, occasional projects cannot manage urban floodplains and stormwater. Each element of the program must support and strengthen the whole.

**Lessons Learned**

We have learned much, flood by flood, and they have been costly lessons.

We learned to appreciate the support base of the National Flood Insurance Program (NFIP). Tulsa joined the NFIP in 1970, and reaching compliance with regulations took many years of heated debates. Without the NFIP, Tulsa would probably have made little progress over the past two decades. We will always be grateful for the vision and support of the NFIP. But before too many years elapsed, we realized that, in an urban area like Tulsa, it is necessary to go beyond the NFIP standards.

We believe strongly that the NFIP’s national standard, which is necessarily a compromise, is insufficient for an urban area. We advocate managing beyond NFIP floodplains, throughout entire watersheds, with floodplains mapped to take into account future basin urbanization.

We learned to preserve the valley storage functions of a stream, to require compensatory storage when someone fills in a floodplain, to install stormwater detention basins throughout watersheds.

We are learning, increasingly, humility in the face of nature. More and more, our program is based on respect for natural laws.

We are learning to emphasize mitigation before, during, and after disasters. We advocate greater national emphasis on predisaster planning and mitigation, and we applaud the considerable progress being made in national mitigation policies.

We have learned to value partnerships. We enjoy particularly effective working relationships with the U.S. Army Corps of Engineers and FEMA. Local governments need to recognize that no one else can do it for us, so we have got to accept local responsibility. But none of us can do it alone, either.

Broad-based planning is key. An important link in our program is provided by our Stormwater Drainage Advisory Board, made up of volunteers who provide citizen advice and guidance to the Tulsa program. They are truly
unsung heroes who have stayed with us through tough times, helping us through numerous controversial community issues.

Program Assessment

As I said earlier, this is not a perfect program. We are still learning, still experimenting, still growing. For example, we have learned a great deal from preparing for this conference. It has forced us into a critical self-assessment and, interestingly, we have learned from the nation's experiences during the Midwest flooding. Frankly, we realized that we had, to some extent, grown complacent, during a necessary period of local program consolidation. We had identified hundreds of millions of dollars worth of needed capital projects, and we were concentrating on implementation. But the Midwest floods reminded us that we still have areas with fragile levees and finite flood protection that may provide a false sense of security, similar to flooded areas along the Mississippi River.

We were reminded that some of the same kinds of problems could occur here, and we are not fully ready. We had an emergency management system that was light-years ahead of the non-system we had 10 years ago, and we had a plan on the shelf for post-flood mitigation, but a 15" rain could still wreak havoc in our community. We had completed master drainage plans for all our watersheds, and we were implementing the priority projects as quickly as possible. But we realized that our plans missed a vital component: what would opportunities and priorities be after our next flood? Now we are trying to develop updated mitigation plans.

We were out of touch with national policies. Without current knowledge of changing federal policies, how could we plan effectively for recovery from our next flood? We were less than effective in coordinating with our state people and programs.

We were working to marry structural and nonstructural projects, and without a doubt we were making tremendous progress. We had a few showcase projects that included recreation, environmental elements, and community beautification. But we were missing the mark in making the most of the tremendous community assets that stormwater and floodplains offer. We had made great strides in water quality and wetlands management, but we were far from a leader in the environmental field.

In short, we discovered that we must redouble our efforts. And we are trying to do that.
Future Directions

What does Tulsa's future hold? We are working on documenting our program, conducting an ongoing self-assessment, and still trying to learn and improve.

We are embarking on a new cycle of contingency planning, looking at problems and possibilities that could arise in our next flood, hoping to map out ways to make the most of mitigation opportunities before, during, and after future disasters—from whatever cause.

We are exploring new avenues of multiobjective management, including new community trails, greenways, recreation, and environmental projects in conjunction with flood and stormwater programs.

We are trying to strengthen our links with emerging state and federal policies and programs.

Much of our successes and our new horizons rest on lessons we have learned from others. To the extent that we can repay this debt by sharing our own lessons, we are pleased to do so.
This is the story of Tuley, the "gathering place," as the Creeks tribe named it. It is the story of their "nania"—the Cherokee word for "all together"—and the spirit of the people here to overcome disasters. It was those disasters that, many decades later, spawned an evolution for Tulsa's floodplain management.

Tulsa was born in Indian Territory, the cradle of the Five Civilized Tribes, in the Arkansas River valley, now in northeastern Oklahoma. The town flourished during the early twentieth century oil boom and proudly claimed the title "Oil Capital of the World."

Like oil, water was also crucial to the area. Early in the century, Tulsans constructed a reservoir that furnished 20 times their daily needs. Water attracted industry and people. Later, an inland port gave Tulsa a direct waterway link to the seas.

But Tulsa's water history has another, darker side. It is the frightening picture of a torrent of water surging through the community, ripping up homes and smashing mobile homes, swirling away trees, cars, and furniture, twisting and flashing its muddy way through the city like a wet tornado, sucking the very life from its victims, crushing dreams as rains become ravaging floods.

Throughout Tulsa's history, headlines have announced floods as the "greatest rampage in history," "Tulsa's worst flood," or "the Arkansas River hit its highest stage in history today." Tulsa had accepted these unfriendly torrents as tricks nature plays on a community so blessed with natural resources.

Historically, Tulsa's rivers and streams have provided food and water, transportation, power, protection, and beauty. So people built homes and settlements in the broad, flat plains of the lowlands. And Tulsa grew, ever closer to the river and the creeks that feed the river—waterways that normally handle the annual rainfall of 37 inches. But a 15-inch overnight downpour can send water gushing through the floodplain like an avalanche careening down a mountainside.

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1This is the script of a videotape shown at the 1994 conference. It was produced by FEMA's Region VI office, and was written by Billy Penn of FEMA, with assistance from Ben Frizzell of FEMA, and Carol Williams and Ann Patton of the City of Tulsa.
For many years, this proud Midwestern city with a thriving pioneer spirit did little to interfere with that pattern, partly because frontier people believed you have a right to do what you want with your land.

Nature had other ideas. During three months of flooding in 1957, some fought the water to a standstill only to be flooded again three days later. The floods of the 1940s, 1950s, and 1960s prodded the Army Corps of Engineers to build levees in portions of Tulsa and the Keystone Dam upstream.

Without a master plan, each project solved only part of a much bigger problem. It was like trying to stop a leaky sieve by plugging one hole at a time. With one hole plugged, another gushed, often with greater force.

The wet years continued, bringing multiple floods in single years. A baby drowned in 1961. More flooding occurred in 1962. In 1963, it rained almost 9 inches in an hour and a half—an inch every 10 minutes.

Still Tulsa grew, ever closer to the river and the creeks that feed the river. Developments fanned out more and more into the lowlands, building near the smaller, flashy streams that overflowed and became the focus of floods that occurred every other year or so.

Once, those streams flooded with little notice. Now, some of the homes built there would be flooded as many as 10 times. Yet few people seemed to notice, so Tulsa did little to regulate floodplain use or protect floodprone structures.

The Mother's Day flood of 1970 brought people together as no previous flood had. Tulsa entered the National Flood Insurance Program and began, slowly, using Federal Insurance Administration models to regulate land use, although regulations were often ignored. The city favored a wave of growth and territorial expansion that was moving them even more rapidly down into treacherous floodprone areas.

A 1971 Labor Day flood reminded the city to use bonds approved in the 1960s that were voted to fund channels and buy up land in the floodplain.

June 1974's $18 million flood triggered a community debate, dubbed Tulsa's "Great Drainage War." Opinions ran wild. As flooding increased, it became more difficult to ignore the impact on the community, and 1974 became known as "The Year of the Floods." Some people took sides to assign blame. With enough sin to go around, the consensus was, "Whoever is at fault, there is no excuse for this water in our homes."

In south Tulsa, the city and the Army Corps of Engineers began developing channels on Joe Creek. Meanwhile, citizens demanded more. They wanted the floodplain cleared. The cumulative damages to some homes exceeded their value, in some cases threefold. Victims appealed to the Federal Insurance Administration. The city responded with a combination of stopgap public and private channel projects. They cleared 33 houses for right-of-way to build a three-mile channel mid-stream on Mingo Creek. But floodplain issues were far from resolved.
The Great Drainage War picked up momentum. Flood victims mobilized and engaged in hot political skirmishes with developers. City leaders formed a partnership with the Federal Insurance Administration and the Corps of Engineers to search for better ways to solve the problems of flooding.

On Memorial Day, 1976, 10 inches of rain fell in three hours. Three people died, 4,000 structures were flooded, and there was $40 million in damage.

Flood fears hit an emotional peak, touching off a revolution in floodplain management. Debate intensified and activity increased. Together, voters approved several flood-control projects. The city broadened its vision. This time, master drainage plans covering entire watersheds called for a Tulsa partnership with the Corps of Engineers to construct channels and stormwater detention basins.

New development was finally being regulated throughout the city. They also used $1.7 million to acquire 30 houses and used those properties to construct detention ponds upstream on Mingo Creek.

Then some dry years came. When the water dries out, so does the commitment. The program lost momentum and progress slowly eroded. Even with the floods of 1979, 1980, and 1981, the city could not shake the lethargy of the dry years. A 1982 report warned, "Tulsa-area creeks will flood again." The report predicted that damage on Mingo Creek alone would average $20 million annually. It concluded that urbanization in the watersheds would increase both the frequency and severity of flooding.

It seemed to Tulsans that holidays meant celebration and anguish: Mother’s Day, Labor Day, Memorial Day, and now Memorial Day again. This time, Memorial Day 1984, the disaster that finally brought Tulsans all together, as the Cherokees would say, a time for their "nania."

People woke up and found disaster everywhere, and all together, decided to come to terms with flooding. Flooding that killed 14, left $180 million in damage, and swamped 7,000 homes and businesses. Flooding that brought nine federally declared disasters in a 15-year span, with the cost of a generation of floods topping $300 million!

Legends from Indian Territory days tell of a Creek tribal chief who once said, "No man could remain chief of my tribe who would place an overnight camp in these bottomlands."

With this thought and the knowledge of history, Tulsans cemented their commitment. People in the hills joined those in the lowlands to demand leadership that would move them to safer ground and put parks in the floodplains. Finally, after years of anguish, Tulsa reached its watershed point in floodplain management.

After the flood of 1984, Tulsa leaders created a strong flood and stormwater management program and levied a service charge on utility bills to finance its work. Tough but fair criteria—by far the toughest in Tulsa’s history
and even tougher than federal standards—would guide growth. Major new
development would have to hold excess stormwater on site and release it slowly
downstream. A network of federal, state, and city agencies cooperated to
establish and enforce these new policies.

The city used proceeds from the sale of flooded houses and interest
from sales tax revenue bonds to purchase more than 300 flooded homes and 200
mobile homes after the 1984 disaster. Insurance claims and a Section 1362
mitigation grant from the Federal Emergency Management Agency (FEMA)
supplemented city funds. The land was dedicated for open space or nonstructural
works.

With this new start, Tulsa developed 14 master drainage plans and spent
nearly a quarter of a billion dollars on flood control projects. In cooperation
with the Corps of Engineers, they improved creek channels and constructed
detention basins. And a local newspaper raised donations to pay for hiking and
biking trails in those special areas.

In a cooperative effort by the city and the local news media, Tulsans
are exposed to flood awareness information. The effort includes promoting the
purchase of flood insurance and provides that people in flood hazard areas
receive regular warnings.

Tulsa extended its vision for floodplain management in the fall of 1986
when rains upstream pushed Corps releases from Keystone Dam to 300,000
cubic feet of water per second. Tulsa’s $3 million in damage was low compared
to neighboring communities, and everyone realized that more homes could have
been saved with a regional plan. So, Tulsa leaders grabbed the chance to make
their programs better. Least terns now nest in a natural detention basin that
replaced a swampy pocket of flooded homes along the west bank of the
Arkansas River, still another example of extending the vision.

Mother’s Day again, this time 1993. A weather system dumped rain on
the city’s watersheds similar to the Mother’s Day deluge of 1970, the storm that
launched Tulsa on its way toward better floodplain management. This time their
efforts paid off. In areas where flood control work had been done, there was no
flood damage. More than two-thirds of Oklahoma’s counties, including every
county in the Tulsa region, received a federal disaster declaration. Yet the city
escaped having to relive the watery nightmare of the ghosts of holidays past.

All of this new development is not without responsibility during severe
weather situations. To ensure the safety of Tulsans, including those who use
these facilities, the Emergency Management and Public Works groups have
combined weather forecasting with the city’s warning systems to get people out
of harm’s way.

The program has accomplished much for the people of Tulsa. Since
new regulations were adopted in the late 1970s, Tulsa has no record of flood
damage to any structure built according to those regulations. Several storms
have challenged the new systems and, in each case, without significant damage.
Tulsa stands today as a model of community floodplain management. Perhaps no city in the country had a more frequent record of flooding. Certainly no other city has come such a long way, from having nine federally declared disasters in 15 years to having the lowest flood insurance rates in America.

The work here has done much to improve Tulsa's quality of life and has received recognition from many quarters. In recent years the Association of State Floodplain Managers twice awarded Tulsa top honors. In 1992, FEMA's National Flood Insurance Program gave Tulsa its highest rating, making flood insurance premiums for the city the lowest in the nation—an award that saves Tulsans a quarter of a million dollars annually. The same year, FEMA presented Tulsa its Outstanding Public Service Award in recognition of all Tulsans have done in floodplain management.

Outside government, the national media has held Tulsa as the standard for floodplain management across the country. From CBS News and the New York Times, to the Des Moines Register and the Kansas City Star, reporters and critics alike are impressed with the accomplishments Tulsans now enjoy.

Tulsa will flood again. It is inevitable. But it will not hurt as much the next time, because of the "all together" Tulsa spirit of "nania"—a commitment by all to strive for the best possible quality of life in one of America's most liveable cities.
JUMPING HURDLES IN PROJECT IMPLEMENTATION: MINGO CREEK LOCAL FLOOD PROTECTION PROJECT

Valerie S. McCaw
Ruben W. Haye
City of Tulsa, Oklahoma

Introduction

Starting with reconnaissance studies in the early 1970s, the Tulsa District of the U.S. Army Corps of Engineers (Corps) has been working diligently to develop a flood control project along Mingo Creek, Tulsa, Oklahoma. On November 17, 1986, P.L. 99-662 was passed authorizing construction of the Mingo Creek Local Protection Project. This project consists of 23 stormwater detention sites and seven miles of creek channelization. The authorized project cost estimate was $169 million. The City of Tulsa is responsible for a cash contribution of 5% of the total project cost and providing all lands, easements, rights-of-way, and waste disposal areas and relocations.

In January 1988, the City of Tulsa signed the Local Cooperation Agreement (LCA) with the Corps for construction of the project. One major advantage of the LCA is that the federal government pays 95% of the construction cost; the biggest disadvantage is the "red tape" that the city must go through to accomplish the project.

The LCA provided for a Memorandum of Understanding (MOU) to be developed by the Corps and the City of Tulsa to define the specifics of how the Corps and the city would communicate during the construction of the project. The MOU established procedures for the city's review of and comments on Design Memoranda, construction plans and specifications, and construction contract administration. A significant provision of the MOU was the establishment of biweekly coordination meetings. As a result, representatives of the Corps and the city meet biweekly to discuss topics relating to the overall project or technical matters.

The project team was multi-disciplined. Not only were design engineers used, the team also consisted of experts in accounting, the law, maintenance, public relations, planning, landscape architecture, traffic engineering, and parks and recreation. In these meetings, the city's personnel established their credibility in floodplain management and significantly affected the course of project design.
However, projects of this size create a number of hurdles that must be cleared in order to be successful. We would like to discuss four major hurdles and how we turned them into project successes for our award-winning team. We offer these examples of our experiences and challenges in implementing the Mingo Creek Flood Protection Project to benefit other floodplain managers who are interested in developing flood control projects with the Corps of Engineers.

**Working with the Public**

The first hurdle was overcoming apathy and accommodating citizens' needs. While making everyone happy all the time is impossible, we still try. Our record flood occurred 10 years ago in May 1984, and memories are fading or flood victims have moved away. Flood control projects are easy to explain to a flood victim, but they become more difficult to justify as time passes. That is why the city has implemented an aggressive program of public meetings and citizen contacts to "sell" our project. We hosted public meetings during different project phases. Often, the first one is right after conceptual design to show the city’s intentions and foster discussion. Sometimes we have meetings right before construction to explain the process and describe some of the inconveniences that we expect and how we will deal with them. Our public speaking as well as our customer orientation skills are well tested at these meetings. The city has developed several aesthetic design features that make the project more "park-like" and encourages multipurpose use. Examples of these are curvilinear trickle trails and perimeter berms, varying side slopes, jogging/maintenance trails, permanent water features, and landscaping. When photos and renderings of these features are shown at the public meetings, some citizen concerns are reduced and they are more receptive to the project.

**Right-of-way Acquisition**

According to the LCA, the city is responsible for purchase of lands for the entire Mingo Creek project. The second hurdle was to minimize right-of-way (ROW) costs and avoid project delays caused by litigation; as a result we have adopted three approaches: negotiation, minor redesign, and redesign. When these approaches failed, condemnation was used as a last resort. Examples of the three approaches are discussed below.

**Negotiation**

We have a site currently under construction that we obtained under a "win-win" negotiation with the land owner. He owned 83 acres of land, much of it in the floodplain. We negotiated with him to donate 23 acres to the city for our stormwater detention facility. In exchange, the excavated soil was used to
regrade the remainder of his land. He now has 60 acres of land ready for development, which will eventually expand the city's tax base. The city saved money on land acquisition, and the Corps saved money on hauling the excavated material. Another negotiation was convincing the Park Department to use an existing city park for stormwater detention. The city saved money on land acquisition and was able to replace and upgrade the 20-year-old park in accordance with the neighborhood's wishes.

Minor Redesign

The project includes two channel improvements in existing easements. On one channel minor redesign changes were made to stay inside the existing easement, and ROW costs were saved. For the other channel, the addition of a retaining wall instead of a sloped bank minimized ROW requirements and maintained the manufacturer's access for his semi-trucks. The savings in ROW cost far exceeded the cost of the retaining wall.

Redesign

The city saved ROW costs by completely redesigning one facility. It was a challenge to get the Corps to consider a major design change so late in the project. The city is paying the Corps $20,000 to redesign the facility, but will recover this cost 10 times over in ROW cost savings. Not everything the city requests is redesigned; actually design requests were made on two sites but the city elected to proceed with only one based on costs.

Coordination within the City

Working with departments that have not been involved with Public Works capital projects is another hurdle. Our Engineering Department used the expertise of other city departments to improve project design. For example, we involved the Maintenance Department in plan review. At their suggestion, we modified projects to improve access for maintenance vehicles and equipment. They suggested entrance ramps, turnarounds, and the unique trickle trail design (Figure 1). This helps to establish "buy-in" from field personnel and, in the end, improves maintenance efficiency and results in lower operation and maintenance costs—long term costs borne solely by the city. The Park Department was involved in developing passive and active recreational uses in the detention facilities during dry times. In Tulsa, detention facilities create large green spaces that people are clamoring to use. The city has leased these facilities to several non-profit soccer and softball associations, who will maintain them at their own expense. We also used Park Department expertise in vegetation and tree planting to develop of project revegetation and landscape plans.
Another hurdle was to have the Corps, traditionally a "big" project organization, treat Mingo Creek as 30 "local" projects. Several key elements were critical to the project's success. While the city needed to make the Corps more sensitive to local problems, we also needed to learn the way the Corps runs a project. We have taken Corps team members to city public meetings and meetings with interested citizens, so they can see up front the issues and
Jumping Hurdles in Project Implementation: Mingo Creek

commits facing the city. The Tulsa District team is more sensitive to our local
concerns for many reasons. One is that the project is literally in their backyard;
their office building overlooks two project sites. One of these sites has been
adopted by the Corps and named after their recently deceased project manager,
Larry Redford. Corps employees use this site to walk or jog during lunch and
have picnics. In addition, many Corps team members live near the Mingo Creek
basin. They therefore have a personal interest in this project.

The city has learned, to our advantage, the "Corps" way of
accomplishing a project. When we started planning we asked the Corps to install
jogging trails in the projects. The Corps stated that recreational facilities were,
according to the LCA, a nonparticipating cost. When the city explained that
many of these also serve as essential maintenance roads, the cost was approved
as part of the project. Compromise on both sides is essential to success.
Examples are the Corps compromise on the aesthetic design features and the city
compromise on the riprap channels. Our maintenance personnel consider riprap
channels hard to maintain, but when the Corps agreed to place a 10-foot-wide
concrete road in the bottom, it eased maintenance concerns.

The final element to a successful project is mutual respect for each of
our roles and capabilities. We all realize how everyone can contribute to the
project. We have some lively "discussions," at times, but we all know that the
project is only improving as we work to complete it.

Conclusion

The city has been successful in overcoming these hurdles. Citizens, for
the most part, feel they have an ownership in what is going on. Recently one
maintenance crew was driving along the maintenance road (jogging trail) doing
routine maintenance. A jogger stopped them and requested that the vehicle not
be driven on "their" jogging trail.

Because the city was willing to modify plans and use sound reasoning
with individual owners, the necessity to enter condemnation has been minimized.

Our willingness to include other departments in our review process has
led to more efficient use of the flood control facilities and has saved the city
money.

We have not used the word "partnering," but the Mingo Creek project
is an excellent example of a successful partnership. According to the Corps
project manager, "It takes a lot of effort on everyone's part to work so closely
together throughout such a large project; and, at times, the stress factor and
frustration levels are very high. It is a lot harder to do it this way, but we are
reaping the benefits now, and everybody likes that." The results are award
winning. Two of the sites produced by this partnership were recently recognized
among 1994's ten Outstanding Engineering Achievements in the United States
by the National Society of Professional Engineers. We noted with pride that we were the only public-public partnership among the award recipients this year.

Through our mutually effective design efforts, the authorized project estimate has been reduced from $169 million to $143 million.
STORMWATER PLANNING AND CAPITAL IMPROVEMENTS IN TULSA, OKLAHOMA

H. Dale Reynolds
City of Tulsa, Oklahoma

Introduction

The City of Tulsa, Oklahoma, experiences frequent, severe flooding. By the 1980s, Tulsa County had been declared a federal flood disaster area nine times in 15 years, more than any other community in the nation. A devastating flood on Memorial Day weekend 1984 left 14 people dead, 7,000 structures flooded, and $180 million in damages. The shock of the event forced Tulsa to develop a comprehensive stormwater program. One of its major components is a planning and capital improvement program that has resulted in over a $200-million investment to date, with millions more planned.

Planning

Basin Drainage Plans

Tulsa consists of up to 30 or 40 (depending on how they are subdivided) small urbanized watersheds. Master drainage plans for the individual basins began in 1977 and proceeded fairly slowly up to 1984. The basin planning process accelerated dramatically after the 1984 flood, resulting in plans for most of the basins being completed by 1994. These basin plans are the foundation of the city’s entire stormwater program. Floodplain maps are developed using city criteria, which are more stringent than that of the Federal Emergency Management Agency (FEMA). City criteria evaluate ultimate development conditions and extend down to 40-acre drainage areas. Flood problems are identified through hydrologic and hydraulic studies, as well as discussions with residents. Different alternatives are evaluated to address the problems and a single, comprehensive plan is adopted that recognizes the complexity of the drainage system and ensures against piecemeal projects that may simply move problems from one location to another.

Citywide Master Drainage Plan (MDP)

As the city approached completion of the many individual basin drainage plans, it became apparent that these plans should be consolidated into a true citywide master plan. This would provide compilation of data to provide a citywide perspective on the magnitude of problems and resources required to
address them. It would also standardize data and criteria used by the many different engineering consultants over several years. The end product of the City of Tulsa Flood and Stormwater Management Plan, 1990-2005, was a citywide list of prioritized projects based on an adopted rating formula that includes economic benefits, street flooding, number of structures affected, and project cost. These needs were balanced against potential funding to provide some general scheduling of when different projects might be constructed.

**Capital Improvement Program**

*Results from Citywide MDP*

The Citywide MDP identified approximately $300 million in additional funding needs beyond those already appropriated to address existing flood problems. An analysis of potential funding indicated about $168 million as a reasonable amount over the 15-year period of the plan. The remaining $132 million in needs had to be deferred beyond the plan period. The projects become a part of Tulsa’s overall Capital Improvement Program, and therefore must compete with streets, water, wastewater, and other public facilities for funding.

**Funding**

Major stormwater projects are funded primarily by a temporary one-cent sales tax, enacted in 5-year periods since 1980, that includes other city capital projects, and by general obligation bond issues. Some projects are funded from "fee-in-lieu of" accounts, which allow private developers, under certain circumstances, to contribute fees toward construction of regional detention sites, rather than providing on-site detention. The city’s stormwater utility fee is not used for major capital projects, although some small local projects are funded by it. Since 1980, over $200 million has been committed to the city’s stormwater capital program, including about $80 million in federal funds for the Corps of Engineers’ Mingo Creek Local Flood Protection Project.

**Types of Projects**

The projects cover a wide range of size and complexity. Small local projects, as small as $10,000 to $20,000, addressing localized problems, are an important part of our program. Many citizen calls, City Counselors’ referrals, and calls to the Mayor’s Action Center are related to these problems. Many FEMA repetitive losses are also related to local problems. These projects can be simple inlets and storm sewers. On a larger scale, we construct large storm sewers; concrete and grass-lined channels; single purpose regional detention basins; and complex, large-scale, multipurpose detention basins.
Mingo Creek

The most complex project underway is the joint City of Tulsa/Corps of Engineers Mingo Creek Local Flood Protection Project. This project is currently estimated to cost $143 million and consists of 23 regional detention sites and about 9 miles of channelization. The project was authorized as a federal project in 1986 and will be completed around 1996, taking 10 years to design and construct. The cost sharing will be about $80 million federal and $63 million local. It will solve most of the major flood problems in the 61-square-mile Mingo Creek watershed, which drains roughly the eastern one-third of the city and represented about two-thirds of the damages in the 1984 flood.

Nonstructural Measures

Tulsa has become more serious about considering nonstructural solutions to many problems. The basin drainage plans evaluated nonstructural solutions to some extent but probably do not consider special circumstances such as mitigation after a flood event. The city undertook such a mitigation effort after the 1984 flood in an effort to break the rebuild-and-reflood cycle. A series of moratoria was adopted to prevent rebuilding of some of the worst flooded structures until a plan could be developed. An acquisition program was developed using FEMA Section 1362 funds, which the city matched on a 50% basis, flood insurance payments, and other local and post-disaster funds. About 300 single-family residents and a mobile home park with 228 pads were acquired. Other acquisition to date has brought the total number of structures acquired close to 1,000. In the last bond issue, the city funded a pilot floodproofing/acquisition program that is still being developed. One report has been prepared developing criteria for prioritizing future acquisition. The goal of the pilot program is to incorporate nonstructural mitigation, before and after a flood event, as a strategy with equal importance to structural projects. A good comprehensive program should give full consideration to all strategies that can help solve the problems.

Partnership Planning

Citizen Participation

The most basic level of partnership planning begins with citizen involvement. Throughout the basin drainage planning process of the last 10 years, and even in project design, the city held hundreds of public meetings and workshops. These meetings can be frustrating to engineers and other staff; the meetings are often emotional, and people can appear irrational to our frame of reference. However, public support is essential; and ideas developed at many of these meetings resulted in significant changes in plans and projects. Often, in
retrospect, the changes resulted in significant improvements. One result of this partnership has been voter approval of every stormwater funding issue since 1980.

City Departments and Other Agencies

At another level, departments and agencies such as the Park and Recreation Department, Public Works Maintenance Division, the Tulsa Public School System, the Oklahoma Department of Transportation, and the Oklahoma Turnpike Authority, have been important partners on many projects. Often in fully developed, older parts of the city, the only vacant land available is park or school land. We have completed several successful projects on each. The Park Department was initially concerned that Public Works would show proper sensitivity to its concerns. After one or two major successful projects, confidence in the partnership concept was well established. The partnership with the school system has been more businesslike, with some difficult negotiations related to value of school property needed for detention projects. Even with the tough negotiations, there has been a good partnering relationship with benefits to both sides.

Corps of Engineers

One of the city’s most successful and long-standing partnerships has been with the Corps of Engineers. A legal document, the Local Cooperation Agreement, was signed in 1988 after the Mingo Creek project was authorized, defining responsibilities of the two parties; and a memorandum of understanding spelled out procedures in more detail. In addition to the formal aspects of the partnership, the City of Tulsa and the Corps have developed an excellent informal, day-to-day working relationship. The fact that the Tulsa District is located in the same city undoubtedly enhances the partnership. The Corps is one of the city’s most valuable partners in solving Tulsa’s flood problems.

Characteristics of Partnerships

A true partnership involves tradeoffs and benefits to all parties. The partnership reaches maturity when all parties truly adopt ownership, and it becomes "our project" rather than "we'll do you a favor to help your project." When adjoining residents start questioning city maintenance crews about what they are doing to "their (the residents') project," that is a sign of ownership. When the Park Department approaches Public Works about expediting joint projects so park facilities can be developed at these sites, that also is ownership. As another example, the Corps "adopted" one of the Mingo Creek sites adjacent to their new office building and dedicated it as a memorial to Larry Redford, a
long-time, highly respected Corps’ employee who was their project manager on Mingo Creek when he died suddenly in 1993.

**Multi-Objective Management**

*Floodplain Resources*

The value of floodplains as resources has been widely extolled in the environmental community. Floodplains provide wildlife habitat, flood control, water quality, and numerous other functions. In urban areas, they often provide less "natural" but equally important functions such as active recreation (soccer, softball), passive recreation (walking, biking), open space for psychological refreshment, and park development. In urban areas, open space is usually at a premium, and floodplains often constitute a major source of open space. Any stormwater project has to be evaluated as an opportunity to enhance, or degrade, these valuable resources. Natural floodplains and engineered detention storage sites are generally used less than 1% of the time for actually storing floodwaters. To be so extravagant as to allow any valuable resource to lie idle and unused 99% of the time simply does not make sense. The demand to use these sites will develop, so it is only prudent to plan for this usage from the beginning.

*McClure Park Detention*

McClure Park was one of the city’s earliest, high-visibility, multipurpose projects. In an older, existing park, a plan was developed that first carefully evaluated the facilities and resources of the site. Existing facilities (including the swimming pool and recreation center and stands of mature trees) were excluded from any construction. Other facilities including tennis courts, a parking lot, and a baseball field were in a deteriorated condition; so they were removed and those areas, along with some open space, were lowered by excavation to provide storage. New, improved facilities were constructed, along with numerous maintenance/walking trails. Extensive landscaping more than mitigated the loss of a relatively few trees that were removed during construction. The result was a much improved park facility, in addition to a stormwater detention basin.

*Turner Park-Rogers High School Detention*

Another example of multipurpose development is the Turner Park-Rogers High School Detention Basin. Part of the facility is on Turner Park, where storage is provided by a berm at the downstream end that enhances existing floodplain storage in the park. This avoided any significant construction in the main part of the park, which had numerous trees, tennis courts,
playground equipment, and a recreation center (which is above flood stage). The portion on school property required removal of an older running track and baseball field and extensive excavation. Using money paid by the city to the school for purchase of an easement, the school built a much-improved new running track in the bottom of the excavated area and a new baseball field on another part of the school property. The entire project is heavily used by the school’s athletes and park users.

**Putting It All Together—Mingo Creek**

The Mingo Creek Project provided the greatest opportunity to impact a large region of the city—positively, if done right, negatively, if done wrong. The heart of the project is about a 2.5-mile stretch that contains several of the largest detention facilities. Initial designs were of functional but single-purpose flood control facilities. Realizing the opportunity, the city formed a team of engineers, planners, and landscape architects to develop concepts that would preserve its functions but also create community amenities. These concepts included such things as curvilinear designs and varying side slopes for a more natural appearance; extensive landscaping; combination maintenance/walking trails; permanent ponds; some open spaces sized for active recreation like soccer and softball; and good access with parking lots. These concepts are being incorporated to some degree in all of the detention sites, with great success and positive community acceptance.

The Mingo Creek Project is a textbook example of all the elements discussed above: comprehensive planning; extensive partnerships at all levels, including public involvement; nonstructural approaches; and multipurpose use as a basic element in every individual project. One acknowledgement of the success of this approach occurred earlier this year when the City of Tulsa and the Corps of Engineers received recognition from the National Society of Professional Engineers for a portion of Mingo Creek as one of the top 10 outstanding engineering projects in the nation.

**Conclusion**

The City of Tulsa has developed a comprehensive program of stormwater planning and capital improvements as a part of its overall stormwater management. The capital improvement program has been successful because it includes, in addition to technical engineering expertise, the elements of comprehensive planning; partnership planning at all levels, beginning with citizen involvement; nonstructural approaches; and multi-objective management. The success is reflected by the ongoing funding support of Tulsa residents and the acceptance of the multipurpose projects as assets to the community.
FINDING LOCAL VISION, LEADERSHIP, AND POLITICAL COURAGE

Kathryn B. Hinkle
City of Tulsa Stormwater Drainage Advisory Board

Introduction: Recipe for Stormwater Success

This paper describes the City of Tulsa’s quest to find the kind of vision, leadership, and political courage necessary to make a local floodplain and stormwater management program work.

Through trial and error, Tulsa has concocted a recipe for stormwater success that includes several essential ingredients that are hard to quantify. They cannot be bottled or bought. But without them, Tulsa would still have no floodplain or stormwater program.

Taken together, they have strengthened and broadened our community base. They have helped sustain our program through its turbulent early years. Today, our program is largely accepted. It is a recipe that has worked for Tulsa, and I believe it can work elsewhere.

Key Ingredients

Tulsa has learned that planning and programs go better, in the long term, with generous shares of involvement by a broad cross-section of interested citizen and community groups. Some of the key ingredients are described below.

Grassroots Citizens

At the grassroots level, many individuals, such as many first-time flood victims, may not be involved in government at all. Yet these are the citizens closest to the problems. They will tell you—and I agree—"Nobody knows my neighborhood better than I do."

They are essential as problem-identifiers. And they may also offer possible solutions. Ultimately, these are the people who must approve funding and political leaders at the polls, so grassroots support is critical.

Citizen Leaders

Grassroots people who have risen to positions of some influence could be called citizen leaders. These are the citizens who are members of neighborhood associations, city committees, boards, planning districts, special-
interest groups, and the like. They also may have considerable knowledge about the government process.

An excellent Tulsa example is Tulsa’s City Councilor Robert Nelson. He was a flood victim, then a flood protestor, then chair of a homeowners’ association, then a member of the stormwater advisory board, and now a member of the City Council.

Citizen leaders may be willing to spend a great deal of volunteer time becoming educated about specific issues. They can be helpful in identifying both problems and options for solutions. Some may well become community-opinion shapers.

**Business Leaders**

This category includes individual businessmen and women, corporations, and Chambers of Commerce. Keep in mind that they may be critical of regulations and additional taxes or fees, and that is often an understatement.

Business leaders can often lend invaluable fiscal or technical expertise. And they certainly can help shape community opinion.

**Technical Staff**

The backbone of any stormwater program is the technical staff. At a minimum, they are the implementers, the people who must toil day in and day out to make things work.

If you are as fortunate as we are in Tulsa, they can also bring vision, creativity, energy, and sound judgment to the task. In Tulsa, the list of staff talent is too long to cite. Some you have already met at this conference, including Charles Hardt, Michael Buchert, Dale Reynolds, and Carol Williams. These are the kinds of people who have brought the program together and who make it work.

**Political Leaders**

Politicians are often held in low regard in this country, but the political art of public policy is a noble calling. Tulsa is fortunate to have been blessed with a long line of able politicians who have functioned not only as consensus shapers but also as leaders. They are the lightning rods for community opinion.

In the beginning, Tulsa’s political leaders had to be able to withstand a lot of flak over this program and they were willing to do what they considered the right thing, regardless of political cost. They have not just followed public opinion. They have mustered the political courage and vision to lead this community, in the best sense of those words.

We have many examples, such as Susan Savage, current mayor, and J. D. Metcalfe, who was the city’s elected Street Commissioner from 1984 to
Finding the Local Vision, Leadership, and Political Courage

1990, during the formative years of our program. Commissioner Metcalfe could well be called the father of Tulsa's floodplain and stormwater program.

Without such political courage and leadership, Tulsa would still be flooding every year.

Outside Help

This category includes national experts, such as your group, the Association of State Floodplain Managers. We have also received stalwart help from state and federal agencies such as the Oklahoma Water Resources Board and Department of Civil Emergency Management, the Federal Emergency Management Agency (FEMA), and the U.S. Army Corps of Engineers. We have also received generous help over many years from private consultants, such as Tulsa's Ron Flanagan and others.

They have been essential to the success of our program. Especially in the beginning, we had to pull in expertise from around the country, until we could develop our own. Many national leaders, such as Gilbert White, have generously shared their expertise, ideas, and resources.

We are fortunate to enjoy particularly effective partnerships now with FEMA and the Corps of Engineers.

Critics

It is imperative in developing a workable process to include your critics. It is hard to love your critics, sometimes even hard to listen to them.

But critics can be agents for change, and you are smart to listen to them carefully, and try to evaluate their ideas objectively. Some of your most valuable critics may be community idealists and visionaries, those rare individuals whose talents need to be nurtured and protected. Remember, a former critic can become your biggest supporter.

News Media

In Tulsa, the news media have been through repeated disasters, and they are remarkably sophisticated about the issues. That does not mean they have always been supportive, but they are an essential element—and often the most critical one—in our chain of communication with the public.

Whatever you do, do not underestimate the value of having an informed and involved news media.

Combining the Ingredients

Now, how do you put it all together? Tulsa's program has combined planners, engineers, lawyers and other staff; elected officials; city board
volunteers and former adversaries turned into supporters. In many respects, Tulsa has just been remarkably lucky in the quality of its leaders and their vision, integrity, and courage. And the public really has been involved. From the beginning, we believed in public participation in this program. You cannot just talk the game, you have got to believe it. We have held literally hundreds of public meetings, at diverse locations such as picnics, creek banks, and detention basins.

When possible, we go out to the citizens. We do not want to make them always come to us. We have held meetings before, during, and after the planning process and at critical policy points and we are still doing so.

One of the things we have learned on the Stormwater Drainage Advisory Board is to include both developers and citizens who are experiencing flooding problems first hand, so we can keep in touch with the broad spectrum of opinions.

We have also learned that just one person can really make a difference, even in a community this size. And one program can make a difference. Our stormwater program has been a catalyst for progress in other areas.

For example, in 1924 Tulsa leaders developed the city's first plan, which envisioned a system of recreational trails along creeks, such as Mingo Creek. The 1924 plan urged Tulsa to become the "Park Paradise of the Southwest" by preserving "hundreds upon hundreds of almost-undiscovered, picturesque acres at her very doors, unchanged since first trod by the Osage and the Pawnee braves."

Years later, stormwater leaders rediscovered that plan, and now we are implementing some crucial parts of it: building maintenance trails along drainageways that are also used as recreational trails. They are popular with joggers, hikers, bicyclists, horse riders. The Tulsa Trails are slowly but systematically being built, networking throughout this community on a backbone of creeks and rivers.

Dedicated stormwater funding is the base that has given the program a chance to prove itself. It is allowing us to help provide school sports complexes, better park facilities, seed money for soccer fields, and a wide range of enhancements—all on the foundation of flood and stormwater projects.

Conclusion

Once you have such a program, your floodplains and stormwater can become resources, and people will congregate there just as they do at our River Parks along the Arkansas River floodplain.

As it turns out, the Tulsa philosophy on community service and leadership was set out well in that 1924 Tulsa Plan I mentioned earlier:
Your city—its growth, enterprise, cleanliness, beauty, and prosperity—is your responsibility. Are you working at it?

A city, like a tree, grows as it is trained, straight or crooked. If selfishness dominates it, it will not thrive, and no one will love it. If generous men and women with vision are its cultivators, it will grow and flourish, and the stranger at its gates will enter and ask for a chance to work for it.

That is the spirit, the essential ingredient, and the key to vision, leadership, and political courage necessary to make a floodplain and stormwater program work.
PUTTING IT ALL TOGETHER,
KEEPING THE SYSTEMS WORKING,
AND PAYING THE TAB

Mike Buchert
City of Tulsa Public Works Department

Introduction

This paper describes the overall organization and financing of Tulsa’s stormwater and floodplain management programs. The Public Works Department was created during FY 1990-1991 as one of the results of the change from the commission form of government to the mayor/council form. Public Works is the result of the consolidation of four departments: Engineering, Stormwater Management, Solid Waste, and Water and Sewer. The Public Works Department currently includes five divisions: Policy Development, Engineering Services, Environmental Operations, Public Facilities Maintenance, and Customer Services. This 1,500-employee department is responsible for planning, constructing, operating, maintaining, and managing city streets, water, wastewater, stormwater, solid waste, engineering, public property, and related customer services.

For FY 1993-1994, the Public Works Department’s operating and capital budget was in excess of $180 million. The department operates with appropriations in eight operating funds and several capital funds. Stormwater expenditures are covered by the Stormwater Enterprise Fund.

Organization

Stormwater programs operate within the five divisions of Tulsa’s Public Works Department. The Assistant Public Works Director oversees policy planning and implementation. This office helps all operating divisions run more smoothly and efficiently in a way that contains costs. It provides support for budget preparation; coordinates external/internal information including public involvement, public awareness, and Community Rating System programs; is responsible for coordination of environmentally related activities between the city, utility authorities, and various state and federal environmental regulatory agencies.

Tulsa’s Engineering and Planning Division plans, designs, and administers capital projects involving water, stormwater, wastewater, and
streets. It monitors the NPDES permit application process, and coordinates the $143 million city/federal Mingo Creek flood control project.

The Environmental Operations Division is in charge of all city water reservoirs, water treatment plants, the water distribution system, stormwater collection system, wastewater collection system, wastewater treatment plants, disposal administration of the trash-to-energy plant, and the Quality Assurance section, which includes all laboratories, industrial monitoring and pretreatment, and stream monitoring. It is responsible for maintaining and operating all the city facilities that deliver these services.

Surface Drainage/Vegetative Management is a section of the Public Facilities Maintenance Division. It maintains the stormwater drainage channels and detention basins using contract labor and in-house crews for routine mowing of flood control facilities and maintenance of public right-of-ways. It used 28,296 hours of "free" labor provided by the Municipal Court’s misdemeanant program to pick up trash and hand clean drainageways.

The Customer Services Division provides services for land development, building plans review and permits, utilities billing and collection, building construction inspection, as well as field customer services involving parking control, water meter reading, and refuse collection administration. The Development Services Section maintains the ALERT System used in Tulsa's flash flood emergency response program. The Utilities and Permit Services Section coordinates accounting, billing, and collection for city utilities including water, sewer, stormwater, and refuse services, and administers the one-stop building permit process.

Funding

In 1985, a special fund was created for the purpose of identifying and controlling all revenues and expenses attributable to stormwater drainage services. Disbursements for costs of data collection, planning, maintaining, operating, and improving drainage services and facilities are made from this fund.

The stormwater fee is based upon a charge of $2.58 a month per equivalent service unit (ESU), which is defined as 2,650 square feet of impervious area. Every single-family residential home is considered to have one ESU. Multi-family, commercial, and industrial developments are charged $2.58 for every 2,650 square feet of impervious area.

That brings in approximately $9.5 million per year. It was about $8 million originally, but we have had a couple of rate adjustments since that time. The major part of that money goes for operations and maintenance (Table 1). No bonds are sold to finance these projects. We will not go into debt for this particular fund.
Table 1. Distribution of revenues generated by stormwater utility fee.

<table>
<thead>
<tr>
<th>Operations &amp; maintenance</th>
<th>$ 6,092,618</th>
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</thead>
<tbody>
<tr>
<td>Small capital projects</td>
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<tr>
<td>Planning &amp; engineering</td>
<td>$ 636,894</td>
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<tr>
<td>Customer services &amp; regulation</td>
<td>$ 746,313</td>
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<tr>
<td>Indirect costs</td>
<td>$ 604,080</td>
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<tr>
<td>Transfers to general fund</td>
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<tr>
<td>Administration</td>
<td>$ 328,207</td>
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<tr>
<td><strong>Total FY 93-94</strong></td>
<td><strong>$ 9,579,112</strong></td>
</tr>
</tbody>
</table>

Capital Projects Funding

Our capital projects in the last 10 years have been over $125 million, and we have somewhere in the neighborhood of $300 million on our needs list.

Paying the Tab

One of our basics that we have used for the past four years is to come up with a five-year financial plan. We submit that to our mayor and City Council. Our budget year starts July 1st and runs through the end of June. Every year we give them a five-year financial plan that tells them basically what expenditures are necessary for the next five years. Every year we update that, drop the previous year, add another year on the end. The key is "no surprises." We include that into the utility rate adjustments for all other utilities, then we bring in revenues with respect to expenditures in the major categories. We come back during the May time frame and present a detailed budget for the City Council.

Maintenance

One of our major areas is operations and maintenance. We clean silt and debris in our major channels at least once a year. We mow 6,600 acres of detention ponds and open space every 7 to 14 days. Debris removal is one of
our major activities. No matter how well we handle our preventative program, we still get a lot of leaves and debris during the fall season.

We also have a cross-connection program in relation to the stormwater NPDES requirements in the area of water quality. We have an inspection program, a testing program, and a prevention program in our maintenance area.

Last, but not least, is our misdemeanant program. We get somewhere in the neighborhood of 30 to 40 thousand hours per year volunteered—I’ll use that word—from prisoners, to help us clean out the drainage channels. This is free labor with the exception that the State of Oklahoma charges us 11 cents an hour. We are happy to pay that charge.
COMMUNITY-BASED FLOOD MITIGATION PROJECTS: A DESIGN CONSULTANT’S PERSPECTIVE

Paul D. Zachary
Barend W. Meiling
McLaughlin Water Engineers, Ltd.

Introduction

The professional engineering design consultant is challenged to market, develop, and produce an engineering product that not only meets the clients' objectives, but also meets the financial demands associated with the generation of the product. Once it has been determined that a project is required, the scope of services for the development and production of that product are defined. The scope of services during the negotiations is made with assumptions that certain variables are fixed. During the fee negotiations, assumptions are made based upon a "tight" scope of services. As work progresses on the project, problems arise that adversely affect the production of the project, which in turn requires additional effort by the consultant, i.e. objections by the public, a variable that was assumed to be fixed is not, "11th-hour" modifications or developments, and/or items thought to be minor turn out to be major points of interest. Any or all of these items has the potential of sending the design consultant’s project budget into the "red."

This paper presents the positive impact of having the "community" participate in the implementation of flood mitigation projects from the conceptual planning stage through construction. A "community" is defined as an interacting body or population of various kinds of individuals with common interests living in a particular area.

Owner/Consultant/Community Relationship Dynamics

Historically, the three-way relationship of owner/design consultant/community has tended to be focused on the owner/consultant relationship. In the past, the community has not been involved until real estate purchase offers were extended or acquisition proceedings were initiated. This type of policy has caused many projects additional time and costs due to length of land acquisition negotiations, the discovery of previously unknown problems, and/or political involvement due to objections raised by constituents. These complications could have been avoided if the community had been involved. In addition to the valid concerns expressed by interested third party members, any presentations after
the plans have been developed will be met by a suspicious, and somewhat threatened audience which believes that it was ignored during the entire development/design process. The idea of viewing the public at large as a source of complaints and problems must be changed to view them as a valuable resource in the various project development stages.

An open three-way relationship must be developed between the owner, consultant, and community. This policy has been adopted by the City of Tulsa in its development and implementation of flood mitigation projects. Beginning with the plan development phase all the way through the construction phase, members of the community have been given the opportunity to share, comment, and interject their input into the process. The dynamics of the various relationships are discussed below.

**Owner/Community Participation (Acceptance)**

The number of problems that an owner has during project development and implementation is inversely proportional to the amount of community involvement. The more community participation, the fewer the problems for the owner. Of course, some will oppose the project regardless of the time spent soliciting their input.

**Owner/Consultant's Efforts (Costs)**

There are two aspects to this relationship. In the first instance—in which the owner is experiencing many problems with the project, i.e., low community participation and acceptance—the consultant will realize an increased level of effort in trying to develop a project that has shifting objectives. The cause of the shifting objectives is receiving little or piecemeal community input. This is in contrast to receiving information in a unified, defined format during a specified time period. The other aspect of this relationship is that as more community involvement is encouraged, the consultant will need additional time to attend public hearings, address various affected groups, and allow for organized question and answer sessions. The budget needed to allow for this involvement is insignificant compared to the fees required to address last minute design modifications.

**Consultant’s Efforts (Costs)/Community Participation (Acceptance)**

Consultants run the risk of budget overruns anytime they are subjected to last minute reviews and project modifications. This risk must be considered during the project’s contract negotiation. When community participation is withheld, the design consultant’s efforts will tend to increase. As the communities’ opinions and/or concerns are heard and incorporated into the original design, the consultant’s fees can be optimized from the owner’s
perspective. Near the saturation point of public involvement, only small gains are made in public participation when compared to the dollars spent on public meetings or other techniques utilized to reach the community. This point in the relationship must be recognized by all parties.

Based upon the dynamics of the three-way relationship, the target area or envelope in which a project should be managed is one that achieves the maximum practical community participation, while optimizing the consultant's efforts, which in turn will minimize the risk, and also minimize the owner's problems and costs associated with the project.

**Tulsa, Oklahoma’s Community-Based Flood Mitigation Project Implementation**

On the weekend of May 26-27, 1984, the City of Tulsa experienced its worst flood in recorded history: 13 inches of rain in a six-hour period, unofficial rainfall amounts in excess of 15 inches in a 24-hour period, 14 lives lost, $180 million in damages, and 6,800 homes and businesses damaged (U.S. Army Corps of Engineers, 1985). This event was a milestone in the city's approach to stormwater management. The volunteer efforts and countless hours provided by city personnel, Corps of Engineers, relief organizations, and citizens all contributed to the collection of information to identify the effects of this flood. The participation of the community is a viable part of the City of Tulsa's stormwater management program.

Community input is solicited during the various development phases, from planning to construction. A flood mitigation project is developed in the following steps: 1) planning—development of a watershed master drainage planning document; 2) capital improvement project list—prioritization of various flood mitigation projects; and 3) design and construction documents.

**Planning**

The planning document for the City of Tulsa flood mitigation projects has been compiled from individual watershed studies called Master Drainage Plans (MDP) or Basin Drainage Studies. The MDP serves several purposes: 1) technical: hydrologic and hydraulic characteristics of the watershed; 2) problem identification and associated mitigation projects; 3) economic analysis of components of the MDP. The study efforts are briefly outlined below, but the community involvement is discussed in more detail.

**Baseline Hydrology and Hydraulics.** The floodplain is defined; structures affected by the floodplain are inventoried; the problem is identified; first public meeting held. This meeting is used to outline the study, introduce the consultant, and solicit information from the community. It is important to conduct the meeting within the watershed at a school, library, church, public
meeting room, etc. The meetings are announced via press releases and mailings to residents, businesses, as well as known homeowner association groups to encourage their attendance. The city urges people to respond in writing on response forms. Typical information that is gathered at such meetings includes photographs of flood damages, high water marks within and near identifiable structures, and actual photographs taken during the flood event.

**Development of Alternative Flood Mitigation Solutions.** Basin resources are inventoried, i.e. parks, open space, schools, easements/rights of way, utilities, transportation plans, etc.; alternative flood mitigation solutions are compiled into three viable basin-wide plans; second public meeting is held. This meeting is used to present the various alternative flood mitigation plans. The consultant presents the study results and the logic used in developing the alternative solutions. The consultants also present their opinion of the most viable plan or individual components of all the plans that should be combined to form the MDP.

**Final Master Drainage Plan.** The consultant and the City of Tulsa review the communities' comments as well as those of City staff. The comments and concerns are considered and addressed during the preparation of the final MDP. The final MDP consists of final hydrologic and hydraulic calculations (residual floodplain); major design elements identified and detailed; economic analysis of the final MDP; an optional third public meeting may be held. Depending on the number of comments collected and the modifications made to the plan components from those already presented to the community, this meeting may or may not be necessary.

**Capital Improvement Project List**

The individual MDP components have been incorporated into a city-wide evaluation program. Projects with high public hazards and benefit/cost ratios are prioritized for inclusion in a capital improvement project list for funding. The community is again involved in the process of preparing the capital improvement list. Neighborhood meetings, council district meetings, etc. are held to present and discuss the proposed project list. The benefits of public hearings and meetings that have preceded this stage of implementation are also realized at this point. By this time, a majority of the individual residents, neighborhood homeowner associations, and businesses in the area have had previous exposure to the proposed projects. This knowledge results in a stronger, positive relationship with the City of Tulsa, which will be evidenced in the affirmative voting of the community.


**Design and Construction Documents**

The design contract is divided into three phases: conceptual, preliminary, and final design. Depending on the project, significant time may have elapsed since the MDP was developed. Regardless, the City of Tulsa’s design contracts include the community input during the various design phases. The steps are summarized below.

1. **Conceptual Design Phase.** The consultant reviews, modifies and/or redevelops the project’s major components as determined in the MDP. The community’s input is again solicited. Several successful techniques that can be used in obtaining this input are:

   - **Public meeting:** This meeting introduces the consultant, obtains information, provides a project update, and discusses the proposed schedule.

   - **Questionnaires with postage paid return envelopes:** The questionnaire format should include a combination of multiple choice and short essay questions and an area where a sketch or diagram can be drawn by the respondent. On one of our recent projects for the City of Tulsa, we distributed a questionnaire in the community. The return ratio was 74%. In this particular area, we have been able to successfully work with the homeowners’ association, which has been involved since the MDP identified this project in June 1981.

   - **Personal interviews with residents:** This is strongly encouraged.

2. **Preliminary Design Phase.** The plans at this point can vary from 65% to 80% complete. These plans are presented in another public meeting. Because of this and previous public contacts and meetings, a positive and supportive environment has been created where the public can realize that their concerns are being heard and addressed, the consultant’s risk of last minute changes is minimized, and the City of Tulsa receives “good press.”

3. **Final Design (to Pre-Construction).** Upon completion of the final design and prior to construction, a "kick-off" meeting should be held. In this meeting, the final plans are presented and a discussion of the temporary inconveniences that should be expected during construction. These inconveniences may include traffic delays, detours, closing of streets, limited access, construction noise, etc. By forewarning the members of the community, the number of complaints during the construction period can be minimized.

The use of these techniques: public forums, questionnaires, mail or hand bill notices, personal interviews, kick-off meetings, etc. have been
successfully participated in by our firm on recent design and construction projects for the City of Tulsa, Oklahoma: South Fork Joe Creek (presently under construction); Audubon Creek Channel Improvements, Phase III (final design completed and scheduled for construction summer 1994); and McClure Park Stormwater Detention Facility (completed 1990).

A Design Consultant’s Perspective

A community-based project will have financial benefits over a project that omits or overlooks public input. The inclusion in the consultant’s contract requiring community involvement throughout the development and implementation will allow the consultant to reduce certain risks that are built into the design fees. Another tangible effect is that right-of-way and easement purchases, although not necessarily pleasant, are obtained in a more positive, team environment. That translates directly to the overall cost of implementing the project.

Conclusions

The development and implementation of a flood mitigation project can be enhanced and made more efficient when the community participation is solicited and when community involvement is openly encouraged. Initiating a watershed management program in an urbanized watershed with inherent flooding problems will often be met with much resistance partially due to the limited open areas and/or the impacts on the environment. Mitigating the flood hazards must be coupled with addressing the issues or problems created by the improvement activity. The improvement, be it structural or non-structural, can be generally accepted by the community if properly planned and presented. A community-based flood mitigation project that is developed and implemented through the City of Tulsa/design consultant/community partnership results in a "win/win/win" situation.

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1985 *Areas Flooded on May 27, 1984 in Tulsa Metropolitan Area.* Map produced and printed by the Corps, Tulsa District.
SAVING YOUR RESIDENTS' MONEY: SOME LOCAL EXPERIENCES WITH CRS

Pat Hoggard
Tulsa Public Works Department

The goals of the Community Rating System (CRS), as stated by the National Flood Insurance Program (NFIP), are threefold:

1. Reduce flood losses,

2. Promote awareness of flood insurance, and

3. Facilitate accurate insurance ratings.

It is a unique program that can help communities:

- Reduce flood insurance premiums for residents,
- Reduce future flood losses,
- Increase public safety,
- Reduce economic disruption, and
- Reduce human suffering from flood losses.

The CRS Coordinator's Manual, which describes the requirements for a CRS application, is well written but somewhat lengthy. It is reasonably easy to follow if it is taken one section at a time. The 2 1/2 pages of acronyms should be studied.

Tulsa's December 1993 CRS application was over two inches thick. It is a complete reverification of the entire Tulsa CRS program, required on a three-year cycle because of our classification. Tulsa's first application, in December 1990, was about half that long. The two subsequent (annual) recertifications were about 1/3 that length.

Developing an application like this is very staff-intensive. The "paperwork reduction act" statement in the CRS instruction manual says "average 16 hours," but this does not scratch the surface of the time required for an application like Tulsa's. However, the 16 hours may be reasonably accurate for a device called "Quick Check." This is a method developed by the
NFIP to quickly determine if a community can qualify for 500 points, obtain Class 9, and save 5% on its residents’ flood insurance premiums. Some activities are mandatory, but they are easy.

FEMA now has a computerized format for this application. It will probably reduce staff requirements after the bugs are worked out.

There are 18 activities that qualify for points; each activity has several elements. Tulsa applied for credit in all but two activities: 530 (Retrofitting) and 620 (Levee Safety). They do not do things to get points (with minor exceptions), they get points for the things they do.

It is significant to note that the activity with the most points is 520 (Acquisition and Relocation), that is, getting people out of the floodplain. During Tulsa’s buyout program after the 1984 Memorial Day flood, it was found that several houses had been paid for two or three times by insurance payments on previous floods.

FEMA and the NFIP solicit your ideas for improving the CRS program. Several improvements have already been made.

- An "impact adjustment" was added to some activities, such as Outreach Projects, to give partial credit for partial work.

- The approach to identifying and measuring elements was significantly simplified in the activity Additional Flood Data.

- Default values were added to some activities.

Some other changes Tulsa has recommended are:

- Give credit for maintenance of underground storm sewers.

- Require complete reverification on some basis other than CRS classification. Perhaps dollars saved would be more appropriate.

The CRS manual is an excellent reference to intrigue you and pique your thought processes toward investigating several activities that can be implemented at little or no cost beyond a bit of staff time—good ideas, things you may have overlooked in your stormwater program.

The CRS is a good program. It can be improved, but this is true of all young programs. It can be staff-intensive but still worthwhile. The Tulsa CRS program will save nearly $250,000 annually for the 3,100 residents with flood insurance. It can be a very worthwhile program. Let us pull together with FEMA and the NFIP to make it better.
Serving as the physical and spiritual lifeblood of early civilizations, rivers and streams have attracted humanity to their banks since the dawn of time. Today, water is available at the turn of a tap—even miles from its source—and scenic waterways are prized for their economic and aesthetic qualities rather than revered for their immaterial, secular value.

This unyielding desire to possess, occupy, and alter floodplains has enabled flooding to plague Oklahomans throughout recorded history. Following catastrophic events in the Mississippi Valley region in 1912 and 1913, widespread levee construction was implemented by the U.S. Army Corps of Engineers to control the flooding. Although 300 people were killed and half the state of Arkansas was inundated by the historic 1927 flood, and lesser disasters continued into the 1930s, it took the combined experiences of the Dust Bowl and Great Depression to persuade the federal government to seek an alternative strategy.

Stating that "floods constitute a menace to national welfare," the Flood Control Act of 1936 led to the eventual control of the nation's rivers through construction of more than 300 reservoir projects economically justified by numerous additional benefits—irrigation, fish and wildlife enhancement, municipal water supply, recreation, and electric power generation. Federal public relief programs were enacted and destitute Americans were put to work in an effort to simultaneously boost the economy and stop the floodwaters.

In Oklahoma, this prolific era of flood control and water development was marked by construction of Denison Dam (Lake Texoma), on the Red River in 1944, and completion of the McClellan-Kerr Arkansas River Navigation System in 1970, then the largest civil works project ever undertaken by the Corps. Collectively, Lake Texoma and the McClellan-Kerr (in concert with upstream reservoirs on the Arkansas River) have prevented more than $600 million in potential flood damages. Statewide, 33 of Oklahoma's 34 major lakes have storage set aside for flood protection.

As the flow of federal funds for large-scale projects was reduced from a gush to a trickle, smaller and less expensive projects began to dominate. The goal of these projects, constructed and primarily funded by the U.S. Soil
Conservation Service (SCS), was to prevent flooding in rural areas as well as to provide water supply, irrigation, and other local needs. The Sandstone Creek project, the first upstream flood control project in the nation, completed by the SCS in 1953, exists in western Oklahoma in the Washita River watershed. Erosion control measures in concert with 24 separate floodwater retention structures protect almost five million acres, primarily farmland and ranchland, and provide supplies for irrigation, stock watering, and recreation. A similar SCS project, consisting of 14 watershed protection lakes, controls flooding in the watershed of the Fourche Maline, a tributary of the Poteau River in eastern Oklahoma. Currently, more than 2,000 SCS flood retention structures exist in the state.

Despite the widespread construction of projects to detain and divert millions of acre-feet of floodwaters, monster floods continued to take their toll. Between 1955 and 1975, losses due to flooding were estimated at $167 billion. The Enid flood of 1973 caused $78 million in damages and took nine lives. State leaders eventually resolved that increased urbanization and encroachment upon appealing floodplains was, in many areas, causing an increase in the magnitude of floods and flood problems. The removal of absorbent soils during such development had vastly reduced the amount of runoff that could be assimilated. The resulting increase in flood velocities accelerated the erosion of valuable topsoil and the destructive cycle continued.

Recognizing that the best approach to mitigating future flood damages is keeping development out of floodwaters' path, rather than often futile attempts to keep floodwaters away from development, authors of the Oklahoma Comprehensive Water Plan formally recommended that the state legislature adopt comprehensive floodplain management legislation. This new law, the Oklahoma Floodplain Management Act, would not only curb development but allow every qualified Oklahoma community to obtain federally subsidized flood insurance.

National Flood Insurance Program

Although the state had participated in a coordinated federal strategy to control development in the floodplain since 1975, most Oklahoma counties lacked proper authority to enact land use regulations to limit such development prior to passage of the Oklahoma Floodplain Management Act in 1980. The Act enabled communities to implement and enforce zoning regulations and other floodplain management tools, thereby allowing their participation in the National Flood Insurance Program (NFIP). Echoing sentiments of the National Flood Insurance Act, which established the NFIP in 1969, the Floodplain Management Act stimulated exceptional growth of the program in Oklahoma.

The NFIP is administered in the state by the Oklahoma Water Resources Board (OWRB) and offers incentives that encourage local
Morris, Vance, Mathis, and Springer

Governments to implement wise floodplain management. Undoubtedly, the greatest incentive is the availability of affordable flood insurance to owners and renters of homes, businesses, and farms in member communities. The ultimate goal of this approach is to reduce flood damages and, in turn, decrease federal damage assistance outlays to state and local governments.

To be eligible for the NFIP, communities must establish a governing floodplain board and restrict development within 100-year floodplain boundaries that have been mapped throughout much of Oklahoma by the Federal Emergency Management Agency (FEMA). Affordable flood insurance is then available to property owners and renters in the community. To date, the program has 354 participants, including 42 counties. OWRB staff provide communities with guidance in adopting these measures and regularly help community officials develop local floodplain management programs and implement flood loss reduction techniques. Regular communication allows staff to point out structural and political modifications necessary to retain eligibility in the NFIP. To further facilitate this communication, the Oklahoma Floodplain Managers Association was created in 1990. An independent, nonprofit organization promoting wise floodplain management, the organization gives local officials a strong, unified voice in the formation of both state and national policy.

Acknowledging that floodplains will remain attractive to potential developers or homeowners and that certain nonresidential projects (such as roads, bridges, and utilities) are required in those sensitive areas for the good of the community, effective floodplain management guides development in a manner that allows safe passage of the regulatory flood. Existing development can also be protected through floodproofing and related flood damage protection techniques. The City of Tulsa, ravaged by regular floods, including the 1984 Memorial Day flood that claimed 14 lives and caused $180 million in damages, has been at the forefront of community floodplain protection and preservation.

In addition to zoning requirements and other local measures to curb development in the floodplain, the state (through the OWRB) recently began policing itself through implementation of permitting requirements for development on state-owned or -operated property. Today, aspects of floodplain management are influenced by numerous state and federal laws, programs and policies, including the federal Clean Water Act Section 401 and 404 permitting programs; Oklahoma MESONET and NEXRAD weather radar; State Dam Safety Program; and State Financial Assistance Program.

Hazard Mitigation

Working in tandem with state floodplain management activities to reduce the vulnerability of Oklahoma communities to flooding is FEMA's Hazard Mitigation Grant Program (HMGP). Created in 1988 under the Robert
T. Stafford Disaster Relief and Emergency Assistance Act, the federal program encourages public and private projects that reduce or eliminate the long-term risk to human life and property from natural hazards. Grants, not exceeding 75% of each project's costs, are awarded by the federal government with individual communities and/or the state contributing the remaining 25%. Eligible project purposes include structural hazard control, such as debris basins or floodwalls; retrofitting or floodproofing to protect structures from future damage; acquisition and relocation of structures; warning systems and accompanying disaster preparedness and mitigation plans; and development of state or local protective standards. Unfortunately, many potentially eligible communities choose not to apply for these projects because sufficient funds are unavailable locally to meet the required grant match. A recent change in federal law in December 1993 reducing the local share from 50% to 25% should improve the situation.

Future Efforts

While considerable flooding problems have propelled the state into the cutting edge of floodplain management and an increasing number of Oklahoma communities join the NFIP each year, there is room to decrease the potential for flood damages even further. As a result, through additional legislation, improved administration of the NFIP, and innovative procedures, a number of recommendations have promise not only to maintain, but also enhance, the implementation of floodplain management strategies in Oklahoma, as well as nationally.

Legislation

- Establish comprehensive State Hazard Mitigation Programs to prevent future flood damages and create state hazard mitigation funds to assist financially strapped communities and facilitate the timely dispersal of state and federal HMGP funds. Implementation of these programs—including education, training, and planning—would encourage communities with frequent flooding problems to participate in hazard mitigation planning efforts before disasters, rather than during post-disaster recovery periods, to reduce the flood risk at the local level. In addition, creation of state funding sources for the required 25% state/local match would accelerate the overall HMGP administration process.

- Enact property disclosure laws to inform consumers, prior to purchase, if land or related structures are in the floodplain. Often, prospective buyers learn that the property is part of the floodplain only at the
closing table. This results in a hardship not only to the buyer, but also to community/county efforts to control floodplain development and maintain eligibility in the NFIP. The Oklahoma legislature is now considering a measure that would require a written property disclosure statement be furnished to prospective buyers.

- Develop local stormwater management plans. In light of recent changes regarding regulation of stormwater discharges under the federal Clean Water Act, local strategies that incorporate stormwater and floodplain management should be emphasized and developed.

- Encourage communities to strengthen enforcement of local ordinances. Too often, local building codes, zoning ordinances, and other floodplain management regulations are disregarded. Allowances for penalties, especially fines, for violations of local ordinances would improve compliance and help retain community membership in the NFIP.

- Encourage FEMA to provide improved technical guidance and develop an alternative methodology for determining flood elevations. FEMA should develop better strategies to guide the construction of fences, bridges, culverts, roads, utility lines, storm cellars, oil/gas/water wells, and related development in floodplains. Also, existing flood zone elevations are often inconsistent with those guiding the operation of federal reservoir projects.

- Increase public awareness and education. There is a genuine need to increase awareness of flood preparedness, prevention, and mitigation procedures. The states and FEMA should develop appropriate education materials for both elementary school students and the general public.

**NFIP Administration**

- Increase enrollment in the NFIP. In Oklahoma, 16 nonparticipating counties and 73 non-member cities and towns have identified floodprone areas but have elected not to join the NFIP; the remaining 19 counties not in the program have not been mapped but are suspected of having floodprone areas. States should seek ways to boost enrollment in the NFIP and increase mapping efforts in cooperation with the federal government. Federal legislation is needed to require counties to be members of the NFIP to receive public assistance following a Presidential declared disaster.
• Develop state floodplain/stormwater management policies. To promote coordinated floodplain protection and development strategies, comprehensive state policies reflecting existing federal policy are required. They should incorporate appropriate state and federal laws, education efforts, and related information on floodplain management.

**Innovative Procedures**

• Investigate a system that limits future development where a high ratio of impervious to pervious land exists. Excessive conversion of natural, open areas to parking lots, roads, housing additions, industrial parks, malls, and other development has severely impeded the land’s ability to absorb runoff, leading to increased flooding problems. Federal and state governments must give serious consideration to the study and establishment of laws requiring a sensible ratio of pervious/impervious land square footage in certain sensitive watersheds or floodplain areas.

• Accelerate implementation of state geographic information systems. GIS is capable of providing significant help to communities in determining local flood zones.
PART THREE

BUILDING AND CONSTRUCTION STANDARDS
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Background

On December 11-12, 1992, the New Jersey and New York coastlines were impacted by significant flooding, damaging thousands of buildings. The losses resulting from the December storm were substantial throughout the New Jersey coastal communities. By closely examining the claims data and building composition of a representative town, it is possible to evaluate the effectiveness of the National Flood Insurance Program (NFIP) building standards. This examination will allow for necessary program modifications that will ultimately lead to the reduction in both NFIP claims and the need for disaster assistance.

Town Selection

Although storms and flooding are an anticipated hazard on a barrier island, Long Beach Island, New Jersey, has an extensive history of flood problems. The December 11-12 storm was particularly damaging to the community of Harvey Cedars, which is a typical Atlantic Coast barrier island community. Harvey Cedars was selected as the representative town for evaluation of NFIP building standards based on the following:

- The December 11-12 Northeaster approximated the "design" (100-year) flood event at this location based on existing data;
- Flood damage incurred by a similar storm before the implementation of NFIP standards is well documented (the Ash Wednesday, 1962 Northeaster) and provides a meaningful comparison;
• It has a balanced mix of pre-FIRM and post-FIRM construction;

• The percentage of NFIP policies is as high as anywhere in the nation (over 50%); thus, extensive policy and claims data are available; and

• Almost the entire community is in the designated floodplain and the number of structures is small enough to permit a thorough investigation, yet large enough to provide meaningful results.

Storm Data

One of the worst storms of record in the Long Beach Island vicinity was the Ash Wednesday storm of 1962. The storm resulted in the destruction of beaches, dunes, shore-protection works, houses, and other structures. Several of the houses that did remain, however, were located on pile or column foundations. Thus, in addition to extensive beach repair effort and numerous raisings of street elevations, the majority of the houses that were rebuilt after the storm were elevated above the 1962 flood levels. Even though regulations did not specify these criteria, the houses were rebuilt in a fashion similar to that specified in the NFIP standards, following the example of their surviving neighbors.

Tide crest gage data from nearby towns indicate the December 11-12, 1992 Northeaster (identified by many as the "storm of the century") is comparable in magnitude to the historical March 1962 storm. Although extreme tides were not predicted during this event, the storm occurred between full moon and the moon in perigee. The high tides resulting from these alignment maxima greatly contributed to the overall impacts of the storm surge.

The December 1992 storm resulted in severe erosion of approximately two-thirds of the town's beaches. The majority of the oceanfront homes incurred damage as a result of this erosion. However, structural damage to foundations and supporting elements was very minor. The damage sustained in the remaining structures (non-oceanfront) was primarily the result of flood waters.

Although the two storms were comparable in magnitude, the degree of flooding for the December 1992 storm was slightly less than the 1962 storm. This was due to the shorter duration of the 1992 storm and the additional protection provided via rehabilitation of and improvements to the roads and dunes since the 1962 storm. There was drastically less damage resulting from the December 1992 storm than from the 1962 storm. This is directly related to improvements in the construction techniques typically employed since the 1962 storm. Before 1962, the majority of the residential houses were constructed on conventional slab or crawl foundations. However, as a result of the destruction of many of these homes, elevated construction became prevalent even before the
implementation of the NFIP. Deep pilings prevented the collapse of numerous oceanfront structures, which lost up to six feet of soil as a result of the December storm.

Methodology and Results

Methodology

A quantitative inventory and analytical assessment of NFIP claims data, which compares the degree of flood damage sustained for the December 1992 storm to building types and other parameters, was performed. The major tasks involved included base map development, structure inventory, damage inventory, and comparative analysis. Once initial results were obtained from the inventories and analysis, the definition and content of the tasks were refined to better adapt to these results.

An inventory and thorough examination of 349 structures were performed. Although these 349 structures represent approximately one-third of the buildings in the community, over one-half of the damage is represented. The section of town inventoried represents the portion of Harvey Cedars most severely impacted by the storm. The area is characterized by a relatively low dune elevation and a narrow distance from bay to ocean. For analysis, the area was subdivided into bayside, oceanside (non-front row), and oceanfront (front row). Damage was investigated based on "design" and "actual" first floor elevation in relation to the BFE. The "design" first floor is the first floor of the structure designed as habitable and does not include lower area enclosures as determined by inspection or from NFIP claims data. The "actual" first floor is the first floor as determined by apparent habitable living space, including framed lower area enclosures as determined by exterior inspections only.

General Structure Data

All of the structures in the town of Harvey Cedars, New Jersey, are located in an A-Zone with a mixture of pre- and post-FIRM construction. Most of the pre-FIRM structures (over 60% at bayside, 70% at oceanside, and 90% at oceanfront), have first floor elevations above the BFE and thus behave as post-FIRM structures. Therefore, clear differentiation cannot be made between the responses of pre- and post-FIRM construction to the December storm. Of the 349 structures inventoried, 143 are bayside, 152 oceanside (non-front row), and 54 oceanfront (front row). Of these, it is estimated that 78% of the bayside, 84% of the oceanside, and 91% of the oceanfront structures are participating in the NFIP. In addition, based on exterior inspection only, it appears that between two and 15 post-FIRM bayside, two and 10 post-FIRM oceanside, and zero and two post-FIRM oceanfront structures are not in compliance with A-Zone
building requirements. Since these generalizations are based on brief exterior inspections of the lower areas only, further investigation of these lower area enclosures is required for a more accurate account of compliance.

**Damage Relationships**

**Design and Actual First Floor Elevations: Pre- and Post-FIRM Status.** The damage sustained was evaluated in relation to the design and actual first floor elevations and the pre- and post-FIRM status. The damage was broken down to general locations: bayside, oceanside, and oceanfront.

Through examination of the damage, it is apparent that there is no correlation in relation to pre- and post-FIRM status. This is evident by the relatively even distribution of damage between the two classifications. The field investigation revealed that the majority of the pre-FIRM structures were elevated to the standards required for post-FIRM construction. Therefore, subsequent analysis of relationships were investigated based on compliance with the "post-FIRM" NFIP building standards, and not the FIRM indication.

As noted, by evaluating the design first floor elevations, it was apparent that numerous structures are elevated at or above the BFE. Several of these structures, though, still incurred damage during the December 1992 storm. When consideration is given to lower areas which appear (by exterior inspection only) to be fully-framed, non-breakaway, and habitable, the number of structures with "actual" first floor elevations above the BFE is reduced. Therefore, it appears that much of the damage sustained was to the lower areas and primarily due to inundation in the bayside and oceanside structures and inundation in combination with erosion for the front row structures.

Based on the study of damage in relation to actual vs. design first floors, subsequent analysis of NFIP claims focuses solely on actual first floor elevations.

**First Floor Elevation and Location Distance.** The elevation of the first floor in relation to the surge and the distance from the flood source are significant factors in determining damage sustained from the December storm.

**First Floor Elevation.** An investigation of the first floor elevation in relation to the number of structures damaged revealed that once this elevation is above the BFE in the bayside and oceanside areas, the percentage of structures damaged is reduced significantly. Approximately 23.5% of the bayside structures with first floor elevations below the BFE reported damage, whereas only 3.8% with first floor elevations at or above the BFE reported any damage. Damage was reported for 30% of the oceanside structures with first floor elevations below the BFE, versus 12.4% of those with first floor elevations at or above the BFE. The first floor elevation relationships cannot be summarized as above for the oceanfront structures, since the data pertaining to structures with first floor elevations below the BFE is too limited.
Claims Paid. The damage reported for various structures ranged from $500 to over $70,000. Similarly, the range for the claims paid varied from under $500 to over $60,000. Claims paid for structures in the bayside amounted to approximately $52,057. Of this amount, $36,595 was for structures with first floor elevations below the BFE and $15,457 for structures with first floor elevations at or above the BFE. The claims paid to the oceanside structures amounted to roughly $165,233 with an average of $77,788 going to structures below the BFE and $87,443 to those above the BFE. The average claim paid to these structures was $8,643 for structures with first floors below the BFE and $7,287 for structures with first floors at or above the BFE. It appears that no matter what the relation to the BFE once the house is damaged, the floor height does not appear to influence the value of the claim paid. The floor height does impact, as noted previously, the number of structures damaged. A significantly smaller portion of the buildings was damaged when the first floor elevation was at or above the BFE.

The claims paid to the oceanfront structures cannot be summarized as above, since the sample of structures below the BFE is not large enough to warrant such a comparison.

Although the average claim paid is higher for those structures with first floor elevations above the BFE, further investigation revealed that a large percentage of the damaged structures with first floor elevations at or above the BFE is relatively large and of newer construction, and therefore often more costly.

Distance from Shoreline Reference. When the design related to the distance from the reference baseline is examined, it becomes apparent that the amount of damage sustained to the oceanside and oceanfront structures generally decreases as distance from the baseline increases.

Conclusion

Harvey Cedars has a history of flooding and suffered severe damage in the 1962 storm. In addition, based on conversations with local officials, insurance representatives, and residences, many of the oceanfront structures were considered to be located in a V-Zone before the 1984 update of the FIRM, which took wave action into account. The combination of the flood history and the previous zone designation has a major impact on the structural composition of this area. The reported damage for the three sub-areas investigated indicates that when structures in the bayside and non-front row oceanside are elevated to the BFE or above, the number of damaged structures is reduced. Only three out of almost 100 post-FIRM structures suffered any damage after the first floors were elevated to or above the BFE.
The reported damage to the oceanfront structures does not appear to follow this trend. It must be noted, however, that all of these structures lie within 20 feet of the dune line, in an A-Zone with a BFE of 10 feet. Even with the consideration of the lower area enclosures, only five of the 54 structures have actual first floor elevations below the BFE. Therefore, it appears that the damage sustained was a result of erosion and inundation of the lower area enclosures, decks, and stairways.

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EROSION HAZARDS AND COASTAL CONSTRUCTION DEFICIENCIES OBSERVED ON KAUA'I AFTER HURRICANE INIKI

A. Todd Davison
Federal Emergency Management Agency

Charles E. Bornman
Greenholme & O'Mara, Inc.

Melvin Nishihara
State of Hawaii, Office of the Director of Civil Defense

Introduction

Since the inception of the National Flood Insurance Program (NFIP) 25 years ago, the contribution of both storm-induced and long-term erosion to coastal property damage has been increasingly recognized (Davison, 1993). An accurate estimate of both the vertical and horizontal components of erosion is a fundamental design consideration for providing adequate foundation embedment for coastal buildings. Based on observations made on the south shore of the Island of Kauai after Hurricane Iniki, this paper describes the general geotechnical setting, hurricane-induced erosion processes, and building failure due to this erosion and offers general design guidance for foundation embedment applicable to Hawaii's coastal zone.

Shortly after Hurricane Iniki struck Kauai County, Hawaii, the Federal Emergency Management Agency (FEMA) Technical Standards Division assembled an interdisciplinary team of building scientists, planners, and professionals versed in mitigation. The team assessed the performance of buildings (both success and failure) subjected to wind, flood, and erosion forces (FEMA, 1993). An area of special interest was the south shore of Kauai. In particular, the resort area known as Poipu Beach suffered considerable damage. In addition, modes of building failure along Poipu Beach due to hydrodynamic loading and debris impact have been well documented (FEMA, 1993).

Geologic Setting and Erosion Processes

Under 44 CFR §60.3(e)(4), NFIP building standards for new and substantially improved construction in coastal high hazard areas require that:
the pile or column foundation and structure attached thereto is anchored [in the underlying substrate] to resist flotation, collapse and lateral movement due to the effects of wind and water loads acting simultaneously on all building components. Water loading values used shall be those associated with the base [100-year] flood. Wind loading values shall be those required by applicable State or local building standards.

To meet this NFIP performance standard for embedment of building foundations along the coast of Hawaii, two geotechnical factors are critical: 1) the thickness of unconsolidated sediments, and 2) a basic knowledge of hurricane-induced erosion processes.

In general terms, the surficial geology along Poipu Beach is characterized by a thin layer of unconsolidated sediments and weathered basalt overlying basaltic bedrock ("lava rock"). The thickness of the unconsolidated sediments is highly variable, ranging from less than 1 meter to 4 meters. The thickness of this layer is important because it governs the type and severity of erosion at a particular building site. Two contrasting examples demonstrate the range of potential erosion and the type and depth of foundations necessary to withstand undermining.

Type 1: Where the layer of unconsolidated sediment is relatively thin (i.e., less than 1 meter), it can be completely removed during hurricanes. The process is termed scarping or "bench retreat" and occurs progressively in a landward direction as the storm proceeds. Adjacent to the coast (i.e., in the first row of buildings), removal of unconsolidated material can be complete down to the bedrock. Thus, shallow building foundations penetrating through this layer and bearing on hard rock can be undermined and buildings completely destroyed during hurricanes.

Type 2: Where the layer of unconsolidated sediment is relatively thick (i.e., 1 to 4 meters), the layer is not completely removed, but the pre-storm grade can be significantly lowered. If the foundation base is above this scour zone, it will obviously be undermined and the building destroyed. If the foundation base is below this scour zone but not deep enough to provide bearing strength to withstand the simultaneous vertical and horizontal loading from both wind and water, the foundation will be compromised and the building will suffer considerable damage or be completely destroyed.

Numerous examples of the building failure modes described above were observed along Poipu Beach after Hurricane Iniki. Considering the number of undermined or compromised foundations observed, most buildings in this area were constructed without an understanding or consideration of storm-induced erosion forces.
Design Guidance

The number of failures observed along Poipu Beach underscores the importance of having a sound understanding of not only pre-storm geotechnical conditions but also how this environment behaves under storm conditions. The geotechnical environment along the coast is a dynamic variable of great uncertainty, not a static parameter. The highly variable bedrock coastline of Hawaii presents design challenges even greater than those experienced along the more homogeneous sandy barrier islands of the Atlantic and Gulf coasts of the mainland United States, where NFIP coastal construction standards originated.

In Hawaii, the design professional must consider the following fundamental criteria for foundation embedment along the coast:

- Depth of the unconsolidated sediment lying above bedrock.
- The maximum potential zone of vertical erosion that may occur during a hurricane.
- The maximum potential zone of horizontal erosion relative to the distance of the building from the coast. This horizontal erosion must be considered over both the short term (the expected penetration of erosion during the next hurricane) and long term (shoreline recession due to the net effect of all storms over the physical life of the building). For the short term, the depth of vertical scour normally tapers in a landward direction.

In the case of Type 1, if the unconsolidated sediment is of insufficient thickness to support a building during severe wind and water loading conditions, the foundation must be keyed or drilled into the lava bedrock and grouted. Figure 1 shows one example of a bedrock-anchored foundation, although alternative designs have been suggested (FEMA, 1993). While anchoring into bedrock is a more expensive proposition, in this case it is the only design that can withstand storm-induced erosion and meet NFIP performance standards for coastal high hazard areas.

In the case of Type 2, if the unconsolidated sediments are of sufficient thickness that a foundation can be driven or excavated below the maximum vertical scour zone, then the embedment design shown in Figure 2 is applicable.
This design should allow for supporting a building under simultaneous wind and water loading during a 100-year flood. The fundamental factor is an accurate estimate of the potential storm-induced vertical scour. Given that our current understanding of geomorphic processes is lacking and geologic conditions are highly variable at different sites, an accurate and confident measurement of storm-induced erosion is tenuous. Thus, a foundation embedment depth that is conservative or includes a safety factor is imperative.

**Conclusions**

To construct a coastal building to withstand wave forces produced during hurricanes such as Iniki, three primary considerations must be met.

1) The building must be elevated to or above the predicted 100-year flood elevation on piles and columns so that waves can propagate unobstructed underneath the lowest floor without transferring the loads to the structure.

2) The building must be constructed with adequate connecting devices to provide a continuous load transfer path such that all wind and water loads are transferred to the foundation.
3) The foundation must be embedded deep enough so that it is not undermined due to the severe vertical and horizontal erosion processes that occur during hurricanes.

While considerable guidance is available concerning design for the first two criteria, a sound understanding of storm-induced erosion for the design of foundations is lacking.

References

Davison, A. T.

Federal Emergency Management Agency
PERFORMANCE OF MANUFACTURED HOMES
DURING HURRICANE EMILY

Albert Romano and Christopher Hanson
Greenhorne & O’Mara, Inc.

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Introduction

On August 31, 1993, Hurricane Emily struck southern Dare County, North Carolina. Preliminary reports from the affected areas indicated that approximately 520 homes (over 160 manufactured homes) were damaged or destroyed. The greatest damage occurred in the vicinity of the unincorporated communities of Avon and Buxton on the Outer Banks. High winds and flooding in those areas originated primarily from Pamlico Sound and resulted in stillwater elevations from 8 to 11 feet above normal sea level. The Cape Hatteras Weather Station anemometer was reported to have "given out" during the storm at a recorded wind speed of 100 mph. The highest wind speed recorded at Avon during the hurricane, 107 mph, is considered to have been the peak gust during the storm.

Immediately after Emily struck, the Federal Emergency Management Agency (FEMA) authorized Greenhorne & O’Mara, Inc., to visit the Outer Banks to conduct a preliminary field assessment (PFA) in the Buxton and Avon areas (including the unincorporated areas of Frisco). The PFA process is one of two major phases of post-disaster building performance assessments that FEMA typically conducts. The other, which is more comprehensive, is the building performance assessment team (BPAT) process. The PFA is typically limited in scope and direction and is intended to be a preliminary evaluation/assessment of the types and severity of damage caused by a given disaster. As a result of the PFA, a BPAT may be recommended and authorized by FEMA in order to conduct a more comprehensive assessment of the structures damaged by the disaster and to identify future mitigation measures.

Some of the major goals established for the PFA visit in the Outer Banks included documenting the nature and magnitude of the damage to manufactured homes (MHs), identifying successful and unsuccessful performance of foundation systems, identifying any units not in compliance with the National Flood Insurance Program (NFIP), estimating the number of MH units affected, assessing the severity and depth of flooding as compared to the 100-year flood elevations depicted on the Flood Insurance Rate Map for the
unincorporated areas of Dare County, and identifying unique site and soil conditions pertaining to structural fill, scour, etc.

**Preliminary Field Assessment**

The PFA was conducted September 13-15, 1993. Of the 60 MH units visited, 46 were located in two MH parks (Tex Ballance Trailer Park in Buxton and Ocean Village Resort Trailer Park in Avon). Single-wide MH units and their foundation systems consisting of pier members, tension straps, and ground anchors were visually inspected. The scope of the field evaluation was limited to identifying performance characteristics (resistance to lateral movement, flotation, and/or collapse) of the MH foundation systems in response to wind, hydrodynamic, and hydrostatic forces generated by the storm. NFIP floodplain management regulations require that MHs be elevated on adequately anchored foundation systems and be able to resist flotation, collapse, and lateral movement during occurrence of the base flood.

"Failure" of a MH unit foundation system, as defined in the PFA, refers to the inability of a foundation system to resist the lateral (wind and water) forces, impacts from incidental debris, and net uplift (buoyancy and wind) experienced during Hurricane Emily. MH units that were not damaged or were flooded above their flooring yet whose foundation systems successfully resisted horizontal and uplift forces were deemed "successful" in meeting the NFIP requirements for resisting lateral movement, flotation, or collapse, even though some of those units' flooring, walls, and contents suffered water damage.

The foundation systems of all of the MH units visited consisted of a steel chassis system (with two I-beams) atop a system of dry-stacked block piers on concrete or block footing pads, tied down with galvanized straps that connected to augured ground anchors. All of these elements were intended to operate in tandem to stabilize an elevated MH unit in its weaker transverse direction against movement, overturning, and flotation (Figure 1). It is important to note that all of these force-resisting links (the chassis, strapping, and ground anchors) need to work together to achieve an overall load transfer path and that the entire foundation system is failure-prone if any of these members is missing, inadequately installed, or poorly maintained.

The factory-made chassis I-beam and floor structure of the MH unit itself is typically fairly rigid in the direction of flood forces. However, the chassis connection to the dry-stacked piers is an on-site fabrication with potentially unstable characteristics.

The gravity and tension-force-resisting chassis-to-pier connection typically began with a simple seat: the chassis I-beam sat on a combination of shims and a wood plate, which rested on top of the pier. The wood plate and
shims were typically not "fastened" to each other or to either the chassis or pier. They were held in position by the weight of the MH unit and the additional force of friction caused by tensioning of the galvanized straps. In effect, the strapping provided a clamping force for all the parts: the piers, the plates, the shims, and the MH.

In general, when the strapping is loosened (for whatever reason) the entire system becomes unstable. In many cases, the MH is acted upon by lateral forces (e.g., floodwater acting above the first floor line in combination with wind) that exceed the horizontal frictional forces from the weight of the MH alone, and therefore movement of the MH occurs. Also, the piers tilt in the direction of the lateral forces. This tilting may then cause rotation at the top of each pier away from the base of the chassis because the chassis remains rigidly fixed to, and at right angles to, the floor of the MH. The effect of the resulting loss of any contact friction between the chassis and the plates/shims greatly reduces the lateral force resistance of the foundation system. Since buoyancy and/or wind uplift forces may be present, they compound the problem by causing the entire separation of the contact surfaces.
As the rotation and tilting of the dry-stacked piers increases, the foundation system below the chassis I-beam becomes unstable. Unlike concretegruited steel-reinforced piers, dry-stacked piers do not possess sufficient "elastic" properties to permit them to return to their preflood alignment once forces acting on them have abated. Consequently, once stormwaters recede and winds diminish, a previously buoyant MH would rest on out-of-plumb vertical supports. And if there is sufficient water current to push the MH farther downstream of the piers, total failure may result.

It was apparent from the observations of the "failed" foundations of MH units after Hurricane Emily that one particular sequence of failure was prevalent. The typical failure began with a shifting of the tops of the piers in the transverse direction most directly in line with the winds and flood current that came from Pamlico Sound in a northwesterly direction. This action caused a rotation of the individual piers and a separation of the connection between the steel chassis members and the tops of the piers, as noted earlier. The resulting movement of the foundation systems as observed was that of piers now out of plumb and, in extreme cases, racked to a point of total collapse. It was apparent that when floodwaters rose above the first floors of many MH units, the structures became buoyant, and as floodwaters receded, the MH units came down to rest off-center on an unstable foundation.

In a second, less-frequently observed, failure mode, where the system suffered significant strap and anchor failure (total anchor withdrawal from the soil and/or broken straps), the MH unit floated or pivoted significantly from its original position and came to rest at trees or other barricades. This failure mode was observed for a few units where total withdrawal of anchors and strap failure occurred. Because of the pure tension failure of the strap and the withdrawal of all anchors, it is suspected that these units (assumed to have been installed properly) may have been subjected to excessive wave forces occurring at or near the units' floor levels. Although wind was an obvious contributor to the foundation system failures, the MH skin (which is designed for 25-psf unit wind loading) did not show the type of damage that would suggest either that wind acted alone or that waves hit the MH significantly higher than the floor level. However, where foundation system failures were prevalent, slack in the straps and inadequate embedment of anchors were observed.

Observations of the results of various degrees of horizontal movement and collapse due to the typical failure modes were made in both the Tex Ballance and Ocean Village trailer parks. Several units had straps that became loosened and anchors that partially or fully withdrew under the stresses of the storm caused by racked or partially racked piers. While many foundation systems failed through the typical modes described above, others of exactly the same design (with or without mortar) experienced identical forces yet performed quite well.
Conclusions

Based on the field evaluation, scour and erosion did not contribute to the observed failures. Rather, it appeared that inadequate installation of the MH foundation systems (e.g., inadequate anchor embedment depth, inappropriate type of anchor used, inadequate connection of straps to I-beam) or lack of maintenance of the tiedown system, or both, significantly contributed to the majority of foundation system failures in the area. Moreover, the fact that many anchors performed well and that many of these were located next to failed anchors brings into question the adequacy of the installation of some of these anchors. One of the Dare County building officials indicated that the county was concerned that some screw augers may have been installed to their full 4-foot embedment with post-hole diggers. This method is contrary to the manufacturer’s recommendations, which allow excavation by post-hole diggers to a maximum of 2 feet and specify that the auger then be turned in by hand the remaining 2 feet and the soil repacked. The basis for the recommended installation method is that auguring in undisturbed soil provides greater pullout resistance than backfilling excavated soil around the auger discs.

When dry-stacked piers were installed correctly to elevate the MH to the base flood elevation (BFE), the piers, in combination with post-tensioned straps and properly installed ground anchors, proved capable of withstanding the wind and flood forces of Emily. This conclusion is reinforced by the successful performance of systems that had the same 36-inch pier height and foundation configuration and that also experienced water and wave damage in excess of their floor lines.

Post-Hurricane Reconstruction

As of April 1, 1994, approximately 71 new MH units had been installed in Dare County to replace those damaged or destroyed by Hurricane Emily. Roughly 10 additional MH units have been replaced by site-built homes. New MH units are being elevated up to two feet above BFE predominantly upon a state-sponsored post-tensioned dry-stacked block pier system with reinforced footings extending below grade designed by a registered professional engineer. Although FEMA has determined that the concept of this design would enable the home to meet the performance standards set forth at CFR 60.3(c)(6), its ultimate success is dependent upon maintaining adequate strap tension and anchor pullout strength. Dare County building officials are tracking the locations of units elevated using this foundation design to enable them to evaluate their performance during future extreme wind and water events. Local and state officials will monitor homeowner maintenance of straps and anchoring systems, including strap tension, anchor installation, and corrosion.
At the request of the state, a pile foundation was designed by FEMA and Greenhorne & O’Mara for use in replacing MHs damaged after Emily and throughout North Carolina. Due to the higher costs and more complex setup procedures for this type of foundation, it has not been used to date in the Outer Banks to replace the damaged MHs.

New Wind Requirements for MHs

Since Hurricane Emily brushed the Outer Banks, the Department of Housing and Urban Development (HUD) published a final rule requiring that the structural components, cladding, and anchoring/foundation systems of manufactured homes destined for hurricane-prone areas be designed in accordance with the design wind pressures and wind speeds specified in the American Society of Civil Engineers standard ASCE 7-88. By July 1994, manufacturers of MH units and of stabilizing equipment (straps and anchors) must redesign elements of the building and foundation system components to meet standards similar to those required for site-built and modular homes. In discussions with FEMA, HUD officials indicated that this higher construction standard may eventually result in the use of more permanent foundations in coastal high wind areas, i.e., no dry-stacked block, and less reliance on straps and anchors to withstand overturning and collapse. Eventually, ground anchors may become obsolete in coastal areas simply because they will not be able to resist increased wind load requirements.

FEMA believes that these higher standards will result in stronger foundation and stabilizing system components, and increased attention to installation practices in the coastal areas affected by the rule. When MH units are properly elevated to or above BFE, this stronger foundation will provide greater resistance to the wind and flood forces produced during hurricanes. Manufactured homes are an important component of the housing stock in the Outer Banks because of the population’s income levels and because they are used as second homes. Although the magnitude of damage to these MHs in Emily did not approach that experienced during Hurricane Andrew (which prompted the development of the new HUD rule), these new standards will better enable manufactured housing to resist the extreme forces produced by the coastal storms that are so much a part of life on North Carolina’s Outer Banks.
DEVELOPING TECHNICAL GUIDANCE MATERIALS ON ELEVATING SUBSTANTIALLY DAMAGED BUILDINGS IN THE MIDWEST UNITED STATES IN RESPONSE TO THE GREAT MIDWEST FLOOD OF ’93

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Introduction

In August 1993, as the floodwaters of the Mississippi River were receding from their peak flood stage, the Federal Emergency Management Agency (FEMA) assembled an interdisciplinary field team of building scientists, architects, engineers, and professionals versed in flood hazard mitigation. The team assessed the performance of buildings (mostly housing) that were subjected to flooding and groundwater increases and prepared guidance on how to elevate residential buildings to reduce future flood losses (FEMA, 1993). The area of special interest was the State of Illinois from Galena south to Hull, within the Mississippi River floodplain. This area included urban, suburban, and rural settings, with a mix of manufactured, stick-built wood-frame, and masonry housing. The vast majority of the housing was wood-frame construction on a variety of foundation types. This paper describes the flood-induced damage to homes, the development of the technical guidance to mitigate this damage through elevation, and how the engineering and cost guidelines were developed through the use of local architectural and engineering expertise to assist localities in meeting the elevation requirement contained in the substantial damage provisions of the National Flood Insurance Program (NFIP) regulations.

The NFIP regulations, 44 CFR 59.1, define substantial damage as "... damage of any origin sustained by a structure whereby the cost of restoring the structure to its before damaged condition would equal or exceed 50 percent of the market value of the structure before the damage occurred." Section 60.3(c)(2) of the regulations states that if a substantially damaged
building located in a designated Special Flood Hazard Area is to be rebuilt, it must be elevated so that the lowest floor is at or above the base flood elevation (BFE). The BFE is the elevation reached by floodwater during a 100-year flood (i.e., the flood that has a 1% probability of being equaled or exceeded in any year). The requirement to elevate substantially damaged buildings must be met regardless of the cause of the damage to the structure. Since little new development has occurred in many of the communities along the Mississippi River in Illinois, many local governments were unfamiliar with this NFIP requirement, even though it is contained in the floodplain management ordinance enacted by each community participating in the NFIP.

Development of Technical Guidance

The field team assembled on Sunday, August 8, 1993, in Moline, Illinois, to tour the flood-affected areas from Moline south to Hull. After surveying the damaged areas, the team developed a typical profile of the building types and methods of construction. Most of the observed damage was a result of inundation of the homes for, in some instances, over a month. This long-term inundation led to the complete saturation of the homes. In northern Illinois, and throughout the state along the Mississippi River and its tributaries, the depth of the standing water generally ranged from 1 to 8 feet. In southern Illinois, the depths ranged from 8 to 16 feet. It was also interesting to note the large number of basement wall and foundation failures that occurred in homes that were not flooded by surface waters but were located in areas with saturated soils outside the floodplain. The typical residence was a one- or two-story (1,000-square-foot) wood-frame structure on a masonry (brick, block, fieldstone) basement or crawl-space foundation or on a slab on grade. After inspecting the types of construction and the damage incurred, FEMA, Greenhorne & O'Mara, Inc. (G&O), and G&O's consultant, Shive-Hattery Engineers and Architects, Inc., promptly assembled additional professionals to prepare and present the technical information on elevating residential structures. This design team consisted of a residential architect, a structural engineer, a civil engineer (an active residential home builder), a floodplain management expert, and a geotechnical engineer. Working together, the team members provided guidance on the feasibility and applicability of the various elevation techniques considered for a typical residential structure in the Midwest. Guidance was also provided on compliance with NFIP, state, and local floodplain regulations and requirements. Computer-generated illustrations of the elevation techniques were produced.

The design team developed seven alternative elevation techniques that were technically feasible and cost-effective for this region of the Midwest.
A Elevating a wood-frame home over a crawl-space structure,

B Creating a new masonry enclosed area on top of an abandoned basement,

C Elevating a slab-on-grade wood-frame structure without the slab (proposed first floor: wood truss),

D Elevating a slab-on-grade wood-frame structure without the slab (proposed first floor: concrete slab),

E Elevating a slab-on-grade wood-frame structure with the slab intact,

F Elevating a wood-frame-over-crawl-space structure on masonry piers, and

G Elevating a wood-frame-over-basement structure on masonry piers.

Figure 1 illustrates the type of information (drawings and wall section details) provided to local governments and homeowners for each of the proposed techniques. The technique shown in Figure 1 allows for the elevation of the typical substantially damaged one- or two-story structure on an existing crawl space by adding to the existing foundation walls, resulting in a structure with a lowest floor or at above the BFE. With the installation of foundation wall openings and the elevation of utilities and mechanical equipment above the BFE, the structure complies with the NFIP requirements. All the proposed techniques comply with state and local building codes as well as NFIP requirements. It should be noted that during the team’s tour of site conditions in Illinois, several of these techniques were seen to have been used by homeowners in the past. Most of the homes that were previously elevated in this fashion survived the 1993 flood with little or no damage.

To address seismic concerns in the southern portion of the state, additional guidance was included in the technical information package. This information was developed in accordance with the National Earthquake Hazard Reduction Program (NEHRP) minimum recommended provisions and consisted of literature, technical drawings, and estimates of the associated costs of seismic retrofitting procedures that could be employed when elevating homes in accordance with NFIP requirements.

The design team then developed detailed cost estimates for the alternative techniques considered using standard construction costing methods (Table I). The team’s local engineering staff was highly experienced in residential development in the Midwest and intimately familiar with the technical challenges associated with the alternative elevation techniques considered. This translated into accurate localized cost estimates for each technique. After the cost estimates were prepared, the pricing structure for each method was con-
Figure 1. Examples of technical guidance materials.
verted into a simplified per-square-foot cost that homeowners could easily use to calculate the cost of elevating their homes. All the cost estimating procedures presented by the team were "user-friendly" and were provided with clear directions for homeowners’ use.

*Table 1. Cost spreadsheet for alternatives.*

<table>
<thead>
<tr>
<th>HEIGHT ABOVE GRADE HOME IS BEING ELEVATED</th>
<th>ALTERNATIVES</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>A²</td>
<td>B²</td>
</tr>
<tr>
<td>1 TO 3 FEET</td>
<td>$20,000</td>
<td>$26,500</td>
</tr>
<tr>
<td>4 FEET</td>
<td>$21,400</td>
<td>$27,900</td>
</tr>
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<td>5 FEET</td>
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<td>$29,300</td>
</tr>
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<td>6 FEET</td>
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<td>16 FEET</td>
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</table>

**NOTES:**

1. Estimated costs are provided for general structural cost guidance only and do not include potential additional costs for compliance with wind load requirements, for new roofing system, for seismic strengthening, or for general contractor charges, or ancillary costs such as electrical, plumbing, finishing, and other non-structural costs.

2. No finish in new masonry enclosed area.

3. Demolition does not include environmental assessment and/or cleanup cost.

The information developed by the team was disseminated to Illinois state and local governmental staff, local architects and engineers, and interested homeowners through a series of meetings with local officials, consumer workshops, and one-on-one technical counseling with affected property owners. A publication containing illustrations of each technique was reproduced and made available by FEMA to local governments, homeowners, contractors, architects, and engineers (FEMA, 1993).
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LOCAL FLOOD PROOFING PROGRAMS

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Introduction

Studies have shown that financing is often the greatest impediment to implementing a flood proofing project. While many people want to flood proof, lack of funds was listed as the most important reason why they did not. Some federal agencies have financed flood proofing projects. Statutory authority and limited resources keep the federal programs from reaching many people.

A few local governments have financed or provided financial support for flood proofing projects. Each community's program was developed differently and is administered differently. The experiences of these communities can be very helpful in guiding other flood prone communities in developing their own approaches to flood proofing.

Purpose

This paper identifies lessons learned that can help communities interested in financing flood proofing projects. It is not a recipe for developing a model program, because each community must design its own approach based on local flood hazards, building conditions, financial needs, and resources. Detailed information is found in a recent Corps publication, Local Flood Proofing Programs, which is also the source for this paper.

General Considerations

Before initiating a flood proofing funding program, certain factors need to be considered by community officials. Six of the most important factors are covered in this paper:

1. Ensure that the projects to be funded are appropriate for the flood hazard.

2. Identify the source of the funds.

3. Get others in the community interested in and supportive of flood proofing.

4. Involve the property owners in the flood proofing and funding decisions.
5. Ensure that the community has the legal authority to fund the projects.

6. Ensure that local staff will be free from liability.

**Appropriate Projects**

The financial benefits of flood proofing can be very attractive to community officials. It is usually cheaper to protect a building in place than to acquire and/or remove it. However, flood proofing techniques that leave a building in the flood plain are not appropriate in areas subject to the high hazards of deep flooding, erosion, flash flooding, high velocity flooding, or heavy debris flows.

Flood proofing is an appropriate flood protection measure only for certain flood hazards and particular types of buildings. A community should develop criteria to decide which properties should be protected by which measures. The Corps publication, *Flood Proofing—How to Evaluate Your Options*, provides guidelines for determining the most appropriate measure for an individual building.

Communities should generally restrict flood proofing projects to areas subject to low velocity and/or shallow flooding. Some limit their funding to the safest types of projects as seen by these examples:

- Des Plaines, Illinois, restricts its funding to sewer backup protection projects.

- The flood protection plan developed by Homewood, Illinois, recommended funding only elevation projects rather than cheaper dry flood proofing projects.

- The Illinois Department of Transportation, Division of Water Resources, helped establish a low interest loan program for communities in 1988. It gave the communities guidelines to determine which types of projects could be funded based on the flood depths and building types.

- Prince George’s County, Maryland, established guidelines for its funding program based on 100-year flood levels developed by the County, assuming a fully developed watershed.

**Funding Sources**

Wanting to finance flood proofing projects is one thing; having the money to do it is quite another. Communities may encounter one or two problems in devoting funds to flood proofing: having adequate funds to start a
new program, and/or having the legal authority to spend the money on flood proofing.

**Property Taxes.** Property taxes are the mainstay of most local governments. There are two kinds of property taxes, general and special purpose. Most communities have a "general corporate fund" or "general revenue fund" that may be used to finance many kinds of activities, especially staff and administrative expenses. Frankfort, Kentucky; Rosemont, Illinois; and Fairfax County, Virginia, identified this kind of fund as one of their funding sources.

A special purpose storm drainage property tax finances the program in Prince George's County, Maryland. Revenue from this separate state-approved tax is deposited in a special fund. King County, Washington, has a special county-wide property tax levy that goes into its River Improvement Fund.

**Sales Tax.** Some states authorize communities to levy sales taxes for special purposes. The Economic Development Council of Kemah, Texas, is supported by a 0.5% sales tax. The Council funds various community improvement activities including drainage projects, flood plain acquisition and flood proofing.

**Bond Issue.** Bonds are usually issued to pay for large public works projects, including flood and drainage improvements. Fairfax County, Virginia, and Homewood, Illinois, identified bonds sold for stormwater or drainage improvement purposes as one of their funding sources.

**Impact Fees.** Some drainage projects in Fairfax County, Virginia, are paid for by contributions from developers. They are required to contribute to the cost of handling the increased stormwater runoff produced by their developments.

**Creative Financing.** A community is limited only by its imagination. Several have found "creative" ways to find funds for flood proofing. For example, Illinois levies an income tax, which it shares with local governments. The city of Des Plaines appropriated $200,000 from this "extra" money to establish a fund for its flood proofing rebate program.

**State Support.** Some states have had special appropriations to support local programs. In 1988, the Illinois Housing Development Authority set aside $500,000 for low interest loans for flood proofing.

**Federal Support.** Several federal agencies, such as the U.S. Army Corps of Engineers and the Tennessee Valley Authority, have directly funded flood proofing projects. The lessons learned from this work are often transferrable to local government programs. One example of this is the Corps’ publication, *A Flood Proofing Success Story*, which provides documents on dealing with property owners and contractors that are applicable to all financing programs. The Department of Housing and Urban Development’s (HUD) Community Development Block Grant and the Federal Emergency Management
Agency's (FEMA) Public Assistance and Hazard Mitigation Grant Programs provide funds for communities to administer.

**Community Interest**

What motivates a community to fund flood proofing projects? Those that have investigated or implemented funding programs cited one or more of the following five broad reasons.

**Economics.** The most frequently cited reason for funding flood proofing was cost. It was shown to be less expensive than other flood protection measures. In some cases, as in Fairfax County, Virginia, and King County, Washington, studies of local flood problem areas reviewed a variety of structural and nonstructural alternatives. Two cautions must be noted. First, communities must remember that flood proofing does not stop street and yard flooding, damage to infrastructure, traffic disruption, and other problems that accompany floods. Second, predicting the actual costs of projects in areas with little flood proofing experience may be difficult.

**Comprehensive Planning.** Some communities have prepared comprehensive flood plain management or flood damage reduction plans. During the planning process, they concluded that flood proofing should be a part of the program. King County, Washington, prepared such a comprehensive plan, which made project recommendations for over 120 flooding and erosion problem sites in the county.

**External Impact.** Sometimes flood proofing is selected because other flood protection measures have adverse impacts on other properties or the environment. Flood proofing can also be less disruptive to a neighborhood than, for example, removing houses or building a large wall.

**Community Rating System.** The Community Rating System (CRS) is a part of the National Flood Insurance Program (NFIP). Once in the CRS, some communities want to improve their insurance rate reduction, so they initiate new programs to receive more credit for more activities. For example, officials in Kemah, Texas, and South Holland, Illinois, have implemented public information programs and have planned funding programs.

**Post-flood Mitigation Programs.** Usually a community becomes interested in flood protection programs after a flood. Not only is there interest in trying new approaches, there may be funds available to support new programs. For example, while processing the applications for grants to repair flooded wastewater treatment plants or other public buildings, FEMA staff identify flood proofing or other mitigation alternatives. HUD's Community Development Block Grant program also has a post-disaster funding program. The Village of St. Charles, Michigan, took advantage of this program to fund a comprehensive flood damage reduction program after it was flooded in 1986.
**Property Owner Involvement**

Voluntary property owner involvement is vital to the initiation and long-term operation and maintenance of a flood proofing project. Keeping residents informed was the recommendation most frequently voiced by communities experienced in implementing flood protection plans. This requires both the right attitude and sound technical data that can be explained in lay terms.

**Statutory Authority**

Two legal questions sometimes arise when considering government involvement in flood proofing: the statutory authority to spend public money on improving private property, and liability for protecting private property. In some communities, legal challenges have prevented implementation of well-planned programs.

Most states do not have laws that address flood proofing so clearly. A few communities reported either that it was against state law or there was no specific authority to use public money to improve private property.

In Illinois, the strongest authority comes from statutory authorizations for communities to undertake community development activities, to bring buildings up to safe and sanitary conditions, and to protect their residents from the health and safety problems of flooding. In most states, there is authority to spend local funds on activities whose costs are shared with a state or federal agency.

**Liability**

What if a flood proofed property is later damaged by a flood? What if the owner failed to maintain a protection measure? These questions have been debated nationally for some time. A community has five ways in which it can protect itself from lawsuits:

1. Staff should become technically competent in the field.

2. Staff should limit flood proofing advice and projects to areas where it is appropriate, i.e., areas of lower velocities and flood depths.

3. The community should enter into a contract or agreement with each property owner. The agreement should specifically exempt the local government from liability.

4. Staff should follow nationally recognized flood proofing guidelines.
5. The community may want to purchase liability insurance or establish a self-insurance pool or plan to protect itself.

Funding Arrangements

The previous section reviewed the factors that a community should consider in establishing a program to fund flood proofing projects. This section discusses how funds actually have been managed. The local programs reviewed fall into one of the following five categories.

Full Funding of Projects on Public Property

Under this approach, a community selects flood proofing as the best way to protect its public facilities from flooding. This is the easiest approach to implement, as it avoids the problems of coordinating activities with a property owner, legal complications of how money should be spent, and concerns about liability.

Full Funding of Projects on Private Property

Under this approach, the community assumes full responsibility for designing, contracting, funding, and managing the flood proofing project. It is similar to full funding on public property except that there needs to be a great deal of coordination with the property owner.

Cost Sharing with State or Federal Funds

Another way to reduce the direct cost to the community is to piggyback with another agency's program. The two most common programs are HUD's Community Development Block Grants and FEMA's post-disaster Hazard Mitigation Grants. The CDBG has funded 100% of the cost to elevate homes in Terrebonne Parish, Louisiana; Kampsville, Illinois; and St. Charles, Michigan. Several communities have used "soft matches" like in-kind services, which are given a dollar value and credited toward the local share.

Cost Sharing with the Property Owner

Having the owner of the protected property contribute to the project's cost has two advantages; the community's funds will go farther, and it gives the property owner a stake in the project. By having an investment in flood proofing, the owner has an incentive to make sure the property is properly maintained.
Low Interest Loans

Low interest loans look attractive to a funding agency. Eventually, the funds will be repaid so they can be loaned to flood proof other properties. Loans also avoid the challenge that the community is "giving" money to improve private property. However, flood proofing loan programs have yielded mixed results. Michigan and Illinois offered them before floods had occurred, but there were few takers. On the other hand, the Small Business Administration’s 4% disaster assistance loans have been widely used to flood proof properties.

Conclusion

The potential for flood proofing to reduce flood losses is significant. Many people have flood proofed their homes or businesses, often by using common sense or self-taught approaches. In the last 10 years, federal, state and local agencies have been researching techniques, promoting flood proofing as a viable flood protection measure, and assisting property owners in implementing projects.
LOW INTEREST LOANS FOR FLOODPROOFING

French Wetmore
French & Associates, Ltd.

Introduction

A major flood in the western and northwestern Chicago suburbs in August 1987 affected over 100 communities, closed O'Hare Airport, and resulted in a Presidential disaster declaration. Some of the areas had flooded in 1986 and some communities were interested in new approaches to flood protection. Because much of the damage was due to shallow flooding and sewer backup, floodproofing measures were viewed as an inexpensive way to protect many people. State agencies promoted floodproofing and offered advice and technical assistance through handbooks, at public meetings, and at Disaster Application Centers.

One program initiated after the flood was a low interest floodproofing loan program. This paper is a review and evaluation of that program. It is based on interviews of participating local officials, bankers, loan applicants, and loan recipients. It is taken from a project conducted by French & Associates for the Illinois Association for Floodplain and Stormwater Management under a contract funded by the Federal Emergency Management Agency's (FEMA) Hazard Mitigation Assistance Program.

The Loan Program

The Illinois Housing Development Authority (IHDA) is a quasi-independent state agency dedicated to helping low and moderate income families obtain housing. IHDA is not financed by annual appropriations. It has a pool of capital that it invests and its operating income comes from interest earned on investments. IHDA can be somewhat flexible in its program design. However, it is limited by law to support low and moderate income housing. It must also ensure that its loans and investments are safe. It cannot give away money and it cannot undertake risky projects.

Soon after the August 1987 flood, IHDA approached the Illinois Department of Transportation, Division of Water Resources (DWR), with an offer to set aside $500,000 for low interest loans. Because there were already many sources of funds for repairs and reconstruction, it was agreed to make the funds available for floodproofing projects. The two agencies' staff developed the basic outline of the program, which is summarized in Table 1. IHDA needed a
program that met its legal constraints and DWR wanted one that would promote additional local flood mitigation efforts.

Table 1. IHDA loan program summary.

- IHDA would make low interest loans available to low or moderate income families, i.e., the total family income is less than $35,000.

- The loans would only be made available within communities approved by DWR.

- The loans would be limited to floodproofing measures as approved by local building departments; they could not be used for disaster repairs.

- The loans would be made through local banks with IHDA providing funding support to the banks.
  - The loans would be for a maximum of $5,000.
  - The interest rate on the loans would be 2%.
  - The loans must be paid off within five years.

- Administrative costs of processing the loans (title searches, etc.) would be borne by someone other than IHDA or DWR.

- The loan recipient must purchase flood or sewer backup insurance, as appropriate.

- To participate, a community must pass a resolution of intent to participate, which promises that the community will:
  - publicize the program,
  - send staff to DWR training on floodproofing,
  - review plans of loan applicants to ensure that the projects are appropriate for the flood hazard, and
  - prepare and adopt a flood hazard mitigation plan by June 30, 1988.
Community Participation

Over 100 Chicago suburban communities were affected by the flooding. The program was publicized to all of them via letter and public meeting. Eventually 18 municipalities and one county signed up. They were organized into five groups with one bank serving several communities.

Allocation of the funds was a critical issue because it was expected that the $500,000 would be used up quickly. A formula was developed based on the number of residents counseled at the Disaster Application Centers’ mitigation tables. This was felt to represent the number of people in each community who could benefit from floodproofing and who needed financial assistance. The formula resulted in allocations of $65,000 to one community, $45,000 to three, and $20,000 to the other 15 communities.

Program Implementation

The funds were not released quickly. Many details had to be worked out, especially on the financial arrangements. IHDA’s Board of Directors was not ready to rush into committing a half million dollars in a new program that had no guarantees. It was six months after the flood when the Board passed the needed resolution and negotiating agreements with the five banks took three more months.

Meanwhile, most of the communities passed their resolutions, publicized the loans, and began their mitigation planning. Thirteen communities passed the resolution by the January 31 deadline. Fewer sent staff to the training. By the June 30 deadline, only 10 had completed acceptable mitigation plans. The plan reviewer noted, "None of them are exemplary plans."

One reason some communities did not have an incentive to meet the deadlines was the lack of applications for loans. By the end of 1988, IHDA reported only 10 loans for a total of $36,900. IHDA and DWR agreed to honor a few pending applications and then shut the program down in May 1989. By then, 14 loans were approved from four banks for a total of $51,600. The amount of the loans ranged from $2,000 to $5,000. The average was $3,685. The median and the mode was $3,500.

Interview Findings

It was difficult to reach all of the participants five years after the loan program operated. Interviews were conducted with 13 of the 19 communities, three of the five banks, and 15 loan applicants (nine loan recipients and six people whose applications were turned down). In general, the local officials were frustrated with the low turnout after all the work they did, the lenders took
the program in stride and incorporated it into their regular procedures, and the recipients of the loans were pleased with the way it was administered.

The respondents agreed on the following specific issues:

- There was a good deal of publicity and the message was delivered in a variety of ways, but many felt there should have been more.

- The application requirements were not burdensome, although a reduction in the paperwork and confusion would be appreciated.

- The 2% interest rate was supported by all.

- Bankers and local officials felt that the $35,000 family income limitation was an important reason why more people did not apply.

- There may have been more applicants if the amount of the loan was more than $5,000, although that amount should cover most projects appropriate for the flood hazard.

One interesting finding was the relatively high satisfaction level of the residents. Some of them had very positive comments, like "very helpful, thanks much," "we would have done something after the 1986 flood if we had the money," and "it was a godsend for us." All of the loans were paid off, often because it was required in order to refinance the first mortgage as interest rates went down.

Projects Funded

Table 2 shows the types of projects the applicants wanted to implement. Four applicants had plans for multiple mitigation measures. Therefore, the numbers add up to more than 15. All but one of the single projects were for sewer backup protection. The multiple projects dealt with basement and yard flooding. Sump pump improvements included drain tile work and battery backups. Dry floodproofing included sealing cracks and

<table>
<thead>
<tr>
<th>Table 2. Projects funded.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sewer backup protection:</td>
</tr>
<tr>
<td>Overhead sewers</td>
</tr>
<tr>
<td>Sewer backup valve</td>
</tr>
<tr>
<td>Basement flooding protection:</td>
</tr>
<tr>
<td>Sump pump improvements</td>
</tr>
<tr>
<td>Dry floodproofing</td>
</tr>
<tr>
<td>Surface flooding protection:</td>
</tr>
<tr>
<td>Yard regrading</td>
</tr>
</tbody>
</table>
replacing basement windows with glass block.

Most of the projects are the kind that takes an experienced contractor to install. This fact, plus the initial project review by the local building departments, means that the projects can be expected to work. All of the measures could be implemented within the $5,000 limit.

**Conclusions and Recommendations**

It is generally held that disaster victims would not participate in a loan program; that they would need grants instead. Illinois' low interest floodproofing loan experience, while small, does not support this contention. Even low and moderate income families wanted and obtained loans dedicated solely for floodproofing. Applications were still submitted as late as a year after the flood.

There remains the frustrating question, "Why didn't more people apply?" This report cannot provide a definite answer to that question. Suppositions had been proposed: too late after the flood to interest people, too little publicity, too low an income level, too much paperwork, and not enough money to cover other floodproofing projects. These suppositions formed the basis of the questions put to the bankers, local officials, and applicants.

With one exception, the answers did not reveal any clear opinion of those involved with the loan program. The exception was that most of the bankers and local officials felt that the income level limited the number of applications and the number of approved applications.

The only other conclusion that can be drawn is that there might be more applicants if all aspects of the program were improved and implemented more quickly with less confusion. In other words, have the procedures, forms, publicity, etc., for a low interest loan program ready to go before the next flood.

More details on the IHDA loan program, the procedures followed, the forms used, the interview findings, and the recommendations for future loan programs are found in *Analysis of the IHDA Floodproofing Loan Program*, September 1993, available from the Illinois Association for Floodplain and Stormwater Management.
Introduction

House raising is one type of flood proofing that can be used to reduce or eliminate flood damage to flood-prone homes. A successful flood proofing project was completed in Goodlettsville, Tennessee (near Nashville). The project, known as the Dry Creek Project, consisted of raising in place 19 homes.

A different administrative approach assisted the Corps of Engineers, Nashville District, in the implementation a successful, cost-effective house raising project. A nonstandard approach was used which reduced administrative costs by minimizing Corps of Engineers' involvement and maximized homeowner involvement. Satisfaction was achieved by allowing homeowners to control many aspects of the project.

Project Background

The Nashville District flood proofed those 19 houses by raising their first floors above the 100-year flood elevation. The flood proofing project cost was $568,000, and the benefit-cost ratio was 1.2. The house raising began in March 1989 and was completed in June 1990. When flood proofing was considered for the 19 houses, a review of the Corps of Engineers' house raising experience revealed two problem areas: high costs, and homeowner apprehension.

The solution to both problems involved minimizing the Corps of Engineers' role and maximizing the homeowner's role. This was accomplished by changing the standard Corps of Engineers' procedure and allowing the homeowners to select their own contractors and direct the work. In very simple terms, the Corps of Engineers said to each homeowner, "You get your house raised, and we will pay for it."

Project Implementation

Information Phase

Project implementation began by communicating with the homeowner. The homeowners were required to obtain at least three proposals from
contractors of their choice and submit them to the Corps of Engineers. All contractors' proposals for the Dry Creek Project were less than the government estimate. The Corps of Engineers' review of the proposals was to insure that the fundamental requirements were covered and other major items of work were agreed upon, such as the size of porches and decks, sidewalks, driveways, and landscaping.

The Corps-homeowner agreement was the last step prior to construction. The agreement contained only four requirements:

1) The house had to be raised at least 1 foot above the 100-year flood elevation;

2) Construction had to pass the codes inspection by the City of Goodlettsville (the prevailing code for home construction and improvement);

3) A provision of flow through the foundation to eliminate hydrostatic pressure had to be allowed for; and

4) The homeowner had to execute a covenant provided by the Corps and later recorded at the courthouse stating that the space below the new first floor would never be converted into living space.

After the terms of the agreement were met, the Corps of Engineers paid the amount of the "offer."

Construction

All the homes in the program were one-story brick veneer, in sound structural condition. The homes ranged from 1,000 to 1,475 square feet, and the raise heights varied from 2 to 6 feet. All homes had crawl spaces under the main portion of the structure. Several residences had finished garages on slabs about 1.5 feet lower than the first floor. The slabs were not raised. Table 1 presents a descriptive list of the homes.

The typical steps and time requirements for construction are:

1) Obtain city permits.

2) Complete a pre-construction inspection and inventory.

3) Complete site work. This usually took 3 to 5 days, i.e., brick removal and disposal, dismantling fences and moving shrubbery, knocking holes in the foundation walls, cutting garage slabs for lifting beams, and other miscellaneous activities.
Table 1. Dry Creek flood proofing project summary.

<table>
<thead>
<tr>
<th>SIZE of HOUSE (sq. ft.)</th>
<th>RAISE HEIGHT (ft.)</th>
<th>CONST. COST** ***</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>5.33</td>
<td>$26,200</td>
<td>3 exits</td>
</tr>
<tr>
<td>1000</td>
<td>6.00</td>
<td>$29,500</td>
<td>3 exits</td>
</tr>
<tr>
<td>1000</td>
<td>5.33</td>
<td>$29,500</td>
<td>3 exits</td>
</tr>
<tr>
<td>1000</td>
<td>4.67</td>
<td>$29,500</td>
<td>3 exits, A/C</td>
</tr>
<tr>
<td>1420</td>
<td>4.67</td>
<td>$35,000</td>
<td>3 exits, finished garage, offset</td>
</tr>
<tr>
<td>1450</td>
<td>4.00</td>
<td>$35,350</td>
<td>2 exits, A/C, fin. garage, offset, paved drive, big porch</td>
</tr>
<tr>
<td>1430</td>
<td>3.33</td>
<td>$34,050</td>
<td>2 exits, fin. garage, offset, fireplace, paved drive, 2 big porches</td>
</tr>
<tr>
<td>1475</td>
<td>4.00</td>
<td>$33,000</td>
<td>3 exits, offset</td>
</tr>
<tr>
<td>1425</td>
<td>3.33</td>
<td>$32,600</td>
<td>2 exits, garage, offset, paved drive, alum. siding, big front porch</td>
</tr>
<tr>
<td>1425</td>
<td>2.67</td>
<td>$31,000</td>
<td>2 exits, garage, offset, big front porch</td>
</tr>
<tr>
<td>1450</td>
<td>2.00</td>
<td>$30,800</td>
<td>2 exits, finished garage, large attached carport</td>
</tr>
<tr>
<td>1065</td>
<td>4.67</td>
<td>$29,700</td>
<td>2 exits, offset</td>
</tr>
<tr>
<td>1275</td>
<td>2.00</td>
<td>$30,200</td>
<td>2 exits, finished utility room (on slab), A/C, partial stone face</td>
</tr>
<tr>
<td>1450</td>
<td>2.00</td>
<td>$31,600</td>
<td>2 exits, finished garage w/false ceiling, C/F fence</td>
</tr>
<tr>
<td>1400</td>
<td>2.00</td>
<td>$31,600</td>
<td>2 exits, finished garage w/false ceiling, A/C</td>
</tr>
<tr>
<td>1450</td>
<td>2.00</td>
<td>$26,500</td>
<td>front porch, garage (rehang 2 doors &amp; window, interior steps)</td>
</tr>
<tr>
<td>1014</td>
<td>2.00</td>
<td>$25,900</td>
<td>2 exits, paved driveway</td>
</tr>
<tr>
<td>1000</td>
<td>2.00</td>
<td>$27,200</td>
<td>2 exits, attached utility room, wood fence, concrete patio</td>
</tr>
<tr>
<td>1450</td>
<td>2.00</td>
<td>$31,600</td>
<td>2 exits, finished garage w/false ceiling, large front porch</td>
</tr>
</tbody>
</table>

* Brick veneer houses in sound structural condition with crawl spaces.
** Includes $4,000 per structure for Corps of Engineers' administrative costs.
*** 1989-1990 prices.

4) Vacate home on the day of house raising and disconnect water and sanitary drainage lines.

5) Raising was usually accomplished with synchronized hydraulic jacking systems and timber cribbing. This required about 1 to 2 hours per vertical foot.

6) Complete temporary utility reconnections and erect temporary steps. Local ordinances should be followed regarding habitability during housing raising activities.

7) Complete the remaining work in from 2 weeks to 3 months, i.e. new footings, masonry block laying, brickwork, plumbing, limited electrical work, new porches and decks, and site cleanup and landscaping.
Factors impacting the time included weather, capability of contractor, availability of sub-contractors, and type of structure.

The only formal "inspection" by the Corps of Engineers was to certify that the terms of the Corps-homeowner agreement were met prior to payment. The Goodlettsville codes department and the homeowners provided the "quality control" for the construction.

Costs

Raising-in-place construction costs for the 19 houses ranged from $25,900 to $35,350, including administrative cost (see Table 1). The major variables that influenced the costs were the number of entrances/ exits, height of raise and foundation perimeter, size of existing porches, offsets, and finished garages. Corps of Engineers' administrative costs of about $4,000 per structure were incurred.

Conclusions

The Dry Creek flood proofing project was a success. The project objectives were achieved.
1) Flood proof the houses in a cost efficient manner.
2) Maximize homeowner satisfaction.
There was nothing unique about flood proofing the houses along Dry Creek; no new construction techniques were developed, and no unusual techniques were used. The uniqueness of the project was the administrative philosophy. This philosophy was to "keep things simple, and stay out of the way as much as possible."

References

U.S. Army Corps of Engineers, National Flood Proofing Committee
1993 A Flood Proofing Success Story along Dry Creek at Goodlettsville, Tennessee.
Appendix

Using Dry Creek Costs as an Estimating Tool

This appendix discusses the applicability of using the cost data included herein as a basis for estimating costs on similar projects at other locations. An equation was developed based on the Dry Creek house raising costs. The variables in the equation are size of structure and raise height, and the equation takes the form:

\[
\text{COMPUTED COST} = K + (K_s)(\text{size}) + (K_h)(\text{raise height})
\]

Constants are: K;

\(K_s\), "size" is the square feet of the ground floor, including attached garage;

\(K_h\), "raise height" is in feet.

The constants derived from the Dry Creek data are:

\[K = 11,360; K_s = 12.6; \text{ and } K_h = 970.\]

This equation should give reasonable planning-level estimates for screening alternatives. Anyone using the equation or its results should recognize the limitations of this method.

THE EQUATION SHOULD NOT BE APPLIED TO SITUATIONS WHICH ARE DRastically DIFFerENT FROM THOSE AT DRY CREEK. SPECIFICALLY, THE EQUATION SHOULD NOT BE USED ON HOMES IN POOR (UNsound) CONDITION OR HOMES ON SLAB.

The Cost Analysis Table on the next page shows the actual cost, the computed cost using this formula, and the percentage of difference for each house raised in the Dry Creek Project.
Table A-1. Cost analysis.

<table>
<thead>
<tr>
<th>STRUCTURE NUMBER</th>
<th>SIZE (square feet)</th>
<th>RAISE HEIGHT (feet)</th>
<th>ACTUAL COST*</th>
<th>COMPUTED COST**</th>
<th>PERCENT DIFFERENCE (Compound vs. Actual)</th>
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<tr>
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<td>2.00</td>
<td>$31,600</td>
<td>$31,570</td>
<td>0</td>
</tr>
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</table>

* Includes $4,000 per structure for Corps of Engineers' administrative costs
** Compared Cost Where K = 11,360; K_s = 12.6; K_h = 970

EXAMPLE:

House No. 5:
COMPUTED COST = K(K_s)(size of house in square feet) + K_h(raise height in feet)
= 11,360 + (12.6)(size of house) + (970)(raise height)
= 11,360 + (12.6)(1420) + (970)(4.67)
= $33,782
FLOODPROOFING OPEN HOUSES

French Wetmore
French & Associates, Ltd.

Introduction

Floodproofing open houses provide flood protection information and advice to floodprone property owners. More than a dozen floodproofing open houses have been conducted in Illinois since 1981 and they have been used in other states in the last few years, particularly after a flood or when it has been concluded that a structural flood control project is not feasible. This paper reviews the findings of a survey of open house participants to determine if the open houses were productive and, if so, how they could be improved.

Floodproofing open houses have four major parts:

1. A slide show or video to provide an overview of floodproofing, insurance, and other flood protection topics;

2. Contractors and government staff available at tables to talk one-on-one with the attendees about their products, services, or agency programs;

3. A "mitigation table" where people could review their flood situation with an objective expert and receive advice on what to do and who at the open house could help; and

4. Manuals on floodproofing and property protection and handouts provided by the contractors and government agencies, which are given to all participants.


The Survey

Of the over 300 participants at the two open houses, 160 returned completed questionnaires. They came from 14 suburbs, the bulk of them from Homewood, Flossmoor, and South Holland. Eighty-one percent of the attendees
Floodproofing Open Houses

had been flooded in November 1990 and 76% had been flooded before then. Sixty-six percent had basement/crawlspace flooding and 7% had flooding in the first floor.

Publicity

These two open houses had a much larger turnout than previous ones conducted within two weeks of floods. The survey responses support the supposition that more lead time coupled with local publicity will bring in more people. Newspapers, local notices, and word of mouth were the major sources of information about the open houses, all of which need lead time. Of the 85 who read about the open houses in the newspaper, 62 listed that as their only notification.

Effectiveness of the Open Houses

Open houses can be judged to be effective if the attendees implement flood protection measures. The ultimate effectiveness can be told if the protection measures actually reduce flood damage in later floods. The survey respondents had one to two years to implement a measure. Those who attended the earlier open house suffered a severe storm two weeks after, which may have provided an important reminder of the need for flood protection.

The survey found that the 2/3 of the respondents (107 of 160) implemented one or more flood protection measure after they attended the open house. As expected, the rate of implementation was higher for those who went to the earlier open house. The majority of those who implemented something did more than one thing. One respondent undertook seven projects. The measures taken are shown in Table 1.

The measures implemented ranged from inexpensive to expensive, from minor alterations to major changes to the building. While it cannot be proven that the open houses were the only reason why the measures were taken, it is likely that they had a considerable impact on the property owner's decision.

As expected, most of the implemented measures dealt with basement or sewer flooding. It is interesting to note that every flood protection measure was implemented by at least three participants from each workshop. It is also significant that there are more cases of expensive measures, such as overhead sewers and backup valves (which cost $3,000 to $4,000), than of the inexpensive measures like standpipes.
Table 1. Flood protection measures implemented by 107 participants after the open house.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Participants</th>
</tr>
</thead>
<tbody>
<tr>
<td>Installed overhead sewers (11)</td>
<td></td>
</tr>
<tr>
<td>Installed sewer backup valve (13)</td>
<td></td>
</tr>
<tr>
<td>Installed standpipe or sewer drain plug (13)</td>
<td></td>
</tr>
<tr>
<td>Installed or added a new sump pump (36)</td>
<td></td>
</tr>
<tr>
<td>Replaced or replaced a sump pump (28)</td>
<td></td>
</tr>
<tr>
<td>Waterproofed basement walls (23)</td>
<td></td>
</tr>
<tr>
<td>Regraded yard/built wall to keep water away (34)</td>
<td></td>
</tr>
<tr>
<td>Protected windows or window wells from flooding (13)</td>
<td></td>
</tr>
<tr>
<td>Bought flood insurance (17)</td>
<td></td>
</tr>
<tr>
<td>Obtained sandbags/made emergency action plan (11)</td>
<td></td>
</tr>
<tr>
<td>Other:</td>
<td></td>
</tr>
<tr>
<td>Drain tile improvements (4)</td>
<td></td>
</tr>
<tr>
<td>Sewer line improvements (2)</td>
<td></td>
</tr>
<tr>
<td>Dry floodproofing (3)</td>
<td></td>
</tr>
<tr>
<td>Raised building (2)</td>
<td></td>
</tr>
<tr>
<td>City fixed problem (2)</td>
<td></td>
</tr>
<tr>
<td>Installed backup electrical power (2)</td>
<td></td>
</tr>
<tr>
<td>Encouraged others to floodproof (1)</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
</tr>
</tbody>
</table>

n=215

The number that bought flood insurance is lower than expected. However, flood insurance may not be useful for the majority of the people concerned with basement and sewer backup flooding. There was a higher rate of insurance purchase for the South Holland attendees and South Holland has a greater overbank flood problem than the other suburbs that were represented.

Effectiveness of the Measures

Were the measures successful? Some of the area was flooded after the open houses were held. However, it must be noted that the later floods were at least two feet lower than the 1990 flood, so some measures would not have been tested. Twenty-nine respondents had had a flood that tested the flood protection measures they installed after the open houses. Twenty-three of them (79%) stated that the measures helped prevent or reduce flood damage. Ten of these implemented one measure and the other 13 implemented multiple measures.
Of the six respondents who reported that their measures did not work, one is having the problem corrected under the contractor’s guarantee. Four others did not implement what was needed for their reported flood problem, one because she could not afford to. It is not known why the sixth person’s measure did not work.

Conduct of the Open Houses

The survey respondents were asked which activities proved most helpful and how they were helped. The handbook, the slide show, the videos, talking with contractors, and talking with other homeowners were rated as most helpful. Talking with government officials was rated as less helpful. However, it should be noted that most of the local officials were present to explain permit requirements, not to provide floodproofing assistance. Further, as noted later, many respondents wanted more information about government programs. The types of assistance people received are summarized in Table 2.

Table 2. Responses to the question, “How did the floodproofing open house help you?”

<table>
<thead>
<tr>
<th>Help</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Helped me better understand my flood problem</td>
<td>19%</td>
</tr>
<tr>
<td>Helped me better understand government programs</td>
<td>12%</td>
</tr>
<tr>
<td>Got flood protection ideas from the handbook</td>
<td>17%</td>
</tr>
<tr>
<td>Got protection ideas from the slide show or the video</td>
<td>13%</td>
</tr>
<tr>
<td>Got flood protection ideas from a government expert</td>
<td>7%</td>
</tr>
<tr>
<td>Got flood protection ideas from a contractor</td>
<td>13%</td>
</tr>
<tr>
<td>Used the services/got materials from a contractor</td>
<td>5%</td>
</tr>
<tr>
<td>Showed me where to go for more information or help</td>
<td>7%</td>
</tr>
<tr>
<td>The Open House confirmed what I had planned to do</td>
<td>8%</td>
</tr>
</tbody>
</table>

Fears that contractors would prey on flood victims, would have an unfair advantage, and would make a lot of sales were not supported. Few contractors made sales and the respondents wanted to talk to more contractors in the future.
Recommendations

Eighty-five percent of those who responded to the question "Would you recommend that more open houses be held in the future?" said yes, either in other areas, later in the same area, or both. Open houses should continue, not only because the participants recommended so, but because the majority of the participants later implemented flood protection measures. Most of those measures worked for those properties that were later flooded.

In addition to acting as a vehicle to provide information, open houses facilitate interaction between flood prone residents and their local officials. The many positive comments show that residents appreciate the service from their local governments and the chance to talk to their local officials.

Self-help flood protection should be viewed as part of a larger community flood protection effort. Open houses should be publicized as one of several flood protection efforts of the community. Neither the publicity nor the conduct should communicate an attitude that the local governments are abandoning their residents.

This conclusion should be viewed in the context of an area subject to shallow overbank flooding, sewer backup, and basement flooding where protection measures are less expensive and less disruptive than other floodproofing measures, such as elevation and floodwalls.

More details on these findings are in a report, Analysis of the 1991 and 1992 Floodproofing Open Houses, available from the Illinois Association for Floodplain and Stormwater Management. The report's recommendations are incorporated into a separate report by the Illinois Association, How to Conduct a Floodproofing Open House.
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PART FIVE

FLOOD CONTROL STRUCTURES
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FLOOD CONTROL PROJECTS
UTILIZING EXISTING COUNTY ROADWAYS

Cecil R. Bearden
Oklahoma Water Resources Board

Introduction

Canadian County, Oklahoma, began with the opening of the Unassigned Lands. Two million acres of central Oklahoma Territory were opened to white settlement with a shot from a cavalryman's rifle at noon on April 22, 1889. By nightfall, 50,000 men and women had staked claims to the land and begun to build homes, schools, and businesses. In the years that followed, development in Oklahoma has remained sporadic and intense. This method of development causes existing public utilities to be strained and creates interruption of vital transportation links due to flooded roadways. With the price of undeveloped land in excess of $4000 per acre, and the dwindling federal budget for flood control projects, communities must investigate multiple purpose alternative projects that utilize existing small dam sites. These small sites can be utilized to provide a means of ingress and egress during most floods and prevent flood damage to roadways and utilities downstream.

Site Selection

In order to select a suitable site for modification to a flood control project, some questions must be answered. Is there development upstream of the site? Is there existing development in or near the proposed flood pool? Is there a need to protect development downstream? Can the existing roadway be raised without creating an access problem in the immediate area? What utilities will be affected in the construction area? Is suitable construction material readily available? Will the construction of the elevated roadway provide access for emergency services during the 100-year flood? Will the floodplain map need to be amended? Will upstream and downstream landowners provide land and material for construction? Is the cost-benefit ratio greater than one? If the answer to a majority of these questions is yes, then the feasibility of the site for modification is good.
Description

The subject site is at the confluence of two streams with a combined drainage area of approximately 450 acres. While this may not appear to be a large drainage area, historically the subject roadway has been inundated as much as 4 feet for as long as 16 hours. There are two reservoirs in the watershed that control the small precipitation events. However, when these reservoirs are full, and precipitation events are of long duration, as experienced when the remnants of hurricanes pass over the Great Plains, the roadway is inundated for a longer period of time. A natural saddle at the left end of the dam can be utilized for an emergency spillway. The total length of the site is 1250 feet with a maximum height of 16.5 feet to the streambed. The roadway surface is two-lane asphalt with a width of 18 feet. The present drainage culverts are one 18-inch diameter CGMP and one 24-inch diameter CGMP. The area upstream and downstream is native pasture and approximately 35% farmland.

The project was designed with a 36-inch culvert with a 2.25% slope and a maximum entrance head of 8 feet. The upstream and downstream slopes were designed with 10-foot-wide berms to facilitate maintenance of fences. A permanent pool of approximately 5 acre-feet was designed and a "dry hydrant" was designed in the project to facilitate local fire protection.

Population

The surrounding development consists of 40 single-family homes ranging in type from mobile homes to multi-story permanent structures. No multiple family dwellings exist in the immediate area. Since the area is rural and development has been sporadic as with most suburban areas, the age of these dwellings ranges from 80 years to 6 months, with approximately 50% being mobile homes. This type of development requires immediate response when fire threatens. Mobile home fires require immediate attack and the entire structure may be engulfed in as little as 10 minutes. As this area is northwest of a major metropolitan area (Oklahoma City), storms that form in the west and northwest area of the state tend to track over this area. Oklahoma has many violent thunderstorms with numerous lightning strikes, and several homes in this area have been subjected to fire damage caused by lightning during the past 10 years, with the loss of one structure. In addition, this area is also a producing oil field (West Edmond Hunton Lime). Lightning strikes have caused numerous fires at well locations during the past 10 years.

Fire response for this area is provided by both the Deer Creek and the Piedmont Volunteer Fire Departments. During flooding incidents, the Piedmont Fire Department cannot access this area and the Deer Creek Department has only limited access with brush fighting equipment only. The population in this
area is as diverse as the dwellings. Homeowners range from retirees to first home buyers and newly married couples with preschool-age children. This type of population requires a dependable emergency medical service. Emergency medical services are supplied by Oklahoma City. During flood events, emergency medical services must be routed through the city of Piedmont, and by using Highways #4 and #3 can deliver patients to the Baptist Medical Center after a 24-mile trip. By utilizing the flood control capabilities in this project and pre-planning a route, approximately 15 miles can be reduced from this trip.

Design Concept

This design concept can be utilized in future developments. The increasing cost of land suitable for development and the more stringent requirements of local governing authorities regarding stormwater runoff makes this design even more attractive. The developer can provide control of the peak runoff from development in addition to providing a sedimentation basin for siltation caused by construction runoff by building this flood control structure before construction of the development.

In addition to reducing liability for litigation resulting from siltation, a reduced cost of development is realized by utilizing existing public property easements for the embankment. The public body realizes a benefit from this structure by the replacement of outdated and insufficient drainage structures, possible elimination of inadequate bridges, and creation of a more stable road surface not subject to water damage requiring additional maintenance.
APPLICATION OF SAND FILTER FOR URBAN RUNOFF CONTROL

Hung V. Truong
D.C. Environmental Regulation Administration

Mee See Phua
The University of The District of Columbia

Introduction

Infiltration devices are the most frequently used BMPs for controlling stormwater runoff in urban areas. However, these conventional BMPs have some limitations due to soil and site-specific constraints. These BMPs may also adversely impact groundwater through the migration of pollutants into groundwater aquifers. Additionally, conventional infiltration systems may not be feasible in an ultra-urban environment because of the large land areas required for their installation. In an effort to mitigate these problems, an alternative design is outlined in this paper to replace the conventional infiltration BMPs where applicable. This alternative system is called the confined Sand Filter Water Quality (SFWQ) Structure. The system uses multiple filter layers combined with a moderate detention time to filter the suspended pollutant particles and hydrocarbons from urban runoff. A multi-layer filter was chosen because it has proven to be more effective than a single-layer filter design.

Background

Infiltration practices have been widely used to improve the quality of urban stormwater runoff. However, there are several limitations associated with the use of conventional infiltration systems. According to the Occoquan Watershed Monitoring Laboratory (1983), the Environmental Protection Agency (1983), and Nightingale (1987), the practice of infiltration may have a negative impact on groundwater quality. In addition, infiltration practices are only recommended for sites with soil infiltration rates higher than 0.27 inches/hour and with a clay content of less than 30%. Recently, a study by the Metropolitan Washington Council of Governments (MWCOG) showed that over 50% of the infiltration trenches installed in the Metropolitan Washington region either partially or totally failed within the first five years of construction (Galli, 1992).

Restoration of both surface and underground infiltration systems is tedious, very costly, and requires the removal of vegetation layer, topsoil, protective plastic layer, stone aggregate, and filter fabrics. If the surface layer
is made of pavement or concrete, the rehabilitation effort becomes even more difficult and expensive. Conventional infiltration systems also require relatively large areas of land for their installation; therefore, this family of BMPs is not feasible due to the high cost of land in an ultra-urban environment.

**Design Rationale**

Whenever a liquid containing solids in suspension is placed in a relatively quiescent state, solids having a higher specific gravity than the liquid tend to settle down, while those having a lower specific gravity tend to rise. The design of the SFWQ structure uses the one-dimensional falling head test in Darcy's law for calculating the head loss of fluid flow through a multiple-layer filter medium to treat stormwater runoff. It utilizes various media layers with different permeabilities to intercept pollutant particles as fluid flows vertically through the filter layers. This principle can be used to accelerate the removal of pollutants by increasing the residence times of stormwater runoff and thus facilitate the filtering process in the filter chamber. The SFWQ structure also utilizes Stoke law for terminal falling velocities of individual particles by allowing time for particles to settle out of stormwater runoff. The average detention time of this system ranges from six to eight hours for optimum design consideration.

**Functional and Physical Description**

The SFWQ structure is a gravity-flow system consisting of three chambers. The facility may be precast or cast-in-place. The first chamber (same as water quality inlet) is a pretreatment facility removing any floating organic material such as oil, grease, and tree leaves. It has a submerge weir leading to the second chamber (filter chamber). It may be designed with a flow splitter or a bypass weir, if the system is designed for off-line storage as illustrated in Figure 1.

The second chamber is the filter chamber that has three feet of filter material. Filter material consists of gravel, geotextile fabric, and sand and is situated behind a three-foot weir. At the bottom is a subsurface drainage system consisting of a parallel PVC pipe system in a gravel bed. A dewatering valve is at the top of the filter layer for maintenance purposes and for safety release in case of emergency. It also has an overflow weir at the top to protect the system from backing up when the storage volume is exceeded, if the system is designed for on-line storage (see Figure 1). Water enters the first chamber of the system by gravity or by pumping. This chamber removes most of the heavy solid particles, floatable trash, leaves, and hydrocarbon material. A submerge weir (designed to minimize the energy of incoming stormwater) conveys the
Figure 1. The Sand Filter Water Quality structure.
effluent to the second chamber and enters the filter layer by overflowing a typically three-foot weir above the bottom of the structure. The water is filtered through various filtering layers to remove suspended pollutant particles. The filtered stormwater is then picked up by the subsurface drainage system that empties into the third chamber. The third chamber also receives any overflow from the second chamber for an on-line system, and overflow from the first chamber flow splitter for an off-line system.

**Applicability**

The SFWQ structure is specifically designed for highly urbanized areas where open space is not available. It works best for impervious catchment areas of one acre or less. Multiple systems are recommended for catchment areas greater than one acre.

The structure may also be designed to provide detention, especially for on-line application when discharge rates must be modified in accordance with local and municipal regulations. Recommended areas where this device may be used include:

- Surface parking lots, underground parking lots, or multi-level garages, parking aprons, taxiway and runway shoulders at airports, emergency stopping areas, parking lanes, and sidewalks.

- Vehicle maintenance areas, on-street parking aprons in residential areas, recreational vehicle camping area parking pads, private roads, easement service roads, and fire lanes.

- Industrial storage yards and loading zones, driveways for residential and light commercial use, and office complexes.

**Conclusion and Discussion**

At the present time, the environmental and economic impacts of the SFWQ structure have not been fully evaluated. A long-term monitoring program is being implemented in Washington, D.C., in order to determine water quality benefits and address long-term maintenance concerns. The results from this monitoring effort will provide important information on the removal efficiency of common urban pollutants. In addition, the monitoring data will provide information on actual head-loss in the system, which will indicate the need for filter replacement.
The authors believe that the SFWQ structure may be used as an alternative urban BMP for highly developed areas where other options are not available.

In conclusion, the design presented here is an attempt to provide an alternative solution to control nonpoint source pollution from urban stormwater runoff. The application of this system should be viewed with some caution, as the structure has not been monitored for optimal effectiveness.

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Truong, Hung V.

Truong, Hung V.

U.S. Environmental Protection Agency
The 1993 flood damaged more than 100 levees in the state of Kansas alone. Under the direction of the Federal Emergency Management Agency’s (FEMA’s) Disaster Field Office in Topeka, an interagency levee team was established to conduct a field inspection of these damaged levees. The team was responsible for inspecting all levees in the state for which an application for repair had been submitted to the Soil Conservation Service (SCS), the Corps of Engineers, or FEMA. The levee team’s responsibility excluded levees clearly eligible for funding under the Corps’ Public Law (P.L.) 84-99 levee program.

The levee team consisted of representatives of four federal agencies that inspected every levee, and also included representatives from other agencies that inspected selected levees. The team members and the agencies represented were:

**Complete Inspections**

Johnny J. Green (team leader)  
Phil Napier  
Lisa C. Bourget  
Dewey Caster  

**Soil Conservation Service**

**U.S. Army Corps of Engineers**

**Federal Emergency Management Agency**

**U.S. Fish and Wildlife Service**

**Selected Inspections**

Russell LaForce  
Bob Barber  

**Kansas Division of Water Resources**

**Environmental Protection Agency**

**Agency Participation and Interests**

The levee team was formed to coordinate the different agencies’ perspectives. The Corps, SCS, and FEMA each had programs for providing funding to repair levees; however, the requirements for these programs differed. The Kansas Division of Water Resources was concerned with permit
requirements, while the U.S. Fish and Wildlife Service and the Environmental Protection Agency focused on environmental impacts and opportunities. Before beginning the inspections, the agencies met to discuss their interests and to develop a field inspection sheet to document all concerns. The field inspections needed to be quick and comprehensive, with enough data recorded to satisfy not only each agency’s needs under its current program, but any anticipated changes that might occur through legislative action.

**Corps Program Requirements**

Under its P.L. 84-99 levee program, the Corps requires a public sponsor and strict maintenance for levees on which it will provide assistance. The public sponsor must have been responsible for the levee before the flood. With program changes in 1986, many levees for which assistance was provided previously are no longer eligible. The main reason for this is that before 1986, public sponsorship was not needed. The Corps gave each levee owner two years after the 1986 program changes to find a sponsor for the levee. Many levee owners opted not to obtain or were unable to find a public sponsor, or ownership changed; these levees were subsequently dropped from the P.L. 84-99 program. The 1993 flood was the first since the program change; thus, many levee owners were expecting the Corps to provide the same assistance it had in the past, even though they had been dropped from the Corps levee program.

**SCS Program Requirements**

The SCS will allow a public sponsor after the flood, but it also requires levee maintenance. However, the SCS’s maintenance requirements may not be as stringent as the Corps’. A memorandum of understanding between the SCS and the Corps limits SCS assistance to levees along drainage areas of less than 400 square miles. This precludes the SCS from providing assistance on the major drainage patterns of Kansas (the Missouri, Kansas, Smoky Hill, Solomon, Saline, and Republican rivers.) Secondary levees that tie into a main-stem levee are considered part of the main stem and are thus ineligible for SCS assistance.

**FEMA Program Requirements**

Like the Corps, FEMA requires good maintenance and a public sponsor before the flood. In addition, the county must be a declared disaster area eligible for public assistance funding. FEMA cannot provide assistance on levees deemed eligible for assistance by the Corps or SCS but not funded for a particular deficiency, such as lack of maintenance or a public sponsor.
Environmental Concerns

The levee team documented whether "potential wetlands" newly created by the recent floods had the potential for enrollment in the anticipated Emergency Wetlands Reserve Program (EWRP), once announced. The objective of the EWRP is to provide agricultural producers with an alternative to rehabilitation of flood damaged land by protecting or restoring wetlands.

Intended Benefits of Cooperation

The team approach was intended to benefit the participating agencies by allowing discussion of findings, coordination of program requirements, and consistent documentation of observations. However, the agencies hoped that this approach would also benefit the individual levee owners and drainage districts. Meeting with all agencies simultaneously would be less disruptive to normal schedules than meeting with each separately. In addition, with representatives present from each agency, questions could be fielded at once by the appropriate representative rather than deferred because it was outside one agency's purview. Finally, the coordination between the team representatives would help eliminate the potential for conflicting information, regardless of whether the conflict arose from the information actually provided or from the listener's understanding of that information; team members could clarify differences in agency requirements on the spot.

Findings

The levee team conducted its inspections in October and November 1993. Most of the levees lay in the northeastern part of the state, primarily along the Missouri, Smoky Hill, Saline, Republican, and Kansas rivers.

Maintenance

The field review of the levees not in the Corps' program indicated a lack of required maintenance. In general, levees within a drainage district tended to be better maintained than privately owned ones; however, there were exceptions. Many levees had large trees, and there was confusion about them. Many landowners and farm operators thought that trees help stabilize the soil against erosion; while this may be true to a point, the size and numbers of trees found on many levees were actually detrimental. Some levee crowns were used as roads, preventing full vegetative cover to protect from erosion and scour. In other cases, farm operations undercut the levee toe. In a few isolated instances, farming operations extended across the whole levee, lowering its height and level of protection.
Several drainage districts were unaware that they were no longer included in the Corps' P.L. 84-99 levee program. These districts will likely attempt to rejoin the program at the earliest opportunity.

Most of the levees did not have a public sponsor before the flood, as required by both the Corps and FEMA. Many counties or communities had since agreed to sponsor these levees and had submitted requests for assistance to the various agencies. However, it is unclear whether these jurisdictions fully understood the implications of being a sponsor or simply were willing to file a request on behalf of the private levee owner.

The primary environmental concerns documented were for wintering bald eagle perching and roosting habitat within the levee area that could be affected by levee repairs. The greatest potential for potential wetland enrollment in the EWRP appeared to be on the Missouri River floodplain.

Reactions from those affected by levee damage ranged from pessimistic conviction that no aid would be forthcoming to indignant demand that "somebody has to fix this." Most recognize that funding for repair is not a given. Some of the landowners had already taken matters into their own hands and were fixing what they could.

Many of the levees observed were built along highly erodible river banks and appeared to have fallen victim to bank erosion, particularly when located on the outside curve of a river. In other cases, levees suffered no apparent structural damage but were overtopped and subject to considerable sand deposition. The levee team also observed several sand boils.

After reviewing 118 levee repair applications, the levee team found the following:
No damage 23%
Referred 11%
No public sponsor 11%
Poor maintenance 5%
Poor maintenance and no sponsor 50%

The high percentage of levees submitted for repair that actually had no damage (23%) arose from two primary areas: apparent misunderstanding of the application process (some jurisdictions submitted a list of all levees without regard to damage) and sand deposition. While sand deposition is damaging to farm operations, it does not necessarily threaten the structural integrity of the levee.

The 11% of the levees referred to a specific agency seemed to meet existing federal program requirements. The 11% of the levees with adequate maintenance but without a pre-flood public sponsor were denied federal program assistance.

Lack of adequate maintenance was by far the most common concern with the levees observed. The remaining 55% of levees with poor maintenance and/or no sponsor were denied federal program assistance.

Current Status

The levee team submitted a report documenting its findings on November 10, 1993. FEMA notified each levee owner of its eligibility for funding under the existing SCS, Corps, or FEMA programs. However, legislation, available funding, and program requirements regarding the Midwest flooding in general and the repair of levees in particular have been subject to scrutiny and change. For levees not already being repaired under the Corps’ P.L. 84-99 program, several other avenues are available to levee owners and operators, provided their site meets certain criteria.

Emergency Wetland Reserve Program

The EWRP, announced in December 1993, allows compensation to landowners who establish or maintain wetlands in levee breach areas. Kansas received 47 inquiries under the EWRP, but only six were suitable wetland sites. Most of those interested were ineligible for funding because wetland hydrology was either not present or too costly to restore. Of the six suitable sites, none has yet been finalized into an EWRP contract.
Economic Development Administration (EDA)

Congress allocated $18 million to EDA to repair levees ineligible for the Corps levee program. Under a memorandum of agreement, the Corps will assist EDA in assessing damage, preparing cost/benefit analyses, performing environmental reviews, and providing other technical assistance. Repaired levees are to be enrolled in the Corps' levee program. Of the 47 levees being evaluated, seven are in Kansas. The total estimated cost to repair these seven levees is approximately $1.2 million, with EDA covering 75%. It is unknown how many of these levees will actually be funded.

SCS

In addition to the $18 million allocated to EDA, Congress earmarked an additional $50 million for levee repair as part of the relief package following the California earthquake. Congress designated that this money would be available through the SCS, regardless of the size of the drainage area. Like the funding from EDA, the SCS money is for levees that are ineligible for funding under the Corps levee program. The levee sponsor or owner must provide 25% of the cost of the work and must agree to enroll the repaired levee in the Corps levee program. Levee repairs must be economically and environmentally sound. Kansas SCS field offices are accepting sign-ups from interested levee owners or sponsors through April 22, 1994.

Conclusions

The Midwest flooding's damage to levees has focused attention on levee policy in general. Despite the interest of levee owners and sponsors in obtaining federal funding for all levee repairs, several policies have emerged consistently between agencies. First and foremost, funding for levee repair is not a given. No repair will be 100% federally funded. In addition, the costs and benefits of levee repair will be closely scrutinized before any federal funding is made available. To be eligible for federal funding, a public sponsor will be required. Finally, good operation and maintenance is expected, with no trees on the levee itself, a good vegetative cover, and no farming on the levee toe or slope. The EDA's and SCS's requirement to enroll repaired levees in the Corps levee program emphasizes the future expectations of continued sponsorship and maintenance and may alleviate some of the catastrophic damages associated with the next major flood.
In areas subject to floods accompanied by substantial sediment loads, the ability of flood-control structures to operate properly may be jeopardized by localized deposition. Such deposition is triggered by sudden reductions in flow velocity, which can be caused by changes in slope, roughness, cross sectional geometry, or flow direction. Flood-control structures that are placed perpendicular to natural flow paths to collect and divert the flows reduce the flow velocity to zero in the direction normal to the structure. In addition, during a flood, the flow paths in such areas may change direction somewhere upslope of the structure.

Even when the flood-control strategy dedicates more volume to store the sediment load than the entire expected load, an unfortunate set of circumstances can result in the failure of a flood-control structure placed perpendicular to the natural flow paths. For example, consider a diversion dike placed perpendicular to the natural flow paths on an alluvial fan. Flows strike the dike at a 90-degree angle and are diverted to the right, to the left, or both along the upslope face of the dike.

At the point where the flood initially strikes the dike, the flow velocity is essentially zero, and the sediment load accompanying the flow begins to be deposited. As time passes, more sediment is deposited at the base of and upslope of the dike, forming an approximately triangular-shaped deposit that is growing in size. As the deposit grows, the point at which flood flows are being diverted moves upslope. While the flood progresses, it is continuously seeking new paths to follow around the deposit.

Eventually, the flood follows a path on top of the deposit. Such a path is, after all, the most direct path locally downslope. Following a path on top of the deposit, the flood again reaches the dike, thereby increasing the depth of the deposit. The process is repeated until the flood has ended or the deposit has reached the top of the dike and the flood follows a path on top of the deposit and over the dike. This situation is depicted in Figure 1.

The amount of sediment necessary to create such a deposit depends on the height of the dike, the width of the deposit at the dike, the slope of the approach to the dike, the slope of the top of the deposit, and the side slope of the deposit. Consider a triangular-shaped deposit with a width w at the top of a dike of height H positioned perpendicular to flow paths having a slope $S_b$. 
The slope of the top of the deposit is $S_t$, and the sides of the deposit are at an angle $\theta$ from the horizontal (ground). The length ($L$) of the deposit is $H/(S_r-S_s)$. If you take the upslope point of the deposit to be the origin and the $x$-axis to increase in the direction of the dike (the dike is at $x=L$), then at any point along the axis you can define the height ($h(x)$), top width ($w_t(x)$), and bottom width ($w_b(x)$) of the deposit as functions of the distance from the origin. The dimensions are shown in Figure 2.

Note that

$$h(x) = (S_b-S_t) x$$
The volume of a differential element of the deposit is

\[ dv = w_t(x) h(x) + \frac{1}{2} h(x) [w_b(x) - w_c(x)] \, dx \]

\[ = w_t(x) h(x) + \frac{h^2(x)}{\tan \theta} \, dx \]
and, therefore, the volume of the deposit is

\[
V = \int_0^L \left[ w_t(x) h(x) + \frac{h^2(x)}{\tan \theta} \right] dx
\]

\[
= \int_0^L \left[ \frac{w(S_b - S_t)}{L} x^2 + \frac{(S_b - S_t)^2 x^2}{\tan \theta} \right] dx
\]

\[
= \frac{W(S_b - S_t)}{3} \frac{L^2}{\tan \theta} + \frac{(S_b - S_t)^2 L^3}{3 \tan \theta}
\]

\[
= \frac{W H^2}{3 (S_b - S_t)} + \frac{H^3}{3 (S_b - S_t) \tan \theta}.
\]

The minimum amount of sediment necessary to reach the top of the dike is that needed to create a deposit level with the top of the dike \((S_t=0)\), no top width \((W=0)\), and side slopes associated to the angle of repose of the material. For example, a deposit of approximately 23,800 cubic feet (0.55 acre-feet) of coarse sand (diameter=1 millimeter; \(\tan \theta=0.7\)) would be level with a dike 10 feet high placed perpendicular to the flow paths over a surface with a slope of 2%. A flow of only 1,000 cubic feet per second (cfs), 5% of which is sediment, delivers that load in approximately 8 minutes. If the slope of the top of the deposit was one-half the ground slope, the volume or, alternatively, the time needed to deliver that load, would double.

The calculation just given is, of course, the minimum amount of sediment necessary to reach the top of the dike. Note that a deposit with those dimensions would have a bottom width at the dike of less than 30 feet. If, in the same example, the slope of the top of the deposit was one-half of the ground slope and the top width of the deposit was 200 feet, then the volume of the deposit would be 714,285 cubic feet (16.4 acre-feet). That is 30 times the minimum. It is also approximately the total sediment load accompanying a flood that lasts 8 hours, has a triangular hydrograph that peaks at 1,000 cfs at 2 hours, and carries a sediment load of 5% by volume of the flow value.
All of the sediment accompanying a flood will not contribute to a particular deposit. Undoubtedly, some sediment will be diverted, with the floodwater, around the dike. In addition, as the deposit is growing, flood paths over the deposit eventually flow over the side, picking up sediment that was deposited earlier. The ratio of the sediment load that contributes to a deposit must be estimated by the design engineer. Obviously, designing for the entire load is the most conservative approach. There may, however, be site-specific information that allows the design engineer to make a more realistic estimate.

Site-specific information may also aid in estimating the dimensions of a possible deposit. For a flood to take a path on top of a deposit, the deposit must be at least as wide as the flood path. For example, if a 1,000-cfs flow is conveyed by a 150-foot-wide path, then a deposit would have to be at least that wide to support a path that could convey the total flow. On the other hand, deposits that are less than 150 feet wide could still support a flow path of a portion of the flow. Such considerations are important in contemplating the growth of a deposit. That is, during the rising limb of the flood hydrograph, there may be restrictions on the minimum width of the flow paths and, therefore, on the minimum size of the deposit.

In addition, there may be a minimum slope that must be maintained for the deposit to grow vertically. The longer the deposit becomes, the less likely it is that floodwater, let alone any appreciable sediment load, will be carried on top of the deposit all the way to the dike.

Slope is also a consideration in estimating the width and number of flow paths. Where slopes change abruptly, sediment is deposited and flow paths tend to bifurcate. The deposition, however, tends to increase the slope locally.

In summary, the design engineer has several quantities to estimate when determining the height of a diversion dike placed perpendicular to flow paths carrying substantial sediment loads. In addition to measuring the slope of the ground upslope of the dike, the design engineer must estimate:

- Total volume of sediment expected during a given event,
- Percentage of total volume that will contribute to the deposit,
- Top width of the deposit at the dike,
- Side slopes of the deposit, and
- Slope of the top of the deposit.

To ensure that the dike is high enough to retain the sediment under the most unfortunate set of circumstances without being overtopped, the design
engineer can compare the volume of the sediment that contributes to a possible deposit to the volume computed using the estimated dimensions of the deposit. Because of the life and property at stake, estimates of the dimensions of the deposit and the percentage of sediment that may contribute to the deposit cannot be taken lightly. Missing a "ballpark" figure by a few percentage points can be the difference between a successful design and a catastrophic failure. A slight underestimate (5 or 10%) would be very unfortunate in light of the fact that increasing the height of the dike by 10% (1.0 foot in the aforementioned example) increases the volume of sediment needed to cause failure by at least 21%.
Introduction

Summerlin is a developing 24,000-acre, award-winning comprehensive planned community on the west side of the Las Vegas valley. It has established objectives of incorporating drainage facilities into parks and open spaces with minimal disturbances to the natural landscape.

The area is impacted by desert washes emanating from the Spring Mountains. Existing washes are well defined and range from 50 to 150 feet wide. Rock outcrops and cemented hardpan banks lined with desert shrubs and cactus offer a visual amenity. The washes are normally dry and convey flow only in response to high-intensity, short-duration, summer thunderstorms. The flash flooding typical of the desert environment transforms the washes into raging torrents.

The desert washes are proposed to be tamed by the utilization of roller compacted concrete (RCC) features. The proposed watershed management technique was developed for Summerlin by Boyle Engineering Corporation (Boyle), in response to certain issues related to the U.S. Army Corps of Engineers (COE) Tropicana/Flamingo Washes Right-of-Way Acquisition Plan, Area 1 (Acquisition Study). The Acquisition Study recommended alignments and right-of-way acquisition for the Corps of Engineers (COE) flood control improvement plans for the Tropicana/Flamingo Washes. The flood control improvements are recommended for implementation as part of a federal project based upon a feasibility study performed by the COE to provide flood control protection to Las Vegas and the surrounding area.

Review of Acquisition Study

A large portion of the study area is part of the presently undeveloped southern portion of Summerlin. Two major tributaries of the Flamingo Wash, which traverse Summerlin, are referred to as the R-4 and F-1 channels.

Boyle has developed a Flood Control Master Plan for the Summerlin Area, The Summerlin Stormwater Management Plan (SSMP), which was generally accepted and incorporated into the Clark County Regional Flood Control District's present Master Plan. Different recommendations were presented in the Acquisition Study.
The COE’s feasibility report for the Tropicana and Flamingo Washes recommended concrete-lined channels as the most economical alternative. The SSMP proposed semi-natural floodways to convey flows through the Summerlin area. The SSMP also proposed detention facilities, while only debris basins were proposed in the COE improvement plans. The Acquisition Study evaluated three alternatives and recommended concrete-lined channels.

The Summerlin planners objected to the use of concrete-lined channels as being inconsistent with their development objectives. Of major importance to Summerlin was the use of detention basins instead of debris basins to reduce the impacts of the conveyance facilities through Summerlin.

The Acquisition Study used criteria that distorted the comparison of a floodway concept versus a concrete-lined channel concept. The floodways in the SSMP were proposed to convey peak flows reduced approximately 80–90% by detention for the R-4 and F-1 channels. Undetained peak flows and non-erosive velocities of less than 5 fps were used in the Acquisition Study. The Acquisition Study therefore, used “extremely wide” floodways in its economic comparison.

**Example: The R-4 Channel**

The Acquisition Study used debris basins that do not reduce peak flows ranging from 3,500 cfs to 4,450 cfs. The proposed floodway widths, used to compare floodways to concrete channels, range from 970 feet to 1,120 feet. This drainage course in the SSMP uses a flow ranging from 410 cfs to 950 cfs, due to upstream detention.

With the floodway criteria similar to that used in the Acquisition Study the impact of detention greatly reduces the floodway width requirement. If a unit discharge of 5 cfs/ft were used for these smaller flows, the required width would be 82 feet at the upstream end increasing to 190 feet.

The natural conditions for this drainage consist of a few braided natural washes incised into a fan remnant. The combined width of the active natural washes varies from approximately 100 feet to 150 feet. The 100-year peak flow of 3,500 cfs, if conveyed by the existing natural washes, would be approximately 2.5 feet deep with a velocity of approximately 9 fps. This type of flow would be a reasonable natural condition, since the existing banks are not highly erodible. The caliche, desert varnish, and desert pavement on the fan remnants indicate that the capacity of the natural washes has not been exceeded in hundreds of years.

The detained flow conveyed by the existing natural washes (950 cfs, 150 feet wide) would be approximately 1 foot deep and flowing at less than 6 fps. Therefore, a floodway width for this drainage course, implemented as proposed in SSMP, could be conservatively limited to 200 feet. This is approximately 800 feet narrower than the floodway width proposed in the
Acquisition Study. With land costs assumed at $45,000 per acre, the cost difference is approximately $826 per linear foot of length!

**The F-1 Channel**

The discussion regarding the R-4 channel can similarly be applied to the F-1 channel. The Acquisition Study used a floodway width of approximately 800 feet and design flow of 3,150 cfs. The SSMP proposed flow varies from 670 cfs to 790 cfs. A floodway width of 150 feet would limit flow depth to approximately 1 foot and velocity to less than 6 fps.

**Floodway Criteria Summary**

The floodway criteria used in the Acquisition Study for an economic comparison to concrete-lined channels resulted in extremely expensive floodways. The land acquisition requirements for floodways could be considerably less than the values used in the Acquisition Study, and the construction costs for floodways are considerably less than for concrete channels. Therefore, the justification of the concrete channels based on the economic analysis presented in the Acquisition Study was considered unreasonable.

**Proposed Semi-Natural Floodways**

Summerlin’s planned objectives include using the drainage features as multi-purpose, parks, and open spaces. The objectives take advantage of the aesthetics of the natural vegetation and features of the wash. The proposed concrete-lined channels with high velocity flow and required fencing, as recommended in the Acquisition Study, are in conflict with the Summerlin objectives. Economic evaluations performed for Summerlin have indicated that land adjacent to natural open spaces has increased value, and land adjacent to concrete-lined channels has decreased value.

Summerlin is one the fastest-growing communities in the nation. Its marketing plan includes emphasis on a master-planned community with numerous recreational features. The parks and trail networks, including cycling and equestrian trails, are an appealing feature of the community.

To better satisfy Summerlin’s objectives, a semi-natural floodway concept, which represents a compromise between wide natural floodways and concrete lined channels, was developed. The semi-natural floodway includes a shallow roller compacted concrete (RCC) channel within the floodway.

This floodway concept is appropriate for the major channels in the southern portion of Summerlin, downstream of detention facilities with slopes of approximately 2.5% to 2% (R-4 and F-1 channels).
Upstream detention greatly reduces the design flows, but the prolonged discharge of sediment-free flow released from the detention basin could be erosive to unlined floodways downstream. Erosion would take place until the sediment transport capacity stabilizes. The amount of erosion would be difficult to quantify since the detention basin would trap the sediment load required to feed the downstream channel. To alleviate this problem it was proposed that a portion of the floodway contain a lined channel to convey the prolonged sediment-free flow released from the detention basin.

This channel is proposed to be shallow and constructed of RCC within the existing natural washes in this area. The floodway alignments follow their natural course, since the existing washes have developed natural armoring and energy dissipation features, and have capacity to convey reasonable flows. The shallow RCC channels are to be designed to meander and aesthetically blend with the naturally occurring hardpan and features of the existing washes. Natural features and open spaces on each side of the washes are preserved as much as possible to be incorporated into linear parks.

The RCC channel portion would be very shallow, little more than 1 foot deep and have riprap transitions into the bed of the natural washes. The RCC would be constructed in horizontal lifts. The floor of the channel would be 2 feet thick. Cracking would not harm the structural integrity. The banks would be built up a minimum of 8 feet wide. Side slopes would vary to improve aesthetics.

The RCC utilizes the existing sand and gravel materials, which would be excavated from the wash bed. The construction would be very simple with no concrete forming, steel reinforcement, or formed joints required. The construction cost savings over a conventional concrete channel are considerable. Excavation would be shallow and confined to the wash bed; deep cuts to divert the natural drainage would not be required.

The natural conveyance of the existing wash could be utilized to satisfy freeboard requirements. At depths exceeding the bank of the RCC channel the majority of flows would continue to be conveyed by the channel with overbank flooding considerably less effective. Any overbank flooding would be wide and shallow, confined to the floodway/park area, and have non-erosive velocities of less than 5 fps.

The floodways could be multipurpose facilities, accommodating trails and bike paths. Summerlin development agreements could include provisions to maintain the floodways/parks/open spaces.

The base width of the proposed RCC channels range from 10 feet to 22 feet, and they are contained within existing natural washes, which are approximately 100 to 150 feet wide.
Detention versus Debris Basins

The COE-proposed debris basins include spillways to convey the probable maximum flood (PMF) and have embankments with 5 feet of freeboard above the PMF pool elevation. For example, the top of the dam embankment for the COE-proposed R-4 debris basin is 22 feet above the spillway crest. Because the costs to incorporate these design criteria are quite high, the additional costs to add the detention requirements proposed in the SSMP are relatively small.

Boyle recommended detention basins with increased storage capacity, but with dam embankments lower than those proposed by the COE. A lower dam embankment would have a less aesthetically adverse effect on the proposed residential developments downstream. Boyle proposed the entire length of the dam embankment be designed to withstand being overtopped by the PMF. This would eliminate the COE freeboard requirements.

RCC is used to protect the dam embankment during overtopping. The RCC is buried and the surface re-vegetated to improve aesthetic appearance and reduce costs of a formed concrete face. It is proposed that a portion of the embankment be left with an exposed RCC spillway. The exposed spillway would have a crest 2 feet below the regular embankment crest and could pass flows exceeding the 100-year event, or if the outlet works became clogged. This would reduce maintenance impacts of emergency situations exceeding the 100-year event.

Cost Comparisons

Boyle prepared a comparison of probable construction costs of debris and detention basins for R-4 and F-1 facilities. It indicated an increase in costs of approximately $2 million for both detention basins. The additional costs for the detention basins may be reduced if gravel mining is used as a method of pre-excavation, before construction. The increased cost of detention facilities is easily offset by the reduced cost of the conveyance facilities, if semi-natural floodways are utilized downstream. The average construction costs for the COE-proposed concrete-lined channels were approximately $420 per linear foot. The average construction costs for the shallow RCC channel and floodway improvements were approximately $195 per linear foot. The full-conveyance concrete-lined channels required right-of-way widths of 70 to 80 feet. The semi-natural floodway widths are expected to average 150 feet, but will also serve as multi-purpose linear parks. The land costs are less relevant to Summerlin, inasmuch as they are the private owners of the land where the flood control facilities are proposed. Even with wider right-of-ways and land costs
taken into consideration, the semi-natural floodways reduce costs over the concrete-lined channels.

Conclusion

The proposed watershed management technique is applicable for an arid West environment. A potentially dangerous, wild, raging desert wash is transformed into a controlled multiple-use floodway, incorporating linear parks with trails, bike paths, and natural open spaces. The cost comparisons to previously proposed full-conveyance concrete facilities demonstrate a more economical, and more aesthetically desirable alternative.

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PART SIX

FORECASTING AND PRECIPITATION RECORDS
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CHOOSING A HYDROLOGIC MODEL FOR FLOOD FORECASTING

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DC Consulting

Introduction

The most common application programs in automated flood warning systems are the runoff and river forecast programs. These programs use observed and, in some cases, forecast rainfall amounts to compute the amount of water that will enter the stream system.

Forecast Models

The purpose of a forecast model is to estimate future river flows and elevations based on observed or forecast amounts of rainfall. In flash flood situations, certain portions of the forecast hydrograph are more important than others. Accurate forecasts of the rising limb, the time to hydrograph peak, and the magnitude of the peak are critical. These are the elements of model output that have the most impact on the flood warning. The model implemented in a flood warning system must consistently perform well in these three areas.

Before model selection, one very important element, rainfall estimation, must be considered. The volume of water under the rising limb of a flash flood hydrograph is primarily surface runoff. Basins with short response times are often characterized by low infiltration rates and steep slopes which efficiently generate runoff. Because these basins efficiently generate runoff, especially during periods of high intensity rainfall, the volume of runoff is very sensitive to the volume of rainfall. This implies that the output of a flash flood forecast model will also be very sensitive to the rainfall inputs.

Flash flood forecast sensitivity to rainfall inputs serves to emphasize the importance of establishing a good measurement system first. The phrase commonly heard in the computer industry, "Garbage in, garbage out," is equally applicable to flash flood forecasting. Good model performance, no matter what model is used, cannot be expected without a good measurement system. The implication for forecast system design is to invest in the measurement and detection systems first, then consider hydrologic models.

There are many different hydrologic forecast models in use. The most commonly used models in local flood warning systems fall into two categories: simple index-type models, and conceptual rainfall-runoff models. Index models keep a running index that reflects current moisture conditions. The moisture index, a "time of year" index, current rainfall, and rainfall duration are
Choosing a Hydrologic Model for Flood Forecasting

generally all that is needed to estimate surface runoff with these models. Conceptual models attempt to provide a more "physically-based" approach to basin modeling by more explicitly accounting for evapotranspiration, interception storage, retention storage, infiltration, surface runoff, percolation, interflow, etc. Table 1 shows the most widely available models for local flood warning systems.

Table 1. Flood forecast models.

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**API Model**

The API (Antecedent Precipitation Index) model was developed by the National Weather Service (NWS) and has been used in various forms since the 1950s. The antecedent precipitation index reflects the current soil moisture based on recent rainfall. A high index means high soil moisture content while a low index indicates dry conditions. The API for a given period is used with a rainfall-runoff relationship, the rainfall amount, and the storm duration to estimate runoff. A unit hydrograph is applied to distribute the runoff. At each computational period, the index is updated based on the additional rainfall and by a seasonally dependent factor. The seasonally dependent factor empirically accounts for changes in the rainfall-runoff relationship due to seasonal changes in evapotranspiration, infiltration, etc.

Complex basins can be modeled by applying the API technique to individual sub-basins that are hydrologically homogeneous. Outflows from sub-basins can be routed downstream and combined with other tributary flows and inflows calculated by the API model for local areas.

Many versions of the API model exist. Most NWS River Forecast Centers that use API have added modifications to "customize" the technique for conditions in basins within their area of responsibility. At least eight different implementations of API are used by the NWS.

The API model is simple and relatively easy to understand. It is also relatively easy to adjust. Forecasters can easily change model parameters or model runoff based on their assessment of the current event to improve model performance.
**ADVIS**

The ADVIS program (Sweeny, 1988), developed by the NWS for local flood warning, includes an API model as its primary hydrologic forecast technique. (All NWS implementations of API are available in ADVIS.) ADVIS is a simplified implementation of hydrologic modeling that produces output appropriate for the user depending upon what type of information is available. For example, ADVIS output includes:

- Categorical forecasts for ungauged watersheds. Categorical forecasts are general forecasts of "minor," "moderate," or "severe" flooding based on the antecedent precipitation index and rainfall estimates.
- Crest stage forecast. ADVIS will generate a crest forecast if the unit hydrograph peak is available.
- Forecast hydrograph. Where the complete unit hydrograph is available, ADVIS generates a complete forecast hydrograph.

The ADVIS program is intended to address relatively simple hydrologic situations at the local level.

**Flood Advisory Tables**

Flood advisory tables are used to provide a quick estimate of peak stage forecasts using indices produced by the API or other modelling techniques. The tables are computed in advance for a variety of antecedent conditions. The current index can be computed on-site or provided by a local NWS office. Local users apply the current index with the latest rainfall estimate to the table to determine the estimated peak stage. An estimated time to peak is usually available based on previous analysis of basin response.

**Sacramento Soil Moisture Accounting Model**

The Sacramento Soil Moisture Accounting Model is a conceptual model designed as a comprehensive representation of the hydrologic processes of the upper soil mantle. Evapotranspiration, direct runoff from impervious areas, surface runoff, percolation, interflow, and two types of base flow are explicitly represented. Runoff calculated for each period is distributed using a unit hydrograph.

Each hydrologic process is represented by a function or series of functions with adjustable parameters. The model is calibrated with historical rainfall and streamflow data by adjusting parameters until the model output adequately represents basin response. The model is applied to individual basins
Choosing a Hydrologic Model for Flood Forecasting

that are hydrologically homogeneous. Complex basins are modeled by combining outflows from individual basins using a variety of available routing techniques.

**HEC1-F**

The Hydrologic Engineering Center (HEC) has developed a forecasting system for Corps of Engineers offices that is also available for local flood warning systems. The forecast technique uses an initial and uniform loss rate to compute runoff, which is applied to a unit hydrograph to produce a basin forecast. Results from each basin can be combined and routed to develop forecasts for complex systems. HEC 1-F uses observed streamflows to set proper loss rate parameters.

HEC1-F can be calibrated relatively easily. Most of the necessary parameters can be obtained from maps. Infiltration parameters and certain characteristics of the unit hydrograph can be estimated initially. During a flood, HEC1-F evaluates model performance against observed stream flow and automatically adjusts the appropriate parameters.

HEC1-F is the forecast version of HEC1, a widely used hydrologic design tool. Many different public and private organizations throughout the United States have used HEC1 to generate flood hydrographs for a variety of purposes from bridge design to floodplain mapping. As a result, many local engineers understand the model and the transition to HEC1-F is relatively easy.

**SSARR**

The Synthesized Streamflow and Reservoir Regulation (SSARR) model was developed jointly by the NWS and the Corps. It is a tool used by the respective agencies in the Pacific Northwest for flood forecasting and reservoir regulation. The SSARR model provides a continuous accounting of soil moisture to determine how much of the incident rainfall and snowmelt will become runoff. Three phases of runoff are computed: direct runoff, interflow, and baseflow. Each phase is routed through a series or cascade of linear reservoirs to produce the total streamflow.

**Hydrologic Model Selection**

Choosing the "appropriate" hydrologic model is a task open to much debate. A widely cited study by the World Meteorological Organization indicated that the API technique, the Sacramento model, and the SSARR model all gave about the same results in humid climates. However, explicit soil moisture accounting models like SSARR and the Sacramento model were clearly superior to the API model for arid and semi-arid climates. In humid environments, soil moisture conditions are less variable than in arid or semi-arid
climates. The added complexity of the explicit soil moisture accounting models to handle wide-ranging conditions does not contribute significantly to model performance when conditions are relatively stable. However, when conditions are rapidly changing, some researchers have found that explicit soil moisture accounting models offer a significant performance advantage.

When reviewing studies comparing the complex explicit soil moisture accounting models with simpler index approaches, an important insight was noted. While the simpler models performed well statistically compared to the explicit soil moisture accounting models, significant deviations occurred at key points. These deviations, while significant, were rare and tended to have little effect on the overall statistics. However, the deviations were frequently observed when extreme hydrologic conditions existed. The complex models could manage the extremes where the simpler approaches were not capable of doing so. These rare events are precisely the events that offer the greatest potential for hazard mitigation.

The choice of models in specific situations remains difficult. After all the analysis of which model performs the best for a given basin, it ultimately depends upon the capabilities and resources of local users. Complex models requiring a high level of support might be appropriate in cases where local skills and resources can handle it. However, the same model may be entirely inappropriate in situations with lower levels of local hydrologic skill and resources.

To summarize model selection:

- Choose a model that is within the capabilities of the local user to understand, operate, and maintain;
- Choose a model that is appropriate for the local hydrologic regime; and
- Choose a model that will provide the best estimate of the rising limb, the time to peak, and the flood peak.

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U.S. Army Corps of Engineers Hydrologic Engineering Center

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World Meteorological Organization
Introduction

After the passage of a particularly severe flood it is not uncommon for the agency responsible for issuing flood warnings and/or operating flood control systems to come under public criticism for the manner in which it carried out its function. In the case of the operation of a flood control reservoir, downstream property owners may complain that the gates to the structure were not opened at the optimal time, thus subjecting them to flooding that should have been prevented by the flood control reservoir. Property owners around the reservoir may complain that the gates were opened too late and caused excess damage to their property. In other instances citizens may not be warned early enough for effective measures to be taken to protect property, or evacuations may be ordered without a flood occurring. Agencies generally operate the flood control systems as well as possible with the information available about the rainstorm and flows producing the problem. Effective operation of flood warning and flood control systems requires accurate information on past, current, and projected flow and rainfall so that good estimates of expected flood flows can be made.

Two important aspects of a flood warning system are lead time and accuracy. These aspects are interrelated in that as the required lead time gets shorter, the accuracy of the projection improves until at a lead time of zero a perfect "projection" can be made. What is required is a long lead time with high accuracy.

The approach to addressing the lead time/accuracy problem will depend on the size of the watershed producing the flood flows. On small basins, flow
estimates for long lead times are heavily dependent on the expected rainfall pattern. For larger basins the flow that will occur over the next few hours is already in storage and transit within the watershed so the accuracy of the flow projection depends on the determination of the quantities of water in the system and the routing of this water to the point of interest. For intermediate-sized watersheds, rainfall forecasts, estimation of abstractions from rainfall, and flow routing all play a role in determining the accuracy of the flood forecast.

**Objectives**

This project was undertaken to improve the flood forecasting and flood warning capabilities of the Civil Defense Office in Stillwater, Oklahoma. The objectives of the project being reported on here are:

- Develop a real-time parameter optimization scheme for a rainfall-runoff model.
- Develop an algorithm for forecasting rainfall on a grid-cell basis based on storm movement, intensity, areal extent, and orientation.
- Develop a continuously updated flood flow prediction scheme using optimized parameters, observed rainfall, and forecasted rainfall.

**Procedure**

A network of nine rain gages and seven water level recorders has been installed in the 276.9 square mile drainage basin contributing flow through Stillwater. Data from these gages are telemetered into the Civil Defense Office where they can be combined with WSRD-88 radar rainfall estimates and used in a hydrologic modeling framework to project flows that are likely to occur within Stillwater over the next several hours. The hydrologic model being used is the SCS TR-20 hydrology model. Model control has been modified to allow for real time calibration of the curve number parameters which are used to estimated runoff volume from rainfall. The total basin has been divided into seven subbasins requiring seven curve numbers to be estimated.

The model and data collection program are synchronized so that every 10 minutes or so new information on rainfall and water levels in streams and reservoirs is used by the model to optimize the value of the estimated curve number. The sequential steps for each time increment are:

1. Input data on current rainfall and water levels.
2. Optimize the estimated curve number for each subwatershed based on the measured rainfall, measured water levels, and the predicted water levels. This optimization is based on a minimization of the sum of squares of the prediction errors involving water levels.

3. Based on current rate of storm movement, estimate the rainfall that is likely to occur over the next two hours.

4. Based on current rainfall, projected rainfall, and the optimized curve numbers, project ahead in time the estimated flow.

5. These steps are repeated every 10 minutes or so as the storm moves across the drainage area.

The advantage of this procedure is that it enables one to use quite complex models with the assurance that the predictions being made by the model are reasonably accurate since at the end of each time step, the model parameters are reoptimized based on the observed data that are being telemetered to the central office and input to the modeling system.

As the radar data becomes more readily available, it will be used to more precisely define the spatial pattern of the rainfall. The actual gages will provide data that will be used to continually calibrate the radar to the ground "truth" in the form of the measured data. Radar patterns will also be used to project several time steps ahead so that an estimate of the amount of rain that will occur over the next hour or so will be made. This rainfall estimate is combined with observed rainfall amounts and used in the hydrologic model to predict flood flows. Since the hydrologic model is calibrated every 10 minutes, error in the estimated hydrographs is limited and is corrected based on the measured data.

Output from the model is displayed graphically as hydrographs at various locations in the basin. The model control and optimization algorithms are programmed in C and TR-20 is written in FORTRAN. An Intel 80486-based microcomputer running at 30 mHz or faster is sufficient to keep up with a storm in real time. The procedure used to address each specific objective follows.

**Objective 1**

This implementation is on intermediate-size basins (276.9 square miles) where all four of the major components of an effective rainfall-runoff modeling system for flood forecasting are considered:

- Estimation of the temporal and spatial distribution of rainfall;
- Transformation of rainfall into rainfall excess;
- Routing rainfall excess to the channel system; and
- Routing flow through the channel system.

Rain gage and radar data will be used to define the rainfall input. TR-20 will be used to convert rainfall into an estimate of streamflow. Initial hydrologic model parameter estimates are based on past experience in the watershed. These estimates will be updated as the storm and runoff event of interest develops in time through a self-calibration procedure programmed into the model. The objective function is a minimization of a sum of squares of deviations between predicted and observed flows weighted to give the most recent observations more importance than earlier flows. Parameter estimates are updated after each time step as the storm develops and additional flow data become available. At the conclusion of the storm, the historical data base will be updated. These updated parameters will then serve in the model for the next storm simulation.

**Objective 2**

There are several characteristics of rainfall that affect runoff. Of major importance are the temporal pattern, spatial distribution, and storm movement. Generally for small watersheds, the peak rainfall intensity is the most important characteristic in determining peak runoff rate. The spatial distribution is needed to account for the variation in rainfall depth within the watershed, and it helps predict runoff for moderate to large watersheds.

Parameters of interest are those that characterize the velocity vector of the storm and the size and orientation of isohyets. The forecasting of these parameters will be used to superimpose a moving storm over a grid of points defining the watershed and then used to simulate the runoff response. Storm parameters will be updated as additional information is obtained from radar.

**Objective 3**

Using the optimized model parameters, observed rainfall, and forecasted rainfall, flow forecasts will be made with the hydrologic model. The entire process of parameter optimization, rainfall forecasting, and flow forecasting will be repeated approximately every 10 minutes in real time as updated information on the development of the rainstorm becomes available from the radar system and observed streamflow data become available from a telemetric stream gaging station. In this way, the flow forecast will be dynamic and improving as any particular forecast time is approached.

Figure 1 shows a sequence of three dimensional plots of rainfall in the Stillwater area for a storm on March 30, 1993. The individual plots are 6 minutes apart. From this figure the progression of the storm across the area is
Figure 7. The sequence of three dimensional plots of rainfall in the Stillwater area.

readily apparent. This is the type of data that will be used as input to the hydrologic model.

Figure 2 shows hydrographs for seven locations in the basin at a particular time. The hydrographs contain the actual or measured data up to the current time and the estimated flow to the current time and the projected flow
for several time steps in the future. It is the ability to anticipate rain and the resulting runoff coupled with continuous calibration of the hydrologic model that makes this approach valuable.

Figure 2. Hydrographs for seven locations in the basin at a particular time on the screen.
USE OF WSR-88D AND SURFACE RAIN GAGE NETWORK DATA IN ISSUING FLASH FLOOD WARNINGS AND MAIN STEM FLOOD FORECASTS

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Introduction

On the morning of June 5, 1991, a series of thunderstorms produced excessive rainfall over Osage County, Oklahoma, ending at approximately 7:00 a.m. This rainfall produced a flash flood over the headwaters of the Bird Creek drainage basin. The runoff ultimately produced a rise on Bird Creek, at Avant, Oklahoma, from 3.3 feet at 7:00 a.m. to the flood stage of 16 feet in less than 12 hours. Bird Creek crested at Avant 24 hours after the rainfall event, at a stage of 22.88 feet, or 6.88 feet above flood stage.

Timely flash flood warnings were issued for the event, although river gage reports at 7:00 a.m. indicated no rise on the stream. Therefore, only rainfall estimates could be used to forecast the eventual flood at Avant, which is the first river gage below the headwaters. Rainfall estimates across Osage County and surrounding areas indicated a maximum amount of 4.00 inches. However, the Weather Surveillance Radar 1988 Doppler (WSR-88D) estimated a maximum of 9.1 inches, and indicated the heaviest rainfall occurred over an area void of surface rain gage stations. In addition, the thunderstorms produced hail, which is known to result in overestimates of rainfall by the WSR-88D (Ahnert et al., 1983).

Forecasters from the Tulsa Weather Service Office (Tulsa WSO) and the Tulsa River Forecast Center (Tulsa RFC) made estimates of basin average rainfall by subjectively combining the radar data and surface reports. These subjective adjustments were quite good and allowed headwater forecast models to predict the flood that occurred at Avant. After the fact, a simple objective analysis was used to combine the two data sources, which also produced a reasonably accurate flood forecast along Bird Creek. Both methods validate that the combination of radar and rain gage data can be used in real-time to make accurate and timely warnings and forecasts.
Chronology

Beginning around 3:00 a.m., June 5, 1991, a series of thunderstorms developed over Osage County, Oklahoma. The convection developed over the headwaters of the Bird Creek drainage basin and moved slowly east, nearly parallel to the basin. During the next three hours, convection redeveloped two more times over the same area.

There were several reports of moderate-sized hail (0.75 to 0.88 inch) during the event. Severe thunderstorm warnings were issued almost continuously during that same time for Osage County and surrounding areas. By 5:00 a.m., the WSR-88D indicated over 5 inches of rainfall had occurred over portions of Osage County, and a flash flood warning was issued. Between 6:00 a.m. and 7:00 a.m., the thunderstorms began moving rapidly southeast away from the basin. Property damage in Osage County was minimal due to the rural setting, though a comparable event over a metropolitan area would have likely resulted in substantial damage.

By 7:00 a.m., the WSR-88D estimated a 9.1-inch storm precipitation maximum just west of Pawhuska. Rainfall estimates from law enforcement agencies, civil defense offices, and the general public were between five and seven inches for storm totals west of Pawhuska. However, official rainfall reports from cooperative observers (Figure 1) were well below the radar estimates, with a maximum of 4.00 inches at Pawhuska. Flash flooding was finally reported just west of Pawhuska around 8:15 a.m., with water 3 to 4 feet deep over highway 60 west of town.

![Figure 1. Isohyetal analysis of rain gage reports, and table of reports corresponding to WSR-88D estimates.](image-url)
It was apparent that main stem flooding was imminent. At that time, forecasters in the WSO made subjective estimates of basin average rainfall; all sources were used and biases were considered. The estimate of basin average rainfall was then used in a local program to estimate a 12-hour river rise at Avant, the first river gage below the Bird Creek headwaters. The program calculated a rise to 19.5 feet by 7 p.m. on June 5. Flood stage at Avant was 16 feet. A Flash Flood Statement was then issued to alert persons along Bird Creek that main stem flooding was likely from Pawhuska to Avant during the afternoon.

The Tulsa RFC also made another estimate of basin average rainfall by using all sources, including WSR-88D, rain gage data, satellite estimates, and unofficial reports. That estimate was used in conjunction with the Sacramento Soil Moisture Accounting Model (Burnash et al., 1973) to determine forecast stages for river gage locations along Bird Creek. At 2:25 p.m., the RFC forecast the stage at Avant to reach 19 to 20 feet (3 to 4 feet over flood stage) by midnight. At that time, a Flood Warning for Bird Creek was issued. At 7:00 p.m., the stage at Avant had already reached 19.5 feet. The RFC issued a revised forecast at 9:25 p.m. for a crest of 22 to 23 feet in the early morning of June 6. The maximum recorded flood crest was 22.88 feet on June 6, at 3:00 a.m., followed by a rapid decline late that day.

Correctly estimating the basin average rainfall, for use in flood and flash flood forecasting, was critical. The maximum rain gage report was 4.00 inches while radar data indicated over 9.00 inches. Although rain gage data provided the most accurate point measurements of rainfall, the WSR-88D provided much better geographical, or spatial, representation of the event. This gave forecasters important information in deciding where and how much rainfall occurred.

Independent Data Analysis

The storm precipitation totals for Osage County were quite varied, as indicated from the surface rain gage reporting network (Figure 1). When data from the WSR-88D was included, it became obvious the reporting network was not sufficient to resolve the event. Surface rain gage data indicated a storm total maximum of only 4.00 inches. Other reports around the area indicated even less rainfall. An objective analysis of these rain gage reports alone indicated a basin average rainfall of only 1.44 inches above Avant. This analysis resulted in a forecast crest of 12 feet, 4 feet below the flood stage of 16 feet (Figure 2). However, analysis of WSR-88D data indicated a basin average storm total of 5.2 inches. Using the radar data alone resulted in a 12-hour stage forecast of 32
feet, the highest stage ever recorded at Avant. This forecast was obviously too high, considering that the WSR-88D estimated almost 3 inches too much rain at Pawhuska. Clearly, a compromise between the two data sets was required.

**Objective Methods of Combining Data**

The subjective analysis of combining radar and rain gage data worked well enough to forecast the resulting flood on Bird Creek at Avant. However, an objective analysis of the data also arrives at a good estimate of basin average rainfall, and therefore a reasonable forecast of the flood at Avant.

*Figure 2. Hydrographs and 12-hour stage forecasts for Bird Creek at Avant, Oklahoma.*
First, a weighting factor of 0.57 was determined by using the 4.00-inch observed rainfall at Pawhuska, and dividing that by the 7-inch radar estimate for the same location. This factor was used to correct the radar estimated basin average of 5.2 inches, resulting in a corrected basin average of 2.96 inches. This value was then used to determine a 12-hour stage forecast at Avant of 19 feet, which compared quite well with the actual 12-hour rise (see Figure 2).

A more rigorous method was also used to determine a weighting factor. This method calculated an average bias from the five surface rain gage reports within and around the Bird Creek Basin. Stations A, F, G, I, and J, shown in Figure 1, were used. An analysis of these data indicated a weighting factor of 0.49, resulting in a slightly lower 12-hour stage forecast of 17 feet. It is important to note that other stations were well away from the intense rainfall, and away from reported hail which would bias the WSR-88D rainfall estimates. Although no hail was reported in Pawhuska, reports were received in the general area, making Pawhuska the closest, best "ground truth" of the precipitation event.

It was clear in this event that rain gage reports provided the most accurate measurements of rainfall. However, because gage reports are scattered, they often fail to measure the maximum rainfall. The WSR-88D is capable of locating rainfall maxima, without gaps. But the WSR-88D is subject to biases in estimating actual rainfall totals. Therefore, objectively adjusting the WSR-88D rainfall estimates with surface rain gage reports provides an optimum data analysis.

### Stage III Analysis

The National Weather Service River Forecast Centers have now automated this objective method of combining data, where WSR-88D data are available. Called "Stage III Analysis," the method routinely compares rain gage data to WSR-88D rainfall estimates. Since the WSR-88D provides better spatial and temporal detail than available from surface rain gage reports, the final Stage III processing provides a superior analysis to anything previously available in river forecasting.

### Conclusions

An analysis of the Osage County flash flood and flood event illustrated several important points. These included the degree to which WSR-88D precipitation estimates are accurate, and where they are most accurate. In addition, it was found that WSR-88D data provided critical spatial and temporal enhancement of surface rain gage data. Also, the characteristics of a thunderstorm, or complex of thunderstorms, can significantly alter the WSR-88D
precipitation estimates over areas less than 1500 square miles.

The WSR-88D overestimated precipitation totals for much of Osage County. This was most apparent at Pawhuska where WSR-88D estimates were between 7 and 8 inches, and the rain gage at Pawhuska collected only 4.00 inches. This was likely the result of high radar reflectivity bias caused by hail in the storms.

However, the WSR-88D provides superior spatial and temporal resolution to that of surface rain gage data alone. When the radar data was subjectively combined with the rain gage data, it provided forecasters with sufficient additional information to confidently issue warnings and statements. Now, where WSR-88D data are available, National Weather Service River Forecast Centers use an objective method to combine rain gage data and radar estimates. This method, called Stage III Analyses, provides rainfall data superior to anything previously available.

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THE USE OF WSR-88D RADAR DATA AND AN INTERACTIVE HYDROLOGIC MODEL IN FORECASTING A SEVERE FLOOD IN NORTHEAST OKLAHOMA

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Introduction

Mainstem river forecast responsibility for the Arkansas, Canadian, and Red Rivers in the south-central United States is entrusted to the National Weather Service (NWS) Arkansas-Red Basin River Forecast Center (ABRFC) located in Tulsa, Oklahoma. Specifically, ABRFC's responsibility extends from the headwaters of the Arkansas River near Granite, Colorado, to Pine Bluff, Arkansas; the Canadian River system from eastern New Mexico to Eufaula Reservoir in eastern Oklahoma; and the Red River system from the Texas Panhandle to Fulton, Arkansas. In complement, the National Weather Service Office at Tulsa, Oklahoma, is entrusted with meteorological forecast responsibility and issuances of hydrometeorological watches and warnings for its local service area, which includes all of northeastern and east-central Oklahoma.

Upon the dispatch of a flood forecast by the ABRFC, the appropriate office of the NWS issues the warning and call-to-action information to the emergency management community, the media, and the public. Coordination between state and local officials and the National Weather Service continues throughout the flood event.

Significant changes in operations and technology are currently transpiring in the NWS as it marches toward the new millennium. Two of several programs associated with the National Weather Service's Modernization and Associated Restructuring (MAR) played a vital role in forecasting a severe flood in northeast Oklahoma during September 24-27, 1993. One of these new programs, the 1988 vintage Doppler weather surveillance radar (WSR-88D), augmented the hydrologic forecast accuracy through hourly precipitation estimates.
Radar Data

At each WSR-88D location within the ABRFC, a clock-hour precipitation estimate is created each hour. The radar sends bursts of electromagnetic energy at a maximum frequency of 1,309 pulses per second. As some of this energy encounters rainfall, a portion is reflected and backscattered to the radar. The amount of energy returned to the radar is proportional to the rainfall rate. The returned energy, or reflectivity, is converted to estimated rainfall by using an algorithm that assumes information concerning raindrop size and distribution. The accuracy of the estimated rainfall is reduced when frozen precipitation (hail, sleet, and snow) occurs with rain. The estimation also suffers when drop size and drop distribution are significantly different from what is considered nominal. Biases in the radar derived rainfall fields can be subjectively determined and adjusted for by considering ground truth gage reports. A feature to be implemented with the radar system is the ability to input a maximum of 50 hourly precipitation reports to objectively determine reflectivity bias for each hour and adjust the rainfall estimate. The final hourly precipitation product developed by the radar is referred to as a Stage I precipitation field. While radar derived rainfall estimates are not perfect, the increased spatial and temporal resolution in the data are an enormous improvement over spotty rain-gage reports typically collected at six-hour intervals (or greater) from cooperative observers.

Hydrometeorological Processing

Stage I products are received from 11 WSR-88D radar sites at the ABRFC for Stage II processing. In the Stage II process, all available data is garnered, including satellite imagery and hourly raingage data—further refining the precipitation estimate. Finally, in the Stage III process, a mosaic of hourly Stage II products is generated, quality-controlled, then utilized in the ABRFC hydrologic models. The Stage III process allows for human interaction to "tidy up" the precipitation field, if the need arises. At the ABRFC, the Stage II (and Stage III) processes are conducted in a Unix environment on HP-9000™ workstations running the Stage II and Stage III software.

The Stage III finished product becomes the primary precipitation input into the NWS River Forecast System (NWSRFS). The output generated by NWSRFS is fed into the Interactive Forecast Program (IFP) developed at the NWS Office of Hydrology for MAR-era operations by George Smith, Donna Page, Thomas Adams, and Steve Wiele. During IFP, the hydrologic forecaster interacts directly with the hydrologic model, creating the final hydrologic
The Use of WSR-88D Radar Data

forecast, which is subsequently issued to the appropriate weather office for public dissemination.

The WSR-88D radar system and the IFP are two of the newest advances in hardware and software technology produced during the NWS Modernization. The WSR-88D hourly-generated precipitation products enable the hydrologic forecaster to rapidly input hourly precipitation estimates into the Interactive Forecast Program, allowing real-time updates of stage forecasts. IFP provides the software framework from which model adjustments to rainfall input, runoff, baseflow, etc., may be conducted. These computer-age tools facilitated rapid evaluation of the hydrometeorological situation that resulted in the prompt issuances of flood forecasts to the appropriate Weather Forecast Office during the flood event of September 24-27, 1993, described below.

The Event

On the morning of September 24, 1993, flash flood guidance values—a reflection of the degree of soil moisture saturation—were quite low. They indicated that a six-hour precipitation event of only 1.0-1.5 inches would result in flash flooding in most of the Lower Neosho River system, while only 2.0-2.8 inches were required for flash flooding in extreme northeast Oklahoma and southwest Missouri. Rain and thunderstorms developed over these areas on the night of September 23 (Thursday night) as a cold front stalled across Oklahoma. The front remained in the area into the weekend and resulted in prolonged rain. Widespread very heavy rains developed Friday night as an upper-level disturbance moved into the plains states and increased the lift near and north of the stalled front.

As precipitation continued throughout the morning of Friday, September 24, 1993, it became apparent that mainstem river flooding unfortunately would also occur. The initial flood forecasts for the Neosho River were issued at approximately 1:40 p.m. Friday afternoon, September 24, 1993, calling for flooding to occur from Leroy, Kansas, to Commerce, Oklahoma, and all intervening forecast points. The degree of flooding would be from "at flood stage" at Leroy, to nearly six feet above flood stage at Commerce, barring additional precipitation. Mother Nature was uncooperative, however.

During the evening of Friday, September 24 and early Saturday morning, additional rainfall amounts totaling 6-8 inches were prevalent in southeast Kansas, southwest Missouri, and northeast Oklahoma, with a maximum of nearly 15 inches falling near Pittsburg, Kansas. Forecasts were updated throughout Friday evening, and by Saturday morning, the flood forecast at Commerce, Oklahoma, was subsequently raised to a crest of 22.0-22.7 feet. As additional precipitation data became available throughout Saturday morning,
the forecast for Commerce was revised to reflect the river cresting at 23.0-24.0 feet for Monday morning, September 27. One final change to the forecast was made on Sunday, September 26, upping the crest forecast to near 24.5 feet. The Neosho River officially crested at 24.1 feet, over nine feet above flood stage, between 10 a.m. and 4 p.m. Monday morning, September 27.

Summary

Through the use of an interactive hydrologic model, ingesting human-corrected high resolution radar-derived rainfall data, the National Weather Service was able to issue a flood forecast for Commerce, Oklahoma, days prior to the flood crest. This flood crest was the fifth highest to date at Commerce. In nearby Miami, flood damage was severe, with approximately 150 people evacuated in and near the city. The only roadway open in the Miami area at the height of the flood was Interstate 44.

While this flood forecast demonstrated the potential of the new technology, a program to augment the technology, and enhance the NWS's ability to forecast floods has subsequently been started by the NWS field offices serving the ABRFC area. This program, a Quantitative Precipitation Forecast (QPF) program, consists of 18-hour rainfall forecasts that specify areas and amounts in six-hour intervals from 1 p.m. to 6 a.m. local time. Such predictions would likely have given the hydrologic forecasters at the ABRFC the information to issue higher flood crest forecasts even earlier in the event.

The implications of the new technologies and procedures in the NWS to floodplain managers are clear. The increased time and space resolution of rainfall-based digitized rainfall data results in the ability to better survey the water flowing into a particular basin. The obvious benefit is increased lead time on flood events through use of interactive hydrologic models ingesting human adjusted radar rainfall estimates. In addition, this improved means of anticipating inflow into a watershed will allow better management of water release from reservoirs and lakes. This will not only provided better flood management, but also will provide increased information to the managers of hydro-electric generation plants and water resource managers charged with ensuring long-term seasonal water supply.
RADAR-RAINFALL DATA FOR
THE GREAT FLOOD OF 1993

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Introduction

For much of 1993, the Midwest was pounded by a relentless series of storms that spawned one of America’s worst natural disasters. Long-standing rainfall records were toppled and river levels were pushed to record heights in seven states. Some reported river levels remained above flood stage for 200 days. A few stations saw sustained river levels above previously record flood crests for as long as 30 days. Fifty flood deaths occurred, hundreds of major river levees failed, and damages approached $15 billion (NWS Central Region, 1994).

The nation’s economy was impacted as the great flood disrupted transportation systems throughout the Midwest. Barge traffic along the Mississippi and Missouri rivers stalled for nearly two months due to high water and treacherous currents. Bridges were out, airports were flooded, major interstate highways were closed, and the trains stopped running.

The region is still suffering. Many homes were destroyed, some never to be rebuilt. Damaged farmlands may take years to recover, if ever. Major rivers reclaimed land that for decades had been denied them by a network of levees and flood control works. So great was the flooding that the foundations of flood control in this country were shaken. Federal and state agencies are revisiting decades-old flood control polices and, in some cases, formulating new approaches (Denning, 1994).

As with any natural disaster, the Great Flood of 1993 is being studied in detail to determine exactly what happened and why. This paper presents a new data set that may help event analysis. A data set derived from a new approach to radar-based rainfall estimates is presented. It includes 15-minute rainfall accumulations in 0.01” increments with 2 km x 2 km resolution for the period April 1 to August 31, 1993, for the entire upper Midwest region. A
comparative data set comprised of traditional observed rain gauge measurements is also presented and contrasted with the radar-based rainfall estimates.

Traditional Rainfall Measurement

Measurements of rain are usually taken using some sort of mechanical rain gauge. Rain gauges used in hydrometeorological applications are typically cylindrical devices that sample rain falling through an orifice 8-12 inches in diameter. Rainfall is commonly measured in a variety of ways. Simple measuring sticks, weighing the accumulated sample, and tipping buckets are typical techniques used to estimate the accumulated depth of rainfall.

The purpose of a rainfall measurement for most hydrometeorological applications is to use the measurement to estimate the amount of rainfall over a much larger area. Often a network of rain gauges is used to estimate the average rainfall over a watershed. The average rainfall over an area is a measure of the total volume of rain entering the area. The total volume of rain is the key parameter of interest.

Rain gauges generally provide adequate estimates of rain falling through the gauge orifice. The difficulty lies in the translation of point estimates to areal estimates. It is not uncommon to use an 8” rain gauge with an orifice that covers just one eighty millionth of a square mile to infer the volumetric influx over 50 or 100 square miles. Hydrologists are routinely forced to accept volumetric inflow estimates using samples on a scale of “parts per billion.” Without additional information, it is difficult to consistently infer accurate areal rainfall estimates from a sparse network of gauges given the variety of meteorological conditions that can occur.

Radar-Based Rainfall Measurement

Radar has long been a logical alternative to rain gauges as an estimator of areal rainfall (Atlas, 1990). Radar signals reflected from rain in the atmosphere provide a continuum of information related to areal rainfall. By integrating radar-determined rainfall intensities over time, rainfall accumulations can be approximated throughout the area of radar coverage. Theoretically, radar can provide measurements of rainfall that are superior to those from rain gauges since radar offers continuous coverage rather than “hit or miss” point estimates.

Unfortunately, historical efforts to estimate rainfall amounts using radar have been plagued by several problems. Ground clutter, anomalous signal propagation, and curvature of the earth’s surface all create serious estimation problems. New technologies and approaches to radar signal interpretation are helping improve radar-rainfall estimation. For example, the National Weather Service is currently installing a new network of Doppler radars (WSR-88D/NEXRAD). The NEXRAD radars are more sensitive, have improved
vertical discrimination, and higher resolution than previous radars. The NEXRAD network includes more complete coverage in the eastern United States and extends coverage in the mountainous West. All of these features are expected to help improve radar-rainfall estimation.

Implications for Hydrologic Applications

Perhaps no other hydrometeorological parameter imparts such a continuing high level impact on the nation’s economy as does water. Hydroelectric power generation, agriculture, transportation, recreation, manufacturing of all types, and the operation of our homes are all inexorably linked to the reliable delivery of water via rainfall. The accurate determination of the volume of falling water affects decisions whose economic impacts run in the billions. Damages from flooding average $5 billion each year. The drought of 1980 cost the United States more than $20 billion. NEXRAD benefits to the nation’s water resources are expected to far exceed the cost of the entire NEXRAD program.

A New Approach to Radar Imaging

Since 1988, WSI Corporation has been assimilating reflectivity data from conventional and NEXRAD (as available) radar sites throughout the country and combining these images into one mosaic of radar reflectivity. The mosaic presents radar images on a base map covering more than 6.5 million square miles at a resolution of 1.5 square miles (2 km x 2 km). These high resolution images are updated every 15 minutes.

Each pixel represents the average rainfall intensity over a 1.5 square mile area at the time of observation and is a composite representation derived from several radar sites. By using data from multiple radar sites to derive rainfall information, more complete coverage is possible than with single site images. Using proprietary three-stage false echo suppression/quality assurance processing, the mosaiced images avoid ground clutter, anomalous propagation, and other non-precipitation artifacts. With several radars viewing the same storm from different angles and distances, a more accurate storm structure emerges.

Rainfall rates associated with various levels of radar reflectivity values are commonly defined by the following relationship:

\[ Z = aR^b \]

where \( Z \) is the radar reflectivity (mm/s/m²) and \( R \) is the rainfall intensity (mm/hr). This equation is also commonly referred to as the “Z/R” relationship. The parameters “a” and “b” can vary considerably. Specific values of “a” and
"b" depend on weather conditions, precipitation type, etc. Optimum values of "a" and "b" can change greatly in both space and time, even on a local scale.

WSI developed a new approach to the interpretation of reflectivity data that overcomes the problems associated with widely varying parameters in the Z/R relationship. WSI has developed an automated empirical weather condition-based approach to process data from both conventional radars and the new NEXRAD sites. A self-adjusting algorithm was developed to automatically select the most appropriate rainfall values for different weather conditions for each pixel in the image. Six- and 24-hour rain gauge reports from NWS 1st-order stations are used to calibrate and fine-tune rainfall estimates.

Rainfall accumulations are determined by integrating the derived rainfall intensities over time. Every 15 minutes the mosaiced reflectivity values, along with observations and computer model forecasts, are input into the empirical model, which generates accumulated rainfall for each 2 km x 2 km pixel in 0.01" increments. The resulting data set represents rainfall accumulations for more than 6.5 million pixels. WSI markets this data set commercially under the trade name PRECIP™.

Data for the Great Flood of 1993

In February 1993, for reasons not associated with the developing flood situation in the Midwest, WSI began archiving the radar-rainfall data set. As the circumstances developed, it became clear that this data set represented an intriguing opportunity to evaluate the region-wide evolution of the Great Flood almost minute by minute with great spatial detail. The data set for the 1993 flood includes rainfall accumulations for each 1.5 square mile pixel every 15 minutes. This is an unprecedented amount of rainfall information to support analysis of an unprecedented flood event.

Detailed analysis of the data has just begun. The sheer volume of data presents handling problems since the complete data set requires approximately several gigabytes of storage. For the purposes of this paper, monthly images of PRECIP for April through August 1993 were analyzed. These images were accessible “on-line” at WSI and reduced the data handling requirements.

Rainfall data for standard surface rain gauges were obtained for the 5-month period for the state of Iowa. These data, obtained from reports published by the National Weather Service’s National Climate Data Center, were derived from 66 recording rain gauges located at National Weather Service, Federal Aviation Administration, and cooperative observer weather stations. Hourly data for each gauge were aggregated into monthly values. The monthly data were evaluated for each of the 66 stations. For one reason or another, monthly records were not complete at some stations due to mechanical failures, fouled gauges, etc. Only complete records were used in this analysis. On a monthly
basis, the number of complete useable records decreased steadily from a high of 55/66 (86%) in April to a low of 46/66 (70%) in July. Just 28/66 (42%) of the stations maintained complete records during the full 5-month period.

To compare the areal radar-based rainfall estimates (PRECIP) with point rain gauge estimates, monthly PRECIP values for the 2 km x 2 km pixels containing the latitude-longitude coordinates of the rain gauges were used.

Results

Gauge-PRECIP data pairs were plotted on scatter diagrams as shown in Figure 1. Each data pair represents a monthly rain gauge total and a monthly PRECIP total for the pixel containing the rain gauge. Monthly averages were calculated for available rain gauge totals each month and their corresponding PRECIP totals. The monthly averages are shown in Table 1.

<table>
<thead>
<tr>
<th>Table 1. Monthly rainfall averages in inches.</th>
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<td>Rain Gauge</td>
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<td>Data Points</td>
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On average, monthly totals for PRECIP were 12-22% higher than observed rain gauge totals. For the entire 5-month period, monthly PRECIP was about 16% higher than the average rain gauge value. The scatter diagrams in Figure 1 show positive correlation but also considerable dispersion. PRECIP produced consistently higher amounts each month. April was the only month with incidences (4) of major underestimation by PRECIP. Closer examination revealed that all four were located in northwest Iowa. This section of Iowa is primarily covered by older network radars located in Huron, South Dakota, Des Moines, Iowa, and Minneapolis, Minnesota. A NEXRAD radar has recently been installed at Sioux Falls, South Dakota, which should improve radar-rainfall estimation in northwestern Iowa.
Analysis

Overall, the performance of PRECIP estimates of rainfall are quite promising. For the entire April to August period, PRECIP averaged about 16% higher than rain gauge totals. Considering that long-term rain gauge measurements have been shown to underestimate actual rainfall by 5-15% (Groisman and Legates, 1994), the PRECIP averages look even better. There is still considerable variation in the data as shown by the dispersion indicated by the scatter diagrams. In general, some variation is expected since PRECIP estimates...
are areal and gauge readings are point values. Both measurements can be "correct" yet be significantly different. More likely, however, variability is introduced by anomalies remaining in the radar data set, uncertainties in the radar-rainfall estimation algorithms, inconsistencies in coverage by the radar network, individual storm conditions, inconsistencies created by merging NEXRAD with conventional radar data, etc.

Conclusions

On average, the radar-based rainfall estimation algorithms for generating PRECIP data performed well. Further experience and research will determine how consistently PRECIP performs on a storm-by-storm basis for individual locations and defined areas, such as watersheds.

Consistency will be difficult to determine in the short term as the conventional radar network is phased out in favor of NEXRAD. While NEXRAD holds great promise to improve radar-rainfall estimation, the "learning curve dynamics" associated with the changeover will be challenging. However, as the new radar network stabilizes, consistency of radar-rainfall estimates should improve.

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National Weather Service Central Region
Introduction

The City of Albuquerque, New Mexico, and the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) have adopted common Development Process Manual (DPM) standards that satisfy Federal Emergency Management Agency (FEMA) flood protection standards. Albuquerque has pursued basic hydrologic field research, literature review, and computer code development in pursuit of appropriate design and consistent methods. The process is ongoing.

For lack of better evidence, the DPM design hyetograph was specified with conventional NOAA-type intensities. Local engineering experience indicated that convective storms have a 30-minute time to peak intensity, \( t_p \). FEMA instructed the City to place \( t_p \) in the second hour, a compromise between the City’s practice and the SCS 12-hour \( t_p \) convention. This timing has design implications, as later peaks rainfall causes a higher peak runoff. This study addresses the following question: At what time after rainfall initiation do storms achieve peak intensity?

Terminology

Periods of 1 hour or more without rainfall identify the initiation and the secession of a rainfall event. In a simple sense, an event starts when measurable precipitation occurs after a dry hour and ends when a 1-hour dry period follows. Were the 1-hour criterion substantially shortened, major storms that pause for 30 minutes would become two independent events. Were the 1-hour criterion substantially lengthened, a brief, minor sprinkle some hours before an intense storm would cause the storm to appear protracted.

Major storm events exceed 1 inch, greater than the 0.6 inch annual event, but less than the 100-year storm, roughly 2 inches.

For consistency, this study uses the maximum 5-minute intensity as the peak intensity. Where a record is at other than 5-minute steps, linear interpolation yields the maximum 5-minute depth.
Data Base

This study draws from six New Mexican data sources. The ARS Experimental Watershed Program maintained six recording gages in the 1960s and 1970s (ARS, 1958; ARS, 1960; ARS 1963-89). Forty-one major events were digitally recorded, generally with 5-minute resolution.

A U.S. Geological Survey urban hydrology gaging project began in 1976 (Fischer et al., 1984; Metzker et al., 1993). Not all gages operated over the full period. The USGS data set includes 44 major events at nine watersheds in the Albuquerque metropolitan area. USGS records are digital, generally with 5-minute resolution.

AMAFCA has several years of raw printout record from the USGS urban hydrology gaging project newer than, or not reported in, Metzker et. al., (1993). The AMAFCA data set documents five major events.

The U.S. Army Corps of Engineers compiled mass rainfall curves with resolution of approximately 30 minutes from 1904 to 1942. Given the rapid intensity changes at 5-minute increments common in the USGS and ARS digital records, the smooth, linear Corps analog records appear to be grossly simplified. The Corps data describe major 40 events. The most extreme event, 10.1 inches in 6 hours, 21.25 inches overall, is "Unofficial." The Corps Design Memorandum #1, Hydrology, Santa Fe River and Arroyo Mascaras refers to "2.1 inches in 1 hour" on July 25, 1968. While records such as these two do not include sufficient data for t_p assessment, they contribute to a general appreciation of peak rates.

La Vigne (1988) evaluated NOAA microfiche continuous daily strip charts, Albuquerque International Airport, 1945-1984, and analyzed the 40 largest for frequency. Of these, five are major events. The NOAA data set is from 24-hour strip charts, providing resolution of approximately 15 minutes.

Burnett (1980) analyzed continuous strip chart recordings and Fisher Porter 5-minute increment punched tapes from the Albuquerque International Airport, 1951-1979. Only four events are major. Of these, three are redundant with the NOAA data set, given slight differences in visual readings. Burnett included records from private observers operating recording gages. One event in this category is major.

Statistical Summary

The 40 Corps major events are of poor quality and are not applicable for t_p analysis. Summary statistics for the 96 remaining major events are shown on the next page.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Min.</th>
<th>Max.</th>
<th>Mean</th>
<th>St. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to peak</td>
<td>0.02</td>
<td>2.83</td>
<td>0.67</td>
<td>0.63</td>
</tr>
<tr>
<td>Precipitation</td>
<td>1.00</td>
<td>5.06</td>
<td>1.72</td>
<td>0.85</td>
</tr>
<tr>
<td>Base time</td>
<td>0.37</td>
<td>10.08</td>
<td>3.59</td>
<td>2.62</td>
</tr>
<tr>
<td>Intensity</td>
<td>0.36</td>
<td>24.36</td>
<td>4.04</td>
<td>3.84</td>
</tr>
</tbody>
</table>

The correlation matrix is

<table>
<thead>
<tr>
<th></th>
<th>Time to peak</th>
<th>Precipitation</th>
<th>Base time</th>
<th>Intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time to peak</td>
<td>1.00</td>
<td>0.0872</td>
<td>0.3971*</td>
<td>-0.2936*</td>
</tr>
<tr>
<td>Precipitation</td>
<td></td>
<td>1.00</td>
<td>0.0916</td>
<td>0.5535</td>
</tr>
<tr>
<td>Base time</td>
<td></td>
<td></td>
<td>1.000</td>
<td>-0.3773*</td>
</tr>
<tr>
<td>Intensity</td>
<td></td>
<td></td>
<td></td>
<td>1.000</td>
</tr>
</tbody>
</table>

where * indicates significance at the 0.05 level. Major events having \( t_p \) less than 1 hour comprise 78% of the sample.

**Spatial Distribution**

Of the 96 total, 68 of the major events are at Albuquerque. The ARS Albuquerque watersheds are on the northwest mesa. All but four of the USGS major events are in the northeast heights. The NOAA airport data represent the southern portion of the city. The Albuquerque events cover the metropolitan area.

As Albuquerque data document few events of the 2-inch range, the addition of surrounding locations helps build a stratified sample. Following are summary t-test statistics by location indicating probabilities that the \( t_p \) data at other locations is statistically consistent with the Albuquerque population.

<table>
<thead>
<tr>
<th>Location</th>
<th>( t_p ) (hr)</th>
<th>( t )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Albuquerque</td>
<td>0.71</td>
<td>1.2923</td>
<td>0.200</td>
</tr>
<tr>
<td>Mexican Springs</td>
<td>0.40</td>
<td>0.9851</td>
<td>0.328</td>
</tr>
<tr>
<td>Santa Fe</td>
<td>0.24</td>
<td>0.0566</td>
<td>0.955</td>
</tr>
<tr>
<td>Santa Rosa</td>
<td>0.70</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Mean \( t_p \)'s for Albuquerque and Santa Rosa are the same, confirmed by the high \( p \) value. Less can be statistically generalized about Mexican Springs and Santa Fe, as they have smaller sub-sample sizes, but the two are within the range of the Albuquerque values.

Santa Rosa has higher intensities than does Albuquerque (8.85 vs. 2.70 in/hr), but \( t_p \)'s in both locations are again similar. Both locations demonstrate
a reciprocal relationship between \( t_p \) and intensity. The harder the storm, the sooner the peak. Drizzles may not peak for several hours.

Storms that last 6 hours tend to peak relatively later than short storms, a logical relation. The very largest storms peak sooner than do the smaller events, but with little correlation. Overall, storm duration and \( t_p \) are unrelated.

While the non-Albuquerque locations show some different storm characteristics, the \( t_p \) attributes are effectively the same. Inclusion of ARS major events more than doubles the sample count above 2 inches and the sample count exceeding 5 in/hr intensity.

Joint Probabilities

There is no standard rule in hydrologic statistics regarding the application of joint probabilities. Is a 100-year event a storm with a 0.01 probability regarding depth, but a typical probability regarding timing? Should the timing also reflect extreme behavior? An answer requires knowledge of covariance. If \( t_p \) and depth are truly independent, a 100-year depth with a 100-year extreme \( t_p \) would describe a storm expected on the average every 10,000 years. If, on the other hand, depth closely correlates with \( t_p \), the combination could be a 100-year storm.

The reasonable and conservative conclusion is that for major events, \( t_p \) is weakly related to depth. As correlation is minimal, the 100-year event should have a 100-year depth with an average \( t_p \), 40 minutes in this case.

A Statistical Model

Regressing \( t_p \) upon depth \( P \), base time \( t_b \), and intensity \( i \),

\[
t_p = 0.359 + 0.1898 P + 0.0595 t_b - 0.0567 i
\]

where \( t_p \) and \( t_b \) are in hours, \( P \) is in inches, and \( i \) is in in/hr. Multiple \( R^2 \) is 0.47. The signs of the coefficients agree with the visual slopes; \( t_p \) increases with \( P \) and \( t_b \) and decreases with \( i \).

Statistical test does not justify such a model, however. The independent variables have minimal verified relationship to \( t_p \). Regression helps, however, to view sensitivity and to compute particular estimates. For the mean Albuquerque 100-year 6-hour event, \( P \) is 2.51 inches, \( t_b \) is 6 hours, and \( i \) is 6.94 in/hr. Regressed \( t_p \) is 0.80 hours, somewhat higher than the overall mean, but given the scatter in the data base, a close value. The statistically legitimate best estimate of \( t_p \) is simply the overall mean, 0.67 hours.
The Event of August 14, 1980

Of the USGS major events, five are for the storm of August 14, 1980, in different watersheds. Of these, the smallest total depth is 2.07 inches. Thus, this storm resembles the 100-year event. The $t_p$ occurred at 1.25, 0.67, 0.75, 1.42 and 1.25 hours. As an alternative to a statistical model drawn from the complete data base, design $t_p$ could be based on this historic record. Were the historic-event approach favored, the August 14, 1980, event $t_p$ is 1.07 hours. A single event is a poor criterion when a broader data set is available. Neither the storm of August 14, 1980, nor any other unique phenomenon should be a sole justification for a standard.

Assignment of Time to Peak

Various estimates of $t_p$ are

<table>
<thead>
<tr>
<th>$t_p$ (min)</th>
<th>Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>Pre DPM engineering practice in Albuquerque</td>
</tr>
<tr>
<td>40</td>
<td>Data base overall mean</td>
</tr>
<tr>
<td>48</td>
<td>Data base regression</td>
</tr>
<tr>
<td>64</td>
<td>Storm of August 14, 1980</td>
</tr>
<tr>
<td>84</td>
<td>DPM, 8/91</td>
</tr>
<tr>
<td>360</td>
<td>SCS II-a, NM</td>
</tr>
</tbody>
</table>

Of the above estimates, this study proposes the 48-minute value for the next DPM revision. A broad data base substantiates this value. This value is reasonable in light of alternative estimates.

Maximum 5-Minute Depths

The $P_5/P$ ratio has a mean of 0.20 and a standard deviation of 0.15, where $P_x$ is $x$-minute depth. The Miller et al. (1973) $P_5/P$ is 0.24. Given the variance of the data base, the difference is of minimal significance. Exact differential significance cannot be calculated without knowledge of Miller’s variance. The four Albuquerque precipitation zones in the DPM average a 0.82 ratio between the $P_{60}$ and the 6-hour depth. Thus the data base $P_5/P_{60}$ is $0.20/0.82 = 0.24$. Miller establishes 0.29 as the $P_5/P_{60}$ ratio.
Hyetograph Sequencing

Hyetograph sequencing is the process of assigning single time-step rainfall depths to the hyetograph array. To preserve the maximum depth-duration relationships, the maximum depth is assigned to the time step containing \( t_p \). The next highest depth is assigned to the immediate left or right member of the array. The next highest depth is assigned to the immediate left or right of the latter pair (Cudworth, 1989)

Rainfall depths before the peak 5 minutes and before the peak 15 minutes were determined for 91 digitized major events and converted to ratios of total precipitation. The mean ratios are:

<table>
<thead>
<tr>
<th>Ratio</th>
<th>Mean</th>
<th>St. Dev</th>
</tr>
</thead>
<tbody>
<tr>
<td>P before peak 5 min/P total</td>
<td>0.27</td>
<td>0.18</td>
</tr>
<tr>
<td>P before peak 15 min/P total</td>
<td>0.16</td>
<td>0.15</td>
</tr>
</tbody>
</table>

As with 5- and 15-minute depths, the above means may be divided by 0.82 to estimate the ratios to \( P_{60} \). To preserve the above bracketing and the \( t_p \) assignment, the time step of maximum depth must be 45-50 minutes, followed and preceded by the second and third greatest depths, respectively. Sixteen percent of the total rainfall must occur in the first 40 minutes.

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Tarleton, L.
A COMPARATIVE STUDY OF RETURN PERIODS
FOR 24-HOUR PRECIPITATION
FROM TWO CONSECUTIVE 30-YEAR PERIODS

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National Weather Service

Milton E. Brown
Southeast Regional Climate Center

Introduction

With the current debate over climate change, there is an interest in updating climate studies that were done over 30 years ago. Studies such as TP-40 (Hershfield, 1961) are based on data from before 1960. Since then, another 30 years of data have been collected. This study used a graphical approach to determine if there is an important difference in the frequency of 24-hour rainfall from two consecutive 30-year periods (1930–1959 and 1960–1989). A set of maps was made for each period. Each map was a plot of the 24-hour rainfall for a specific return period (10, 25, and 50 years). A comparison of the map pairs for each return period was expected to give an indication of the change, if any, in the rainfall frequency values during the latter period.

Situation

Although climate change is a popular topic in the environmental field today, the actual extent of climate change and its importance to persons working in related fields is debatable. The climatic record is short, with most data covering less than 100 years. With such a short span of time for comparison, there was interest in making use of the most recent data available in environmental design and planning.

Engineers, planners, floodplain managers, and other professionals concerned with environmental matters use rainfall frequency data. Much of the rainfall frequency information available was based on studies done prior to 1962. The Weather Bureau Technical Paper Series (U.S. Weather Bureau, 1955, 1956, 1958) was an example.

Two questions that this study addresses are: Do studies like TP-40 need to be redone using more recent data or longer periods of record? and, Are these recent data more relevant for use today?
Method

This study used a method of computation similar to that used in TP-40. The precipitation data used were derived from the "Daily Precipitation" section of Climatological Data (National Climatic Data Center, 1930-1989). Precipitation amounts were for the 24 hours preceding observation time. All extreme precipitation events were assumed to be non-frozen; i.e., rainfall. In TP-40, a partial duration series was used. It was shown that for return periods of greater than 10 years the partial duration and annual series yielded the same return period values. An annual series consisting of the greatest 24-hour precipitation amount for each year was used in the computation of the return period values. The annual series was ordered, and the return periods were computed using Weibull’s Formula (Lindsey et al., 1975, p. 340):

\[ T_r = \frac{n+1}{m} \]

Where:
- \( T_r \) = the return period in years
- \( n \) = number of values in the data set
- \( m \) = rank order of magnitude in the data set;
  - \( m=1 \) being the largest value and \( m=n \) being the smallest

When plotted on extreme value probability paper, the return period values approximated a straight line (Gumbel, 1958). The reduced variate was linear on the probability scale of the extreme probability plot and was related to the probability of exceedance by (Lindsey et al., 1975, p. 345):

\[ P = 1 - e^{-e^y} \]

Where:
- \( P \) = the probability of exceedance
- \( e \) = the base of napierian logarithms
- \( y \) = the reduced variate, a function of probability

For values greater than the mean (\( T_r > 2.33 \) year), a straight line was fitted to the plotted values using a least squares technique of simultaneous equations and Cramer’s rule. A value for each return period of interest was then computed from this line and multiplied by 1.13 to adjust from 24-hour to 1440-minute values (Hershfield, 1961).
Construction of Maps

Return period values for 27 stations in South Carolina, North Carolina, and Georgia were plotted on six maps, one pair for each return period of 10, 25, and 50 years. These maps were analyzed, and isohyets were drawn. The resulting regional rainfall frequency maps are similar to those in TP-40 (Figures 1 and 2).

Conclusions

Comparison of the map pairs indicated lower return period values in the most recent 30-year period (1960–1989) for most of South Carolina. However, there was an increase in the eastern portion of the state. The amount of difference in the two data periods increased with the return period. A conclusion may be drawn that there was a difference in the rainfall frequency values for the two subsequent 30-year periods with the latter 30-year period yielding lower values over most of the state. An explanation of the increase in a small portion of the study area was beyond the scope of this graphical analysis. Perhaps a more sophisticated statistical study will yield answers. The total period of record was too short for drawing any conclusions as to long term climatic change, but new studies incorporating data for the entire period of record would obviously be of value.

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EXPLANATION

Contour shows change in heavy precipitation events, in inches. -1 indicates increase in rainfall.

25-year Return Period
24-hour Duration
Change in Heavy Precipitation Events
1930-1959 Period to 1960-1989 Period

Figure 1. Twenty-five year return period.
Contour shows change in heavy precipitation events, in inches. + indicates increase in rainfall.

50-year Return Period
24-hour Duration
Change in Heavy Precipitation Events
1930-1959 Period to 1960-1989 Period

Figure 2. Fifty year return period.
National Oceanic and Atmospheric Administration

U.S. Weather Bureau

U.S. Weather Bureau

U.S. Weather Bureau
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PART SEVEN

MODELING, COMPUTER APPLICATIONS, AND GEOGRAPHIC INFORMATION SYSTEMS
Introduction

To join the National Flood Insurance Program (NFIP), a community must adopt and enforce the minimum floodplain management regulations required for participation. The Federal Emergency Management Agency (FEMA) works closely with state and local community officials to identify flood hazard areas and flood risks. The floodplain management requirements within the flood hazard areas are designed to prevent new development from increasing the flood hazard and to protect new and existing buildings from anticipated flood events. Communities must ensure that their adopted floodplain management regulations and enforcement procedures meet NFIP requirements, and must update the regulations when additional data are provided by FEMA or when federal/state standards are revised.

In support of the NFIP, FEMA has identified flood hazards and mapped them on Flood Insurance Rate Maps (FIRMs) and, in some cases, Flood Boundary and Floodway Maps. Several areas of flood hazard are commonly identified on the FIRMs, based on detailed hydrologic and hydraulic analyses. One of these areas is the Special Flood Hazard Area (SFHA), defined as an area of land that would be inundated by a flood having a 1% chance of occurrence in any given year, a flood also referred to as the base, or 100-year, flood. Development may take place within the SFHA, provided that it complies with local floodplain ordinances that meet the minimum federal requirements.

Many SFHAs were determined from detailed hydrologic and hydraulic analyses performed by reputable engineering firms or federal agencies that contracted with FEMA to perform these analyses and to prepare flood maps and reports for the community. From the analyses and maps, FEMA prepares and distributes Flood Insurance Study (FIS) reports and FIRMs that present the limits of the SFHAs, base flood elevations (BFEs), and flood insurance risk zones.
To change the flood hazard information presented in the FIS report and on the FIRM, NFIP regulations require that scientific or technical data be provided to demonstrate that the change is warranted. If physical changes that would change the BFEs have occurred along a stream or flooding source, several procedures are in place to effect a revision to the report and map. One procedure involves revising a specific FIRM panel based on technical data submitted by the community or an individual appellant. If changes to the floodplain have occurred since the FIS was completed, it is the community's responsibility to furnish the data reflecting the nature and effects of the changes. Once these data are provided, a map revision can be accomplished by physically changing the FIRM or issuing a Letter of Map Revision. Community officials and others who wish to request revisions to NFIP maps may find it necessary to obtain the supporting hydrologic and hydraulic data used to establish the SFHA. These supporting data usually include the results of analyses performed using computer programs. To ensure that these programs are available to all parties impacted by the flood insurance/floodplain mapping developed or revised through the NFIP, specific requirements for the availability and use of computer programs have been established and are contained in the NFIP regulations.

Computer Programs Acceptable for NFIP Use

Numerous computer programs (models) have been used to support the determinations and designations of SFHAs on NFIP maps. The most frequently used hydraulic computer program for determining water-surface elevations in riverine situations is HEC-2, developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center. The WSPRO model, developed by the U.S. Geologic Survey/Federal Highway Administration (FHWA), and the WSP2 model, developed by the U.S. Soil Conservation Service, are other examples of widely used one-dimensional steady-flow models developed and supported by federal agencies.

However, in many instances, complex flow conditions may dictate that one-dimensional steady-flow models alone are not sufficient to determine the water-surface elevations in these situations. One-dimensional unsteady-flow and two-dimensional steady- and unsteady-flow models are being used to analyze these more complex conditions. Many of these complex conditions can be found in natural river systems, but many more have been caused by the construction of human-made structures in the floodplains (e.g., roads, levees, bridges, culverts, buildings).

DAMBRK and DWOPER, developed by the National Weather Service, are examples of one-dimensional unsteady-flow models accepted by FEMA for NFIP use. FESWMS-2DH, developed by FHWA, is a finite-element surface-water modeling system used to simulate steady and unsteady two-dimensional
flow in the horizontal plane, and has been used to determine water-surface elevations in support of the NFIP. Specific regulations relating to the acceptance of these and other computer programs for NFIP use are discussed below.

**NFIP Regulations Relating to Computer Programs**

Computer programs used to perform hydrologic or hydraulic analyses in support of an NFIP map revision must meet all of the requirements of Paragraph 65.6(a)(6) of the NFIP regulations. The purpose of these requirements is to ensure that all parties requesting revisions have access to the supporting data used to establish the SFHA on an NFIP map. These programs must meet several criteria:

- The program must have been reviewed and accepted by a governmental agency responsible for implementing programs for flood control and/or the regulation of floodplain lands. For computer programs adopted by non-federal agencies, additional certifications by a responsible agency official are required for review, testing, and acceptance.

- The program must be well documented, including source codes and user's manuals.

- The program must be available to FEMA and all present and future parties impacted by flood insurance/floodplain mapping developed or revised through the use of the program. For computer programs not generally available through federal agencies, the source code and user's manuals must be sent to FEMA free of charge with fully documented permission from the owner that FEMA may release the code and user's manuals to such impacted parties.

For the purposes of certification by non-federal agencies, computer programs adopted by regional flood control districts involved in designing flood control structures or in regulating floodplain lands are accepted only if all other requirements of Paragraph 65.6(a)(6) of the NFIP regulations can be met. Even if a computer program (model) meets the NFIP review and acceptance criteria, the correct application of the model to the particular flow conditions is the user's responsibility and review of its acceptability in support of a revision request will be determined under Part 65 of the NFIP regulations.
Examples of Applications of These Models

Discussed below are some typical examples where more complex flow situations have been analyzed through one- and two-dimensional steady- and unsteady-flow models.

**Example 1—Large Tributary Inflows to Main Stem**

In this example, river flows are controlled by upstream dams and reservoirs. For this reason, tributary inflows have a significant effect on the resulting 100-year water-surface elevation in the main stem of the river. During significant flooding, flows from the tributary will cause unsteady flow in the river’s main stem.

The DWOPER model was used to determine the effects of tributary inflows on the main stem of a controlled river. In this case, the tributary inflows were combined with the main stem base flow and then routed to determine the flows above and below the confluence point. The resulting flows were used in the steady-state backwater program to calculate the water-surface elevations. The main stem water-surface profile was compared to the tributary-influenced profile to determine the controlling water-surface profile for NFIP purposes.

**Example 2—Effects of Levees on Peak Flows**

In this example, a major levee is located on the stream. When overtopped, the levee will allow off-stream storage behind it. Flood peaks will be affected by these levee overflows and off-stream storage. Encroachments in the off-stream storage areas were evaluated to ensure that flood peaks downstream would not be increased by future development (fill) in these areas due to loss of storage.

The DWOPER model was used to simulate the progression of the 100-year flood wave through the reach of stream affected by the levee. The DWOPER model was used because it can simulate flow over and storage behind levees. These resulting peaks were used in the steady-state backwater program to calculate water-surface elevations and floodways.

**Example 3—Bridge, Many Islands, and Bifurcations**

In this example, a river reach that is hydraulically complex, with a bridge, many islands, and bifurcations present during 100-year flood conditions, is to be modeled. Because of the hydraulic complexity, the FESWMS-2DH model was used. For purposes of developing a floodway, the FESWMS-2DH model results were used to calibrate the 100-year water-surface elevations determined in the one-dimensional HEC-2 model. The HEC-2 model was then used to establish an equal-conveyance floodway.
A STOCHASTIC INTEGRAL EQUATION ANALOG
FOR RAINFALL-RUNOFF MODELING

T. V. Hromadka II
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Abstract

The complexity of rainfall-runoff modeling and the apparent lack of success in significantly improving the accuracy of such modeling are well documented. In this paper, a multi-linear unit hydrograph approach is used to develop subarea runoff, and is coupled with a multi-linear channel flow routing method. The spatial and temporal rainfall distribution over the catchment is equated to a known rainfall data source. The resulting model structure is a series of stochastic integral equations, one equation for each subarea. A cumulative stochastic integral equation is developed that includes the spatial and temporal variabilities of rainfall. The resulting stochastic integral equation is an extension of the well-known single-area unit hydrograph method, except that the model prediction of a runoff hydrograph is a distribution of outcomes (or realizations).

Introduction

The complexity of rainfall-runoff modeling and the apparent lack of success in improving its accuracy are well documented (for example, Jakeman and Hornberger, 1993; Loague and Freeze, 1985; Hornberger et al., 1985; Hooper et al., 1988; Beven, 1989; Hromadka and Whitley, 1989). An apparent barrier to improvement in modeling accuracy is the lack of accurate rainfall data. Raines and Valdes (1993) state that "the estimate of the rainfall parameters is the most subjective task and seems to be responsible for the major sources of error." In this paper, unit hydrographs are used to estimate subarea runoff, which is then coupled to a multi-linear channel flow routing analog to develop a link-node model network. Jakeman and Hornberger (1993) observed a "predominant linearity in the response of watershed over a large range of catchment scales even if only a simple adjustment is made for antecedent rainfall conditions. The linearity assumption of unit hydrograph theory therefore seems applicable in temperate catchments and works just as well for slow flow as for quick flow."
Stochastic Rainfall-Runoff Model Development

The catchment is divided into hydrologic subareas, $R_j$, such as discussed in Hromadka et al. (1987). Each $R_j$ is homogeneous in that a single loss function transform, $F_j(\cdot)$, applies in the subarea. The effective rainfall (or rainfall less losses) is given by $e_j(\cdot)$, for storm event $i$, where

$$e_j^i(t) = \int_{R_j} \int F_j(P_i(x,y,t)) \, dx \, dy / A_j$$

(1)

where $A_j$ is the area of $R_j$. The point rainfall is written as a sum of proportions of the available rain gauge data by

$$P_i(x,y,t) = \sum_{k=1}^{n_p} \lambda_{xy}^i \Theta_{xy}^i \gamma_{g}^i(t - \Theta_{xy}^i)$$

(2)

where $\lambda_{xy}^i$ is a proportion factor at coordinates $(x,y)$ for event $i$, and $\Theta_{xy}^i$ is a timing offset at $(x,y)$ for event $i$. Combining (1) and (2),

$$A_j e_j^i(t) = \int_{R_j} F_j \left[ \sum_{k=1}^{n_p} \lambda_{xy}^i P_{g}^i(t + \Theta_{xy}^i) \right] \, dR_j$$

(3)

Let $F_j$ satisfy the conservative property

$$F_j \left[ \sum_{k=1}^{n_p} \lambda_{xy}^i P_{g}^i(t + \Theta_{xy}^i) \right] = \sum_{k=1}^{n_p} \lambda_{xy}^i F_j(P_{g}^i(t + \Theta_{xy}^i))$$

(4)

(An example of such a loss transform is $F_j(\cdot) = C_j(\cdot)$, where $C_j$ is a constant for $R_j$.)

The runoff contribution for subarea $j$ is given by

$$q_j^i(t) = \int_{s=0}^{t} e_j^i(t-s) \phi_j(s) \, ds = \int_{s=0}^{t} \int_{R_j} \sum_{k=1}^{n_p} \lambda_{xy}^i F_j(P_{g}^i(t - \Theta_{xy}^i - s)) \phi_j(s) \, dR_j \, ds$$

(5)
We can introduce nonlinearity with the $\phi_j(\cdot)$ based upon the magnitude of $e_j(\cdot)$, such as $\phi_j(\cdot) = (\phi_j(\cdot) | e_j(\cdot))$. One method is to define subarea transfer functions according to the severity of storm, i.e., by storm class (e.g., mild, moderate, severe, flooding, etc.). From (6), randomness is inherent in the $\lambda_{xyk}$ and $\theta_{xyk}$ values, for each storm event $i$.

Channel Flow Routing

Using a multilinear flow routing analog, without channel losses, (e.g., see Doyle et al., 1983; Becher and Kundzewicz, 1987),

$$Q_{j+1}^i(t) = Q_j^i(t) + \sum_{k=1}^{n_r} \alpha_k Q_j^i(t-\beta_k)$$

where the link is known given nodes $j$, $j+1$; node $j+1$ is downstream of node $j$, $n_r$ is the number of flow routing translates used in the analog; and the $\alpha_k$ and $\beta_k$ are constants. The Convex, Muskingum, and many other flow routing techniques are given by (7).

Runoff at node $j$ is given by upstream contributions of runoff

$$Q_j^i(t) = \sum_{k'=1}^{n_j} \left( \sum_{\langle k \rangle < j'} \alpha'_{\langle k \rangle < j'} q_j^i(t-\gamma_{\langle k \rangle < j'}) \right)$$

where $n_j$ is the number of subareas tributary to node $j$; the $\langle k \rangle$ is index notation for runoff contributions as summed over index $i$, for index $k$.

Rewriting,

$$Q_j^i(t) = \sum_{k'=1}^{n_j} \int_{s=0}^{t} F_j(P_{\gamma}^i(t-s)) \sum_{\langle k \rangle < j'} \alpha'_{\langle k \rangle < j'} \psi_{\gamma}^i(s-\beta_{\langle k \rangle < j'}) \, ds$$
A Stochastic Integral Equation Analog

\[ F_r(P_g^i(t-s)) \Psi_j^i(s) \, ds_1 \sim_1 \Psi_j^i(s) = \sum \alpha_j^{<k>_y} \Psi_j^i(s - \beta_j^{<k>_y}) \] 

(10)

Runoff Prediction on a Storm Class Basis

In prediction, the distribution of \( P(x,y,t) \) is unknown. The possible outcome for runoff, at node \( j \), is a distribution of realizations given by \([Q_j^{*o}(\cdot)]\) where

\[ [Q_j^{*o}(t)] = \sum \int_{s=0}^{t} F_r(P_g^*(t-s)) [\Psi_j^{o}(s)] \, ds \] 

(11)

where \([\Psi_j^{o}(s)]\) is the stochastic process of realizations from storm class \( o \), where for node \( j \),

\[ \Psi_j^{o}(s) = \sum \alpha_j^{<k>_y}[\Psi_j^{o}(s - \beta_j^{<k>_y})] \] 

(12)

The expectation is given for (11) by

\[ E[Q_j^{*o}(t)] = \sum \int_{s=0}^{t} F_r(P_g^*(t-s)) E[\Psi^{o}(s)] \, ds \] 

(13)

Equation (13) forms a basis of the unit hydrograph procedure commonly used for flood control design and planning.

The Unit Hydrograph Method (Single Area)

The well-known single-area unit hydrograph (UH) method may be developed by the expectation, for the case of prediction of runoff for rainfall event \( P_g^*(\cdot) \),

\[ E[Q_g^*(t)] = \int_{s=0}^{t} F(P_g^*(t-s)) E(\Phi(s)) \, ds \] 

(14)
where $E[Q^*_e(*)]$ is a single runoff hydrograph (usually filtered); and $E[\hat{\Phi}(\cdot)]$ is the calibrated transfer function. In order for $E[\hat{\Phi}(\cdot)]$ to be a UH, normalization is needed by letting

$$\eta = \int_{s=0}^{\infty} E[\hat{\Phi}(\cdot)] \, ds$$  \hspace{1cm} (15)

and the UH is simply $\frac{1}{\eta} E[\phi(\cdot)]$

**Conclusions and Discussion**

Methods have been in use for decades for transferring UH relationships to locations where stream gauge data are not available (for example, see Hromadka et al., 1987). In order to transfer the stochastic relationships of variability in the $[\hat{\Phi}(\cdot)]$, the same UH transferability techniques may be used. That is, by scaling the distribution of $[\hat{\Phi}(\cdot)]$ outcomes with respect to $E[\hat{\Phi}(\cdot)]$, then as $E[\hat{\Phi}(\cdot)]$ is transferred in UH form, so is the distribution $[\hat{\Phi}(\cdot)]$. This approach has been implemented in the recent hydrology manuals for the counties of Kern (1992) and the largest county in the mainland United States, San Bernardino (1993). The approach is currently being developed for the hydrology manual of the county of San Joaquin (1993).

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TWO-DIMENSIONAL MODELING; A CASE STUDY

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Introduction

Floodplain maps have been an integral part of the National Flood Insurance Program since its inception. Local officials rely almost exclusively on them to determine whether development is in a potentially hazardous location and subject to floodplain regulations. Almost without exception, the detailed maps produced for riverine flooding have been based upon results produced by one-dimensional steady-state computer programs. The most commonly used of these models are step-backwater models such as the Corps of Engineers' HEC-2 or the Soil Conservation Service's WSP-2 program. When experienced engineers apply these programs properly, they normally provide a good representation of the extent of flooding, depths, and velocities during a selected flood event.

However, in many situations in the State of Washington and elsewhere, results from a one-dimensional model are not a good representation of the actual risk of flooding or severity of the potential hazard. The Nooksack River in Whatcom County in Northwest Washington is one such example. It normally empties into Puget Sound after traveling approximately 80 miles from its headwaters at over 10,000 feet above sea level on Mt. Baker. The last 36 miles of its journey is through a very wide valley where there can be multiple flow paths during major flood events. One of these flow paths is over a low interbasin divide that empties into the Fraser River basin in Canada. During two major floods in November 1990, which were approximately 10- to 25-year events, severe flooding occurred both in Whatcom County and in British Columbia. High water marks from these events have been measured along the lower 30 miles of the river and the overflow into Canada. These flood elevations were in some cases up to six feet higher than those predicted by FEMA for the 100-year event. Other areas that were predicted to be flooded remained dry.

Purpose

The purpose of developing a two-dimensional model of the lower Nooksack River is to create a better set of tools for long-term flood "hazard" management along this reach of the river by Whatcom County. The County and several small communities within the valley no longer want just to react to flood events, but to permanently reduce the hazards and recurring costs associated
with them. To help develop a Comprehensive Flood Hazard Management Plan for the Lower Nooksack River, the County formed an advisory committee that reviews all actions and policies associated with flooding within the county. This committee makes recommendations to the County Council for adoption.

The advisory committee and the communities desire to implement a cost-effective combination of non-structural and structural solutions to flood problems that goes beyond the traditional approaches to "flood control" or "floodplain management." With the development of the two-dimensional model and associated maps, the County will have tools to use in making land use decisions, analyzing alternatives and explaining regulatory actions to the public.

**Analytical Steps**

The first step in the process is to develop 1" = 200' scale digital topographic maps with a contour interval of 2 feet. The entire 125 square miles within the potential floodplain of the lower basin has been mapped to this scale using aerial photography. The photos are used not just in the mapping process but also to determine existing land uses. The elevation information is then transferred into a CAD format (Microstation PC) to allow for the electronic development of the finite-element grid system used in the two-dimensional model.

The second step is to develop the finite-element model of the existing river and floodplain topography using the FESWMS-2DH program that was originally developed by the U.S. Geological Survey with assistance from the Federal Highway Administration. The program is a two-dimensional unsteady-state model that can easily handle multiple flow paths and the effect of large storage areas. It uses a finite-element grid system composed of quadrilaterals and triangles. It solves for the depth of flow, direction of flow, and velocity of the flow at each node in the grid system as well as at the center of the element and of each element side. The results of the model can be plotted as water surface elevation contours as well as velocity vectors showing the direction and magnitude of flow. Figure 1 is a plot of velocity vectors along a reach of the Nooksack.

Normally the predicted 10-, 50-, 100-, and 500-year flood events are modeled for FEMA's Flood Insurance Studies. Since the purpose of the Nooksack River model is not to determine zones for insurance, but to analyze existing flow paths and the impacts of alternative solutions on the depth, velocity, and direction of flow, other flows are also being examined. These include the bank-full condition and the 2- and 5-year events.

The model will initially be used to develop inundation, water surface contour, and velocity vector maps for the predicted 100-year flood event, as shown in Figure 1, and other flood frequencies as necessary. Normally, once
floodplain maps are developed by FEMA they are used to regulate the floodplain and floodway without modification. In our case the maps will be used to assist the advisory committee and County Council when making decisions concerning land use, mitigation sites, regulations, and structural alternatives.
Decisionmaking

The decisionmaking process for the completion of the comprehensive plan will begin with deciding which areas that currently flood should always be allowed to flood. These areas will be selected based upon the occurrence of high flow velocities, depth of flooding, frequency of flooding, potential for channel migration, historical channel location, and current land use. Once these areas are designated we will use the two-dimensional model to determine the impacts on the rest of the floodplain of allowing development. For this analysis we will assume that all land not designated for flooding will be completely filled to the flood-protection elevation with no compensatory storage required, or will be protected by an adequate levee. The results of this model run will be compared with the existing conditions model to determine the impacts of allowing the development. A two-dimensional model is essential for this analysis due to the multiple flow paths within the floodplain.

The anticipated impacts of new development include increased depths and frequency of flooding in locations upstream and downstream of the allowed developments, increased flow velocities, and potentially increased overflows into Canada. As an example of how two-dimensional modeling can predict the impacts of floodplain filling, a section of the floodplain in Figure 1 was removed from the model. The resulting impacts of the filling are shown as contours of water surface elevation in Figure 2. Thus, incremental changes in flood elevations and velocity can be determined easily at any point within the floodplain.

These impacts will be discussed with the committee to determine whether they and any required mitigation are acceptable. If not, the model will be revised until an acceptable level of impact is obtained. One of the most important questions the committee will be dealing with is equity. What price is the community willing to pay to allow some of the land to be protected from flooding, or filled to above the flood elevation? The answer to this question once the community is presented with the impacts of its desired actions will be very interesting. For example, much of the area outside of the cities and within the floodplain is currently used for agriculture. The County has placed a very high priority on the preservation of these lands for agricultural uses. Therefore, while there is little desire for any changes in land use, there is, for example, a definite desire to allow existing dairymen to construct critter pads, which are filled areas for cattle to congregate on during a flood. One facility by itself has little impact, but if 30 or 40 critter pads are built along 10 miles of the river a significant impact may occur. If so, is that acceptable to everyone who is impacted?

Another issue will be the interbasin overflow to Canada. Any increase in current levels of overflow will be unacceptable, or must be mitigated to everyone's satisfaction. Other more common issues concern the protection of
existing development in the cities of Ferndale, Lynden and Everson. If these areas are no longer allowed to flood through the construction of levees, what impact will that have on flood velocities and flow paths?
Results

The results of the two-dimensional modeling will be used by local officials in conjunction with other environmental, engineering, and economic studies to predict the impact of potential structural projects along the river and develop a comprehensive management plan for the Lower Nooksack River that will minimize the hazards in a manner acceptable to the citizens of the county. A new set of management policies and regulations will be developed to implement the desires of the county and minimize flood hazards. These will include the prohibition of new structures in areas shown by the model to be hazardous (i.e., the floodway) and potentially the requirement of compensatory storage in areas where storage volumes are critical, but development can be allowed. Also, by showing the existing velocity and depth of flow over roads and driveways, the requirement for dry land access to all new development may become more acceptable. By using this model and deciding where development is desirable and permitted, there will be no encroachment on needed conveyance or storage capacity. It will be an informed community decision instead of one that is perceived to be handed down from the state or federal governments.

Conclusions

The principle advantages of using two-dimensional modeling for floodplain analysis are the ability to accurately simulate complex flow patterns, such as split flows; to determine flood hazards at any point within the floodplain in terms of water depth, direction, and velocity; and to evaluate the impacts of potential flood hazard management measures. Conventional one-dimensional floodplain modeling is not capable of such tasks in the case of the Nooksack River. The 100-year floodplain maps developed using the two-dimensional modeling will better represent the actual risk of flooding than do FEMA’s existing maps for the river. They will be submitted to FEMA, along with the management plan and accompanying regulations, to show compliance with the NFIP in Whatcom County. The maps can also be used to show the locations where flood insurance is required. The new standards will help to increase the County’s standing in the Community Rating System program and reduce flood insurance premiums for its residents.
AUTOMATED HEC-2 MODELING USING CAD

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Introduction

Computer-aided drafting (CAD) software has been used for many years to speed up and automate the tedious and mundane tasks involved in drafting, updating, and maintaining architectural and engineering drawings. Recent advances in CAD software have provided "hooks" in which customized programming can be linked with off-the-shelf CAD software. This enables development of customized engineering CAD applications. These special purpose CAD applications can eliminate some of the tedious and mundane tasks involved with engineering, analysis, and design, in the same fashion as CAD has done with drafting. Replacing these manual tasks with automated processes, CAD can improve both the speed and quality of the entire engineering process.

Using AutoCAD and ADS (AutoCAD Development System) programming, we have developed an application (BOSS HEC-2 for AutoCAD) that automates most of the tasks associated with HEC-2 water surface profile modeling.

Development of this application started in the spring of 1989, after recognizing a need to marry CAD technology with our existing hydraulic and hydrologic engineering software. The application was first released as a commercial product in January 1992. Continued improvements, enhancements, and updates have been added to the application since then.

Key concerns during development of this application were its ease of use, functionality, and analysis output.

Ease of Use

An important concern during the development of this application was ease of use. We wanted an engineer to be able to use the product easily with little or no AutoCAD training. To do this, easy-to-use menus and straightforward data entry dialog boxes were developed to allow an engineer to quickly become proficient at using this application for performing HEC-2 modeling. To further improve ease of use, all data input, analysis, review of analysis results, and output of results is performed from within the AutoCAD interface.
Functionality

Early during development, the following features were identified to provide maximum functionality to the engineer.

1. Support for all HEC-2 features, including:

   - Special Bridge
   - Special Culvert
   - Floodplain Encroachments
   - Subcritical Flow
   - Imperial Units

   - Normal Bridge
   - Split Flows
   - Channel Improvements
   - Supercritical Flow
   - Metric Units

2. Importation of all types of HEC-2 models, using either fixed format or free format card files.

3. Exportation of HEC-2 card files.

4. Data input to be as flexible as possible, including:

   - Cut cross-sections by simply drawing a line across a 3-D digital topo map, with contour elevations automatically determined.

   - Cut cross-sections from either a paper topo map, 2-D digital topo map, or 3-D digital topo map.

   - Topo map not required, but can be added at any time to the model if desired.

   - Import cross-sections from multiple HEC-2 files, XYZ point files, and station elevation files.

   - Construct a cross-section by stitching together data from multiple sources.


   - Quick computation of Normal Q, Normal WSEL, Critical Q, and Critical WSEL for any cross-section.
5. System to be fast.

6. Use of a rule-based expert system to check the HEC-2 data for modeling errors and potential problems.

7. Allow several HEC-2 models to be defined, maintained, and supported within a single AutoCAD drawing.

8. Allow user-assisted linking of pre-existing HEC-2 data sets to topo maps, thereby allowing a pre-existing HEC-2 model and its analysis results to be displayed on a topo map of the region being studied.

Analysis Output

Once a HEC-2 analysis has been performed, output results are easily displayed on the cross-sections. Single or multiple profiles can be displayed on the same cross-section plot, with complete control over scale, grid size, axis graduation, line styles, and line colors.

Profile plots can be created at any time—even before running the analysis. However, output results can only be displayed after an analysis has been performed.

A method of automatically creating fixed size profile plots was devised. This allows profile plots for long river studies to be quickly created.

Complete control over profile plot scale, grid size, axis graduation, line styles, line colors, and line symbols is provided. Single or multiple profiles can be displayed on the same profile plot. Plotting multiple profiles on the same profile plot helps the engineer compare results from different flow discharges.

All bridge, culvert, and roadway structures can be displayed on the profile plots. This aids the engineer, for example, in determining for which discharges a particular bridge structure begins to experience pressure flow.

Flood inundation maps can be quickly created, displaying the edge of water stationing on the topo map cross-section cuts. Straight lines are used to connect the edge of water stationing between cross-sections. The edge of water line can be easily stretched and shaped by the user to follow the ground topography. Additional tools are provided to help draw floodplain boundaries.

Future Enhancements

Further automation in this application is desired. The following capabilities have been identified and are being investigated.
Integrated Surface Modeling using DTM Technology

Integration of our AutoCAD Digital Terrain Modeler (BOSS DTM for AutoCAD) and our AutoCAD HEC-2 application is planned. Integration of these two applications will enable surface intersection techniques to automatically map the edge of water for river reach regions between the specified cross-sections, using the topo map ground topography and water surface.

GIS Interface

Linkage with a geographical information system (GIS) will further automate HEC-2 modeling, by automating the retrieval and updating of floodplain mapping information. A GIS can be used as the underlying data source to this application, vastly speeding up and simplifying the data retrieval tasks for creating, updating, and maintaining floodplain maps. Linkage with ESRI ArcCAD GIS is being investigated.

For the past year, the Wisconsin Department of Natural Resources (Lulloff, 1994) has been using this AutoCAD HEC-2 application and ESRI ArcInfo GIS in a pilot project to demonstrate the feasibility of automating the tasks associated with updating and maintaining flood inundation maps using a GIS.

Conclusion

Recent advances in CAD software have provided opportunities to automate many aspects of engineering. In this paper we have shown one such application, integrating HEC-2 and AutoCAD to automate water surface profile modeling.

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THE USE OF HEC-2 FOR FLOOD INSURANCE STUDY REVISIONS: PROBLEMS AND HOW TO AVOID THEM

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Introduction

HEC-2 is the most common step-backwater program used for preparing and revising Flood Insurance Studies (FISs) for the Federal Emergency Management Agency (FEMA). HEC-2 is also the most versatile federally developed computer program available to calculate one-dimensional, gradually varied flow in channels. This versatility is reflected in the large variety of options that can be selected in the job control and other various records in HEC-2. However, it is because of this versatility that the use of one or a combination of the various methods can lead to inconsistent results between HEC-2 analyses for the same reach of stream. The National Flood Insurance Program (NFIP), administered by FEMA, aims to provide a consistent set of criteria by which to establish base (100-year) flood elevations and sound floodplain management criteria. Often because of the multitude of options available in HEC-2, inconsistencies can occur that make it difficult for individuals submitting FEMA map revision requests to do so in an efficient, accurate manner. Inconsistent application of these options may result in processing delays and ultimate rejection of revision requests due to technical inadequacies or apparent non-compliance with NFIP regulations.

Issues

Use of NH Records

NH records are used to define Manning’s roughness coefficients, "n" values, for an individual cross section that has varying channel and/or overbank "n" values. When an NH record is used to define multiple "n" values within the defined channel, problems may occur when attempting to perform a floodway run. Specifically, when multiple channel "n" values are used, the HEC-2 program computes a composite channel "n" value if both channel bank side slopes are steeper than 5:1 (horizontal to vertical). In the case of a floodway run, although a composite "n" value is not computed for the 100-year natural profile, the program will compute a composite "n" value for the encroached profile if the encroachment stations are at the channel bank stations. For the
encroached profile, the program computes a different side slope based on the artificially high elevation of the encroachment station. This may result in a higher surcharge value that is unrealistic.

Shifting the encroachment station using Method 1 by one foot to ensure that the station is not coincident with the channel bank station will eliminate this problem. By making this change, the HEC-2 program will not compute a composite channel "n" value for the encroached profile. This approach will not interfere with the capability of the HEC-2 program to compute the composite "n" value when the side slopes are actually steeper than 5H:1V for the channel portion.

Use of HVINS

The HEC-2 program contains an option that computes interpolated cross sections when the velocity head difference between consecutive cross sections is greater than the amount specified on field seven of the X1 record. Use of this option can result in problems during both a multiple profile run or a floodway run. Specifically, the program will compute a different number of interpolated cross sections for each profile, and may result in problems in developing consistent water surface elevations in multiple profile runs and encroachments in a floodway run. For the purpose of FIS revisions, it is not recommended that the HVINS option be used. If necessary, additional cross sections should be input using additional X1 records into the HEC-2 model to properly model the flow conditions.

Bridge Encroachment Option

For performing floodway runs, the HEC-2 program has various encroachment methods. The most widely used are Method 1, where encroachment stations are manually input, and Method 4, where encroachment stations are computed based on equal conveyance reduction method. In either case, the standard encroachment specified on the ET records in the HEC-2 model, by using 10.4 or 7.1 for example, does not consider proper encroachments at structures subject to weir flow. In those cases, an additional option available in the HEC-2 program known as the bridge encroachment option should be utilized.

This can be done by adding a value of .01 to the code describing the encroachment method (e.g., 10.41 or 7.11). This enables the program to encroach properly on the weir flow area over the road profile such that proper flow distribution is achieved from the downstream section, through the road profile, to the upstream section. Encroachment of the road profile does not imply that the road will be filled outside the encroachment stations. Since the floodplain at the upstream and downstream sections can be filled up to the
encroachment stations, the effective flow area over the roadway is limited to the area between the encroachment stations.

Use of the bridge encroachment option should not impact encroachment computations for bridges not subject to weir flow. Consequently, it is a good practice to always add .01 to the code describing the method of encroachment at all structures to eliminate the possibility of the incorrect encroachment.

**Special Bridge Modeling**

The HEC-2 model utilizes several procedures to compute low flow through structures (bridge and culvert) using the Special Bridge methodology. Two types of flows that can cause problems are Class A and Class B low flows. Classification of Class A and Class B low flows are based on the momentum principle. For a subcritical profile run, if the flow through the structure is also subcritical, the flow type is classified as Class A low flow; if the flow through the structure is supercritical, the type of flow is classified as Class B low flow. For Class A low flow the upstream water surface elevation is computed by adding the losses through the structure, using Yarnell’s equation, to the downstream water surface elevation. For Class B low flow the upstream water surface elevation is determined based on the critical momentum within the structure.

Generally the losses through the structure computed using Yarnell’s equation are small. Therefore, upstream water surface elevations for Class A low flow conditions can be lower than upstream water surface elevations computed using Class B low flow. This can cause significant problems in analyzing the impact of bridge/culvert projects for compliance with NFIP regulations.

In one particular instance a proposed bridge structure was analyzed using Special Bridge and the analysis determined the flow type to be Class A low flow. This analysis indicated that the structure did not result in increases in 100-year water surface elevations greater than those allowed under NFIP regulations. Subsequently, when the project was completed, information was submitted in support of a revision to the NFIP maps. As part of construction of the bridge, downstream channel modifications were undertaken that resulted in slight decreases in downstream water surface elevation over those indicated in the proposed analysis. This slight reduction in downstream water surface elevation resulted in a change in flow type from Class A low flow to Class B low flow. The losses through the bridge structure computed for Class B low flow were higher than those computed at the proposed stage under Class A low flow. As a result the analysis of the completed bridge reflected increases in water surface elevation greater than those allowed under NFIP regulations.

One solution to avoid this problem is to use Normal Bridge method for analyzing low flow through structures.
Options for Selecting Friction Loss Computation

The HEC-2 program utilizes the average conveyance equation as the default option for computing the friction slope. The use of the J6 record also allows a user to choose one of the following three friction slope equations: average friction slope, geometric mean friction slope, and harmonic mean friction slope. The use of a value of 1.0 in field 1 of the J6 record will prompt the HEC-2 program to select a friction slope on a reach by reach basis from one of the three optional methods listed above, but not the default option of using the average conveyance equation. There are several problems that arise when allowing the program to choose the friction slope method on a reach by reach basis.

1. Most streams studied using HEC-2 in FISs use the default method of average conveyance equation. Any revisions using one of the other methods will produce inconsistent results.

2. When a value of 1.0 is input in field 1 of the J6 record, the program selects the friction slope method based on flow conditions. For a floodway run, flow conditions for a particular reach in the 100-year natural profile can be different from the flow conditions in the same reach for the encroached profile. This can result in unacceptable surcharge values due solely to these varied methodologies.

3. When analyzing the impacts of any floodplain modification projects, any changes in flow conditions could yield varying results for pre- and post-project conditions. Increases in 100-year water surface elevations could then be incorrectly attributed to the construction of the project and result in an incorrect determination.

The HEC-2 manual does not provide specific guidance concerning which method is more correct. However, use of the default (average conveyance friction slope) option will ensure the most consistent results for the purposes of requesting a revision to NFIP maps.

Conclusion

The HEC-2 program has different options to analyze water surface profiles. Selection of the proper options is essential in obtaining consistent and accurate determination of water surface elevations for NFIP purposes. Additional research should be performed for areas where the selection of a particular option is unclear.
CHECK-2:  
THE AUTOMATED HEC-2 REVIEW PROGRAM

Zekrollah Momeni  
Moe Khine  
Dewberry & Davis

Introduction

Since 1974, Dewberry & Davis (D&D) has served as a technical evaluation contractor for the Federal Emergency Management Agency (FEMA) in administering the National Flood Insurance Program. One of our major functions is to ensure the technical accuracy of flood hazard analyses used to prepare and/or revise Flood Insurance Studies (FISs). Most FISs were prepared utilizing the U.S. Army Corps of Engineers' HEC-2 hydraulic backwater model to analyze riverine flood hazards. Therefore, D&D established a procedure for evaluating and reviewing HEC-2 models to ensure that flood hazards are analyzed accurately and within the Corps' guidance outlined in the HEC-2 User's Manual. This procedure, used successfully for many years, involved the creation of several spreadsheets that helped reviewers identify areas of potential concern within a given HEC-2 model. D&D is now developing a computer program that automates the HEC-2 review that was historically performed manually. This program, CHECK-2, is described below.

The Program

CHECK-2 consists of five different programs (modules) running under one menu:

The J3 Program  
The NVCE Check Program  
The XSEC Check Program  
The FLOODWAY Check Program  
The BRIDGE Check Program

The J3 Program

In order to retrieve certain specific information for each check, it was necessary to create a program that would insert "customized" J3 records into a HEC-2 input file and produce new output files with the customized summary tables. There are three specific summary tables that were created in order to
retrieve the appropriate data to perform the checks. The variables in each J3 record are:

| J3 | SECNO | CLASS | XLCH | CWSEL | HV | EG | HL | OLOSS | 10K*S | EGLWC | EGPRS | EGOC | EGIC |
|----|-------|-------|------|-------|----|----|----|-------|-------|-------|-------|------|------|------|
| J3 | SECNO | QPR   | QWEIR| QCULV | Q  | QCH| ELMIN| XNCH | XLBEL | RBEL  | ELTRD | .01K |     |      |
| J3 | SECNO | DIFKWS| CRWS | TOPWID| KRATIO| TELMX| SSTA | STENCL| STCHL | STCHR |       |      |      |      |
| J3 | 200   |       |      |       |     |    |     |      |       |       |       |      |      |      |

This program also deletes any J5 records in the HEC-2 input file.

**The NVCE Check Program**

This module checks HEC-2 input data files only. The other three modules (XSEC, FLOODWAY, and BRIDGE) check both the HEC-2 input and output files. The NVCE module checks the following items in a HEC-2 input file:

- **Cross Section Table** (identifies structures)

  Creates a table showing the "n" values used for the channel and overbanks and the contraction and expansion loss coefficients at each cross section. It also identifies those cross sections where a structure is modelled.

- **Summary of Statistics Table**

  Creates a table listing the maximum and minimum channel and overbank "n" values, and contraction and expansion coefficients for the HEC-2 file being tested.

- **Roughness Coefficient Check**

  Produces messages when "n" values for the cross sections fall outside the following limits:

<table>
<thead>
<tr>
<th></th>
<th>Minimum</th>
<th>Maximum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>0.025</td>
<td>0.075</td>
</tr>
<tr>
<td>Overbanks</td>
<td>0.040</td>
<td>0.200</td>
</tr>
</tbody>
</table>
• Starting NC Record Check

Checks for a complete NC Record at the beginning of the HEC-2 input file

• NC and NH Record Check

Checks that NC records (or another NH record) exist immediately following a cross section using NH records.

• NV Record Check

Reads the input file and identifies cross sections where an NV record is used.

• Transition Coefficient Check

Checks that transition (contraction and expansion) coefficients at structures modeled using normal and special bridge and special culvert routines following guidelines set in the HEC-2 Users Manual, Table 1, Page III-17.

The XSEC Check Program

This program checks the HEC-2 input and output files for a given profile and checks the following:

• Type of Bridge Check

Lists whether special bridge, normal bridge, or special culvert routines were used to model a structure.

• Spacing Check

Checks velocity head change, conveyance ratio, and top width ratio between cross sections to see if additional cross sections are required. The following criteria are used:

1. Difference in velocity head is more than 0.5 foot
2. Conveyance ratio is outside the range of 0.7 and 1.4
3. Top width changes by more than a factor of 2.0
• Ineffective Flow Area Check

Reads input file and identifies cross sections in the natural (unencroached) profile that use ET and X3 records to define areas of ineffective flow.

• Location Check

Checks the location of a cross section upstream of a cross section where critical depth occurs.

• Discharge Check

1. Checks whether or not discharges decrease in upstream direction.

2. Checks whether or not discharges upstream and downstream of a structure are equal.

• Starting WSEL Check

Checks whether starting slope is too steep or too mild.

The BRIDGE Check Program

This is the most complex module to develop because it tests for the many types of flow that may occur at a structure. This module tests for the following:

• Channel Bank Station Check

Checks stations on BT records against channel bank stations defined in the X1 record.

• Maximum Low Chord Elevation and Minimum Top of Road Check

Checks that values calculated from the BT record match values specified on the X2 record.

• X3 Elevation Check

Checks that the limiting elevations used at upstream and downstream of a structure are not outside the maximum low chord and minimum road elevation range from the BT data.
Low Flow Check

Checks type of flow, pier coefficient value (XK value between 0.9 and 1.25).

Pressure Flow Check

Checks type of flow, orifice coefficient value (XKOR computed matches specified XKOR value in SB record), X3 record elevation.

Weir Flow Check

Checks whether weir length (WRLEN) is equal to top width (TOPWID).

Normal Bridge Check

Checks for type of flow by comparing CWSEL to maximum low chord elevation.

Manning’s N Value Check

Checks for "n" value changes, and contraction and expansion coefficients at bridge sections.

Special Notes and Messages

The following messages are searched for from the detailed printout and printed:

1. Downstream energy of X higher than computed energy of Y
2. Possible invalid solution, 20 trials of EG not enough.
3. Bridge deck definition error at stations X and Y.

The FLOODWAY Check

Checks HEC-2 "with floodway" (encroached) profile and compares to 100-year natural profile for the following:

Encroachment Method

1. Whether each cross section has an encroachment method selected.
2. Whether bridge cross sections have bridge encroachment option (a value of 0.01 added to the code on the ET record that describes the method of encroachment).

- **Starting Water Surface Elevation**

  Checks that the starting WSEL of the floodway profile be equal to the WSEL of the natural profile plus the specified target surcharge value on the first ET record.

- **X5 Records**

  Checks for the use of X5 records in the input file.

- **Floodway Width**

  Checks that:

  1. Floodway top width does not exceed unencroached 100-year flood top width at any cross section.

  2. Encroachment stations are not set inside of defined channel bank stations.

  3. X3 record exists that overrides encroachment stations specified on ET record at a cross section.

- **Surcharge Value Check**

  Checks whether:

  1. Maximum allowable surcharge value for a specific state or within the FEMA maximum of 1.0 foot has not been exceeded.

  2. Negative surcharges exist.

**Conclusion**

We believe that this program will enhance Dewberry & Davis' ability to evaluate flood hazard analyses and hence allow FEMA to conduct and review FISs in a more efficient and accurate manner. This program will also be made available to any other users of the HEC-2 program including FEMA study.
contractors and revision requesters. Use of this program by study contractors and revision requesters will ensure that HEC-2 models are checked before they are submitted to FEMA. This, in turn, will lead to reduced costs to all parties involved, as it should eliminate the resubmission of models for inaccuracy or incompleteness. It must be noted that this program does not replace sound analyses and common sense, but rather it is intended to highlight areas of potential modelling problems for further investigation and scrutiny.

D&D is testing and finalizing the program and anticipates releasing a BETA version of the CHECK-2 program in July 1994. A copy of the BETA version can be obtained for review by writing directly to Mr. John Magnotti, III, Federal Emergency Management Agency, Mitigation Directorate, Hazard Identification Branch, 500 C Street, S.W., Washington, D.C. 20472.

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DIGITAL FLOOD INSURANCE RATE MAPS: STANDARDS FOR SHARED DATA

Alan A. Johnson
Federal Emergency Management Agency

David P. Preusch
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Introduction

The Federal Emergency Management Agency (FEMA) is working on a multi-year project of converting Flood Insurance Rate Maps (FIRMs) prepared using manual graphic processes to computer digital format using Geographic Information System (GIS)-based software. FIRMs will be available in digital format for a limited number of communities starting in 1994. The Study Contractors (SCs) who perform Flood Insurance Studies (FISs) and restudies for FEMA will be required to submit floodplain maps in digital format in the near future to facilitate preparation and storage of information as a digital FIRM (DFIRM). SCs, communities, or private property owners who prepare revisions to FIRMs to incorporate floodplain changes due to channel improvements, floodcontrol projects, better data, improved models, or other reasons may use available digital information or supply new digital data. New digital data supplied to FEMA must be horizontally controlled and prepared in a format that allows (1) ready use for converting the digital data into a standard, formatted DFIRM, (2) separation of flood data into four themes, and (3) separation of base map information from flood information.

Standards for shared digital data are not intended to specify the usage of any data capture procedure, production system, or software. The standards are primarily intended to assure that the captured data are compatible with many production systems to facilitate interchange of data, to support automation of DFIRM production, and to support automated spatial data analysis.

Background

FEMA will prepare DFIRMs in its Countywide Format, in which the FIRM depicts the floodplains in both the unincorporated and incorporated areas of the county. Corporate limits for the incorporated areas are shown. Consequently, unincorporated and incorporated areas will be mapped at the same scale on any given panel. DFIRM panels will be printed at scales of 1" = 2000', 1" = 1000', and 1" = 500'. Map paneling will conform to the U.S. Geological
Survey (USGS) 7.5-minute series topographic quadrangle maps. Quadrangles will be quartered and further quartered depending on the printed map scale of the DFIRM.

Flood information is to be stored as continuous data for the entire county across the corporate limits and panel boundaries. When new information is received for part of the county, it is to be sewn into the master file of the entire county. During final DFIRM processing, panel boundaries are to be used to break the information into separate map panels.

All linear and curvilinear features on a DFIRM, such as stream center lines, floodplain and floodway boundaries, corporate limits, and panel boundaries, are to be represented as series of lines or vectors (line strings). Curvilinear lines are to be drawn by making a series of very short lines by "zooming in" on the area. These short lines, when printed at the map scale, appear as curvilinear lines. No nonlinear geometric functions are used to represent these data. These line strings are connected to form polygons, which represent an area of flood data. No two lines can cross without breaking and there can be no free endpoints on a line string. A FIRM is, therefore, subdivided into areas or zones. Each area contains a centroid, and attributes are assigned to each area that define characteristics such as flood zone designation and base flood elevation (BFE). An exception to this is the hydrography, which includes the stream center lines. This information is stored as linear features and does not have to form polygons. All linear features are defined by their attribute codes.

Roads are to be shown on the DFIRM as single lines, representing the road center line. Therefore, roadway width and right-of-way information will not be needed.

**Thematic Layers of Data**

To facilitate the use of digital information, data in digital files must be separated into different themes by using layers (levels) or by assigning attributes to individual data. Each theme is stored in a separate file. The four themes are:

1. **Political Areas**: Jurisdictional boundaries such as city, county, and state boundaries;

2. **Map Panel Areas**: Edges of FIRM panels that correspond to the USGS quadrangle maps;

3. **Hydrography**: Stream centerlines, water-control structures, and cross sections; and
4. **Flood Hazard Zones and Floodways:** Floodplain and floodway boundaries that outline inundated areas and floodways. Inundated areas are assigned attributes such as flood zones and BFEs.

These four themes of data comprise the DFIRM-DLG file, which is a separate data file of jurisdictional flood information. Base map information, such as roads and other planimetric features, is not included on the DFIRM-DLG file. The DFIRM-DLG file is the digital product that will be available to the public. For data supplied to FEMA, no floodplain screening or floodway cross hatching is necessary. These will be added by FEMA during final processing of the DFIRM.

**Data Formats**

Data files used to store FIS/FIRM information may be exported in one of the following formats: (1) DLG (Digital Line Graph), (2) DXF (Drawing Exchange Format), (3) ARC/INFO export format, (4) Microstation (DOS or UNIX) Design Files, or (5) AutoCADD Drawing Files. These files are to be created by segregating the data into the themes shown above.

Specifications for DFIRM-DLG file format are contained in *National Flood Insurance Program, Standards for Digital Flood Insurance Rate Maps* (FEMA, 1993a), which specifies the type of information stored on each layer/level, attribute codes, file header information, file naming conventions, and National Flood Insurance Program symbols. FEMA coordinated with the National Mapping Division of the USGS to establish a topological structure for DFIRMs consistent with USGS DLG-3 specifications.

For the other file formats (i.e., DXF, ARC/INFO, Microstation, and AutoCADD), specifications are given in Appendix 7 of *Flood Insurance Study Guidelines and Specifications for Study Contractors* (FEMA, 1993b), which specifies the same type of file formatting as discussed in the previous paragraph. It also presents three options for file formatting. One option may be more suitable or efficient for use with specific hardware or software than another.

**Horizontal Control and Accuracy**

The lack of horizontal control on manually produced FIRMs required lenders and floodplain managers to use "due diligence and good faith" in determining the location of a property with respect to the 100-year floodplain (Special Flood Hazard Area). This is done using the relative location of hydrographic features and roads with or near the floodplain, using additional information such as land parcel maps overlaid on the FIRM. FEMA makes
determinations by comparing the first-floor elevation with a BFE obtained from
the flood profiles presented in the FIS report.

DFIRMs are horizontally controlled (within the floodplain and at the
four corners of the panel) with USGS quadrangle maps, which are mapped using
Universal Transverse Mercator (UTM) coordinates. The quadrangles are
prepared at a scale of 1:24,000 (1"=2,000') and meet National Map Accuracy
Standards, which specify that "90% of all points tested must be accurate to
within 1/50 of an inch at the printed map scale." Therefore, the quadrangle
maps are accurate to within 40 feet.

Base map information as well as floodplain information provided to
FEMA as a result of a study or restudy performed by an SC for FEMA or a
map revision request performed by a local agency or consulting firm must meet
or exceed these specifications in order for FEMA to accept the work as digital
information. Most coordinate systems can be converted easily to UTM by
existing software. Therefore, coordinates such as State Plane coordinates are
acceptable and will be converted to UTM before they are incorporated into the
DFIRM.

Maps that are enlarged or reduced to a scale of 1:24,000 may not meet
the National Map Accuracy Standards for 1:24,000-scale maps. The accuracy
of the map at the original scale is critical. For instance, USGS quadrangles at
a scale of 1:100,000 are accurate to within 167 feet (1/50 inch at the printed
map scale). Enlarging these maps to a scale of 1:24,000 does not improve the
horizontal accuracy and would, therefore, not meet the DFIRM standard.
Additionally, DFIRM users cannot use the scale of the published FIRM as the
basis for estimating the horizontal accuracy of the flood data.

Base Mapping

Base mapping includes all planimetric features, such as roads, railroads,
airports, bridges, and contour lines. This information must be stored in a
separate file or files to allow FEMA to easily separate the flood information
from the base mapping. Additionally, individual base map features, such as
roads, railroads, contours, spot elevations, and bridges, must be isolated on
separate layers/levels or by attribute because not all of these features are shown
on the printed DFIRM.

New photogrammetric data may be necessary along a restudied stream.
Information obtained by field surveys or photogrammetry or from other sources
must meet National Map Accuracy Standards and must be plotted on a
geographic projection or control grid (State Plane Coordinates or UTM).

Existing base map data for other areas may be available from other base
map sources. Sources of digital base mapping include USGS quadrangle maps,
U.S. Census Bureau TIGER files, and other data available locally.
Not all USGS quadrangle maps have been digitized by the USGS. USGS 1:100,000-scale digital data are available, but they may not meet the horizontal accuracy standards of a 7.5-minute quadrangle, which is the standard for a DFIRM. Additionally, the USGS 7.5-minute quadrangles do not have all the names of streets in the floodplain, which is necessary for final processing of the DFIRM.

The TIGER files have variable horizontal accuracy and would have to be controlled before they could be used. The advantage of the TIGER files is that they have an associated database of road names, street addresses, and zip codes, which could be used for other GIS applications. In addition, road names can be placed on the final DFIRM using an automated process that eliminates labeling each road.

Data obtained locally, for example from a community GIS, can be used but these data again must meet National Map Accuracy Standards and must be plotted on a geographic projection or control grid. The primary advantage of using community-furnished data is that the resulting flood overlay will be compatible with community base maps in a GIS environment to perform spatial analysis using flood data. This will be an extremely useful tool for local planners and floodplain managers.

When proprietary base map information is obtained from the community or other source and used to develop the DFIRM, only a printed copy of the DFIRM and the DFIRM-DLG data file will be provided upon request to interested parties. Only when the community has "explicitly waived" any objection of release of this data will these digital base map data be made available to the general public.

Summary

Setting standards and specifications for the use of shared data with FEMA will allow for efficient use of supplied data in preparing the final product—the DFIRM. If data are not supplied in a standardized format, it may be too costly for FEMA to separate and format the data. The available format options do not require the use of any specific production system, hardware, or software. Finally, data must meet horizontal accuracy standards and be mapped on a control grid in order for the flood information to be accurately overlaid with other digital information for spatial data analysis.
References

Federal Emergency Management Agency

Federal Emergency Management Agency
THE USE OF GEOGRAPHIC INFORMATION SYSTEMS TO MANAGE NEW JERSEY’S HISTORICAL SHORELINE DATA

Mark N. Mauriello
New Jersey Bureau of Coastal Regulation

Introduction

Historical shoreline data are becoming increasingly important for coastal planning and regulatory programs, as well as for public information purposes, throughout the U.S. coastal zone. With the prospect of new federal flood insurance legislation, including erosion zone mapping provisions, the management of long-term historical shoreline data will become even more critical in the future. The use of geographic information systems (GIS) provides a means to digitally map coastal features through the use of verifiable shoreline data and enhanced computer graphics. This has yielded the highest quality data on shoreline movement, which can be accessed on a user-friendly, menu-driven personal computer. The New Jersey Department of Environmental Protection and Energy (DEPE) GIS has proven to be the most efficient way to compile, compare and display shoreline data of varying forms, scales, and sources, dating from the 1840s to the present.

Coastal Dynamics

Coastal shorelines are very dynamic areas that are subject to significant long-term and short-term changes resulting from sea level rise, altered sediment supply, tidal inlet processes, storms, and human intervention. These landforms are extremely mobile and are subject to both gradual and avulsive change, making oceanfront shorelines quite vulnerable to damages from storm surges, storm waves, and associated flooding. The patterns and rates of shoreline change are not uniform, and vary locally depending on the nature and magnitude of coastal processes operating within specific shoreline segments. Because of these dynamics, coastal shoreline management, particularly along the oceanfront, has become a major focus for local, state, and federal agencies, as well as for coastal residents and property owners.

Comprehensive coastal shoreline management is dependent on the availability of accurate historical shoreline data, which is used to evaluate past shoreline changes and to project future changes. These data are critical to the
understanding of coastal processes and the impacts of human intervention on these processes and associated shoreline response.

Data Sources

Historical shoreline data are reflected in the large number of maps and surveys of oceanfront areas, which have been compiled since the mid-1800s. These map data include hydrographic and topographic surveys at varying scales, prepared by the U.S. Coast and Geodetic Survey, the National Ocean Survey, the U.S. Army Corps of Engineers, and the New Jersey State Geological Survey. Aerial photographs produced since the 1940s also provide a valuable source of shoreline data, although these photographs require rectification before being used as part of the historical shoreline data base.

Prior to the use of GIS for shoreline mapping and data management, the only method available to the DEPE for compiling and comparing historical shoreline data involved the use of photo enlargements and zoom transfer scopes. Although these two techniques are simpler and less expensive than digital mapping and analysis, the final products are hand traced maps that do not meet National Map Accuracy Standards. While these techniques may be acceptable for evaluating general shoreline change patterns, they are not well suited for quantitative shoreline analyses, due to the degree of error associated with the mapping techniques (Leatherman, 1983). Therefore, GIS represents the most reliable method available for the mapping, compilation, and comparison of shoreline data, and for the production of accurate shoreline change maps.

GIS Applications for Shoreline Data Management

To evaluate this large volume of shoreline data for use in regulatory, planning, and educational programs, the DEPE has developed a GIS that allows for the compilation, comparison, and display of large amounts of shoreline data. Such comparisons are required to establish historical shoreline change rates, to define erosion and accretion areas, and to develop erosion hazard area maps for use in planning and regulatory programs. In addition, this GIS capability facilitates the production of maps and overlays for use in public information and education programs undertaken by the DEPE and other agencies at all levels of government, as well as by academic institutions.

The primary use of this historical shoreline mapping program is to implement the Department's Rules on Coastal Zone Management (N.J.A.C. 7:7E-1.1 et seq.), specifically the Erosion Hazard Areas rule (-3.19). This rule requires that most types of development be located landward of the defined erosion hazard area for the proposed development site. The application of this method for calculating historical shoreline change rates and construction setbacks
Use of GIS to Manage New Jersey’s Shoreline Data

was previously described in detail by Mauriello (1991), and has been approved by the Federal Emergency Management Agency for use by the DEPE in making imminent collapse certifications pursuant to the Upton-Jones Amendment to the National Flood Insurance Program. The long-term historical shoreline data are jointly evaluated with other information such as past or on-going shore protection activities, navigational dredging projects, and past storm events, which may help to explain the change rate determinations.

This shoreline mapping and comparison procedure also allows for shoreline change map plots to be overlaid on a base photograph or survey, so that a property owner can have the benefit of visually understanding the history of shoreline movement for that specific area. This is important in helping to educate the public in the area of hazard identification and management, and in explaining how the history of shoreline changes in an area can be examined and used to project future changes. With the ability to combine other data layers onto these shoreline change map plots, the final map products can be annotated to make them easier to interpret and understand.

**GIS Flexibility**

As mentioned above, another benefit of managing historical shoreline data through a GIS is the ability to overlay other data layers onto a map containing the shoreline data. For example, a map that displays historical shoreline locations can be annotated to include additional information such as geographic coordinates, streets and roadways, county and municipal boundaries, flood hazard area boundaries, soils, regulatory boundaries, and much more. The capability to combine historical shoreline map data with other data in this manner makes the information usable for a greater number of applications. In addition to the large number of data sets which can be accessed and displayed through the use of GIS, perhaps the greatest benefit of using GIS to manage historical shoreline data is the ease and speed at which information can be processed.

**Summary**

The use of GIS has proven to be the most efficient method for mapping, compiling, comparing, and displaying historical shoreline data of various scales, forms, and sources. In addition to the ease with which this information can be accessed and displayed, the digital historical shoreline data files are very easy to distribute to other agencies involved with coastal management in New Jersey. With the advent of less expensive, high powered personal computers and plotters, this digital data will become even more useful
in the future, since more people will have the capability to access data that were previously very difficult to compile and compare.

In addition, it allows for periodic updating of the digital shoreline data files, as more recent shoreline data are generated, thereby allowing the program to remain current. The ability to overlay additional data layers with the shoreline data also expands the scope of potential users, and therefore provides a greater overall return on the GIS investment.

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GIS TO THE RESCUE: GIS AND THE MISSISSIPPI RIVER FLOODING

Sue Hoegberg
Dewberry & Davis

Much has been written about what went into predicting, tracking, analyzing, and cleaning up after the floods in the Midwest last summer, and about how geographic information systems (GISs) played a role in this effort. One of the most encouraging things to have come out of the response to the disaster is the true cooperation among the many parties using GISs to identify and solve these problems. A disaster of such monumental proportions just cannot be handled by any single agency or entity.

The Federal Emergency Management Agency (FEMA) is the lead federal agency for disaster assessment and assistance, and its mission is to coordinate real-time response to disasters and to cooperatively fund the recovery efforts. In the agency's role of coordinator, it was able to pull together software, hardware, data, and personnel, both at headquarters in Washington, D.C. and in the field, to use GIS as part of the response. FEMA maintains a GIS data base called the All-hazards Situation Assessment Prototype GIS data base, or ASAP for short. FEMA is putting together a GIS that will allow for the collection, integration, and analysis of satellite imagery, transportation data files, point elevations, demographic data, and locations of critical features. These data can then be used for real-time analysis and relief planning.

FEMA and the U.S. Army Corps of Engineers collected up-to-date satellite imagery for use in the relief planning. The Corps obtained hard copy maps for use in the field. These were 32"x44" georeferenced images with a plotted latitude and longitude grid. FEMA obtained georeferenced vector files that had been converted from the raster imagery, showing the extent of the flooding.

As would be expected, conventional aerial photographs were also provided to the Corps of Engineers. Four hundred river miles were flown daily at approximately 12,000 feet above ground level for 60 days, beginning July 8, 1993. These photographs allowed for constant monitoring of the situation by the Corps and will also allow for historical comparisons with similar photos taken in 1973. While these photographs were essential to the Corps' needs, the cloud cover was quite extensive in many of them, and they were not able to be georeferenced, so they were not particularly useful for GIS applications.

FEMA and the National Aeronautic and Space Administration (NASA) also gathered radar imagery. The radar was used to penetrate the cloud cover that was so extensive and continuous, identifying the flooded areas by what the
return was from the water as opposed to the dry land. The extent of the flooding was mapped by extracting the water classification from the radar images. These data were provided to FEMA, the National Oceanic and Atmospheric Administration, the Illinois Department of Energy and Natural Resources, as well as to NASA. NASA then merged the radar images with satellite imagery to allow viewers to see both the flooded areas and the underlying terrain.

The sharing of this type of information is critical to our ability as a nation to respond to emergencies, and we need to keep the vehicle for data exchange in place for situations like this. The events in the Midwest last summer forged some new relationships that will be kept alive. In fact, a similar response was experienced when the Laguna Beach, California, fires of October and November 1993 were raging. These 26 fires destroyed over 200,000 acres of land and thousands of people were displaced from their homes. Many private and government entities worked together to assemble a fire response team, with contributions of equipment, software, data, expertise, photography, imagery, and more.

FEMA's technical evaluation contractors are currently contracted to provide FEMA with digital Flood Insurance Rate Maps. Both CADD and GIS software packages are used to do this work, and one of the first things done was to digitize floodplain information in the affected areas from the hard copy maps. They also did some data conversion of maps showing the extent of the flooding in local areas. In addition, they were called upon to help incorporate these and other types of data into FEMA's all-hazards GIS data base. In addition to the technical evaluation contractors, many other companies and agencies were directly involved with FEMA, supplying hardware, software, data, and personnel for the preparation of situation reports and briefing graphics of map data.

FEMA's all-hazards GIS data base was first established in 1992 during the Hurricane Andrew cleanup efforts. As part of this effort, FEMA has been building a nationwide data base of critical features that need to be monitored during the response to a disaster. Developing a data base of this magnitude is no small task and this one will likely be added to and improved for a very long while to come.

In order to try to provide meaningful figures and analysis, FEMA started by amassing as much data as possible for the affected areas. State and county boundaries, rivers, cities, and statistical attributes were gathered. In addition, road and railroad locations, street names, and street types were added. FEMA also had certain types of point features that had been worked with for quite a while in the ASAP GIS. These included airports, chemical plants, dams, electric power plants, General Services Administration facilities, hospitals, interstate highway bridges, and tank farms. Each of these features has database information such as facility name, address, type, etc. attached to it. Additional point features were created for public buildings such as fire stations, police
stations, prisons, and many government agencies. These features also came with attribute data filled in for facility name, address, type, etc. FEMA had also previously created point coverages of census block centroids from the U.S. Census Bureau STF1A data files. These point coverages contained a useful distillation of the enormous amount of information contained in the Census files. These data were being used for reports of housing units, both occupied and unoccupied, total population, and number of families affected by the flooding.

So FEMA had all of this data and wanted to know what was being impacted by the flooding. To do that, the agency needed an outline of the area of flooding. Several sources were combined over the course of time, as the flood kept increasing and as newer data became available. One interesting thing that could be done is to date-stamp the data, to show how the flooded area was changing. However, at the time, FEMA's primary concern was the maximum extent of the flooding. Sources of the flooded areas data included data that were digitized from Corps and U2 imagery, as well as polygons generated by a Thermal InfraRed Observation Satellite (TIROS). The TIROS data are collected by daily satellite passes as raster imagery, which must be georeferenced, interpreted, and vectorized. The images were analyzed to separate the water cover from the drier land.

The TIROS data were very "blocky" looking because of the resolution and pixel size of the raster imagery and the size of the grid cells that were used. In addition, on many days the cloud cover was so extensive that the ground was obscured too much to make an evaluation of the extent of the flooding. Therefore the TIROS data were augmented with data from other sources. The polygons generated from the TIROS imagery were subsequently combined with the other digital files showing extent of flooding, to make one big flooded-areas polygon. In addition, for certain analysis requests, this flooded-areas polygon was buffered by a given distance to create a new area of concern. For instance, one request was to identify the population at risk of mosquito infestation within 5 miles of the flooding, so the flooded areas were buffered by 5 miles.

This question and other similar ones are answered by using the GIS to overlay the points or roads with the flooded-areas polygon, and then to count the number of features within the area of concern. GISs are very good at doing this task, and the output can be summarized and formatted into a table or report. Thus, FEMA was able to generate reports of all sorts of data within a reasonably short period of time, including the number of acres of land affected by the flooding, the number of miles of different classes of roads that were affected, and the number of bridges, schools, hospitals, etc. affected. These types of data were being requested almost hourly by people preparing situation reports and briefings. This data set acquisition, manipulation, and report generation was going on at a fast and furious pace. In addition, plots showing these data in various combinations and permutations and at various scales were also being output at a comparable pace.
Improved data on the extent of the flooding continued to become available over time. This allowed for more detailed and accurate assessments to be made from all of these data sources that FEMA had collected. The work with the data sets that were gathered has continued to this day, and some of these data are being distributed to emergency planners for their real-time use. Digital photographs were taken of some of the flood-damaged structures and integrated into the GIS data base. This allows people who are remote but need to assess the damage to see the effects of the flooding without getting their feet wet. It also makes for some truly robust GIS applications.

None of the analyses or applications described here is pushing technical boundaries. But they are pushing agencies to work together and communicate and share data. The machines and the people are talking to each other and that is what is really needed. The next step in the evolution of this type of data base is to continue with data acquisition and improvement. The entire United States needs to be covered by all of the data sets that FEMA wants to analyze. Undoubtedly as this happens, the questions people want to answer will grow and the amount of information needed to answer those questions will grow as well. In addition, the location of all of the features to be analyzed will be improved as the data sets evolve.

As digital orthophotos become available for the entire United States, individual structures will be precisely located as point features, and attribute data can be attached to them. The U.S. Geological Survey plans to have Digital Orthophoto Quarter Quads available for the entire country within five years. These raster images will be used for locating point, line, and polygon vector features with a great deal of accuracy. Census data could be attached to each house location in the United States in a massive data base (or series of data bases). Roads, bridges, flood control structures, etc. could be equally precisely located and attributes attached. As the use of global positioning systems increases, field data will also be transmitted back to the master data bases for continuous updates.

FEMA's data base is not at this level of precision yet, but a wonderful start has been made, and through the collective efforts of many players, it will keep growing.
Introduction

The Great Flood of 1993 caused catastrophic damages to the Midwest. Four hundred and twenty five counties in nine states were declared disaster areas by the President of the United States. What made this disaster different was the geographic size and the duration of the area that was affected. In earthquakes and hurricanes, the area that is usually affected is only a few counties at most and the event is over in hours. This flood lasted for months. This may not have been the most costly disaster but the area it covered was one of the largest areas that was ever handled by this agency.

Problem

The Federal Emergency Management Agency’s (FEMA) role is not limited to disaster assistance. The Federal Insurance Administration (FIA) is also a part of FEMA and one program under the FIA is the National Flood Insurance Program (NFIP). For a community to participate in the NFIP it must adopt sound floodplain management principles. This essentially means that the community does not allow any new development or substantial improvement in the floodplain.

With the great number of damaged structures after the 1993 flood, many communities were overburdened with requests for building permits and pressured by citizens to start getting their lives back to a pre-disaster state. To assist them with this, an inventory of potential substantially damaged structures was developed by FEMA.

Method

The old way to develop this inventory was to have teams of trained floodplain management personal drive the floodplain in automobiles. A list of the addresses for structures they believed to be substantially damaged would be developed. This tabular list than could be placed in a database for easier management and the product was then presented to the community.
With this disaster a new way of developing an inventory was implemented. Using new technologies, not just a tabular list but also mapping and digital photos were developed for the Mississippi River area within the State of Illinois.

The need to have teams in the field to collect this data had not changed but the team members and the equipment had. Now each team consisted of an information specialist from GeoResearch, Inc. of Billings, Montana, and a general adjuster from the NFIP. Teams were equipped with a Global Positioning System (GPS) receiver to georeference each location. Also, information about the structure was recorded for each location on a lap-top computer. Each team also had a digital camera to capture a photographic image of each structure. These images were then added to the database of location information.

After this information was collected it was downloaded into a geographical information system (GIS) at the Rock Island District of the U.S. Army Corps Of Engineers. The data were then combined with other geographic features to develop other products.

**Products**

The main products developed from the inventory were maps, data sheets, and a database. A map was developed for each county along the Mississippi River and smaller scale maps were also produced for every incorporated community within the county. The map not only showed the location of the inventoried structures but also their relationship to the floodplain. This application demonstrates the use of GIS technology at showing how different types of data can be related to each other.

Another product was the observation data sheet. Each data sheet is comprised of three elements; a location map, the observed data, and a digital image of the structure. The location map shows the general area with a square for the location of the structure. With the location map the coordinates of the structure were also shown. This gives anyone the ability to locate the structure in the field using a GPS receiver. The observed data consists of the following; location (street address, city, county), depth of flooding, type of use, displaced from foundation, number of stories, and type of construction. The final part of the data sheet was the digital image. This image was probably the most effective in getting the message across to the local official. A byproduct of the data collection is a database of damaged structures. This database is now being used as a base for the mitigation projects database for Illinois.
The goal of this project was to help local officials in administering their floodplain ordinances. This was proven on August 26, 1993. The *Quad City Times* had an article on rebuilding after the flood. One of the pictures had a building inspector using an observation data sheet with a home owner to help in the determination of substantial damage. This shows that the product was being used and was helpful to the local official.
SMALL WATERSHED MODELING AND ASSESSMENT USING GIS

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Tarrant County WCID Number One

Introduction

A five-year cooperative project between Tarrant County Water Control and Improvement District Number One (District) and the USDA-Soil Conservation Service (SCS) began in October 1992. The District controls five major reservoirs supplying water to Fort Worth and several other metroplex communities and industries. The methodology being developed in this project is being used by several entities to meet requirements of Texas Senate Bill 818 that requires river basin assessments of water quality every two years.

Partners in the project are using the SWAT (Soil and Water Assessment Tool) model developed by USDA Agricultural Research Service (ARS). Scientists with Texas Agricultural Experiment Station (TAES) have developed the interface between the geographic information system (GIS) databases and SWAT to provide required model inputs.

The intent of the project is to assess water quantity and quality under current and projected management conditions. Results will detect critical areas contributing to sedimentation and related nonpoint source water quality problems in drainage areas of the reservoirs.

Description of Study Area

The Upper Trinity River Basin is located in north and east-central Texas (Figure 1). It encompasses all or portions of 19 counties. Five major reservoirs owned and/or managed by the District control runoff from 6,474 square miles and serve a population of 1.5 million people with municipal, industrial, and recreation water. The reservoirs include Lake Bridgeport, Eagle Mountain Lake, Lake Benbrook, Richland-Chambers Lake, and Cedar Creek Lake (Srinivasan et al., 1992b).
Agricultural land uses are dominant in the basin and without adequate treatment and management, soils are subject to accelerated erosion. Best management practices (BMPs) for alleviating water quality problems are unique to each soil type, location, and land use. Large amounts of sediment are being deposited in the water supply reservoirs, depleting water storage volume and increasing treatment costs.

**Concept of Projects through Partnership**

The Texas SCS Water Resource Assessment Team (WRAT) was formed in late 1992 and co-located with the ARS and TAES laboratory to accommodate transfer of SWAT modeling technology. Responsibility for the Upper Trinity Watershed Project was assigned to WRAT. The emphasis for the SCS team has been to develop projects involving small watersheds and to use the SWAT model and GIS applications at levels of greater detail. Partnerships on the Upper Trinity Cooperative Study have to date involved SCS, ARS, TAES, the District, Texas Water Development Board, Trinity River Authority,
and Texas Natural Resources Conservation Commission for at least some portion of the project. Many other agencies have been involved in development of GIS data layers. There is widespread interest in development of the SWAT technology for nonpoint assessment of small watersheds and large river basins.

**Geographic Information System**

The Soil Conservation Service uses the U.S. Army Corps of Engineers’ raster-based Geographic Resources Analysis Support System (GRASS), a public domain GIS (Srinivasan et al., 1991). Simulations using SWAT are being performed in UNIX on the SUN workstation platform. INFORMIX is the relational database management system used by SCS. Most of the work involving GIS at the ARS/TAES laboratory has been with a base scale of 1:250,000, which is readily available for most if not all of the United States. These GIS layers are the foundation for the HUMUS (Hydrologic Unit Model for the United States) project, a cooperative effort between SCS, ARS, and TAES at the Temple, Texas, laboratory. The purpose of the HUMUS project is to assist in the Resource Conservation Act (RCA) assessment of the status and condition of water resources of the nation under current and projected management conditions. SWAT model technology was originally developed for the HUMUS assessments.

The WRAT staff has assembled or developed most of the GIS layers at a scale of 1:24,000 for use in modeling the smaller watersheds. Collection of this data is the most critical element to model the watersheds (Srinivasan et al., 1993b). Basic layers and/or relational databases include information on soils, land use, topography, watershed, or basin boundaries. Other databases include historical streamflow and weather data, political boundaries, point sources, confined animal feeding operations, oil and gas well locations, agricultural statistics, census data, and geology. The GIS interface also allows the user many graphic displays for viewing model output. Choices include single and multiple line graphs, pie charts, bar graph, scatter plot, comparative map generation, and statistics.

**The Swat Model and GIS**

SWAT is a basin-scale, continuous time water quality model integrated with a GIS to extract input data to simulate basin hydrology and conditions. Development of SWAT involved combining a routing procedure to the SWRRB (Arnold et al., 1990) simulation model. This allows loadings at sub-basin outlets to be routed through the stream network on a real time basis to the receiving reservoir or point of interest. Integration of GIS and SWAT eased the task of providing input for hundreds of sub-basins and multiple simulations.
Srinivasan and Arnold (1993) applied the integrated system to simulate the upper portion of the Seco Creek basin by subdividing the area into 37 sub-basins. They found that average monthly streamflow agreed with measured monthly streamflow values for the period January 1991 through August 1992.

SWAT has a unique feature that allows the output of other model runs to be imported at stream routing nodes throughout the watershed simulation. A simulation using very detailed data for a small sub-basin of the watershed can be integrated into a general assessment of the entire watershed above a reservoir. This can indicate the targeted basin’s effects on loadings at a basin outlet or reservoir. SWAT can handle other features such as point sources of water inflow/outflow and can accommodate irrigation diversions, return flows, wastewater treatment outfalls, and other municipal or industrial permitted uses. To be a realistic simulation of the watershed, the model must handle both nonpoint sources and all permitted point sources as well as water transfers in or out of the basin. Thus predicted streamflow can be compared to measured stream gage records in the GIS.

The need for assessments of smaller areas with a high level of detail requires that greater detail of GIS databases be available. The HUMUS project (Srinivasan et al., 1993a), as an example, used the STATSGO (Srinivasan et al., 1992a) soils geographic database (1:250,000 scale base) as one of the GIS layers in simulating entire river basins. STATSGO polygons represent soils associations that may include 20–30 individual soil series. The SCS soils and land use or cover for the Upper Trinity Project is a full coverage of the CBMS (computer based mapping system 1:24,000 scale) data that will provide more detail in the GIS layer and model input. Each soils polygon in CBMS represents an individual soil series. A link from the spatial data to the relational soils database provides soil properties for each soil to SWAT model input.

Use of SWAT and GIS by Tarrant County

Plans for the Upper Trinity Project extend far beyond making a few simulations and preparing a report for the bookshelf. The District will receive the working simulation model and complete GIS database for its project area on hardware to be used in the office. Updating of both the model and databases is to be an ongoing process. The District intends to use the SWAT model initially as a management tool to help develop future sampling programs for the assessment of the watersheds that feed its reservoirs. It is anticipated that this and other models will be applied to the District’s watersheds to help determine the areas contributing to sedimentation of reservoirs or nonpoint source pollutant loadings. As these programs are developed, the data generated will be used to supplement the ongoing work and ultimately provide a validated model designed around site specific areas. The District’s future intention is to link this watershed
model with the District's reservoir model to help evaluate the benefits to their reservoirs from implementation of BMPs in the associated watersheds.

Summary and Conclusion

The SWAT and GRASS GIS integrated as a modeling tool can guide management decisions regarding runoff, sediment, and nutrient and pesticide loadings for small watersheds. This tool allows assessment or evaluation of effects from a watershed based on hydrologic and hydraulic boundaries consistent with basic principles and standards for planning treatment alternatives in water resource projects.

The integration of the water quality model and GIS reduces significantly the time to prepare input data for models and simplifies model operation. As GIS layers become readily available, the effort to simulate current versus projected management will involve minimum timeframes and personnel.

References


Srinivasan, R., J. Arnold, W. Rosenthal, and R. S. Muttiah


Introduction

Prince George's County, Maryland, is located just east of the District of Columbia with approximately 725,000 permanent residents in urban, suburban, and rural areas. There are 41 major watersheds in the County draining approximately 480 square miles including the Patuxent River, which forms the entire eastern boundary. Eventually, all County waters drain to the Chesapeake Bay, the nation’s largest and most productive estuary. To date, flood management studies have been completed for nearly 80% of the County over a 15-year period. Only rural or relatively minor watersheds still need to be evaluated. The major tasks of the flood management studies include identifying all existing flood-prone areas, evaluating in detail all viable alternatives to mitigate these problems, recommending the "best" solution and then developing a watershed-wide management plan. The effort to complete the studies for the remaining watersheds as well as to update the existing studies, which were conducted either before or during the development boom of the late 1970s and early 1980s, will require a significant amount of time and resources.

In addition, the County has embarked upon a major effort to perform comprehensive water quality studies for all 41 watersheds. Many of the tasks for the water quality studies are the same as those for the flood management studies. However, the additional effort required to adequately address the multi-faceted water quality studies, which include chemical, biological, and habitat assessments; stream restoration; stream classification and enhancement; wetland assessment and analysis; and public education, to name a few, is tremendous. Also, these studies must be undertaken on several levels: regional, watershed-wide, and sub-basin. The time factor to complete such a program probably approaches and exceeds the 15 years it took to complete the flood management studies. Therefore, Prince George's County decided the best way to manage
both the flood management and water quality studies is to take advantage of their rapidly developing ARC/INFO geographic information system (GIS) database.

**Flood Management Studies**

The tools currently employed by County staff to complete flood management studies on a planning level are the USDA Soil Conservation Service's Technical Release 55 (TR-55) and 20 (TR-20) hydrologic models and the U.S. Army Corps of Engineers Hydrologic Engineering Center's Water Surface Profiles (HEC-2) hydraulic model. The first step was to automate the TR-55 model to calculate at any specified location the drainage area (DA), runoff curve number (RCN), and the time of concentration (Tc) on an easy, user-friendly interface. The interface that was developed by County consultant, Innovative System Developers, Inc. (ISD), is Geo-GUIDE. Geo-GUIDE allows the user to by-pass all ARC/INFO commands and follow menu-driven "point and click" directions or options. The interface is an extremely important aspect in the success of widespread staff use of the model(s) because the numerous and complex commands of ARC/INFO require extensive training. All current GIS models utilize ARC/INFO version 6.1.1 on a UNIX-based SPARC-1 Sun workstation.

The TR-55 dialog box can only be accessed through the Geo-GUIDE interface. By selecting one of five buttons on the dialog box, the user can

- Run the TR-55 model;
- Produce channel profiles and a 3-dimensional surface image;
- Perform "what if" analysis for proposed land-use changes;
- Update existing data sets; and
- Modify or change model assumptions.

To run the TR-55 model, the user simply identifies an area of interest by "clicking" on a point along the stream network. The software then automatically determines the drainage area and runoff curve number to the specified point. A runoff curve number represents the combination of a land use and a hydrologic soil type and their effect on potential surface runoff. This is a major time saver as the software overlays the soil type with the land use within the defined watershed and then determines the area of each polygon. A report can be produced similar to the PC-based TR-55 model displaying the land use and soil types used to generate the runoff curve number and the total drainage area in acres. The entire process takes approximately 20 minutes to complete no matter the size of the watershed. Previously, this same procedure
done manually took days or even weeks, depending on the diversity of the land use and/or size of the watershed.

The time of concentration (Tc) and flow path can be determined from any point along the ridge line to the area of interest for the 1-, 2-, 5-, 10-, 25-, 50-, 100- and 500-year 24-hour rainfall event using the same dialog box. The Tc is the time it takes for runoff to travel from the hydrologically most distant point in the watershed to the point of interest. The user simply chooses a point on the ridge line and the software determines the flow path and then visually displays it within the drainage area. By accessing another dialog box, the profile of a cross-section along the Tc flow path can be graphically illustrated. Again, a report can be generated with the values broken down into sheet flow, shallow concentrated flow, and channel flow with the total time given in hours. This time the process takes approximately 5 minutes to complete. The results can be viewed on screen or printed in hard copy reports for evaluation then or at a later date. By initiating the "what if" dialog box, land uses can be modified to estimate the effects a proposed land-use change would have on the watershed.

Water Quality Studies

Again, as a requirement for completing any type of water quality study, a user-friendly interface was necessary for County staff to use. The Watershed Simulation Model Program (WSMP) was developed in conjunction with continuous simulation output data from the Storm Water Management Model (SWMM) by the County's consultant, Tetra-Tech, Inc., and also operates on a menu-driven productivity software tool allowing for the greatest number of users. This model is the first step in developing a comprehensive watershed water quality management strategy to be used county-wide. WSMP enables planning level assessments to be done at a watershed level by estimating pollutant loads and flows for current land-use conditions as well as evaluating ultimate build-out scenarios. Pollutant removal rates using various stormwater control structures can also be approximated.

Continuous simulation output data (time series) from SWMM were generated in hourly intervals for nine land-use types including high density residential, medium density residential, low density residential, barren land, agricultural land, forested land, open space, commercial, and industrial areas. Since the SWMM time series was calibrated with sampling data collected during the County's Part I and Part II National Pollutant Discharge Elimination System (NPDES) permit application process, it is assumed that the land-use specific time series generated by SWMM are representative of the land uses in the County. In addition, the time-series data base files were used to generate flow and loadings for 12 different pollutants including biological oxygen demand (BOD5), chemical oxygen demand (COD), total phosphorus (TP), dissolved
phosphorus (DP), total nitrogen (TN), ammonia and organic nitrogen (NH₃+ON), total suspended solids (TSS), dissolved solids (DS), copper (CU), cadmium (CD), lead (PB) and zinc (ZN). All 41 of the County’s major watersheds have been digitized into the data base as well as the existing land-use conditions. Table 1 illustrates two of these watersheds with their respective pollutant loadings. The first watershed, Lower Northeast Branch, has an approximate drainage area of 4,504 acres with predominant land uses of 53% medium density residential, 9% high density residential, 24% commercial, and 12% forested land. The second watershed, Mattawoman Creek, has a drainage area of 15,375 acres (three times greater than Lower Northeast Branch) with land-use conditions of 73% forest, 19% agriculture, and 5% low density residential. The first watershed is highly urbanized, which is typical of areas near the District of Columbia while the second is still rural, as are most of the watersheds in the southeastern portion of the County.

**Table 1. Pollutant loading comparison.**

<table>
<thead>
<tr>
<th>POLLUTANT</th>
<th>LOWER NORTHEAST BRANCH</th>
<th>MATTAWOMAN CREEK</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>TOTAL LBS</td>
<td>LBS PER ACRE</td>
</tr>
<tr>
<td>BOD₅</td>
<td>279636</td>
<td>62.1</td>
</tr>
<tr>
<td>COD</td>
<td>694926</td>
<td>154.3</td>
</tr>
<tr>
<td>TP</td>
<td>6076</td>
<td>1.349</td>
</tr>
<tr>
<td>DP</td>
<td>4408</td>
<td>0.9790</td>
</tr>
<tr>
<td>TN</td>
<td>29808</td>
<td>6.62</td>
</tr>
<tr>
<td>NH₃+ON</td>
<td>17146</td>
<td>3.81</td>
</tr>
<tr>
<td>TSS</td>
<td>886378</td>
<td>196.8</td>
</tr>
<tr>
<td>DS</td>
<td>1124817</td>
<td>249.7</td>
</tr>
<tr>
<td>CU</td>
<td>250</td>
<td>0.0555</td>
</tr>
<tr>
<td>CD</td>
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</tr>
<tr>
<td>PB</td>
<td>323</td>
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</tr>
<tr>
<td>ZN</td>
<td>2229</td>
<td>0.4850</td>
</tr>
</tbody>
</table>
As Table 1 suggests, the total pollutant load should not be the only consideration. The load per acre generated by the land use may be equally or more important in identifying potential pollutant problems. For example, the total pounds of BOD5 are nearly the same for both watersheds, while the pounds of BOD5 per acre for Lower Northeast Branch is almost four times that generated in Mattawoman Creek and therefore, probably more of a problem.

The use of WSMP is very simple. A simulation run only requires the user to choose the name of the particular watershed of interest from a list of all 41 watersheds. Once the simulation run of the watershed has been completed, the results window can be accessed by "pointing and clicking" on the option that allows the pollutant loadings to be viewed. The options available in the results window include watershed analysis, comparative analysis, loads by land use, and statistical analysis. Each option allows the user to further define the display of the results. These options include either graphical or tabular format of annual loads (see Table 1), total loads by land use, monthly loads, mean monthly loads, all monthly loads, or daily loads. In addition, statistical analysis can be accessed for each watershed indicating storm runoff, pollutant loads, or cumulative loads. After a watershed has been analyzed using existing land-use conditions, another simulation run can be made by modifying the land use to evaluate the effects of a proposed development on the pollutant loadings within a watershed.

Conclusions

These two models illustrate that planning-level comprehensive flood management and water quality studies can be done quickly and accurately by capitalizing on the investments already made in a GIS and developing user-friendly applications. Not only do the these models yield information in minutes versus days or even weeks using conventional methods, the engineer can now use the extra time to evaluate more alternatives on a cost-effective basis. In addition, flood management solutions are typically not compatible with water quality alternatives, but when a GIS is used, they can be evaluated together more efficiently, instead of independently. These are just the first steps Prince George's County is taking to completely automate these types of studies. Already, a preliminary GIS-based model of the TR-20 has been developed by ISD, which will live on Geo-GUIDE, utilizing and enhancing the TR-55 model already completed, soon to be followed by the HEC-2 model. Tetra-Tech is also developing a watershed management methodology model that will not only help prioritize the watersheds and identify both point and non-point pollutant sources but also develop a stepwise method to address and integrate pollution prevention plans, stream restoration methods, retrofitting structures, establish new on-site controls, and water quality master planning. These and other software additions greatly enhance the value of an existing GIS.
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PART EIGHT

WATER QUALITY,
EROSION, AND SEDIMENT
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INTRODUCTION

Motorboat propellers can stir up stable bottom sediments and dislodge aquatic plants with repeated passes, as well as affect benthic communities; and it is possible for motorboats to effectively remove all vegetation at a water depth of three feet (Yousef, 1974; Wagner, 1990). As water clarity is reduced, aesthetic and habitat values can be adversely affected. In turbid water, rooted aquatic vegetation growth is prohibited because insufficient light penetrates to the lake bottom.

Rooted aquatic vegetation is an important component in aquatic ecosystems for several reasons. The leaves and stems of rooted vegetation produce oxygen and serve as forage and habitat for fish, wildlife, and insects. Plants provide attachment surfaces for case building insects. Beds of aquatic vegetation can diminish wave action and help hold sediment in place which, in turn, improves or maintains water clarity (Jackson and Starrett, 1959). Without sufficient water clarity neither the aquatic vegetation nor the associated aquatic community can become established.

METHODS

In addition to other water quality parameters, total suspended solids concentration, boat traffic, and wind speed were monitored monthly between May and October and on a 24-hour basis on four pairs of Saturdays and Wednesdays in June and July. Mid-depth water samples were taken once per day or at three-hour intervals during 24-hour sampling. Boat passes were counted for a 10-minute interval at the sampling site.

RESULTS AND DISCUSSION

Data analysis indicated that power boating significantly (P<0.05) affected the concentration of total suspended solids, a measure of water clarity. The 24-hour monitoring indicated boat traffic influences the concentration of suspended solids in water three (r²=0.458) and six (r²=0.25) feet deep over
silty sediments (Figure 1). The strength of the relationship between boating and suspended solids concentration decreased with increasing water depth and when bottom sediments were more cohesive (muck) or settled faster (sand, marl). Wind significantly \((r^2=0.293)\) influenced the concentration of suspended solids in water eight feet deep over silt (Figure 2).

Water clarity was better on Wednesday than on Saturday and varied during the day. The concentration of suspended solids was lowest (water clarity was best) during the early morning or late night when boats were not present. Soon after boats appear on the lake, suspended solids concentrations rise, water clarity is reduced, and the water remains turbid during the day. The water clears sufficiently for growth of rooted vegetation three to six hours after the cessation of boating activity, but this occurs primarily at night when sunlight is absent.
Figure 2. Relationship between wind speed and concentration of suspended solids at four sampling sites. Sites which exhibit a negative relationship with increasing wind velocity were more affected by boat traffic. Boats pass more frequently at low wind velocities. Wind affects water clarity at deeper sites.

Monthly sampling indicated mean boat passes/foot depth accounted for 84% of the variance in suspended solids concentration ($r^2=0.3122$, $P>0.05$) over all sampling sites. Mean wind speed/foot depth was not significantly related to suspended solids concentration over all sites ($r^2=0.96$, $P<0.05$), but accounted for 96% of the variance in suspended solids at the open lake sites ($r^2=0.96$, $P<0.05$). Water clarity was not related to site depth ($r^2=0.003$, $P>0.05$).

The passage of boats through areas three feet deep, at frequencies of 30 passes per hour, generated as much or more suspended sediment as a 20 mph wind in the same area. During 235 hours of water quality sampling, boat pass
frequency exceeded 30 per hour about 20% of the time. During the same time frame, winds exceeded 20 mph during only 3% of the time. The Fox Chain O'Lakes is highly susceptible to boating impacts because 65% of the lake acreage is less than six feet deep with silt sediments.

By maintaining turbid conditions daily and seasonally, boat traffic is preventing the establishment of rooted vegetation and the associated habitat. Restoration and maintenance of the existing aquatic habitat of the system will not occur without reducing the impact of boats. The environmental effects of boats can be reduced by slowing boats to no-wake speeds in shallow areas and restricting boating activities to areas where the water is more than six feet deep.

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MISSISSIPPI TRAGEDY:  
IT DIDN'T HAVE TO HAPPEN

John R. Sheaffer  
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The announcement for this year's conference stressed the need to look at floodplains, stormwater runoff, wetlands and water quality issues holistically. In addition, as the ghost of Peter Palchinsky would remind us, it will be beneficial to view floodplain management plans within their political, social, and economic contents (Graham, 1993). Palchinsky wanted planners and engineers to be hard-headed realists who evaluate problems in all their aspects, particularly the economic ones.

There is a growing awareness that floods cannot be controlled. One can always look forward to a bigger flood in the future. Stephen M. Wolf, chairperson of United Airlines, wrote, "Perhaps it is human nature to lapse into a sense of false confidence, a feeling of being superior to animals and even nature itself. We believe we are in command of the elements; we control our own destinies. Or so we think. Recent events—from earthquakes, floods, and fires to hurricanes and ice storms—demonstrate that, no matter our level of knowledge and technological sophistication, we remain at nature's mercy. . . . As brutal and terrifying as natural disasters can be, however, they also give us glimpses of something good. They remind us that we cannot rely upon the structures and warning systems we construct for protection from the elements, but we can rely upon each other for survival" (1993).

As the threat of new flooding becomes evident in 1994, it is being reported that occupants of the floodplain are "thinking of quitting altogether. We're just too tired" (Tribune, 1994). Control structures such as levees, which offer a degree of protection for the small and moderate floods, offer little hope against the large floods. The 1993 flood has shaken the confidence of some residents in levees.

Much has been written about the Great Flood of 1993. The potential mitigating effects of wetlands, the effect of levees on flood stages, the need for nonstructural alternatives, and the adequacy of the 100-year flood standard are topics that are being debated both in the scientific world and the popular press.

The White House has established a Floodplain Management Review Committee to re-evaluate national policy in light of the 1993 flood. The committee will need to identify rational or wise uses of a natural resource (the floodplain). Can a national program be formulated that will be general enough to allow local variations and individual initiatives? If such flexibility is achieved, it will allow plans to be developed that reflect the local political, social, and
economic conditions. This will be a first step in achieving the elusive goal of wise use of floodplains.

This paper focuses on the issue of water quality. Water quality is of concern not only during periods of flooding, but also when the river is within its banks. Pollutants are discharged into our waterways every day. During nonflood periods, they are in the form of partially treated sewage effluent. When floods occur, the discharges often are exacerbated when hydraulically overloaded or inundated treatment plants spew raw sewage into the waterways.

Efforts to improve water quality can have an important influence in floodplain management efforts. The need for clean water can stimulate efforts to implement greenways. The establishment of greenways often involves changes in land use, which in turn produces a reduction in the flood hazard. Fishing, boating, biking, hiking, and bird watching activities that are enhanced by greenways and clean water improve the quality of life.

Former Superintendent of the Forest Preserve District of Cook County, "Cap" Sauers, once referred to the Des Plaines River greenway as a shining red apple with a worm in the middle. The worm to which he referred was the polluted Des Plaines River.

A comprehensive floodplain management program will generate linkages between people and waterways. Such linkages can be symbiotic. Just as clean water helps to trigger and sustain efforts to establish greenways, the establishment of greenways removes floodprone development from the floodplain.

Traditional sewage treatment plants are located downstream of the communities they serve, generally at the lowest elevation to maximize the use of gravity sewers. This places them on the floodplains. According to published reports, the Environmental Protection Agency said about 425 sewage treatment plants were damaged during last summer's flooding. The treatment plants were "in harm's way" to facilitate the discharge of partially treated effluent into the rivers. Two negatives are at work by this practice. First, severe flood damage occurs to the treatment plants. Second, the essentially untreated discharges deteriorate the water quality.

Nitrogen, a primary plant nutrient in fertilizer, can be used to illustrate the adverse effects partially treated effluent can have on water quality. Untreated municipal wastewater will contain 35 mg/l nitrogen. After secondary treatment it will contain 25 mg/l nitrogen. A community with a population equivalent (PE) of 500,000 will discharge 10,425 pounds of nitrogen each day (50.0 mgd x 25 x 8.34). On an annual basis, this amounts to 3,805,125 pounds of nitrogen. This is the quantity of nitrogen that would be found in 761,025 50-pound bags of 10-10-10 commercial fertilizer. Obviously, three quarters of a million bags of commercial fertilizer, when dumped into a river, will affect water quality.
Linkages between pollutant recycling and floodplain management are presented in the Federal Water Pollution Control Act Amendments of 1972 (P.L. 92-500) and in Section 73(a) of the Water Resources Development Act of 1974. The 1972 Amendments state: "The Administrator shall encourage waste treatment management which combines 'open' space and recreational considerations with such management" (Sec. 201 (f)).

Federal agencies are required to evaluate nonstructural alternatives when formulating a flood loss reduction project. The nutrient recycling possibilities inherent in nonstructural floodplain management were well recognized, as the following quotation from Charles R. Ford, former Deputy Assistant Secretary of the Army, shows:

The authorities in P.L. 92-500 regarding the acquisition of sites for the land treatment process for wastewater, when combined with the authorities in Section 73, offer an outstanding opportunity for multiple uses of flood plains while preserving green space and providing recreational opportunities. Why not use our flood plains in urban areas for crop production, golf courses, forests, and other uses which can capitalize on the nutrients in our wastewater and provide tertiary waste treatment at the same time? Such land-treatment sites can be located on the higher areas of the flood plain, but they can also be designed to store flood water when necessary without permitting the release of the stored water except through the soil filtration process (1975).

The State of Illinois has recognized the potential to use floodplains to improve water quality. The EPA allows the use of floodplains above the 10-year floodplain as irrigation areas for reclaimed water so that the nutrients can be reused or recycled. The national goal was to eliminate the discharge of pollutants into the navigable waters by 1985. We have missed the deadline, but the goal still remains. Technology exists that allows communities to use wastewater as a raw material or resource. Rather than discharging partially treated wastewater into a river, wastewater is reclaimed and used in the production of food and fiber. When this is done, traditional treatment plants can be removed from vulnerable floodplain sites and the elimination of discharge will improve water quality, which in turn will support efforts to establish greenways.

Wastewater reclamation and reuse technology is being implemented in many states and several foreign countries. Figure 1 depicts the technology often referred to as a circular system. The question is, "What investment must be made to use the wastewater beneficially?" rather than "What expenditures must
be made to dispose of or relocate wastes?" It is another weapon in the floodplain manager’s arsenal. Proper use of technology will assist our national efforts to achieve two elusive goals: clean water and reductions in flood losses.

![Diagram of wastewater reclamation and reuse system]

Figure 1: Elements of wastewater reclamation and reuse system.

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INTRODUCTION

Located on the eastern edge of the Central Great Plains in Kay County Oklahoma, Newkirk Lake was established by the impoundment of a tributary to Wolf Creek in the early 1900s. The Santa Fe railroad used this reservoir as a water supply for their locomotive steam engines. Ownership was transferred to the City of Newkirk in 1953 and the reservoir renamed Newkirk Country Club Lake. The lake was used for boating, swimming, fishing, and picnicking. Present day recreational uses include only picnicking and limited fishing because of the restricted access to boatable and fishable water. To address the impairment of recreational uses, a study ("Clean Lakes") was proposed to the U.S. Environmental Protection Agency through section 314 of the Clean Water Act requesting $107,171 (70% federal, 30% state matching funds). The proposal was funded and a Clean Lakes workplan was developed to evaluate the causes of impaired recreational uses and develop feasible restoration measures.

The Clean Lakes study utilized two separate evaluation techniques, one for the lake and another for the watershed. The lake evaluation was performed by the Water Quality Programs Division of the Oklahoma Water Resources Board through a bathymetric survey and monitoring of tributary and lake water quality. The lake watershed was evaluated at the Environmental Modeling and GIS Laboratory, School of Civil Engineering and Environmental Science, University of Oklahoma under contract with the Oklahoma Water Resources Board. Through the use of a geographic information system (GIS) and a non-point source pollution model (AGNPS), the location and severity of non-point source pollution were identified in the watershed (Vieux et al., 1993).
Lake Evaluation

Historical records indicate an original maximum depth of 25 feet (7.6 meters), surface area of 41 acres (0.16 km²), approximate volume of 430 acre-feet, and a watershed of 1,510 acres (6.11 km²). A bathymetric survey performed in 1990 revealed a maximum lake depth of 6.5 feet (2.0 meters), surface area of 45 acres (0.18 km²), and approximate volume of 125 acre-feet. Reduction of volume is the primary cause of the loss of recreational use of the lake.

Water quality was monitored from July 1992 through June 1993 to chemically characterize Newkirk Country Club Lake. Mean annual chlorophyll-a concentration measured at the central sampling station was 27.7 mg/m³. Mean annual total phosphorous concentration measured at the central sampling station was 75 mg/m³. Mean annual total nitrogen concentration was 1,900 mg/m³. Approximately one third of the total nitrogen present was in the form of nitrate. An examination of chlorophyll-a concentrations showed a reservoir supporting a highly productive phytoplankton community. The nutrient concentrations present indicate that nitrogen and phosphorous are not the factors limiting phytoplankton growth.

The dominant visual feature of Newkirk Country Club Lake is a standing crop of aquatic macrophytes. The lake margin is dominated by emergent aquatic plants. Cattails (Typha latifolia) are found near to shore, while a mix of water willow (Justicia americana) and water primrose (Ludwigia peploides) are found farther from the lake shore. Free-floating rafts of water willow were observed in the open water areas of the lake. It is presumed that storms occasionally break off and wash stands of this plant into the lake. The rest of the lake is colonized by coon-tail (Ceratophylum demersum). Areal coverage by this species varies from 50% to 95% of the open water area. It is likely that phytoplankton productivity is limited to the top few inches of the lake while the coontail is dominant in the open water area of the lake. Senescence of the standing crop of aquatic macrophytes in the fall is a source of sediment for Newkirk Lake.

Monitoring of dissolved oxygen concentrations showed the water column below the stands of coontail to be anoxic from May through October. From November through April, when plant growth was minimal, lake water was oxic. The implications of anoxia are the solubilization of sediment bound nutrients into the water column.

Water quality samples taken from the lake tributary had settleable solid values below the detection limit (<0.1 mg/L). Mean total phosphorous was 0.151 mg/L. Mean total nitrogen was 8.91 mg/L. Nitrate accounted for just over two-thirds of the total nitrogen. Local residents tell of two springs in the lake’s watershed. USGS records show one ephemeral spring. Water quality sampling
of the spring showed mean total phosphorous values of 0.050 mg/L, total nitrogen of 13.32 mg/L, and nitrate making up 97% of the total nitrogen. Sampling of stormwater entering Newkirk Lake showed mean total nitrogen in water and sediment as 4.4 mg/L and 2.54 mg/L, respectively. Mean total phosphorous in water and sediment was 0.30 mg/L and <0.1 mg/L, respectively. Mean total solids of the inflowing stormwater was 942 mg/L.

The evaluation of the lake revealed a reservoir with approximately one-third of its original volume. In 1990 Newkirk Lake was shallow enough for coontail to monopolize the open water area. Contributors of sediment and nutrients to Newkirk Lake are both internal and external. The resident aquatic plants and inflowing storm water contribute sediment, while the anoxic lake sediments and inflowing water contribute nutrients. Making the lake depth exceed that which light will penetrate will eliminate the nuisance aquatic macrophyte growth and reduce the internal sources of nutrients. External sources of sediment and nutrients must be addressed to effectively allow for the restoration of recreational uses.

Watershed Evaluation

The Kirkland-Tabler-Bethany soils comprise approximately 50% of the soils in the watershed. These soils are on broad, very gently sloping to rolling uplands. The thin surface layer does not absorb much rainfall in a short duration. For this reason, runoff and erosion are greater than at other places in the watershed. About 80% of this association is cultivated. The Newtonia-Summit-Sogn series comprises 44% of the watershed. These soils consist of generally well-drained soils with depth to limestone greater than four feet. About 60% of this association is cultivated for winter wheat. The remaining 40% is native pasture. Cropland comprises 78% of the entire watershed. Pasture and meadowland make up approximately 22%. Urban development constitutes approximately 8% of the watershed. A marshland lies immediately upstream of Newkirk Lake. Table 1 summarizes land use for the Newkirk Lake watershed.

Digital soils, land use, hydrographic, and topographic base maps were compiled using the geographic resource analysis support system (GRASS) GIS developed by the U.S. Army Corps of Engineers. From GRASS the information was recoded into model parameters that were used to run the agricultural non-point source pollutant (AGNPS) model at 2.5-acre resolution. Grid cell resolution effects were investigated by Nickisch (1993). To quantify the relative effect of management practices in controlling or reducing pollution of Newkirk Lake, four scenarios of various land use/cover were generated. These scenarios
Table 1. Land use in Newkirk Lake watershed.

(NHEL = not highly erodible land, HEL = highly erodible land)

<table>
<thead>
<tr>
<th>Land Use Description</th>
<th>area (acres)</th>
<th>area (% cover)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Smallgrain (Terraced/NHEL/Waterway)</td>
<td>313</td>
<td>21</td>
</tr>
<tr>
<td>Pasture (Moderate)</td>
<td>250</td>
<td>17</td>
</tr>
<tr>
<td>Smallgrain (Not Terraced/NHEL/No Waterway)</td>
<td>238</td>
<td>16</td>
</tr>
<tr>
<td>Smallgrain (Not Terraced/NHEL/Waterway)</td>
<td>192</td>
<td>13</td>
</tr>
<tr>
<td>Legume and Rotation Meadow</td>
<td>79</td>
<td>5</td>
</tr>
<tr>
<td>Smallgrain (Terraced/NHEL/No Waterway)</td>
<td>75</td>
<td>5</td>
</tr>
<tr>
<td>Park/Golfcourse</td>
<td>69</td>
<td>5</td>
</tr>
<tr>
<td>Smallgrain (Not Terraced/HEL/Waterway)</td>
<td>61</td>
<td>4</td>
</tr>
<tr>
<td>Urban (21-27% impervious)</td>
<td>42</td>
<td>3</td>
</tr>
<tr>
<td>Marsh</td>
<td>49</td>
<td>3</td>
</tr>
<tr>
<td>Water</td>
<td>42</td>
<td>3</td>
</tr>
<tr>
<td>Smallgrain (Terraced/HEL/Waterway)</td>
<td>37</td>
<td>2</td>
</tr>
<tr>
<td>Roads</td>
<td>33</td>
<td>2</td>
</tr>
<tr>
<td>Farmstead</td>
<td>22</td>
<td>1</td>
</tr>
<tr>
<td>Pasture (Good)</td>
<td>4</td>
<td>&lt;1</td>
</tr>
<tr>
<td>Woodland</td>
<td>4</td>
<td>&lt;1</td>
</tr>
</tbody>
</table>

were conditions estimated to be (1) present conditions, (2) worst case conditions, (3) management practices applied to worst case conditions, and (4) management practices applied to present conditions. The rainfall series (1959-1991) was simulated to obtain the full range of effects for the four scenarios. The simulations assume that the practices functioned as intended for the full range of precipitation events. Most conservation practices are designed for the 10-year, 24-hour storm. An AGNPS input file was generated for each of the four scenarios. Each scenario input file was then used with the actual storm events to simulate long-term averages of yield to the lake.
Table 2 contains a summary of various model constituents delivery to Newkirk Lake. The modeling results showed soil erosion and sedimentation to be greatest in the cropland areas. Water erosion was also shown to be greatest in areas of highest slope. Phosphorous contributions were predicted to be dominated by sediment transport from the Kirkland-Tabler-Bethany soils found in the western half of the basin. Sediment and erosion control practices applied to cropland in this area were predicted to produce the largest reduction of phosphorous delivery to Newkirk Lake. Further reductions of nutrient contributions to Newkirk Lake can be achieved by nutrient management. By simulating management practices to existing cropland and improving the retention abilities of marsh area, it is predicted that sediment loading to the lake can be reduced 28% from present conditions.

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Sediment Yield (tons)</th>
<th>Clay Yield (tons)</th>
<th>Soluble Nitrogen (ppm)</th>
<th>Sediment Attached Phosphorous (lbs/acre)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>61.29</td>
<td>45.09</td>
<td>3.82</td>
<td>0.18</td>
</tr>
<tr>
<td>2</td>
<td>67.20</td>
<td>50.64</td>
<td>5.51</td>
<td>0.19</td>
</tr>
<tr>
<td>3</td>
<td>63.38</td>
<td>49.16</td>
<td>4.99</td>
<td>0.19</td>
</tr>
<tr>
<td>4</td>
<td>44.11</td>
<td>28.50</td>
<td>2.66</td>
<td>0.14</td>
</tr>
</tbody>
</table>

**Discussion and Conclusions**

Recreational uses of Newkirk Lake have declined over time due to sedimentation. The reduction in volume has allowed aquatic plants to colonize virtually the entire surface area of the lake. Deepening the lake should eliminate the nuisance growth of aquatic macrophytes and one source of nutrients and sediment. Water quality monitoring shows a highly productive phytoplankton community limited by intense aquatic macrophytic growth. Deepening the lake without nutrient controls would allow for excessive phytoplankton growth and result in a lake that is not aesthetically pleasing. Control of the nutrients flowing into Newkirk Lake will be essential for the restoration of recreation uses. Through the use of a GIS and hydrologic model, it has been shown that by the manipulation of land use within the lake watershed, the delivery of sediment and
nutrients to the lake can be reduced. Reversing pasture or meadow conversion to cropland would have the greatest impact on reducing the sediment yield to the lake. Addressing the sediment delivery to Newkirk Lake will concomitantly address the greatest identified source of nutrients from the watershed. Enhancing the trapping ability of the marshlands immediately above Newkirk Lake will further reduce sediment and nutrient delivery to Newkirk Lake.

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CHARACTERIZATION OF SHORELINE ERODIBILITY
AND RECREATIONAL BOAT-GENERATED
WAVE EROSIVITY
ON THE FOX RIVER CHAIN O’ LAKES

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Introduction

The purpose of this study is to characterize shoreline materials with respect to their inherent erodibility and consequent sensitivity to wave impacts. The study area is located within the Illinois portion of the Fox River watershed, and contains the Chain O’ Lakes and portions of the Fox River. The Chain O’ Lakes is a series of interconnected glacial lakes, and the Fox River is a principal tributary that conveys headwaters into the Chain O’ Lakes and flows downstream from the Chain O’ Lakes into the Illinois River. The study area encompasses approximately 123 miles of shorelines. The termini of the study area are at the Wisconsin/Illinois state line and Route 62 in Algonquin.

Methodology

Shorelines along the study areas were mapped with respect to the types and proportions of materials, surficial parent materials, and surface soil types. Sampling transect locations were determined through use of this mapping information. Field sampling entailed 1) shoreline soil sample collection, classification, and testing; and 2) slope and plant cover characterization. Soil erodibility factors were then determined for each sampling site’s soil type(s).

Erosivity characteristics of recreational boat-generated waves impacting Fox River Chain O’ Lakes shorelines were determined by 1) using numerical relationships derived for computing maximum heights of recreational boat-generated waves, effective wind velocities and durations needed to generate similar wave heights, and various wave properties; 2) using boat count and Fox River Chain O’ Lakes users’ telephone survey response data to determine approximate mean numbers of waves generated by recreational boats; and 3) correlating the aforementioned data with corresponding shoreline material mapping and erodibility characterization sampling transect data.
Conclusions

Approximate proportions of structurally unprotected shorelines along the erosion study area shown in Table 1.

Table 1. Study area shorelines.

<table>
<thead>
<tr>
<th>Study Area Component</th>
<th>Approximate Proportion (%) of Structurally Unprotected Shoreline</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>WI/IL State Line to McHenry Lock and Dam</td>
</tr>
<tr>
<td>Lakes</td>
<td>52</td>
</tr>
<tr>
<td>Channels</td>
<td>72</td>
</tr>
<tr>
<td>Rivers</td>
<td>31</td>
</tr>
<tr>
<td>Total</td>
<td>50</td>
</tr>
</tbody>
</table>

Approximately 12% of the erosion study area shorelines between the Wisconsin/Illinois state line and Route 62 in Algonquin are city, county, state, or privately owned parkland, of which 91% are structurally unprotected shorelines.

Surficial parent material deposits along the erosion study area shorelines consists of a) peat, muck, or marl; and b) glacial tills having various combinations of sand, silt, and gravel. Soil types present along sampling sites ranged from coarse gravels to silty clays and peats. Coarse-grained soils were primarily present along lake, exposed soil, and grass/lawn shorelines, while fine-grained soils were primarily present along channel and tree/shrub shorelines. A majority of the Fox River Chain O’ Lakes shoreline soils contain high to very high levels of organic matter.

The sampling transects had level to very steep slopes. Slope steepnesses per gradient zone generally decreased as the number of backshore gradient zones increased. Classification of sampling transect slope steepnesses indicates that backshore slope zones are subjected to high erosive forces.

The principal zone-of-influence for wave impacts within swash zones is basically consistent for structurally unprotected Fox River Chain O’ Lakes
shorelines with regard to lengths of swash zones measured during sampling. Swash zones ranged from two to 17 feet in length. Heights of nearly vertical slopes encountered during sampling ranged from five to 34 inches. Most of these nearly vertical slopes occurred at water-shoreline interfaces and also had undercut banks.

Slope shapes of the sampling transects were predominantly convex, while there were similar proportions of slopes having uniform and concave shapes. Convex slopes generally experience faster surface runoff velocities than concave and uniform slopes.

Structurally unprotected channel and river shorelines have more undercut banks and are more susceptible to bank failures than those along lake shorelines. Tree/shrub shorelines are highly susceptible to bank undercut and potentially experience more severe bank failures than those composed of grass/lawn and exposed soil cover. Angularity of undercut banks was steepest in clay soils and most gradual in silts.

The effects of plants upon undercut bank stability can be very significant. Root masses generally help retain soil peds, thereby increasing bank stability. However, the presence of plants along banks can result in increased loss of bank material during their failure process.

Erodibility of soils increases as their soil erodibility factor (K) values increase. Proportions of sample-site soils having K values greater than the maximum of those for clays and gravels indicate that structurally unprotected channel and river shorelines and shorelines composed of exposed soil and tree/shrub cover are the most susceptible to erosive agents, with tree/shrub shorelines being the most susceptible. It can be assumed that shorelines composed of cattails are equally or more susceptible to erosive agents than tree/shrub shorelines.

Defining L as length of boat, \( w_i \) as wake type zone-of-influence, \( H_m \) as maximum wave height, \( x \) as distance between boat and wave gage (shoreline), \( U \) as effective wind velocity, \( F_e \) as effective wind fetch, \( d \) as depth of water at boat, and \( K_w \) as rate of soil loss per wave impact, empirical and boat-count site relationship results indicate that:

a) Per \( L \) and \( w_i \), \( H_m \) values decrease as \( x \) increases.

b) Per \( L \) and \( w_i \), \( U \) values needed to generate respective \( H_m \) values decrease as \( x \) increases.

c) \( H_m \) values increase as \( L \) values increase.

d) \( H_m \) are highest within transition zones, intermediate within open zones and least within no wake zones.
e) Per $U$, $H_m$ increase as $F_e$ increases.

f) The impacts recreational boats have on wave generation are very substantial when compared to the impacts of wind on wave generation.

g) Wave heights of waves generated by an average Fox River Chain O' Lakes wind velocity are negligible when compared to those of recreational boat-generated waves.

h) Per $L$ and $w_t$, $H_m$ values decrease as $x/d$ increases.

i) Per $L$ and $w_t$, $U$ values decrease as $x/d$ increases.

j) $H_m$ values increase as $L$ values increase.

k) $H_m$ values are highest within transition zones, intermediate within open zones, and least within no wake zones.

l) $K_w$ decreases as $x/d$ increases.

m) $K_w$ increases as $L$ values increase.

n) Per $L$ and $w_t$, $K_w$ tends to decrease as $x/d$ increases.

o) Shorelines along transition zones experience faster $K_w$ than shorelines along open and no wake zones, with $K_w$ being least along no wake zone shorelines.

Both the number of waves generated per hour and per day on weekends were three times greater than those generated on workdays. Structurally unprotected shorelines within the vicinity of the boat-count sites are substantially susceptible to wave impacts, especially structurally unprotected shorelines within transition zones.

The product of soil erodibility factor and wave power values used in trend analysis shows that mean rates of soil loss per wave impact were five times faster along shorelines within transition zones than those along open zones.

Non-Corps of Engineers' resource management actions that would produce positive impacts upon erosion (e.g., reduce rates of accelerated erosion) are those that: a) reduce boat velocities near shorelines; b) move zones of boat passage away from shorelines, especially transition zone locations; c) decrease the number of boats using the waterways, that is, reduce the number of wave impacts; d) decrease the maximum range of boat lengths allowed on the
waterways; e) optimize boating operations that minimize travel distances needed to transcend to and from open and no wake zone velocities and that maximize streamlining of hulls; f) provide streambank protection (which can also produce negative impacts); and/or g) reduce fetch.

A Corps of Engineers' permitting activity that would impart positive impacts upon erosion is to "Approve on Case Basis if other Limits are in Place." Positive impacts would ensue if mitigation requirements, for instance, streambank protection, were included with permit approval.
FEMA: LOMR(ABQ) = Q_{100} + Q_S
(IN ALBUQUERQUE, FEMA INCLUDES SEDIMENT IN THE FLOOD EQUATION)

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Robert A. Mussetter
Mussetter Engineering Inc.

Albuquerque’s Geologic Setting

Flood control agencies in the arid Southwest United States are becoming increasingly aware of the impacts of the sedimentation process when determining flood-prone areas and designing drainage facilities. Located in central New Mexico, at an elevation between 4900 and 6300 feet, the City of Albuquerque experiences much of the sedimentation problems common to the Southwest. Because of some unique terrain features, there are aspects of alluvial processes that present special challenges to Albuquerque’s engineers and floodplain administrators.

Immediately west of the city, the Manzano and Sandia mountains steeply rise to an elevation over 10,000 feet. Through the center of the city, sediment deposition in the Rio Grande and the construction of levees have caused the river to be several feet higher than the surrounding developed areas. Between the mountains and the Rio Grande, an alluvial fan zone lies at the mountain front, followed by a 3 to 4% slope pediment zone. The upper portion of the pediment zone is incised and armored with large boulders. Most of the pediment is a depositional zone with shallow braided arroyos and frequent avulsion areas. To the west of Albuquerque is a relatively flat topped mesa that is underlain by deep sand and gravel from old alluvial deposits. Base lowering of the Rio Grande over geologic time has resulted in development of high density drainage and badlands areas at the mesa slope.

Development and Sedimentation History

Development in Albuquerque has mostly occurred along the Rio Grande floodplains and on the sloped pediment below the mountains. The western mesa tops and slopes have only recently begun to experience rapid development. As areas developed, natural arroyos were replaced by storm sewers and concrete-lined trapezoidal channels. Traditional drainage analysis has largely ignored the
potential for sediment problems at these facilities. The National Flood Insurance Program (NFIP) mapping is largely based in earlier studies that did not consider sediment impacts on dams and constructed channels, and did not consider the potential erosion of natural arroyo banks. Where all of a watershed was fully developed with lined channels, this was not a problem. However, many watersheds in the area have substantial undeveloped areas and natural conveyances. At these locations, sediment can impact constructed facilities and existing development.

In 1981, a report titled Design Guidelines and Criteria for Earth Channels and Hydraulic Structures on Sandy Soils (Simons, Li and Associates, Inc., 1981) was prepared for the Urban Drainage and Flood Control District in Denver, Colorado. This report quickly became a standard guidebook for Albuquerque, and in 1983 was incorporated by reference into an update of the Development Process Manual (City of Albuquerque, 1982). The Manual contained the following guidance concerning sedimentation:

A channel's stability can be defined in terms of its ability to function properly during a flood event without serious aggradation and/or degradation. . . While channel stability problems are largely associated with earth and flexibly lined channels, concrete lined, supercritical channels are not immune.

From 1982 to 1990, these provisions were not generally addressed by local engineers and agencies when preparing or reviewing plans.

In 1987, two new dams (Raymac and Don Felipe) were completed in southwest Albuquerque. In June 1988, a storm in the watersheds above the dams produced over 10 times the sediment volume that had been predicted during the design of these facilities. A major storm at the Embudo Canyon watershed on July 9, 1988, produced substantial amounts of water and sediment damage, and resulted in one death. Video recordings taken during the storm clearly indicated high concentrations of sediment. Photos of plugged arroyo channels and large rocks on bridge railings provided further evidence of sediment and debris problems. Following this storm, the Federal Emergency Management Agency (FEMA) "postponed" further review of revisions to the NFIP maps for the Albuquerque area. Reviews were re-initiated in March 1990 with the following requirement:

Because of the alluvial nature of watersheds and streams contributing to flood hazards in the City of Albuquerque, each request for a revision to the Albuquerque FIRM and FBFM will require supporting information on how the sedimentation
and debris processes impact the base (100-year) flood. Since the City of Albuquerque experiences flooding of an alluvial nature, all requests submitted after October 1, 1989 must either demonstrate that the site in question is not subject to alluvial flood hazards or comply with Section 65.13.

FEMA suggested that the U.S. Army Corps of Engineers (Corps) engineering manual, Sedimentation Investigations of Rivers and Reservoirs (U.S. Army Corps of Engineers, 1989) would provide comprehensive guidance for evaluating sedimentation and debris conditions. They noted that the Corps document was "FEMA's primary reference in reviewing proposed changes to FIRMs and FBFMs involving alluvial conditions." After reviewing this document and following consultation with local Corps technical staff, it became apparent that the Corps manual did not provide detailed guidance necessary for analysis of 100-year flood conditions at the steep ephemeral arroyos common to the Albuquerque area. In order to obtain this detailed guidance, the Albuquerque Metropolitan Arroyo Flood Control Authority (AMAFCA) retained the firm of Resource Consultants and Engineers, Inc. to prepare a Sediment and Erosion Design Guide (Resource Consultants and Engineers, Inc., 1994). A public review draft of the Design Guide was available in March 1992, and in August 1992, a "pilot course" was conducted to review the document and receive input from area engineers and agencies. In March 1993, FEMA staff provided review comments that contained the following statements:

We have reviewed the draft version of the report and find it to include valuable procedures customized to the Albuquerque and Bernalillo County area which address the requirements for managing alluvial channels. In addition, the report outlines the parameters appropriate for planning and designing drainage facilities in the floodplains in this area, including projects which may require issuance of a Letter of Map Amendment (LOMA) or Letter of Map Revision (LOMR) by FEMA. We believe that this design guide will be useful in the design of these facilities, and that used in conjunction with the appropriate NFIP regulations, can be used to satisfy the requirements outlined in our letter dated March 8, 1990.

Following input from agencies and extensive additions to the procedures identified in the draft, the final version of the Design Guide was released by AMAFCA in March 1994.
Lateral Erosion—the Prudent Line and Erosion Envelope

An important element of the Design Guide was the establishment of a setback distance from natural arroyos to avoid or minimize the potential for damage due to flooding and erosion; the setback location has been named the "prudent line." The concept considers both long-term erosion, which can occur over many years due to a series of frequent runoff events, and short-term erosion, which results from a single 100-year storm. AMAFCA currently uses a 30-year period to define long-term erosion. The prudent lines are defined by the 100-year floodplain limits, or by the additive effects of short-term and long-term erosion, whichever is greater. Included with the Design Guide is a computer program, CURVCALC, that can be used to estimate lateral erosion migration for channels based on bend geometry, bank height, and sediment transport. While the prudent line procedure is essential for many projects, it is analytically complex and time intensive. An alternate procedure was established to estimate maximum erosion distance based on geomorphic relationships between the meander wavelength, channel width, and minimum radius of curvature of a channel bend; this procedure defines the "erosion envelope."

Sediment Transport

Total sediment concentrations of 500,000 ppm by weight have been documented in arroyos. Such concentrations can increase the volume of the water sediment mixture by 40% or more. Few, if any, available sediment transport relationships are applicable for these conditions. The work of H.S. Woo (1985) resulted in a complex differential equation to account for the significant changes in fluid characteristics with increases in sediment concentrations. Mussetter (in press) linked Woo's relationship with the Meyer-Peter & Muller (MPM) bed-load equation to obtain a method for computing bed material in streams carrying high concentrations of suspended sediment. Results obtained from this method were compared with the results from other available relations and, to the extent possible, with measured yield data. The new method should provide more realistic results over the range of flow and sediment transport conditions encountered in the Albuquerque area. The MPM-Woo method was used to estimate bed material transport capacity for a broad range of hydraulic and bed material conditions typical of the Albuquerque area. The results of these computations were then used by Mussetter to develop the following power function relation using multiple regression:

\[ q_s = a V^b Y^c (1 - C_r)^d \]  

(1)
where \( q_s \) is the bed material transport capacity in cubic feet per second per foot of width, \( V \) is the velocity in feet per second, \( Y \) is the flow depth in feet, \( C_r \) is the fine sediment concentration in ppm by weight, and the coefficient (a) and exponents (b, c, and d) can be determined from Figure 1.

*Figure 1. Coefficient and exponents for Equation 1.*

**Flood Wall Scour**

The computation of scour at a flood wall adjacent to a natural arroyo has become an important design consideration for many developments and is a logical consequence of lateral erosion analysis. When flow impinges on a wall at a sharp angle, the procedures commonly used for bridge abutments can provide guidance for flood wall design. When flow is parallel to a wall, the bridge abutment procedures are not directly applicable, and scour may be more related to relative shear stress. For most flood wall conditions at arroyos, flow is not likely to be parallel under all conditions, and will commonly impinge on the wall at an angle. The potential scour at an arroyo changes as the arroyo evolves in planform. The angle of impingement can be estimated based on the ideal meander geometry and the available unconstrained valley width. With the flow angle established, Mussetter developed the following relationship for determining scour depth:
In Albuquerque, FEMA Includes Sediment

\[
\frac{Y_s}{Y_1} = [(0.73 + 0.14 \pi F_r^2) \cos \theta] + [4 F_r^{0.33} \sin \theta]
\]  

(2)

where \(Y_s\) is depth of scour, \(Y_1\) is flow depth, \(F_r\) is Froude number, and \(\theta\) is the angle between the flow direction and the flood wall.

Other Sediment Issues

The Design Guide provides information on aggradation, annual sediment yield, antidune scour, armor layers, bulking factors, continuity analysis, contraction scour, culvert outlets, detention and debris ponds, equilibrium slope, geomorphology, Manning's roughness, pier scour, trap efficiency, and counter-measures (i.e. riprap, soil cement, check dams, spur dikes, guide banks, jetties) that are essential elements of a comprehensive sediment evaluation. In addition, an interim procedure for determination of avulsion probabilities (Heggen, 1994) is allowing a systematic evaluation of this condition.

Conclusions

It is anticipated that the above concepts and relations will provide a practical tool to evaluate sedimentation in the Albuquerque area. For similar areas in the arid Southwest, the Design Guide procedures may provide the alluvial watershed information required by FEMA for the NFIP.

References

City of Albuquerque

Heggen, Richard J.

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U.S. Army Corps of Engineers

Woo, H. S.
SEDIMENT MANAGEMENT AND REGULATION IN WASHINGTON STATE

Philip A. Noppe and A. M. (Tony) Melone
KCM, Inc.

Alluvial rivers draining from the Cascade and Olympic Mountain ranges in western Washington State transport large sediment loads to downstream locations. Deposition in downstream channel reaches may reduce channel capacity, leading to increased frequencies and magnitudes of flooding. Removal of gravel from riverbeds is one of a number of alternatives that can be considered by affected jurisdictions to reduce flood hazards to downstream residents. While the action may be supported by local residents, regulatory, environmental, and economic issues need to be addressed before a program of removals can become a viable alternative.

KCM, Inc. is currently preparing a Comprehensive Flood Hazard Management Plan (CFHMP) for the Nooksack River in Whatcom County, Washington (see Figure 1). The Nooksack River, with a mean annual flow at Ferndale of 3,867 cfs, drains the western slopes of the Cascade Mountains. A portion of Mount Baker, a glaciated inactive volcano with a peak elevation of 10,750 feet, contributes flow at the river headwaters.

Nooksack River Case Study

The Nooksack River is subject to severe flooding. The most recent major flood event, in November of 1990, caused damages estimated by the U.S. Army Corps of Engineers to be $21 million. The 57,000-cfs flow gauged at Ferndale during this event is estimated to have a recurrence interval of 50 years. During large events like the 1990 flood, the river overflows its banks at Everson and floodwaters are conveyed north into Canada. The resulting flooding causes considerable damage and disruption to important facilities in British Columbia. This transboundary flooding is the major focus of the Nooksack River International Task Force, made up of U.S. and Canadian officials.

The severity of the 1990 flood and other recent floods prompted the County Commissioners to form a Flood Control Zone District and fund the Comprehensive Flood Hazard Management Plan. As one element of the plan, KCM has completed a preliminary analysis of issues relating to gravel management in the Nooksack River. The analysis focused on historical practices and current status of gravel removals, a preliminary economic analysis, and a regulatory review including compilation of performance standards required by
relevant regulations. This work, coupled with other CFHMP tasks, is intended to answer the following questions:

- Is sediment accumulation a major cause of flood problems?
- Can gravel removal be an effective flood hazard management strategy?
- Does gravel removal cause adverse environmental impacts?
- What are the practical problems of gravel removal? (For example, how much gravel can the market absorb?)
- Is sediment accumulation causing more frequent and larger overflows at Everson, and if so, should the channel be dredged?
Historical Practices, Current Status, and Economics

As the three forks flow out of the western foothills of the Cascade Mountains, they carry substantial quantities of sediments along steep river reaches. In the vicinity of the confluences of the three forks, the river slope decreases dramatically. Decreased river slopes reduce transport capacity, resulting in deposition of coarser materials in braided reaches in the vicinity of and downstream from Deming. Sediment grain sizes decrease with distance along the river and the river generally flows within a single channel downstream of Everson.

To determine the amount of gravel present in any reach of a river, the following components must be known:

1. The amount deposited from the watershed or from upstream reaches of the river;

2. The amount deposited from erosion of the channel banks within the reach being studied;

3. The amount conveyed downstream with the river flow; and

4. The amount removed from the reach by excavation.

Quantification of these components will determine the feasibility of reducing flood hazards by removing gravel. To estimate one of them—the amount removed by excavation—records of past removal were examined. The amount of gravel removed in the past can approximate how much can reasonably be removed in the future. This estimate can then be compared to calculations of how much gravel must be removed to reduce flooding. These calculations have yet to be performed.

Gravel has been removed from the Nooksack River for over 30 years for a variety of purposes. Private operators, who have carried out the majority of gravel removal, are generally responsible for obtaining required permits, excavating the material, processing it, finding purchasers, and transporting the material to the purchaser. Operators are required to obtain a lease agreement and report regularly to the Washington State Department of Natural Resources on the volume of gravel they remove. Data from these reports were used to establish a data base of information on past gravel removal volumes. Annual removal volumes were extracted from the data base.

The total reported volume of gravel removed annually from 1960 to 1993 ranged from none to 252,000 cubic yards. The level increased substantially from 1990 to the present. Average annual gravel removal was 55,700 cubic
yards from 1963 through 1987 and 191,800 cubic yards from 1990 to 1993, an increase of over 300%. River gravel removed by operators is used for a variety of purposes, including cement concrete, asphalt concrete, drain material, and gravel backfill. Current removal practices to obtain raw materials for these products include the following steps:

1. Logs, roots, and other large woody materials are removed from the surface of the bar.

2. Gravel is excavated by either pushing material into a windrow (a long linear pile) using a bulldozer and carrying it off the bar with a front-end loader, or moving material to a stockpile out of the river using a self-loading scraper/earth mover.

3. Gravel is transported from the bar to the shore by way of temporary routes built along the shoreward portion of the bar. Where allowed by permit, temporary bridges are used to cross low water channels. Bar-to-shore routes are washed away with seasonal high water and therefore frequent re-establishment is required.

4. Gravel is transported from the shore to a county road or nearby processing area. Access charges based on the amount of material transported are often assessed for private property crossings.

5. Raw river gravel may be processed to produce secondary products. Processing can involve washing, crushing, and screening the gravel. It can also be mixed with other materials to make such products as cement concrete and asphalt concrete. Stockpiles of unprocessed and processed material are sometimes produced.

6. Raw or processed materials are transported to the end user along public roadways.

The cost to excavate gravel from a Nooksack River bar and transport it to a processing site within three miles is estimated to be from $2.00 to $2.50 per cubic yard. The cost for transport beyond approximately three miles is additional and varies with distance.

Prices paid by buyers of river gravel depend on how the gravel is processed. Raw pit run gravel is typically sold in Whatcom County for $5.00 to $6.00 per cubic yard delivered. If the material is screened and washed, the price increases to approximately $9.00 to $10.00 per cubic yard.
Regulations and Performance Standards

A number of local, state, and federal regulations apply to gravel removal in rivers, with objectives ranging from collection of fees for extraction of state-owned resources to protection of fisheries. Pertinent regulations are:

- County Shoreline Management Program (SMP),
- Washington State Aquatic Land Management Regulations,
- Washington State Hydraulic Code Rules,
- Washington State Environmental Policy Act (SEPA),
- Section 401 of the Clean Water Act,
- Section 402 of the Clean Water Act, and
- Section 404 of the Clean Water Act.

Performance standards for gravel mining activities are required on a site-specific basis by state and local agencies with jurisdiction over gravel removal. These requirements are described in permit conditions developed from published regulations and are based on permit application materials and visits to the proposed project site. Permits issued under the County Shoreline Management Program and the State Hydraulic Code both contain site-specific performance standards. A summary of the typical performance standards listed in these permits and their rationale is presented in Table 1.

Conclusions

The preliminary analysis summarized here is a first step in the potential development of a sediment management program to reduce flood hazards along the Nooksack River. This work will be coupled with future analyses to:

1. Locate areas of net deposition of sediment,
2. Predict the level of flood reduction for various gravel removal plans,
3. Determine the economics of making gravel removal viable, and
4. Define environmental issues and determine ways to address them.
Table 1. Performance standard rationales for gravel removal projects.

<table>
<thead>
<tr>
<th>Performance Standard</th>
<th>Rationale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform removal of gravel from bars</td>
<td>Non-uniform removal could promote channel changes during flood events</td>
</tr>
<tr>
<td>Total amount of sediment removed from the bars should not exceed the amount of</td>
<td>Maintains sediment balance equilibrium</td>
</tr>
<tr>
<td>sediment entering the system</td>
<td></td>
</tr>
<tr>
<td>Limited working hours</td>
<td>Minimizes negative impacts on nearby property owners</td>
</tr>
<tr>
<td>Limitations on screening, washing, crushing, and stockpiling gravel on bars</td>
<td>Activities may contribute sediment and other pollutants to river,</td>
</tr>
<tr>
<td></td>
<td>degrading fish habitat and water quality</td>
</tr>
<tr>
<td>Seasonal limitations on gravel removal activities</td>
<td>July to August is the preferred time for gravel removal activities</td>
</tr>
<tr>
<td></td>
<td>because the majority of salmon outranmigration has occurred by this time,</td>
</tr>
<tr>
<td></td>
<td>return of adult fish upriver has not started, gravel bars are accessible</td>
</tr>
<tr>
<td></td>
<td>due to low flows, and risk of floods are low</td>
</tr>
<tr>
<td>Slope requirements (typically 0.5 to 2 percent), potholes to be filled in, berm</td>
<td>Reduces likelihood of fish stranding</td>
</tr>
<tr>
<td>prohibited between the water and the bar</td>
<td></td>
</tr>
<tr>
<td>No equipment allowed to enter area of flowing water</td>
<td>Avoids disturbance of fish habitat, reduces potential for pollution</td>
</tr>
<tr>
<td></td>
<td>from oils, greases, and other contaminants on heavy machinery</td>
</tr>
<tr>
<td>Site specific prohibitions on gravel removal including requirement of riprap</td>
<td>Prevents bank erosion in areas of higher erosion potential</td>
</tr>
<tr>
<td>installation</td>
<td></td>
</tr>
<tr>
<td>Prohibition against cutting standing timber close to the bank and timber greater</td>
<td>Protects fish habitat—standing trees provide shade and reduce water</td>
</tr>
<tr>
<td>than 6 inches in diameter</td>
<td>temperature; roots maintain stability of soils near banks</td>
</tr>
<tr>
<td>Blind channels and pits within them</td>
<td>Blind channels are channels excavated to the side of the main channel</td>
</tr>
<tr>
<td></td>
<td>and connected it at one end; the channels and excavated pits associated</td>
</tr>
<tr>
<td></td>
<td>with them enhance fish habitat during gravel removal and allow for</td>
</tr>
<tr>
<td></td>
<td>additional volumes of gravel to be removed during scalping operations</td>
</tr>
<tr>
<td>Placement of stumps and logs in blind channels</td>
<td>Enhances fish habitat</td>
</tr>
<tr>
<td>Noise level restrictions</td>
<td>Minimizes negative impacts to nearby property owners</td>
</tr>
<tr>
<td>Refueling to be done landward of the OHTWM and off the gravel bars</td>
<td>Reduces potential for pollution from oils, greases, and other contaminants on heavy machinery</td>
</tr>
<tr>
<td>Hazardous spill response plan required</td>
<td>Provides direction in case of accidents, and minimizes potential for</td>
</tr>
<tr>
<td></td>
<td>water pollution.</td>
</tr>
<tr>
<td>Vehicular access restrictions including construction of paved access aprons,</td>
<td>Minimizes potential for air and water pollution, protects health and</td>
</tr>
<tr>
<td>wetting of access roads, prohibition against tracking mud and debris on County roads,</td>
<td>safety, and meets legal access requirements</td>
</tr>
<tr>
<td>sight distance requirements for access points from work sites to County roads,</td>
<td></td>
</tr>
<tr>
<td>obtaining easements for access</td>
<td></td>
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</tbody>
</table>

Sediment management can become an important part of a flood hazard management program on the Nooksack River if quantifiable flood hazard reductions are found to be achievable, gravel mining operations are conducted according to all relevant regulations, and the economics of excavation and use of river gravel are favorable.
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PART NINE

POLICIES AND PROGRAMS
FOR
FLOOD HAZARD MITIGATION
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Introduction

Australia is the driest continent. McMahon (1982) presented a comparison of world and Australian hydrology showing that in general Australia's streams are considerably more variable than other rivers. For example, relative to mean annual runoff, mean peak annual floods are about an order of magnitude larger in Australian rivers than elsewhere. It is this large variation in flow that leads to significant flood problems in Australia. This paper outlines the system of floodplain management in New South Wales, the most populous state in Australia.

Early History and Settlement Trends

European settlement in Australia commenced in Sydney, the capital of New South Wales, in 1788. From that time towns were established on the fertile floodplains of the state's rivers. Awareness of the flood hazard by the early settlers was generally outweighed by the more pressing demands for survival, and development of the floodplains proceeded. Flood events, even those of great severity, had little discernible impact on the patterns of urban development. This is a trend familiar to floodplain managers the world over.

Institutional Aspects

Political Framework

Australia has a three-tier government. It has a federal government covering national issues. At the second level is a set of six state and two territory governments. The third level is local government. In New South Wales there are 177 local government authorities with populations from less than 2,000 to more than 200,000.
**Distribution of Responsibility**

All three levels of government share responsibility for flood-related issues in New South Wales. The primary responsibility rests with local government, which develops land use planning (i.e. zoning) instruments, called local environmental plans (LEPs), and determines applications for development consent under those plans. The state role is to set policy and provide technical and financial assistance to local government. It also provides the framework for emergency management, response, and recovery. The federal role is primarily to provide financial assistance, both in implementing floodplain management measures and in providing emergency relief during and after natural disasters.

**Evolution of Floodplain Management**

Floodplain development in New South Wales proceeded with some awareness of flood hazard, but with limited reaction to its impact, from the eighteenth century until well into the twentieth. The 1940s and early 1950s saw a series of major floods in New South Wales that caused considerable urban and agricultural losses. The most severe event, the 1955 flood on the Hunter River, inundated 5,000 homes, destroyed 160 houses, killed 14 people and caused enormous urban and agricultural losses. In today’s terms, those losses would be valued at about $600 million (Australian dollars).

**Engineering Management**

In the wake of this event, the state government established a statewide program for subsidizing local government in the construction of engineering flood mitigation works. The program was aimed at containing urban and agricultural losses by reducing the frequency of inundation and by providing good post flood drainage, rather than by necessarily excluding floodwater.

**Planning Management**

At the commencement of this mitigation works program the state government introduced the Hunter Valley Flood Mitigation Act (1956). That Act provided legislative backing for the construction of works and established a system for controlling development on the floodplains of the Hunter River. For 30 years the Act served successfully to prevent development in the most hazardous areas and to prevent development that would, because of its adverse impact on flood behavior, increase the flood hazard for others. However, the control systems in the Act were not extended to other valleys in the state, as might have been envisaged at the time of its implementation. As a result, outside the Hunter floodplain, development of flood-liable land continued unabated. In the mid 1970s a review of floodplain management was initiated in the wake of
another series of significant floods. The review highlighted that, due to increased
development on the floodplains, flood losses had been growing throughout the
life of the flood mitigation works program. A simple planning policy was then
introduced to encourage local government to restrict development on flood-prone
land. It can be briefly summarized as follows:

- No development on land inundated by 5% floods, which were
designated as floodway;
- No development on land inundated by 1% floods where flood-free sites
existed; and
- Removal of existing development from the most hazardous floodways.

This approach between 1977 and 1984 was combined with engineering
flood mitigation works. Effective implementation of the policy required mapping
of flood-liable lands. The mapping was done by state government agencies,
whereas floodplain management was the responsibility of local government.
Consequently, maps were at times published by an agency without a council
being in a position to indicate how the problem would be managed.

By 1982, considerable opposition to the policy had mobilized, the main
catalyst being the identification through floodplain mapping of thousands of
flood-prone properties in the western suburbs of Sydney. Many of these areas
had been developed in ignorance of the existence or the size of the potential
flood hazard. Where mapping identified flood-liable areas, the policy severely
restricted use of the land. Consequently, there was dismay, disbelief, and angry
reaction at the news.

The resulting pressure from land owners and local government forced
a thorough review of the policy and ultimately adoption of a new policy in 1984.
As the primary focus of objection was on floodplain mapping, this was halted
and the associated simple statewide planning rules were put aside. Also, the 1%
flood was abandoned as the statewide standard for defining flood-liable land, in
favor of a flood standard to be determined by each council.

**Merit Management**

Like its predecessors, the new floodplain management policy built on
past initiatives. It retained the primary objective of flood loss reduction, but
determined that this should be achieved via consideration of the merits of the
local situation, rather than through application of standardized planning
restrictions. This philosophical change from a "prescriptive" to a "merits"
approach resulted in a more balanced and flexible attitude to floodplain
management.
The New South Wales government *Floodplain Development Manual* (1986) was set up to outline a process. Although it had to fit into the legal framework of the development approval process it was not written as a prescriptive, clear-cut set of roles. The "non-cookbook" approach is perhaps the strongest feature of the manual.

**Integrated Floodplain Management System**

The current system of floodplain management described in the manual is based on merit and implemented by a classic carrot and stick mechanism. The stick is "duty of care," a long-standing legal concept enshrined in English law and tested in the courts. In lay terms, it pressures a local authority to make a responsible development decision in recognition of any potential hazard of which the authority should reasonably be aware. If a responsible decision is not taken, an owner or developer suffering due to a hazard, such as a flood or erosion, may succeed in a suit for damages on grounds of negligence.

The carrot involves a legislative amendment to the Local Government Act, giving indemnity to authorities from claims for damages from flooding to development they approved, unless it can be proved they did not act in accordance with the principles contained in the manual.

*The Floodplain Management System*

The floodplain management system is a systematic process by which a floodplain management plan can be developed, tailored to the needs of a community and have regard to both the environment and the local flooding characteristics.

The system, now sitting between duty of care and indemnity, is simple in principle but complex in practice. It involves the weighing of dissimilar considerations to achieve an acceptable compromise or balanced decision. The factors to be weighed are social, economic, ecological, and hydraulic facts. The manner and order in which they are addressed is shown in Figure 1.

**Figure 1.** Operation of floodplain management system.
The system can only be effectively implemented at the local government level where the significance of area-specific social, flood, and economic facts can be judged. This presents a problem for local councils which may not have the specialized technical facts and economic capacity. However, this is addressed by the state providing professional and financial support throughout the process and with the federal government also assisting financially, within certain limitations and budgetary constraints. In New South Wales the Environmental Planning and Assessment Act (1979) provides the framework for regulating development and protecting the environment. It requires that in determining development applications, councils consider the impact of the development on the environment, the social and economic effects of the development and "... whether the land to which that development application relates is unsuitable for that development by reason of its being, or likely to be, subject to flooding, tidal inundation, subsidence, landslip, or bush fire or to any other risk ..."

The floodplain management system dovetails neatly with the planning and environmental law of the state.

The Committee

The floodplain management committee is formed by the local council. Its role is to assist the council in the decisionmaking involved in preparing and implementing a management plan. It also provides an opportunity to introduce affected local community representatives into the process of floodplain management at the very start of the process.

The Flood Study

The flood study defines the nature and extent of flood behavior in a particular area. The flood behavior is summarized, in diagrammatic form, showing flood surface contours and velocities. Such diagrams are produced for a range of floods and effectively replace floodplain mapping with a far more detailed picture of the potential flood hazard.

The study report is generally based on a mathematical model that can be used during the management study to define the impact of proposed development or mitigation strategies on the flood situation.

The Flood Standard

The flood standard defines the area of land subject to flood-related planning and development controls. Its selection involves balancing social, economic, and ecological considerations against the consequences of flooding, with a view to reducing the potential for property damage and the risk to life and limb. Councils are encouraged to think hard about adopting a standard other than the 1% flood.
The Management Study

The floodplain management study identifies appropriate management measures and assesses their effectiveness in mitigating the effects of flooding on existing and potential development. It can involve a suite of studies primarily concerned with evaluating impacts:

- the impact of flooding on development;
- the impact of mitigation on flooding;
- the impact of development on flooding; and
- the ecological impacts of mitigation, etc.

As well as evaluating impacts, the management study is the place where economic, social, engineering, and ecological facts are brought together and weighed by the local authority in order to achieve a balanced decision. The flood study would usually include a physical or mathematical model. Use of the model during the management study allows the hydraulic impacts of different management options to be gauged. This includes the impact of large-scale development on flood behavior and losses. A holistic evaluation of the fixture situation removes the problem of the cumulative impact of multiple actions, each of which individually has little impact. From such results, economic, social, and ecological impacts of flooding and floodplain management proposals can be generated.

The Management Plan

A management plan involves the formal adoption by a council of a defined floodplain management strategy. Its development is essentially a balancing act. The plan is the means by which flood-prone land is managed, developed, and controlled in both the long and short term. It provides a common rationale for both site-specific and general decisions, and a sound basis for decision making in respect of mitigation works and management measures.

Implementation

The current New South Wales policy was announced in December 1984. A draft Floodplain Development Manual was released for public comment late in 1985 and indemnity legislation was enacted in 1986. The present manual was gazetted in February 1987. Since that time it has been actively embraced by most councils.
Future Implications

The floodplain management system described in this paper is appropriate to today’s social attitudes in New South Wales and sets optimum solutions as a goal. The Floodplain Development Manual renders achievement of that goal a practical reality. There were initial reservations that the manual and its management process, with its emphasis on site-specific management plans rather than a statewide standard cookbook for planning control, would not work. In practice, however, the process has worked well.

A recent review of the operation of the manual has been carried out. The greatest fault found was confusion between the concept of the local management plan based on merits, and the use of the guidelines for individual development applications, again on merits. Individual developers often argue that assessment on an area-wide cumulative approach contradicts the merits approach. This argument is fallacious and, if accepted, merely perpetuates the problem of the cumulative impact of ad hoc decision making. As the interim situation no longer applies, sections relating to the dealings with individual proposals on an ad hoc basis, are being removed from the manual. The manual is currently being redrafted to fine-tune areas identified in the review as requiring adjustment. However, the overall approach will remain the basis of floodplain management in New South Wales for many years to come and will carry us into the third century of European settlement.

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In the introduction, the Great Flood of 1993 is highlighted, emphasizing the economic, human, and environmental costs associated with decades of unwise land-use decisions, attempts to control the natural phenomena of flooding, and the loss and degradation of floodplain functions throughout the watersheds of the Mississippi and Missouri rivers. The paper attributes the human disaster to inconsistent statutory mandates and fragmented planning and jurisdictional responsibilities across numerous government agencies. In recent years, there has been increasing interest in formulating a more comprehensive, ecosystem approach to protecting and managing human and natural systems to ensure long-term economic and ecological health. A unified national program for floodplain management provides a framework for such an approach.

Effective implementation of a unified national program will mitigate the tragic loss of life and property, and the disruption of families and communities, caused by floods. In addition, it will provide benefits relative to protecting and restoring the viability of riparian ecosystems and contributing to sustainable development of riverine communities. This paper focuses on the strategies and goals presented in the 1994 document, *A Unified National Program for Floodplain Management*, which provides a conceptual framework for achieving the dual purposes of floodplain management: reducing the loss of life and property and preserving and restoring the natural resources and functions of floodplains.

**A Unified National Program for Floodplain Management**

Maintaining the flood-carrying capacity of rivers and streams, preserving and restoring wetlands and other critical riparian habitats, ensuring continued viability of prime agricultural soils, and protecting the health, welfare,
and safety of the public should be viewed as being mutually compatible and consistent with sustainable development. Furthermore, there are a number of intangible benefits relative to quality of life issues such as the basic human need to experience and enjoy natural environments near water (see Wilson, n.d., for example). A unified national program seeks to achieve these goals through wise use of floodplain lands and waters.

The Federal Interagency Floodplain Management Task Force, established in 1975, is charged with carrying out the responsibility of the President to prepare for the Congress proposals necessary for a Unified National Program for Floodplain Management. The 1994 Unified National Program document differs from previous versions in two important ways. First, it includes a new floodplain management strategy—preserving and restoring the natural resources and functions of floodplains. This strategy is presented as being not just an end in itself, but an effective means to reduce human losses as well. Second, in addition to promoting better interagency and intergovernmental coordination, it recognizes the need to establish long-term national goals to be achieved over the next 30 years. Each agency can therefore carry out its mission as directed by Congress, but also further floodplain management goals by augmenting their existing policies and programs.

One of the goals developed by the Task Force is "to reduce by at least half the risks to life and property and the degradation of the natural resources of the Nation's floodplains" by the year 2020. Reducing these risks should be viewed as being concurrently achievable through the strategy of preserving and restoring the natural resources and functions of floodplains and by a coordinated, integrated approach to resource protection and hazard mitigation. An important means to achieve this goal includes conducting an inventory of the structures and resources in those areas most at risk. Technical assistance in this regard could be provided by geographic information systems, floodplain and wetland maps, and data from NASA's Mission to Planet Earth, to name a few.

An Integrated Watershed Approach

As early as the 16th century B.C., the Chinese Emperor Yu recognized that to protect rivers it was necessary to protect the mountains. In the 16th century A.D., Leonardo da Vinci concluded that flooding in Florence was due primarily to upstream deforestation in the Arno River Valley. However, in America, starting in the early 19th century and continuing until recently, federal government policies emphasized a structural approach in trying to control floods and maintain navigation. In addition, because wetlands were deemed to be desolate wastelands and generators of disease, federal policies encouraged and supported the conversion of millions of acres, mostly to create highly productive...
agricultural lands. As we have come to learn all too well, the adverse environmental and economic impacts of these policies have been significant.

In recent years management goals for our rivers have broadened to include improving water quality, protecting wildlife habitats, encouraging waterfront revitalization, enhancing recreational opportunities, and balancing public and private property rights. However, these efforts have often been single purpose and generally local in nature. In progressing toward sustainable use of our riverine resources it is important to identify how best to integrate various programs so that they are not implemented independently of, or in opposition to, each other, but rather in ways that are both compatible and complementary and that protect natural resources while meeting the needs of local communities. Preserving our national parks must continue, but our vision for the future must include a greater emphasis on protecting and restoring the land and water resources where we live, work, play, and spend most of our time.

The administration has recently expressed the need for an ecosystem and watershed management approach as a means to ensure sustainable

Figure 1. The Yellowstone River.
development and environmental quality for present and future generations. A recent report by the National Performance Review, Reinventing Environmental Management, underscores this by stating, "It is self-evident that the federal government should do its utmost to ensure the sustainability of our human communities and the ecological systems upon which we depend." To facilitate this approach it would be appropriate to consider integrating, both procedurally and substantively, the elements of those programs that, taken together, could mitigate flood frequencies and provide a multiplicity of human and environmental benefits. These might include, for example, the flood hazard mitigation provisions of the National Flood Insurance Program, wetlands and watershed protection programs of the Environmental Protection Agency, ecosystem management by the Fish and Wildlife Service, the restoration of degraded rivers and streams by the Army Corps of Engineers, river protection planning by the National Park Service, and best management practices for forests and farmlands by the Forest Service and Soil Conservation Service. In addition, because sound policy must be based on good science, a hydrologic determination of the nexus between effective watershed management at the regional level and a reduction in flooding potential at the community level could provide the necessary technical data to preserve and restore natural resources throughout the watershed.

The Corps of Engineers, for one, has modified its mission to become more sensitive to environmental quality issues. Lieutenant General Williams, Chief of Engineers, succinctly articulated this when he stated, "Our objective must be sustainable development . . . No public works project should be constructed that causes irreparable environmental degradation, for over the long run such a project can neither improve nor even maintain quality of life" (Williams, n.d.).

Conclusion

The challenge now is for all levels of government and the private sector to focus attention on the need for an integrated, sustainable approach to managing the human activities and natural resources within floodplains. This new way of thinking and achieving the proposed national goals will bring us closer as a nation to successful implementation of a Unified National Program for Floodplain Management.
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EMERGENCY WETLAND RESERVE PROGRAM: SUCCESSES AND FRUSTRATIONS

Robert M. Bartels and Mike W. Anderson
Soil Conservation Service

Introduction

The Soil Conservation Service (SCS) is currently involved in implementing a new approach to addressing the recovery from a major flood disaster. This approach, the Emergency Wetland Reserve Program (EWRP), is a voluntary program that gives landowners an option to restoring their damaged cropland and levee systems by offering to pay them to set the land aside for restoration as a wetland. Congress authorized and instructed the U.S. Department of Agriculture (USDA) to use some of the $60 million in emergency funds they provided the agency to implement this process in August 1993 under the Emergency Supplemental Appropriations for Relief from the Major, Widespread Flooding in the Midwest Act of 1993, P.L. No. 103-75, 107 Stat. 739 (1993). The first EWRP signup resulted in an expenditure of over $17 million for 25,000 acres. A second signup began April 1, 1994, and will continue until December 30, 1994. Funding for this second signup comes from the $340 million in emergency funds authorized by Congress in February 1994, to further address disaster recovery, including the protection of floodplain storage/wetland restoration in the Midwest, under the Emergency Supplemental Appropriations, P.L. No. 103-211, 108 Stat. 3 (1994). The actual amount spent from this second allocation for EWRP will depend on the interest in this latest signup and whether USDA implements an environmental easement program.

Partnerships/Cooperation

The program has been most successful in locations where many different interest groups and landowners have worked together to implement the program. The Louisa 8 Levee District in Iowa and the Frost Island Levee District near St. Francisville, Missouri, are two examples in which multiple landowners needed to have their concerns addressed before EWRP could be implemented. This meant recognizing the overall need of the group and applying the program to address the entire impacted area, not just each individual landowner. Those portions of the area that could meet the requirements of the program were offered the opportunity to join the program. In Missouri, over 75% of the land enrolled in EWRP from the first signup involved working with a group of landowners so that the levees did not have to be rebuilt. When the
SCS program could not meet all of the concerns of the local landowners, other interest groups including the Fish and Wildlife Service (FWS), local state agencies, and various special interest groups, worked with SCS and the landowners to ensure implementation of EWRP. Everyone worked toward a situation where the levees would not be replaced and as much of the land as possible would be restored to a wetland/flood water storage area. At least 10 such group implementations are included in the applications selected from the first signup.

**Eligibility and Priority Criteria**

The interim rule for the EWRP was published in the *Federal Register* November 29, 1993 (U.S. Department of Agriculture, 1993). This rule included a listing of items to be considered in determining the eligibility of a particular site and what the individual states were to include when establishing a priority ranking process. Some of the items included in the eligibility discussion were:

- The land had to have been flooded during the Midwest floods of 1993.
- The fair market value of the restored land must be less than the cost of restoring the land and repairing levees/channels.
- The land must have historically been a wetland and likely to have its wetland value restored with minimal costs.
- The land must have been cropped in at least one of the five previous crop years.

Items identified to be in the priority-setting process were:

- Floodway expansion.
- Protection and enhancement of habitat for migratory birds and wildlife and contribution to the recovery of threatened and endangered species.
- Proximity to other protected wetlands.
- Level of wetland hydrologic conditions that could potentially be restored.
- Wetland functions and values.
• Likelihood of successful wetland restoration.

• Cost of restoration and easement purchases.

Impact to Date

The first EWRP signup closed December 30, 1993, with 498 applications received for consideration. The applications covered approximately 43,600 acres of land impacted by the flood. Early evaluations determined that almost 80% of the applications met the minimum requirements of the program. The FWS and SCS personnel evaluated each site to determine eligibility, define the area that could be included in the easement offer, and determine the characteristics of the site that impacted the priority assigned to the site. These data were reviewed at the SCS state offices and a priority was assigned each application. Once the distribution of funds was known, each state offered the program to the highest priority sites and others were notified that their application could not be covered with the initial $17 million allocated for EWRP. About 250 applications were selected from the first signup, covering about 25,000 acres. More than 12,000 acres of the 25,000 acres was land that previously was protected by levees and now the levees will not be rebuilt. In other places, through the use of this program landowners have reconstructed the levees, but farther from the river than they were before the flood.

Congress passed a second emergency funding bill in February 1994 (P.L. 103-211), that included over $340 million for the SCS to use in addressing disasters across the United States. The intent of SCS is to ensure that as many of these funds as possible are made available for EWRP or a similar program to offer the landowner the option of returning the damaged cropland to its natural state, usually a wetland, instead of intensive crop production. The EWRP program requires that the land enrolled in the program be restored to a wetland. Many of the areas of severe damage in Missouri and some of the areas in Iowa and Illinois had too much sand deposited to meet the wetland restoration requirement. Therefore, we are currently working within the USDA to see if we can develop an environmental easement program that is acceptable to multiple interest groups as well as landowners.

Definitions/Restraints

The implementation of this program has been an educational process for both our own agency personnel and our partners. We are still defining and documenting the program’s expectations and the meaning of different terms. P.L. 103-75, passed August 12, 1993, authorized the use of emergency supplemental appropriations for EWRP with the following wording:
Provided further, that if the Secretary determines that the cost of land and levee restoration exceeds the fair market value of an affected cropland, the Secretary may use sufficient amounts from the funds provided under this head to accept bids from willing sellers to enroll such cropland inundated by the Midwest floods of 1993 in any of the affected States in the Wetlands Reserve Program as authorized by subchapter C of chapter 1 of subtitle D of title XII of the Food Security Act of 1985.

P.L. 103-211, covering emergency supplemental appropriations, passed February 12, 1994, included almost the exact same wording.

Many questions have surfaced as USDA/SCS addresses the implementation of this new program.

- Which agency in the USDA is to implement it? The Emergency Watershed Protection Program, named in the appropriations bill, is managed by the SCS, while the Wetlands Reserve Program (WRP) is directed by the Agricultural Stabilization and Conservation Service (ASCS). Discussions at the USDA occurred for over 60 days on this issue and finally in October 1993, it was decided that SCS would be the one to develop the rules and manage the Emergency Wetland Reserve Program.

- What exactly is meant by the term fair market value? Is that the value of the land as it exists the day after the flood, as it existed the day before the flood, or the value it will have when it is restored by the landowners using both their own funds and government assistance? This term applies to two phases of the program as it is being implemented. The first is to decide if the land is eligible for consideration for enrollment in the program and the second is to help determine what a fair easement value is for the land.

- Should the program be implemented by having the landowners submit bids for inclusion of their land or should some type of fair easement value be established for the different areas in the state and the landowners offered that value if they enroll? It was decided that the fastest way to implement would be through the easement offer format (U.S. Department of Agriculture, 1994). Therefore, when landowners express interest in the program, they know the value they will receive for granting a perpetual easement on their land. This greatly speeded up the acceptance/planning process when compared to the bid process

- Was it the intent of Congress that only those lands that could be restored to wetland conditions be included in the program? By using the term Wetland Reserve Program in the bill, the SCS/ASCS/FWS have attached to EWRP almost all of the rules/restrictions in the Wetland Reserve Program. Therefore, many of the areas that were covered with sand during the flood are not eligible to be enrolled in the program. In these cases, the farmer only has two options: accept the fact that land is useless and will never provide income, or spend a lot of funds to recover the land and rebuild the levees. It is hoped that we can address these areas by implementing some kind of environmental reserve program that will allow the landowner an option to restore the cropland and rebuild the damaged levees and channels.

- Should this land be kept in private ownership, or should the SCS work with other partners to use funds from the emergency appropriations to help purchase the land with a federal or state agency taking over ownership and management of the land? Here the SCS has determined that since Congress referred to the Wetland Reserve Program in the emergency funding bill, USDA/SCS was to implement EWRP using easements, perpetual if possible. The current owner will still have limited use of the land and can control access it.

- How detailed an evaluation is needed to determine the reclamation costs of the cropland and levees to ensure that the reclamation costs do exceed the fair market value? This is one of the first criteria the application must meet before the site can be considered for EWRP. This question has caused concern because not every impacted state calculated the costs using identical procedures. As discussed earlier, it took USDA about 60 days to decide who would implement and an additional 45 days to publish the guidelines and rules. During this time, all SCS offices were being pressured by landowners as to whether their land was or was not eligible for consideration for EWRP. When the interim rule was published, the signup began almost immediately and SCS offices used the best procedure available to determine eligibility.

Conclusions

This program is in its infancy and appears to do a good job of addressing many issues. In the long term, it will save the expenditure of future disaster funds by removing the land from intensive crop production. In the short
term, it provides the landowner an option to commit considerable capital and
time to recover the cropland or enroll in LWRP. All of the land enrolled in
EWRP will provide long-term floodplain storage and other environmental
benefits associated with the riverine wetland landscape.

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NEW DEVELOPMENT IN DEEP FLOODPLAINS IS BAD PUBLIC POLICY: THE NATOMAS BASIN EXAMPLE

Gary W. Estes
Citizen

The Public Policy Issue

The flood protection programs of the U.S. Army Corps of Engineers (Corps) and the National Flood Insurance Program (NFIP), administered by the Federal Emergency Management Agency (FEMA), work together to increase the number of people and buildings at risk of catastrophic flooding. This increased risk is caused by encouraging more people to live and more buildings to be constructed in deep floodplains, such as Natomas Basin. This result is caused by the Corps building flood control structures, like levees and dams, creating a false sense of safety. Once a floodplain is considered "protected" from the 100-year flood by such structures, then urban development can proceed without any NFIP restrictions.

The NFIP compounds this false sense of safety by making flood insurance available to people who move into the "protected" floodplain, but not requiring flood insurance. The NFIP encourages floodplain development by offering the federal government's "seal of approval" that floodplains are safe for development. This paper argues that to knowingly encourage floodplain development that increases the risk to public health and safety is bad public policy.

The Physical Location

Formed by the confluence of the Sacramento River and American River, the Sacramento floodplain contains 116,000 acres (181 square miles). A portion of this floodplain, known as Natomas Basin, was formed by constructing over 41 miles of levees. This 55,000-acre human-made basin was created in 1914 to "reclaim" wetlands and floodplain lands for agriculture. Water marks its boundaries. Some 20.6 miles of canals plus another 20.6 miles of the Sacramento and American Rivers encircle the Basin. Approximately 7,300 acres

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1This is a summary of a 20-page public policy issue paper. If you want the complete paper, please write the author at 4135 Eagles Nest, Auburn, CA 95603, or call (916) 889-9025, or fax: 916-823-5844.
(13%) of the land is in urban use and the remaining 47,600 acres (87%) is agricultural and vacant land available for development (U.S. Army Corps of Engineers, 1991). Flood depths range from 8 to 23 feet.

Increasing the Risk to Public Health and Safety

Natomas Basin was considered "protected" from the 100-year flood by 41 miles of encircling levees. Like elsewhere in America, urban development was proposed to replace farming in Sacramento's floodplain. When officials of Sacramento City and Sacramento County decided to approve urban development, it made sense at the time. Natomas Basin is flat land and a 15-to-30-minute drive to downtown Sacramento. Since the level of flood protection met the minimum federal standards, urban development proceeded.

In February 1986, record-breaking rainfall in Northern California caused the Sacramento and American rivers to reach new record high flows. The Natomas Basin levees held, but weaknesses were found. Urban development stopped because the FEMA 100-year flood control standard was no longer met. Once that standard is restored, urban development can continue on the vacant and agricultural land totaling 47,600 acres (74 square miles) in Natomas Basin—an area larger than the District of Columbia (69 square miles).

What are the possible consequences from further urban development in Natomas Basin? In its report on Sacramento flood hazards, the Corps of Engineers identified the flaw in all the flood control alternatives examined for protecting Sacramento: All flood control alternatives increase the risk to public health and safety. Why? More people and buildings will be exposed to flooding due to further urban development (U.S. Army Corps of Engineers, 1991).

Proposed urban development plans by local governments would add over 170,000 people and over $13 billion of new buildings and their contents in Natomas Basin. What magnitude of human and economic disaster will befall the Sacramento area when a flood inundates a fully urbanized Natomas Basin? To answer this question let's compare the Great Midwest Flood of 1993 to a future flood in Natomas Basin with 200,000 people living in 93,000 homes and over $15 billion worth of structures and contents. Table 1 shows the comparison.

The comparison is striking. In the Midwest, the flood damage and destruction of $12 to $15 billion was spread over 31,250 square miles beside rivers stretching hundreds of miles. In Natomas Basin, the estimated destruction of $8 to $10 billion is concentrated in 86 square miles. Crop damage is half of the Midwest damages because flooding occurred during the growing and planting season. Property damage is the entire source of damages in Natomas Basin. Twice as many homes would be damaged in Natomas Basin (93,000) as in the
Table 1. Comparing the Great Midwest Flood of 1993 to a future flood of an urbanized Natomas Basin.

<table>
<thead>
<tr>
<th></th>
<th>Great Midwest Flood of 1993*</th>
<th>Future Flood Urbanized Natomas Basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deaths</td>
<td>48</td>
<td>20 to 900</td>
</tr>
<tr>
<td>People Evacuated</td>
<td>100,000</td>
<td>200,000</td>
</tr>
<tr>
<td>Homes Damaged</td>
<td>45,000</td>
<td>93,000</td>
</tr>
<tr>
<td>Total Damages</td>
<td>$12 to $15 billion</td>
<td>$8 to $10 billion</td>
</tr>
<tr>
<td>Property Damage</td>
<td>$6 to $7 billion</td>
<td>$8 to $10 billion</td>
</tr>
<tr>
<td>Crop Damage</td>
<td>$6 to $8 billion</td>
<td>0</td>
</tr>
<tr>
<td>Square Miles Flooded</td>
<td>31,250</td>
<td>86</td>
</tr>
</tbody>
</table>

* (Sacramento Bee, 1993) Actual and estimated as of Friday, August 6, 1993.

Midwest (45,000 as of August 6). The potential for loss of life is dramatic: 20 to 900 people for Natomas Basin (Sacramento Department of Planning and Development, 1993). Why would we knowingly create a catastrophe?

Severity of Flood Destruction

Why does flooding in Natomas Basin cause so much destruction? Described as a bathtub without a drain, the physical features of Natomas Basin cause deep flooding of long duration. These features are:

- River and canal levels are higher than the ground level inside Natomas Basin, during flood events.
- Rivers and canals surround Natomas Basin.
- Levees surround Natomas Basin on all sides.
- Levees are 15 to 20 feet higher than the inside land area (forming the bathtub walls).
- Natomas Basin has no drain.
These physical features result in:

- Flood waters filling Natomas Basin whenever levees fail.
- Flood duration of 30 days.

Together, flood depth and duration have a significant impact on property damage in Natomas Basin. The Corps estimated over 31,000 people and 13,730 structures called Natomas Basin home in 1990. The value of the structures and contents estimated at $2.4 billion would suffer flood damage estimated at $1.6 billion, which is over 67% of the market value. The Corps also estimated damages to all types of buildings and contents would reach 100% where flood depths exceed 13 feet (U.S. Army Corps of Engineers, 1991). For single-story residential buildings, flood depths of 8 feet cause 100% damage to the structure and contents (Sacramento Department of Planning and Development, 1993). A total of 91% of the land area (or 50,000 acres) could flood to depths exceeding 8 feet. Approximately 59% of Natomas Basin's land area (or 32,450 acres) could flood to depths exceeding 13 feet and 32% (or 17,600 acres) could flood to depths of 8 to 13 feet. Even if a higher level of flood control is provided, the depth and duration of flooding in Natomas Basin is the same. Severity of flooding is the same no matter the frequency, or probability, of flood (U.S. Army Corps of Engineers, 1991).

**Accountability for Development Consequences**

Who will be held accountable for the consequences of further urban development in Natomas Basin? In the minds of land speculators, developers, and the local government officials of Sacramento City, Sacramento County, and Sutter County, further urban development is the "manifest destiny" of Natomas Basin.

After 100-year flood protection is restored to Natomas Basin, FEMA through the NFIP will give its "seal of approval." Development will continue. To local promoters and decisionmakers, this means the flood risk has been determined by FEMA to be acceptable to the federal government. FEMA’s acceptance allows the flood risk caused by approving further development to be shifted from land speculators, developers, and local government officials to federal taxpayers. The land speculators and developers make their $5 to $10 billion of profits and leave the disaster cleanup bills for federal taxpayers to pay.

The accountability for decisions will only occur when institutions and individuals making decisions are held accountable for the resulting consequences. Without such ultimate accountability for their actions, land speculators
and developers will pressure and encourage local government officials to allow further development in Natomas Basin. Continuing to shift the accountability for development consequences to the federal government, and ultimately federal taxpayers, is bad public policy.

**Correcting the Problem**

How can the accountability for local land use decisions be left with the decisionmakers? The answer is found in the Coastal Barrier Resources Act (COBRA) enacted in 1982. COBRA prohibits new development in designated coastal barrier areas from receiving flood insurance and other federal financial assistance. By removing the federal encouragement to development (i.e., flood insurance, disaster assistance, and loans), land speculators, developers, and local government officials are held totally accountable for the consequences of their land use decisions. Development is still allowed in the floodplain, but the federal government does not provide financial assistance nor does it provide flood insurance (Federal Emergency Management Agency, 1989). All the risks and profits remain with those land speculators, developers, and local government officials who are willing to invest their money in floodplain development. The buck stops at the local level, where it belongs.

**Conclusion**

The basic public policy issue is whether or not the federal government should increase the risk to public health and safety by encouraging additional urban development in deep floodplains, such as Natomas Basin. The arguments against encouraging further development are based upon these values:

- Government should reduce risk and protect the public health and safety, not increase such risks.

- Government should spend limited tax dollars protecting public health and safety, not waste it on projects increasing the risk to people and property.

- Predicting and controlling the forces of nature are subject to unacceptable error and mistake, not an activity government should depend upon for protecting public health and safety.

- The accountability for the consequences resulting from decisions should remain with the decisionmakers responsible, not transferred to others.
• Each generation should evaluate the short- and long-term impacts of its actions, not create deficits and billion-dollar blank checks payable by future generations for future flood disasters.

• Tax dollars should benefit the larger public good, not produce windfall profits for a few land speculators and developers.

Urban development in Natomas Basin is a prime example of federal policy gone wrong. Encouraging further urban development in deep floodplains is bad public policy. The Great Midwest Flood of 1993 shows the folly of continuing business as usual. Saying, "it has always been done this way" is no excuse for continuing the practice. Now is the time to make fundamental changes.

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U.S. Army Corps of Engineers
FOREST PRACTICES AND THEIR EFFECTS ON FLOODPLAIN ANALYSIS

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Introduction

Unlike many other papers of this kind, I will not try to point out the affects that forestation, or more properly, deforestation has on rainfall/runoff. The main purpose of this paper is to state a preliminary policy of the Federal Emergency Management Agency (FEMA) when we are approached by client groups that wish to study the effects of deforestation practices on rainfall/runoff.

From time to time, questions are raised at local community meetings regarding the effects of logging practices in basins. A variety of questions arise with respect to water quality, sedimentation, and water quantity. Generally, local constituents cannot believe the 100-year designation on our maps and tend to look for reasonable ideas for the floodplains being so wide and the elevations being so high.

Discussion

In the Northwest, logging has especially come under increased scrutiny. It is easy to see large areas of watersheds denuded, and subsequently conclude that this is the reason for higher flows and, therefore, increased floodplain widths.

In early 1993, King County, Washington, initiated a flood study on the Raging River near the Snoqualmie-Fall City area of the county. King County totally funded this study, and its purpose was to identify flood hazards in an area that is currently identified as an Approximate A zone. The limits of the study extended from the confluence of the Snoqualmie River to the downstream detail limits of an existing Flood Insurance Study, near Interstate 90, a distance of about 6.5 miles. Since the study was to tie into an existing detailed study area and was to be placed on a FEMA map as a revision, the study would need to be coordinated with our office.

During the initial stages of the county contract, the consultant for the county identified an interesting phenomenon in his hydrologic analysis. The statistical analysis of existing gage records reflected significantly higher discharges in the period from 1975 to the present than from the early gage records, from 1946 to the 1974. For the basin of the Raging River, coinciden-
tally, logging practices began in 1969, increased steadily and reached a steady
deforestation rate in 1975 and have continued at that rate ever since.

The latter statistical analysis, the one from 1975 to the present,
identifies 100-year flows 250% higher than the analysis for the first 29 years of
record. Clearly, since the latter analysis 100-year flows were over 100% higher
than the existing FEMA 100-year flows, we were very interested in the
statistics.

King County is the premier community in the Northwest when it comes
to sound floodplain management and innovative thinking that results in lower
flood losses. Naturally, the county looked at the statistics and was alarmed with
the higher flows. The reasoning behind their concern was simple. The was no
expectation of changing the forestation practices, so would not the risk be more
conservatively identified by using the later gage records, the higher flows? The
county asked for a meeting with our office to discuss this issue.

Since one of the objectives of the study was to have our maps formally
revised, the county had to have concurrence from our office on the final
discharges. After deliberations among the county, the regional office of FEMA,
and FEMA headquarters, the following is the essence of our preliminary policy
regarding forest practices on gaged streams.

logging activities in the watershed, which is far shorter that the entire gage
record, should not by itself be used to determine the 100-year discharge. Using
a long, uninterrupted period of gage record to perform a statistical analysis is
the most appropriate method of estimating the 100-year discharge. However, a
basic requirement for this type of analysis is that conditions within the watershed
during the period of gage are similar and that record data are consistent.
Whether logging within the watershed would affect the discharge depends mainly
on the amount and location of the logging activities.

"The entire gage record should be used to perform the statistical
analysis to determine the 100-year discharge. However, adjustments will have
to be made to the gage records of the before-logging period so that they are
consistent with existing conditions of intensive logging activities. This can be
done by first examining the gage records and several storm events to determine
if the increase in discharges is indeed the result of logging in the watershed. If
comparisons show that the amount of runoff is consistently higher for the
selected storm events after logging than corresponding events before logging,
this indicates that the increase in runoff is due to logging. The storm events
selected should be comparable mainly in the amount of rainfall and antecedent
moisture conditions. If such a comparison shows that the increase in runoff is
a result of the increase in logging, then the effect of logging could be
approximated by establishing a correlation between rainfall and peak flows
during the before-logging and after-logging periods. After this correlation is
established, the before-logging discharges can be multiplied by an adjustment
factor to make them consistent with the more recent records. However, we recommend that the U.S. Forest Service be consulted for determining adjustments to flow. After all necessary adjustments have been made, a Log-Pearson Type III (LP 3) analysis can be performed for the entire gage record to determine the 100-year discharge."

We prefer that the gage record be used in the statistical analysis to compute the 100-year discharge. However, if the county does not want to use the gage record, we suggest using either one of the following computer modeling techniques: A single-event computer model, such as the U.S. Army Corps of Engineers HEC-1, calibrated using events that took place after logging; or a continuous streamflow model calibrated using the after-logging period record. After the model parameters are calibrated, rainfall data can be used in the continuous simulation model to generate peak flows for the before-logging period. An LP 3 analysis then can be performed for the entire record, which includes the before-logging simulated flows and the after-logging recorded flows.

Since the gaging site at this particular stream is located some distance away from the study area, standard prorating techniques must be used to establish the correct discharge values.
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PART TEN

FUNDING STRATEGIES
AND
MEASURES OF COST-EFFECTIVENESS
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synergism (sin'er jiz'em) n. [ModL synergismus, synergos, working together, see SYNERGY] 1 the simultaneous action of several agencies which, together, have a greater total effect than the sum of their individual effects.
—Webster's New World Dictionary, Third College Edition

In American Indian culture the term Nania means "All together." This is a powerful concept when looking for creative common sense strategies to help individuals and communities cope with repeated flooding. For that reason, Nania was the name of the 18th annual Association of State Floodplain Managers conference, held this year in Oklahoma.

Increasingly, individuals—residents, business owners, community leaders, and taxpayers—are becoming fed up with the hardship and costs associated with repeatedly rebuilding structures in areas that flood year after year. People living in flood hazard areas know only too well the high costs and emotional traumas associated with rebuilding, only to face another devastating flood.

The costs of rebuilding from repeated flooding go well beyond the repair of individual structures. There are costs to local governments—responding to crisis situations and repairing roads, bridges, and infrastructure. There are also costs to volunteer agencies, private organizations, and insurance companies and their premium payers.

Americans are generous in times of disaster. Time and again we see outpourings of support and donations to people hit by catastrophe. Communities come together and people help their neighbors. Despite this empathy for the plight of victims, the question is often raised: Why must taxpayers' money subsidize people who live along coastal or river areas that flood again and again and again?

As a government, we do not dictate where people can live, own property, or operate their businesses. We can, however, use sound zoning regulations and floodplain management programs to help ensure that people who remain in flood-hazard areas follow guidelines that minimize future losses.

However, nationwide we are finding that people are willing to move out of the floodplain. Wherever people are subject to repeated, devastating floods—from Aroostook County in Maine, to the Massachusetts coast, to
The Patchwork Quilt

communities on the Mississippi, Missouri, and Platte Rivers—people are clamoring to find ways to relocate away from their unfortunate situations.

Accomplishing this objective is not simple. No single agency or program exists that effectively addresses all the diverse needs in areas impacted by repeated floods. But by Nania—working all together—creative strategies can be crafted for individuals and communities and, thus, turn vision into reality.

We must all work together to bring about a successful relocation, acquisition, or buy-out program for a neighborhood or even an entire community. We must utilize what can be called a patchwork quilt approach. This concept is based on the American idea that scraps of "this and that" can be turned into a useful, warm, and very valuable object by one or more persons who possesses a vision of the final product.

This is not an easy or rapid process: it requires constant attention to what we refer to as the "10 Ps":

1. **Posterity.** We hold the earth in trust for future generations. We must think long term and broadly, finding creative solutions. Just because something has "never been done that way before" does not mean it will not work now.

2. **People.** Put people first—*all people*, including victims, public officials (who may also be victims of the disaster), taxpayers, and future generations.

3. **Patchwork.** No single program exists to meet all the needs of the community or each individual. We need to take a bit of this and that.

4. **Persistence.** Never give up. Keep talking. Keep negotiating. Keep searching for the right answers and the right programs to meet specific challenges.

5. **Problems.** Keep focusing on problems. Synergy is important. Bring resources together. Communicate. Focus. How do allies, partners, and skeptics view the problem? How can differences be resolved and critical needs met?

6. **Prudence.** Focus efforts on achievable goals. Everyone's time is limited. Do not squander time on roadblocks. Move on and come back later.

7. **Personal Decisions.** Following a flood, people must make critical decisions about their lives, their families, and their futures. Remember
that this is a democracy and their decisions must be made within the framework of laws and regulations. They will probably require much help and support, as well as crisis counseling, which may be vital.

8. **Pro-Active.** Take initiative. Seek help. Expand your staff. Take advantage of the limited window of opportunity to create, fund, and complete the program.

9. **Patience.** This is a difficult time for everyone—victims, community leaders, and people assisting with the recovery. We need patience. We need to maintain calm. Help is available for everyone.

10. **Plain Common Sense.** If we can describe our programs in a straightforward way, the concepts should "sound right." They should sound like the logical solutions—the "common sense" things to do.

**Creating the "Patchwork Quilt"**

The analogy of a "patchwork quilt" is useful in clarifying the process for communities seeking viable, common sense solutions to complex problems. Communities need to know where to start and how to proceed. Assessing needs, accessing help, and identifying funding sources requires creativity, vision, leadership, and time.

*The Quilter: Community Leadership with Vision*

As the community picks up the pieces after a disaster and begins to rebuild, there is a window of opportunity. It is a time to fashion a new vision of the future, where people are safe from the fear of yet another flood. The quilter must show strong leadership to develop and implement a comprehensive plan that will leave a legacy for the future.

*The Pattern: Getting Technical Assistance*

Whether building a house, sewing a quilt, or relocating a community, a pattern or plan is needed. Imagine a quilter without a pattern. The quilter could get material and thread and sew the pieces together into a quilt, only to find that there is too much of one type of fabric and not enough of another. Colors and patterns may clash. Thus, time, energy, and money are wasted in trial and error.

The more efficient way is to create a design, map out a plan, and measure each piece. Some quilters have the time, energy, and experience to create their own designs. Others turn to proven patterns but choose their own
fabrics and colors. The same is true when fashioning a relocation project. Just as quilters look to patterns for guidance, community leaders can turn to a number of resources for the technical guidance needed to complete a complex project.

Technical assistance can be provided by a variety of resources: state hazard mitigation officers, the Federal Emergency Management Agency (FEMA), regional planning commissions, councils of government, and universities. FEMA in particular provides valuable assistance because of the agency’s statutory role in coordinating the efforts of all federal agencies in disaster recovery.

The Fabric: The Array of Programs

Just as with any quilt, the ultimate appearance depends upon the fabric chosen. In the case of relocation, the fabrics are the various programs that provide funding and services that can make the quilter’s vision a reality. In addition to seeking out expertise to formulate the pattern, the quilter can also look to resource guides such as the one developed following the Great Flood of ’93 in Iowa.

Sewing it All Together: Taking Action

In the early days of this country, an old fashioned quilting bee would bring together community leaders; residents; business owners; and various government, private, and volunteer agencies. Likewise, a community can take action to create synergy for a better tomorrow.

Working All Together
and How it All Works

Assembling the pieces, at first, can seem mind-boggling. It requires assessing the desires of each individual and business owner in an area, balancing their needs with broader community objectives, determining the best course and the right funding sources, and putting the process in motion.

Take a look at a hypothetical community—Anywhere, Rivertown, U.S.A.—to get a clearer picture. Picture an agricultural community of 4,000 people located along the majestic banks of the Great Fast River. The small-town government has only a few full-time employees or officials. Some of these officials wear many public hats and run their own businesses, too.

The people in the town are used to the floods, which occur every few years. Usually, basements get flooded, and when waters recede people dry out their furniture and start over. The last flood was different. Water levels were higher than ever. Houses that had only had basement flooding in the past were
soaked to the roof-line and remained under water for months. Some were washed from their foundations.

One neighborhood of 25 homes was hit particularly hard. The flood undermined many public roads and caused severe damage to private wells and septic systems. As the recovery process began, a few resources were already in place for the community:

- The town participates in the National Flood Insurance Program (NFIP) and FEMA representatives had already made community leaders aware of flood insurance program requirements for rebuilding substantially damaged homes.

- The state awarded a $150,000 Department of Housing and Urban Development (HUD) Community Development Block Grant (CDBG). Town officials planned to target $100,000 of this money to help the neighborhood in question. The remaining CDBG funds were used town-wide for other flood recovery activities. Town officials approached the regional planning agency to help develop a strategy to maximize use of these funds.

Working together with the regional planning agency, community leaders developed a "patchwork quilt" strategy. The result was the acquisition and demolition of the 25 hard-hit homes along the Great Fast River and their replacement with new, energy-efficient homes built away from the flood hazard zone. The new area was provided community water and sewer. The vacated area was replaced with a park, restored wetlands, and a centerpiece historic landmark. These efforts required the help of no less than 20 different agencies and programs.

Let's look at some of the patchwork (Figure 1).

**Acquiring the Properties:**

**Elements of a Buy-out**

Funding sources may differ. Qualified homeowners with flood insurance can make use of the National Flood Insurance Program 1362 program funds. Those with no flood insurance may combine funds from the CDBG and the FEMA 404 Hazard Mitigation Grant programs. Most programs must be applied for separately, and each has its own guidelines. Some programs require matching funds from the community. Others provide specific requirements that must be followed after a property is acquired.
### Acquisition/Relocation Programs

Has your community explored all the options?

<table>
<thead>
<tr>
<th>Morel</th>
<th>Emergency Services</th>
<th>Community Rating: Townwide Benefits</th>
<th>Crisis Counseling</th>
<th>IRS Casualty Losses</th>
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</thead>
<tbody>
<tr>
<td>EPA: Various forms of assistance</td>
<td>ARC: Transient Accommodation</td>
<td>Wetland Reserve and similar programs</td>
<td>HUD Home Funds; Section 108</td>
<td>EDA: Other Funds</td>
</tr>
<tr>
<td>FmHA Community Water/Sewer</td>
<td>Historic Preservation</td>
<td>Red Cross/VOAD labor and funds</td>
<td>U.S. Dept. of Energy</td>
<td>Town Crews: soft match</td>
</tr>
<tr>
<td>FEMA IFG Minimal Home Repair</td>
<td>Elder Affairs/Crisis Counseling</td>
<td>Private funding</td>
<td>FEMA Section 1362</td>
<td>FEMA Public Assistance II</td>
</tr>
<tr>
<td>Dept. of Transportation</td>
<td>FEMA Public Assistance</td>
<td>NFIP SBA FmHA</td>
<td>FEMA Section 404</td>
<td>CDBG</td>
</tr>
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<td></td>
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</tbody>
</table>

**Figure 1. The patchwork quilt.**

### Funds to Individuals:

**How Do They Get Through the Process?**

Once homeowners have decided to move and have found appropriate sources for acquisition expenses, they will be concerned about the costs of moving, buying a new home, and starting over.

Whether acquisition funds are provided by CDBG, Section 404 of the Robert T. Stafford Disaster Relief and Emergency Assistance Act, or the NFIP, individuals can expect to be paid pre-damage fair market value for a damaged property. Flood insurance proceeds and any federal funding provided for minimal repairs will be included in the final price.

In addition to funds for acquisition, homeowners may expect financial help from other sources. They may utilize low-interest disaster loans from the Small Business Administration. Grants from FEMA's Minimal Home Repair
Program or the state-administered Individual and Family Grant program may be called into play. Often, disaster survivors can get some cash relatively quickly by applying for refunds through the IRS disaster casualty loss program. If they still have needs, voluntary agencies like the Red Cross or the Mennonites can provide building materials, labor, or other types of assistance.

Affected individuals must be supported and counseled. Agencies such as the state or local department of elder affairs can help. In many cases, the state department of mental health will implement a crisis counseling program to address disaster survivors’ needs—especially those who are facing major changes.

**Funds to the Community:**
**Putting it all Together**

Buying up neighborhoods, building new subdivisions, and creating parks and open spaces requires funding and skills. We have talked about funding sources for acquiring properties. Yet, where do funds come from to administer aid, handle permitting, build new infrastructure, and preserve historic properties?

For starters, if there is a declaration for a public assistance disaster, FEMA funds can be used for building permit review, demolition, environmental review, and possibly some legal work related to demolition and rebuilding. Other agencies that may help include the U.S. Army Corps of Engineers, the Department of Energy, the Economic Development Agency, the Environmental Protection Agency, the Department of Housing and Urban Development, the Department of Transportation, and the National Trust for Historic Preservation.

Some funding sources require local and state matching funds. Town crews can be utilized to satisfy the requirements of these programs.

To round out the package, private resources are sometimes available. Local fund-raising efforts can support such things as business development and historic preservation.

**Time, Patience and Synergy . . .**
**A Whole Greater than the Sum of its Parts.**

Time and patience are required in putting together the "patchwork quilt." The devastation may have taken many forms, and the recovery may take months or even years. But by working *all together*, balancing each individual’s needs with the community’s long-term objectives, Nania, *the synergism*, takes form.
COST-EFFECTIVENESS AND HAZARD MITIGATION: A MARRIAGE MADE IN THE U.S. CONGRESS

Gary L. Sepulvado
Federal Emergency Management Agency

Introduction

The hands of cost-effectiveness and hazard mitigation were joined in the U.S. Congress with passage of the Stafford Act in 1988. The bells did not ring, rice was not thrown, and only a small reception was held for the newly wed couple. Everyone was simply exhausted by the struggle of getting to the altar. It was a benign marriage for a couple of years. But marriage invites change, however imperceptible it may be. This paper is about change—the change in hazard management brought on by the marriage of cost-effectiveness and hazard mitigation, particularly the change in floodplain management.

Cost-effectiveness assessments (which some call the "CE" assessment, pronounced "see") and hazard mitigation are linked in profound ways; their rather quiet marriage belies the revolution that the union is causing in reducing hazard losses. The Federal Emergency Management Agency's (FEMA) Hazard Mitigation Grant Program is, for example, using CE assessments to look at the sufficiency of proposed mitigation grants, which include such things as disparate as historic structures and emergency power generators. Another major program, the National Flood Insurance Program's "1362" acquisition program is beginning

1A wise person once said, "If you steal from one author, it's plagiarism; if you steal from many, it's research." I am indebted to many people who produced the information in this article, including Kenneth A. Goettel, Ph.D., Gerald L. Horner, Ph.D., Robert A. Olson, and Clifford Oliver and Ugo Morelli of FEMA. I am responsible, however, for any misrepresentations of their work that may appear here.


3Following the seminal work in FEMA's earthquake program, the agency's mitigation grant program investigated the possibility of a method to determine the cost-effectiveness of hazard mitigation measures, whatever the hazard agent. A cross-fertilization occurred, producing a method applicable to any measure suggestive of mitigating future damages and losses.

444 CFR 206, Subpart N, Hazard Mitigation Grant Program.
to use CE to round out analytically the potential for reduced flood damages. Soon, state and local planning agencies, including emergency management agencies and offices, will use CE assessments to identify risks and concomitant mitigation measures.

Old Stuff with a New Flair

This paper sketches how an old economic model, cost-benefit analysis, is used with a new flair to avoid future disaster damages. Basically, a CE assessment produces a benefit-cost ratio (BCR) that demonstrates whether the net present value of avoided future damage exceeds the cost of the mitigation measure in question (for example, the cost of elevating a home or buying out a homeowner). In other words, in a CE assessment, if the BCR is better than 1.0 for the location and type of structure under consideration, then, for the purposes of hazard mitigation, it makes economic sense to incur the cost today to avoid damages in the future. As shown below, this means that proponents of hazard mitigation have a new window for viewing the world of hazard management, whatever the hazard.

To reiterate and rephrase, a "cost-effective" mitigation measure has a net present value of future benefits (avoided damage and other losses) that exceeds the cost of the mitigation measure. This meaning differs from the conventional meaning used by economists and engineers. In conventional usage, cost-effective means the least expensive way to achieve a pre-defined objective (e.g., flood protection to a desired level). Thus, in conventional usage, a cost-effective measure may have benefits that are worth less than the cost. But this is not necessarily the case in reducing the impact of natural hazards.

The Variables

Considering the new approach to hazard mitigation that CE provides, some rather familiar economic and hydrologic variables are used to compute the BCR of flood mitigation measures. It is the way these variables are put together

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5. 44 CFR 77, Acquisition of Flood Damaged Structures.


7. Economic and hydrologic assumptions are important since they are integral to the mathematical equations used in calculating the BCR. Unfortunately, because of the brevity of this paper, these assumptions must be inferred by the reader who is familiar with these sciences.
Cost-Effectiveness and Hazard Mitigation

is a reduction in expected damage, expected benefit is defined as the sum of expected avoided damage. Five variables are used in the calculation: (1) scenario damage (for floods, the expected damage at a certain flood depth); (2) the annual probability of the hazard’s occurrence or recurrence interval (10%, 2%, and 1% floods, for example); (3) expected annual damage (the product of scenario damage and the annual probability); (4) the effectiveness of the mitigation measure in reducing expected damage (25%, 50%, or 100%, for example); and (5) expected avoided damage (the product of expected annual damage and effectiveness). The relationship of these variables is illustrated in Table 1. Although riverine flooding is used in the example, this model applies to other natural hazards as well.

Table 1. The relationship of variables in calculating the benefit-cost ratio (BCR) of riverine mitigation projects.

<table>
<thead>
<tr>
<th>Flood Depth (ft)</th>
<th>Scenario Damages (b)</th>
<th>Annual Probability (c)</th>
<th>Expected Annual Damage ( (b \times c) ) (d)</th>
<th>Mitigation Effectiveness (e)</th>
<th>Expected Avoided Damage ( (d \times e) ) (f)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>$20k</td>
<td>10%</td>
<td>$2,000</td>
<td>100%</td>
<td>$2,000</td>
</tr>
<tr>
<td>2</td>
<td>$25k</td>
<td>5%</td>
<td>$1,250</td>
<td>80%</td>
<td>$1,000</td>
</tr>
<tr>
<td>3</td>
<td>$35k</td>
<td>2%</td>
<td>$700</td>
<td>50%</td>
<td>$350</td>
</tr>
<tr>
<td>4</td>
<td>$50k</td>
<td>1%</td>
<td>$500</td>
<td>25%</td>
<td>$125</td>
</tr>
<tr>
<td>Total:</td>
<td>$4,450</td>
<td>Total: $3,475</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

An Example

Note that there are three different types of damage to consider in the example: scenario damage, expected annual damage, and expected annual avoided damage.

In this example, the scenario damage (column b) indicates the expected damage each time a flood of given depth (column a) from 1 to 4 feet occurs at
the residence. Scenario damage is not dependent on how frequently such floods are expected to occur. The annual flood probabilities (column c) indicate the degree of flood risk at the site under consideration. The expected annual damage (column d) is the product of scenario damage and annual flood probability (columns b and c).

The expected annual damage ($4,450 in this example (column d)) is the best estimate of the average damage per year expected at the site. These estimates do not mean that such damage will occur every year. The expected annual damages are those without undertaking the mitigation measure. The effectiveness of the mitigation measure (column e) is an estimate of how much expected damage will be reduced by the mitigation measure under consideration. The expected avoided damage (i.e., the benefits (column f)) is the product of expected annual damage and the effectiveness of the mitigation measure (columns d and e). The expected avoided damage ($3,475 in this example) is the expected benefit of undertaking the mitigation measure. After discounting to the net present value, the BCR is calculated by dividing the benefit by the cost. If the BCR is less than 1.0, then the feasibility of the project should be questioned. On the other hand, if the BCR is greater than 1.0, then the project is feasible. The BCR thus determined, the analyst has developed a powerful argument with numberable applications.

Data Needs

In carrying out the CE assessment, the analyst needs key pieces of information and a scientific calculator, or a computer program (available this year from FEMA) that performs the actual calculations. In the case of flooding, examples of needed information include hydraulic information (including flood discharges), the structure's first floor elevation, function, type, and size (single-family, wood frame, square footage), the effectiveness of the mitigation measure, the life of the mitigation measure in years, and the cost. FEMA's computer program automatically performs regression analyses to determine the likelihood of floods and damage to the structure and contents at various discharges, and then calculates the net present value of benefits and costs to arrive at the BCR.

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8 The CE assessment can be used "vertically" and "horizontally". That is, vertically in the sense of studying a single project to compare the BCR of alternative measures and selecting the most prudent measure, or horizontally for multiple projects to compare the BCR of projects and selecting among the most prudent projects.
Conclusion

Assessing the CE of proposed mitigation projects suggests the ability to peer into the future. In many important ways, the CE approach provides a crystal ball for the analyst to see the damage that is likely before a home is placed in a floodprone location, for example. This capability constitutes a prospective approach to floodplain management. The value of this capability is only beginning to be appreciated and explored. What is the impact of CE assessment on state and local hazard mitigation planning? On setting priorities when only limited public funds are available for hazard mitigation? On refining insurance rates? On ordinance administration? On the ability of the analyst to advise decision-makers? These are but a few of the questions generated by the ability to conduct CE assessments in natural hazard management.
INTRODUCIVE PROCEDURES FOR FUNDING FLOODPLAIN STUDIES:
COST, TIME, AND RESOURCE SHARING

Lawrence Basich
Federal Emergency Management Agency Region X

Introduction

For the past 10 years or so, the Flood Insurance Study budget for the entire country has just hit the eight-figure mark and has held that mark fairly consistently. With this budget, the Federal Emergency Management Agency has been able to finish initiating and continue to upkeep studies in over 18,000 communities across the United States and Commonwealth countries. At slightly over $500 per community per year, this is a pretty amazing feat.

However, as is true with all public agencies, our budget undergoes scrutiny, and the pot may get smaller in the future. Even if the funding level stays the same, the needs far outweigh the means. The purpose of this paper is to examine other existing means of meeting our study needs.

Discussion

How do we continue to keep all of the existing studies up to date? It is called magic and a very long priority list. In our region alone, we have identified over 180 restudy needs. They fall into several categories: fixing errored detail studies; fixing grossly overstated Approximate A zones; extending detailed study into previously unstudied areas; adding detailed study where no study was thought of before because of a change in demographics; and just updating worn out studies, mainly those whose discharges no longer reflect reality.

We have five basic sources for identifying study areas: first, the community officials themselves; second, as a result of good coordination between the local governments and the states, our state coordinators recommend study areas; third, through our close working relationship with the Corps of Engineers and other federal agencies, many recommendations for studies arise from their internal sources; fourth, as a result of Community Assistance Visits, FEMA staff identifies problem areas; and last, FEMA staff identify problem areas and study needs through our normal dealings with local communities and our daily activities in and out of the office.
The real trick is prioritizing the list of studies and picking 10 studies or so out of the 180 on the list. Since March of 1993, we have received over 35 requests for studies, so the list grows faster than it can be depleted. We started a process two years ago that involves our state coordinators during one of our semi-annual state coordinators meetings. We ask each coordinator to identify the top three study needs in their state. With this list and our list, we hammer out a final studies priority list. With increased interest from the Corps and local communities, this year we will pursue developing a studies task force whereby we can exchange ideas, needs, and information to come up with a more cogent, meaningful list.

In the past 11 years, our regional monies available for studies have dwindled from over $1.7 million per year to around $390,000 per year. Because of the increased need for quick fixes, most of our monies are set aside into a pot called Limited Map Maintenance Program (LMMP). With the scene changing to one of less funding and quick fix type studies, our mode of approaching getting the studies job done has changed. We see an increased need for searching for any mechanism available to meet the study update need.

I would like to focus on the different mechanisms for getting studies done. The following focus not only on cost share but time and resource sharing as well.

1) The first mechanism is, and probably always will be, the FEMA study/restudy/LMMP funds. Currently we cycle about $10 million a year through our procurement process.

2) Section 60.3(b)3 of the National Flood Insurance Program regulations requires that new base flood elevation data be included in new proposals for development of 5 acres or 50 lots, whichever is less. The purpose of this regulation was to assure that our maps would be updated by developers as the development pressures entered areas that could not have been foreseen at the time of the study initiation.

3) State organizations have set aside monies for getting projects started. In Washington, the Department of Ecology (DOE), through FCAAP, has provided monies for comprehensive planning, of which a portion may be used for studies. Use of these funds requires examination by a state committee and then cooperation by the local government. For example, studies have been cost shared with FEMA on the Methow River in Okanogan County; DOE funded studies on alluvial fans in Wenatchee. On this study, the FEMA regional office helped write the scope of work for the project, sat on the contractor selection board, interviewed prospective consultants, and has offered to help monitor the contract for the City; DOE funded a 2-D model of the main stem of the
Nooksack River in Whatcom County. The FEMA regional office participated on the contractor selection committee and helped write the scope of work for the contract. As you can see, there is a commitment of help in these last two cases with no funding attached. We view this as one of our most common forms of cost sharing.

4) The Corps of Engineers is providing technical assistance monies to totally fund studies. The Walla Walla District totally funded a reanalysis of the effect of development in a suspended community, when we made it clear that we could not set a high priority on funding that community study. The community has since joined the NFIP, thanks to this reanalysis and our coordination with the community. In Pendleton, Oregon, the local government unknowingly sited a proposed Emergency Operations Center in the 500-year floodplain. We asked the Corps to reexamine the model and they were able to determine that the levees contained the 500-year flood. The Corps, Portland District, has been digitizing the floodplain overlays for the major metropolitan areas in Oregon. This was an added benefit to an existing RFIS in Salem and an LMMP in Washington County, Oregon. The Seattle District has performed nearly 40% of the studies in their District. We constantly receive updates and revisions to existing FIS work that they perform on their own initiative.

5) Saving money on studies does not necessarily mean saving money out of the regional study money pot. It costs a significant amount of technical evaluation contractor (TEC) review time to process a study. In two instances, the Teton River in Madison County, Idaho, and four alluvial fan studies in Boise, Idaho, we saved those TEC review costs by having the TEC perform the studies for us. Unfortunately, with the ever-increasing work load of the TEC, we do not expect to receive this type of assistance in the future unless there are very special circumstances.

6) We have had limited success with cost sharing with local communities other than for mapping. In two instances in Washington, we were able to piggyback two studies on streams that the locals were performing. This type of cost share only happens when we know that a community is funding a study, and we have an interest and money to fund the remainder of the project.

7) King County, Washington, funds studies totally on its own. We consider ourselves extremely fortunate to have a community who recognizes the same needs that we do, and has established a yearly
budget to fund these types of studies. To date, the County has funded projects on the Raging River, Middle Fork Snoqualmie River, Tolt River, and South Fork Snoqualmie River. These are all large watercourses near urbanizing areas. Our role in these projects is one of coordination with the county and its contractor to assure conformance with our "Guidelines and Specifications." No other community in our region has this study capability planned in their budget.

7) As in most regions, we have a few communities who do not believe our studies. They have expressed this opinion by not joining the NFIP. Instead of leaving these communities alone, the regional office has offered to perform some minor hydrologic and hydraulic investigations to determine if the study needs to be refined. This type of technical assistance goes a long way in helping convince the non-believers, and helps us see their side of the story. The region is also looking at enhancing existing studies where study monies are not available.

8) The last type of money-saving exercise we use is to provide extensive technical assistance to clients who are seeking improvements to our study data. The Clackamas County Regional Park and the Tri-Met Light Rail project in the Portland metro areas are good examples. In both cases, a community and a pseudo-governmental agency had proposals for projects in the 100-year floodplain. Both groups performed hydrologic analyses and arrived at different discharge values than that shown in the FIS. In order to get their projects going, they had to obtain Conditional Letters of Map Revision, which meant close contact with the regional office of FEMA and the TEC. We were able to have four streams reanalyzed in Clackamas County and three updates along the light rail project, with only review costs being expended.

Conclusion

I suppose the simplest way to conclude this topic is to say we must always have our ears and eyes open to each of our client groups, states, local communities, each other, and developers. By satisfying their needs, we most often satisfy our own as well.
STORMWATER UTILITY FEE CREDIT COMPUTATIONS BASED ON BEST MANAGEMENT PRACTICES EFFECTIVENESS

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Introduction

Urban stormwater utilities are becoming an increasingly popular method of funding stormwater programs throughout the United States. Many of these utilities have rate structures that comprise three components: 1) a basic fee and rate concept, 2) secondary funding methods, and 3) rate modifiers. A common method of equitably modifying the rate structure is a fee credit system that reduces the stormwater fee based on a structural control's ability to reduce the impact of runoff from a property to the receiving stormwater system.

On-site structural controls (best management practices or BMPs) can reduce the impacts of runoff to the drainage system caused by development. Therefore, a property owner who owns and maintains a BMP should pay a lower utility fee because of his or her reduced impact on the system.

Fee Credit Structure

A fee credit system should complement the funding base of the stormwater utility. The City of Charlotte selected the impervious area of a parcel as the base utility rate. Factors leading to selection of this base rate methodology were 1) simplicity—impervious area as an indication of the amount of runoff from a property can be easily explained to the general public; and 2) open space—because undeveloped land pays no fee, this structure encourages green space and limited density or clustered development. Therefore, the fee credit system was developed with impervious area as the basis. The theory was that the credit should be based on the extent to which a BMP can reduce the impacts and
associated public costs on the stormwater system by reducing the "effective impervious area."

An analysis of the fiscal structure of Charlotte's stormwater management program indicated that the total cost is allocated approximately in proportion to the following three impacts on the drainage system:

- peak flow—50%,
- flow volume—25%, and
- water quality—25%.

Therefore, Charlotte's credit system was structured to grant a fee reduction based on the ability of BMPs on a property to reduce the effect on the receiving water course for each of these three impacts.

The method of computation for fee credit purposes is to determine each of these impacts at the exit of the site for the following conditions:

- existing conditions prior to development,
- developed conditions without controls, and
- developed conditions with controls in place.

An assumption was made that each of these impacts varies linearly with impervious area of the site. Therefore, an "effective" impervious area is computed by the following formula:

\[ I_2 = I_1 + \left( \frac{Q_2 - Q_1}{I_3 - I_1} \right) \left( \frac{I_3 - I_1}{Q_3 - Q_1} \right) \]

where:

- \( I_2, \) "effective" impervious area;
- \( I_1, \) impervious area without development (always assumed to be zero);
- \( Q_1, \) pre-development peak, volume, or pollution runoff;
- \( I_3, \) post-developed impervious area;
- \( Q_3, \) post-development peak, volume, or pollution runoff; and
Q2 = post-development with controls for peak, volume, or pollution runoff.

Figure 1 illustrates the "effective imperviousness" concept.

![Effective Imperviousness Diagram](image)

**Figure 1. Effective imperviousness diagram.**

**BMP Design Standards**

The City of Charlotte determined that the fee credit system should initially be based on two BMPs: the extended detention basin and the wet pond. Other BMPs were not selected at the onset of the utility due to the inexperience of local engineers in determining the pollution reduction of other BMPs and the inability of the city to actively monitor the maintenance of such facilities. In addition, other BMPs do not provide significant peak flow attenuation in order to achieve peak flow or volume credit. The design standards were developed
consistent with the *Charlotte-Mecklenburg Stormwater Design Manual* and are listed as follows:

- **Peak flow**: 10-year, 6-hour storm event.
- **Flow volume**: total runoff volume in 12-hours from the start of runoff for the 2-year, 6-hour storm event.
- **Pollution**: annual loading of lead, BOD5, and total phosphorous.

The 10-year storm was selected for peak flow calculations because it is believed to be the mid-range control for the majority of detention basins in the city. The 2-year storm was selected for flow volume calculations because it is considered to be the "channel forming" event. Channel forming and erosion problems are considered to be a major cause of many of the maintenance problems in Charlotte. The 12-hour period measured for flow volume was estimated to be the time during which the majority of flow can be considered base flow. Both the peak flow analysis storm event and flow volume analysis storm event were based on the 6-hour storm duration due to previous calibration efforts within the city of Charlotte.

Three constituents were chosen for the pollution reduction fee credits: lead, BOD5, and total phosphorous. These three constituents were selected to cover the varied spectrum of possible urban pollutants: lead as a common measure of toxic trace metal production; BOD5 as a common measure of the oxygen demand within the stream system (which typically is a good measure of the overall stream health); and total phosphorous as a measure of nutrient loading. Also considered were: different pollutant protection requirements for different water bodies, the pollutants' different origins, the pollutants' different impacts on the aquatic ecosystem, and the different pollutant removal efficiencies provided by various BMPs.

### Existing Detention Basin Retrofitting

The city of Charlotte investigated the feasibility of private property owners retrofitting their existing detention basin's configuration in order to maximize the available fee credit. The investigation focused on five facilities in Charlotte that had varying physical properties in order to show a diverse set of possible retrofitting opportunities. The property location within the watershed, the contributing watershed size, the property land use, the existing detention basin's storage volume, and the downstream conditions were evaluated during
the site selection process so that all hydrologic, hydraulic, site design, and policy issues could be addressed and demonstrated.

All of the detention basins in the study had been designed and constructed under the outdated requirements of the Charlotte Engineering Department, which required the design of the basin with a "Modified Rational" method. Studies have determined that the Modified Rational method typically underestimates the required storage volume of the basin by 20% to 60%. Therefore, it was expected that most of these sites would not receive a full peak flow fee reduction. In addition, it was expected that most of these sites would not receive any flow volume or pollution control fee credit because most of the basins would not provide the required extended detention time or required wet pond volume.

The results of the retrofitting study are presented in Table 1.

Table 1. Results of retrofitting study.

<table>
<thead>
<tr>
<th>Site</th>
<th>Total Impervious Acreage</th>
<th>Unadjusted Monthly Fee</th>
<th>Non-Retrofitted Monthly Fee</th>
<th>Retrofitted Monthly Fee</th>
<th>Cost of Retrofit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Site 1</td>
<td>31.4 acres</td>
<td>$1,110</td>
<td>$887</td>
<td>$525</td>
<td>$29,200</td>
</tr>
<tr>
<td>Site 2</td>
<td>1.8 acres</td>
<td>$64</td>
<td>$60</td>
<td>$17</td>
<td>$5,600</td>
</tr>
<tr>
<td>Site 3</td>
<td>36.3 acres</td>
<td>$1,283</td>
<td>$373</td>
<td>$284</td>
<td>$6,000</td>
</tr>
<tr>
<td>Site 4</td>
<td>96.7 acres</td>
<td>$3,418</td>
<td>$3,418</td>
<td>$3,048</td>
<td>$81,685</td>
</tr>
<tr>
<td>Site 5</td>
<td>8.2 acres</td>
<td>$290</td>
<td>$221</td>
<td>$124</td>
<td>$30,154</td>
</tr>
</tbody>
</table>

Several conclusions were drawn from the results of the retrofitting study. First, most of the existing detention basin sites received little or no fee credit. The fee credit ranged from 0% to 24%. One site, which contained a large permanent pool facility with additional storage volume above the permanent pool elevation, achieved a 71% fee credit. Second, retrofitting the structures insignificantly increased the fee credit. The range of fee credit shifted to 11% to 78%. However, the cost of retrofitting was excessive for the amount of savings provided by the fee credit. Typical payback periods were computed to range from 5.6 years to 25.8 years.
Conclusion

The fee credit system provides an equitable means of redistributing the costs of a stormwater program to the pro rata share of the properties’ impact on the system. The City of Charlotte experienced the effects of two changes within its program that make the evaluation of the fee credit system difficult for existing basins. The implementation of more accurate detention basin design criteria—publication of the Charlotte-Mecklenburg Stormwater Design Manual, in July 1993—resulted in many existing detention basins throughout the municipality that did not meet the increased design requirements. In addition, no existing detention basin had been purposely designed for water quality control or flow volume control. Second, the actual publication of the Credit Application Instruction Manual initiated a completely new administrative policy and technical procedure.

The fee credit program has been in service for approximately 16 months. During that time approximately 50 fee credit applications for existing sites have been received by Stormwater Services. This number is a small percentage of the estimated 2,000 detention basins constructed during the last 15 years. Generally, existing basins were determined to be eligible for minor fee credit (typical ranges from 0% to 24%). Conversations with many of the property owners and private engineers within Charlotte indicated that the payback period for the engineer design fees will usually range from four years to 15 years. In addition, the property owners must maintain the BMP to city standards to receive a fee credit. Such maintenance is not otherwise required. Therefore, the majority of property owners with existing detention basins have opted to not pursue the fee credit.

However, new developments designed under the updated stormwater detention design regulations ensure that additional design fees will not have to be paid in order to calculate the peak flow fee credit because the majority of the computations would be prepared in conjunction with detention basin design and approval. Therefore, the majority of new developments have applied for the peak flow fee credit. Flow volume and pollution control fee credit are not specific requirements of the Charlotte-Mecklenburg regulations and therefore volume and pollution control have not been used extensively in the new development process. Only in the case where a permanent pool is proposed as an amenity has the property owner constructed a BMP to control pollution or flow volume and applied for the corresponding fee credit. It is expected that as designers become familiar with BMP design, more property owners will take advantage of fee credits.

In summary, the policy requires a significant effort to determine the appropriate credit for previously developed properties and BMPs, resulting in
a limited number of such applications. However, the additional effort to apply for credit in conjunction with the approval of new development plans is very small. In fact, the engineer of new development has an opportunity to refine the design of required on-site BMPs to maximize credits for the site, which will benefit the owner indefinitely.

References

Ogden Environmental

Andrew J. Reese

Ogden Environmental
Introduction

This paper describes how value engineering was used on a large flood control project designed by the Los Angeles District of the U.S. Army Corps of Engineers. The project is the modification of an existing flood control system in the Los Angeles County Drainage Area (LACDA). It is designed to increase the flood control capacity of the lower Los Angeles River and the Rio Hondo Diversion Channel to compensate for the urban development that has occurred since the original system was constructed. The paper first gives an overview of the value engineering process. Then it tells how value engineering was applied to the project, the results that were achieved, and the impact of the recommendations on the design and the designers. Finally, the paper will discuss how even greater results can be achieved by performing the studies before finalizing the feasibility study.

Value Engineering Process Overview

Value engineering (VE) can be defined as a systematic study of functions using teamwork and creativity to identify alternatives with the lowest life cycle cost without sacrificing the required functions or appropriate quality. In today’s environment of escalating project costs and diminishing budgets, VE must be an essential element of the design and construction process. VE is the most effective tool available to obtain the required functions at the minimum cost without sacrificing the needed quality of the project. The time has come to recognize that money is a precious commodity that must be considered thoughtfully.

The VE job plan or process consists of pre-workshop preparation, the workshop, and post-workshop activities. The specific process is described in more detail below.

Before the Workshop

The pre-workshop period is a time to get prepared for the actual workshop. During this time, the team leader will assemble the study team. This will be accomplished after reviewing the project material and interviewing key
owner and designer staff about the project. This gives the team leader insight on the issues and concerns on which the team should focus. From this information, the team leader will determine the disciplines necessary for the team and the workshop duration, i.e., three, four, or five days. This is followed by a coordination effort on the workshop logistics.

Also during the pre-workshop phase, the team leader will review the cost data on the project and begin assembling a cost model. The cost model helps the team to focus on areas of the project where most of the money is being spent. The results of these cost models often surprise the owner and even the designer.

Other activities during this phase include an independent review of the project cost estimate by the VE team's estimator and project document review by other VE team members.

**Workshop**

The workshop is the focus of the VE study effort. It is then that the VE study team analyzes the project functions and generates alternatives to the designer's concept for accomplishing those functions. The workshop is broken into five distinct phases: information; creative; judgment; development; and presentation.

**Information Phase.** The objective of the information phase is to give the VE team a thorough understanding of the project. This education will begin with presentations about the project from the owner and designer. After the presentations, the team will spend some time reviewing the project documents in more detail and tour the actual project site, if possible. The review is followed by an intense function analysis of the project.

Function analysis is the heart of the VE process. During function analysis, the team dissects the project into distinct elements. It is from this that the VE study team develops the unique perspective of the project that can only be accomplished through this process.

**Creative Phase.** The next phase of the process is the creative phase, which is used to generate a large number of ideas without regard to their practicality. The intent is quantity of ideas, not quality. The technique most often used for the idea generation is brainstorming.

**Judgment Phase.** This phase is used to evaluate the ideas generated during the creative phase, and to select those worthy of further consideration. Several group evaluation techniques are available, but this project used a voting process followed by a brief discussion. This allows the top 20% of the ideas, often 200-300 in number, to be evaluated in about two hours. The ideas remaining at the end of the judgment phase are carried on to the next phase.

**Development Phase.** The purpose of this phase is to turn the ideas into a recommendation supported by engineering calculations, sketches, cost
estimates, and life cycle cost analysis. Approximately half of the workshop is dedicated to this phase.

**Presentation Phase.** This phase is used to present the recommendations developed by the VE study to the project decisionmakers. This time is used for further explanation of the recommendations, not for debating the acceptability of the idea. For this project, this phase actually occurred a few weeks after completion of the development phase. In most cases, however, it will immediately follow the previous phase.

**After the Workshop**

The post-workshop activities are to determine acceptability of the recommendations, define the implementation procedures, and document the study effort. After the conclusion of the workshop, the VE team leader provides the owner and designer with a copy of the workshop materials. This is reviewed and an implementation meeting scheduled. At this meeting, decisions are made about which recommendations will be implemented into the design. After this meeting a final report is developed to document the study and decisions.

**VE Study: Los Angeles County Drainage Area**

**Project Background**

This project was designed to increase the flood control capacity of an existing system located in the Los Angeles County Drainage Area (LACDA). The work is primarily focused on the lower reaches of the Los Angeles River, the Rio Hondo Diversion Channel, and Compton Creek. The proposed fix by the Corps of Engineers' Los Angeles District involves constructing parapet walls on top of existing levees. Due to clearance problems, 27 bridges were originally scheduled for reconstruction at a higher elevation. After significant physical modeling performed by the Waterways Experiment Station, the Corps determined that only 10 needed to be reconstructed and the other 16 could be modified with pier extensions. Other significant elements of the work included changing the large trapezoidal channel at the confluence of the Los Angeles and Rio Hondo to a rectangular cross section.

The overall project was aimed at increasing the flood protection level to a 133-year event. Economic factors in this highly urbanized area justified a higher level of protection, but this would require reconstruction of the Century Freeway Bridge, which substantially lowered the benefit-cost ratio, to the point at which it was not cost effective.

The VE team consisted of a CVS team leader, two hydraulic engineers, two civil/structural engineers, and a structural/bridge engineer. This team was tailored to the project based on information obtained from the cost model.
developed for the project. The model showed that the project costs were concentrated on concrete parapet walls, bridge modifications, and the confluence modification. After the team was assembled, each team member was given eight hours to study the project documents before the workshop began.

In the information phase, the VE team was informed that the project cost had been significantly reduced as a result of the extensive physical modeling. The modeling allowed the designer to test more economical modifications to the bridges. However, some parts of the project had not been modeled, for example, the confluence and the lower reaches of the project where the flows went subcritical.

During the creative phase, the VE team generated over 150 ideas for project improvements and cost reductions. During the judgment phase this number was reduced to the best 35 ideas. This number was based on the number of ideas the team was capable of developing in the time given for the development phase. After the team performed its evaluation, the owners/designers were invited in to review the short list of ideas. This is done to ensure that the VE team has not missed an important issue that would make an idea totally unworkable and therefore not worthy of further effort. The Corps only removed two ideas from the VE team’s list but replaced them with two other ideas that they wanted to see developed.

The Corps chose to combine the presentation of the recommendations and the decisionmaking process into one meeting. The result of this meeting was the acceptance of several proposals, which offered alternatives to the standard L-shaped parapet wall in the project design. The designers did not feel that any one of the proposed alternatives was appropriate for the entire project but they saw benefits to each design alternative that they could apply where appropriate. This saved an estimated $10 million. Another suggestion was made to detour traffic rather than construct temporary bridges for those being reconstructed. This idea saved the project over $8 million. The Corps and county accepted other ideas related to the bridges totaling another $9 million in construction savings. The Corps is performing some further studies to evaluate a VE recommendation to physically model the entire project, which the VE team estimated could save the project over $30 million. Another significant proposal that the Corps is still evaluating concerns reducing the level of protection at selected bridges to postpone reconstruction until the end of the bridges’ useful life. While the Corps and the county can see merit to this proposal it may not be implemented because it would require resubmitting the feasibility report for approval. Depending on the current political priorities of the Corps’ division office, headquarters, or Congress, the project could be delayed or canceled.
Achieving Greater Results

Although the results of this study were phenomenal, far greater results could have been achieved if the study had been planned for and conducted early in the planning and design process. Any time you are looking at a project with the intent of identifying design changes, the earlier it is done the better. For a project of this size, a study should be done at the conclusion of the planning effort, before finalizing the feasibility report. Once the feasibility report is approved, it becomes a significant effort to make changes. Particularly difficult are those that result in changes to criteria, such as the level of flood protection provided or the method by which protection will be provided.
PART ELEVEN

REMEMBERING
JAMES E. GODDARD
James E. Goddard is inextricably woven into our nation’s history of floodplain management. He stands as one of the true pioneers of management approaches in common use today, approaches that we employ without an understanding of the difficulties encountered and work required in gaining their acceptance.

To reach some understanding and appreciation for his important contributions, we need to consider them from a historical perspective. It was the early 1950s. The National Flood Insurance Program would not be created for another 15 years. The National Environmental Policy Act was just as far in the future. Congress had spent more than $11 billion since 1936 for flood control projects, mainly in response to major events that occurred during that decade. Even as these projects were being completed, there were those who began to question the wisdom of overreliance on structural measures to control the paths of flood waters. Among the prominent voices was that of Gilbert F. White who, in a 1942 Ph.D. dissertation, had advocated "adjusting human occupancy to the floodplain environment."

By the 1950s some disturbing trends had developed. Because of the rapid growth of urban areas after World War II, the national flood damage potential was increasing faster than it could be controlled with existing flood protection construction programs. Employing wise land use management practices in flood-prone areas, advanced by Gilbert White and others, seemed to many enlightened observers to be a neglected alternative to these construction programs.

This new alternative was first applied on a broad scale by the Tennessee Valley Authority (TVA), a federal agency created by Congress in 1933. Working with state and local planners, TVA water resources engineers in 1953 embarked on a pioneering cooperative program to tackle local flood problems. Under this program, flood damage prevention was considered a matter of adjusting the use of the land to the conditions existing in areas subject to flooding. Jim Goddard was selected to lead this new TVA venture. History would show that the agency could have not made a better selection. He would apply his leadership and considerable enthusiasm and energy, first to the task of working with state and local governments in the Tennessee River watershed to encourage consideration of the full range of policies and actions for ensuring
wise use of floodprone lands, and later in seemingly inexhaustible efforts to share the TVA experience nationally.

After only a few years of experience, TVA was convinced that this floodplain management assistance program had real merit and was suitable for national application. Under Goddard’s leadership a little-known report was prepared and submitted to Congress 35 years ago in 1959 proposing *A Program for Reducing the National Flood Damage Potential*. In transmitting the report, TVA stated that

> Communities throughout the Nation are engaged in a new contest with their rivers and they are losing. They will continue to lose unless steps are taken to provide a new perspective—and a new channel of action—with respect to floods. TVA believes that local communities have the responsibility to guide their growth so that their future development will be kept out of the path of floodwaters. With the states and communities of the Tennessee Valley, TVA has developed a means of putting this proposition into action. It is saving lives and property in the area while diminishing the future demands of the Nation for flood-relief and flood-control expenditures. We believe the same results can be accomplished by adapting this experience to other areas throughout the United States.

TVA went on to state that "it is essential that a working relationship be established between Federal agencies which can furnish and interpret the data [on storm probabilities and the behavior of floodwaters], and State and local bodies which can use it in preparing their development plans." Finally, the report recommended adoption of a new approach to the problem of flood-damage prevention—"adjusting the use of land to the flood hazards"—to complement the traditional approach of controlling the extent of flooding by the construction of protective measures. This approach had been advocated by Gilbert White a decade earlier, and now had been put into practice and strongly endorsed by a federal agency.

Armed with this successful experiment and a report advocating a national floodplain management program, Jim Goddard fervently carried out extensive efforts for nearly a decade to promote the floodplain management concept throughout the United States. His efforts paved the way for creation of a floodplain management services program by the Corps of Engineers in the early 1960s, and showed the feasibility of a national flood insurance program.

TVA files contain dozens of papers he and his staff prepared and presented during this period at regional and national conferences and others that were published in various periodicals. He also found time to serve as Chairman of the Flood Control Committee of the American Society of Civil Engineers'
Wright

Hydraulics Division and as Chairman of its Flood Plain Regulations Task Force. As part of his extensive promotional efforts, he sought permission to reproduce and distribute every document he discovered pertaining to some aspect of floodplain management. Through this process, over 200 different documents were reprinted and tens of thousands were distributed throughout the Nation from his office. Under his direction TVA supported a series of academic studies, such as Jack Sheaffer’s analysis of floodproofing, that were pioneering in the field of floodplain management and yielded information of national significance.

Jim Goddard retired from the TVA in the mid 1960s to lend assistance to the creation or improvement of other floodplain management programs. His involvement and contributions to floodplain management transcend the TVA experience. He was a frequent participant in this Association’s annual conferences and remained a strong advocate for floodplain management until his health failed him last year. He died at his home in Tucson on March 17, 1994, at the age of 87.

In recognition of his innumerable contributions, he, along with Gilbert White, were honored by the Association in 1984 by being designated as its first Honorary Members. In further recognition of their contributions, the Association at that time named its highest award for distinction in floodplain management the Goddard-White Award.

Although the TVA experiment would have been carried out, and adjusting human occupancy and use of the floodplain to the flood hazard would have emerged eventually as a needed alternative to flood control measures, the progress and success of both efforts can be attributed in considerable part to the tireless labors of Jim Goddard, starting some 40 years ago. He indeed left his "footprint" on the floodplain management programs that evolved from his pioneering work.
The Tennessee Valley Authority's position was central to much of Jim Goddard's contribution to the shaping of floodplain management, and from the TVA base he carried on his missionary work in a variety of local, state, and federal fields. Jim Wright has appraised those efforts admirably.

At least four other aspects of Jim's service deserve further specific mention: his encouragement of scientific research; his development of the floodplain information services of the Corps; his major role in national policy reviews; and his manner in carrying out all of those concerns.

When he took on his responsibilities at Knoxville there was only a small amount of scientific research relevant to floodplain management beyond the hydraulic and hydrologic studies basic to delimitation of floodplains and calculation of discharge, elevation, and return intervals of flood flows. Clearly, much more needed to be learned about land use and resources and about the technical and social conditions affecting the suitability of various adjustments to flood hazard. Jim gave support to a series of academic studies aimed at remedying some of the recognized deficiencies. His support always supplied enthusiastic encouragement and technical advice, sometimes involved arranging for use of study areas in the Tennessee Valley, and occasionally provided necessary funding and publication.

Especially notable was the first thorough examination of floodproofing, in the city of Bristol, Tennessee, by John R. Sheaffer (Sheaffer, 1960). Another was the investigation by Robert W. Kates of perception and choice with respect to flood hazard in LaFollette, Tennessee (Kates, 1962). A comparative examination of choice of floodplain use in six communities included one town in the Tennessee Valley (White, 1964). Likewise, the pioneering investigation of floodplain land use by Francis C. Murphy, a young engineer in the Corps of Engineers, included the regulatory experience of cities in the Tennessee Valley and throughout the nation (Murphy, 1958). The Murphy study was the first careful appraisal of the limited experience with regulations that affect channel encroachment, zoning, subdivisions, building codes, and related public policy.

The town of Chattanooga was among the 17 selected across the United States in 1957 to discover the extent to which urban floodplain use had changed in selected cities of the United States after enactment of the Flood Control Act of 1936 (White, 1958).

The "changes" study and the Murphy study of floodplain regulation provided a solid assessment of experience upon which the new Corps of
Engineers program to provide floodplain information to communities was partly based. When that program was launched by the Chief of Engineers, and Jim was invited to give directions, it was not supported with enthusiasm by any substantial number of Corps personnel. It was the first service program to be offered by the Corps, and Jim, as its first administrator, was obliged to practice large persistence and patience in order to assure participation.

In two influential reviews of national floodplain management policy, Jim played a major role. He helped organize and had an influential part in the completion of the Bureau of the Budget Task Force report in 1966 (U.S. Congress, 1966). He also was consistently helpful in the review committee that produced the Action Agenda based on the national assessment of 1992 (National Review Committee, 1992). His ideas were broader than a conventional structural approach, and his willingness to try new methods also ranged widely.

Any who worked with Jim knew from first-hand experience that he was consistently gracious and considerate in his dealings with others. Our daughters, who were quite young when he began visiting our Chicago household, were impressed by his courteous behavior. They happily put on their nice dresses when they knew he would be a dinner guest. One of them still affectionately describes him as "courtly." Whether dealing with generals or local officials or little girls across the dinner table, Jim Goddard always was a gentleman with a strong dedication to public service and with sensitive concern for his fellow humans.

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U.S. 89th Congress, 2d Session

National Review Committee
PART TWELVE

A VISION OF THE FUTURE
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LEARNING FROM THE FLOOD OF 1993:
FLOODPLAIN MANAGEMENT INTO THE 21ST CENTURY

Gerald E. Galloway, Jr.
U.S. Military Academy

It is a great pleasure for me to be here to tell you about the group that I am working with—the Interagency Floodplain Management Review Committee. The Committee was formed by the Administration’s Flood Recovery Task Force, headed by Secretary of Agriculture, Mike Espy, and a sub-group of that Task Force, the Floodplain Management Task Force, headed by Katie McGinty at the Office for Environmental Policy at the White House; T. J. Glauthier, the Associate Director of the Office of Management and Budget for Natural Resources; and Jim Lyons, the Assistant Secretary of Agriculture. We work for this latter group.

Our charge is to report in June to the Administration through the task force on what happened with the flood of 1993, what were the good things that went on, what were the programs we had in place that worked well, and what did not work well. From this review, we are to report what changes in policies, procedures, and programs are needed and what legislative initiatives the Administration might pursue to bring some order into this entire business of floodplain management. The draft will be circulated among the major agencies and interest groups who participated in the process. We hope to get comments back by early June and then have the final version out by the end of June.

We have done our review in an open process. Our effort really began in January, and since then we have become involved with federal and state agencies. We have visited nine flood-affected states and been in over 63 communities in those states. We met with governors’ flood recovery task forces. We have spent time with many of you in this room, and we very much value your wise advice and counsel. We have had several meetings with the Association of State Floodplain Managers’ representatives, and they have kept the agenda of the ASFPM in front of us. We understand where you are coming from, and we appreciate this viewpoint. We have had advice from interest groups and from individual citizens. We even had a wonderful letter from a 5th grader from a flood-affected area who gave me a program to reduce the size of levees and said, "This may not work, but I just want you to know that I’m here to help." I think that is the message that we have received throughout the upper Mississippi basin: "We want to help."

What have we learned? Let me tell you a few things that we have learned so far, and then I will get into the issues and implications for the future.
The flood was a rainfall event. Now that is a blinding flash of the obvious to some, but not to others. This was a meteorological event of historic proportions. A large amount of rain, as our good councilman told us a few minutes ago, creates problems. The damages were high, somewhere between $12 and $16 billion. We cannot put our finger on the total amount of damage because once we declared the disaster, for all intents and purposes, people seemed to stop collecting data on damage. There are some problems with this lack of data collection, and they go back to the 1960s when Gilbert White and some of his colleagues found this same lack of data collection. To really understand a flood, you have got to be able to capture information about what damages occur during a flood.

Somewhere over 15,000 square miles were flooded. Somewhere between 55,000 and 100,000 homes were damaged. Most of the agricultural damages were upland, not in the floodplain, not in the riverine bottoms. And about 50% of the damages to homes occurred not from riverine flooding but from sewer backup and groundwater intrusion into the residences.

Those are the kinds of damage that you can count and see. The untold damage includes the impact on the physical and the mental well-being of individuals affected by this flood. We already can sense some of the mental health problems that came out of the flood. Monsanto ran a study of farmers and the problems they are facing: "When are we going to move back? What's going to happen to those of us who live in a flooded area?"

We have already seen some indications of misbehavior in the schools by the children who are associated with the floods. We have also seen some increase in spousal and child abuse. We have not developed specific numbers, but there is enough out there to tell us we should continue to investigate. We now must look at these non-monetary damages and recognize that they may be far greater, in some instances, than monetary damages.

During the flood of 1993, flood control structures and floodplain management activities made a difference. Flood control structures that were put in place as part of the 1936 Flood Control Act and those that were built by local communities and individuals prevented over $19 billion in damage. The effect of the National Flood Insurance Program (NFIP) and floodplain management programs of the states reduced the potential for loss in many, many areas. We found that the number of pre-NFIP structures at risk continues to go down. In our visits to communities, officials showed us place after place where people have been moved out and where zoning or land controls kept people from harm that would have occurred this year. You deserve a pat on the back for those programs and the efforts you have made so far.

We have lost a lot of floodplain and upland storage. We have also lost a lot of habitat both in uplands and in lowlands, and that is a problem we must recognize. These losses began not in 1936 or in the 1950s. They began in the
1800s and have continued since. We have a past to live with, but we must move forward and protect these resources in the future.

Floods will continue. Now that again is a blinding flash of the obvious. But I think it is important that we tell everyone. We think it important that our Review Committee point that out. The President said in the State of the Union address that the 1993 flood was a 500-year flood. Many people now say, "Well my goodness! I'm not going to last 500 years, so I'm safe from another flood." We are trying to emphasize that floods will continue to occur. Only on one segment of the Mississippi and on the Missouri did we encounter 500-year flood stages. In many places, it was a 100-year event; in many other places, it was only a 50-year event. Had the stage been a few inches higher, many 100-year levees and 150-year flood walls might have been overtopped. We are trying to get out the message that there is a large residual risk, especially for those that live behind levees. Levees provide a degree of protection, but this level of protection can be exceeded and should be expected. We think that it is important that the people of the United States know that flood control structures do work. But they only work under some conditions.

We have established, as part of our process, goals for floodplain management that should guide us into the 21st century.

- Reduce the vulnerability of the nation to the damages that result from floods. Inherent in this goal would be appropriate protection of homes, industry, and agriculture when such flood protection is justified and reasonable or moving people out of the floodplain and discouraging new development where protection is not appropriate. The end result would be the elimination of threats to life, property, the environment, and the mental health and well-being of floodplain occupants and ensuring the viability of critical infrastructure.

- Preserve and enhance the natural value of the floodplain. Treat the floodplain as part of a physical and biological system that includes the floodplain within the larger context of its watershed. Seek to identify and enhance the cultural, historic, and aesthetic values of the floodplain. Where appropriate, restore and enhance bottomland and related upland habitat and flood storage. Using programs that we already have, acquire over time environmental interest in these lands from willing sellers. Ensure the consideration of social and environmental factors in all actions affecting the floodplain.

- Streamline the floodplain management process.

- Capitalize on technology to provide information required to manage the floodplain.
The principal recommendation of our report will be to change the nation's flood damage reduction strategy from reliance on flood control to full use of all structural and nonstructural means. We have recently adopted a new approach to use of wetlands: avoid, minimize, and mitigate. This same paradigm equally applies to floodplain management. We should avoid the risk of the floodplain. When we have to take the risk, we should minimize it. If the risk still exists and we are subject to the devastation of floods, we should mitigate the damages.

Let me share with you a number of issues that we have identified.

First of these is the need to define the division of responsibilities among federal, state, and local agencies. Floodplain management, in the Administration's view, is a state responsibility. The federal government is there in the role of facilitator, handling interstate activities, coordinating and providing funds where appropriate, and supporting state activities in floodplain management. It is very clear from this particular flood that for a flood reduction program to be effective, there must be some ownership. A program that places all of the responsibility at the federal level discourages state and local efforts. There must be cost sharing; there must be an approach that everyone at state and lower levels participates not only in the setting of goals but also in financing goal attainment.

How do you organize the federal government to best support floodplain management? How do we provide coordination at the federal level? How do we provide better state/federal coordination? We are trying to address these issues by looking at mechanisms that can be implemented to improve the situation.

How do we get the federal government to set the example? As I talked to many of you, as I traveled throughout the Midwest, when I met the Corps of Engineers' floodplain managers, state mitigation managers, and FEMA personnel, you all raised your hands and said, "It's really nice for the federal government to talk to the states about what should be done in the floodplain, but let me tell you about this federal facility that was built in the floodplain; let me tell you about this federal activity that is going on in the floodplain." The report will address the subject of federal example.

Another question is how to focus on watershed activity. Water flows downhill. So what begins in a watershed creates problems downstream in the floodplain. We need to ensure that watershed activities are well coordinated. We have Environmental Protection Agency programs. We have Soil Conservation Service programs. We have Fish and Wildlife programs. We have other programs that are coming on-line. At the federal government level, we need to make sure that these are working together to produce the results we want and in a manner that will lead to effective floodplain management.

We need to decide how to reduce the vulnerability of those who are currently in the floodplain. Buyouts, the programs described by Dick Krimm, have really been a tremendous success. That is the wonderful thing we see as
we go out into the Midwest. In 1992, had anyone called for a buyout to get people to leave their homes or their bottomland agriculture, many would have called for the shotgun and the tar and the feathers. The federal government would be interfering in a way of life. Yet today, there are people who are coming into FEMA and saying, "We made mistakes." We received a wonderful letter from the members of the board of commissioners from a county in southern Illinois. It said, "We farmed land that should not have been farmed, and we need your support in getting out of the muck."

It is a win-win situation. We can take marginal land and put it in a federal program. That will enhance habitat and provide for additional flood storage. The buyout programs have been effective, but how do we ensure that they continue to be effective?

Against what flood threat should we target our damage activities? For many, many years we have heard the term "standard project flood," but we have moved away from its use in the current risk-avoidance procedures. We are driven by "good economics." The Review Committee is concerned that good economics does not necessarily address the social, environmental, and other costs associated with a flood. We need to look very carefully at the standard we have established as a risk level. This is especially important for population centers and for our critical infrastructure. We also need to define critical infrastructure. You cannot make a blanket statement that all interstate highways are critical infrastructure. The duration of the flood that might be expected might determine what is critical. For example, an interstate under water for 5 hours is a problem, but an interstate under water for 15 days or three weeks is a disaster. We need to be able to make those kinds of determinations.

How do we make current federal land-acquisition programs more effective? There are lots of them: conservation reserve and wetlands reserve programs, Corps of Engineer programs, Forest Service acquisition programs. How do we better coordinate them and make them more flexible? When the flood occurred, we went out to see the levees that needed to be repaired. The option given to farmers at that point in time was to either have your levee repaired or not have it repaired. Even though land acquisition might have been the best approach, our programs were not sufficiently flexible to provide the dollars and the opportunity immediately. How do we create the flexibility to buy land to enhance the natural environment and provide flood storage and to do this right after the flood?

How do we ensure that in the long term the guidelines used at the federal level to decide what projects are built and not built reflect the true value of all the activities in the floodplain? I am speaking particularly of Principles and Guidelines, the document that guides the activities of the Corps of Engineers, the Soil Conservation Service, and the Tennessee Valley Authority,
and which possibly should be extended to more activities. Does it give appropriate credit to the social and environmental thrust of our actions?

Other issues include how do we streamline our pre-disaster, recovery, and post-disaster recovery operations? We captured a lot of lessons as a result of the flood of 1993. (I would like to personally compliment Director Witt for his efforts to streamline these programs. I met a member of Congress from one of the most severely affected flood states the other day, and he said that he saw no one individual stand out during the flood as much as Director Witt. He was there, responsive, ready to listen, and ready to coordinate. This was a big change from what Congress had seen in the years past. Director Witt, I am very pleased to report that everywhere we went the FEMA flag flies very high. I would also like to compliment Jim Bates for the tremendous efforts in the Corps of Engineers. There have been many fine things said about the Corps of Engineers following the 1993 flood.)

Another issue is how we make the NFIP more effective? How do we deal with substantial losses? How do we make rules and stick with them? What is the right waiting period for insurance activation? We need to come up with these answers.

How do we do better flood mapping for the entire business of operating in the floodplain? The technology exists today from overhead platforms to create digital elevation models. We must move to the digital world. When I met with you in Asheville and closed that particular session, I told you that would be the challenge ahead. And if we do not get snake oil salesmen selling us the wrong platforms, we will recognize that the big task will be to feed the hungry monster, the GIS. Nothing could be closer to the truth than our experience this year. One part of our committee, the group called the SAST, the Scientific Assessment and Strategy Team, went out to Sioux Falls, South Dakota, and tried to create a major GIS for the Midwest. It created a GIS, and it is truly a monster—600 gigabits of data. That is somewhere on the order of 200 CDs of digital information. A lot of data are out there; but they have not been digitized, and they are in many formats. We need better standards, and we need to all work together. The GIS is where we are going.

When do you floodfight? Is it always wise? There is always something inherently good sounding about floodfighting. "Let's get out there and put sandbags on top of the levees." But what if those sandbags are pushing water on the levee across the way and will cause it to overtop? Who should be in charge? Who should say no? In one place in the basin, the police were sent out to stop a floodfight because the floodfight threatened a neighboring area. We need to have better ground rules ahead of time.

The last issue we are still debating is how to get our hands around the Mississippi basin as a basin. How do the local, private, and public levees that exist in the basin tie together? What is the hydraulic influence of one on the other? Should all be there? We clearly learned from the analysis that went on
in Sioux Falls that there are places in the Missouri basin where you should not build levees. How do we prevent them from being built in the future? How did we involve the federal government in a program that replaces levees that should not be there in the first place?

What does our effort mean for you? Floodplain management is going to be a bigger deal than it ever has been. It is going to require a mindset change. You all have got to be very positive. You have got to move forward. You have got to sell it. I have met with four of the nine governors. I have met with the senior assistants to the governors in the rest of the flood-affected states. The sun, the moon, and the earth are lined up for the first time in a manner that will enable us to move ahead in floodplain management—if we seize the moment. You need to capture the moment and put it to your best use. First, to sell the program, and second, to grab the dollars necessary to support the technological changes that you are going to need to make.

We are going to propose in our report a program to assist the states in improving their floodplain management organizations. You will need to make sure that the states come along with their share of the dollars. We have got to struggle with level of protection. We are wrestling with a requirement for insurance for those behind levees, even if they are protected for a 100-year standard. You send people the wrong message when you tell them that they are protected by a 100-year levee.

As always, it is great to be here. You have a big challenge ahead of you. Our study is going to put a lot of focus on floodplain management when we turn it in to the Administration and the Congress. We may not offer the solutions that you want. We may not have the answers you seek. But I can assure you that the report will generate a lot of discussion. And it will provide you the opportunity to move ahead and meet the challenges of the 21st century and to profit from the flood of 1993. Good luck!
WHERE DO WE GO FROM HERE?

Jimmy Bates
U.S. Army Corps of Engineers

The question, "Where do we go from here?" on flood damage prevention has certainly been on the agenda at the White House, and I was delighted to hear General Galloway's report on his Floodplain Management Review Committee's work.

I think we can agree that changes are needed in policies, programs, and procedures to enable us to better implement the principles of floodplain management. We also wholeheartedly agree that we need greater consistency among federal as well as state, tribal, and local agencies in regard to floodplain development policies.

The flood of 1993 will long be remembered as a record-setter in terms of sustained high water levels and damage to property. It may also prove to be a benchmark in our nation's policy on flood damage reduction. I submit that a comprehensive, holistic floodplain policy should encompass all four concepts outlined in the 1992 Interagency Floodplain Management Task Force Assessment, with full consideration of actions to:

- Modify flooding;
- Modify susceptibility to flooding;
- Lessen the impact of flooding, through disaster assistance and insurance programs; and
- Restore and preserve floodplains' natural values.

The Corps is actively involved in all four approaches. Certainly, we modify floods with reservoirs, levees, floodwalls, channel modifications, cutoffs, floodways such as those at New Madrid and Bonnet Carré, and other structural measures.

We work to preserve the natural and cultural values of floodplains through the Upper Mississippi River System Environmental Management Program, the Riverlands demonstration project near St. Louis, and similar efforts. And we follow the "modify susceptibility to flooding" approach through non-structural flood damage reduction projects such as Village Creek, Alabama, where we are relocating about 640 homes. We are successfully developing, and implementing with local partners, multiobjective projects like Mingo Creek, here in Tulsa. That project won an award from the National Society of Professional Engineers as one of the "Top 10 U.S. Engineering Achievements of 1993."
We also work to modify susceptibility to flood damages through two programs familiar to many of you: Floodplain Management Services and Planning Assistance to States. The Floodplain Management Services Program has been in the business of providing technical guidance to local governments and property owners since the mid 1960s, has responded to over a million requests for services, has put out numerous publications on flood proofing and other measures, and is still going strong. It is one of our most effective and efficient programs.

With the Planning Assistance to States, or Section 22 Program, meanwhile, we encourage states to develop statewide plans for use, development, and conservation of almost anything related to water—including floodplain management. Over the years, we have given assistance to all 50 states, the District of Columbia, and six territories. Since 1993 these studies have been cost-shared on a 50-50 basis, and so far in Fiscal Year 1994 we have signed cost-sharing agreements with 23 states and five Native American tribes.

In response to a House committee resolution, we recently began an 18-month assessment of floodplain management along the Upper Mississippi and Lower Missouri Rivers and their tributaries. This assessment will be carried out on a broad conceptual basis, using a system approach. I must stress that, although this assessment and the review being performed by General Galloway’s committee complement one another, they are separate and distinct in purpose and scope. While his committee wrestles with broad national policy and procedure issues, our effort will be to evaluate environmental, economic, and social data in greater detail and look at a broad array of alternative land and water resource actions.

Our study will also provide recommendations for any subsequent detailed studies necessary for specific projects. We will certainly make use of whatever data the Review Committee collects during its efforts, and it would not surprise me if, in order to implement some of our alternatives, some of the Committee’s recommendations would need to be put in place first. Therefore, close coordination between the two efforts is essential.

The Corps projects that now exist in the area are very effective for localized floods. Our districts and divisions coordinate operation of the projects in response to widespread events like those last summer, but the process is less than state-of-the-art. The 1993 flood demonstrated the need for a mathematical model of the Mississippi Basin, and we are developing it in stages, starting with the Mississippi above Cairo, Illinois; the Illinois River; the Missouri below Gavins Point, South Dakota; and eventually adding other rivers. This model will help us coordinate actions on the Mississippi mainstem during floods and droughts, assess the impacts of levee breaching and floodway operation, assess the potential effects of proposed projects, and identify navigation hazards.
There has been a great deal of debate in the media concerning the levees along the rivers—how well did they perform? We need to keep some points in mind.

First, nature can always make a flood bigger than we can economically justify protection against. But—equally important—most of the time that does not happen. Spring rains and snowmelt commonly bring high water sufficient to cause floods in the Midwest, but the levees, floodwalls, and reservoirs do their job of keeping towns and farms dry. Even in the 1993 flood, the loss of life and property would have been far worse had levees, dams, and reservoirs—especially the federal ones—not been in place.

We must also remember that the levees in the Upper Mississippi and Missouri Basins were built and maintained by many different entities: individual property owners, cooperative levee districts, public authorities, local and state governments, and the federal government; and were built to varying engineering standards and levels of protection.

Since the flood, the Corps has been involved in assisting state and local as well as federal authorities in rehabilitation of damaged levees. The estimated cost for repairing an estimated 200 levees eligible for repairs under our program is about $250 million. In the aftermath of the flood, we set out to inspect the levees as soon as possible—in some cases using all-terrain vehicles, the only way to travel the muddy ground. To date, we have started (or in some cases, completed) work on 110 of these levees. Sub-zero wind chills, high water, and super-saturated soil have delayed construction in several locations. In others, there have been delays in negotiating cost-sharing agreements. From the beginning, our estimate was that it would take until December 1994 to complete the levee repair program; and we believe that estimate is still on target.

The overall question to be asked in discussing levee rehabilitation and all aspects of flood policy is, what role do we want rivers and floodplains to play in society? Navigation, flood damage reduction, water supply, recreation, industrial and economic development, agriculture, environmental preservation, and habitat restoration are all legitimate uses we need to balance.

I can tell you two extreme positions that are not likely outcomes of the 1993 flood. The entire area is not likely to go back to nature, nor will the whole river be lined with levees. Somewhere between those two positions is an answer we can all live with. Although some past development may have been unwise in light of our knowledge today, we have to deal with what is there. We cannot simply pick up Des Moines and put it on a hill.

In this process of planning the best combination of approaches, we need to work with local governments and citizens on what they want to live with. "User pay, user say," is the guiding principle of the Water Resources Development Act of 1986. To give an example of that principle in operation, in Iowa there are two neighboring cities on the Mississippi, Davenport and
Bettendorf. The Corps recommended similar flood protection projects for both cities. Bettendorf decided to have levees, and paid their portion of the construction costs. Davenport said "no," they did not want a project that would block their access to the river. Even after the flood, they don't want a wall in their town, and are willing to take the risk of flooding near the waterfront.

The Midwest flood of 1993 was a clear reminder that, even with flood damage reduction projects in place, flood losses will still occur. It is a challenge for the Corps and others to do a better job of considering all alternatives in preventing flood damages, with particular emphasis on ecosystem preservation and restoration. Engineering is about more than designing projects—deciding how much concrete will build what size floodwall that will offer protection against how big a flood. It is about working within our policies and authorities with people to develop solutions that meet their needs and those of their children and the generations to come.
Why are More Disasters Happening?

The 1990s are being termed the Decade of Natural Disaster Reduction, but they are beginning to look more like the Decade of Natural Disasters. In 1989 we had Hurricane Hugo, in 1992 Hurricanes Andrew and Iniki; 1993 saw some of the most serious flooding the Midwest has ever experienced, and in 1994 California was hit by the Northridge earthquake. Between 1979 and 1988 the nation averaged 35 Presidentially declared disasters each year. But in 1989 there were 31, in 1990 there were 38, 1991 had 43, and 45 were declared in 1992. And we should remember that 80-85% of all disasters are flood related.

The cost per taxpayer for response, relief, and disaster aid for all these disasters is very large, and that says nothing about the cost of business time loss, environmental losses, direct flood losses, and lost opportunities. But remember, every disaster also presents an opportunity for prevention of similar or even worse losses the next time around.

Questions We Should be Asking

In the light of the high national costs of disasters, and the apparent increase in the number of Presidentially declared disasters, which bring federal funds and other resources into the picture, there are number of issues we ought to be examining.

- Do the benefits of developing areas subject to hazards outweigh those costs?
- Do current federal, state, and local policies encourage increased losses and increased exposure of people to risk?
- Have the results of those policies improved our quality of life?
- Why do people continue to build and live in ways that put them at risk from natural disasters?
• Should the people who live at known, predictable risk assume all the costs, rather than the taxpayers?

• How can effective and equitable federal, state, and local management policies outweigh these costs without unduly imposing on private property rights?

What Have We Tried?

Let's talk about the four basic approaches that have been used in the past to try to reduce disasters and their costs.

Disaster Relief

We have been paying those who suffer losses during disasters, and have been trying to do so more and more expeditiously. We have been simply accepting that disasters will happen from time to time and that, politics being what they are in this country, victims will end up being compensated. To some extent we have attempted to concentrate on using disaster funds wisely.

Internalizing Costs

Some attempts have been made at passing on some of the costs of living at risk to those who do live at risk. The more obvious example is requiring property owners to purchase insurance, and providing coverage through the National Flood Insurance Program. We have actually had some success with this approach. The concept itself has certainly stood the test of time, politics, and media attention. The difficulties lie largely in its implementation, and the reform bills passing through Congress now will help remedy the more glaring deficiencies, like lack of enforcement of the mandatory purchase requirement.

We should remember, however, that insurance, even if the program is self-supporting, does not cover all costs of flood disasters. The really heavy costs, like public infrastructure, are still paid out of tax dollars. And agricultural losses, which are not touched by the NFIP, account for fully half of all disaster losses.

Regulating Development

Through the NFIP the nation now has over 18,000 communities regulating their flood hazard areas by means of floodplain management ordinances. This widespread regulation has led to significant success in increasing awareness among local officials and to a lesser extent, the public; in reducing losses to much of the nation's new development; and in identifying flood hazard areas, although some maps are better than others.
Perhaps the biggest problems with this approach are that it is doing little to reduce risk to existing structures, which do not seem to be "phasing" themselves out as quickly as originally envisioned; it does not protect today's development from tomorrow's runoff, which always seems to be higher than anticipated, due to urbanization; and it does not account for coastal damages, either from erosion or storm surge.

**Controlling the Rivers and Oceans**

Our principal strategy over the last century has been that of using federal agencies and funds to "control" rivers and oceans, and thereby prevent them from "causing" damage. The nation has spent over $25 billion in tax money on dams, levees, channels, and shore protection, but flood losses as measured in real dollars continue to rise. As noted in *Floodplain Management in the United States: An Assessment Report*, this structural approach is not working. The 1993 floods illustrated this vividly. This approach was geared toward the federal government's *solving* the problem, and letting citizens, localities, and states ignore it.

**Adjusting the Techniques We Have Tried**

None of the four approaches is a bad idea. But none of them is working perfectly, either, and there needs to be better combinations of approaches as well as improvements in implementation. Let's look at some improvements that would be good for the nation's taxpayers and floodplain citizens alike.

**Disaster Relief**

Probably our best strategy on disaster relief is simply to accept that in the end we will have to provide it in some form, so let us set up reasonable conditions for receiving it. Some of those might be:

- Do not use disaster relief to rebuild as is, at risk. Instead, we should require mitigation whenever we can.

- In particular, we should require mitigation for public infrastructure and facilities.

- Establish a principle that, if no mitigation action is taken, disaster relief funds will not be paid to the individual (or locality) next time.

- Provide equity between cost-sharing for structural and non-structural approaches.
• Use the opportunity of a disaster to restore natural systems/floodplains by moving levees back. Restore wetlands by acquiring easements from willing property owners.

• Expand our use of natural channels that do not pass flooding or sediment problems downstream.

• Disaster assistance cost sharing to each state should reflect the effort that state is putting into preventing disasters. We might begin with a base 50/50 division of costs, then provide incentives over that for good floodplain management and emergency management programs to perhaps 75/25. It is difficult to see how 90/10 encourages positive actions.

**Increase Costs to Those Living at Risk**

No one should get benefits from the NFIP who does not pay for the risk—whether that be erosion on the coast or non-A zones (stormwater flooding). We need to explore ways to pay for good maps. For example, would people want to be mapped in the floodplain if that were the only way to obtain insurance? Lenders should be required to escrow flood insurance, as they do for fire insurance.

• We should lengthen the waiting period for coverage to 30 days.

• The NFIP must pay for better maps, and use GISs, but care should be taken to adopt only proven digital mapping systems that can be readily updated and are reliable. Maps of unique hazard areas, like alluvial fans, debris flows, etc., are essential.

• Agricultural disaster losses need to be addressed. Studies have shown that it is less expensive for the taxpayer to pay for a crop reinsurance program than to pay disaster costs, equity payments, etc. for high-risk agricultural land. That seems to suggest an approach relying heavily on easements, even if the land is to be farmed regularly, as long as levees on such lands are avoided.

**Regulate New Development**

Most localities (18,000 of them) now have floodplain regulations in place, and that is an admirable situation, but some improvements are needed.
Freeboard of from 1 to 2 feet is needed, along with a zero-rise floodway without easements.

Substantial damage thresholds should be 50% and counted cumulatively for each structure.

Is the 100-year standard the optimal one? Certainly critical facilities should be protected to the 500-year level.

Future runoff conditions should be taken into account, especially for stormwater and coastal erosion.

Encourage, with incentives, stronger state programs and capabilities. States should provide training and technical assistance to locals to be most effective, and integrate the many federal and state programs that must be dealt with by locals.

The Test of Time

Two basic approaches have been used in the past to cope with flood problems. First, federally planned, sponsored, and built structural projects such as dams, levees, and channels, which were generally single-purpose projects. It is true that some are multi-purpose, but that is not same as "multi-objective."

The second technique is a largely nonstructural one, which takes the form of locally developed projects that acquire hazard areas, relocate structures, and achieve many community goals beyond flood loss reduction, e.g., recreation, water quality, housing improvement, economic development, energy management, greenways, waterfront improvement, environmental management, and others.

Which of these approaches will best stand the test of time? When they are built, structural projects are often viewed as a boon to the local economy. They are especially promoted by those who are either protected from some flooding by the structure, or by those who have property that is not developable now, but could be developed at a lower cost if the project were built. But there are a couple of problems with the structural approach that are often overlooked or glossed over.

First, all projects are designed to a certain size flood, usually 1% or 2%. Sooner or later they will be overtopped or fail, as we saw in the 1993 flood. When that happens, it is inevitable that the damage will be worse than if there had been no protection at all, because few if any preventive measures will have been taken by landowners in the "protected" areas.
Second, all structures have a design life, just as cars do. To even reach that life requires lots of money for operation and maintenance (which is often neglected), until at some point replacement is required anyway. When the community is faced with replacing the expensive structure or taking it out because it can no longer perform adequately, there really will be no choice. Because of the increased reliance on the structure, and the increased development behind or below it, the community cannot remove it and will be forced to invest in another structure, whatever it costs.

The non-structural projects tend to stand up better because:

(1) They rely on natural systems, allowing nature and the water to maintain flood storage and conveyance.

(2) Future development will not be dependent forever on operating, maintaining, and ultimately replacing, a structure.

(3) Future development is not placed "at risk," with that dangerous false sense of security.

(4) Because they are generally multiple-objective, and locally developed, they have better community support.

**Which Level of Government Should "Address the Problem?"

Experience shows that it works best when plans are developed and implemented through a local, bottom-up process. So how do we help locals meet regional, state, and federal goals for policies on flood loss reduction, disaster reduction, and environmental protection? It is clear that we need at least some new institutional arrangements. One good approach would be to set up regional frameworks to establish goals and broad parameters and priorities. Such a scheme would be based on watersheds, not on one subbasin or other small geographical area. Then locally developed plans would address local issues within that broad framework, and would solve multiple local problems.

**Empower the Locals**

- State and federal governments can help with technical assistance, data, and funding.

- These efforts should proceed in a multi-hazard fashion, e.g., show dam failure on flood maps.
• All local interests should come to the table to develop local land and water plans.

• Both pre and post-disaster settings should be used.

**Involve the Private Sector**

The private sector contains the professionals with skills to help locals put together comprehensive local plans. There are simply not enough state and federal personnel to do the planning and design, and the ones that are involved should be coordinating instead. This will require a fundamental change in government roles as we have viewed them in the past, with the federal agencies and staff steering rather than rowing, and needing to package the programs much as was done with the "patchwork quilt" resource directory in Iowa. At the same time, the states must become the leaders and take over the roles and responsibilities that they should have had all along.

Multi-objective watershed management has been done and it does work, but it requires the coordination and cooperation of all levels and agencies. On the bright side, it probably will require little new money. Regional plans can be made through intrastate compacts, with the states and federal government at the table to agree on the framework.

**How Can Floodplain Managers Help?**

All floodplain managers are the future of floodplain management and flood loss reduction. Join with others to make it work. Be persistent—success often comes in small steps. Many of us have been working for 25 years to make changes in the nation's response to flooding. The 1993 flood has gotten the attention that decisionmakers need to make that happen. We must be ready to seize this moment!

While we are getting inspired, we must take care to avoid actions today that will require correction tomorrow. Likewise, we must build off the numerous successes we have had. And we must work together and use other programs to achieve our ends and at the same time bring in new actors, people, and programs, like those of the National Park Service, the Environmental Protection Agency, the Department of Energy, housing agencies, environmental groups, and programs for economic development.

With continued persistent effort by us all working together, we may in our lifetimes see numerous places in this nation where people no longer feel it good or necessary to "control" our rivers, but where people understand that we and our rivers can and must live in harmony.
MAKING THE CASE FOR GREENWAYS

Christopher N. Brown
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Introduction

Greenways are sweeping the country. From Portland, Pocatello, and Lake Ponchartrain to Davis, Dallas, Davenport, Denver, and Des Moines to Tallahassee, Tulsa, and Tucson, communities are opening and embracing greenways.

But what is the relationship of greenways to flood loss reduction? Non-structural alternatives, multi-objective planning, and greenways are, if not the "new kids on the block," still considered cutting-edge concepts in floodplain management. They are "green," and "soft"—newly politically popular, but of assailable utility and cost-effectiveness when it comes to the "real" work of reducing flood damage. In some, cases they may not be feasible at all.

We do have the Federal Emergency Management Agency's Director James Lee Witt saying, "We can literally change the landscape of this country by putting mitigation first and doing it year round instead of only when the disaster happens." And we have Gerry Galloway of the White House Floodplain Management Review Committee calling for far wider use of non-structural methods.

But, given the inertia in the floodplain management community and local pro-development politics, those of us who believe greenways are important have a ways to go to make the case. Here is a start.

First, working definitions: Greenways are linear corridors in which natural vegetation predominates and which provide multiple societal benefits. Multi-objective floodplain management is a process in which a flood loss reduction scheme is carried out so as to incorporate as many diverse benefits as possible. The multi-objective approach may rely heavily on protecting unobstructed open space in a river's natural floodplain—greenways, wetlands, natural areas—as the most environmentally benign and least costly alternative, even when there will be initial costs to buy out or relocate existing structures.

A strong argument for multi-objective greenways will rest on three assertions:

(1) Greenways work; they solve flood problems.

(2) Greenways are cost effective.
(3) Greenways are politically supportable because they address the big issues of our society.

Greenways Work

We can point to cases where greenway-type solutions have been successful; some are described in the National Park Service (NPS) publication *Managing Rivers for Multiple Uses*, including that of the Kickapoo River in Soldiers Grove, Wisconsin, and the Charles River in the Boston metropolitan area. Others are documented elsewhere: the American River Parkway in Sacramento, the Virgin River Parkway in St. George, Utah, the Platte River Greenway in Denver, and the Colorado River Waterfront Project in Grand Junction, Colorado.

While each of these has a locally designed and tailored plan, a unique solution in a particular local and regional context, they as a group provide a body of experience and practice from which we can say, "greenways work." Each has many recreational, cultural, wildlife, and other environmental amenities, but has proved itself for flood loss reduction as well.

Greenways are Cost-Effective

This assertion must be qualified with,"It depends." What is the current level of development in the floodplain? The topography? The land values, the flood history, the feasibility of relocation? Many factors go into cost-effectiveness. But, beyond these, there are observable, quantifiable, but frequently unrecognized benefits from greenways which must be factored in if a true picture of cost-effectiveness is to be achieved. Many of these are documented in an NPS publication, the *Economics of Protecting Rivers, Trails and Greenway Corridors*.

These benefits cluster under a number of headings:

- Rising property values—Surveys of property owners and real estate professionals indicate that real property values tend to increase in areas adjacent to or near trails and greenways. This can mean an increased tax base as well as happy property owners.

- Recreational dollars—People are spending increasing amounts of money on recreation. In California in 1988, for instance, residents spent an average of 12% of their total personal consumption on recreation and leisure. The existence of trails and greenways close to home keeps more of the money in the community as residents find recreational opportunities in their own backyards.
Increased economic activity—The agencies and organizations that manage protected land provide jobs and spend money as they go about their missions. The county of Sacramento, California, for instance, spent over $1 million on servicing, supplying, and hiring for the American River Parkway, a 5,000-acre greenway, in 1989-1990.

Tourism—Tourism is big business, especially if your greenway becomes a significant regional attraction like the Chattahoochee National Recreation Area in Atlanta. Tourism is highly labor-intensive and has continually outperformed the overall economy in job creation for many years. The Riverwalk in San Antonio, Texas, for example, is the second most important tourist attraction in the state.

Enhanced quality of life/corporate location—Protected areas add to the quality of life in a community and corporations rate these considerations highly when looking for a place to locate their operations. The Joint Economic Committee of Congress found that businesses are attracted more by a city's quality of life than by purely business-related factors.

Reduced public spending—Conservation of rivers, trails, and greenways can help reduce the need for constructing sewers, roads, and schools—expenses that in many areas are not recovered by the revenue increases from development. Public spending may also be reduced in such specific areas as stormwater management with establishment and maintenance of vegetation, especially tree cover. In Tucson, U.S. Forest Service scientists estimate savings in stormwater management costs were over $600,000 annually.

Hazard mitigation—Greenways or parklands established in hazard-prone areas, such as floodplains or other unstable land, avoid potential public costs for damages. In Dayton, Ohio, runoff from an intensive storm was reduced by a crucial 7% off the peak by trees. In Richmond, California, in 1980, the Trust for Public Land pre-acquired land for inclusion in Wildcat Canyon Regional Park that was slated for residential development. Major storms in ensuing years caused landslides on the property that would have destroyed any development and would have resulted in multi-million dollar claims against public agencies.

Pollution control—Buffer strips of vegetation help control water, air, and noise pollution, which may decrease pollution control and public health costs borne by public agencies. One recent study showed that 1/2
million trees in a city like Tucson, Arizona, could remove 6,500 tons of particulate pollution per year, with an "engineering value" of $1.5 million per year.

- Reducing energy costs—The cooling, largely by evapotranspiration, of our present 100 million mature urban trees is estimated to reduce energy use, saving $2 billion in annual costs.

- Biological diversity—Maintenance of rare and endangered species habitat has become not only a biological and moral imperative, but also a significant factor in the economic calculus. Greenways contribute significantly to biodiversity without always requiring that large blocks of land be protected.

**Greenways Address Critical Societal Issues**

John Crompton of Texas A&M University recently wrote about repositioning park and recreation services: "The key to securing additional tax funds . . . is to position [your issues] so they contribute to alleviating problems which constitute the prevailing political concerns of those policy makers who are responsible for allocating tax funds." This assertion challenges us: how do we cast greenways as helping solve national problems like the federal deficit, crime, health, jobs, and changing demographics?

Direct cause and effect may be harder to establish here, given the complexity and magnitude of the issues. But logic and considerable evidence point toward the conclusions that

- Non-structural techniques will lower disaster costs and reduce future demands for federal relief funds.

- Recreational open spaces help reduce crime by providing social outlets and opportunities for youth at risk. In addition, demographically, the next quarter century is conservatively estimated to add 40 million Americans, and 80% of the increase will be members of racial and ethnic minorities. Throughout the country we see new immigrant and ethnic populations drawn, as are longer-time residents of the United States, to rivers for sustenance, for recreation, for open space. Greenways will play a major role in social integration, serving as a place for informal contact and acculturation.

- The nation's health and wellness can be substantially affected by parks and greenways. From a cleaner, less illness-causing environment, to
spaces for health-giving exercise, to the measurably increased rates of recovery from illness when exposed to green spaces, greenways undoubtedly will contribute to reducing the overall burden and cost of health care in this nation.

• Job creation is likely, in an era when tourism ranks as the first, second, or third most important industry in almost every state.

While economic impact analysis has its shortcomings, those who are making the case for greenways must advance all these arguments where we can, and quantify them when possible.

Conclusion

In making the case for greenways, we are not simply talking about another flood loss reduction technique. We are talking about a new mindset. We are talking about, wherever possible, making floodway and river corridors and stormwater management channels into greenways, and into networks of greenways that will become, as one high administrative official has said, the new green infrastructure or "greenfrastructure," for the 21st century. Greenways will be the lungs for clean, cool air, the arteries for fresh water and wildlife and for safer, less costly, energy-efficient transportation and recreation, the spill-over for floods, and the outlets for social ills. The vision that some of us are working toward is of a greenfrastructure for our metropolitan areas that is every bit as vital to the functioning of our communities as the infrastructure of highways, water mains, sewers, and electrical utilities is today.

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I have been invited here today to talk about the challenges floodplain managers face in the future in the context of other hazards and from the objective viewpoint of an academic setting. Before I begin, I would like to preface my remarks with a few caveats. First, I want to warn you up front, that my "hazards" roots are in floods. Before moving to the University, I worked for several years in the water resource agencies of the states of North Dakota and Illinois in their floodplain management offices. As a result, I tend to look at other hazards in the context of floods, and not vice versa. Second, having benefitted from the experience of being a "practitioner"—a state floodplain manager who spent a lot of time driving the highways and byways of those two states to work with local communities on their floodplain management programs—I cannot claim that my comments are as "objective" as they might be coming from a different representative of the academic community. Finally, for the past few years, I have had the opportunity to work on a fairly regular basis with Gilbert White. Hence, I am somewhat "contaminated" by his ideas. In particular, since last summer we have worked together on flood-related projects. As you might suspect, this has been a floodplain manager’s dream come true. I have learned a tremendous amount just being around Gilbert, and hope that I can remember at least half of what he has taught me. In no way is he responsible for what I have to say today, but let me take this opportunity to publicly thank you, Gilbert, for the encouragement and friendship you have given me so generously for the past few years.

What are the major challengers for future floodplain managers? Several have been raised during this week, but I suggest that there are five major issues that are changing or evolving to present both challenges and opportunities to floodplain managers in the future.

Placing Design Standards in Context

The first of these challenges is that of the 100-year standard. For many years, we have relied on the 100-year or 1% standard as a basis for many of our flood management programs. What has been forgotten however, is that from the first, the 100-year standard was regarded as only a minimum standard for these programs. In using this standard, by default there seems to have developed a
widespread belief that if we are protected from a 1% chance flood, then we are "safe" and not at risk from floods.

There is a reason uniform national standards have become commonplace in the United States. They are relatively easy to define and enforce, and they create the impression of even-handedness, a notable virtue that has been embraced by both members of Congress and the federal agencies. But do they serve well the needs of widely differing communities?

The need for some uniform national design standards is obvious. There must be a clear definition of the scope of any public program. But these public programs are applied at unique locations in the country and they must be flexible enough to be adapted to those locations.

Just as uniform federal standards are needed for certain federal purposes, so too are site-specific local standards needed to address appropriately the widely varying conditions of the nation's flood-prone communities and states. The federal 1% standard does not necessarily make sense as a local floodplain management standard because it is unrelated to the specifics of the local flood problem. The definition of the hazard zone should depend upon each community's own unique hydrologic, topographic, economic, and demographic characteristics. This was demonstrated beautifully in Jack Page's presentation about Tulsa, in which he described that City's regulatory program, which far exceeds minimum standards.

What was originally intended to be a politically acceptable minimum standard of protection has too frequently become the only standard, and an inappropriate one in many circumstances. It has had the unfortunate effect of encouraging public officials, developers, and the general public to believe that land outside the A zone on a Flood Insurance Rate Map is not subject to flood risk. There are many of us, I am sure, who have seen a line on a map and gone to find that line in the field and try to explain why the land on one side of the line is subject to regulation while the other side is not. Further, this default 1% standard has given many the false presumption that whenever any flood control project is in place it is sure to keep flood waters away forever. We saw this last summer when agricultural levees along the Mississippi River designed to protect against frequent small floods engendered a false sense of security, encouraged development behind them, and increased the damages suffered when the flood of 1993 struck.

The challenge for floodplain managers is to help each community seek the maximum net benefits from its floodplain management planning and regulation program. It has been pointed out that such a goal was suggested as far back as 1936, when the Flood Control Act of that year proclaimed that for federal projects, "the benefits, to whomsoever they may accrue, shall exceed the costs." This language offers only a constraint to protect against development
which is unduly costly to the nation's taxpayers. An appropriate goal at the local planning level would be to maximize net benefits of floodplain land uses.

**Defining Costs and Benefits**

A natural followup to this discussion is the next major challenge I see for floodplain managers: defining "benefits" and "costs." Most often these words are construed only to refer to short-term monetary benefits and costs. While I want to say this should not be the case, the fact of the matter is that decisions made about flood protection programs—by local, state, and federal politicians—frequently are based on short term (i.e., the length of their term in office) fiscal prudence. We do not have the benefit of as many visionary people like J. D. Metcalfe as we would like to in this world. As a result we have difficulty in determining the true costs and benefits—both tangible and intangible—of many of the public policy decisions that are made. The challenge to floodplain managers is to do a better job of identifying, documenting, and quantifying—in monetary terms—especially the non-tangible costs and benefits of occupying or not occupying flood-prone lands and of various structural and nonstructural programs in the long run. It must be done in such a way that decision makers and the public, who have so many other items on their agendas, can clearly have all the information they need to make wise decisions.

**Making Flood Insurance Work**

Since its inception in 1968, the National Flood Insurance Program (NFIP) has been unsuccessful in getting people to purchase flood insurance. In particular, the number of policies in force has stayed fairly constant over the past decade. While I applaud the commitment the new Federal Insurance Administrator, Elaine McReynolds, has made to "increase market penetration," I remind all of you that this is not the first time we have heard such a statement from a new administrator. I see three major reasons for the failure of flood insurance. The first has to do with the lack of compliance with the mandatory purchase requirements. Perhaps the solution to this particular part of the problem will soon appear if the current legislation in Congress to reform the NFIP passes with sufficient penalties for lending institutions that fail to comply. This is not going to be the full answer to the problem, however, as it applies only to structures with loans. The second major reason is disaster policy. Current disaster policy provides no incentive, and sometimes it provides disincentives, for victims of floods to carry flood insurance. Unless strong requirements are put in place for flood victims who receive federal disaster relief to acquire and maintain flood insurance, insurance will never be the powerful tool it could be to promote mitigative behavior. The third reason flood
insurance is a problem is that it fails to act like private insurance. With private insurance, when a claim is made against a policy, the insured soon learns that his or her premiums go up. If a second claim is made on that policy, the insureds often discover that they will no longer be covered. At this point, the individual has to make a decision—she can take steps to mitigate further potential loss and qualify for insurance again, she can decide not to file a claim and assume the costs herself, or she can take the risk of not being covered for a catastrophic event.

Let me give you an example. I live in a condominium complex comprising mainly town homes with wood shake shingles. When it came time to renew our policy this year, we were told flatly that we would not be renewed because we had more than 50 units with wood shake shingles that were more than five years old. Period. End of discussion. The company claimed that wood shake shingles were too vulnerable to wind and hail damage. While we were able to find another company to carry us, we are starting a reroofing project this summer that will make our complex more resistant to damage from wind, hail, and fire. Insurance is the "stick" that is causing us to take mitigative behavior. Why should people who carry flood insurance be any different? Why shouldn't it be designed to encourage people to take steps to reduce their vulnerability to damage? I realize that attempts have been made in the past to increase rates for repetitive loss structures and that Congress has failed to do so. This, however, is one of the big challenges for floodplain managers—to keep fighting that battle.

Using Windows of Opportunity

I would like to be able to say that new reforms in disaster policy might put some teeth into making individuals and communities more responsible for the unwise decisions they have made, which often turn natural hazards like floods into natural disasters, but I think it unlikely that state and federal politicians will forego the opportunity to bail out victims of disaster. As you know, right after an event, there is a tremendous amount of interest in, and political, public, and financial support for, implementing mitigation programs. The smart floodplain manager will recognize this well in advance of an event and be prepared to take advantage of such opportunities. So the challenge to you is to do "pre-event" planning for "post-event" recovery. If you are ready to begin recovery, your community will fare much better.

For example, the City of San Jose, California, after experiencing minor damage from an earthquake in 1984, decided it was critical to create a Comprehensive Earthquake Master Plan. This plan was finished, and slowly and incrementally the City has been implementing the plan. However, the implementation process got a big shot in the arm when hazard mitigation funds became available after the Loma Prieta earthquake. Because the city had done
advanced planning and had already evaluated buildings that needed to be retrofit for seismic safety, and had cost estimates in hand, they were ready to move forward with decisions about which buildings to retrofit. They did not have to start from square one. Their planning process—nicknamed "Plan Ahead Yesterday"—in which the city spent money planning for unknown future funding sources, paid off for them.

San Jose provides a good case example to show that if plans and processes for recovery are in place before an event takes place, then decisionmaking for recovery can be done in a wise fashion. The floodplain manager can play a very important role in this process. While you might see this as something that makes more work for you, mark my words—pre-event planning will make the job of recovery, not if, but when, the flood occurs, easier.

Incorporating Resource Management

Finally, I am not the first this week to talk about the fact that there is a growing trend to view floods and floodplain management in a broader resource management context. In fact, that is part of what this whole conference and its theme—Nania—is all about. The floods of this past summer brought to the forefront the notion that floodplains are meant to be shared; that there is a need to balance human use of floodplains with the natural components of the landscape. The floods reminded us that conventional wisdom about how we do or can deal with floods is changing. We no longer look at floods with tunnel vision of simply trying to reduce flood losses by keeping flood water away from people or people away from flood water. Rather, we are recognizing that the sustainability of our communities, our regions, our states, and our country is dependent on how well we manage floodplains as part of a whole. Natural hazards, like floods, present a true challenge to society. The sustainability, if you will, of a society can be measured by how resilient it is to disaster. As floodplain management professionals you have a tremendous challenge as well as opportunity to help society deal with disasters and hence make the environment more resilient.

This challenge must be met with the understanding that flood loss reduction efforts—indeed, all hazards reduction or management efforts—must be a day-in and day-out process, not a disaster strategy. It is a process that must consider "quality of life" as well as the protection of health, safety, and welfare.

This is the hard part. You cannot meet this challenge with a tunnel view. You cannot just think about regulating development, preserving natural functions, or controlling flood waters. Rather you must think about how every decision made every day by your local and state government, by developers, and by individuals either increases or reduces the likelihood that flood damages in
the future will be worse. And, you must think about how you can influence those decisions.

I think the Association has done a tremendous job in promoting this concept of sustainability by forging new partnerships with other organizations, especially those with environmental interests to preserve the natural resources of our great country. This is a good start, but the work must be continued—to maintain and nurture those partnerships that have been created, to translate them from talks among professional organizations at the national level to their counterparts at state and local levels, and to draw even more partners into the fold, especially the private sector, which invests the capital into our communities.

So these are the challenges I see ahead. I look forward to working with all of you as our Association continues to meet the challenges and make the world a safer place.
THE LOCAL OFFICIAL’S ROLE

Fred R. Brusso, Jr.
City of Norfolk, Virginia

In the past, the local official’s role has been underestimated, often ignored, and/or considered subservient by lending institutions, banking facilities, and state and federal agencies. Likewise, the local official has at times treated these groups as well as the citizens they serve in an antagonistic or cavalier manner. These actions and reactions between groups are changing, as they must, through the programs of the Association of State Floodplain Managers, the new direction of the Federal Emergency Management Agency under the leadership of James Lee Witt, and the disasters delivered by Mother Earth.

As we all are aware, Mother Earth has given us Hugo, Andrew, Iniki, The Blizzard of the Century, and the Flood of the Century—all in the last five years. There is one school of thought that Mother Earth has used these disasters to draw our attention to the greatest disaster of all, the way we have been independently reacting to these recurring natural events. We have heard during news media reports and testimony of experts that the damage is caused by too much rain, soils that are supersaturated, etc. Our blame is placed on nature, not on ourselves, where the blame truly lies.

Finally, through our experiences with the Midwest floods, we now are recognizing this true disaster and as such we can begin mitigation and recovery. Each of us now has a choice. We can

- Cry and comment on the situation until the public is tired of us and no conclusion is reached, or
- Move together into a future that is remembered as an era of cooperation and accomplishments.

I am proud to say from the discussions and meetings during this national convention we all are assuming new roles and understandings to accomplish what we could only dream of a year ago.

To stand before you and explain the duties and challenges the local official faces is, especially with the large number of local officials present, preaching to the choir. But, as you and I have at times seen, some members of the choir need reminding and all of us need to be informed of which hymnal and page to sing from. Therefore with only a little reminding let us look into my city-issued crystal ball and outline the role of the local official of the future.

First we need to know, Who or what is a local official? Since the National Flood Insurance Program began, the local official has been either the
Building Official or Zoning Administrator for a town, county, or independent city.

What was/is our role? According to many at the state and federal level, our role has been to interpret the Flood Insurance Rate Map, inspect buildings, and maintain a set of regulations that the regional FEMA office has approved, thus keeping new development out of hazard areas or, if allowed, assuring that construction is completed in a prescribed manner.

Is this an accurate description of our duties? No! It is incomplete. In addition to these duties generated by the NFIP, the local official must:

- Prepare a budget;
- Oversee employee concerns;
- Plan for structural as well as organizational office modifications;
- Spec and write contracts for GIS systems and other computer systems;
- Oversee erosion and sediment regulations;
- Oversee construction structural concerns;
- Oversee or coordinate stormwater concerns involving both quality and quantity issues;
- Enforce American Disabilities Act regulations;
- Prepare public education programs for all activities;
- Testify in court on issues involving all activities;
- Write and review new ordinances;
- Prepare new forms and applications;
- Speak at council, commissioner, and civic groups;
- Do determinations of FIRMs for determination companies;
- Check bars and restaurants to enforce proper hours of operation;
- Investigate complaints concerning neighbors' lights that are too bright, cars parked on the lawn, and commercial vehicles in residential districts; and
- Play host to state and federal officials who want to check on how their specific program is proceeding or being enforced.

While the list can continue, I have already provided duties that many will have difficulty remembering. An easier way to think of the current duties of the local official is to consider the local official as the catcher on a baseball
team. He or she calls for a specific pitch and then blocks a wild pitch. We are the only player on the field who can see the entire field of play and all of the players: local administrators, citizens, lending officers, insurance agents, neighboring officials, state and federal agents, etc. Also, we are the last line of defense and must try to correct the errors of all the others.

Additionally, the local official is a bus driver. We are assigned a vehicle, a prescribed route, and the responsibility to return the bus in good shape while delivering passengers safely and on time to their destination. All while others are blocking our path, parking in our stops, and at times actually physically attacking us.

Finally, the local official is a parent who with love and dedication nurtures and provides for several programs.

With the changes we are participating in, what will our role as a local official be? Will there be additional duties? Will there be a modification of duties? I believe that in the future:

• I will have to be a team player who gets results, not someone who protects a process.
• I will have to realize that all members of the team—local, state, federal, and citizen—are important.
• I will have to communicate and coordinate activities within the locality with regard to the construction of buildings, management, identification of stormwater issues, and conservation and the wise use of the environment.
• I will have to communicate and coordinate activities with neighboring localities with regard to the construction of buildings, management, identification of stormwater issues, and conservation and the wise use of the environment.
• No longer will I be able to be satisfied with a robotic existence.
• I will have to be open minded.
• I will have to approach problems with an attitude of solution not condemnation.
• I will have to be a part of the floodplain management family.

Sounds a lot like a Scout pledge or a parents' promise to a newborn, but to be successful in the future, dedication will be required.

With the local official as a member of the floodplain management family there will be many external events that will shape the future. Most of these events are just below the horizon where we cannot see them and will
surprise us. Some of the surprises will be pleasant experiences, like the current spirit of cooperation we are experiencing with FEMA. Others, while unseen, can be classified as legislative issues, training and education, and policy changes at local, state, and federal levels

Legislative Issues

We have to be aware of the pending changes to the floodplain regulations on state and federal levels. We also must be aware of changes to neighboring communities, whether they or right or wrong. Through the Association, the status of pending legislation is reported in a most timely manner. We must be concerned with what new regulations on a local, state, and federal level are being developed which, while not affecting floodplain regulations, will if adopted affect our ability to devote sufficient time to the management of floodplains.

Training

Often we ask, Do I have the time and resources for training? Then immediately ask, Do I have the time and resources to ignore training? There is an old saying, "Learn to do the job right. Afterwards, quick and pretty will follow." Look to the various training classes and sessions being developed. These need to be completed and offered to all local officials. Perhaps completion of specific training could be used to grant credit for Community Rating System communities.

Policy Changes

This may be the largest question mark on the horizon of the each local official. Laws may change, training increase or decrease, but policy changes always seriously alter the way we do business. And they occur without public hearings or comment. One such example being considered on the local level is that of privatization of services. I am not here to say privatization is good or bad, just that when it occurs the role of the local official will change. Already many localities are experimenting with a modification of duties by contracting to the lowest bidder responsibility for police and fire protection. Programs are in the planning stage in some localities to include school operations and inspection services. Some smaller communities are already experiencing a form of privatization through agreements with neighboring communities. The extension of this privatization into the duties and services we now are providing is assured because of the reduction of funding sources. The major question we face is the extent of it.
I could have stood before you today and told you local officials work hard, and have a lot to do, and not held you for the past ten minutes. To do so would have been a disservice to all, for without understanding the trail the local official walks on, no one could have understood what our future will be. To remember the local official at times has to say no to neighbors and family, while others work with a concept is most important.

The future local official's role will be that of the spotter in the field learning from Mother Earth. With this knowledge we will be administrators, visionaries, and technicians. To accomplish this goal we only ask to be received, supported, and considered a member of the floodplain management family. Then together we all can accomplish the ultimate goal of protecting the citizens, property, and environment from the injury, loss, and destruction associated with floods.
FLOODPLAIN MANAGEMENT IN THE 1990s

Phillip M. Demery
Santa Barbara County Department of Public Works

Over the past 20 years, flood control districts, cities, and counties have become well versed in the efforts and processes required for implementing structural flood control solutions. Such solutions often require feasibility studies, preliminary planning and design, public workshops, environmental documentation, project design, and permit processing. Project approval and financing is never guaranteed. Even when local governments are successful, many years of effort are required before benefits are realized. Lacking the revenue, personnel, time, or public support needed to implement a major capital improvement program, many local agencies have implemented floodplain management practices as non-structural alternatives. A floodplain management partnership has been formed between local and federal government which defines a three-step process whereby: 1) flood risks are identified; 2) communicated to the public; and 3) minimized by local regulation.

However, floodplain management has become much more complicated since the early 1980s, especially in California where land is at a premium and environmental activism at a maximum. The traditional three-step process no longer assures flood protection, nor does the traditional local/federal partnership have the ability to resolve floodplain management conflicts.

The traditional three-step process may protect the floodplains from incompatible human intervention, but it does not necessarily preserve the flood-carrying capacity of the watercourses, our true goal as floodplain managers. In Southern California as in other arid or semi-arid regions, most watercourses are ephemeral in nature: alluvial systems that continue to change in position and shape. It is the rule rather than the exception that banks erode, sediments are deposited, and floodplains undergo modification with time. For example, in Santa Barbara County there have been creeks that have completely filled with rock and sediment upon flow events, creeks that formed new courses due to blockages of downstream bridges and culverts, a river that degraded over 16 feet during one winter, and a river that in four years became so choked with 30-foot-high willow trees that you could not walk within the riverbed.

The traditional three-step process really works only for stable geomorphic conditions, not for alluvial systems. The only reasons the process has worked effectively in the past in arid and semi-arid areas are that population densities in the impacted communities have remained low, the creek or river has been turned into a concrete canal, or the creek or river has been maintained
Floodplain Management in the 1990s

simulating stable conditions (routine removal of flow-obstructing vegetation and sediment accumulations to provide similar channel capacities year after year).

Communities that maintain their watercourses in order to manage their floodplains are finding that it is becoming difficult, if not impossible, due to the interpretation of state and federal environmental laws and the state and federal resource agency enforcement of environmental mandates. In many cases the community’s floodplain regulations, adopted in the 1970s and 1980s, were based on maintenance of the watercourses. If the watercourses cannot be maintained in the 1990s, not only do the regulations become meaningless, but also many people thought to be safe will be exposed to flood damages.

Although flood control officials in Southern California have been struggling with this maintenance conflict for about seven years, because of a prolonged drought the damages which result have only been observed within the last three years of runoff. However, in Southern California alone, flooding occurred on the Mohave River in San Bernardino County, the Santa Ynez River in Santa Barbara County, and Murietta Creek in Riverside County as a result of the inability of the flood control officials to obtain environmental permits necessary to maintain the watercourses. In addition, it has been reported that the inability to provide maintenance has been a key factor in erosion damages along the Santa Clara River in Ventura County and the destruction of two of three bridges across the Santa Ana River in Redlands, San Bernardino County. These events resulted in millions of dollars in property damage and, in most cases, life-threatening situations.

The traditional local and federal government partnership has provided the basis for floodplain management throughout the country. In regard to the maintenance conflict affecting floodplain management in arid and semi-arid communities today, this partnership is dysfunctional. On one hand, the Federal Emergency Management Agency (FEMA) and the U.S. Army Corps of Engineers (Corps) are actively participating with local government in the three-step process to reduce flood losses. On the other hand, the federal regulators (the Corps, the U.S. Fish and Wildlife Service, and the Environmental Protection Agency) are preserving air quality, water quality, wetlands, riparian habitat, and endangered species. The Congress has adopted a myriad of environmental laws spreading authority for preservation among the regulating agencies, yet the responsibility for flood protection lies solely on the shoulders of the local flood control agencies. The federal government has removed itself from the inherent conflict, letting local government fend for itself while weaving through the federal regulatory maze. The irony is that upon flooding, the federal government provides the community with disaster assistance, but can reserve the right to subrogate on any claim in which flooding was caused by the lack of maintenance.
Solutions

Operating a preventive maintenance program in the 1990s requires a strategy that allows for achievement of stated goals. This strategy must recognize that environmental attitudes and values are part of our society. It is important to remember that without environmental permits, there will be no maintenance. Our goal in Santa Barbara County is to provide the historical level of flood protection, but in an environmentally sensitive way. The obstacles that have continued to stand in our way have been process time and costs, therefore our strategy was to streamline process in an effort to maximize productivity and minimize costs.

In streamlining process time and costs, the Santa Barbara County Flood Control District prepared a comprehensive environmental document for its preventive maintenance program. In addition, a task force was formed with representation from state and federal resource agencies as well as the public, for the express purpose of developing standard maintenance practices, associated policy statements, and an annual planning process consistent with the stated goal. The result was the first program EIR adopted for creek maintenance in the State of California and a revised creek maintenance program that was developed with input by many.

Generation of annual maintenance plans has provided multiple benefits: the plans serve as a basis for demonstrating need, analyzing alternatives, proposing mitigation, and selecting the most effective and least environmentally damaging maintenance practice. The plans also allow for priority-based budgeting as well as management of individual projects.

The Program EIR and revised maintenance program development resulted in a direct savings of $75,000 in the first year and $66,000 in the second year. Permit processing time has been significantly reduced. In some instances, state and federal permits which had previously taken six months to obtain have been issued in one day. However, the biggest success of this program has been measured by the fact that only minor flooding occurred in Santa Barbara County in the 1992-93 storm season, despite the heavy rains in southern California; and no flooding occurred during 1993-94, despite a major watershed burn and normal rainfall. Without maintenance, many of the watercourses would have flooded, causing a great deal of damage with significant costs.

In summary, communities in arid or semi-arid areas of the United States that depend on creek maintenance need to develop a plan. To derive any benefit, the plan must be coordinated with state and federal resource agencies. Upon plan acceptance, the agency or community then needs to pressure the resource agencies for a streamlined process and/or general permits. Santa Barbara County Flood Control District has shown that a successful plan will
cover 75-90% of required maintenance projects each year. Program success can be measured easily in terms of reduced cost, reduced permit processing time and operational efficiency.

Despite the local planning effort, there will still be 10-25% of the necessary projects not mutually accepted by the resource agencies, requiring an inordinate amount of time, huge expense, and a tremendous effort to resolve. For these projects, legislative relief or oversight is necessary and the federal government must engage in the process. In the author’s opinion, FEMA has a vested interest, and should be the lead federal agency in this effort. The maintenance conflict must be resolved now, as nature will not allow us to ignore the issue any longer.
Publications of Related Interest

from the
Natural Hazards Research and
Applications Information Center
Campus Box 482
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Boulder, Colorado 80309-0482
(303) 492-6819

Special Publications


SP21 The Natural Hazards Data Resources Directory. Compiled and edited by Leaura Hennig, 1990. 150 pp. $15.00.


Monographs


Working Papers


WP68  Flood Insurance and Relief in the U.S. and Britain. John V. Handmer. 1990. 43 pp. $4.50.


