Floodplain management in a multifaceted world: Proceedings of the Twenty-First Annual Conference of the Association of State Floodplain Managers, Apr. 28 to May 2, 1997

Association of State Floodplain Managers
Floodplain Management in a Multifaceted World

Association of State Floodplain Managers

Proceedings of the 21st Annual Conference
April 28—May 2, 1998  Little Rock, Arkansas
FLOODPLAIN MANAGEMENT
IN A
MULTI-FACETED WORLD

PROCEEDINGS
Twenty-first Annual Conference of the Association of State Floodplain Managers
April 28 to May 2, 1997
Little Rock, Arkansas
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Preface

"Floodplain Management in a Multifaceted World," the 21st Annual ASFPM Conference held in Little Rock, Arkansas, during the week of April 27, 1997, included sessions on managing hazards, hydraulic modeling, mitigation, partnerships and planning. At the conference sessions, we looked forward to the 21st century and a more enlightened approach to flood loss reduction. We looked back at the early days of floodplain management and the structural attempts to protect development from disaster—measures that were gradually destroying the environment.

The many break-out sessions included watershed planning topics, partnerships, river restoration, and other open space uses that preserve the natural and beneficial values of the floodplain. Many sessions included papers on flood damage reduction planning in combination with other natural hazards to which a community might be susceptible. There was also a lot of mention of partnerships, team building, working together, and sharing resources to move forward toward disaster-resistant communities. It is hoped that we will all sustain this attitude as we apply the latest technology available and get ready for the 21st century and the next ASFPM conference in Milwaukee in 1998.

In the closing plenary session, Dr. Gilbert F. White pointed out that we have been making progress, but we still have a lot to do. As we go through the next few years to the year 2000, we should all heed Dr. White's common-sense approaches to natural hazard damage reduction. Also during that session, Bob Shea of FEMA's Mitigation Directorate shared with us the direction that FEMA will be taking now that the Flood Mitigation Assistance Program is available and the Hazard Mitigation Grant Program is expected to be "streamlined." He also shared the efforts that will be going into the "re-engineering" of the Hazard Identification Branch and the development of more accurate mapping products.

When the conference was over, we looked at another historical restoration and marveled at the progress that we have made over the last century. Then we danced in the street. It seemed to be the perfect way to begin the journey into the future.

Terri Miller
Chair, Association of State Floodplain Managers
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This conference could not have taken place without the help of a lot of people who were willing to work hard and contribute their time and talents. Special thanks go to Randy Young, Executive Director, Arkansas Soil and Water Conservation Commission (ASWCC) and the ASWCC Commissioners for allowing staff time to work on the conference. Thanks also to the Little Rock District Corps of Engineers for providing the boats for the technical tours, and the Federal Emergency Management Agency Region VI for their support.

Many unnamed people assisted as well as those identified below. It was truly a team effort. Thanks to all who contributed to the organization and development of the conference!

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Part 1
NATIONAL POLICY AND PERSPECTIVES
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MANAGING HAZARDS INTO THE 21ST CENTURY

James Lee Witt
Director, Federal Emergency Management Agency

INTRODUCTION

With all the floods that have taken place in the last few years throughout our country, the importance of good floodplain management at the federal, state, and local levels is very obvious. Here in Arkansas we have 22 counties that have been declared flood disaster areas. Many of you in the audience have been working very hard in those disaster areas, and I thank you for that. I remember when I was here in Arkansas, we would travel to the local communities at night trying to get them to join the National Flood Insurance Program. What was really bad was that I was out trying to get others to join the NFIP and I could not even get my own county to join. Because a good friend of mine came to our meeting one night and he said to me, "You can't tell me where to build my barn on my own farm or how to build my barn!" and that ended it. Some of the cities joined, but the county has not joined to this day!

Last week I went with President Clinton to see the flood damage in North Dakota and it was devastating. We have never been through a disaster in which we have lost entire cities—like Ada, Breckinridge, and Moorhead City, Minnesota, and Grand Forks and East Grand Forks, North Dakota, and Watertown, South Dakota. They have fought and lost their battle up there, and our hearts go out to them. This is the worst winter that I have ever seen; but it is the best of human nature that I have seen in those three states: friends helping friends, neighbors helping neighbors. I saw people working until late in the night, helping somebody else's grandmother sandbag her house. We saw the phone company sandbagging inside and outside trying to save the facility so that they could have phone service for those people—and they were unsuccessful.

In Crookston, Minnesota, one high school was sheltering 3,500 people. We saw 25 schools inundated and destroyed in North Dakota. One Minnesota town of 2,400 lost their hospital, their clinic, and their nursing home. They lost the community center that they had raised $1.4 million to build. They lost their school. The school superintendent was taking me through the school. The water had been several feet deep in there, but what was really bad was that the basement had had asbestos in it and it
floated upward, so the whole thing was a loss. And he said, "My wife and I bailed water out of our house for three days because we didn't have any electricity. And after three days we just gave up." Tears were streaming down his face. President Clinton was very moved by what he saw. As we were flying over Grand Forks, looking down at the tops of the houses peeking out of the water, he said very softly, "Every one of those houses in another life story."

THE FEDERAL ROLE

All of you here today know that the federal government can only help so much. We cannot replace everything that people lose. Our programs are not designed to do that. But we are working around the clock with people like you to help get those towns back on their feet. The President has directed 100% federal funding for the direct aid that agencies are providing. Of course our first priority right now is fast, effective response in flood damaged areas. We are doing everything we can, but nothing we can do will make those people whole. People cannot expect the federal government to come in and rebuild and replace everything that they have lost. They have to assume some responsibility themselves—individuals and communities and elected officials. That is why we need to think more about flood management so that in the future we can think less about flood control.

I was asked today to talk about managing hazards into the 21st century. It is a good topic. I believe we are at the turning point in hazards management—a turning point that started in the 1993 Midwest floods, when we began to change the way we do business. We have two good responses: mitigation and flood insurance. Insurance will help people replace things they have lost, just like fire insurance—because our other programs will not. As for mitigation, I saw a quote the other day that said, "Humans master nature not by force, but by understanding." We cannot stop floods, but we can keep communities from becoming victims, or at least lessen their risk. We can bring down the cost of disasters to individuals and communities, but we will never eliminate it.

NEW INITIATIVES

The 1993 Midwest floods led to our first real understanding of mitigation. We learned that we not only had to be ready for cleanup, but had to avoid having anything to clean up in the first place. We began the first wide-scale use of acquisition to reduce future flood losses. The Administration did a major review of the nation’s flood policy, the outcome of which was the report of the Floodplain Management Review
Committee, *Sharing the Challenge*, also known as the Galloway report. Many major FEMA initiatives over the last several years implemented measures recommended in the Galloway report. Our efforts have centered on working with state and local governments—building that partnership, mitigating against damage, and better organizing the government response to both floods and floodplain management. For example, we have increased both the role and responsibility of the states through the Performance Partnership Agreements. We have funded the State Hazard Mitigation Officers. There have been changes in how FEMA administers the Section 404 Hazard Mitigation Grant Program. We have implemented appropriate provisions of the National Flood Insurance Reform Act, and many of those came straight from the Galloway report. And I am pleased to announce that today the interim final rule for the Flood Mitigation Assistance Program goes into effect. FEMA targets repetitively flooded structures insured under the NFIP in an effort to reduce future flood damage and protect the National Flood Insurance Fund. As of today there is $16 million available to states and localities for planning, technical assistance, and mitigation projects. The funds will be allocated by the FEMA Regional Offices this week. And I want to thank the Association of State Floodplain Managers and the rest of you in this room who worked so hard in the passage of this legislation and in the development of the FHMA program itself; it is quite an accomplishment.

I have more good news. The Association of State Floodplain Managers and FEMA will begin a cooperative project to develop an academic fellowship for floodplain management and flood risk reduction. The fellowship will support work in such areas as comprehensive and land use planning, engineering design and construction, materials testing, public policy, and public education. As you well know, floodplain managers come from many fields—engineering, planning, hydrology, and many more. The fellowship’s support will draw attention to how important it is to take advantage of all of the different ways there are to reduce flood losses. We look forward to the fellowship’s success. This is the kind of long-term thinking that we need to be doing, and the kind of effort that will begin to make a difference.

**LONG-TERM SOLUTIONS**

One of the lessons we have learned from the recent floods is that we need more long-term solutions. We need more buyouts. We need more elevation. We need to move the levees back from the rivers to give more flowage easements. And we want to work very closely with the Corps to employ these solutions. On the Red River, I saw that if the levees had been scooted back to give more room for flood waters to flow, we may
not have had as much damage. And we have many, many more ways to
get long-term solutions. One of our goals for the next four years at
FEMA is to reduce the costs of disasters. We can no longer tolerate the
rising costs; it is estimated that disaster costs are up 400% in the last 10
years. And the human cost cannot be reckoned. We have got to break the
damage-repair-damage cycle. It is safer, it is cheaper, and it is easier to
limit destruction than to go back and fix it.

Buyouts

After the 1993 floods we worked with Congress and the
Administration in passing the Vollkmer Bill, which increased funding for
postdisaster mitigation. Since then we have bought out over 10,000 pieces
of property in the Midwest, Houston, Georgia, and many other places.
Individual homes and businesses that had been flooded will never flood
again. That land has gone back to the localities for parks, jogging trails,
and open spaces. In 1995 it was no surprise that the areas we bought out
were flooded again, but this time nobody lived there to get flooded. That
is the difference mitigation can make.

Arnold, Missouri, is about 20 miles southwest of St. Louis, right
where the two rivers come together. The floodplains of both rivers and
local creeks have been extensively developed over the last 50 years.
Buildings that started out as fishing huts became year-round residences.
Flooding outpaced the efforts of the Corps to mitigate it. In 1991 the City
of Arnold adopted a floodplain management program. The 1993 floods
were devastating. But because Arnold's floodplain management program
showed its commitment to making a difference in the future, many of the
flooded properties were bought out. When it flooded in 1995, people did
not live there. The total federal assistance to Arnold after the 1993 floods
was $2 million. After the 1995 floods it was $40,000.

Mapping

The effort to identify and map the nation's floodplains is absolutely
critical if we are going to have a successful mitigation program. A good
map is the most cost-effective pre-flood mitigation tool there is. FEMA is
working to improve our mapping program and bring it up to date. Our
goal is to improve the accuracy of the floodplain boundaries. In
Moorhead, Minnesota, they built a subdivision of homes priced at around
$250,000. When I went into that subdivision, water was already coming
across the road. People had sandbagged all around their houses about
four feet high. One gentleman told me he spent $9,000 just on
sandbagging his house. I said, "Do you have flood insurance?" He said,
"No." I said, "Why not?" He said, "Because the 100-year flood boundary is 300 feet behind my house." He thought because he was 300 feet away he would never get flooded. The entire town of Ada, Minnesota, was out of the mapped floodplain, yet the whole area was flooded. We have to make sure that flood maps are in place, and we have to make people understand that whether they are in or out of a 100-year floodplain or a 500-year floodplain they need to look and be careful where they site their homes, their businesses, and their communities.

We are going to be doing several things to meet those goals. First, we are developing process to make sure that all maps that need updates are identified. Second, we are going to be providing flood insurance studies and information on the Internet and on CD-ROM. We are conducting a study to identify currently unmapped but floodprone communities, to provide them with flood maps in a cost-effective manner. We are looking at ways to shorten the review time for map revisions and amendment requests with the possibility of delegating some revision authority to the private sector. We are trying to find faster ways to complete a community's restudy.

**Disaster-Resistant Communities**

We need to continue to work to change the emergency management culture from one that simply responds to disasters to one that works to keep communities and individuals from becoming disaster victims. Our word for this is "disaster-resistant communities." This is a vitally important new initiative that we will be taking on for the next few years. It will be a public-private partnership for emergency management in communities to reduce risk through mitigation: retrofitting a public building in an earthquake zone, elevating a home in a flood hazard area, putting storm shutters up and using hurricane clips to anchor a house. It is not a fancy government program: it is just using good common sense.

We are going to select four communities nationwide as pilot communities: one for floods, one for fires, one for earthquakes, and one for hurricanes. Working with these communities, we will develop a model for other localities around the country. It will be a federal/private/local project to identify and minimize the risk in those communities. What will this do for those communities? First, we are going to bring in private industry, the insurance industry, real estate brokers, homebuilders associations, the Chambers of Commerce, and others, as partners with us in that community. The initiative will save lives. It will create jobs. It will minimize the losses to residents. It will change the mortgage agreements, lower the insurance premiums, give the locality a better bond rating. And the residents, officials, and business
leaders of that community will have accepted responsibility for a safer and better community—for themselves and their children and grandchildren for years to come.

Public Awareness

We have a big public education job to do and we need to get started. A few years ago, private groups and industry and schools all across this country started a public awareness campaign about recycling. Now, children are willing and eager to recycle. If we start now to educate children and young people in communities, then we can help change the mindset into one of minimizing risk. We need people in schools and communities talking about how to site and build better and safer communities and showing what happens when they put their homes in places prone to floods or earthquakes. We need to start this at a young age, so that when they grow up they will understand its importance.

We need to raise the public’s consciousness about the importance of having flood insurance. We have 19,000 communities that have adopted floodplain management ordinances and participate in the National Flood Insurance Program. And it works. Structures built to the minimum standards of the NFIP suffer 77% less damage in floods that other structures. As of 1995 it is estimated that local floodplain management ordinances prevent over $770 million annually in disaster costs. Yet only 11% of the people in the Midwest had flood insurance in 1993. The same people who would not dream of living without fire insurance do not even think of buying flood insurance. No one thinks it can happen to them.

Conclusion

Over the past four years, with the help of a lot of very dedicated FEMA employees—who are spread so thin now but somehow just keep on working—I think we have accomplished a lot of what President Clinton promised when he said that we would be there in time of need. We have done it by changing the way we do our business. We have gone from being reactive to being proactive. We have done a pretty good job of demonstrating to our country and our communities that mitigation makes a difference. That it saves lives. That it saves money. That we can be prepared. We still have a long way to go. But with the help of dedicated people like you in the audience today, and working along the lines of the initiatives I have described to you, I believe that we can keep ourselves out of harm’s way in the future, and minimize our nation’s disaster costs.
I want to thank the Association for having me come out for the second year in a row to address this very important conference. Specifically, I would like to acknowledge and give my appreciation to Larry Larson and George Hosek for the good relationship we have built over the past year. The Corps has enjoyed an excellent, long-standing partnership with the Association and we think that is very important.

As floodplain managers, engineers, and scientists, you have some of the most important jobs in government and the private sector. You also have some of the greatest challenges, some of the biggest headaches, and a lot of work ahead of you. Already this year—and we are only at the end of April—we have experienced devastating floods in California, the Pacific Northwest, the Ohio River valley, and now in the Red River and North Dakota. Now is an appropriate time to rethink our floodplain policies, and you have to be an integral part of the rethinking process if we are going to be successful. It will take the technical, physical, and political energy of all of us at the federal, state, and local levels to make this work. We must act in partnership if we are going to affect long-term sustainable changes in how we deal with our floodplains. Perhaps the most important aspect of these changes is in our support to local communities. We can provide technical tools at the state and federal levels to the communities, but the communities and local governments must be prepared to work with us and they must be prepared to help make choices even when the choices are very difficult.

The Corps has played a leadership role in flood damage reduction and floodplain management for many years. We have worked with you and local communities in this area extensively. We are committed to continue in this role and perhaps increase it where appropriate. Since we met last June, many significant things have happened that will help the Corps as we endeavor to improve our role in floodplain management planning. I would like to briefly mention some of these things that many of you may know about but I’ll repeat them here because they are so important. First I’ll talk a little about the Corps strategic plan, our vision
of where the Corps is going over the next five to 10 years. As a senior leader in the Corps I’ll share with you some of the thoughts that we have. I’ll talk a little about the Water Resources Development Act of 1996 that passed last fall and a few current Administration initiatives related to floodplain management. Finally, I’ll talk specifically about some things the Corps is doing in watershed planning in floodplain management.

**The Corps' Strategic Plan**

Every agency or organization needs a road map or strategy as required by the Government Performance Act. We have to put one together for the Corps and by August of this year we must send a final plan to the Office of Management and the Budget, and by September to Congress. I have had the good fortune of being asked to help develop that plan for the Corps. Some very talented people in the Corps and I are trying to develop that strategy as to how we are going to proceed and (to steal some words from our great leader after whom this room is named) we are going to build a nonstructural bridge to the 21st century with the Corps of Engineers.

We have a draft plan and the first part is to develop some goals for the Corps Civil Works Program. We have developed and adopted five basic goals that really form the framework of this strategic plan. First, the Corps has a lot to offer from an engineering, project management, planning, and real estate perspective, and we want to maintain that expertise. We do not want to become just a operation and maintenance organization where we are merely caretakers of existing projects and infrastructure. We think that there are many existing and future challenges. We need to maintain this engineering and planning expertise and to do this we will have to have projects. We have to have good projects and the Corps is actively pursuing those things, in more environmentally friendly projects. We are doing much work for other agencies like the Environmental Protection Agency and the Department of Energy to help maintain this engineering expertise.

The second goal, which is very important to me, is that we have officially elevated our environmental mission within the Corps to a level equal to our engineering mission. This is a pretty bold statement coming from the Corps. We think that environmental restoration and solving environmental problems will be a big part of the Corps' future. In fact, it is already a big part of the President's FY1998 budget request, as almost 20% of the $3.7 billion is for environmental restoration projects. You can add another $1 billion to that, if you look at the work we are doing for EPA and DOE and other agencies, so the Corps is clearly shifting its focus to some extent to the environmental arena. We are certainly
promoting prosperity, democracy, and national security through our efforts with the military and our flood damage reduction and navigation projects. Today, society is asking the Army to do different things—perhaps not to abandon completely the flood control and navigation mission—but to look at other things as well. And a big part of those other things will be environmental restoration. The Corps is doing major environmental restoration around the country. Perhaps the largest restoration project in the world is in south Florida, where the Corps has the lead. We have many similar projects all over the country.

The third goal basically states that neither of the first two goals is important if you do not perform. We have got to continue to do a good job on how we provide products to the public, the people who are paying for part of it anyway. We’ve got to improve our process within the Corps. We are taking a hard look at how we study problems, how long it takes to study those problems, and how much it costs to come up with solutions. We had a tendency to study all problems the same way—we looked at the $500 million dollar project the same way we looked at the $20 million project. In many cases this is unnecessary and we are re-thinking how we do that. We have some initiatives underway to improve our study process.

The fourth goal is an internal one, from the Secretary of the Army’s office on through the Corps districts. We have got to speak with one corporate voice. We must clearly understand what our mission is and what our mandates are from Congress and from the Administration and we are working on this internal communication process as well.

Finally, the fifth goal concerns external communication. We must more clearly articulate to the public and to you as potential sponsors and users of the Corps products what we can do and what we cannot do and we have not always done that. So, those are the five principal goals that really form the underpinnings for our strategic plan.

**WATER RESOURCES DEVELOPMENT ACT OF 1996**

Let me shift now to the Water Resources Development Act of 1996. Several substantial things were enacted as part of the bill that affect that way we do our job and how it impacts you. Overall, we think that WRDA 1996 was a good bill. We got a lot of what we wanted and we asked for a lot of things and got them. Let me touch on a couple of things that are important. There were substantial changes in cost sharing or at least changes in cost-sharing provisions for flood damage reduction projects. We now have a ratio of 65% federal and 35% non-federal for both structural and nonstructural flood damage reduction projects. This is not as much as we asked for, because we wanted a 50/50 ratio, but
Congress decided on a more moderate approach. We have had a lot of serious discussions with committee members and committee chairs and they felt that this incremental progress was the only way to get there. So perhaps we can take another step in a later WRDA if moving toward this 50/50 cost sharing is where we would like to be.

Another important provision was the prerequisite for Corps participation in flood damage reduction projects of the development and implementation of a local floodplain management plan. We think this is a very important part of continued federal involvement. We are developing guidance on how we will work with communities to put together these plans. Another important provision that we asked for and received was the ability to use P.L. 84-99 disaster funds for nonstructural solutions, so as we respond to emergencies we can use this money for nonstructural approaches as well. In fact, we have provided interim guidance to our South Pacific division on how they can take advantage of this new statutory provision in California right now. WRDA 1996 also expanded the authority of our Planning Assistance to States program so that we can now provide assistance on a watershed or ecosystem basis to states and local communities. It also expanded our authority under the Section 1135 program, which allows the Corps to go back in and take a look at environmental damage that resulted from Corps projects. In the past, that authority was narrowly interpreted by the Corps but now that interpretation has been broadened and we can do much more. One of the most exciting things that came out of WRDA 1996 was a brand new authority for the Corps, Section 206, which gives the Corps broad ecosystem restoration authority. We can now go out and, subject to certain limitations in costs per project, work on ecosystem restoration. This does not have to be associated with any Corps project. We can work on any aquatic ecosystem problem and help come up with a solution under this authority.

**Administration Initiatives**

There are several things going on within the Administration right now regarding floodplain management. On February 18, the White House put out some guidance directing federal agencies to fully consider nonstructural alternatives as we respond to flood emergencies and as we look at long-term responses to these flood emergencies. We are already implementing that, and the Corps has been tasked to put together and lead teams to make sure that this is happening. We have a very effective team in place right now in the Central Valley in California responding to that situation. We have identified nonstructural alternatives, and our approach is to repair levees in the short term, but in the long term this guidance
clearly gives the agencies a mandate to more seriously consider nonstructural approaches instead of firing up the bulldozers and putting these levees back automatically.

We are also revisiting the Galloway Report. It had many good recommendations and we have done some of them and made progress since the 1993 floods. But there are a lot of things we need to be working on. We are doing an assessment right now of what is in that report, what we have accomplished and what we have not accomplished.

**Watershed Planning**

Let me shift to things that the Corps does specifically in the context of watershed planning and floodplain management. We have a long history of dealing with water resources and watershed issues and we have many Civil Works planning studies underway, several in response to the recent focus and emphasis on watershed planning. WRDA 1996 added a new authority for the Corps to do technical planning, design, and assistance to nonfederal interests for watershed management and restoration at specific sites in Arizona, California, Georgia, Nebraska, Pennsylvania, and West Virginia. The Corps is developing guidelines for watershed studies and one of the critical components is the identification of conflicts and tradeoffs that have to be made in a watershed context, so as we contemplate using land and water resources, the local, state, and federal agencies can make more informed decisions.

Comprehensive planning and watershed planning are taking hold with the regulatory community as well. In our regulatory program we are doing 34 special area management plans, mass identification processes around the country to look at comprehensive watersheds and how resources should be utilized or not utilized to help us make better decisions. The Corps supports watershed planning through its Flood Plain Management Services program and its Planning Assistance to States Program and again through its regulatory program.

The Flood Plain Management Services program was established to assist states and locals in mitigating flood damages. We think this is an important program and in the President's FY1998 budget request we asked for additional funding for this program up to $9 million, more than was appropriated in FY1997. This program provides free technical services to state and local governments. We just allocated $750,000 to look at some problems in 22 counties in the Central Valley of California associated with the recent flooding there. This program is highly effective, very efficient, and very productive in terms of what we have been able to do. Since 1970, we have responded to over 1.5 million requests for information though this program.
The Planning Assistance to States program is very similar and WRDA 1996 provided explicit authority to provide watershed and ecosystem planning assistance. In this program we can also look at flooding, droughts, wetlands, water supply distribution, floodplain management, and watershed issues in general. We are also asking for additional funding for this program in the President's FY1998 request. PAS studies are cost shared 50/50. We have completed 350 studies in 47 states and 18 Indian tribes using this authority since 1991. We also have three watershed studies right now where we have completed the scope of work and have cost-sharing agreements signed. Funding has been traditionally a problem with both these programs and we need to do a better job of justifying our budget requests.

Finally, I'll just mention quickly the regulatory program. I think it continues to be a vital part of the overall watershed and floodplain strategy. It is not the total solution but it is a very big part and we have got to use it as backstop if we are going to be successful in the long term in improving our floodplain and wetlands policies.

CONCLUSION

These are just a few examples of how the Corps can help with some of the tools in our toolbox. I emphasize our commitment to continue to work with the Association as well as states and localities to help solve problems. We have many challenges ahead in protecting our water resources and our floodplains. If we are going to be successful, we must meet these challenges head on, and together. The recent floods in the Northwest, central California, and Ohio Valley have caused substantial property damage and will cost taxpayers billions of dollars, and most importantly, human lives. Our dedicated field staff witnessed the destruction and the landowners' fears first-hand. It is time that we seriously re-examine our floodplains and our floodplain policies. We must ask if our current approach is sustainable in terms of effective flood protection, fiscal investment required, and the impact on our natural resources. Our short-term objective must be to help communities recover from devastation. Our long-term objective, however, must be to take a serious look at all options, not just an automatic return to structural solutions that are no longer appropriate or may no longer be effective.

If we carefully evaluate all these options we can demonstrate that we do not have to choose between flood protection and environmental protection. Working in partnership the way we have done in the past at the federal, state, and local levels, we can be successful in these efforts.
MANAGING NATURAL HAZARDS
INTO THE NEXT CENTURY

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BACKGROUND
Over the past several years a large group of dedicated people have undertaken (and nearly completed) the Second National Assessment of Research and Applications on Natural Hazards at the University of Colorado. This project, funded by the National Science Foundation, was intended to be a followup to the first assessment, which was conducted in the early 1970s. Its goals were to consider all natural and related technological hazards and all adjustments to those hazards and (1) summarize our knowledge about them; (2) take stock of the progress made in the last 20 years; (3) identify the research that is still needed; and (4) make recommendations for changes in policy and perspective. The team has included about a dozen advisory panel members, about a half dozen sponsors, 10 subgroups and their leaders, and many scientists, researchers, practitioners, and over 100 contributing authors. The project is culminating in reports and books, and a draft of a summary volume is nearing completion, to be published in 1998.

My remarks today are going to give you a glimpse of one of the assessment’s recommendations; that is, that a shift in national perspective is needed in the way we think about and deal with hazards—and flooding is one of the principal ones.

METHOD
The main way we tried to determine what changes, if any, were needed in our nation’s overall approach to coping with hazards was simply to provoke our imaginations. We asked ourselves a series of seemingly ridiculous questions, and then brainstormed the results. For example: Imagine what could be possible if hazards mitigation were truly integrated across different professions. Imagine what it would be like if the people who replace us in the next generation were sufficiently trained across all the physical and social sciences and engineering, instead of having one or two narrow specialties like we do now. Imagine what could be possible if hazards experts worked in close cooperation with those who manage the
environment, natural resources, economic development, and even with the private sector. Imagine what could happen if we just stopped using mitigation that has short-term payoffs and creates worse hazards for future generations. Imagine how much easier our jobs would be if we found ways to reduce disaster losses that also contributed to developing sustainable local economies and high-quality lifestyles. Imagine the possibilities for hazards mitigation if the public were educated so that they demanded safer communities from their political leaders.

**Losses and Data for Twenty Years**

As part of the assessment, we examined the last 20 years of data on losses resulting from hazards across the country. We found that deaths and injuries are down for most hazards, but dollar losses from catastrophic events are rising. Floods remained the most costly in terms of dollars.

We concluded from our study of the statistics that natural hazards losses, like the national debt, are being postponed to future generations. We have created a national loss debt that we pass on to the future. Losses are on the rise now because we are someone else’s future generation. Our actions to mitigate for the short term do avoid some losses but postpone others.

We also concluded that non-hazards factors have a bigger impact on losses than we ever imagined. For example, our population is larger now, and the concentrations are denser in hazardous locations. As a nation, we are older and aging, the number of working poor is on the rise, ethnic and racial diversity is increasing, as are single-parent families. It is a fact that older people, the poor, and ethnic and racial minorities all bear disproportionately larger shares of losses in disasters.

**Comparison with Other Nations**

We lead the world in using interdisciplinary approaches to understand and manage hazards, but we are not even close to where we need to be. We lead in hazards-related education but we do it so narrowly that most of us are blind to the big picture. We lead the world in coming up with new and useful ideas but we lag behind in putting them into practice. We lead many nations in experimenting with new programs but we fall behind in evaluating them. We must, for example, evaluate the effectiveness of the National Flood Insurance Program. We have the front position at saving lives and reducing injuries but we continue to select approaches that increase our dollar losses.
FLAWS IN THE CURRENT APPROACH

Our deliberations and review of past research, activities, and loss statistics brought us to the conclusion that our way of thinking about hazards is fundamentally flawed. Our traditional perspective has us viewing risk on a hazard-by-hazard basis. And then we take a profession-by-profession approach to coping with that risk. We are mistaken in our belief that all mitigation and preparedness is good. We blame "constraints" for our failure to make more headway (pressure for economic development; the low priority of hazards for the public, and decentralized political system). We focus on short-term gains rather than long-term implications. We look for singular solutions and technological fixes. We have a retrospective viewpoint that keeps us from considering the future. Our current approach to dealing with hazards is linear and views risk as relatively static instead of ever changing and non-linear.

We need to adopt a more holistic view of hazards and of ourselves—seeing both as part of larger environmental, social, and economic systems. We need to change our cultural attitude and admit that we will never be totally "safe" from all the forces of nature. We need to change how we think in non-linear, dynamic ways instead of traditional ones. We need to change how we are organized so different government agencies and private organizations do not work at cross purposes.

We need to realize that some mitigation makes things worse in the long run, because events always seem to happen that exceed what our mitigation measures were designed for. But they happen after our mitigation was used to rationalize putting more people and property at risk in hazardous areas. Also, some of today's mitigation will be tomorrow's hazards.

A HOLISTIC APPROACH TO MITIGATION

We believe that continuing along the same hazards research and practice will bring increased frustration (and losses) for everyone. We need an approach with a much broader perspective so that far more complexity in both natural and human systems can be taken into account. We need an approach that is compatible with the social, cultural, and economic forces that cannot be changed. We need a paradigm that ensures true long-term mitigation and loss reduction that is as permanent as we can imagine, avoiding burdening future generations with risk. We need to be able to design strategies not only to reduce losses, but also to increase the long-term equilibrium between humans and the environment.

We propose a new framework for hazards research and management. Although the new paradigm will embrace the idea of adjusting to the
environment, it will go far beyond that. It will be underlain by a global systems perspective; it will embrace the concept of sustainability; and it will derive its moral authority from local consensus. We call this new approach "sustainable hazards mitigation." Its goal is not simply reducing losses, but building sustainable local communities throughout the nation. Under the new approach, actions to reduce losses would only be taken when they are consistent with the other five principles of sustainability: environmental quality, quality of life, disaster resiliency, economic vitality, and inter- and intra-generational equity. We emphasize that all five must be incorporated to achieve true sustainability.

What it Would be Like

Under the new approach, divergent local stakeholders would be organized into "hazard mitigation networks." They would get technical, scientific, and some financial support from state and local governments. Each local network would interact to create shared visions of the future for that locale. They would use a consensus-building approach to determine their community goals for the five aspects of sustainability. Then they would plan the mitigation and other actions they need to take today to bring that future into existence. Each sustainable mitigation network would produce a potentially different vision of their local indigenous tolerance for future disaster losses in terms of, for example, lives lost, injuries, homeless, interrupted critical facilities and lifelines, transportation system damages, and dollars lost to damages in other sectors of the constructed environment and economic systems.

Computer models would construct scenarios of anticipated losses in all categories for credible future disaster events for each network's geographical area. The gap between the two estimated sets of losses—the level of losses and damage the locality decides is tolerable vs. the likely future losses as predicted by the model—would constitute the "mitigation gap" that local networks would work to close. Thus, progress in sustainable hazards mitigation would be gauged against baselines in the future rather than in the present. The same approach would be used to estimate progress toward the goals of environmental quality, inter- and intra-generational equity, quality of life, and achieving a sustainable local economy. Work to close the mitigation gaps would be work to construct disaster-resilient communities in terms that are acceptable to the localities themselves.

This approach would charge local mitigation networks with "designing" their own future disasters. It would empower locals for hazards mitigation in two ways. First, it would install the unavoidable point of view that the decisions made today determine what losses are
experienced in the future. Second, it would have locals consider disaster losses and mitigation in the long-enough term to include future disasters that can go unnoticed when shorter time horizons are operative.

**What it Would Take**

We would have to reorganize, and empower local area decision-making and action. We would have to abandon our top-down approach of using individual programs in individual agencies to deal with problems. Sustainable hazard mitigation would require state-of-the-art risk assessments for the geographical areas under the decisionmaking authority of each network. Deterministic and probabilistic maps of potential disaster agents need to be constructed at national, regional, urban, and site-specific scales for various scenarios and exposure times.

Sustainable hazards mitigation as we have envisioned it would require computer-generated models capable of estimating the likelihood of various loss levels in different geographic regions. Ideally, future models would estimate with reasonable accuracy what today's models already offer, but would also project alternative levels of vulnerability based on future population growth and other factors; losses in future disasters based on alternative mitigation decisions made today, such as different land use and building code decisions; and impacts on and changes in other aspects of sustainability like environmental quality, economic vitality, and social equity. The models would enable network decisionmakers to "see" the community-of-the-future consequences of every decision they make.

Sustainable hazards mitigation could only succeed within a much more holistic management framework than now exists. Most of the hazards-related state and federal laws and policies in place today are an amalgamation of separate, well-intentioned ideas that sprung up at different points in history. Each focuses on narrow program objectives and on measurable individual goals, and most are based on the perspective that any narrow slice of mitigation is good, without considering how separate actions may interact to affect actual future risk. Work should be mounted to holistically re-examine mitigation and preparedness across all hazards and to integrate and render consistent all the policies and programs related to hazards and sustainability at all levels of government in the United States. We call for a holistic review, a "Sustainable Hazards Mitigation Congress," and then integration of the appropriate policies and programs. This effort should be designed from the locality's viewpoint.
CONCLUSION

The dramatic shift that we have proposed for how the nation conducts its hazards-linked work should not seem possible to most of you. Our proposals are counter to many fundamental traits in our national culture, they work against how most of us have been educated and our individual career interests, they contradict the individual motivations of some of our nation’s bureaucracies, they decentralize power and place it in the hands of our nation’s communities, and they should seem too sweeping to comfortably handle given our current world view.

But the record of the ever-increasing losses and the seeming ineffectiveness of many of our current approaches, dictate that we be open to more fundamental changes than have previously been conceivable. It is time for us to engage in some truly innovative, broad-based, and holistic thinking about how we have been coping with risks from hazards. We have to borrow the spirit of those who believe more in the dreams of the future than the history of the past or the resignations of the present. To quote Thomas Jefferson, "Our nation has always been a treasurehouse of the unprecedented and global testament that the power of words can transform the future."
LOOKING TOWARD THE HORIZON: PROSPECTS FOR FLOODPLAIN MANAGERS

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When I first considered the possibility of taking on this assignment of anticipating the future, I realized that there would be a strong temptation to spend preliminary time in looking back. For example, I recalled that my first appearance in a national forum on this topic occurred—give or take a few weeks—just 60 years ago. The occasion was a national conference on planning, and in my prepared presentation I reviewed such facts as that there were then three states exercising statutory authority to regulate encroachments on river floodplains. That body of information did not arouse major comment, but in off-the-record remarks on that same occasion, I ventured the suggestion that no federal funds for construction of flood control dams in California should be authorized unless the state enacted legislation to control any further encroachment upon floodplains. Word of those views reached the California delegation, and shortly thereafter the appropriate Congressional committee was directed to investigate that youthful staff member of the National Resources Planning Board who was promoting "un-American" ideas! I survived and the dams were authorized without any such conditions.

Looking ahead, I have found it both exciting and sobering to review the immediate foreground in floodplain management. I offer for your consideration some preliminary observations about the present levels of flood damage in the United States, some of the factors that I think are affecting the present scene, and four concepts that we ought to take into account in trying to look ahead.

LEVEL OF FLOOD DAMAGE

We all realize that our information about the precise amount of flood damage in the United States is crude at best. The data that are available from a variety of sources are incomplete and often internally inconsistent. The nation still does not have a thoroughly designed and executed system for making these estimates.

But taking just the data from the Illinois group that has tried to collect them and from the actual expenditures, we know that, in constant
dollars, we have had a long (almost 100-year) period of rising average annual flood losses, with the highest loss year in history being 1993 (Yen and Yen, 1996). This is in spite of continual efforts—structural, non-structural, insurance—to lower those figures.

Another, more consoling, way of looking at these numbers is to normalize them by comparing them to annual gross national product. If we do this, the long-term trend is seen to be slightly downward, though the losses are still substantial.

**Conspicuous Features in the Foreground**

Let us consider some of the situations and actions that are relevant to the ways we should be setting policies and programs in the years ahead.

• One of the very clear facts we have is that federal declarations for flood disasters have increased over the years. The number of declarations reached an all-time high of 72 in 1996. We have arrived at the point where 85% of all applications for federal declarations are granted. We are in an era of increasing national support for public relief for those who suffer in and after floods.

• Since 1993, an unprecedented and impressive array of major policy analysis documents has been placed before the people and Congress. We are familiar with the Galloway report, the Corps Assessment, and the Unified National Program for Floodplain Management. What has come from them? The record is very slim indeed. I think that, except for an executive order issued on February 18, 1997, asking federal agencies to pay attention to the Galloway Report and some earlier actions, there has been no concerted movement. This is a sobering situation for all of us concerned with national policy and direction as applied to local situations.

• We can note, with satisfaction, that needed reforms were made to the National Flood Insurance Program, and that is encouraging. But they were limited.

• There has been progress with legislation encouraging buyouts of floodprone properties rather than the award of traditional disaster relief.

• There has been more serious consideration of whether or not levees ought to be automatically reconstructed after a flood disaster.
• There is underway a task force effort on the natural and beneficial uses of floodplains. This has been reviewing and bringing together in a coherent fashion the widespread concern among environmental groups and others about the condition, use, and biodiversity of floodplains in their natural conditions.

• The takings issue with regard to local and state administrative groups has to be counted as having been a significant factor in affecting how local and state agencies act with regard to exercising regulatory authority over their floodprone lands.

• A few years ago, when an appraisal was made of professional schools where land use planners are trained, only 20% of them reported giving any systematic instruction for how to deal with land use problems related to hazards. We have, therefore, generations of land use planning experts coming onto the scene with very little preparation for dealing with hazards-related problems.

• Also at the local level (though not as a primary result of professional training) we are seeing more interest in watershed planning and management, which involves cooperation among environmental, planning, and development groups in trying to understand the ways in which communities within a particular drainage basin can effectively plan for and manage their development.

• We have the beginnings of an assessment of the National Flood Insurance Program's Community Rating System. In addition, we have been treated to a wide and useful debate—brought about primarily by the insurance industry—about the wisdom and feasibility of extending national insurance to other hazards like earthquakes and hurricanes. This debate has progressed to the stage of having proposals introduced before Congress.

• In the seventh year of the International Decade for Natural Disaster Reduction, we have witnessed an emphasis on distributing and sharing scientific information about the wide range of vulnerability and impacts from extreme events in the world today. But I would like to question whether, given this amount of world-wide attention, any net benefit has come out. It can be argued that the efforts of the Decade have tended to be counterproductive. That is, because of the increased public discussion of risk of disasters, people feel more comfortable that something is actually being done to cope with or
minimize losses. This counterproductivity becomes even more evident when it is juxtaposed against the earlier expectation of the U.S. Committee for the Decade that, during the Decade, average annual losses from all disasters would be reduced by about one half. Even without having accurate statistics, we all realize that this simply is not going to happen.

**Looking to the Horizon**

Taking those previously mentioned circumstances into account, and considering that we are operating somewhat in the dark as to the magnitude of our flood losses both in an absolute and a relative sense, I suggest that there are at least four main concepts that floodplain managers need to consider in planning their programs, policies, and activities for the coming decades.

**Post-audits of Experience**

We have had a National Flood Insurance Program for almost 30 years. But we still have not had a careful, thoughtful, incisive assessment of what effect the program has had on the land use and vulnerability of communities around the country. We have a lot of information about the number of policies, premiums paid, and claims paid. We have systematic sets of community assistance visits, but what did they achieve? We know that the NFIP's Community Rating System has been widely implemented, but what has its effect been? We do not have a sense of what has happened on the land, locally.

We should realize as well that the United States has had only one national environmental planning program in the last 20 years and that has been the Coastal Zone Management Program, administered by the National Oceanic and Atmospheric Administration. We still do not have a careful appraisal of what it has achieved, although there are a few efforts underway to attempt to assess it, notably that by the Heinz Foundation. The point is that we have come all this way without knowing precisely what the positive and negative lessons have been.

**Watershed Planning**

The notion of watershed planning and management was very much affected in the 1930s by attempts to divide flood problems into two categories—the upstream "problems" being handled primarily by the Soil Conservation Service (now the Natural Resources Conservation Service) and the downstream ones by the Army Corps of Engineers. In part as a result of that, we have had ever since a situation in which the concern
about what happens to floods in a drainage area is divided between those two agencies. This was (and still is) exacerbated by the fact that the Clean Water Act as finally passed paid little attention to non-point source water pollution, and focused instead on point sources of pollutants, such as local facilities. It did not take into account the consequences of broader land uses throughout a drainage basin on the quality of water and soil in that area.

I suggest that floodplain managers have been somewhat successful at trail and conservation planning for floodprone areas of the sort that the National Park Service has been promoting. But they have yet to come fully to grips with their role in integrated watershed study, which is what will command the attention of local groups in the future.

Disaster-resilient Communities

A third concept is that of the invulnerability or resistance of communities with regard not just to flood but to other natural extremes like earthquakes, hurricanes, etc. Whether we use the term wise use, smart use, sustainability, or resiliency, this concept is bringing us rapidly to the practical need for some kind of system by which communities can look at their total condition and consider the array of information and regulatory measures they have available to help achieve safety and well being for themselves—not just for one hazard but for all sorts of risks. Comprehensive planning, multi-objective management, and consensus-building are techniques we have been using thus far, but I suspect that as this concept grows we as floodplain managers are going to need even more sophisticated, and even broader tools at our disposal.

Improved Communication Technology

Finally, we need to take account of the fact that our whole system of information communication and distribution has changed significantly in the last 10 years and that this affects the kinds of programs and policies that we need to be thinking about.

We need to change our communication and networking systems to help floodplain managers. These technological advances show themselves in several ways. As we heard this morning, our method of disseminating information about flood hazard is changing as a result of mapping improvements and of electronic procedures for distribution. We also have the capacity for the kind of monitoring and data collection that we could not have dreamed of before. With global positioning systems, geographic information systems, portable computers, and the like, we can achieve almost instantaneous correlation of, say, the extent of flood damage to a
structure with the position of that structure in relation to the predicted flood height as shown on a flood map with a record of the structure's past damage and insurance claims. We also have the capacity to reach groups on a wide scale with unprecedented speed. And I've been quite taken with the idea of distributing training and educational materials through the Internet. It's not just a matter of using web pages, which now are needed for basic information provision, but of using this electronic system to reach school after school, home after home, with sophisticated, up-to-date information about hazards and ways to cope with them.

CONCLUSION

That leads me to what I think is the challenge here, for those of us in this Association. That is to figure out how best we can in our Strategic Plan for 1997 incorporate this whole range of concepts and develop what will probably be a rather fresh approach to floodplain management in the United States. We will have to work to assess and consolidate our past experiences into meaningful lessons and databases. We will have to find more and more ways to work within the natural framework of watersheds. We will need to capitalize on the broader and potentially more unifying theme of achieving safer, resilient communities. And, if we are smart, we will put to good use these extraordinary advances in communications technology that are available to us now. These are what I see as the fundamental opportunities in the field today. They are couched in a situation of having no unified federal guidance for floodplain management as we look toward the years on the horizon.

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Interagency Floodplain Management Review Committee

U.S. Army Corps of Engineers

Yen, Chin-lieh and Ben-Chie Yen
Part 2
STATE AND LOCAL PLANNING AND MANAGEMENT FOR FLOOD MITIGATION
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The City of Simonton, Texas (Fort Bend County), a small community with a population of 717, was seriously flooded in 1991 and again during the October 1994 East Texas flood. Based upon the Section 205 Initial Appraisal Study (Corps of Engineers, 1995), 110 structures flooded in the City of Simonton during the 1991 flood and 125 structures flooded in 1994. Brazos Valley subdivision was developed in the 1950s and its 200+ structures comprise the western portion of the City of Simonton adjacent to the Brazos River.

The Brazos River drains 21,380 square miles below Possum Kingdom Reservoir and the 100-year peak discharge is 181,000 cfs in Fort Bend County near Simonton. Major floods have been recorded on the Brazos River in 1899, 1900, 1913, 1915, 1929, 1991, and 1994. During the 1913 flood, it was reported that waters from the Brazos, San Bernard, and Colorado rivers met in Fort Bend County below Rosenberg.

In 1996 after the devastating floods of 1991 and 1994, the City of Simonton initiated a Flood Protection Planning Study (Claunch & Miller, 1996) funded by the Texas Water Development Board (TWDB). Both the TWDB and the Corps of Engineers studies determined that a flood protection levee was economically feasible for the City of Simonton. Figure 1 shows the proposed flood protection levee to protect Simonton from Brazos River overflows. However, the Brazos River at Simonton is the political boundary between Fort Bend and Austin counties. To construct a flood protection levee along the Brazos River, the City of Simonton must coordinate with the U.S. Army Corps of Engineers, Texas Natural Resource Conservation Commission, Brazos River Authority, Texas Division of Emergency Management, Fort Bend County, Austin
Figure 1. Proposed flood protection levee for Simonton, Texas.
The City of Simonton initiated immediate steps to reduce the impacts of flooding and acted upon the nonstructural recommendations from the Flood Protection Planning Study:

- A new flood disaster protection ordinance was adopted that requires the lowest floor of new and substantially improved structures to be elevated one foot above the 100-year BFE;

- All citizens and property owners were encouraged to purchase flood insurance;

- Public meetings were held to inform citizens about elevation requirements, availability of flood insurance, availability of increased cost of compliance (ICC) insurance, retrofitting of floodprone structures, acquisition and relocation, and to encourage open space uses and discuss structural alternatives;

- The City of Simonton submitted a formal request to the Corps of Engineers to initiate a Section 205 study for the Brazos River at Simonton for a federal flood protection project.

The City of Simonton initiated drainage improvements throughout the city to minimize the risk of flooding from the 1,067-acre drainage area that flows into the city and outfalls into the Brazos River. The Corps of Engineers plans to initiate a detailed hydrologic and hydraulic analysis as part of a Section 205 study of the Brazos River to redefine the 100-year flood. The 1991 and 1994 Brazos River floods approximated the 100-year base flood elevations at Simonton where the Corps reported that the 1991 flood only had a 10- to 15-year return frequency and the 1994 flood only had a 15- to 20-year return frequency. The Corps plans to redefine the Brazos River peak discharges and corresponding base flood elevations as published in the current Flood Insurance Study (Federal Emergency Management Agency, 1992). Fort Bend County and Fort Bend County Drainage District have offered “in-kind” personnel and equipment assistance to the City of Simonton to construct an interim levee and diversion channel. An interim levee, if constructed to Corps of Engineers standards, could become the alignment for the proposed 15,000-foot-long flood protection levee system.

Fort Bend County has produced GIS mapping to assist the County Engineering Department, City of Simonton Drainage District, and others.
Orthophoto quadrangle mapping with 1 meter and 3 meter pixels was produced in addition to accurate aerial mapping of the Brazos River and adjacent Bessie's Creek.

The Texas Department of Transportation (TxDOT) responded to a request from the city and installed six additional culverts under FM1093, a major roadway that bisects the Brazos River floodplain adjacent to the City of Simonton. The roadway culverts will allow floodwaters from within Simonton to outfall into the area designated for a proposed bypass channel.

The Texas Water Development Board funded the Flood Protection Planning Study (Claunch & Miller, 1996). The TWDB has recommended that the city proceed with the Corps of Engineers Section 205 study and to obtain a FEMA Conditional Letter of Map Change for the proposed flood protection levee.

Should a flooding disaster occur prior to construction of a flood protection levee, the City of Simonton now has a plan in place to request Hazard Mitigation Grant Funds for acquisition and relocation and retrofitting of floodprone structures.

Unfortunately, the Brazos River has an active erosion rate that will soon isolate the area known as Boot-Hill. Several roadways have been lost and properties within the erosion path will soon be lost. Nature will soon create a bypass and the only recourse of the homeowners will be the National Flood Insurance Program.

The Texas Division of Emergency Management (TxDEM) administers the Hazard Mitigation Grant Program in Texas. Using unallocated funds from the 1991 flood, TxDEM has initiated a grant to the City of Simonton for construction of structural improvements identified by the TWDB and Corps of Engineers studies.

The Brazos River floodway and floodplain is shared by both Fort Bend and Austin counties. The alignment for the flood protection levee for Simonton was based on a HEC-2 analysis that resulted in a zero-foot rise in the 100-year base flood elevation. The HEC-2 analysis is described in Table 1 showing the natural model without new survey cross section and a revised model with new survey cross sections added. The Brazos River channel has changed due to erosion and the existing HEC-2 model cross sections are based upon the 1977 Corps of Engineers Brazos River Flood Plain Information Report (Corps of Engineers, 1977) and the 1992 Fort Bend County Flood Insurance Study. The changing river cross section supports the justification for the Corps of Engineers proposed Section 205 study.
Table 1. Brazos River HEC-2 analysis, Fort Bend County, Texas.

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<th>Revised Model (includes new cross section)</th>
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The floodplain problems facing the City of Simonton are seemingly insurmountable but by utilizing the federal, state and local resources, a structural solution appears within reach. In the meanwhile, the city continues to address the problem utilizing nonstructural solutions.

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U.S. Army Corps of Engineers, Galveston District
1977   Flood Plain Information, Brazos River, Fort Bend County, Texas.
Hazard mitigation as a strategy to reduce losses and protect people and property from the impacts of natural hazards has become an organizing tool for change in Rhode Island. A shift in emphasis from emergency response to pre-disaster mitigation planning and implementation has created an opportunity to bring together diverse interests, all of which have a stake in maintaining sustainable communities and preventing devastating losses from natural disasters.

Building partnerships based on a common perception of risk is not easy, especially since Rhode Island has not seen a major natural disaster in over 25 years. Hurricane Bob, a Category 2 storm in 1991, caused over $124 million in direct damage to private and public property and some $73 million to utility services, the scenic Cliff Walk in Newport, and boating and fishing interests. Yet there is limited public awareness of the vulnerability of Rhode Island to natural hazards. As the years pass, fewer people remember the storm surge and winds that decimated much of the state in the 1938 hurricane and Hurricane Carol in 1954. Many of the destroyed areas were rebuilt bigger and better—not necessarily safer. Since 1954 the number of houses on many coastal barriers and low-lying coastal floodplains has tripled. The value of coastal property covered by property casualty insurance (excluding flood insurance) increased by 153% between 1980 and 1993, from $33 billion to $83 billion.

Inland flooding on river systems "controlled" by dams or gates, many of which are inadequately maintained, could be a risk rivaling major coastal storms. Low probability/high loss events like earthquakes and wildfires pose additional threats. The challenge is to heighten public awareness about hazards, risks, and vulnerability, and to build capacity at the local and state level to plan ahead and to implement actions to reduce future damage and costs of recovery.
The approach implemented by the Rhode Island Hazard Mitigation Project (the Project) has truly been multi-faceted. The sheer number and variety of partners involved has been a key to success. Coordinated by the University of Rhode Island's Coastal Resources Center Sea Grant Program (CRC/Sea Grant) and the Rhode Island Emergency Management Agency (RIEMA), partners include the state Hazard Mitigation Committee, the Federal Emergency Management Agency (FEMA), the Insurance Institute for Property Loss Reduction, the National Oceanic and Atmospheric Administration Coastal Services Center, over a dozen Rhode Island towns, and the private sector (insurance, banking, and building).

The Project goal is to make hazard mitigation the cornerstone of emergency management, by helping localities, state agencies, the private sector, and homeowners incorporate hazards risks into daily decisions and practices, so that the next event is not a disaster waiting to happen. The focus on partnerships and the emphasis on local involvement is essential.

Although there are many "stones" in place that incorporate mitigation, rearranging them to create a solid cornerstone takes time and relentless effort. It requires developing and nurturing relationships based on mutual interests, while responding to individual priorities. Building the capacity of local/state emergency managers, planners, public works directors, and building officials is critical to ensure that mitigation is incorporated into all decisions. The integration of public and private sector interests is essential, though at times they seem mutually exclusive.

The Project strategy involves four interdependent spheres, each relying on the other to achieve the goal of reducing hazards losses:
CREATING A STATE HAZARD MITIGATION STRATEGY

In 1995, RIEMA formed a partnership with CRC/Sea Grant to make hazard mitigation a reality rather than a catch-all phrase. RIEMA institutionalized its commitment to mitigation through its Comprehensive Agreement with FEMA, which set goals and objectives for the agency and its partners. Using a "two-track approach," which works simultaneously at the community and state levels, and with experience from two pilot regions, the Project aims to establish state policy that guides municipalities and state agencies to develop and implement hazard mitigation. Gaining state commitment to incorporate local strategies into the statewide mitigation plan is crucial to the success of the Project.

Following Hurricane Bob, RIEMA expanded its traditional emergency management role by organizing a State Hazard Mitigation Committee (Rhode Island Building Commission, National Flood Insurance Program coordinator, Coastal Resource Management Council, Department of Environmental Management, CRC/Sea Grant, and others) to review and select Hazard Mitigation Grant Program (HMGP) projects funded by FEMA. Many mitigation partnerships were initiated through the Committee. For example, CRC/Sea Grant worked with the Rhode Island Coastal Resources Management Council to develop a hazard mitigation component for state-mandated harbor management plans. HMGP money was leveraged with CRC/Sea Grant funds to initiate a local multi-hazard mitigation planning process. The State’s floodplain manager in the Statewide Planning Program has worked closely with RIEMA and the State Hazard Mitigation Committee to provide technical assistance for grant application review and with communities to help define risks and mitigation strategies. Recently the Committee’s membership and mission has been expanded to include community representatives and private sector stakeholders. This will help broaden the advocacy and support base for mitigation, ensure the coordination of statewide hazard mitigation strategies and provide the impetus for public-private partnerships to implement mitigation initiatives.

DEVELOPING LOCAL STRATEGIES

Identifying risks is the first step in building local constituencies and creating a demand for hazard mitigation. Regional workshops were designed for community officials to develop a preliminary risk assessment and mitigation strategy for their community. In Rhode Island eight regions have been defined by identifying adjacent communities vulnerable to similar hazards. Two regional workshops have taken place so far.
In facilitated roundtable discussions, local planners, building officials, public works and emergency management officials identified local hazard "hotspots" with the assistance of state and federal officials and maps created with information from Rhode Island's geographic information system (RIGIS) that displayed vulnerable areas. Matrix posters guided the groups in classifying risks and selecting mitigation alternatives. During this short exercise the groups identified many ways that mitigation could fit into their daily activities and responsibilities, such as planning, development permitting, infrastructure and maintenance, and public outreach. Another benefit was the initiation of new partnerships for emergency management. In most instances, the workshop was the first time this combination of officials had worked together.

This community focus has two primary goals. One is to identify a list of mitigation initiatives that should be included in the State Hazard Mitigation Plan, and the other is to incorporate hazard mitigation into long-term strategies of the community. In consultation with one of the participating communities, Charlestown, CRC/Sea Grant decided that mitigation could best be institutionalized into a community's policy and practice by weaving it into state-mandated, local comprehensive plans. These plans include elements such as land use, economic development, historic preservation, natural resources, facilities, and infrastructure. CRC/Sea Grant researched background information to support the findings of Charlestown local officials at the regional workshop, and produced a draft mitigation plan for review by the Charlestown Planning Commission. At the town's request, for each action item in the draft plan CRC/Sea Grant provided references for sources of technical assistance and examples of similar actions from other communities and states.

The Planning Commission and other local officials are enthusiastic about the draft plan and the process used to create it. They strongly support incorporating mitigation into the town’s comprehensive and emergency operations plans, and are delighted with the associated products created by the Project—the RIGIS maps showing flood zones and land use together, a local disaster fact sheet, a poster combining a topographic map with flood zones—as well as the possibility of receiving local RIGIS data files with hazards information. On the other hand, they have expressed concern about adequate funding for mitigation activity, as well as the process the state will use to prioritize mitigation projects.

The community will hold a series of workshops with a broader audience to develop an implementation strategy for the town and to build public support for it. Based on public input and analysis of local and state capabilities, the town will approach the Rhode Island General Assembly for any necessary action to formalize the planning process.
During 1997, the Project will package the Charlestown plan to serve as a model for other communities in Rhode Island. RIEMA will work with the Statewide Planning Program to codify this framework and develop guidance for communities to incorporate hazard mitigation into their local comprehensive plans.

**Building Public-Private Partnerships**

In 1996 CRC/Sea Grant extended the mitigation network by developing a partnership with the Insurance Institute for Property Loss Reduction (IIPLR) and the National Oceanic and Atmospheric Administration/Coastal Services Center (NOAA/CSC) to develop and implement private sector financial incentives that would encourage mitigation. An informal network of private sector interests (stakeholders) in Rhode Island has been created, which includes property casualty insurers, banks, builders, and building supply stores, thereby establishing a firm foundation for public-private partnerships. Members of the network are working together to establish criteria for financial incentives for mitigation, to develop methods to implement them in a timely and coordinated fashion, and to create education strategies for building officials, contractors, architects, engineers, and homeowners.

Collaboration with private sector organizations such as IIPLR has been a critical element in public-private partnering. IIPLR (whose mission is to reduce injuries, deaths, property damage, economic losses and human suffering caused by natural disasters) has led the way in breaking down public-private sector barriers and has lent credibility to the Project among other private groups. The approach used to form the private sector network has also been successful. Organizing the partners to work on specific projects, such as identifying criteria for an insurance incentive or retrofitting a building for training purposes, has proven to be an effective way to bring partners together and engage them around a common objective—to reduce losses from natural hazard events—while producing a tangible result/product. The projects and ideas stimulated by the dialogue help each partner recognize potential market niches or profit centers for their businesses, which serves as additional motivation to become and remain involved in the project and the partnership.

Outreach strategies to build private sector partnerships and market the mitigation message have been implemented through joint presentations at meetings, newspaper coverage, and articles in trade magazines. To involve homeowners, the end users of the incentives, CRC/Sea Grant organized a meeting of neighborhood and beach association officers, contractors, coastal zone managers, and engineers to review IIPLR’s draft publication *Retrofit Guidelines for One and Two-Family Dwellings*. This
activity will not only improve the publication but has helped build constituencies and educate both homeowners and practitioners.

**INFLUENCING NATIONAL POLICY AND PROGRAM DEVELOPMENT**

The Rhode Island Hazard Mitigation Project has been greatly influenced by the basic principles of the FEMA National Mitigation Strategy and the IIPLR Strategic Plan. It is not an accident that the Project reflects the principles embodied in both—recognition that most mitigation strategies and actions are implemented locally (although their shape and size are often influenced by federal and state policies and regulation), and that those who knowingly choose to assume greater risk must accept responsibility for that choice and bear an appropriate share of the costs, whether they are state or local governments, individuals, or businesses.

The IIPLR Strategic Plan identifies five key result areas: public outreach and education, community land use, new construction, retrofit of existing buildings, and information management. Since the Project is also concentrating in these areas, it is viewed as a "living laboratory." Lessons learned in Rhode Island may be transferred to IIPLR's Showcase Communities and FEMA's Model Communities program, demonstrating exemplary pre-disaster mitigation. The American Planning Association Growing Smart Project will develop a natural hazards element for a local comprehensive plan, and most likely will draw on the Rhode Island experience. The NOAA/CSC will be using elements of the Project as a case study for a regional coastal hazards solution-building course to be offered to coastal zone managers, thus transferring lessons learned to practitioners and managers in other parts of the country.

**CONCLUSION**

Although currently the phrase *hazard mitigation* is not in every Rhode Islander's lexicon, and the concept is not generally well known, through continued work on the Project at every level—individual, local, state, federal, and private sector—CRC/Sea Grant and RIEMA and our many partners hope to make the reduction of future disaster losses a reality in Rhode Island and across the nation. Already the model plan, risk assessment matrices, and other tools created as part of Rhode Island's project are being used in other states and are providing real-life experience for FEMA, IIPLR, APA, and other programs to use. As work progresses, it is hoped that the incremental steps taken now will add up to great strides for the future of natural disaster loss reduction.
In today's world of downsizing, right-sizing and being asked "to do more with less" we are all being challenged to be more effective in doing whatever it is we do in floodplain management. We in the Los Angeles District, Corps of Engineers (Corps) planning group are experimenting with an approach that will provide more effective knowledge about, and access to, relevant federal and state water resource programs.

We call this effort Task Force Based Flood Plain Management (TFBFPM). In Arizona we are working with the Arizona Department of Water Resources (ADWR) and other water resource agencies, to provide support to local communities in their efforts to access/develop/implement water resource programs and projects. The effort is specifically focused on smaller communities concerned with flood damage reduction programs because they usually lack the staff to dedicate to developing and implementing flood damage reduction programs.

There are numerous potential benefits to providing timely flood damage reduction information to communities. These benefits would accrue both to local communities as well as participating agencies. Timely and current information will allow a community to begin making informed decisions on how to manage their floodplains. It focuses the information on available agency programs to specific problem areas. It allows groups of agencies to provide staff in a timely manner and focus their expertise on the problem. One would also expect some synergy through multiple agency participation.

The task force approach will allow local communities to receive immediate response and guidance. At the same time, agencies will provide information in a timely fashion. This initial effort is not intended to be a long-term effort, but rather a focused first contact.

Multiple (federal, state, and local) agency participation results in a combined effort to identify problems and opportunities. Agencies can explain their programs, and a community can evaluate them at the same time. A discussion of how programs interact with each other can be
carried out, and how local needs can be met.

TFBFPM allows an open forum format that will allow local communities to develop dialogue with all participating water resource agencies, receive answers to questions, and access to planning expertise.

A team approach will create synergy in the initial evaluation of the problem(s) facing the community. Combining talents from different agencies' perspectives will result in productive brainstorming sessions that could result in a comprehensive approach to solving the local community problem(s). It may also form the basis for seeking additional assistance, including the identification of the appropriate program and agencies to be involved.

**Approach**

The proposed format would provide assistance and information by way of on-site workshops including field trip(s). Typically, individual workshops will consist of five phases. Ideally, workshops will be of maximum one or two days in length.

Phase 1 will consist of lead preparation in advance of the scheduled workshop. All appropriate documents such as existing maps, aerial photos, historical and related drainage information, etc. will be gathered. A summary list of the known water resource problems will be prepared. The local community will be requested to perform this item.

Phase 2 will consist of an introductory presentation of problems by the local community. The task force, whose formation is explained in Phase 4 below, will gather at the offices of the community for an orientation to the area, an introduction to the local participants who will provide a summary of available data, as well as a presentation of the local perception of problems.

Phase 3 will consist of a site inspection. This will be led by relevant local officials who will have obtained any right of entry permits during Phase 1. Arrangements for proper vehicles should be made in advance.

Phase 4 will consist of assistance development. Typically, this will take place at the community offices, unless other arrangements have been made. Problems and opportunities will be discussed, data interpreted and/or developed, and solutions developed. Return trips to the site may be necessary.

Phase 5 will consist of feedback, initially at a briefing immediately after the workshop so that all task force members are present. Draft minutes will be prepared and circulated to all task force members. After the minutes are finalized, they will be delivered to the local community to supply additional feedback and reaffirm any commitments made.
The task force membership would consist of one or more representatives of a variety of federal, state, and county agencies who have an interest in water resources development, and whose expertise is considered to be needed based on the initial evaluation.


Potential members at the state level may include the Department of Water Resources, Parks Department, Department of Environmental Quality, and Fish and Game Department.

Depending on the type of workshop anticipated, other technical expertise can be invited to augment the membership. This may include private engineering consultants. Essentially, anyone who can bring something to the table will be encouraged to attend.

Task force members are expected to bring their own tools to include laptop computers, cameras, survey equipment, reference materials, and soils equipment. These items can be used in developing data to support task force findings.

**Prototype**

The Corps and ADWR initiated in June 1996 a prototype of TFBFPM. Two communities in the state of Arizona were identified: Navajo County and the City of Globe (Figure 1). These are typical of the communities that would be targeted by the program.

The key results of the Navajo County meeting, attended by federal, state, and local agencies, was to focus agency effort on initiating a watershed study effort. Navajo County utilized the TFBFPM process to focus their efforts to scope the process to initiate a Little Colorado River watershed study. In addition, key agencies were made aware of the need for the watershed study. Funding sources and authorities were identified and plans were initiated that would continue the preplanning necessary to implement the desired watershed study effort.

The Globe meeting focused on the community’s concerns for accurate floodplain mapping. The perceived lack of good floodplain information was seen by the community as a impediment to local land use planning and proposed economic development. The results of the TFBFPM meeting was an excellent airing of concerns, and an agreement was made that additional meetings would take place to provide specific information on floodplain mapping. The community was encouraged to plan, with the state’s help, their vision of how economic growth, and specifically the
Figure 1. Navajo County and Globe, Arizona.
land use associated with that growth, would be integrated into a community-wide floodplain management plan.

Following the two sessions, a debriefing of agency participants was held at the ADWR. The purpose was to determine the relative worth and approach of the planning process. The following is a reiteration of the questions asked and the respective responses.

1. Compare and contrast the two communities in which meetings were held. What were the strength and weaknesses?
   In general it was felt that Navajo County was prepared and had made a commitment to the process. It was felt that Globe was less prepared. In part this was due to the lack of real up-front preparation of the communities for the meeting. It was concluded that this planning process needs to be augmented with advance field work by a small group to prepare and determine if a community is in fact ready for this type of planning process.

2. Is this planning process a better way, another way, or a worse way for your agency to provide services or products to a community?
   Without exception, the participants felt that the task force based approach was better. This response was surprising in that it was expected the response would lean towards "another way" to do business. However based on discussions, it became apparent that the discussions and cross dialogue that occurred in the meeting helped the participants think of new opportunities or ways to provide assistance. (The process enhanced the creative thinking process.)

3. What are the barriers that prevent your agency from participating in future planning efforts or participating in the implementation of a multi-objective project?
   Time and money. Specifically, these planning efforts could lead to a significant time commitment as well as a need for implementation. Budgets and authorities for participation were a problem.

4. Did the communities benefit from this planning process?
   Yes. This was supported by the positive responses and the reaction to the planning assistance in both communities.

5. How can this process be improved?
   More up-front time to do preparation work with communities and to provide more advance notice for scheduling purposes.
6. **Would you recommend to your agency continued involvement in this type of planning process?**
   There was unanimous support for future involvement.

7. **Would you recommend to your agency that they fund this type of planning effort?**
   There was strong sentiment that funding should be found for staff resources and small amounts for studies and publications. However, the real problem appeared to be that only a few of the participants could point to a direct authority for this type of project.

8. **Is external facilitation necessary, or could it be handled by participating agencies?**
   All felt that external facilitation was important. It allowed for better communication and direction, and set aside the concern about a single agency driving the effort. When asked if the facilitator should be technically knowledgeable it was felt that the facilitator should be knowledgeable of the issues and programs. When asked if, due to limited budgets, it would make sense to use a facilitator that was less knowledgeable and presumably would have a lower rate, the feeling was that for more generic planning this might work, but in general an independent, knowledgeable facilitator was important to the process.

**CONCLUSION**

The conclusion of the prototype effort to the Task Force Based Flood Plain Management process was that the approach was introduced to Arizona-based agencies and to the communities of Navajo County and the City of Globe. The planning process met the stated objectives and, based on agency and community reaction and follow-up, was a successful planning effort.

The cross dialog was important to the communities because they could quickly draw on multiple resources and experts. The agencies also appeared to benefit from a process they found stimulating and productive. The planning process did identify the need for additional follow-up with each of the communities.
In the early 1980s Pierce County began a long and often arduous process of beginning a Comprehensive Flood Control Management Plan. The impetus for this plan was that Pierce County was not given any gravel removal permits during a routine summer program in the early 1980s because of the never-ending and debatable issue of detriment to the fishery industry.

From the beginning of the plan process, Pierce County sought and used the advice of an intergovernmental coordinating committee. This committee helped guide the process of the plan to its adoption. Along the way many partners and players helped in their specific roles. The U.S. Geological Survey (USGS) helped with many studies used in the plan. The USGS completed a sediment transport study to help identify the locations within the river system of both aggradation and degradation areas. These findings helped Pierce County secure gravel permits in later years after the plan adoption. The USGS also completed a channel capacity study that defined the existing conditions and the necessary elevation changes that would bring the levee system up to the 100-year storm level standards.

The U.S. Army Corps of Engineers (USACE) was helpful with guidance about the only flood control reservoir, Mud Mountain Dam, within the Puyallup River system. Mud Mountain Dam controls flood waters from the White River, one of three contributing river systems within the Puyallup River basin. Washington State Department of Fisheries (WSDOF) guided the study, "Effects of Gravel Bar Scalping on Juvenile Salmonids." While the study results are still inconclusive, many parts of the study are helpful and used by both the environmentalists and the engineering/contracting communities. Washington State Department of Ecology (WSDOE) helped in putting together the final plan document. With the help of a grant program implemented through WSDOE, Pierce County hired a consultant to put all the pieces of the plan together. The Puyallup Tribe of Indians helped with fishery issues. The Puyallup Tribe also had agreements with Pierce County on vegetation management.
within the Puyallup River basin. King County played a role because of the joint agreement with Pierce County for maintaining the White River levee system.

With the adoption of the Puyallup River Basin Comprehensive Flood Control Management Plan (CFCMP) in 1991, Pierce County began the implementation phase of the plan. Many alternatives were available with non-structural solutions preferred over structural solutions. The list of non-structural solutions contained modifications to Mud Mountain Dam outflows during storm events, floodplain land acquisitions, modifications to development regulations, public education programs, flood warning system, and privatization. Structural solutions consisted of levee repair and maintenance along with gravel removal, with many variations to these alternatives.

Many of the alternatives have been implemented since the adoption of the plan, with the most successful implementation coming after the largest storm in the most recent history, the February 1996 Presidentially declared disaster. This storm reached near record rainfall and runoff, which devastated the area. Thirty thousand lineal feet of levees were damaged and of that, 20,000 lineal feet of levees were completely washed away. Four mobile home parks were partially to completely destroyed. Pierce County estimated nearly $40 million in damage. This storm changed the direction of Pierce County's River Improvement Division. Implementation of the CFCMP would be accelerated due to this disaster.

Major shifts in funding responsibility between the Federal Emergency Management Agency (FEMA) and USACE finally became reality with the local governments. Pierce County became caught in a policy web with no assistance from FEMA or USACE. The reason for the change was the Midwest floods three years earlier. The effects of the policy changes left little time for Pierce County to prepare for the impact of no financial assistance. At the beginning of the disaster, FEMA established a levee task force for all project reviews. The project review process left the County vulnerable to any proposed alternatives initiated by us. Pierce County received minimal help from the USACE because of a new policy that all levees prior to a disaster must have been included in the PL 84-99 program to receive assistance. Pierce County qualified for very few levees, with most levees not included because of maintenance problems and because the benefit-to-cost ratio was not greater than one.

There was a bright spot in this situation. FEMA established another committee to review ways local governments could exercise CFCMP alternatives using section 403 and 406 funding sources. From this committee work Pierce County secured alternative project funding to repair levees with section 406 funding under the Stafford Act. The
alternatives followed the County’s adopted CFCMP and focused on acquisition of flood-prone properties impacted by a five year event or less.

This alternative project began a series of other opportunities made available to the County to continue a comprehensive plan project of acquiring property and homes, creating a corridor of undeveloped property in a riverine setting. This also reduced the risk of both property owners and overall levee maintenance to the County. Additional funding sources opened up from the Department of Housing and Urban Development using Community Development Block Grant funds, the State of Washington using Flood Control Assistance Account Program funds, and Hazard Mitigation Grant Program funds from FEMA. The funds available to the County totaled approximately $5.6 million.

Work began immediately on title reports, appraisals, and purchase negotiations for 27 homes and property. FEMA funds were directed to 18 homes and property while other funds were being used for vacant land and homes not included within the original FEMA grant. The uniqueness of the grant fund program involved the voluntary basis of the buyout program.

In addition, Pierce County was able to secure up to $8 million for levee rehabilitation and reconstruction along the Puyallup River from the PL 84-99 USACE program. Working with USACE and the adopted CFCMP, a setback levee was proposed in an area that needed a structural solution. Even though properties were purchased to move residents out of harm’s way, the City of Orting located downstream of the damaged levee system lies within a 100-year floodplain of the Puyallup River. Without some structural solution, the washed-out levees would allow the two- to five-year storm event to flow behind the existing levee system and impact the City of Orting.

Through the efforts of Pierce County River Improvement working with FEMA, USACE, the State of Washington and having an adopted CFCMP, many of the success stories would not have been possible. The success of the current program may never have another opportunity like the one Pierce County had after the February 1996 Presidentially declared disaster. It is the responsibility of each community to be prepared when the opportunity arises and have a plan ready to be implemented.
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FLOOD DISASTER MITIGATION IN UNINCORPORATED OTTAWA COUNTY, OKLAHOMA

W. Kenneth Morris, J. Gavin Brady, and Charlene Littleton
Oklahoma Water Resources Board

HISTORY

Ottawa County is located in the extreme northeast corner of Oklahoma, bordered on the north by Kansas and on the east by Missouri. The Neosho River, Tar Creek, and Spring River systems flow north to south in this county and into Grand Lake O’ the Cherokees. Major floods of record occurred on the Neosho River and Tar Creek in May 1943, April 1944, July 1948, July 1951, February 1985, October 1986, May 1993, April 1994, and May 1995.

The City of Miami and Ottawa County have experienced five floods within the past 10 years (1985, 1986, 1993, 1994, and 1995). The 1985 flood on Little Elm Creek was less than a 10-year flood, but six homes with flood insurance were damaged in Fountain East and Eastgate subdivisions. Before entering the regular phase of the National Flood Insurance Program (NFIP) on December 16, 1980, Miami and Ottawa County had experienced no major flooding since the flood of July 1951, the most severe flood in Miami’s history, which caused an estimated $5 million in damage and left some 3,000 persons homeless. The 1951 flood crested at 778.52 feet above mean seal level NGVD and was measured as the flood of record for the Miami area. It exceeded the 1943 flood of record by 9.5 feet. Since 1951, two Kansas flood control projects have been constructed on the Neosho River, John Redmond Dam, north of Burlington, and the Council Grove Reservoir; another dam was built on the Cottonwood River, a tributary of the Neosho.

On November 19, 1980, the Ottawa County Board of Commissioners, adopted a Model B Federal Emergency Management Agency Ordinance and entered the emergency phase of the NFIP. The flood map adopted for the county was a flood hazard boundary map with no base flood elevations (BFEs). By the end of 1984, the Eastgate and Fountain East subdivisions southeast of Miami (Figure 1) contained more than 40 structures. These subdivisions are located in the regulatory floodplain, Zone AE, as shown on the current Flood Insurance Rate Map,
Figure 1. Eastgate and Fountain East subdivisions in Ottawa County, Oklahoma.
dated December 2, 1988. As no floodplain development permits were issued or requested in these subdivisions, the exact date of construction would be difficult to determine. BFEs in the area range from 770 feet to 772 feet above mean sea level (Table 1). Also, four large sewage lagoons, used by these subdivisions, lie in this floodplain adjacent to the Neosho River and have no protective dikes. When a major flood occurs, sewage water from these lagoons more than likely mixes with the flood waters and aggravates the situation.

Many of these structures have flood insurance policies in force and NFIP repetitive loss data indicates more than 40 claims have been paid in these subdivisions (see Table 1). As of July 31, 1996, 157 flood insurance claims for $2,587,197 had been paid county wide. After the April 1994 flood, county officials determined 63 structures had been substantially damaged. Additionally, the county floodplain administrator determined eight of these substantially damaged structures were not feasible to elevate. As a result, they now sit vacant.

County officials would like to mitigate future flood losses in the Eastgate and Fountain East subdivisions, but have no experience in hazard mitigation techniques. This paper evaluates flood losses in these subdivisions and provides flood loss reduction assistance for county officials.

**OPTIONS AVAILABLE**

When first considering a hazard mitigation project, several structural and nonstructural options are available. Drainage improvements, detention basins, channel straightening, and dam construction could be feasible and should be considered, as well as acquisition, relocation, and demolition. The primary flooding factors involve the backwater effects from Grand Lake and associated tributaries. The floodplain is very broad and deep with an extensive floodway so the construction of dams or detention basins is not recommended. The U.S. Army Corps of Engineers has shown that levee construction does work in some cases, but it can be risky and is not considered here.

Stormwater runoff flows primarily west into Little Elm Creek then south to the Neosho River. Tar Creek enters the Neosho about 4,000 feet upstream from the mouth of Little Elm Creek. There is one unnamed drainage that lies between Eastgate and Fountain East that could be improved for short-term frequency storms, but with little benefit for the 50- to 100-year frequency flood.

The following mitigation options are presented for this paper, but should not be considered the only options available to local officials. The
Table 1. Fair market values for structures in Eastgate and Fountain East subdivisions, Ottawa County, compared to repetitive loss claims from 1985, 1986, 1993, 1994, and 1995 floods.

<table>
<thead>
<tr>
<th>STRUCTURE # OF CLAIMS</th>
<th>FAIR MARKET $ VALUE</th>
<th>$ CLAIMS PAID BLDG. CON.</th>
<th>RATIO x PAID W/O CON. W/CON.</th>
<th>FIRST FLOOR ELEVATION (ft) BELOW BFE</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>$46,272</td>
<td>$45,961 $ 3,693</td>
<td>1.0</td>
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<tr>
<td>2</td>
<td>2</td>
<td>NROS</td>
<td>$28,595 $10,500</td>
<td></td>
</tr>
<tr>
<td>(garage)</td>
<td>2</td>
<td>NROS</td>
<td>$ 8,163 $ 5,000</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>$43,842</td>
<td>$42,854 $10,870</td>
<td>1.0</td>
</tr>
<tr>
<td>4</td>
<td>2</td>
<td>NROS</td>
<td>$16,368 0</td>
<td></td>
</tr>
<tr>
<td>5</td>
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<td>$31,710</td>
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<td>6</td>
<td>4</td>
<td>$27,219</td>
<td>$70,652 $2,166</td>
<td>2.6</td>
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<td>7</td>
<td>3</td>
<td>$29,526</td>
<td>$60,994 $ 7,031</td>
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</tr>
<tr>
<td>8</td>
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<td>$14,324</td>
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<td>13</td>
<td>2</td>
<td>$23,728</td>
<td>$45,804 0</td>
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</tr>
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<td>14</td>
<td>3</td>
<td>$20,429</td>
<td>$74,727 $25,700</td>
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<tr>
<td>15</td>
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<td>SR</td>
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<tr>
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<td>2</td>
<td>$26,201</td>
<td>$23,015 $ 5,193</td>
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<td>21</td>
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<td>23</td>
<td>3</td>
<td>$20,526</td>
<td>$69,773 0</td>
<td>3.4</td>
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</tbody>
</table>

NROS - No Record of Structure
SR - Structure Removed
cost figures used here were taken from personal communications with the Tulsa District Corps of Engineers Floodplain Management Division and Corps publications.

**ELEVATION IN PLACE EXAMPLES**

In 1984, the relocation of a typical large, slab-on-grade house from a floodplain to a flood-free site in Tulsa County cost about $68,100. In 1989, 19 houses were elevated by the Corps in Goodlettsville, Tennessee. Each home was raised to one foot above the BFE (raise heights ranged from 2 to 6 feet), and all homes had crawl spaces. Costs ranged from $25,900 to $35,350 per house, which includes $4,000 administrative expenses per house.

**Elevation Options**

Some factors need to be considered for Ottawa County. The BFEs here range from 771 to 772 feet above sea level. The actual ground elevation in this area ranges from 792 feet along State Highway 10 and Eastgate Boulevard to 762 feet at the intersection of S. Treaty and Angela roads. Based on the elevations reported in Table 1, each house would need to be elevated on the average at least 8 feet (6 to 10 feet height raise range) and would put each lowest floor 0.8 feet above the BFE. To elevate a residential structure six feet from a slab is estimated to cost $11,638 and to elevate it 8 feet, $13,964. If all 22 structures were elevated on the average of 8 feet above the ground, the total cost is estimated to be $307,000. This price includes new wood floors over a crawl space, if the structure was slab on grade. If the structure had an existing crawl space, the estimate would be about $220,000, which would include a new masonry crawl space. Some administrative expenses could increase this total expense and should be considered.

Even if these structures were elevated at least one foot above the BFE, egress and ingress would still be restricted due to flood waters and would need further consideration in any mitigation plan. Considering the compliance issues associated with elevating structures on piers this alternative is ill advised and discouraged.

The claim payments made for all 22 residential structures totaled $1,058,739 and with contents payments totaled $1,153,970. If these structures had been elevated before they had been repetitively damaged, the NFIP would have saved over $700,000. Other payments that have not yet been examined include the individual family grant and emergency minimal repair payments. This would result in additional emergency assistance savings.
DEMOlITION

To demolish these 22 residential structures the expenses would include the purchase of each structure, the land it is sitting on, and the demolition/removal costs. Based on information from the Corps, demolishing a 1,200-square-foot home costs about $5,500. Total cost for this alternative is estimated to be $697,004 for the 22 residential structures. Without considering any administrative expenses, the NFIP would have saved $456,966, compared to the total claims of $1,153,970. This land would then belong to the county and could be utilized for restricted floodplain uses.

ACQUISITION/RELOCATION

This alternative will likely be the most expensive. Property in the county runs about $2,000 per acre. To relocate 22 houses near this area, but outside the 100-year floodplain would require about 160 acres, bringing the cost to $320,000. The cost to relocate a 1,200 square foot house is estimated at $8,500, bringing the expense to $507,000 (320,000 + 187,000), not including administrative expenses. Other expenses to consider are the installation of sanitary sewer lines or other septic systems.

COMBINATIONS

Eight of these structures were substantially damaged during the 1994 flood. These eight structures would be candidates for demolition and removal. The property would need to be purchased at the fair market value. Several structures would be candidates for elevation in place, and some structures may be candidates for relocation.

SUMMARY

This paper presents several options for consideration by local officials to address repetitive flood losses in the Eastgate and Fountain East subdivisions in Ottawa County, Oklahoma. More detailed analysis of these and other options should be undertaken before local officials select a course of action. Public participation in such a plan is essential to a successful project. The Oklahoma Water Resources Board, Oklahoma Department of Civil Emergency Management, and the Federal Emergency Management Agency stand ready to assist local officials in the hazard mitigation process.
MONTGOMERY COUNTY FLOOD MITIGATION ALTERNATIVES ANALYSIS

Lynn M. Mayo
Dale A. Lehman
Woodward-Clyde

Daniel Harper
Montgomery County Department of Environmental Protection

A townhouse development in Montgomery County, Maryland, has been damaged by flooding several times in the last 30 years. The repetitive damage and potential risk to human safety prompted Montgomery County to use structured problem solving and alternative analyses to evaluate and select the most appropriate flood mitigation action. Woodward-Clyde has been assisting Montgomery County in the selection and design of a flood mitigation alternative for the site. Structured problem-solving techniques were used to identify the best alternatives and included the following steps:

- Describe the Problem
- Determine the Cause(s)
- Choose a Solution (including brainstorming, list reduction, and point scoring)
- Plan Action Steps and Follow-up.

In order to choose a solution, brainstorming was used to identify 13 possible mitigation alternatives and 22 ranking criteria. The list of possible alternatives was then quickly analyzed and reduced to six alternatives. Based on additional analysis, point scoring, and a public meeting, the two best alternatives were identified. These two alternatives were then further analyzed and during a second public meeting, one alternative (construction of a levee) was selected. This paper discusses the mitigation alternatives analysis that was used on this project.

DESCRIBE THE PROBLEM

The townhouse development, called Montclair Manor, was built in the 1960s. The development is not within a Flood Insurance Rate Map
floodplain. However, the townhouse development has been damaged by flooding several times in the last 30 years. The worst recent flooding was in 1989, when an approximately 10-year frequency storm event caused 4 feet of flooding in seven townhouse units. To determine the extent of possible flooding, Woodward-Clyde used TR-20 and HEC-2 computer models to determine the 2-, 5-, 10-, 25-, 50-, and 100-year floodplain elevations. Montgomery County also mailed out a survey to the homeowners in the area requesting information regarding past flooding. Based on this information, the computer models were calibrated. The modeling showed that, in addition to the group of seven townhouses that received flooding in 1989, a group of five other townhouses in Montclair Manor are in the 100-year floodplain. It was also determined that two nearby single-family houses, which were not known to have ever received flood damage, were above the 50-year floodplain elevation but below the 100-year floodplain elevation. In the Montclair Manor townhouse complex, the basement of one of the townhouses is 10.5 feet below the 100-year floodplain, six townhouses are 5 to 6 feet below, and five townhouses are 1 to 2 inches below the 100-year level.

**DETERMINE THE CAUSE(S)**

Montclair Manor is flooded by a creek that flows adjacent to the townhouse complex. Immediately downstream of Montclair Manor the creek is piped under a major traffic thoroughfare (Veirs Mill Road) through a corrugated metal arch pipe approximately 16.5 feet by 10 feet. The pipe was installed by the Maryland State Highway Administration in 1955. The state's design for the pipe used the Rational Method to calculate runoff to the culvert. Presently, the Rational Method is used only for small watersheds (less than 100 acres) and is not recommended for use on watersheds greater than 1 square mile (640 acres). The watershed at Montclair Manor is approximately 900 acres. The state study was also based on a low runoff coefficient representing a watershed that is mostly forest and cropland (C = 0.3 to 0.4). The watershed is presently very developed and has a considerably higher runoff coefficient. Most of the watershed’s development predates stormwater management regulations and there are no stormwater management facilities in the watershed. Based on Woodward-Clyde’s TR-20 calculations for present conditions, the water backs up at this culvert and the creek will overtop the road between a 5-year and 10-year storm. In addition, several of the Montclair Manor townhouses were built at elevations lower than Veirs Mill Road. Consequently, no overland relief is provided.
CHOOSE A SOLUTION—BRAINSTORMING

Brainstorming is a method used to generate a list of ideas about a given subject. It is a technique that effectively collects information by stimulating the ideas of those involved in the brainstorming process as they listen to and think about ideas that have already been listed. Brainstorming was used to identify possible mitigation alternatives and to identify criteria that would be used for ranking the alternatives.

A brainstorming meeting was held in February 1996 with representatives of the Montgomery County Department of Environmental Protection, Montgomery County Department of Public Works and Transportation, Maryland-National Capital Park & Planning Commission, Woodward-Clyde, and Loiederman Associates (a subcontractor to Woodward-Clyde). During this meeting, 13 potential mitigation alternatives were identified. In addition, the surveys that were mailed to the homeowners requesting information on past flooding also requested input regarding potential mitigation alternatives. Although the homeowners did not identify any mitigation alternatives that had not been developed at the brainstorming meeting, the survey began a well-received public involvement component of the project. The 13 potential mitigation alternatives that were identified are shown in Table 1.

Table 1. Potential mitigation alternatives.

<table>
<thead>
<tr>
<th>No.</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>No Action</td>
</tr>
<tr>
<td>2</td>
<td>Increase Veirs Mill Road Culvert Capacity</td>
</tr>
<tr>
<td>3</td>
<td>Construct Two Upstream Stormwater Detention</td>
</tr>
<tr>
<td>4</td>
<td>Construct A Levee</td>
</tr>
<tr>
<td>5</td>
<td>Floodproof The Homes</td>
</tr>
<tr>
<td>6</td>
<td>Acquire The Property</td>
</tr>
<tr>
<td>7</td>
<td>Enclose The Creek Adjacent To Montclair Manor</td>
</tr>
<tr>
<td>8</td>
<td>Open-Up The Creek Upstream Of Montclair</td>
</tr>
<tr>
<td>9</td>
<td>Elevate The Buildings</td>
</tr>
<tr>
<td>10</td>
<td>Construct Upstream Stormwater Detention</td>
</tr>
<tr>
<td>11</td>
<td>Construct Upstream Stormwater Detention</td>
</tr>
<tr>
<td>12</td>
<td>Construct Upstream Stormwater Detention</td>
</tr>
<tr>
<td>13</td>
<td>Construct Upstream Stormwater Detention</td>
</tr>
</tbody>
</table>
**Choose a Solution—List Reduction**

List reduction is a quick and efficient technique for cutting down a large number of items to a workable few. During the brainstorming session we identified 22 criteria for ranking the alternatives. The representatives from Montgomery County Department of Environmental Protection, Montgomery County Department of Public Works and Transportation, and Maryland-National Capital Park & Planning Commission rated these criteria in order of importance (1 through 22). The ratings were then averaged. It was determined that the most important criteria for selecting flood mitigation alternatives were:

- Public Safety
- Level of Protection
- Benefit/Cost
- Constructability
- Impact to Residents

Woodward-Clyde then quickly analyzed each of the 13 alternatives regarding these five criteria. Based on this analysis, Montgomery County chose the first six alternatives from Table 1 for further consideration. The analysis showed that alternatives 7 (enclose the creek adjacent to Montclair Manor) and 8 (open up the creek upstream of Montclair Manor) would not significantly reduce the 100-year floodplain elevations, and the townhouses would continue to be within the 10-year floodplain. Therefore these alternatives were removed from the list. Alternative 9 (elevate the buildings) was not selected for further consideration since floodproofing would provide a greater degree of public safety and higher benefit-cost ratio than elevating the buildings. Alternatives 10 and 11 (construct one detention pond at two different sites) were not selected since the largest pond that could be constructed provided minimal additional protection. Alternatives 12 and 13 (construct one detention pond at two other sites) were not considered because separately they would provide marginal reductions in the floodplain elevation. The alternative of constructing ponds at each of these two sites was selected for additional analysis.

**Choose a Solution—Point Scoring**

Point scoring is a method used to evaluate and rate a small number of options by comparing them against a set of criteria. Since criteria are not equally significant, the criteria are weighed. For Montclair Manor the 22 ranking criteria that were identified were divided into three groupings.
The three groupings of criteria were then given weighting factors of 10 (for the 5 most important criteria), 3 (for the next 9 criteria), and 1 (for the least important 8 criteria). The six alternatives were then scored (1 through 5) for each of the 22 criteria, with 1 being very negative and 5 being very positive. These scores were then weighted and a total weighted score was calculated for each alternative. The scores were as follows:

- 302 - levee alternative
- 279 - floodproofing alternative
- 275 - acquisition alternative
- 241 - no action alternative
- 180 - detention basins alternative
- 178 - increase culvert capacity alternative.

These results were presented at a public meeting. At that meeting a second survey was distributed to the affected townhouse owners asking them to rank their preferred alternatives. Acquisition was the most preferred alternative for three of the homeowners in the group of seven townhouses that are most impacted by flooding. Two of these homeowners had levee as their second alternative. Levee, followed closely by acquisition, was the preferred alternative for one of the homeowners in this group. The remaining three homeowners in the group of seven townhouses did not respond to the survey. There was minimal response from the other homeowners in the area. Based on this analysis, it was clear that the detention basins and increase culvert capacity alternatives were not viable alternatives. The county also determined that the no action alternative was not acceptable. Since the scores of the remaining three alternatives were relatively close, at this point there was not a clear "best" alternative for Montclair Manor.

Based on the analysis and second homeowner survey, the county decided to study two alternatives in additional detail: the levee and acquisition. For this second phase a subsurface soil investigation was conducted, conceptual designs were prepared, the hydraulic calculations were modified based on the conceptual designs, the benefit/cost ratios were calculated, and a detailed analysis was prepared. It was determined that the main advantages of the acquisition alternative were:

- 7 townhouses removed from floodplain
- No maintenance required
- No potential for structural failure
- Positive impact on remaining residents
- Fewer potential permitting issues.
The main advantages of the levee alternative were:

- No displaced homeowners
- Easier to implement
- Significantly lower initial costs ($340,000 versus $1,140,000)
- Higher benefit/cost ratio (1.2 versus 0.5).

A second public meeting was held in November 1996. The additional information was presented at this meeting. Based on the additional analysis and second meeting, the county chose to proceed with the levee.

**PLAN ACTION STEPS AND FOLLOW-up**

The last step in any problem solving process is to plan action steps and follow up on implementing the chosen solution. For the Montclair Manor project, the county has requested funds in the capital improvement plan for design and construction of the levee. The County Council is reviewing the request and it is anticipated that design of the chosen alternative will start in the summer of 1997.

**CONCLUSION**

By following standard problem solving techniques, Montgomery County was able to relatively quickly and cost effectively identify the "optimal" flood mitigation alternative for Montclair Manor. Within nine months of holding the initial brainstorming meeting, 13 potential mitigation alternatives were identified and quickly evaluated, six of these alternatives were analyzed in more detail (including hydraulic modeling and cost estimates), two alternatives were chosen for detailed analysis (including geotechnical investigation and benefit/cost estimates), and one alternative was selected. The public participation was an integral part of the project and included two homeowner surveys and two public meetings. This gave the community a sense of ownership in the final solution. The structured problem solving also increased public acceptance for the chosen alternative since the public understood the selection process and it provided defensibility to the County officials for authorization of mitigation funds. As a result of Montgomery County's proactive efforts, homeowners that have been subject to periodic flooding for the last 30 years should soon be protected from the 100-year flood.
FLOOD HAZARD MITIGATION IN
SANTA BARBARA COUNTY, CALIFORNIA:
A MULTI-FACETED APPROACH

Thomas D. Fayram
Santa Barbara County Flood Control &
Water Conservation District

INTRODUCTION

Flood hazard mitigation is the foundation for our work as professionals in
the field of flood control. In Santa Barbara County a special district, the
Santa Barbara County Flood Control and Water Conservation District,
was formed to help control and minimize the impacts of flooding on our
community. Records from before the turn of the century document
repetitive damage due to flooding.

Santa Barbara County is located on the Pacific Coast approximately
100 miles north of Los Angeles. With a population of about 350,000,
Santa Barbara County has a wide variety of terrain and environments. A
coastal plain that actually faces south is home to approximately one half
of the county’s population. In the north, inland valleys dominated mostly
by agriculture are inhabited by the balance of the county residents.

Although a semi-arid region, Santa Barbara County can receive
extremely high rainfall volumes and intensities due to its location and its
steep mountainous terrain. Most of the populated areas of the county
receive an average rainfall of 13 to 20 inches per year although annual
totals of over 45 inches have been recorded. In addition, the mountains
above Santa Barbara have received in excess of 80 inches of precipitation
in wet years. The significance of these numbers is amplified because the
vast majority of this rainfall occurs in a four month window between
December and March.

In addition to the highly variable climate, Santa Barbara County has
diverse topographical settings including alluvial fans, steep watersheds
with short times of concentrations, flat agricultural plains, and larger
rivers with drainage areas of 900 and 1,700 square miles. Urbanization
and productive agriculture exists in all of these scenarios, thus
challenging the Flood Control District with a variety of problems.

The City of Santa Barbara (population 80,000) and many other urban
areas of the county have been in existence since well before the turn of
the century. All of these urban areas are located on or near a stream or river, which was common in the 1800s when these cities were founded. As a result, there is a significant portion of the population, and corresponding property, located in flood prone areas. In some areas of the county, home values can easily exceed $1 million. A simple relocation effort is not economically justified nor is it possible given the taxation limitations of Proposition 13 in California.

To reduce flood damage and protect public health and safety, the Santa Barbara County Flood Control District operates a multi-faceted flood hazard reduction program to not only preclude new development from building in high risk areas, but also to offer flood protection to existing properties. This multi-faceted approach implements three very different techniques all with a common goal of reducing or eliminating flood losses. These three programs are regulation of development through floodplain management policies, construction of capital improvements to enhance flood flow capacities, and maintenance of natural and human-made watercourses to preserve the flood flow capacities of these facilities. Although different in nature, these techniques complement, and in fact, rely upon one another to increase the overall effectiveness of the flood hazard reduction program.

**Floodplain Management—New Development**

Floodplain management has been practiced for many decades throughout the country. In recent years, the methods, policies, and standards employed have become more stringent and effective. Santa Barbara County became a formal participating member in the National Flood Insurance Program (NFIP) in March of 1979. The Flood Control District utilized numerous floodplain management techniques for many years prior to joining the NFIP. Upon entering the NFIP, Santa Barbara County adopted floodplain management standards that far exceeded FEMA requirements. In addition, a variety of planning tools and policies have been developed over the years to help maximize the effectiveness of the floodplain management program.

**NFIP Standards Exceeded**

Santa Barbara County encourages new development to avoid defined floodplains. Should this avoidance not be feasible, all development in the floodplain will have its lowest floor elevated 2 feet above the recognized 100-year flood elevation or base flood elevation (BFE). The additional 2 feet provides a valuable factor of safety to account for uncontrollable variables that may increase flood elevations. As in many parts of the
country, many areas remain unstudied and thus lack defined floodplain limits and BFEs. In these instances, developers are required to prepare hydrologic and hydraulic studies in conformance with FEMA requirements for establishing 100-year flood limits and elevations. The same 2-foot factor of safety is applied to these results. In addition, Santa Barbara County adopted a setback ordinance which requires all new development to be set back at least 50 feet from the top of banks of creeks and 200 feet back from the top of banks of major rivers. This setback helps preserve the floodplain from encroachment and protects new development from erosion hazards. Other conservative requirements exist such as in Coastal High Hazard Zones where an additional 5 feet of elevation is required above the BFE.

**Planning Tools**

In addition to the FEMA flood maps, Santa Barbara County has compiled a library of resources to help make accurate assessments of floodprone areas for development considerations. Detailed watershed maps, accurate digital aerial topography, historical aerial photography (including flights flown immediately after floods), and various special studies by other agencies provide information needed to make wise planning decisions.

**Other Policies**

Development is also subject to riparian protection and zoning considerations. Open space requirements are usually met by preserving areas in and around watercourses as open space. Project-specific policies may also require developers to construct stormwater retardation facilities, storm drain improvements, channel improvements, or other structural improvements that help protect not only new development but also existing development.

**MAINTENANCE OF FACILITIES**

Most of the streams in Santa Barbara County are ephemeral, flowing only during the winter months. It is common for some streams to not flow at all in drought years. The large variance in rainfall in any given year causes natural watercourses to experience tremendous sedimentation in wet years and growth of obstructive vegetation in moderate or drought years due to the lack of flushing flows. With Santa Barbara County's moderate climate, vegetation can flourish throughout the year. Either case causes potential flood risks with the associated reduction in flow capacities. Some areas of Santa Barbara County are founded on alluvial
fans. These fans have formed through a series of debris and sediment movements. Consequently, the channel locations have migrated through time. Without ongoing channel maintenance, these channels will cease to exist in their present form and locations.

Homes and business structures are stationary, therefore, allowing this channel migration has the potential to cause millions of dollars of damage and even loss of life. A maintenance program of sediment removal and vegetation clearing tends to stabilize channel alignment. With property values ranging from hundreds of thousands to millions of dollars, relocation out of the fans and floodplains is simply not feasible. Preservation of the existing stream corridors is a highly cost effective approach to flood loss mitigation. Unlike some parts of the country, maintenance of natural and human-made channels in Santa Barbara County is essential and never-ending.

**CAPITAL IMPROVEMENTS**

**Structural Improvements**

Clearly the era of concrete channelization of natural watercourses is over. This does not mean that there is not a place for other structural improvements in a flood control system. Structural improvements remain a valuable alternative to help reduce flood losses. Recent construction of storm drains, channel improvements (particularly in non-riparian areas), debris basins, and retardation basins has prevented untold damage and misery. Particularly in high density urban areas, structural improvements can be an economical option. In some cases, it is the only feasible alternative.

**"Soft" Capital Improvements**

In addition to structural improvements, various other capital improvements that do not involve concrete can be highly effective in preventing flood losses. These "soft" treatments can include increasing channel capacities by widening a channel while still keeping a soft channel and native vegetation. Other soft treatments such as biotechnical bank treatments and improvements that allow or encourage vegetation can offer increased flood protection. Such a project on Mission Creek in the City of Santa Barbara is being pursued with the backing of environmental groups. Clearly capital improvements, both structural and soft, can provide a community with a cost effective way to reduce flood damage.
THE MULTI-FACETED APPROACH

In Santa Barbara County, economics and the environmental factors that exist dictate that a true multi-faceted approach be used in a flood loss reduction program. This multi-faceted approach is highly effective because it acknowledges not only the strengths and weaknesses of each element, but it recognizes that for the program to be effective these elements are interdependent on each other for success. Because of this fact, any single program cannot be overemphasized or eliminated because this would weaken the other programs and result in increased flood losses not only to people’s homes and businesses, but to the tremendous investment in our public infrastructure.

For example, effective floodplain management cannot be successful on its own. Without maintenance of our highly dynamic channel systems, the assumptions we make on new development today (through FEMA flood maps) may well be invalid in future years. A maintenance program preserves the assumptions we make today, which prevents flood losses tomorrow. Likewise, the capital improvements we invest in today will prove worthless without preserving the design capacities. Removing sediment, debris, and vegetation from these facilities protects our investments and renders great returns in the form of reduced flood losses. And finally, through development, regional flood control improvements can benefit not only the new development but also offer increased protection to existing development, all at no cost to the community.

CONCLUSIONS

Recently, “mitigation” has been promoted as the new wave in flood loss reduction with a clear bias against past proven practices. The definition of “mitigation” has thus emerged as a practice of avoidance with a clear desire to favor only nonstructural approaches to flood loss reduction. Unfortunately, this form of “mitigation” has been embraced by many federal, state, and local officials as the emerging direction in floodplain management without regard to the potentially adverse impacts to communities or individual property owners across the country. This ignores the realities of different environments throughout the country and abandons proven cost-effective methods of reducing flood losses.

Structural improvements can still play an effective and cost-efficient role in minimizing or preventing flood losses. The City of Carpinteria presents a classic example of how structural improvements prevented untold costs and misery from flooding. Prior to the 1970s, Carpinteria suffered almost annual bouts with floods. Since that time, an extensive system of debris basins and channelization of major creeks has been
constructed by the Natural Resources Conservation Service. In 1995, while many parts of Santa Barbara County suffered from flooding spawned by record rainfall, Carpinteria was protected from major damage.

But structural improvements alone will not work without ongoing maintenance of these facilities. Without maintenance, a structural facility will not perform as designed and may not offer the protection it was intended to deliver. In many areas of the country, failure to provide maintenance in natural watercourses exposes part of the community to an unnecessarily high flood risk. Maintaining corridors free of obstruction is a highly cost effective way to lessen flood damage. Atascadero Creek is a prime example of how a channel maintenance project (permitted just before the 1995 floods) spared an estimated 100 homes an unnecessary flood risk.

In Santa Barbara County, as in many counties in the western United States, this program of multi-faceted flood hazard mitigation is effective and worthy of continued support. Santa Barbara County’s flood hazard mitigation program makes use of all of the tools available to deliver an efficient and effective service to the taxpayers. It is in the best interests of FEMA and other disaster-related agencies to actively support programs such as Santa Barbara County’s and to help reform and streamline the cumbersome environmental process for permitting both capital projects and maintenance efforts. We all share the same goal of flood loss reduction. To prejudge, discount, or otherwise overemphasize any single technique, for whatever reason, goes against the common goal we share. As professionals we are obligated to serve our constituents, the taxpayers, with cost effectiveness and sensitivity to the environment. Flood hazard mitigation is best accomplished by using all the tools available to meet the desired end.
FLOOD HAZARD MITIGATION PLAN FOR THE
FIVE-PARISH AREA OF ASSUMPTION, LAFOURCHE,
LOWER ST. MARTIN, ST. MARY, AND TERREBONNE

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INTRODUCTION

In the five-parish area of Assumption, Lafourche, Lower St. Martin, St. Mary, and Terrebonne parishes in south Louisiana, frequent flooding is a serious problem. Studies in these areas have shown that recent floods have caused millions of dollars in damage. Furthermore, the changing physical conditions, including ground subsidence, marsh deterioration, and deltaic formation of the Atchafalaya River, will likely exacerbate area flooding in the future.

Numerous flood damage reduction actions, originating from federal, state, and local levels of government, are in progress or are being proposed and evaluated. There is a need to coordinate multiple efforts to ensure the best use of limited resources and facilitate the implementation of the various damage reduction measures. This document describes the guidance provided in the form of a flood hazard mitigation plan.

STUDY AUTHORITY

The study was conducted under the federal Planning Assistance to the States Program as authorized by Section 22 of the Water Resources Development Act of 1974 (P.L. 93-251), as amended, to help states prepare comprehensive plans for the development, utilization, and conservation of water and related land resources. Under Section 319 of the Water Resources Act of 1990 (P.L. 101-640), the study was cost-shared 50% with the Louisiana Office of Emergency Preparedness.

STUDY PURPOSE AND SCOPE

The purpose of the study was to develop an active flood hazard mitigation plan to serve as guidance in coordinating and implementing flood damage reduction policies, programs, and projects for the five-parish area. Using available information and consultations with state and parish governments, all existing and proposed flood mitigation measures in the
study area were identified. Given the available resources and the priorities determined by the local governments, a plan was developed to facilitate the flood mitigation actions. Methods were also established to periodically evaluate and update these mitigation plans.

This plan is envisioned to be the basis from which potential pre- and post-disaster mitigation projects are funded, and will focus on solutions that are capable of being implemented by the state, parish, and local governments eligible for funding under the Hazard Mitigation Grant Program (HMGP). Essentially, the development of a hazard mitigation plan will facilitate the receipt of funds from the Federal Emergency Management Agency after a disaster. The Corps of Engineers served as the primary agent in preparing this document, along with the state and various parish agencies.

**LOCATION OF STUDY AREA**

Assumption, Lafourche, Lower St. Martin, St. Mary, and Terrebonne parishes are located in south-central Louisiana. The parishes are bounded by the Mississippi River on the east, the East Atchafalaya River Protection Levee on the west, and the Gulf of Mexico to the south. All five parishes consist mostly of wetland and agricultural areas, with urban areas covering about 3% to 4% of each parish. Surface runoff generally drains away from the major and minor tributary ridges to interconnecting canals and bayous, to the wetlands and the Gulf of Mexico.

**DESCRIPTION OF FLOODING PROBLEMS**

During the past 15 years, at least four major floods occurred due to runoff from heavy rainfall, and two were caused by Hurricanes Andrew and Juan. The actual source of flooding varies according to location. All five parishes are subject to headwater flooding caused by excessive rainfall, but the area is also susceptible to backwater flooding from the Atchafalaya River. The coastal parishes are also prone to flooding from tidal surges associated with hurricanes and tropical storms.

Over the years, the coastline has become more open and less able to resist normal high tides so that impacts are experienced regularly in much of the study area. The high tides consume the available storage for runoff from the developed portions of the parish; therefore, there are times when rainfall runoff cannot be detained. Since coastal erosion is occurring more rapidly, the frequency of flooding will increase.

The total FEMA flood claims paid for the study area between 1978 and May 1991 by parish were: Assumption—$1,817,364; Lafourche—$16,287,644; Lower St. Martin—$1,400,831; St.
Mary—$3,234,075; and Terrebonne—$29,404,554. In October 1985, St. Mary Parish flood damage associated with Hurricane Juan was estimated at $16,469,500. In August 1992, Hurricane Andrew caused flood damage in St. Mary Parish estimated at $7.8 million.

HAZARD MITIGATION COMMITTEE

On December 14, 1993, the Louisiana Office of Emergency Preparedness and the Corps of Engineers entered into an agreement to prepare a Flood Hazard Mitigation Plan for Assumption, Lafourche, Lower St. Martin, St. Mary, and Terrebonne parishes. The Hazard Mitigation Committee consisted of one representative from each of the five parishes and assembled monthly at different sites throughout the study area. A Steering Committee consisting of federal, state, and local agencies also met periodically to provide input to the plan, while the Statewide Hazard Mitigation team provided overall guidance and direction.

GOALS AND OBJECTIVES

Goals and objectives were formulated based on flooding problems, potential solutions, and available funding programs. The goal of this effort is to develop a comprehensive plan to reduce existing and future flood damage in the study area. The objectives of the plan include coordination of all flood damage reduction activities to maximize flood damage reduction and minimize adverse environmental impacts to the environment; identifying federal and non-federal funding sources for each element of the comprehensive plan; identifying all potential federal, state, parish, and local flood damage reduction projects planned for the study area; identifying projects that are eligible for funding from the FEMA Hazard Mitigation Grant Program; developing a comprehensive plan to reduce flood damage with structural and nonstructural elements; establishing a priority funding sequence to facilitate implementation of the plan. Different programs may fund the study and/or design of a mitigation project while another fund would be used for project construction. Because various federal, state, and local agencies are involved in managing and implementing funded programs, coordination of these agencies is an integral part of plan implementation.

FUNDING AND RESOURCES

The resources required to implement all flood damage reduction measures will likely exceed the financial capabilities of each of the parishes. Some outside funding sources that are available through state and federal programs are discussed below.
Louisiana Statewide Flood Control Program

The Louisiana Department of Transportation and Development administers an annual fund of $10 million for flood damage reduction projects. These funds are usually cost-shared, up to 70%-30% state-to-local ratio. While these funds have been limited, parishes in the study area have utilized this program with significant benefit.

Office of Emergency Preparedness, Hazard Mitigation Program

The Louisiana Office of Emergency Preparedness (OEP) has a limited program for funding hazard mitigation projects. Program guidelines are similar to the Statewide Flood Control Program and funds are typically provided on a cost-sharing basis of up to 50%-50% state-to-local.

Federal Emergency Management Agency

FEMA makes hazard mitigation funds available after a disaster for both structural and nonstructural projects. Up to a 75% federal share is available. The federal government's share in buy-outs of homes and businesses in flood-prone areas increased from 50% to 75% and there are specific conditions under which such buy-outs are acceptable. FEMA plans to make funds available for pre-disaster hazard mitigation projects. The parishes in the study area have utilized FEMA funding with significant benefits.

Corps of Engineers

The Corps of Engineers is investigating the feasibility of flood damage reduction measures for the Mississippi River and its tributaries (including the Atchafalaya River) through two flood control studies: the Lower Atchafalaya and the Morganza-to-the-Gulf studies. These studies require a 50% local cost share. Projects identified as cost-effective and environmentally sound may qualify for federal participation, including up to 65% federal funding. The two studies will be done in four years, with project construction occurring 5 to 10 years thereafter.

Community Development Block Grants

The Department of Housing and Urban Development Community Development Block Grants (CDBG) provide funds for limited flood damage reduction projects and to renovate or elevate homes in the 100-year floodplain. Block grants require that a homeowner be of low income. Currently there is a $20,000 per house renovation cap.
Natural Resources Conservation Service

The NRCS (formerly the U.S. Soil Conservation Service) may provide assistance to water resource projects that provide water conservation. In some cases, water conservation (retention) could also provide flood damage reduction. In the study area, such a condition is not common but has been implemented for the Lake Verret area.

Mitigation Plan

To alleviate damage due to tidal surge, river backwater, and internal stormwater flooding in the five-parish area, a plan consisting of structural and nonstructural projects is proposed. The total cost of these flood damage reduction improvements is estimated to be over $500 million. Because such a proposed capital program is well beyond the financial capabilities of the five parishes, additional funding from the state and federal government will be required to successfully implement the plan. Numerous parish projects are planned by local agencies, ranging from small drainage improvements to major front-line levees and flood damage reduction structures that are also included as part of the Corps plan.

The Corps of Engineers, through the Lower Atchafalaya and Morganza to the Gulf studies, is evaluating the feasibility of constructing a system of front-line levees, major channel modifications, floodgates, and pump stations from (and including) the Atchafalaya River east to Bayou Lafourche. Reconnaissance investigations have revealed that four major projects have potential for future federal construction funding: St. Mary—Terrebonne Parish Barrier Plan, Terrebonne—Lafourche Parish Hurricane Protection Plan, Lower Atchafalaya River modifications, and channel modifications for upper regions of the Atchafalaya River.

These projects would provide front-line flood damage reduction for the study area. Solutions to local drainage problems would not be included in the federal projects. There would, however, be significant indirect benefits from the federal projects, especially lowering of backwater stages throughout the area.

Under a best-case scenario, the Corps projects would not be fully constructed for at least 10 years. Also (at the time of this writing), federal policy changes are proposed that would prevent federal participation in some of the projects. In consideration of this, the parishes should plan their local projects without relying on the federal plans.

A description of the federal projects is included in the mitigation plan, including project name, description, cost, type of flooding addressed, area protected, level of protection, number of structures
benefitted, average value of structures benefitted, flood damage
prevented, potential funding source, project status, and required actions.

There are numerous local projects that, if constructed, would
significantly reduce flood damage in the five-parish area. These projects
primarily address localized needs and would complement the large federal
projects under study. In some cases, large local projects overlap with the
federal plans and would be incorporated in the Corps projects. Should the
parishes construct any part of the approved federal plan, they could
receive cost-sharing credit if the federal project is constructed. All of the
parishes have limited financial capability and are seeking funding for any
or all of their flood damage reduction projects.

FEMA encourages the buy-out and relocation of repeatedly flood
damaged properties and have made funds available for such action. The
parishes should strongly consider buy-outs as a integral part of the flood
hazard mitigation plan. More importantly, the parishes should evaluate
the cost effectiveness of property relocation as an alternative or
complement to many of their proposed structural flood damage reduction
projects. All five parishes are members of the National Flood Insurance
Program and regulate new construction. They have aggressive programs
that have been quite successful in significantly reducing flood damage
vulnerability of new development. As an integral part of their mitigation
plan, all five parishes intend to continue enforcement of this program.

The following information was provided for each project identified in
the local communities: project name, description, cost estimate, type of
flooding addressed, area protected, level of protection, number of
structures that would benefit, potential funding source, project status,
parish priority, and required actions.

**PLAN IMPLEMENTATION AND UPGRADING PROCEDURE**

Each parish government, and/or levee or drainage district will have the
primary responsibility for implementing the required actions listed in this
plan. The state OEP will monitor parish actions and periodically evaluate
progress. OEP will also coordinate future meetings of parish
representatives to update the plan and to review changes in assistance
programs. Such updating should be done on annually and in conjunction
with state and parish annual budget preparations.
INTRODUCTION

Lafayette Parish, located in southwestern Louisiana (Figure 1), has a long history of flooding. Historical events show that a large percentage of flooding occurs along the Vermilion River. The Lafayette Parish Bayou Vermilion District (BVD) recognized a need for improving the flood warning and preparedness plan for the parish. Flood warning and preparedness plans are implemented to reduce flood damage by providing the maximum warning time, forecasting a storm's magnitude before flood conditions, and educating the emergency response teams and public on the appropriate actions before, during, and after a flood. Warnings and forecasts are usually made using a network of gauges in a given watershed. Gauges generally consist of both precipitation and stage recorders that may be manually read and/or automatically logged.

The Bayou Vermilion District teamed up with the U.S. Army Corps of Engineers (USACE), New Orleans District, (NOD) to reduce the impact of flooding in Lafayette Parish by improving the current flood warning system. The study was initiated under the Corps' Planning Assistance to States Program (PAS) in March 1996.

A kickoff meeting brought all interested parties together to discuss the study scope and direction and the level of involvement required from each group. Participants included BVD, the Lafayette Office of Emergency Preparedness (OEP) director, various local authorities and city officials, National Weather Service (NWS), U.S. Geological Survey (USGS), and NOD. The current flood warning system was discussed along with the locals' needs and ideas on how to improve it. This report documents the method used to design the recognition system and the components of the flood warning system designed for Lafayette Parish.

IDENTIFICATION OF FLOOD HAZARD AREAS

To design an effective flood threat recognition system, it is essential to determine the areas that could benefit from reliable flood warning information. A planning meeting was held before implementation of
Reciently Installed DCP Locations
1. Head of Vermillion River, Precip, Stage
2. Vermillion River at Lake Martin Rd., Precip, Stage
3. Vermillion River at Surrey St., Precip, Stage
4. Vermillion River at Hwy 733; Precip, Stage
5. Isaac Verot Coulee at Hwy 733; Precip, Stage, Discharge
6. Vermillion River at Perry, LA, Precip, Stage

Proposed DCP Locations
A. Bayou Calahan, in the City of Villebone
B. Coulee Isle des Cannes, near the city of Ossun
C. Indian Bayou, below intersection of Indian Bayou and Bayou Que de Tortue
D. Vermillion River, between Pinkhook Bridge and Long Bridge
   (flood profile, staff gauge)
E. Coulee Mine, below fork located in the city of Lafayette
F. Coulee Isle des Cannes, Route 342

Figure 1. Location and vicinity map with installed and recommended gauge locations.

The flood preparedness plan to identify areas prone to riverine flooding. Locations also were identified where stage and precipitation information could be beneficial for river forecasting purposes, but not currently collected, or collected by antiquated means. Local officials stated that flood damage in Lafayette Parish typically results from riverine flooding caused by intense rainfall, headwater runoff from the north, backwater from the Vermillion River, tropical storms, hurricanes, and combinations of the aforementioned events. Therefore, in order to monitor the river successfully, there should be gauges both to the north and south of the parish. It was also noted that the majority of the riverine flooding occurs near the residential areas along the river in the City of Lafayette.

A follow-up meeting was held with various local agencies to identify flood-prone areas other than those located along the Vermillion River. These areas will only be addressed in this plan as recommendations for future studies. Areas located in west Lafayette Parish were reported as
It was noted that placing a data collection platform (DCP) gauge northwest of the parish would benefit the flood recognition system for the Vermilion River. A recommendation was made to install USGS flood profile gauges/staff gauges along the flow reversal channel reaches, defined at the meeting. These gauges provide high water elevations at each location as well as the current stage. This information will benefit local residents monitoring stages, insurance issues, and future study area considerations. DCPs are not expected to benefit this reach due to the extremely rapid rates of flooding. Staff gauges at boat launches and by the office of Public Works in Lafayette Parish were suggested as additional river gauging sites for the Vermilion River.

**Flood Threat Recognition System**

Flood threat recognition systems are used to determine weather conditions and the level of threat imposed. The system's main components are the precipitation and river stage gauges used to monitor and/or forecast the effects of a given event. These efforts should enable an effective warning dissemination and insure that appropriate emergency response activities are executed.

**Gauging Network**

Gauging requirements for flood warning were discussed at the planning meeting. It was suggested that priority be given to designing a system with satellite and telephone telemetry, thereby providing Lafayette with real-time precipitation and stage data. It was decided that a mixed reporting system, using a combination of interrogation, event reporting, and timed reporting techniques, will be used. This provides the user with data on a routine basis, as a storm occurs. The communications media used to transport this reporting information to and from remote locations is a combination satellite, telephone modem, and Internet communications system. This provides a redundant means for the capture of real-time stage and precipitation data. Satellite systems collect data from DCPs on the earth's surface. Data is transmitted from a DCP to a satellite, which relays the signal to a ground receiving station or local readout ground station. Telephone systems are a standard form of telemetry in automated data collection systems. The initial costs are low, and the data transfer rates can be exceptional based upon the baud rate. The data collected at each DCP site is stored on the Internet by the USGS. The Internet data includes a table listing and graphs of all real-time sites.

In order to interpret stage and precipitation data in a user friendly environment, the installation of a computer base station with the
The capability of retrieving, viewing, and plotting data was specified. This HydroMet base station is run from the BVD office in Lafayette Parish. The base station is linked directly to each remote DCP via a telephone line. This will enable the BVD user to view, archive, and provide to the OEP office real-time text and graphics. The USGS and NWS are capable of receiving information via satellite, which is expected to be the most reliable communications option during a flood. This data will be reviewed and faxed to the OEP parish office during flood conditions. Phone modems will be used to relay the real-time data to parish officials.

**Gauge Locations**

The DCP gauges along the Vermilion River and Isaac Verot Coulee have a dual purpose. They were initially installed to collect river data for the NOD's Lafayette Parish Flood Control study. The stage and rainfall data collected from these gauges are being used to create a computerized hydrologic model of the Vermilion River. Implementing such a system demanded that a sufficient number of stage and precipitation gauges be installed along the river. The network of gauges was also designed to incorporate timely, reliable, and accurate river forecasts for flood-prone areas along the Vermilion River. The selected locations were based upon professional judgement and familiarity of the study area, location of flood hazard areas, river geography, historic flooding events, and basin characteristics (accessibility, wind, safety, etc.).

Six sites are included in the gauging network for the Lafayette Parish area, including one site in Perry, south of Lafayette Parish. A digital collection platform with satellite telemetry and automatic precipitation and stage recorders will be located at each of the six sites. Four new river gauging sites were selected. Two existing gauges will be modified and incorporated into the proposed network.

**Weather and River Forecasting**

The primary reason for installing the gauging system is to inform and warn the general public of potential disaster. River forecasts are provided by the NWS. Based upon limited hydraulic and hydrologic data and the complexity of the river, river forecasts for the Vermilion River are based upon flood forecast tables that can be used to forecast the maximum river stage and time to crest. The River Forecast Center in Slidell and the NOD believe that a sophisticated computer model for the Vermilion River can be developed under the coordination of the two agencies. This effort will provide timely, reliable, and accurate forecast to residents and businesses affected by the river.
Benefits of Flood Threat Recognition System

The implementation of the flood threat recognition system is expected to provide warnings that yield sufficient time for the general public to respond appropriately to the flood at hand. Flood damage can be reduced as well as postflood health hazards if the following mitigation activities are completed: place sandbags around the structure and valuable equipment, move mobile vehicles and machinery to higher elevations, protect immobile machinery with waterproof covers or water-repellent grease, move contents to the highest location feasible, shut off electrical, gas, and water supplies, and secure objects that may become damaging debris in flood waters. When ample warning times are provided, residents are expected to complete these mitigation measures, as well as evacuate from hazardous flood areas with personal property.

Funding Opportunities

Follow-up meetings should be scheduled to review the recommended gauge locations. Sources of funding for these additional gauges and for the river forecasting model are suggested to be the LAOEP, BVD, and NWS. Funding may also be pursued through a USACE flood control study, Section 205, under the Continuing Authorities Program for the installation of the recommended gauges and the flood forecast model. A PAS study can be initiated to develop only the proposed forecast model of the Vermilion River.

FLOOD PREPAREDNESS PLANNING

The information provided by the flood threat recognition system is critical in determining the type and extent of implementing flood fight activities. Without the proper planning and training for future floods, execution and performance will suffer, and the best stage and precipitation information will be irrelevant. Lafayette Parish has determined its organizational structure and has established procedures and responsibilities to insure that all necessary response actions are efficiently completed during a flood. With the new recognition system, the procedures and responsibilities currently in place at the parish level will be minimally affected. The primary change is the introduction of the BVD base station receiving real-time data, from which the data is directly forwarded to the parish OEP office. It will be necessary for the BVD coordinator to appoint and train a staff member to capture and interpret real time hydrological data at the HydroMet base station. Once the data is retrieved and implications of flooding are realized, a decision will have to be made on whether to warn. At this point, the established procedures and responsibilities should
be put into action, with the exception of the staff needed to retrieve data. With the flood threat recognition system, it will not be necessary for an individual to manually read staff gauges or retrieve data at each river location, since the data will be sent to each parish office via modem, Internet, and/or fax. This capability will "free up" staff for other duties.

**FLOOD TRACKING CHART**

The six DCP locations and their respective flood stages are presented on a flood tracking chart of the Vermilion River Basin. It provides the public with the river stage data essential in preparing for a flood. Anyone can use the chart to track the river stage as it rises, and see the likelihood of a flood. A local newspaper printed the chart in the paper, along with a guide on how to respond to a particular flood threat, evacuation procedures, and flood insurance information. The Internet address where the stage data is located was also presented in the text.

**CONCLUSIONS**

A flood threat recognition system has been implemented to improve river forecasting along the Vermilion River in Lafayette Parish. The installed system consists of stage and precipitation recorders at six sites along the river. The system provides the parish OEP director with real-time information that can be disseminated to the general public. This will enable parish residents to make informed decisions to protect human life and personal property against flood damage.

It is recommended that the parish consider extending the warning system to include the entire parish of Lafayette (possibly to neighboring parishes) and producing a forecasting model of the Vermilion River. A model would generate more accurate and timely forecasts.

The cost of implementing the entire flood threat recognition system totaled $94,300. The dollar benefits are based upon the reduction of flood damage to personal property and residential, commercial, and industrial structures. Although dollar benefits were not computed for the anticipated reduction in damage to structures and contents, first costs plus annual operation and maintenance costs are expected to be considerably less than the anticipated dollar benefits, so a positive benefit-to-cost ratio is inevitable.
Part 3

WATERSHED MANAGEMENT
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ENVIRONMENTAL SYSTEMS APPROACH TO BASIN MANAGEMENT: FUTURE ALTERNATIVES IN THE AMITE RIVER BASIN

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INTRODUCTION

The Amite River basin drains part of southeastern Louisiana and southwestern Mississippi and empties into the Pontchartrain basin (Figure 1), a hydrologic link that has existed for the past 5000 years (Autin, 1993). This evolutionary relationship influences many of the functions that sustain modern environments in the Amite River and Pontchartrain basins. Human landscape changes in the twentieth century have been imprinted upon the setting created by this millennia-scale evolution.

The key public issue in the Amite River basin is the increase in the lower basin's flood hazard and continued suburban land development (Governor’s Interagency Task Force, 1990). Repeated large floods since 1977 and a record peak event in 1983 (Figure 2) resulted in hundreds of millions of dollars in property damage and a public outcry for flood protection. Control projects proposed to date include a reservoir to store flood water, a diversion channel to redirect flood flow to the Mississippi River, and channel enlargements to accept larger flows below bankfull stages. Non-structural alternatives and hazard mitigation strategies have received significantly less attention, in spite of the inability of engineering project proposals to pass the scrutiny of environmental impact and cost/benefit analysis. Also, the public has expressed a lack of willingness to pay the costs associated with expensive engineering projects.

PHYSICAL SETTING AND GEOMORPHIC EVOLUTION

The Amite River floodplain formed over geologic time as a series of meander belts (Autin, 1992, 1993). Floodplain characteristics arise from a natural response to the basin's hydrology and sediment supply, along with sea level rise and sedimentation patterns in the Mississippi River.
Environmental Systems Approach to Basin Management

Figure 1. Location of the Amite River basin.

delta plain. However, the channel also changes its geometry in response to large floods because of a differential resistance of floodplain sediments to erosion. Sedimentary deposits beneath the floodplain consist of a lower sand and gravel deposit and an upper silty deposit.

Before modern human settlement, the Amite basin consisted primarily of mixed deciduous and evergreen forests with small areas of native grassland. Human activity since then has produced one of the most disturbed drainage basins in the northern Gulf of Mexico region. Land use alterations include the conversion of natural forest habitats to managed pine forests and agricultural land, suburban growth in Baton Rouge, significant stream channelization, and intensive floodplain mining.
for sand and gravel resources. These changes have coincided with channel dredging, concrete lining, re-alignment, and diversion. Stream channelization and floodplain mining have probably aggravated downstream flooding, increased stream turbidity, and induced channel instability (Mossa, 1985; Governor’s Interagency Task Force, 1992; Mossa and McLean, 1997). The cumulative effect of human activities has likely induced a hydrologic and sedimentologic response that is only partly understood. The system’s physical response probably is triggering related ecological responses to terrestrial and aquatic habitats. Changes to the basin’s hydrology are not yet quantified.

**HYDROLOGIC EFFECTS OF LAND USE PRACTICES**

**Development Patterns and Practices**

The Baton Rouge metropolitan area provides an example of how the pattern of suburban growth impacts surface hydrology. Before 1960, most residential dwellings were built using pier and beam construction, allowing living areas to be elevated generally 2 feet or more above the land surface. The present building preference is to construct dwellings as slab on grade. Community growth over time has produced a mostly mixed settlement pattern of residential and commercial structures that increase the percentage of impervious cover across the landscape. Growth
into naturally flood-prone areas along with infill of previously developed areas has produced measurable changes in effective runoff (Greene and Cruise, 1995, 1996).

**Canalization and Dredging**

In the late 1950s and early 1960s, the Amite River and Tributaries Project of the U.S. Army Corps of Engineers began a period of significant drainage modification. Channel dredging along the lower Amite River and its principal tributary, the Comite River, enlarged both of these channels. A diversion channel was also created along the lowermost course of the Amite River to more effectively send stormwater into the nearby swamps and into Lake Maurepas. In Baton Rouge, a locally sponsored program straightened, enlarged, and concrete lined several smaller Amite River tributaries. Both of these programs were designed to more effectively drain the rapidly developing areas.

**Gravel Mining and Channel Changes**

Sand and gravel is mined in the Amite River by hydraulic dredging from floodplains and stream terraces flanking major valleys. The process locally denudes the floodplain landscape and leaves behind a mosaic of lakes, ponds, and barren areas of sandy mine tailings (Vernon et al., 1992; Mossa, 1995; Mossa and McLean, 1997; Mossa and Autin, in press). Hydraulic mining of floodplains is considered a factor associated with channel instability and changes in channel bed elevation. Mossa (1995) suggests that reduced channel capacity could be aggravating the local flood problems in the Amite River downstream of mined areas. Channel straightening and widening, along with a steepening of channel slope tends to increase the hydraulic gradient, resulting in a more energetic channel during floods. The selective removal of gravel relative to sand and finer materials also can contribute to a total increase in sediment transport during moderate to large scale floods. The lack of an effective floodplain reclamation program has hindered efforts to restore floodplain habitat (Mossa, 1995; Vernon et al., 1992).

**STATUS OF FLOOD CONTROL EFFORTS**

There has been a relatively long-standing effort to resolve flood problems in the Amite River basin with flood control projects designed to permanently alter the basin’s surface water hydrology. These projects have been fraught with technical, economic, and political difficulties. The central project in this effort has been the proposed Darlington Reservoir, a multi-use flood control/recreational reservoir on the upper Amite River.
The U.S. Army Corps of Engineers determined this project to be economically infeasible in 1990. The Comite River Diversion is a proposed canal designed to send the peak flow of the Amite’s principal tributary, the Comite River, directly into the nearby Mississippi River north of Baton Rouge. This project is presently authorized by the federal government, but engineering concerns about potential problems with canal stability are still not fully resolved. Also, a financially capable state or local sponsor has not been established. The East Baton Rouge Tributaries Project is a proposed enlargement and alignment of tributary channels west of the Amite. This project also has federal authorization, but voters recently turned down a bond issue that would have provided its local cost share. The Livingston Parish and Ascension Parish Tributaries Projects are proposed to enlarge and align tributary channels east of the Amite River. Technical feasibility studies of these projects are still underway. Collectively, these proposed structural projects, if implemented, could require in excess of $1 billion in public monies.

**Basin Management and Flood Control Options**

Solutions to flood problems in the Amite River basin are likely to require a combination of 1) significant changes in present floodplain management practices, 2) government regulation designed to minimize the future risk from natural disaster, and 3) implementation of selected river engineering alternatives. Current technical information needed for management decisions is inadequately developed and incompletely integrated, thus preventing the formulation of workable alternate solutions. This inadequacy inhibits the objective assessment of natural resource planning and mitigation alternatives, definition of floodplain management alternatives, and evaluation of the possible impacts of structural alternatives in the Amite River basin. Both the public and the government have been divided into factions by a host of varying opinions, a suite of plans and proposed solutions that are mutually exclusive and incompatible with the ideas of opposing interests, and a lack of clear direction for planning the reduction of flood damages.

A basin management plan would provide direction and increase public confidence and governmental consensus in the definition and resolution of flood issues in the basin. Relevant scientific and technical data should be integrated with socio-economic data in an objective decision-making process. Solutions to the problems of Amite River flooding need to incorporate wise planning and engineering designs that 1) provide a reasonable reduction in flood risk, 2) enhance channel stability through environmental rehabilitation, 3) produce the maximum societal benefit, and 4) maximize cost-effective use of public monies.
Suggested Course of Action

Environmental rehabilitation of the Amite River basin may have benefits beyond the restoration of the surface hydrologic and sedimentologic balances necessary for self-sustaining terrestrial and aquatic ecosystems. Rehabilitation could show significant benefits for 1) watershed management, 2) floodplain reclamation, and 3) channel restoration. Watershed management goals should encourage developments that produce no significant aggravation to existing surface hydrology when land use is altered. For example, watershed retention and detention in both urban and rural tributaries could significantly trim the peakedness of the trunk stream's flood hydrograph and increase the quantity and diversity of permanent aquatic habitat in the basin. Mine reclamation of floodplain lands and reconstruction of meandering channel patterns to a pre-disturbance state could help to balance flood hydrology and sediment transport and increase the quantity and quality of floodplain habitat. Collectively these restoration efforts would tend to reduce the peakedness of the flood hydrograph, lowering flood stages for a given event.

If environmental rehabilitation is blended with appropriately designed structural improvements that are maintained properly, flooding could possibly be eliminated on the fringes of the natural floodplain in the middle and lower Amite River basin. Areas developed on lower landscapes will still experience flooding, and buildings in these flood prone areas should be adequately floodproofed, elevated, or relocated. Both structural and non-structural modifications should be designed to maximize geomorphic stability in the drainage system.

The potential benefits of environmental rehabilitation in the Amite River, when blended with logical floodplain management and hazard mitigation, could produce significant reductions in flood hazard, improvement in downstream water quality, and increases in ecological resources. Such an approach is likely to be cost-effective, resolve significant public environmental management conflicts, and help return the Amite River basin to a self-sustaining watershed with a significantly reduced hazard from flooding.

References

Autin, W. J.


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BACKGROUND
DuPage County encompasses 336 square miles directly west of Chicago. There are 40 municipalities in the county with a total population exceeding 843,000. The county has gone through rapid urbanization over the last 45 years: in 1955, 58.5% of the county was in agricultural production compared to 5.3% in 1995. This conversion of agricultural land translates to a change in the county population from 154,599 in 1950 to 781,666 in 1990, more than a 500% increase. Much of the urbanization occurred with disregard to stormwater and floodplain impacts. Even after the Federal Emergency Management Agency (FEMA) floodplain maps were developed for the county in the late 1970s and early 1980s, urbanization effects altered the accuracy of these maps. From 1980 to 1994, the county population grew by more than 180,000. Over the same period, the county valuation grew from $5.5 billion to $17.4 billion. This increase shows the level of development in the county was not solely due to residential construction, but also large industrial and commercial development. While many of these developments stayed out of the floodplains, they did have a profound impact on the hydrology and hydraulics of the streams in the County. The level of development, number of communities, degree of stormwater and floodplain issues, and inadequacies of the FEMA maps all contributed to the need for a regional approach to stormwater and floodplain management.

PROGRAM DEVELOPMENT OVERVIEW
In 1986, DuPage County organized a joint committee of county and municipal representatives to address stormwater issues. During the same year, the State of Illinois passed legislation P.A. 85-905, which authorized northeastern Illinois counties to develop regional stormwater management programs. In August 1987, severe flooding caused $150 million in damage in DuPage County. The following year, the current County-Municipal Stormwater Management Committee was formed under the authorization guidelines of the state legislation to oversee the DuPage County, Department of Environmental Concerns, Stormwater
Management Division. DuPage County is a leader in the creation of such programs in northeastern Illinois. In September 1989, the Stormwater Management Committee and the DuPage County Board adopted the DuPage County Stormwater Management Plan. The DuPage County Countywide Stormwater and Flood Plain Ordinance was adopted in 1991 to promote effective, equitable, acceptable, and legal stormwater management measures. The plan and the ordinance set the foundation upon which the DuPage County Stormwater Management Division works.

The Stormwater Management Division (SMD) has 28 full-time employees. Its responsibilities are countywide and include: 1) implementation of the Stormwater Management Plan goals and objectives, 2) ordinance implementation and enforcement, 3) watershed plan development, 4) regional project design and construction, 5) floodplain mapping, 6) stream maintenance, 7) wetland plan/wetland banking program, and 8) annual budget and 10-year financial plan.

**Stormwater Management Plan**

The Stormwater Management Plan has six objectives and 16 policies. Key program elements include:

- **Clear Stormwater Management Plan Priorities**—Set priorities taking into account severity and frequency of damages, cost-benefit, financial planning. Comprehensive program includes regulatory, watershed planning, regional capital improvement design and construction, stream maintenance, streambank stabilization, voluntary buyout program, and floodplain mapping.

- **Joint Municipal-County Board Stormwater Management Committee**—Equal representation of County Board and municipal government representatives on the committee.

- **Joint Municipal-County Staff Technical Committee**—Technical recommendations are developed and reviewed by a committee of municipal engineers and SMD staff.

- **Consistent Minimum Stormwater Regulations Countywide**—Including general stormwater, floodplain, wetland and riparian, and one-stop permitting.

- **Accurate Information**—Geographic information system.

- **Financial Plan**—Funded primarily through stormwater tax levy.

- **Coordination**—Close coordination with federal, state, county, and municipal agencies.
Ordinance & Enforcement

The SMD is responsible for countywide permitting of developments impacting stormwater runoff. The DuPage County Countywide Stormwater and Flood Plain Ordinance, which has been revised twice, sets forth uniform technical requirements for all development. It addresses nearly every aspect of stormwater and floodplain management including stormwater runoff and detention, sediment and erosion control, floodplain impacts, riparian and wetland impacts. The ordinance also sets forth requirements regarding administrative procedures, performance security, enforcement and penalties, appeals, and variance procedures. Some unique aspects of the county's ordinance include: 1) sufficient detention storage to allow a post-development 100-year release rate of 0.1 cfs/acre of development, 2) compensatory storage equal to at least 1.5 times the volume of floodplain or depressional storage displaced and at the same incremental flood frequency elevation as the flood storage displaced, 3) wetland mitigation ratios of 1.5:1 for regulatory wetlands and 3:1 for critical wetlands, 4) mitigation or avoidance of all wetlands regardless of size, 5) zero increases of floodplain elevations for all developments, and 6) mitigation for any riparian function impacted by development. With uniform countywide minimum regulations in place, the county is establishing one-stop permitting. The SMD has negotiated delegation authority with both Illinois Department of Natural Resources, Office of Water Resources (IDNR) and the U.S. Army Corps of Engineers. In 1995, the Corps issued a general permit to the DuPage County SMD delegating the authority to review and permit wetland impacts. DuPage County is the only county in the United States with this authority.

Watershed Plan Development

DuPage County has six watershed planning areas: Salt Creek, East Branch of the DuPage River, West Branch of the DuPage River, Sawmill Creek, Des Plaines River Tributaries, Fox River Tributaries. These plans will help identify structural and nonstructural projects to alleviate current and anticipated flooding problems; index significant natural areas, storage areas, and wetlands; and update and revise floodplain maps.

DuPage County is unique in its development of the hydrologic and hydraulic models used in its watershed planning and floodplain mapping. The county utilizes continuous simulation and dynamic routing models for several reasons. First, the continuous simulation hydrologic model captures the effects of antecedent moisture on runoff volumes and peaks, and accounts for a non-uniform precipitation distribution over the
watershed. Second, the effects of backwater, floodplain storage, and complex urban stream systems have a significant impact on the hydraulics of DuPage County streams. Thus, an unsteady flow model has been adopted for use in DuPage County watershed studies. This approach produces continuous flow and stage information based on precipitation that has occurred in the past. From this continuous data, flow and stage duration information is readily available for not only large events, but also for dry conditions and small runoff events. The continuous simulation approach provides the county with the necessary information to properly implement stormwater programs such as floodplain mapping, flood forecasting, water quality protection and enhancements, wetland creation, and project analysis.

Currently, nearly 80% of the county's watershed areas have watershed models developed. These models will project stream flows and flood heights under various land use and storm conditions. Watershed plans are developed using the watershed model to analyze flood control alternatives. Depending on the complexities of the watershed, it takes approximately one year to complete a watershed plan.

Regional Project Design and Construction

Regional stormwater management projects are considered for county implementation and funding if a problem area meets the regional criteria, generally if multiple jurisdictions are affected or the drainage area is over one square mile. Watershed models are used to analyze possible alternatives, which are presented to the Stormwater Management Committee and County Board. The Stormwater Management Committee looks for solutions that will address all reported or projected flood damages. Alternatives include capital improvements, voluntary buyouts, and floodproofing. Generally, the alternative that is the easiest to implement and most cost effective is chosen by the committee and board. The committee and board have identified more than $148.0 million in stormwater capital improvement projects. About $91.3 million has been expended through 1996 on these projects.

Since 1991, the county has removed 23 homes through a voluntary buyout program (not including buyouts by FEMA). The county has also identified over 100 homes that meet the criteria for voluntary buyout. The county is currently working with FEMA to secure funding to purchase 47 homes in the Valley View subdivision along the East Branch of the DuPage River. Several of the county's flood control projects identified in the watershed plans have been constructed or are currently under construction (Table 1).
Table 1. Flood control storage for various projects.

<table>
<thead>
<tr>
<th>Project</th>
<th>Proposed Storage (acre-feet)</th>
<th>Completed Storage (acre-feet)</th>
<th>Completion Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elmhurst Quarry Reservoir</td>
<td>8,300</td>
<td>8,300</td>
<td>1996</td>
</tr>
<tr>
<td>Wood Dale-Itasca Reservoir</td>
<td>1,775</td>
<td>400</td>
<td>2002</td>
</tr>
<tr>
<td>Meacham Grove Reservoir</td>
<td>600</td>
<td>600</td>
<td>1997</td>
</tr>
<tr>
<td>Louis Reservoir</td>
<td>210</td>
<td>210</td>
<td>1994</td>
</tr>
<tr>
<td>Klein Creek</td>
<td>190</td>
<td>15</td>
<td>1997</td>
</tr>
<tr>
<td>Tributary No. 4</td>
<td>70</td>
<td>70</td>
<td>1995</td>
</tr>
<tr>
<td>Winfield Creek</td>
<td>110</td>
<td>110</td>
<td>1997</td>
</tr>
<tr>
<td><strong>TOTALS</strong></td>
<td><strong>11,255</strong></td>
<td><strong>9,705</strong></td>
<td></td>
</tr>
</tbody>
</table>

Floodplain Mapping

With the rapid urbanization of DuPage County since the 1970s and 1980s, the FEMA flood maps have become outdated. The SMD will create new maps using the continuous simulation and dynamic routing models developed for the watershed plans. They will reflect changes in land use, topography, and modeling technology. Ginger Creek was the first watershed to be re-mapped using the DuPage approach, and has been approved by IDNR. This was a pilot project to gain IDNR and FEMA approval of the county’s procedures. The remaining streams will be re-mapped over 5 years when the procedures are approved.

Stream Maintenance

The Stormwater Management Committee and County Board implemented the Stream Maintenance Program in 1991. To date, more than 85 of the 360 stream miles have been cleaned. Under this program, the SMD removes debris and nuisance vegetation from stream corridors to restore natural flood conveyance. The Stormwater Committee began an Adopt-A-Stream Program in 1994 to gain citizen involvement. A streambank stabilization program began in 1994 under which the SMD provides project design and permitting assistance to individuals or groups who want to stabilize eroding creek banks with bioengineering techniques. Bank stabilization is important because sediments resulting from erosion clog culverts and reduce conveyance of flood flows.
Wetland Plan/Wetland Banking Program

DuPage County has a progressive wetland protection plan to ensure no net loss of wetland functions. The plan is unique in several aspects. First, the plan protects all wetlands, not just Corps jurisdictional wetlands. Second, efforts are focused not just on the environmental aspects (plant, habitat, endangered species) of wetlands, but also on the stormwater management (stormwater storage, water quality) aspects.

The wetland banking program began in 1993 with the establishment of the criteria by the Stormwater Committee and the County Board under which a wetland bank would be certified. Under this program a fee is charged to developers based on detailed cost estimates for the land cost, design, construction, restoration, management, monitoring, and long-term maintenance (20 years) of the bank. Mitigation takes place in the same watershed as the impact occurs. Banks can be run either publicly or privately. All collected funds must be expended within 10 years of collection. To date there are two active wetland banks. The Cricket Creek Wetland Bank in the Salt Creek watershed was certified in 1993 and will create 30 acres of wetland. Phase I (20 acres) was constructed in 1996 and is in the planting stage. The Winfield Creek Wetland Bank in the West Branch DuPage River watershed was certified in 1993 and will create 50 acres of wetland. Final design is underway for Phase I (10 acres). There are two public and two private banks scheduled to be certified in mid 1997; they will create 40 acres of wetlands.

Annual Budget and 10-Year Financial Plan

The Stormwater Management Program is funded primarily by a $10.0 million annual stormwater property tax levy. The rate is $0.055/$100 assessed valuation. Other sources of funding include permit fees, miscellaneous fees, and construction funds received from other entities (i.e., State of Illinois, federal government, municipalities, developers, etc.). In 1991, a $69.0 million, 30-year bond issue was sold to fund countywide regional flood control projects. Nearly $10.0 million of state funding has been received to construct the Salt Creek watershed flood control projects. The SMD is responsible for preparing and maintaining the annual budget and implementing a 10-year plan. The budget and plan are submitted each year for approval by the Stormwater Management Committee and the County Board. Unencumbered funds are carried over year to year to help fund more expensive projects.
THE LOWER SALT CREEK WATERSHED PLAN

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INTRODUCTION

The Salt Creek watershed has experienced rapid urbanization since the 1950s. This has increased runoff and flooding problems from severe storms that regularly develop over the watershed. Many storms have produced enough rainfall to cause damage to businesses, residences, landscaping, streets, treatment plants, and other facilities within the watershed. The most severe storms on record occurred in October 1954, July 1957, August 1972, and August 1987. The largest on record was the August 1987 event, with more than 13 inches of rain falling on parts of the watershed over a period of 4 days. O'Hare International Airport recorded 9.4 inches in 24 hours. Communities within the Salt Creek basin reported flood damage to properties valued at over $200 million during the 1987 flood (Black and Veatch, 1991). The widespread nature of the flooding heightened public concern about stormwater problems and led the Illinois Legislature to pass Public Act 85-905. This Act allowed five counties surrounding Cook County to develop stormwater management programs that would address stormwater issues on a regional basis. This enabled the counties to adopt stormwater management plans and develop countywide ordinances, regional flood control projects, and the means to fund such projects. DuPage County is a leader in the creation of such a stormwater management program.

The current Stormwater Management Program is under the direction of the Stormwater Management Committee and the DuPage County Board. The directives of the committee are executed by the staff of the Department of Environmental Concerns, Stormwater Management Division. Staff is currently developing watershed plans for each of the major river basins within the county. Each plan will identify regulatory requirements, maintenance requirements, and capital improvement
projects that are necessary to reduce and control the potential for catastrophic flooding within DuPage County.

**Watershed Description**

The Salt Creek watershed is located approximately 15 miles west of Chicago. It flows in a southeasterly direction, from Lake County, through Cook County and into DuPage County near Elk Grove Village. Salt Creek reenters Cook County near Hinsdale and flows to the south, where it joins the Des Plaines River at Riverside. The watershed consists of 117 square miles of tributary area at the point where it leaves DuPage County.

The watershed is divided into two main areas: the upper Salt Creek watershed and the lower Salt Creek watershed. The upper Salt Creek watershed consists of the area beginning at the headwaters in Lake County to the Busse Woods Reservoir in the Ned Brown Forest Preserve, Elk Grove Village. The lower Salt Creek watershed begins at the outflow of the Busse Woods Reservoir and continues until Salt Creek joins the Des Plaines River. The lower Salt Creek watershed was the main focus of this watershed plan.

The lower Salt Creek watershed consists of approximately 17.8 miles of mainstem channel with the following major tributaries: Elk Grove Tributary, Devon Avenue Tributary, Spring Brook Creek, Westwood Creek, Sugar Creek, Oak Brook Tributary, Ginger Creek, and the Bronswood Cemetery Tributary. The mainstem channel is relatively flat with an average gradient of two feet per mile.

The Salt Creek watershed is extremely urbanized, which has resulted in the loss of many of its natural storage areas. Increased impervious areas, the encroachment into the floodplain, and the loss of natural storage that has accompanied this urbanization greatly contributes to the widespread flooding throughout the watershed. The Lower Salt Creek Watershed Plan, which addresses these issues, was developed utilizing a hydrologic, hydraulic, and economic analysis. These will be discussed briefly below.

**Hydrologic Analysis**

The LANDS module of the Hydrocomp Simulation Program (HSP) developed by Hydrocomp International, Inc. is used to create the hydrologic inputs needed for the hydraulic analysis. The LANDS model incorporates infiltration, interflow, depressional storage, snowmelt, overland flow, evapotranspiration, and changes in soil moisture in determining the runoff from a land cover category. The model is able to
account for the effects of both a non-uniform rainfall distribution and non-uniform or changing land use throughout the basin.

Output from the LANDS module is a continuous time series file of runoff for each land cover type and rain gage. A wide range of historical rainfall events were selected from this continuous time series to create a 'TSF' for use in watershed planning and alternatives analysis. The term 'TSF' refers to the time series files of runoff for selected rainfall events in a specific format.

**HYDRAULIC ANALYSIS**

The dynamic flood routing model known as Full Equations (FEQ) developed by Delbert Franz of Linsley, Kraeger Associates, Ltd., is the hydraulic model used for project analysis and watershed planning for DuPage County watersheds. FEQ can read the TSF created from the LANDS output and can adequately represent the effects of floodplain encroachment, on-line and off-line storage, diversions, channel improvements, bridges, culverts, dams, weirs, and other flow impediments. Complex hydraulic structures and complicated flow paths can also be represented readily in FEQ.

FEQ models were developed assuming a 1985 land use condition and included those hydraulic structures which were in place in August 1987 in the Salt Creek watershed. This model was calibrated to historical stream gage records and high water marks collected during the flood of August 1987. Using the calibrated model as a base, land cover input was updated to reflect ultimate future development. Any permitted flood control projects were added to the future condition model to yield the 'base condition' model. Proposed projects were incorporated into the base condition model to yield the models used for alternatives analysis. Alternatives were evaluated by comparing the resulting damage from the base condition to those remaining after a given alternative was simulated.

**ECONOMIC ANALYSIS**

The DEC-1 economic model was used to compute flood damage resulting from overbank flooding associated with a given rainfall event. Only certain types of damage are easily quantifiable and can be determined with the damage model. These include damage to structures and their contents, traffic damage, emergency services, and other associated damage (e.g., yard flooding). Other damage not accounted for in the economic analysis includes that resulting from backup of sanitary sewers into homes and failure of local drainage systems. These types of damage are extremely difficult to quantify accurately, but they should not be
neglected when making decisions. The economic analysis results presented here provide estimates for relative differences in quantifiable damage only.

**IDENTIFICATION OF WATERSHED PROBLEMS**

The base condition hydraulic model for Salt Creek has been used to identify the areas subject to overbank flooding. Future condition land use is assumed for base conditions and all alternatives. Flooding in the Salt Creek basin can be characterized as virtually continuous overbank flooding along the mainstem, with some extensive damage areas set back from the channel. Total base condition damage for the historical events on the Salt Creek mainstem are presented in Table 1 (Department of Environmental Concerns, 1991).

**Table 1. Total damage for historical events, 1949-1987 base condition.**

<table>
<thead>
<tr>
<th>Damage Category</th>
<th>Dollars, $</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residential</td>
<td>4,792,500</td>
</tr>
<tr>
<td>Business</td>
<td>23,480,400</td>
</tr>
<tr>
<td>Traffic</td>
<td>6,995,400</td>
</tr>
<tr>
<td>Associated</td>
<td>1,997,300</td>
</tr>
<tr>
<td>Emergency Services</td>
<td>479,300</td>
</tr>
<tr>
<td>Total Damage</td>
<td>37,744,900</td>
</tr>
<tr>
<td>Average Annual Damage</td>
<td>967,800</td>
</tr>
</tbody>
</table>

**ALTERNATIVES INVESTIGATED**

The recommended Capital Improvements Plan is based on the evaluation of various combinations of structural and non-structural improvements. The projects considered included large regional reservoirs, smaller localized storage projects, channel modifications, and nonstructural measures such as buyouts. Seven different alternatives made up of various combinations of projects were analyzed and evaluated. Each
alternative was evaluated against the criteria set forth by the DuPage County Stormwater Management Plan, the Stormwater Management Committee, and the DuPage County Board. Each alternative was evaluated against the following criteria: hydraulics, reliability, flexibility, constructibility, environmental impacts, permitting, capital costs, operation and maintenance, and benefits.

**RECOMMENDED PLAN**

The directive given to staff by the Stormwater Management Committee was to eliminate 90% of the stormwater damage from a storm of the magnitude of the 1987 event. Of the seven alternatives analyzed in detail, Alternative 7 achieved this directive and met all other criteria established for alternatives evaluation. Alternative 7 consisted of the Meacham Grove Reservoir, Lake-Villa Reservoir, Wood Dale-Itasca Reservoir, Elmhurst Quarry Reservoir, and the Addison Dam and Pump Station along with the purchase of 62 of the most heavily damaged homes. The projects making up Alternative 7 are briefly summarized below.

The Meacham Grove Dam and Reservoir Project is located in Bloomingdale, within the Meacham Grove Forest Preserve. The project consists of placing a dam with a box culvert across Spring Brook, which is a major tributary to Salt Creek. Base flows will continue downstream via the box culvert, while flood flows will be retarded by the dam. Flood waters will eventually flow over a labyrinth weir and spillway into the reservoir where they are temporarily detained before being released back to Spring Brook by gravity. This dam and reservoir project will provide an additional 575 acre-feet of flood storage for Spring Brook.

The Wood Dale-Itasca Reservoir is located at the confluence of Spring Brook and Salt Creek in Wood Dale. This project consists of a series of three gravity drained cells and one large pump evacuated cell. The gravity drained portion of the reservoir will provide 325 acre-feet of storage while the pump evacuated portion will provide 1450 acre-feet.

The Addison Dam and Pump Station and the Lake-Villa Reservoir were constructed as a joint project. The Addison Dam and Pump Station consists of a dam across Westwood Creek just upstream of its confluence with Salt Creek. The dam will prevent Salt Creek backwater from inundating the residential neighborhood immediately upstream. The pump station is needed to lift the flow of Westwood Creek over the dam into Salt Creek. Since previously available flood storage was eliminated by the dam, the 210 acre-foot Lake-Villa Reservoir was constructed as floodplain compensation.
The cornerstone of the Lower Salt Creek Watershed Plan is the Elmhurst Quarry Flood Control Project. This project converted the Elmhurst Chicago Stone Company's Elmhurst Limestone Quarry into a flood control reservoir. It was designed to reduce flood flows and stages on Salt Creek through gravity diversion of flood waters into the quarry. Approximately 8,300 acre-feet of flood storage is available in the combined east and west lobes of the quarry. Water that is stored in the quarry is pumped back into Salt Creek when stream levels have receded.

In spite of all of the capital improvement projects being constructed there will still be homes in low-lying floodplain areas that continue to get flooded. The number of residential units eligible for buyout under this alternative is estimated at 62. A residential structure is considered eligible for buyout if, during the hydraulic analysis, it floods by 1.0 foot or more in any storm in the period of record, or if it floods by 0.5 ft in two or more events.

In addition to those projects identified in Alternative 7, two additional projects by other agencies can provide flood control benefits along Salt Creek in DuPage County. The construction of the Busse Woods Dam modification and the rebuilding and raising of the Lake Street-Villa Avenue intersection bridge are projects which are not under the control of the Stormwater Management Committee; however, these projects are supported by the committee.

The recommended plan results in an 81% reduction of the total quantifiable damage for the period of record. This includes an 80% reduction of business damage from $23,480,400 under base conditions to $4,803,000 with the projects in place. When looking at the effects of the 1987 storm event on the recommended plan, total quantifiable damage is reduced from $17,486,600 under base conditions to $1,533,600, which is a reduction of 91% (Department of Environmental Concerns, 1991).

**Status of Watershed Plan**

Since the approval of the Lower Salt Creek Watershed Plan in October of 1991, construction of the Addison Dam and Pump Station and the Lake Villa Reservoir was completed in 1994. Construction of the Meacham Grove Dam and Reservoir as well as the Elmhurst Quarry Flood Control Project was completed in 1996. Approximately 760 acre-feet of the proposed 1775 acre-feet of total flood storage at the Wood Dale-Itasca Reservoir has been provided. Fifteen flood-prone homes throughout the Salt Creek watershed have been purchased through the FEMA buyout program. In addition, the reconstruction of the Lake Street Bridge at Salt Creek was completed by IDOT-Highways in 1996.
Of the eight major tributaries to lower Salt Creek, a revised floodplain map for Ginger Creek has been approved by FEMA; watershed plans are underway on Spring Brook Creek, Sugar Creek, and Bronwood Cemetery tributaries; and a watershed plan has been approved for Westwood Creek. Plans for the remaining four tributaries will be developed in the next few years. Floodplain mapping on all tributaries to Salt Creek as well as the construction of all major flood control projects will be completed before remapping on Salt Creek begins.

REFERENCES

Black and Veatch, Woodward-Clyde Consultants, Donohue Engineers

Department of Environmental Concerns, Stormwater Management Division
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Part 4

COASTAL ISSUES
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FLOODPLAIN MANAGEMENT IN THE COASTAL ZONE

John P. Ivey and John S. Grounds
Halff Associates, Inc.

Diane Calhoun
Federal Emergency Management Agency

Communities in the coastal zone are faced with a multitude of floodplain management issues including:

- Velocity zones
- Coastal Barrier Resources Act (CBRA) zones
- Coastal erosion
- Dune protection and coastal set back requirements
- Special coastal construction requirements
- State and federal agency coastal and environmental permits and regulations, and
- Riverine floodplain and floodway requirements.

We can further complicate floodplain management when we add subsidence in the coastal zone. In this paper we address the coastal subsidence issue and offer recommendations for coastal communities that must deal with subsidence in addition to coastal flooding and/or combined riverine and coastal flooding. Coastal communities subject to subsidence are unique in that the National Flood Insurance Program (NFIP) regulations do not properly address their floodplain management requirements. The NFIP regulations (44 CFR Section 60.22.c.11), “Planning considerations for floodprone areas should [include] the requirement that all new construction and substantial improvement in areas subject to subsidence be elevated above the base flood level equal to expected subsidence for at least a ten year period.” This section of the NFIP regulations does not differentiate between riverine, coastal, and combined riverine and coastal flooding. Subsidence is addressed in the Flood Insurance Study Reports for communities in Harris and Galveston counties, Texas (FEMA, 1996). The effect of land subsidence is minimal in riverine flooding (inland flooding not associated with coastal flooding) and described by FEMA as flood depths remaining relatively constant and base flood elevations generally subside as the ground subsides.
This is not the case for areas subject to coastal flooding and/or combined riverine and coastal flooding. In these areas, storm surge elevations generally are not affected as the ground subsides. However, as a result of subsidence, increases in flood depths and flooding of additional inland areas will likely occur (Figure 1).

The coastal areas in Harris and Galveston counties have subsided as much as 9 feet since 1906 (U.S. Geological Survey, 1990) (Figure 2). Subsidence related problems prompted creation of the Harris-Galveston Coastal Subsidence District (HGCSD) to regulate groundwater withdrawal and to mandate conversion to surface water. The efforts of HGCSD have paid off and subsidence in the coastal areas has decreased substantially. Subsidence measurements recorded with bore hole extensometers (HGCSD, 1972-1996) show coastal area subsidence along Galveston Bay to be approximately zero since 1988. The floodplain management problem can, therefore, be summarized as a datum problem. The Harris and Galveston County Flood Insurance Studies and FEMA elevation Reference Marks (RMs) were based on 1973 National Geodetic Vertical Datum (NGVD), which are now 23 years old based on the latest flood insurance study dated 1996.

The USGS and HGCSD recognized the need for local stable RMs. Releveling in the subsidence area requires an extensive and costly survey effort that must originate at a stable first-order survey monument outside the subsidence area. In 1973, the USGS and HGCSD began installing a network of borehole extensometers throughout Harris and Galveston counties. The network of 13 extensometers are the only stable RMs in the subsidence area.

The Seabrook (Texas) Extensometer (HGCSD, 1996), for example, recorded 1.5 feet of subsidence between 1973 and 1995. The City of Seabrook is among 21 municipalities in the Galveston Bay subsidence area that are subject to coastal and/or combined riverine and coastal flooding and all of the communities share the problem of RMs 23 years out of date.

Floodplain mapping has not kept pace with the subsidence rate and communities along Galveston Bay continue to issue building permits based upon RMs that have subsided 1.5 feet or more. Within the combined probability area or tidal influenced zone, a community can issue a building permit based on the current Flood Insurance Study and Flood Insurance Rate Map (FIRM) and a local surveyor can prepare an elevation certificate based on the FEMA RM. The community is happy, the banker or lender is happy, FEMA has not complained, and everything appears to be in order except the finished floor elevation of the new structure will be 1 to 2 feet below the actual
Figure 1. Land subsidence schematic: A—hurricane/tidal surge flooding; B—Riverine flooding (FEMA, 1996).
base flood elevation (BFE). This routinely occurs even with the FEMA regulations that “suggest” that the community subject to subsidence adopt the criteria that takes into account a projection of current subsidence for a 10-year period.

Surprisingly, the solution is fairly simple and included in the text of the November 1996 Harris County Flood Insurance Study under Section 3.4 “Effects of Land Subsidence.” It states that “In areas experiencing ground subsidence, the most recent adjusted reference mark elevations must be used for reference level elevation determinations.” To mandate the requirements described in the November 1996 Flood Insurance Study, coastal communities subject to subsidence must be required to utilize current or releveled reference marks. The HGCSD in cooperation with the USGS and the Texas Society of Public Surveyors can easily identify adjusted RMs within the coastal and combined probability zones and
publish an annual or biannual listing. Communities participating in the NFIP should be required to utilize only these adjusted RMs for floodplain management purposes. For the solution to work, FEMA must require that the coastal communities comply.

Before publication of the initial flood insurance studies, the City of Taylor Lake Village in Harris County required that all new construction be elevated to 16 feet. But when the initial FIRM showed a BFE of only 11 feet, the city was pressured to lower its requirements. The city compromised and established 14 feet as the minimum elevation or 2.6 feet above the BFE of Taylor Bayou, which is the source of flooding. In 1995, the city learned that the rate of subsidence has been as high as 1 inch per year since the initial FIRM (based on 1973 datum) was published. In 1996, the city conducted a level loop survey from a stable benchmark and learned that the RMs within the city had subsided as much as 1.6 feet lower than the elevation published in the latest Flood Insurance Study. Even though the subsidence rate is near zero, the city recently raised the minimum finished floor elevation requirement back to 16 feet. The City of Taylor Lake Village should be commended but what about other coastal communities that either do not know and quite possibly do not understand the dangers of using 20+ year old RMs? In most communities, floodplain management is 99% mandatory minimum requirements and 1% long range planning. Now is the time to rethink mandatory minimum requirements.

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HGCSD
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MITIGATION ON ERODING COASTS: SHOULD FEMA NOURISH BEACHES?

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INTRODUCTION

The Federal Emergency Management Agency's National Mitigation Strategy proposed by 2010 "1) to substantially increase public awareness of natural hazard risk . . . and 2) to significantly reduce the risk of loss of life, injuries, economic costs, and destruction . . . from natural hazards" (FEMA 1995:15). Even as FEMA seeks to achieve these goals on the coast and elsewhere, it confronts an inexorable opponent: itself. FEMA is charged by Congress under the Stafford Act to provide public assistance (PA) for restoration of infrastructure after a Presidential disaster declaration. According to the U.S. General Accounting Office (1996, table 1.1), PA expenditures grew by 550% between two 5-year periods—1983 to 1988 and 1989 to 1994—from $1.051 billion to $6.437 billion (in constant 1995 dollars). As observed by the House Bipartisan Task Force on Disasters (U.S. Congress, 1994, as quoted in the National Mitigation Strategy), federal generosity in disaster assistance may actually undermine nonfederal investment in preparedness and mitigation:

... if state and local governments believe that the Federal Government will meet their needs in every disaster, they have less incentive to spend scarce state and local resources on disaster preparedness, mitigation, response, and recovery. This not only raises the cost of disasters to the federal taxpayers, but also to society as a whole, as people are encouraged to take risks they think they will not have to pay for.

It is essential therefore that public assistance, and hazard mitigation grants for that matter, not foster a false sense of security that leads to greater rather than less exposure to disaster loss.

MITIGATION ON THE COAST

Nowhere are FEMA's mitigation goals more difficult to achieve than along the nation's shorelines. The coasts of the United States are
vulnerable to many types of natural hazards: flooding, erosion, landslides, wind, and tsunami. They are also the locus of extremely costly homes owned by politically well-connected individuals. About three-quarters of NFIP coverage is in coastal communities. The Insurance Institute for Property Loss Reduction projects private insurance claims of $20 billion to $52 billion when a category 4 or 5 hurricane strikes a major coastal urban region (IIPLR, 1995).

Net erosion dominates most non-bedrock shorelines, although the pulses of loss and gain vary from reach to reach and over time, and are influenced by structural intervention (Bush et al., 1996). Damage to structures on erodible shores is thus highly probable. Hard shoreline stabilization is widely disfavored due to cost, aesthetics, and the loss of beaches that it causes. Beach nourishment is increasingly the choice of states and local governments to maintain a recreational beach and protect landward structures. But "beach nourishment is an uncertain science applied in an uncertain environment, by neighbors who aren’t sure they ever want to deal with each other," (Campbell, 1996).

BEACH NOURISHMENT: FEMA's TOE IN THE WATER

Despite the many uncertainties of beach nourishment (enumerated below), FEMA has tentatively begun to provide assistance for restoration of beaches and dunes in selected locations pursuant to disaster declarations. Beach nourishment is authorized under Category B, "Emergency Facilities (44 CFR 206.225 and Category G, Permanent public works—parks, recreational, and other (limited to "engineered beaches" defined below) (44 CFR 206.226). Beach nourishment may potentially be eligible for hazard mitigation grants (HMGs) if cost effective (44 CFR 206.434). However, the Mitigation Directorate is internally discouraging the use of HMGs for this purpose.

Although FEMA beach restoration activities have been modest in number and cost so far, political pressure can be expected to grow as beaches continue to erode and structures are endangered. FEMA can act much faster than the Army Corps of Engineers, which requires a specific Congressional authorization and extended period for design and environmental impact assessment. FEMA reimburses for 75% of projects costs vs. 65% or less under Corps programs. Also, FEMA is a less-visible political target for opponents of beach nourishment since these efforts are included in the overall process of disaster recovery, which is politically popular in the affected area. But popularity does not necessarily equal good policy. Beach nourishment may be a scientific and political quagmire. The following are a few of the uncertainties that confront FEMA regarding beach nourishment.
PHYSICAL UNCERTAINTY

Beaches are components of a complex system of coastal geomorphology that also includes offshore sandbars, dunes, sand sources, tides, wind, waves, and littoral currents. These elements interact in a volatile physical environment. The width and slope of the visible beach results from a "dynamic equilibrium" among the various elements, which varies from one location and time period to another (Pilkey and Dixon, 1996:23). The longevity of a beach nourishment project depends in part on grain size, length of reach, quantity of sand, time of year, and weather. Expected longevity of beach nourishment is hotly debated among coastal geologists and coastal engineers. Can all these physical parameters be adequately analyzed in the haste of post-disaster recovery (particularly for Category 8 emergency assistance)?

ELIGIBILITY UNCERTAINTY

FEMA limits beach nourishment under Category G (permanent public works) to "engineered beaches," meaning: "(i) The beach was constructed by the placement of sand (of proper grain size) to a designed elevation, width, and slope; and (ii) A maintenance program involving periodic renourishment of sand must have been established and adhered to by the applicant" (44 CFR 206.226). What constitutes "periodic renourishment"—a fixed amount of sand at regular intervals covering an entire designated project area or merely a few truckloads to fill hot spots when needed? The criterion would appear to favor more affluent communities that budget funds for renourishment over other communities that may deal with it in an ad hoc manner. What about beaches in front of private communities or resorts?

Furthermore, eligibility for FEMA PA funding will not be approved "when another federal agency has specific authority to restore facilities damaged or destroyed by an event which is declared a major disaster" (44 CFR 206.226(a)). Does this depend on whether the Corps of Engineers is authorized to provide emergency beach nourishment? Should FEMA rush in if the Corps holds back?

ECONOMIC UNCERTAINTY

FEMA requires that beach nourishment (as hazard mitigation or as emergency projects) must be "cost-effective." For this purpose, the Mitigation Directorate has established a benefit-cost analysis procedure (FEMA, 1996). As with any benefit-cost analysis, the procedure involves estimating the immediate and recurring annual costs, and the expected benefits amortized over the project life. Future costs and benefits are
discounted to present values for purposes of comparison using a discount rate. Beach nourishment presents several issues with respect to estimates of cost effectiveness, e.g.:

- **What is the lifetime** of the project? (Pilkey's data indicates that "designed" project lifetimes for Corps projects are usually overestimated. Renourishment provided in haste after a disaster presumably is even less likely to last as long as predicted.)

- **What are the future benefits** of a proposed project? FEMA limits benefit/cost analysis to consideration of "federal benefits," i.e., "avoiding future costs associated with physical damages to a facility, emergency work, and injuries or loss of life associated with a facility" (Wingo and Shea, 1994). Recreation and private property values are thus not included as explicit project benefits, but they may be nevertheless implicit to the benefit calculation. The value of oceanfront structures depends in part on whether they are protected from undermining and flooding, which in turn depends on whether a beach is maintained. Should the maintenance of private property values along oceans be a federal expense, regardless of whether recognized in the benefit-cost ratio?

- **What is the appropriate discount rate** to apply to future benefits and costs? This is a perennial issue with Corps of Engineers benefit/cost analysis estimates. The lower the interest rate, the higher the present value of future costs and benefits. But since costs are substantially present, and benefits entirely future, a low interest rate overvalues benefits in relation to costs.

**LEGAL/POLITICAL UNCERTAINTY**

Any nourishment of an "engineered beach" requires, by definition, a commitment by the nonfederal sponsor (state, county, community, special district) to pay for periodic renourishment over the projected lifetime of the project (e.g., 50 years). This applies either to a Corps or a FEMA-funded project. How will FEMA ensure that the beneficiary of the project will fulfill this responsibility?

Beach nourishment may induce new construction or expansion of existing structures along shorelines that appear to be protected by the project. Thus the total value of property at risk and therefore loss exposure of the NFIP, may be significantly increased due to the project unless the local sponsor deters such infilling with land use regulations. But states and local authorities tend to weaken rather than strengthen
beachfront land use and building regulations after a disaster. According to the National Research Council Committee on Beach Nourishment and Protection:

There are pressures for relaxation of construction standards in response to hazard mitigation benefits provided by a beach nourishment project. . . . There is no guarantee that a local community will meet its obligations to maintain a beach nourishment program. If the NFIP were to accept lower construction standards, it would thus become hostage to the uncertainties of local sponsor support without the means to force retrofits of buildings to meet more stringent standards (1995:77).

It follows that a beach nourishment project cannot be equated to a levee affording a similar estimated level of protection. Building standards and state/local setbacks landward of nourished beaches must be enforced over time because the beach may substantially disappear long before planned. Nonfederal recipients of federal beach nourishment assistance, either through FEMA or the Corps, must be held accountable to enforce their own laws even when they exceed minimum NFIP standards (e.g., in requiring setbacks along eroding shorelines).

**ENVIRONMENTAL UNCERTAINTY**

Beach nourishment involves removal of beach material from a borrow site (often bottom sediments of navigable waterways or accessible sandbars). The material is then conveyed by barge, truck, or pipeline to the nourishment site along the eroded beach. Environmental impacts of many types thus arise in both the areas of sand extraction and sand deposition as well as along the route of conveyance in the case of overland pipelines. Impacts may be inflicted on tidal wetlands and mudflats (shellfish habitat), upland biological communities, and the beach itself (e.g., nesting habitat for piping plover and sea turtles). How will FEMA evaluate and mitigate environmental impacts of beach nourishment projects that it sponsors? Does it comply with Section 404 of the Clean Water Act, the Endangered Species Act, and the National Environmental Policy Act (NEPA)?

**ALTERNATIVES?**

Under NEPA or any rational standard of public decisionmaking, alternatives to a proposed action must be considered to select the most cost-effective and least environmentally damaging way to accomplish the
public objective. In the case of beach nourishment, potential alternatives include some form of structural protection (including artificial reefs), more stringent land use and building standards along eroding coasts, public acquisition, landward relocation of structures, or doing nothing at the federal level. In many instances, beach nourishment may be desired by states and local communities but FEMA's interest in damage reduction may be accomplished more cost-effectively by other means.

**CONCLUSION**

The inevitability of beach erosion, combined with the political complexity of obtaining federal assistance through the Corps of Engineers, suggests that FEMA will be under heavy pressure to contribute to additional beach renourishment projects in the future. Each project serves as precedent for additional requests, and in the heat of disaster recovery, such requests are politically difficult to refuse.

But beaches are natural features, not infrastructure. They are not equivalent to roads, bridges, sewers, or other objects of public assistance that may be expected to last for their projected design lifetime with little or no further federal involvement. Coastal processes are inherently unpredictable and the lifetimes of nourished beaches are usually much shorter than originally planned. Beaches may be expected to attract new development and upgrading of existing structures, which in turn are at risk in future coastal storms. If nonfederal authorities neglect to provide costly renourishment on a regular basis, the beach will erode once again, and the stage is set for greater losses than if it had not been renourished in the first place. Beach nourishment, unless accompanied by ironclad controls over landward development and periodic maintenance, is the antithesis of mitigation.

Beach nourishment may be cost-effective for states and local governments in terms of recreation, tourism, and protection of shoreline structures. But the costs of providing those benefits should be assumed by the beneficiaries through property taxes, special assessments, or other funding mechanisms. It is not FEMA's job to provide those benefits. Furthermore, participation in local beach nourishment in effect commits FEMA to continue renourishing the same beach indefinitely in order to forestall ever-rising potential liability of the NFIP for structures attracted by the illusion of a "permanent" beach. FEMA's "toe in the water" is really a "thumb in the dike"—once provided, it cannot be withdrawn. Beach nourishment is an unwise use of public assistance funds that counteracts the goal of mitigating future coastal hazard losses.
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Part 5
LESSONS FROM HURRICANE FRAN
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THE HURRICANE FRAN
COASTAL ZONE MANAGEMENT EXPERIENCE:
REGULATORY AND REDEVELOPMENT ISSUES ON
NORTH CAROLINA BARRIER ISLANDS

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North Carolina Coastal Management Program

INTRODUCTION

From the beginning of North Carolina's Coastal Management Program, we had measured our security in terms of Hurricane Hazel. It had become a nebulous sort of benchmark, a category-four storm that struck in 1954—before many coastal property owners were born and 20 years before North Carolina lawmakers passed the Coastal Area Management Act. Today, Hazel is a blurry memory for many of those who lived through it. For the many more who didn't, the big hurricane has been a story to read about in history books or to hear at a grandparent’s knee.

Nineteen ninety-six changed that, with two hurricanes and the remnants of one tropical storm battering our coastal counties within three months. The largest of these storms was Hurricane Fran, which made landfall on the southern portion of North Carolina's coast on September 8—just two months after Hurricane Bertha swept through the same area. Both storms caused significant beach erosion and widespread damage to piers and bulkheads along the ocean and sound shorelines. Fran caused significant housing damage as well.

Fran showed us the strengths of North Carolina's 23-year-old program for managing coastal growth and development. Indeed, our regulatory requirements for siting oceanfront development, strict building standards, and local land use planning all worked to mitigate damage and to make post-storm decisions easier and more effective.

However, Fran also showed us where we need to make improvements—both at the state and local levels—in how we prepare for, and respond to, major storms. This paper will summarize some of the most important issues the Division of Coastal Management has faced since Hurricane Fran. With many of those issues, we have found a common lesson: You must have clear rules to guide your post-storm regulatory decisions.
HURRICANE FRAN AND COASTAL ZONE MANAGEMENT

THE DAMAGE

Hurricane Fran was the biggest storm in the history of the North Carolina Coastal Management Program, affecting 11 of the state's 20 coastal counties. Together, hurricanes Fran and Bertha, and the remnants of Tropical Storm Josephine, damaged more than 120 miles of ocean beaches. That's a little more than a third of North Carolina's ocean beaches—and more than half of the beaches that are developed.

From the Cape Fear River to Beaufort Inlet, the storms eroded beaches, destroyed dunes, and wiped out stabilizing vegetation. About 90% of all oceanfront structures in the area were damaged. Farther inland, waves and high water destroyed thousands of private piers and bulkheads along coastal rivers and sounds.

Because damage estimates have changed frequently since September, we have had a difficult time getting solid numbers on buildings and infrastructure damaged or destroyed. But loans and grants handed out since the storm give a picture of what the damage was like:

As of November, the Federal Emergency Management Agency (FEMA) had paid out more than $20 million in housing grants to residents of nearly 7,000 houses in coastal counties. Small Business Administration loans for under- or uninsured property neared $26 million. Assistance to public entities, including local governments, topped $16 million. Tourism losses are still being calculated, and local governments are predicting significant tax-base reductions because of buildings lost and property that is now under water.

EROSION SETBACKS AND DUNE VEGETATION

Along Fran's path, erosion varied widely, from as little as five to as much as 50 feet in some areas. Before the storm, many of the affected areas had large, well-vegetated dunes that were higher than the base flood elevation. Fran destroyed these dunes in some areas, leaving only remnants of the vegetation that had been located landward of the dunes. In other, lower areas, vegetation was lost to washover erosion or burial.

These dramatic changes in the physical characteristics of the beachfront have important implications for the application of rules governing the siting of new development and the repair or replacement of damaged structures.

A major component of North Carolina's program to mitigate damage caused by storms and chronic erosion is to site development according to building size and the area's long-term erosion rate. For small structures, those less than 5,000 square feet in total floor area, the setback is determined by multiplying the annual erosion rate by 30, with a minimum
setback of 60 feet. Larger structures must be set back a distance equal to 60 times the erosion rate.

These setbacks are measured landward from the first line of stable, natural vegetation. This line represents the boundary between the normal dry-sand beach, which is subject to waves, tides, and wind, and the more stable, upland areas. It usually is found at, or immediately oceanward of, the toe of the frontal dune or erosion escarpment. The vegetation line generally is well-defined and offers a consistent point from which to measure. However, Fran left stretches of beach several miles long with no vegetation to use as a setback baseline.

Expecting an immediate demand for setback line determinations, the Division of Coastal Management worked to develop an alternate measurement line. At our request, the North Carolina Coastal Resources Commission approved a temporary rule that allowed us to estimate the location of the vegetation line. That rule allows DCM to establish the line by using 1) the vegetation line shown on aerial photography taken just prior to Hurricane Fran, and 2) measurements of the extent that the vegetation line receded in areas where there is vegetation intact after the storm. By subtracting the distance the line receded from its pre-Fran location (a range of five to 70 feet), we are able to establish a point from which to measure setbacks in areas where there is no vegetation left. This line is easy to establish and has been an effective method of responding to questions about rebuilding and repairing damaged structures.

**POST-STORM REDEVELOPMENT ISSUES**

Not all redevelopment questions have been that simple, however. Hurricane Fran destroyed a large number of oceanfront buildings. In some instances, houses appeared to vanish—with no trace remaining on the lot. In others, much of the lot itself disappeared.

The extreme cases have been the easiest to decide. But our field representatives and local permit officers have been faced with questions about hundreds of buildings with missing roofs, collapsed exterior walls, or with foundation pilings that had been damaged but had left the building itself in place.

Under North Carolina’s rules, a *replacement* permit is required if the cost of making repairs is greater than half of the physical value of the building. Buildings requiring replacement permits must meet all current development standards, including setbacks from a post-storm measurement line. If the cost of repairs is less than half of the building’s value, the building may be repaired in place.

Local building inspectors are charged with determining whether damage to a particular building exceeds the 50% mark. Prior to the 1996
storms, inspectors had to make such determinations only in those rare cases when structures were damaged by normal erosion, fire, or normal deterioration. But when the number of structures requiring assessment reached the hundreds and stretched across more than 10 local government jurisdictions, we began to see problems.

The first problem that came to light was one of inconsistency. Some counties and towns used tax valuations to estimate pre-storm values; others used replacement costs; and still others used market value. We quickly realized that these differences would make it difficult for us to apply coastal management rules evenly throughout the coastal counties with storm damage.

To complicate matters further, we learned that the factors evaluated under damage assessments for the Federal Emergency Management Agency (FEMA) were different than those we needed to consider. FEMA is concerned with the costs of restoring a structure to its pre-storm conditions, including interior work. At the Division of Coastal Management, we are concerned with the costs of returning the structure to compliance with state building codes and safety standards. Had we adopted FEMA's repair estimates, hundreds of additional structures would have required rebuilding permits—and many of those would not have been allowed back.

We found a solution to this problem by working with FEMA to develop a software program that uses local information on building costs and standardized methods for damage assessment that take into account the information needs of both agencies. Coastal Management purchased the software and supporting information and donated it to the local governments. FEMA provided training for local government staff. Local governments like the program because it is easy to use, gives building inspectors a standard basis for their decisions, and generates an itemized report of results. We like it, because it has helped us consistently apply our rules, which will greatly improve our ability to successfully defend future challenges to our permit decisions.

**SAND BERM CONSTRUCTION**

Cooperation between agencies also played a key role in resolving problems with plans for the construction of emergency berms along Fran-damaged beaches.

Immediately following the hurricane, FEMA began identifying those beaches that did not have dune systems sufficient to give existing development protection from a five-year storm. For each beach surveyed, FEMA prepared a Damage Survey Report, which identified beach
scraping as the sole source of material for berm construction and which recommended funding on that determination.

Coastal Management's review of those reports showed that there was not enough sand material on the beaches to construct the berm as designed. In addition, the design of the berms called for a base that extended seaward of normal high tides. We asked FEMA to reevaluate the reports, identifying additional sand sources and expanding funding to a more realistic level. We were particularly interested in using sand sifted from storm debris to augment the berms. Other sand sources included upland borrow areas and old, diked dredge spoil disposal areas that contain significant amounts of material. After a series of meetings with federal officials, the original damage reports were modified to approve funding for acquiring sand from the alternative sources.

We also were able to obtain an additional sand source for the berms by working with the U.S. Army Corps of Engineers. The Atlantic Intracoastal Waterway is located behind the barrier islands along the southern coast of North Carolina. Material dredged from the Waterway as part of the Corps’ routine maintenance may be placed on ocean beaches if it is determined to be compatible with naturally occurring beach sand. That maintenance coincided with the period of storm recovery and berm construction, and the Corps worked with state and local officials to determine where that sand was most needed for berm construction. In addition, the Corps implemented plans for widening channels that historically have required frequent dredging. These widening projects had the additional benefit of generating another source of sand for berm construction in critical areas.

These cooperative projects taught us a great deal about FEMA's requirements for berm construction and funding. With this knowledge, we will be able to help future emergency berm construction go forward much faster than it did after Hurricane Fran.

**Future Issues**

The widespread damage left by the storms of 1996 underscored the risks associated with developing North Carolina's barrier islands. A few residents have considered the storms a wake-up call and plan to sell their property and leave. Most, however, plan to stay, posing new challenges for those of us who regulate development on North Carolina's coast.

For the most part, our regulations have been developed to apply to new construction. Prior to Hurricane Fran, we had not needed to make decisions about rebuilding over such a large area, and we had not needed to respond to such a large volume of requests for permits. In addition to the three issues described in detail above, our experience with this storm
has revealed a number of ambiguities and deficiencies that will require future policy development and rulemaking adjustments to make post-storm decisions easier and more consistent.

For example, we have had difficulty applying standards for buildings in making decisions about the replacement of ancillary features, such as decks, paved parking areas, and septic tank systems. Trying to apply the same standards used for the main structure frequently has caused confusion and uncertainty. We may need to review the criteria on which we base decisions to allow repair or replacement of these structures.

The Coastal Resources Commission, our policy and rulemaking body, also is examining our rules to determine whether, and where, they need to be altered to give property owners added protection from the next storm, and to help us respond when there is damage. The Commission began that examination by hearing from several scientists who have new information on erosion patterns along the North Carolina shore.

In addition, there are larger policy questions still to be answered. Those answers will require a significant commitment from the public—and from the North Carolina General Assembly.

After Hurricane Fran, Governor Jim Hunt appointed a cabinet-level task force to review disaster recovery in North Carolina and make recommendations for improvements. During that review, the Task Force raised the issue of the wisdom of building on fragile barrier islands and recommended that a legislative study commission examine establishing a state high hazard area, similar to those areas designated under the Coastal Barrier Resources Act, in which public money could not be spent to subsidize new development. The Task Force also has asked that a study commission look into establishing an acquisition fund for purchasing property—at a fair value—from barrier island residents who are ready to get out. And for those who are considering buying at the beach, the study commission would consider requiring a hazard notice, attached to property deeds, that would spell out the risks of living on the shore.

We would like to think North Carolina would never have another summer like 1996. But we probably will, and the storms that hit next could be as bad or worse. If we do our jobs well, we will be able to look back and say that Josephine, Bertha—and especially Fran—have served us well by highlighting what we do best and what we need to change.
POST-FLOOD ANALYSIS OF THE BENEFITS OF FLOODPLAIN REGULATIONS IN BEAUFORT COUNTY, NORTH CAROLINA

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INTRODUCTION

This study examines structures affected by Hurricane Fran in Beaufort County, North Carolina, to determine the extent to which building standards of the National Flood Insurance Program (NFIP) protected post-FIRM (Flood Insurance Rate Map) structures. Presumably, structures built in accordance with the NFIP regulations will not be significantly affected by floods with a recurrence interval of less than the 100-year regulatory standard. The total observed benefits are dependent upon the degree of community compliance with NFIP standards and can be compared to the total potential benefits that are realized if a community rigidly enforces floodplain building standards. The value of these benefits can be measured through relatively straightforward analysis of flood damage under various scenarios. This method for calculating the benefits of NFIP building regulations may be used as a management tool in demonstrating to homebuilders the value of strict adherence to floodplain building standards.

A goal set forth in the Unified National Program for Floodplain Management (Federal Interagency Floodplain Management Task Force, 1994) is to examine the effectiveness of the NFIP in reducing monetary flood losses to residential structures. The Unified National Program, as well as the Report of the Interagency Floodplain Management Review Committee (1994) to the Administration Floodplain Management Task Force express an urgent need for methods to measure the benefits of floodplain management regulations in the United States. A stated goal of the National Mitigation Strategy (FEMA, 1995) is to “communicate mitigation successes to decision makers, government agencies, business and industry, and private citizens.” A prudent time for communicating these successes is in the aftermath of a major flood when damage averted during that specific event are held in high regard by those recovering from and repairing sustained damage.
The Federal Insurance Administration (FIA) has attempted to enumerate the benefits of the NFIP through analysis of flood insurance claims data collected since program inception. Unfortunately, these claims data underestimate the flood damage averted because flooded post-FIRM structures that are not damaged due to their elevated floor level are not represented. In 1993, the deputy administrator for the FIA told the House Subcommittee of Consumer Credit and Insurance that “after communities join the NFIP, [post-FIRM] buildings that are damaged sustain 83% less damage than existing [pre-FIRM] structures. The annual historical reduction in flood damage is estimated at $569 million” (FEMA Office of Public Affairs, 1993). While the source of these figures is not stated, they are presumably derived from the FIA records of flood insurance claims.

**Methodology**

The most important floodplain building requirement that NFIP communities must adopt is that the lowest floor of all new structures built within the regulatory floodplain are required to be elevated to or above the base flood elevation (BFE). Thus, a good approximation of averted damage and potential benefits can be based on flood heights versus building heights in a community. This method for measuring damage averted examines the direct monetary benefits to homeowners after a single flood as a result of elevating new construction to the BFE.

After a flood, the damage averted as a result of elevating post-FIRM structures can be estimated based on depth-damage curves, which predict a percentage of structure value damage based on the depth of floodwaters above the building’s lowest floor. The benefits accrued by a single structure after a flood are calculated as the difference between damage that would have occurred without the NFIP provisions and actual damage. In order to calculate the benefits accrued to the whole community in the aftermath of a flood disaster, the benefits from each structure are summed. Thus, the benefits accrued for a large number of structures is equal to the aggregated damage to hypothetical structures at grade (from depth-damage curve analysis), $D_N$, minus the aggregated actual damage sustained by post-FIRM structures, $D_A$.

If the post-FIRM structures in a community are in complete compliance with regulations requiring elevation to the BFE, this study assumes that potential damage is at a minimum. Potential damage is that which could be experienced by any structure, regardless of elevation of the lowest floor, during the 100-year flood. A community’s level of compliance can be assessed by calculating the unnecessary damage, or the
difference between the observed damage, $D_A$, and the damage predicted if all post-FIRM structures had been fully elevated to BFE, $D_C$.

The equation variables used in this process are summarized in Figure 1, which depicts the stage of a flood less than the base flood, under three scenarios. Scenario A shows the homes built with the lowest floor at grade, in absence of elevation requirements, with flood damage equal to $D_N$. Scenario B depicts the actual post-FIRM construction scenario, with partial compliance and flood damage equal to $D_A'$. The structures in Scenario C depict 100% compliance, where all structures are fully elevated to the BFE, with flood damage equal to $D_C$.

**DATA COLLECTION**

To calculate the total benefits, potential damage, and unnecessary damage in a community after a flood, several data needs must be addressed. Due to the large amount of data involved, a computer spreadsheet for data entry simplifies the process. Since this study proposes to measure the benefits of floodplain regulations, only post-FIRM residential structures are examined. Although the FIRM effective date for Beaufort County is February 4, 1987, building permits are only available for homes built after 1990. Floodplain building permit log entries are “tagged.” Each entry indicates building type or proposed alteration, owner name, and permit number, allowing easy identification of all residential structures built in the floodplain, moved into the floodplain, or elevated above BFE. Permits are filed in alphabetical order by owner name. Manufactured home permits are similarly recorded in separate log books. Over 400 building permits were issued for residential structures and manufactured homes in the floodplain areas of Beaufort County between 1990 and September 1996. If no permit file exists for a log entry, the entry is excluded from the study because, presumably, the structure was not built. Few permits were “active” when the hurricane struck. All are excluded from the study because only a foundation inspection had been conducted, and further construction was minimal.

Each of the remaining permit files is carefully examined. All NFIP communities are required to maintain a surveyor’s or engineer’s certification of the lowest floor elevation of post-FIRM structures. Beaufort County inspectors have kept a careful record of this information using FEMA’s elevation certificates and, in some cases, surveyor certifications by letter. If surveyor-certified information in the file shows that a building site elevation is above the BFE, the structure is excluded.

Lowest adjacent grade is the level at which floodwaters begin to affect a structure, and is noted on the NFIP’s elevation certificates.
Figure 1. Damage calculated under three scenarios.
Elevation certificates show the construction methods used for the lowest floor and indicate the existence of a basement when applicable. Likewise, to calculate the lowest floor for a minimally compliant structure, the BFE must be known. Lowest adjacent grade, reference level, and the BFE for all structures is gathered from the elevation certificates or surveyor's letter, and recorded in the spreadsheet. The value of the house or manufactured home at the time of construction is gathered from the permit file, as well as the number of stories. This information will be necessary for the depth-damage curves. The value of the structure is corrected using the county tax assessor's depreciated assessed value database whenever possible. The nature of the database makes locating individual structures by owner name extremely difficult.

Of the 312 structures included in the study at this point, 43 were missing at least the lowest floor elevation. County inspectors require benchmarks to be set at all construction sites, and the location and elevation of those benchmarks is available in the permit file for 21 of the 43 structures needing lowest floor elevations. Field surveys are conducted to fill in the missing data. Other benchmarks, nearby post-FIRM structure elevations, or an estimate of 0.0 feet mean sea level are used to complete the remaining blanks. Forty-eight permit records were missing the elevation of the lowest adjacent grade. This elevation was gathered by visiting the structures and using a tape measure to subtract the height of the foundation (or pilings) from the known lowest floor elevation.

Structures not affected by floodwater during Fran are excluded from the study. Flood heights from the hurricane at all remaining study structures are gathered from a variety of sources, including emergency managers who conducted field surveys immediately after the storm; homeowners; building inspectors; and several surveyed high water marks. Ideally, high water marks should be gathered immediately after the storm. Beaufort County water bodies that flooded during the hurricane were typically nontidal creeks such as Pungo Creek and Broad Creek. The Pamlico River, the largest water body in the county, also flooded low-lying areas along both shores, especially peninsula and beach communities along the western extent of the river. Reportedly, flood levels did not reach the predicted levels of the BFE at any point in the county. Hurricane Fran had sustained winds of approximately 115 miles per hour, with some gusts reaching at least 125 miles per hour (NOAA, 1996). As precipitation coupled with storm surge flooding of the Pamlico River, the Town of Washington, county seat of Beaufort County, recorded a flood stage of 8.5 feet above mean sea level (Warner, 1996).

The dollar value of flood damage actually sustained by each study structure must also be collected through a combination of methods. The
FIA collects information on federal flood insurance claims processed for the storm. This information has been requested from FEMA, and will be supplemented by interviews with homeowners who did not have flood insurance, or did not file flood insurance claims. Preliminary damage estimates or homeowner interviews conducted by emergency management agencies may also be useful in obtaining damage estimates for uninsured structures. Ongoing field work, consisting of interviews with emergency workers, recovery specialists, as well as homeowners is necessary to obtain suitable damage estimates for all affected post-FIRM structures. A complicating factor in assessing this data will be trying to negate the effects of Hurricane Bertha, which struck Beaufort County less than two months before Hurricane Fran.

**DATA ANALYSIS**

Several important assumptions are being applied to this study as executed in Beaufort County. First, in the absence of floodplain regulations, structures will be assumed to be elevated two feet above grade. Discussions with the building inspector, observation of pre-FIRM structures in the county, examination of the county’s building code, and the high water table in many areas of the county indicate that this assumption is valid. Therefore, only structures that experienced at least two feet or more flooding are evaluated. The depth-damage curve indicates that flood levels equal to or below the lowest floor elevation inflicts minimal damage. The high water table in Beaufort County precludes building structures with basements; therefore, homes that did not contain a reference level in the permit file to indicate the type of construction are considered to be constructed on a crawl space. Building inspectors know of only one area in the county where residents have enclosed areas below the BFE after final inspection. These structures are visited, and the lowest floor is adjusted to the lowest adjacent grade elevation when appropriate. These assumptions may not be valid in other applications of this method.

Data collection, calculation, and analysis are simplified in this study through the use of a spreadsheet. In this manner, averted damage may be easily calculated for individual structures, as well as for all post-FIRM structures in the community. Compliance with the Flood Damage Prevention Ordinance adopted by the county in 1987 is very good; therefore, the unnecessary damage is expected to be minimal and may only reflect several manufactured homes that were placed in pre-existing manufactured home parks and were not sufficiently elevated above BFE.
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Federal Emergency Management Agency


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Interagency Floodplain Management Review Committee

National Climatic Data Center (NOAA)

Warner, Jimmy
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BUILDING PERFORMANCE ASSESSMENT:  
HURRICANE FRAN IN NORTH CAROLINA

Clifford Oliver and Mark Vieiera  
Federal Emergency Management Agency

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BACKGROUND
On September 5, 1996, Hurricane Fran made landfall near Cape Fear, North Carolina, generating considerable rainfall, high winds, storm surge, and strong waves. In response to the considerable losses, President Clinton declared many parts of North Carolina to be a federal disaster area. The National Oceanic and Atmospheric Administration estimated that Hurricane Fran generated one-minute sustained winds of 115 miles per hour. A maximum storm surge of 11.9 feet above mean sea level (msl) was recorded at Figure Eight Island, and a high water mark of 15.4 feet msl, including wave effects, was recorded at Kure Beach.

An assessment of damage conducted by the Federal Emergency Management Agency (FEMA) showed widespread damage to the ocean-front row of one- to four-family residences on Topsail Island. FEMA's Mitigation Directorate then deployed a Building Performance Assessment Team (BPAT) to study the hurricane's impact on other barrier island structures from Kure Beach to North Topsail Beach. Ocean-front damage was concentrated within the three incorporated communities on Topsail Island, which are Surf City, Topsail Beach, and North Topsail Beach.

During the assessment process, it became apparent to the BPAT that the vast majority of damage was not a result of high winds, but a result of flooding, including storm surge, wave action, debris impact, erosion, and scour. Therefore, the BPAT focused its efforts on assessing the performance of buildings and other structures related to flooding.

THE BUILDING PERFORMANCE ASSESSMENT TEAM REPORT
The North Carolina BPAT was composed of federal, state, and private sector representatives from insurance, engineering, and floodplain
management disciplines. As a result of the BPAT's efforts, a report entitled *Building Performance Assessment: Hurricane Fran in North Carolina* was completed in March 1997. The report presents detailed observations and recommendations. Observations focus on both failures and successes that provide insight into how buildings and other structures performed. The recommendations provide guidance on how buildings and other structures in coastal areas can be designed and constructed to significantly reduce or eliminate much of the damage observed along coastal North Carolina. Specific design, construction, and regulatory recommendations for building foundation systems (including piles, columns, and cross bracing details), breakaway walls, slabs-on-grade beneath elevated buildings, on-site utility systems, corrosion resistance, and manufactured home foundations, are presented.

**THE NATIONAL FLOOD INSURANCE PROGRAM AND STATE BUILDING AND COASTAL MANAGEMENT REQUIREMENTS**

All the communities assessed by the BPAT participate in the NFIP. Under the NFIP, each community had adopted and was enforcing a floodplain management law or ordinance that met or exceeded the NFIP's minimum requirements. Each community was issued a Flood Insurance Rate Map (FIRM) by FEMA, and the FIRM had been adopted as each community's regulatory flood map. In the period since FEMA last conducted a floodplain restudy of the communities on Topsail Island, FEMA's coastal floodplain study methodology changed. In response to Hurricane Fran, FEMA immediately began a flood insurance restudy of the communities on Topsail Island. Advisory maps have been issued to the affected communities, and FEMA will formally issue revised maps when the restudy is completed for the communities to legally adopt as their new regulatory floodplain.

In addition to coastal communities adopting and enforcing a NFIP-compliant floodplain ordinance, the State of North Carolina further regulates coastal construction through the state's building code and the Coastal Area Management Act (CAMA) provisions. The state building code sets forth specific prescriptive requirements for buildings located on barrier islands. One of the building code requirements that had the greatest impact on the survivability of ocean-front, one- to four-family residential structures is the requirement for pile depth embedment. Before January 1, 1986, structures built on barrier islands were required to be elevated on piles that were embedded at least eight feet below grade. Effective January 1, 1986, one- to four-family residential structures within the area regulated by CAMA were required to be elevated on piles embedded 16 feet below grade, or to an elevation of minus five msl,
whichever is shallower. The CAMA sets forth construction setbacks from established coastal features and other requirements with the intent of minimizing long-term coastal erosion and protecting coastal structures from the effects of long-term erosion.

**OBSERVATIONS**

The BPAT conducted an aerial assessment of coastal damage from Cape Fear to Emerald Beach. A more detailed, on-the-ground assessment was conducted from Carolina Beach to North Topsail Beach. Both the aerial and ground assessments indicated that most of the damage on the barrier islands was a result of storm surge and not wind. The widespread loss of ocean-front, one- to four-family residential structures was a direct result of storm-induced velocity flood flows, wave action, debris impact, and erosion and scour.

Coastal areas from Cape Fear to Cape Lookout experienced significant storm-induced erosion and scour. In many locations, frontal dunes were lost, and general erosion of the beach profile was observed. The combined loss of the dune and the erosion of the beach resulted in a vertical loss of four to six feet of sand beneath many ocean-front buildings. The loss of supporting soil from erosion and scour, combined with flood and wind loadings acting simultaneously on the structures, resulted in the collapse of more than 100 ocean-front houses.

Many sections of Topsail Island suffered complete loss of the frontal dune due to the combined effects of Hurricanes Bertha and Fran. Loss of the dune created serious problems for buildings on Topsail Island. The loss of the dune resulted in loss of soil that supported the piles of elevated buildings located on or directly adjacent to the frontal dune. Secondly, where the dune was breached, storm surge and accompanying waves and velocity flow migrated landward across Topsail Island.

**Building Foundation Systems**

Within the communities on Topsail Island, four categories of residential structures were identified: structures that are not presently located within a Special Flood Hazard Area (SFHA); structures within the SFHA that were built before the community entered the NFIP (pre-FIRM); structures within the SFHA that were built after the community entered the program, but before the change in the state building code; and post-FIRM structures located in the SFHA that were built to meet the state's current pile embedment depth requirements.

Prior building performance assessments had already demonstrated that ocean-front, pre-FIRM, coastal buildings often perform poorly when
exposed to hurricane conditions, while the structural components of ocean-front, post-FIRM buildings often performed well. However, the BPAT noticed a significantly differing trend on Topsail Island: many ocean-front, post-FIRM, one- to four-family residential structures performed poorly. In response to this trend, FEMA investigated the performance of these residential structures on Topsail Island.

Under FEMA’s Hazard Mitigation Technical Assistance Program, a consulting engineering firm was tasked to investigate the structural performance of several damaged and undamaged ocean-front, post-FIRM, one- to four-family residential structures that were built under the present embedment requirements for structures under the purview of the CAMA. The results of this investigation, which are summarized in the Hurricane Fran BPAT report, indicated that many of the piles supporting these newer structures were not embedded in accordance with the current state building code.

Ocean-front structures collapsed when columns and piles failed. Most vertical foundation members collapsed from the loss of supporting soil. In a few cases, it was suspected that debris impact contributed to vertical foundation member failure. Decks, porches, and roof overhangs on many ocean-front and landward structures collapsed because their supporting piles or columns were not installed to the same depth as the main building supports.

Breakaway Walls Beneath Elevated Buildings

While the team did not observe many instances where breakaway walls may have resulted in structural damage, many deficiencies in their design and construction were noted. Deficiencies worth noting include the placement of exterior sheathing of breakaway wall panels continuously over adjacent piles, breakaway walls connected to structural members with excessive fasteners (usually nails), and the placement of breakaway walls immediately seaward of cross bracing. All of these deficiencies resulted in unanticipated loads being transferred to structural elements.

Below-Building Concrete Slabs

Concrete slabs installed beneath elevated buildings were observed to have generally not caused structural failure of building foundation systems. These slabs are intended to break into small pieces once undermined by storm-induced erosion and scour and to break cleanly away from the building’s foundation system. There were some notable deficiencies that may have directly contributed to structural damage, including slabs that were too thick, continuous wire mesh through the
control joints, slabs with insufficient joints to promote breakage, and slabs connected to vertical foundation members with steel dowels.

**On-Site Utility Systems**

Both ocean-front and landward structures on Topsail Island suffered significant damage to on-site utility systems, including electrical, water, sewer, septic, cable TV, and telephone. Much of the damage was a result of improper installation. For example, utility systems were installed on platforms that collapsed, installed below the flood elevation, or installed in such way that they were damaged when breakaway walls detached.

**Corrosion of Structural Metal Components**

As previous BPATs have observed, there is an increasing trend towards the use of partially exposed metal structural components in coastal areas, such as hurricane straps and clips, stamped metal plates on floor diaphragm trusses, and manufactured home and RV tie-downs. With this trend comes an increased observance of corrosion of these components. The BPAT did not observe any structural failures linked to this corrosion in site-built structures, but it is important to note that the corrosion will continue, possibly leaving those buildings in a structurally weakened condition when a future hurricane occurs. The team did observe damage to manufactured home and RV tie-downs that may have been a result of tie-down corrosion.

**Building Performance Successes**

Post-FIRM, ocean-front, one- to four-family residential buildings on Topsail Island that were built to the current state building code pile embedment requirements performed very well, in comparison to both pre-FIRM and post-FIRM buildings built to the pre-1986 building code requirements.

Buildings on Topsail Island, landward of the ocean-front row, performed extremely well. As a result of building code requirements and local contractor practices, almost every one- to four-family residential structure on Topsail Island had been elevated at least eight feet above grade on piles embedded eight feet below grade. This was observed both within A zones on the communities' FIRMs and areas that were outside the regulatory floodplain. This practice clearly resulted in a significant reduction in damage on Topsail Island.

Beach nourishment, with the construction of a protective dune, appears to have substantially reduced damage in Wrightsville Beach and
Carolina Beach. In these areas, the artificial dune eroded but helped to prevent damage to nearby structures.

**RECOMMENDATIONS**

**Building Foundation Systems**

Piles must be properly embedded to be able to resist loads associated with the simultaneous occurrence of both hurricane-force winds and associated storm surge, wave action, and debris impact. Embedment must take into consideration storm-induced erosion and scour and the accompanying loss of supporting soil. Several documents provide guidance on proper coastal foundation design and construction practices, including FEMA’s *Coastal Construction Manual* (FEMA, 1985) and *NFIP Technical Bulletin No. 5* (FEMA, 1994); and the American Society of Civil Engineer’s *ASCE 7-95 Minimum Design Loads for Buildings and Other Structures* (ASCE, 1995a) and *Flood Resistant Design and Construction Prestandard* (ASCE, 1995b). Other recommendations in the BPAT report include: pile foundations for building extensions such as decks, porches, and roof overhang supports must be designed to the same performance criteria as the main building foundation system; to survive coastal flood forces, the lowest floor of buildings, decks, and porches must be elevated above the expected flood elevation; the use of cross-bracing should be minimized; any use of cross-bracing must take into account flood forces; wood structural members must be of sufficient quality that performance intended in the design is achievable; solid perimeter foundation walls should be avoided in coastal areas subject to storm-induced erosion and scour; and foundations supporting manufactured homes and permanently-installed RVs in coastal areas must be designed and constructed to take into consideration wind and flood forces acting simultaneously as well as any storm-induced erosion and scour.

**Breakaway Walls Beneath Elevated Buildings**

FEMA’s *Coastal Construction Manual* (FEMA, 1985) presents design and construction practices that, when followed, result in walls that break away without causing damage to the building’s structural members. The construction deficiencies observed by the BPAT should be avoided to ensure proper performance of breakaway walls.
Below-Building Concrete Slabs

Below-building concrete slabs must be designed and constructed to break cleanly away from structural members without causing damage. Minimizing slab thickness to four inches, installing a sufficient number of slab joints to promote breakage, proper use of wire mesh, eliminating connections between the slab and vertical structural members, and ensuring the grade beams and slabs are not monolithic, will help ensure that concrete slabs on grade do not cause damage to structural members.

On-Site Utility Systems

Many of these losses could have been avoided if relatively inexpensive and simple flood-resistant design and construction practices had been applied. Simple steps that can be used to minimize damage to on-site utility systems include: the proper construction of platforms supporting compressors; proper placement of utilities in relation to breakaway walls; and the use of vertical foundation members to protect utility connections. *Protection of Metal Structural Components from Corrosion*, FEMA's NFIP Technical Bulletin No. 8 (FEMA, 1996) provides guidance on how to protect metal structural components from corrosion.

REFERENCES

American Society of Civil Engineers


Federal Emergency Management Agency


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Part 6
HYDROLOGY AND HYDRAULICS
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HYDROLOGY AND HYDRAULICS MASTER PLANNING
FOR THE CHITIMACHA INDIAN TRIBE

Mark R. Wingate
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INTRODUCTION

The Chitimacha Reservation, home to about 400 people, is located in Charenton, Louisiana, in St. Mary Parish adjacent Bayou Teche. The reservation lies about 40 miles southeast of Lafayette, Louisiana, and 70 miles north of the Gulf of Mexico. Morgan City, a major oil field support center, is located approximately 24 miles southeast (Figure 1).

Historically significant tribal achievements include the establishment of its 283-acre reservation in 1919, and federal recognition of the Chitimacha Tribe in 1971. Development intensified in the 1970-80s and included a tribal center in 1974, an educational facility in 1978, and housing along Chitimacha Loop Road in 1978. In 1988, high stakes bingo was introduced, which provided funds to construct office buildings, new homes, sanitary sewer facilities, and a fire station. The Chitimacha Tribe is now in the enviable position of generating employment opportunities and revenues through the operation of a land based casino. In an effort to promote tribal growth, the Chitimacha Tribe acquired approximately 950 acres of undeveloped land for future residential and commercial use.

In March 1995, the Chitimacha contacted the U.S. Army Corps of Engineers (Corps), New Orleans District (NOD), seeking planning and technical assistance in developing the recently acquired 950 acres. NOD explained that the area was subject to flooding and that flood reduction measures be investigated through a hydrology and hydraulics (H&H) study. NOD personnel explained that assistance and 50% funding could be provided through the Corps’ Planning Assistance to States program.

EXISTING CONDITIONS

In general, runoff flows from north to south, and east to west based on ground elevations from +3.0 NGVD in the south to +10.5 NGVD in the northern portions, to a maximum elevation of +16.0 on the eastern portions. Excluding a small section of the northern acreage, the 950 acres are subject to rainfall and hurricane surge flooding. The current 100-year base flood elevation (BFE) is +10.0 NGVD.
The 950-acre study area was divided into four basins referred to in this paper as sub-areas A, B, C, and D. The highways and railroads extending east and west served as the major ridges or separation features (Figure 2).

Sub-area D receives inflow from approximately 556 acres of land to the north via Bayou Choupique and 132 acres of land to the east via overland flow and drain to sub-area C. A total of 984 acres of runoff are drained by Bayou Choupique at Mary Garret Road. Sub-area C drains to sub-areas B and A via Bayou Choupique. This area receives inflow from approximately 134 acres of land to the east via overland flow. A total of 1398 acres of runoff are drained by Bayou Choupique at Louisiana Highway 182. Sub-area B drains to sub-area A via Bayou Choupique. This area receives inflow from approximately 136 acres of land to the east via overland flow. A total of 1685 acres of runoff are drained by Bayou Choupique at Southern Pacific Railroad. Sub-area A drains to Bayou Choupique at Highway 90. The flow
then proceeds south to the Intracoastal Waterway. A total of 1906 acres are drained by Bayou Choupique at Louisiana Highway 90.

**EXISTING CONDITIONS HYDROLOGIC AND HYDRAULIC (H&H) ANALYSIS**

An existing conditions H&H analysis was completed to determine flood conditions in the study area as a result of hurricane surge and rainfall conditions. A Hydrologic Engineering Center rainfall-runoff model (HEC-1) was developed to emulate existing conditions for rainfall flooding.

Sub-areas A and B begin to experience flooding as a result of the 10-year hurricane. A limited portion of sub-areas C and D begin to experience flooding in the 25-year hurricane. In the 100-year hurricane, sub-areas A and B would be flooded to a depth of 5 and 3.5 feet, respectively. Sub-areas C and D would be subjected to approximately 2.5 and 1.5 feet of flooding during the 100-year hurricane, respectively. Each of the sub-areas experiences “nuisance type” flooding as a result of the 100-year rainfall.
The estimated flooding depths, especially due to hurricane flooding, in sub-areas A, B, and portions of C and D, serve as a major constraint to development. In order to advance the plans for future development, several flood reduction measures were analyzed. The primary purpose was to develop measures yielding a 100-year BFE equal to natural ground elevations in the study area.

**PROPOSED CONDITIONS**

Four flood reduction measures to reduce hurricane and rainfall flood stages were investigated: 1) ultimate conditions, 2) scenario A, 3) scenario B, and 4) scenario C. The investigated plans considered options such as levees, pumps, and culverts. Flood reduction features in the above four measures considered guidelines and specifications developed by the Federal Emergency Management Agency (FEMA). Retention ponds and land filling were considered during the analysis, but not deemed feasible due to required acreage and cost. Implementation of flood reduction measures will enable the Chitimachas to develop a floodplain management plan required for participation in the National Flood Insurance Program (NFIP).

**Ultimate Conditions**

Flood reduction measures were emulated for protection against hurricane and rainfall events assuming urbanized conditions throughout the study area. The measure called for a 100-year hurricane protection levee according to FEMA requirements, gravity drainage structures designed to drain a 5-year rainfall event, and 25-year rainfall frequency pumping stations (see Figure 2). The gravity drainage facilities were designed to drain a 5-year rainfall event yielding minimal or no flooding in the 950-acre study area. The primary purpose of these structures was to provide an outlet for typical rainfall events, thus eliminating the need for day-to-day pumping. Based upon hydrologic boundaries (roads, railroads), existing elevations, and natural drainage via Bayou Choupique, sub-areas A, B, and C each required a separate gravity drainage structure. Flow from sub-area D discharges into sub-area C without warranting any additional improvements. Scour protection will be required upstream and downstream of each drainage structure.

Forced drainage facilities drain the 25-year rainfall event with little or no flooding on the site during hurricane or non-hurricane conditions. Two 125 cubic feet per second (cfs) pumps, two 95-cfs pumps, and three 267-cfs pumps are required for sub-areas A, B, and C, respectively. Runoff from area D flows to the pumping facility in area C via gravity.

Based upon average ground elevations in sub-areas A, B, and D, flooding is not expected to occur as a result of rainfall or hurricane events under ultimate conditions. Under this measure, sub-area C would be the only area to experience rainfall flooding as a result of the 100-year rainfall. In this
area, only a small percentage of the area would experience nuisance flooding, approximately 7.4 inches. Inundation will be overcome by using fill material in all proposed construction in area C. The 100-year hurricane would not yield flooding in sub-area C.

Although ultimate conditions is expected to provide 100-year flood relief to the study area, three additional scenarios, A, B, and C, were investigated to determine flood conditions if the characteristics of the pumps or culverts were modified. These scenarios were investigated to provide "qualitative and quantitative decision making information" to the Chitimachas.

**Scenario A**

This scenario emulated a flood reduction measure that consisted of a 100-year hurricane levee in place (same levee layout as ultimate conditions), 100-year gravity drainage in lieu of 5-year gravity drainage (same location as ultimate conditions), and no pumping capacity. The rationale for investigating this scenario was to determine if lower frequency culverts (100-year) would be feasible in draining the study area without the use of pumps under non-hurricane conditions. Based upon the HEC-1 model, three 60-inch, two 60-inch, and five 60-inch diameter corrugated metal pipes were required for sub-areas A, B, and C, respectively. Sub-area D would be drained by the gravity drainage structure located in sub-area C. The 950 acres can be effectively drained for storms up to the 100-year frequency via the gravity drainage described above for each sub-area. As mentioned above, this scenario is for rainfall flooding only without the condition of hurricane tidal surge.

**Scenario B**

This scenario emulated the same flood reduction measure as scenario A, but under hurricane conditions, i.e. 100-year tidal conditions (+10.0 NGVD) on the unprotected side of the levee system. As in scenario A, forced drainage (pump stations) was not used, and the culverts were not allowed to flow due to surge conditions. The reason for investigating this scenario was to determine how interior flooding would be affected, and to what limits, if any, would new development be required to elevate finished floor elevations to obtain flood insurance.

Based upon the above data and average ground elevations, the 950 acres would be subjected to flooding under scenario B. Sub-areas A, B, C, and D would be subjected to approximately 1, 2, 4, and 3 feet of flooding, respectively, during the 100-year rainfall and hurricane events. This implies that in sub-area A, development may be feasible without the use of forced drainage, but would require hurricane levee protection and gravity drainage for non-surge conditions. Although the BFE can be reduced in sub-area B, the reduction is not significant, and it appears forced drainage, as well as hurricane levee protection and gravity drainage, is necessary. The BFE
increased from +10.00 to +11.55 for sub-areas C and D. Therefore, to reduce flooding in sub-areas B, C, and D below the current BFE, forced drainage is warranted, as shown in the ultimate conditions investigation.

**Scenario C**

This scenario emulated the same flood reduction features as ultimate conditions. However, the design constraints allowed for "nuisance" flooding over the entire study area. The reason for this constraint was to reduce pump size by allowing for "minimal" flooding.

This investigation showed that two 118-cfs, two 89-cfs, and two 363-cfs pumps would be appropriate for sub-areas A, B, and C, respectively. With respect to the pump sizes determined under ultimate conditions, the reduction in forced drainage capacity is minimal, and thus a significant cost savings is not anticipated.

**Construction Costs**

Based on a unit cost of $5.50 per cubic yard, construction costs for filling would easily exceed $25 million plus required interior drainage improvements. This alternative was determined cost prohibitive. One hundred-year levee construction costs are estimated at $2.3 million, 25-year forced drainage costs are estimated at $6.0 million, and 5-year gravity drainage costs are estimated at $600,000.

**Recommendations**

This study provides decisionmaking information to the Chitimachas with respect to future development. A key consideration to future development is following FEMA regulations, specifically developing according to the FEMA 100-year BFE, in order to participate in the NFIP.

The current BFE in the study area is well above natural ground elevation. Thus flood reduction improvements are warranted. A 100-year hurricane protection levee is necessary to prevent surge inundation. However, if levee protection is provided without forced drainage, the BFE will increase in sub-areas C and D due to interior ponding. Although the BFEs in sub-areas A and B would decrease without forced drainage, fill requirements would remain cost prohibitive. Thus, to effectively reduce the BFE, 25-year forced drainage is required. In addition, 5-year gravity drainage is recommended to drain high-frequency events to reduce pump operation and maintenance costs.
COMPARISON OF VERIFIED ROUGHNESS COEFFICIENTS FOR GRAVEL-BED STREAMS IN CENTRAL ARIZONA WITH OTHER AREAS OF THE WESTERN UNITED STATES

Jeff V. Phillips and Todd L. Ingersoll
U.S. Geological Survey

INTRODUCTION

Manning’s roughness coefficient, n, commonly is used to represent flow resistance for hydraulic computations of flow in open channels. The procedure for selecting n values is subjective and requires judgment and skill developed primarily through experience. The expertise necessary for proper selection of n values can be obtained, in part, by examining characteristics of channels with known or verified roughness coefficients.

In cooperation with the Flood Control District of Maricopa County, Arizona, the U.S. Geological Survey has undertaken a two-phase investigation to assess n values for stream channels in central Arizona. Thomsen and Hjalmarson (1991) concluded the first phase by publishing guidelines for determining n values and presented estimated n values for 16 stream channels in central Arizona. Phase two objectives include determining the validity of phase one results by verifying Manning’s n for representative streams.

This paper presents verified n values for 13 discharge measurements at 5 selected gravel-bed streams in central Arizona and compares them with data from similar studies in other areas of the western United States. The verification data are used to develop an empirical relation between Manning’s n, hydraulic radius, and median grain size. This relation can be used to transfer results to similar gravel-bed stream channels.

DATA COLLECTION

Site-selection and data-collection techniques used in this study generally were selected to meet, as closely as possible, criteria presented by Jarrett and Petsch (1985) for accurate n-verification measurements. Discharge

*This manuscript benefited substantially from helpful discussions with H. Hjalmarson, T. Lehman, J. Tran, B. Aldridge, R. Jarrett, K. Nolan, and J. Capesius.*
Comparison of Verified Roughness Coefficients for Gravel-Bed Streams

used for each of the verification measurements was obtained by the current-meter method or from a well-defined stage-discharge relation. A transit-stadia survey was done at each reach either at the time of the current-meter measurement or soon after flow subsided to obtain accurate water-surface elevation and channel-geometry data. A particle-size distribution of the bed material was obtained by measuring the intermediate axis of 100 particles selected at random from the study reach (Benson and Dalrymple, 1967). These data were generally obtained after flows and used to determine median grain-size diameter \(d_{50}\) for each site.

**DATA ANALYSIS**

**Computation of Manning's n**

The fundamental equations on which many open-channel hydraulic computations are based include the Manning, the continuity, and the energy equations. The computer program NCALC, developed by Jarrett and Petsch (1985), is based on these equations and was used to compute the values of total roughness \(n\) presented in this report (Table 1).

**Table 1. Summary of verification measurements including the magnitude of total \((n)\) and base \((n_b)\) roughness, the factors required to adequately describe flow resistance, and various channel and hydraulic parameters.**

<table>
<thead>
<tr>
<th>Date</th>
<th>Discharge ((\text{cfs}))</th>
<th>(n)</th>
<th>(n_b)</th>
<th>(n_r)</th>
<th>(n_t)</th>
<th>(n_u)</th>
<th>(m)</th>
<th>(R) ((\text{ft}))</th>
<th>(d_{90}) ((\text{ft}))</th>
<th>(R/d_{90})</th>
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<td>0.000</td>
<td>0.000</td>
<td>1.0</td>
<td>1.29</td>
<td>0.28</td>
<td>4.61</td>
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<td>0.000</td>
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<td>0.036</td>
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<td>0.000</td>
<td>0.000</td>
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<td>1.71</td>
<td>0.29</td>
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<td>0.035</td>
<td>0.000</td>
<td>0.000</td>
<td>0.000</td>
<td>1.0</td>
<td>0.90</td>
<td>0.29</td>
<td>3.10</td>
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<td>0.034</td>
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<td>0.98</td>
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<td>0.030</td>
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<td>0.31</td>
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<td>3.94</td>
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<td>0.000</td>
<td>0.000</td>
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<td>1.0</td>
<td>1.00</td>
<td>0.36</td>
<td>2.78</td>
</tr>
</tbody>
</table>
Components of Manning's n

The general approach for estimating resistance to flow in stream channels is to first select a base value of n for the bed material (Thomsen and Hjalmarson, 1991). The base value of Manning's n (nb) is represented by the size and shape of the grains of the material that form the wetted perimeter and produce a retarding effect on flow (Chow, 1959). Cross-section irregularities (n1), channel alignment (n2), obstructions (n3), vegetation (n4), are then added to the base value of n; and the n value is then multiplied by a correction factor for channel meandering (m). Because the sites were selected for reach and cross-sectional uniformity (Jarrett and Petsch, 1985), factors or components of n (n1 through n4) at the sites were considered to have no effect on total roughness (Table 1).

Base Value of Manning's n for Gravel-Bed Streams

In the absence of vegetation and other bank obstructions, roughness in a uniform gravel-bed stream generally decreases with increasing depth (see Table 1). As flow approaches bankfull stage, however, roughness may asymptotically approach a constant value, as shown by several previous investigations (Blodgett, 1986; Benson and Dalrymple, 1967).

The basic roughness coefficient for gravel-bed streams should not vary greatly with depth of flow if the relative roughness (ratio of hydraulic radius, R, to intermediate diameter of the streambed material, d50) is between about 5 and 276 (Benson and Dalrymple, 1967). Existing data indicate trends between hydraulic radius, median grain-size diameter, and verified base values of n for gravel-bed streams in some regions of the United States. For example, Blodgett (1986) examined verified values of n for 48 perennial gravel-bed streams in California, Colorado, Idaho, Montana, and Washington. Blodgett developed an equation that relates Manning's n to hydraulic radius (assumed to approximate mean depth of flow) and median grain size of the bed material (Table 2). A similar equation was developed for gravel-bed streams in central Arizona.

Table 2: Equations for the relation between base values of Manning's n, hydraulic radius (R), and median diameter of bed material for gravel-bed streams.

<table>
<thead>
<tr>
<th>Source</th>
<th>Equation</th>
<th>Range in d50 (ft)</th>
<th>Range in Manning's n</th>
<th>Correlation Coefficient</th>
<th>Location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blodgett (1986)</td>
<td>n = 0.0226 R^{1/4} 0.794 + 1.85 log R/d50</td>
<td>(1) 0.035 to 1.5</td>
<td>0.020 to 0.150</td>
<td>0.66</td>
<td>western U.S. (excluding arid regions)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Maricopa County, Arizona, U.S.</td>
</tr>
<tr>
<td>central Arizona</td>
<td>n = 0.0226 R^{1/4} 1.46 + 2.23 log R/d50</td>
<td>(2) 0.28 to 0.36</td>
<td>0.030 to 0.038</td>
<td>0.93</td>
<td></td>
</tr>
</tbody>
</table>
Manning's $n$ is plotted against relative roughness to compare data for gravel bed streams in different sites in the western U.S. (Figure 1). To compare the equations developed (see Table 2), trendlines also are plotted for $d_{50}$ values equal to 0.3 feet and $R$ values between 0.6 and 6 feet.

**DISCUSSION**

Although several of the verified $n$ values incorporated into Blodgett's data set are in close proximity to the data obtained from streams in central Arizona (see Figure 1), most $n$ values are substantially larger for similar values of relative roughness. If the equations presented are to be properly used as aids in determining base values of Manning's $n$, adequate descriptions of channel characteristics from which the data were obtained must be presented. This discussion, therefore, presents potential factors that may account for the differences between the data sets (Figure 1).

As noted by Blodgett (1986), the large scatter in data points of the verification measurements used to develop equation 1 may reflect extraneous flow-retarding effects associated with irregularities in bank shape and changes in channel alignment. Many of the sites used by Blodgett are located in relatively pristine mountain areas where streams are unhindered by human influences. Three of the central Arizona sites, however, are located in river reaches that have been channelized. In

![Figure 1. Relation of Manning's $n$ and relative roughness for gravel-bed stream channels in central Arizona and the western United States. For simple comparison of equations, the value of $d_{50}$ used to plot the trendlines is constant and equal to 0.3 feet.](image)
addition to stabilizing channel banks, channelization projects generally
tend to increase conveyance by straightening rivers, potentially resulting
in a decrease of flow-retarding effects associated with channel meanders
and other irregularities. Anthropogenic effects to river systems, therefore,
may be one explanation for the differences in the data sets (Figure 1).

Another explanation may be that the selected sites in central Arizona
lie at relatively large distances from the river's source, where the stream
is considered base level. For base-level streams, individual particles can
be rounder, and grain-size distributions may reflect better sorting and
homogeneity than particles in higher-gradient piedmont channels (Leopold
et al., 1964). Many streams used by Blodgett (1986) are higher-gradient
piedmont streams. As suggested by Leopold et al. (1964), for these types
of channels, particles that are substantially larger than the median can
play an important role in flow resistance by increasing local energy losses
and, compared to base-level streams with similar values of \( d_{50} \), greater
turbulence may occur near the channel bed, resulting in larger values of
\( n_b \). Additionally, the range in median diameter of particles for streams in
central Arizona is much narrower than the range used to develop the
equation for gravel-bed streams located in other states in the western
United States (see Table 2). The sites with relatively large median grain
sizes (boulder channels with values of \( d_{50} \) up to 1.5 feet, for example)
that were employed in the development of Blodgett’s equation may have
had a disproportionate effect on roughness, a consequence that may skew
or weight the line of best fit toward higher values of \( n \).

A final explanation for the apparent shift in relations may be found
by examining photographs and descriptions of Blodgett’s (1986) sites.
Although somewhat conjectural, the examinations indicate that the flow-
retarding effects associated with bank vegetation may have contributed to
the overall value of \( n \). Several of the sites in question are presented in
Barnes (1967). If the contribution of bank vegetation to total flow
retardance was not considered at a substantial number of sites, the result
could be an apparent upward shift for the relation between \( R \), \( d_{50} \), and \( n \)
(see Figure 1). Sites used to develop equation 2 for gravel-bed streams in
Arizona, however, were carefully examined so that no extraneous flow-
retarding elements (such as bank vegetation) contributed to \( n_b \).

Whatever the cause for the differences in verified \( n \) values for the
separate regions of the United States, the vertical difference between
trendlines indicates the application of Blodgett’s equation to gravel-bed
streams in central Arizona may result in gross overestimates of \( n_b \) (see
Figure 1). Fortunately, recently published guidelines for estimating \( n \)
values in Maricopa County suggest values of \( n_b \) similar to those obtained
from equation 2 (Thomsen and Hjalmarson, 1991).
SUMMARY AND CONCLUSIONS

Thirteen roughness coefficients determined for five selected gravel-bed stream channels in central Arizona are presented here. Computed roughness-coefficient values ranged from 0.030 to 0.038 and median size of the streambed material ranged from 0.28 to 0.36 ft. Hydraulic radius, median grain-size diameter, and the verified n values obtained from streams in central Arizona were used to develop an equation that can be applied to similarly characterized streams. The data obtained for gravel-bed streams in central Arizona are compared to data gathered for other sites in the western United States. Although the equations derived for the separate regions are similar in form, the vertical difference between trendlines suggests the application of Blodgett's equation to gravel-bed streams in central Arizona may result in gross overestimates of n_b. The data set from which equation 2 is derived is limited in size and range and caution must be exercised if the equation is applied to channel conditions substantially beyond the range of data. Further study is required to extend equation 2 to larger flow depths similar to those at flood stages.

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Blodgett, J.C.

Chow, V.T.

Jarrett, R.D., and H.E. Petsch Jr.

Leopold, L.B., M.G. Wolman, and J.P. Miller

Thomsen, B.W., and H.W. Hjalmanson
CONTINUOUS HYDROLOGIC AND HYDRAULIC MODELING FOR FLOODPLAIN MAPPING ALONG THE WEST BRANCH DUPAGE RIVER, DUPAGE COUNTY, ILLINOIS

Frank Lan, Steve Rogers and John Sikora
Woodward-Clyde Consultants

Jeff Dailey
DuPage County Department of Environmental Concerns

INTRODUCTION

A new approach for estimating floodplain limits using continuous-simulation modeling and statistical analysis on the simulated peak stages was performed for the West Branch DuPage River in Illinois. FEQ, a one-dimensional unsteady flow hydraulic model with flood routing capabilities is coupled with a continuous-simulation hydrologic model to compute flood hydrographs and river stages.

The model was constructed using a large amount of field surveyed data consisting of river and floodplain cross sections and hydraulic structure data. The river network was divided into computational branches connected by representations for hydraulic structures, such as bridges, culverts, reservoirs, spillways, etc. The main stem model has approximately 100 branches, 20 reservoirs, 5 braided sections of channel, 3 in-stream dams and 55 bridges, culverts, and other hydraulic structures. The watershed hydrology was simulated using HSPF (EPA, 1993) and was developed using land use data, soil type information, and precipitation and evaporation records for the area. The precipitation data was obtained from six rain gages with approximately 50 years of record.

The hydraulic model was calibrated to U.S. Geological Survey continuous recording stream gauge records and high water marks along the river for recent large storm events. The calibrated model was verified by comparing simulation results with recorded peak discharges, stages, and volumes for a 50-year continuous record period through 1994. The calibrated model will ultimately be used to determine flood levels and delineate the floodplain for the West Branch DuPage River watershed based on a peak-to-volume statistical analysis that utilizes the simulated peak stages and flow volumes to estimate peak stage exceedence probabilities. In addition, the model has been used and will continue to be
used for evaluating strategies for floodplain management and flood hazard reduction within the basin.

The West Branch DuPage River flows through a developing area of DuPage County, Illinois, a suburban area approximately 80 km (50 miles) west of Chicago. The West Branch DuPage River has a drainage area of 328 km² (126.7 mi²), a main channel length of 51.2 km (32.0 miles), and an average channel slope of 0.06%. The watershed is predominantly residential with some light industry, business, roads, and open space. The watershed has approximately 66 km² (25.5 mi²) of impervious area. The river is prone to flooding due to its very flat slope and the large amount of development that has occurred in the watershed over recent years. The watershed is very complex and has large amounts of floodplain storage, low basin relief, a wide variety of hydraulic structures, and varying soil conditions.

The FEQ program (Linsley, Kraeger Associates, 1995) is a fully dynamic flood-wave-routing model. FEQ is designed to take outputs of a continuous hydrologic model to simulate the flood wave moving through river reaches and hydraulic structures. The continuous-simulation hydrologic model utilized in this analysis was the Hydrological Simulation Program-FORTRAN (HSPF) (EPA, 1993). The HSPF model was used to develop runoff time series of unit runoff for different combinations of land cover, soil type, and ground slope. The time series file is then used in the FEQ model to compute the lateral inflows to each branch and reservoir in the model. This approach differs from the standard engineering practice where a single-event rainfall-runoff model is developed and a steady-state hydraulic model is used. The continuous-simulation unsteady flow model has many advantages, including:

- backwater and floodplain storage effects are represented;
- historical precipitation records can be utilized to produce long, continuous flow records;
- actual storm events are simulated rather than hypothetical events that never occurred;
- spatial and temporal patterns of rainfall are considered;
- soil moisture conditions are tracked from storm to storm;
- potential impacts of development on flooding can be simulated;
- effects of proposed flood hazard mitigation projects can be simulated; and
- frequency analysis can be carried out on water levels from continuous simulation rather than on storm rainfall or peak discharges.
Model Development

The hydraulic model for the West Branch DuPage River was developed in three segments to facilitate model development and computational debugging. Figure 1 shows a schematic representation of the project area. The model was developed through a joint effort by Woodward-Clyde Consultants (WCC), Rust E&I, Linsley, Kraeger Associate, and DEC. The continuous hydrologic model, HSPF, was developed by the Northern Illinois Planning Commission (NIPC). Land use was based on DuPage County’s Planning Department 1990 Surveys and the subbasin areas were delineated using DEC’s 2-foot contour mapping (DuPage DEC, 1995) and USGS topography.

Surveying for the main stem of the West Branch DuPage River was performed by several surveying/engineering firms. Additional cross sections were extrapolated from the County’s digital topographic mapping when no other survey data was available.

Figure 1. West Branch DuPage River, DuPage County, Illinois.
A utility program, FEQUTL (Linsley, Kraeger Associates, 1995), was used to develop tabular representations of hydraulic through hydraulic structures including culverts, embankments, dams, and overflow. The Federal Highway Administration program WSPRO (U.S. Department of Transportation, 1990) was used to compute the flow characteristics at bridge openings.

**MODEL CALIBRATION AND VERIFICATION**

A flood in August 1987 was a large storm and was used to calibrate the model. For this event, rainfall amounts were adjusted to account for spatial variation of rainfall using factors based on a isohyetal map developed by DEC. The simulated flood elevations were compared with high water mark observations at stations supplied by the Illinois Department of Natural Resources, Office of Water Resources (Figure 2). In addition, simulated vs. observed hydrographs (both discharge and stage) at two USGS continuous recording gages were compared. Close agreement between simulated and observed high water levels, general shape of hydrographs, flow discharges, and water levels was achieved.

![Graph](image-url)

*Figure 2. Comparison of simulated and observed high water level during August 1987 storm.*
Figure 3. Comparison of predicted and recorded peak flow and flow volume for storm events from 1985 to 1994.
The model was utilized to simulate 30 storm events between 1985 and 1994 for model verification. Figure 3 shows the predicted versus recorded flow volumes and peak flow for these storms. These figures show a general agreement between simulated and observed flow volumes and peak discharges. The figures also indicate that the model underpredicts the flow volume slightly and over-predicts the peak flow. The model was then used to simulate 50 years of continuous flow records. The results from this simulation will be used to statistically determine exceedance probabilities for peak river stages.

**THE USE OF THE MODEL AS A FLOODPLAIN MANAGEMENT TOOL**

The FEQ model of the West Branch DuPage River has been used as a floodplain management tool. Structures and development within the floodplain can be easily modeled and the effects of these projects on the continuous simulation record can be determined, along with impacts of flood hazard mitigation measures. For example, the model was used to analyze the effects of different operating scenarios for an existing flood control reservoir on the West Branch that has not been used because of dam safety inefficiencies. The model predicted that the reservoir could be utilized to effectively reduce flooding potentials downstream without adversely impacting upstream residences. As a result, design measures to rehabilitate the dam to meet dam safety regulations and an operation scheme for the reservoir have been proposed.

**REFERENCES**

**DuPage County, Department of Environmental Concerns**

**Linsley, Kraeger Associates, Ltd.**

**Linsley, Kraeger Associates, Ltd.**

**U.S. Department of Transportation**

**U.S. Environmental Protection Agency**
INTRODUCTION

Estimates of the magnitude and frequency of flood-peak discharges and flood hydrographs are needed for many purposes, including the design of bridges and culverts, flood control structures, and floodplain management. These estimates are often needed at ungaged sites where no observed flood data are available for analysis. Two approaches are often used to estimate the frequency of flood-peak discharges and flood hydrographs at ungaged sites: (1) methods based on rainfall characteristics and a deterministic watershed model that uses equations and algorithms to convert rainfall excess to flood runoff, and (2) methods based on statistical (regression) analysis of data collected at streamflow-gaging stations.

For many years, the U.S. Geological Survey (USGS) has developed regional regression equations for estimating flood magnitude and frequency at ungaged sites. These equations are developed by relating flood-peak discharges at streamflow-gaging stations to watershed and climatic characteristics that explain the variability in flood characteristics from site to site. Flood-peak discharges, such as the 100-year or 1% annual chance flood, are estimated at ungaged sites by the use of the regression equations and watershed and climatic characteristic values that are measured from topographic maps or taken from precipitation-frequency reports. The regression equations generally are developed for statewide or metropolitan-area usage as part of cooperative studies with such agencies as the state department of transportation (DOT). Most state DOTs use the regression equations to estimate flood discharges needed in the design of bridges and culverts. Furthermore, the Federal Emergency Management Agency (FEMA) recommends USGS regression equations for estimating flood-peak discharges for ungaged streams for floodplain management purposes as part of the National Flood Insurance Program (Federal Emergency Management Agency, 1995).
In 1993, the USGS, in cooperation with FEMA and the Federal Highway Administration, compiled all the current (as of September 1993) USGS statewide and metropolitan-area regression equations and incorporated them into a computer program titled the National Flood Frequency (NFF) Program (Jennings et al., 1994). The computer program contains regression equations for estimating flood-peak discharges and techniques for estimating a typical flood hydrograph for a given recurrence-interval or percent-chance flood for rural and urban watersheds. Since 1993, new or updated regression equations have been developed by USGS for various areas of the nation. These new equations are being incorporated into an updated version of NFF.

**Version 3.0 of the National Flood Frequency Program**

The USGS, in cooperation with FEMA, is (1997) revising and improving the NFF program and documentation by (1) updating the regression equations for states that have published new ones since September 1993, (2) converting Version 1.4 of NFF, a DOS program, to a Windows application, (3) improving the user interface and graphical output, (4) providing the option of computing flood-peak discharges in inch-pound or metric units, and (5) providing a more complete description of the input data and the limitations and accuracy of the statewide equations.

Since September 1993, USGS regression equations have been published for Alabama, Alaska, American Samoa, Arkansas, Delaware, Georgia (urban watershed equations), Hawaii (Island of Oahu), Maryland, Missouri, New Mexico, North Carolina (urban watershed equations) and Virginia. These new equations are being added to NFF in addition to urban watershed equations for South Carolina that were inadvertently omitted previously. Updating regression equations is a part of ongoing USGS cooperative programs with state agencies and selected cities.

Equations in Version 1.4 of NFF are described and documented by Jennings et al., (1994). Future updates of the documentation will be published as individual fact sheets for each state, thereby keeping each state’s documentation current. Fact sheets for each state and the NFF computer program are available at http://water.usgs.gov/software/.

**Capabilities of the National Flood Frequency Program**

As noted earlier, NFF has regression equations for estimating flood-peak discharges and a typical hydrograph for a given flood. Regression equations for Alabama (Atkins, 1996) are used to illustrate the new format for describing the input data to NFF and the accuracy and limitations of the regression equations for Alabama.
Alabama is divided into four hydrologic regions (Figure 1). The regression equations were developed from data at 270 streamflow-gaging stations in Alabama and parts of adjacent states. The regression equations, average standard errors of prediction, equivalent years of record, and the applicable range of watershed characteristics (drainage area in this example) are shown in Table 1 for region 1 only.

**Table 1. Regression equations for estimating flood-peak discharges for streams that drain rural areas in Alabama.**

(Q<sub>T</sub>, peak discharge, in cubic feet per second, for recurrence interval T; A, drainage area).

<table>
<thead>
<tr>
<th>Regression equation</th>
<th>Average standard error of prediction (percent)</th>
<th>Equivalent years of record</th>
<th>Applicable range of drainage area (square miles)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Q&lt;sub&gt;2&lt;/sub&gt; = 227A&lt;sup&gt;0.672&lt;/sup&gt;</td>
<td>35</td>
<td>3</td>
<td></td>
</tr>
<tr>
<td>Q&lt;sub&gt;5&lt;/sub&gt; = 374A&lt;sup&gt;0.669&lt;/sup&gt;</td>
<td>34</td>
<td>4</td>
<td></td>
</tr>
<tr>
<td>Q&lt;sub&gt;10&lt;/sub&gt; = 428A&lt;sup&gt;0.668&lt;/sup&gt;</td>
<td>35</td>
<td>5</td>
<td></td>
</tr>
<tr>
<td>Q&lt;sub&gt;25&lt;/sub&gt; = 627A&lt;sup&gt;0.668&lt;/sup&gt;</td>
<td>37</td>
<td>7</td>
<td></td>
</tr>
<tr>
<td>Q&lt;sub&gt;50&lt;/sub&gt; = 739A&lt;sup&gt;0.667&lt;/sup&gt;</td>
<td>39</td>
<td>7</td>
<td>0.44 - 1027</td>
</tr>
<tr>
<td>Q&lt;sub&gt;100&lt;/sub&gt; = 855A&lt;sup&gt;0.667&lt;/sup&gt;</td>
<td>41</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Q&lt;sub&gt;500&lt;/sub&gt; = 1,135A&lt;sup&gt;0.666&lt;/sup&gt;</td>
<td>46</td>
<td>9</td>
<td></td>
</tr>
</tbody>
</table>

The average standard error of prediction is a single measure of the accuracy of the regression equations when predicting peak discharges for similar ungaged watersheds. The equivalent years of record is another accuracy measure and represents the years of streamflow record needed to equal the accuracy of the equation. The applicable range of drainage area informs the user of the applicability of the equations. The predicted discharges have a higher standard error of prediction and lower equivalent years of record when drainage area is used outside the quoted range.

Regression equations for estimating flood-peak discharges for urban watersheds in Alabama also are available (see Olin and Bingham, 1982). They are based on drainage area, in square miles and percentage of the drainage area that is impervious. The equations were developed from data from 23 streamflow-gaging stations in Alabama. Flood characteristics can also be estimated for urban watersheds in Alabama and all other states by nationwide regression equations developed by Sauer et al. (1983).
Figure 1. Flood frequency regions for Alabama.
Figure 2. Example computation of flood discharges and hydrographs for a 15-square-mile watershed in Alabama.
Flood hydrographs can be estimated for a given flood-peak discharge using a dimensionless hydrograph method described by Inman (1987). Inman's method is applied by estimating the peak discharge from regression equations provided in NFF, estimating the basin lagtime, and using the dimensionless hydrograph ordinates to estimate a design hydrograph. The user must provide an estimate of basin lagtime for rural watersheds but can use the urban lagtime equation developed by Sauer et al. (1983) included in the NFF program. The dimensionless hydrograph ordinates used by NFF in estimating flood hydrographs are those developed by Inman (1987) using streamflow data for rural and urban watersheds in Georgia. This technique has been applied nationwide with reasonable accuracy, except in some flat, slow-runoff areas.

Figure 2 shows a screen from an NFF session after computing rural and urban flood-peak discharges for a 15 square-mile watershed in region 1 in Alabama. The plot shows the average, or typical, hydrograph for both the rural and urban 2-year recurrence interval flood. The urban discharges and hydrograph were computed from the Sauer et al.'s (1983) nationwide regression equations, but could have been computed from the Alabama urban equations of Olin and Bingham (1982). As shown, the user interface and graphics in Version 3.0 are improved.

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COMPUTING FLOODWAYS
WITH UNSTEADY FLOW MODELS

Moe Khine
Dewberry & Davis

Richard Laramie
Camp Dresser & McKee, Inc.

INTRODUCTION

Whereas steady flow models use peak discharges to compute water surface elevations, unsteady flow models route the discharge hydrographs hydraulically through the stream system to determine water surface elevations. Traditionally, floodways are determined by steady flow models using the equal conveyance reduction principle, and discharges for the unencroached and encroached conditions are considered to be the same. In reality, however, the discharges for the encroached condition can be higher than for the unencroached condition because of the reduction in floodplain storage if the fringe areas are allowed to fill. The situation is exacerbated in the case of a fully developed watershed. Because of this problem, a procedure was established to determine floodways using an unsteady flow model, which considers the equal conveyance reduction principle and the loss of floodplain storage in computing floodway widths. The procedure was applied to a flood insurance study in Puerto Rico. Hydrologic computations were performed by M.I.T. Catchment (MITCAT) program, hydraulic computations were performed by the National Weather Service DAMBRK unsteady flow program, and floodway widths were determined by the Natural Resources Conservation Service (NRCS) FLDWY program. The same procedure can be followed by using other Federal Emergency Management Agency (FEMA) accepted hydrologic, unsteady flow, and steady flow programs.

NFIP Regulations and FEMA Policies

NFIP regulations 44 CRF 65.6(a)(6), 65.6(e), 65.7(b)(4)(i) and suggestions in FEMA document #37, Guidelines and Specifications for Study Contractors, were followed in establishing the procedure and selecting the programs.
PROCEDURE

The following procedure should be followed to determine floodways when using an unsteady flow model.

(1) The hydrologic parameters should be calibrated and verified with the known storms. The peak discharges and volume of hydrographs for different frequencies of floods should be checked against log Pearson Type 3 analysis based on the Bulletin 17 B guidelines at gaging stations or U.S. Geological Survey (USGS) regression equations.

(2) The roughness coefficients and losses at the structures in an unsteady flow model should be verified with the known high water marks.

(3) After the hydrologic and hydraulic parameters are calibrated and verified, the discharges and corresponding water surface elevations for 1% annual chance flood at the cross sections in the unsteady flow model should be determined.

(4) The unencroached discharges and the corresponding water surface elevations for the 1% annual chance flood at the cross sections in the unsteady flow model should be used to determine the floodway widths based on the equal conveyance reduction principle. The present unsteady flow programs cannot perform this task internally. The NRCS FLDWY program or the U.S. Army Corps of Engineers (USACE) HEC-2 program can be used to determine the floodway widths for different surcharge values. When using the HEC-2 program, the X5 record must be used at each cross section to specify the water-surface elevations from the unsteady flow model for the unencroached discharges.

(5) The cross sections in the unsteady flow model should be cut off at the encroachment stations obtained from step 4 and the water surface elevations should be recomputed. The water surface elevations thus obtained are for the encroached condition assuming that the floodway fringe areas will be filled. The difference between the encroached and unencroached water surface elevations will give the surcharge value. This value should not be more than the allowable value. The floodway can be optimized by rerunning the unsteady flow model several times selecting different encroachment stations from different target surcharge values determined in step 4.
If the floodway fringe is already developed, it should be possible to consider the storage in the fringe area as storage area but not as the conveyance area in the computations of the unsteady flow model. However, the present unsteady flow models do not provide this option.

**APPLICATION OF THE PROCEDURE**

The above procedure was applied to Rio Espiritu Santo basin in Puerto Rico. The previous effective study for the basin was dated December 1990. The 1% annual chance flood elevations and the floodways were determined by the HEC-2 program. CMA Architects & Engineers (CMAAE), consulting engineers for the Coco Beach project (Coco Beach is on the eastern bank of Rio Espiritu Santo near its mouth), submitted an analysis performed by Camp Dresser & McKee (CDM) to revise the effective study analysis. After coordination among CMAAE, CDM, FEMA, and Dewberry & Davis (D&D) (technical evaluation contractor for FEMA), it was decided that the MITCAT program would be used for the hydrologic analysis, the DAMBRK program would be used for the unsteady flow analysis, and the FLDWY program would be used for the floodway width computations.

**Project Area**

The Rio Espiritu Santo basin lies on the northeastern coast of Puerto Rico. The Rio Espiritu Santo has a drainage area at its mouth of about 29.8 square miles. The largest tributary is the Rio Grande, the mouth of which is just downstream from the bridge crossing at Puerto Rico Highway 3 east of the Town of Rio Grande. Before reaching the ocean, the Rio Espiritu Santo flows through a low-lying coastal area between Highway 3 and the ocean. This coastal plain area is approximately 3 miles wide, and a great part of it is covered with mangrove swamp forests. On the eastern side of the coastal plain, Quebrada Gonzalez and Quebrada Suspiro also drain into the Rio Espiritu Santo.

**Calibration of the MITCAT Model**

The October 1970 storm (Haire, 1975) was selected to calibrate the MITCAT model.

**Calibration of the DAMBRK Model**

The October 1970 storm was used to calibrate the DAMBRK model, and the September 1960 storm was used to verify the parameters.
Design Storm Hydrograph Development

Four-day design storm hyetographs were developed by using the rainfall depths from the U.S. Weather Bureau Technical Papers 42 and 53. The peak discharges of the resulting hydrographs from the MITCAT model compare very well with the results obtained from LP3 analysis at gage 638 on Rio Espiritu Santo.

Determination of the 1% Annual Chance Flood Elevations

The 1% annual chance hydrograph at the confluence of Rio Espiritu Santo and Rio Grande from the MITCAT model was inserted into DAMBRK model as the upstream boundary condition, and the combined flows of Quebradas Gonzales and Suspiro were input as the lateral inflow hydrograph. A constant stage of 3.28 feet was used as the downstream boundary condition. The 1% annual chance water surface elevations and the corresponding discharges at 11 cross sections obtained from the DAMBRK model were then used to determine the floodway widths.

Determination of the Floodway Widths

The NRCS FLDWY program was used to determine the floodway widths based on the equal conveyance reduction principle for target surcharge values of 0.1, 0.3, 0.5, 0.7, 0.8, 1.0, 1.2, 1.5, and 2.0 feet. The FLDWY program also provides left and right encroachment stations corresponding to the floodway widths.

Determination of the Floodway Water Surface Elevations

As the first attempt, the ground stations outside the encroachment stations at cross sections A through K for a target surcharge value of 1 foot were eliminated. The topwidth-stage relationships at each cross section in the DAMBRK model were then revised. The DAMBRK model was rerun using the same 1% annual chance hydrographs from the unencroached (natural) condition at the upstream boundary and at the lateral inflow location. The downstream boundary condition was fixed at 4.28 feet. The computed water surface elevations represent the floodway water surface elevations. The difference between the floodway water surface elevation and the natural water surface elevation is equal to the true surcharge value. Several trial runs were performed by selecting different floodway widths at different cross sections until the surcharge values were not more than the allowable value of 1 foot at any cross section. The final selected floodway widths for different target surcharge values and the computed surcharge values at cross sections A through K are shown in Table 1.
Table 1. Target surcharges, floodway widths, and computed surcharges.

<table>
<thead>
<tr>
<th>Cross Sections</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>0.1</td>
<td>0.1</td>
<td>2.0</td>
<td>1.2</td>
<td>0.5</td>
<td>1.5</td>
<td>0.7</td>
<td>0.5</td>
<td>1.2</td>
<td>&lt;0.1</td>
<td>1.7</td>
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<tr>
<td>Floodway</td>
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<td>4481</td>
<td>4392</td>
<td>3609</td>
<td>2433</td>
<td>4065</td>
<td>3324</td>
<td>2057</td>
<td>1130</td>
<td>615</td>
</tr>
<tr>
<td>Computed</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.9</td>
<td>1.0</td>
<td>1.0</td>
<td>0.9</td>
<td>0.8</td>
<td>0.2</td>
<td></td>
</tr>
</tbody>
</table>

Comparison of Discharges, Water Surface Elevations, and Surcharges between DAMBRK and HEC-2 Models

A HEC-2 model was created using the same cross sections and the final selected encroachment stations from the FLDWY model. The discharges from the unencroached condition run of the DAMBRK model were used for both the natural and floodway profiles of the HEC-2 model following the standard practice for flood insurance studies. (Please note that discharges for the unencroached and encroached runs for the DAMBRK models were different.) The roughness coefficients at the cross sections and the distances between the cross sections were the same for the DAMBRK and HEC-2 models. The cross sections, floodway widths, discharges from natural and floodway runs of DAMBRK models, with and without floodway water surface elevations, and surcharge values of DAMBRK and HEC-2 models are shown in Table 2.

Table 2. Comparison between DAMBRK and HEC-2 models.

<table>
<thead>
<tr>
<th>Floodway Width</th>
<th>Discharge</th>
<th>Without Fldwy</th>
<th>With Fldwy</th>
<th>Surcharge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Secno</td>
<td>Naturl</td>
<td>Fliday</td>
<td>HEC-2</td>
<td>HEC-2</td>
</tr>
<tr>
<td>A</td>
<td>451</td>
<td>45021</td>
<td>3.3</td>
<td>4.3</td>
</tr>
<tr>
<td>B</td>
<td>2374</td>
<td>45137</td>
<td>7.8</td>
<td>8.8</td>
</tr>
<tr>
<td>C</td>
<td>4481</td>
<td>47380</td>
<td>9.0</td>
<td>10.0</td>
</tr>
<tr>
<td>D</td>
<td>4392</td>
<td>48914</td>
<td>9.2</td>
<td>10.2</td>
</tr>
<tr>
<td>E</td>
<td>3609</td>
<td>42684</td>
<td>9.8</td>
<td>10.7</td>
</tr>
<tr>
<td>F</td>
<td>2433</td>
<td>44201</td>
<td>11.5</td>
<td>12.4</td>
</tr>
<tr>
<td>G</td>
<td>4065</td>
<td>47063</td>
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<td>H</td>
<td>3324</td>
<td>48667</td>
<td>13.3</td>
<td>13.4</td>
</tr>
<tr>
<td>I</td>
<td>2057</td>
<td>49599</td>
<td>14.2</td>
<td>14.1</td>
</tr>
<tr>
<td>J</td>
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<td>50712</td>
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</tr>
<tr>
<td>K</td>
<td>615</td>
<td>52078</td>
<td>22.7</td>
<td>23.9</td>
</tr>
</tbody>
</table>

COMPARISON OF DISCHARGES, WATER SURFACE ELEVATIONS, AND SURCHARGES BETWEEN DAMBRK AND HEC-2 MODELS
The following observations can be made by reviewing the results from the above table. The peak discharges for the floodway profile are increased when the same flood hydrographs of natural profile are routed through the floodway in the unsteady flow model. The increase is caused by the reduction in floodplain storage resulting from the assumption that the floodway fringe areas will be filled. The steady flow models cannot determine the change in peak discharges between the natural and floodway profiles caused by the reduction in floodplain storage. Therefore, the steady flow models underestimate the floodway discharges, and, consequently, the floodway water surface elevations will also be underestimated.

Using the same floodway widths, the surcharge values obtained from the unsteady flow model are close to the allowable surcharge value of 1 foot at the downstream cross sections while the steady flow model gives surcharge values much lower than the allowable surcharge value. The reason is that the steady flow models do not consider the hydrograph volume and only the peak discharges are used when computing the water surface elevations. If the steady flow model is used in this case, there is a potential that the floodway widths will be narrowed during a revision process by using higher target surcharge values, or simply narrowing the floodway widths using method 1 encroachment (for HEC-2) to raise the surcharge values to be close to the allowable surcharge value of 1 foot. If that procedure is followed, the true floodway water surface elevations can be much higher than what is computed by the steady flow model when the 100-year flood hydrograph passes through that narrower floodway since the present floodway is at the maximum allowable surcharge value at a couple of cross sections according to the unsteady flow model. Therefore, present flood insurance studies using steady flow models have a potential of reducing the floodway widths solely by looking at the surcharge values and not accounting for the volume of hydrograph and reduction of floodplain storage. This will defeat the intent of the National Flood Insurance Program to reduce the flood hazard.

**CONCLUSION**

A procedure was implemented to determine the floodways using unsteady flow models based on the present FEMA policies and regulations. This procedure can be applied to any combination of steady flow and unsteady flow models FEMA has accepted to be used for the flood insurance studies. Serious thought should be given to using unsteady flow models when restudies or new studies are performed. Communities should also use the same unsteady flow model to compute the hydrographs and corresponding water surface elevations for both the natural and floodway...
profiles based on the fully developed watershed conditions. FEMA and communities should work together to implement a combined flood insurance and floodplain management map based on the results from the unsteady flow models. FEMA should coordinate with the developers of the unsteady flow models to include a procedure within the unsteady flow models for determining the floodways based on the equal conveyance reduction principle and accounting the reduction of storage volume from 0 to 100% in the floodway fringe areas. If these recommendations can be implemented, the nation will be one step closer to reducing the flood hazard for the long term.

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ACCOUNTING FOR PLAYA STORAGE IN WEST TEXAS

Michael D. Vinson and Michael J. Latham
Michael Baker Jr., Inc.

INTRODUCTION

Drainage basins in some areas of west Texas contain natural depressions known as playas. A playa is a lake bed found in arid regions, in the lowest part of an enclosed valley with centripetal, or inward, drainage. During a storm that produces runoff, a playa acts as a retention pond. After the storm, the typically shallow depths of water in the playa are quickly evaporated.

Playa volumes can have a significant impact on hydrology. The playa volumes may vary from 1 acre-foot (ac ft) to over 1000 ac ft. The contributing drainage area to the playa also may vary from less than 1 square mile (sq mi), to over 40 sq mi, with no apparent correlation between the size of the drainage area and the size of the playa. The volume of a specific playa may have an insignificant effect on runoff peak, or may exceed the total runoff volume from that drainage area for a given storm.

Because of the lack of available stream gage data and the fact that regional regression equations may give erroneous results depending on the presence or absence of playas, rainfall-runoff models are frequently relied upon for determining discharge-frequency relationships. Rainfall-runoff models typically account for surface depression storage by subtracting the volume from the rainfall as an initial abstraction. Clearly, the playa volumes in west Texas are more extensive than typical surface depression storage. Based on the different results obtained using various modeling techniques, it is apparent that how the playa volumes are incorporated into the rainfall-runoff models can significantly affect the accuracy of the results.

RAINFALL-RUNOFF MODELING

Three methods of accounting for the playa volumes in rainfall-runoff models were tested to determine which approach provides the most reasonable results. The three methods were adjusting the land cover/use Natural Resource Conservation Service (NRCS) (formerly the Soil Conservation Service) Curve Number (CN) (U.S. Department of
Accounting for Playa Storage in West Texas

Agriculture, 1986) to incorporate the playa volumes into the precipitation losses; incorporating the playa volumes into the precipitation losses as an initial loss and a uniform loss rate; and modeling the playas as simple reservoirs.

The HEC-1 model (U.S. Army Corps of Engineers, 1991) was chosen due to the flexibility it offers for applying the three methods used to account for playa volumes. The Snyder's unit hydrograph procedure was used for consistency with other studies in the area. NRCS CN information was available to determine precipitation losses based on soils and land cover/use. Playa volumes were determined from topographic maps. Any drainage areas with playa volumes greater than the 500-year runoff volume were eliminated from the model.

For a detailed comparison, a 71 sq mi drainage area in Midland County, Texas, was modeled. The drainage area was subdivided into six subbasins, ranging in size from 5 sq mi to 22 sq mi. Each subbasin included playas, with volumes ranging from 190 ac ft to 510 ac ft. Figure 1 is a comparison of the runoff hydrograph from a single subbasin tested. Table 1 lists relevant data for the six subbasins.

---

**Table 1. Data for the six subbasins.**

<table>
<thead>
<tr>
<th>Drainage area (sq mi)</th>
<th>CN</th>
<th>Playa volume (ac ft)</th>
<th>Adjusted CN</th>
<th>Initial loss (inches)</th>
<th>Uniform losses (inches)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5.06</td>
<td>51</td>
<td>300</td>
<td>31</td>
<td>3.03</td>
<td>4.56</td>
</tr>
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<td>52</td>
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</tr>
<tr>
<td>22.07</td>
<td>59</td>
<td>510</td>
<td>56</td>
<td>1.82</td>
<td>1.34</td>
</tr>
</tbody>
</table>

The runoff characteristics of peak flow, total runoff volume, time-to-peak, and runoff hydrograph shape were evaluated for the individual subbasins, as well as larger subbasin combinations. The effects of the different modeling techniques were also evaluated for their impact on...
Figure 1. Comparison of hydrologic methods for single subbasin.
discharges at the downstream point of a 403 sq mi watershed. Each method is described in detail below.

**Adjusting the CN**

A composite CN was computed to account for playa volumes as well as the land cover/use precipitation losses. The total storm cumulative precipitation excess was computed based on the land cover/use CN and point rainfall using the NRCS rainfall-runoff relationships,

\[ Q = \frac{(P - Ia)^2}{(P + 0.8*S)}, \quad Ia = 0.2*S, \quad S = \frac{1000}{CN - 10}, \]

where CN is the soils and land cover/use parameter, Ia is the initial rainfall abstraction, S is the potential maximum abstraction, P is the cumulative precipitation, and Q is the cumulative precipitation excess. The playa volume, in inches (volume/drainage area), was added to Ia and subtracted from the total storm cumulative precipitation excess (Q). Using the increased initial abstraction (Ia = 0.2*S + playa volume) and the correspondingly reduced total storm cumulative precipitation excess, the adjusted CN was computed and input into the HEC-1 model.

The advantage to this approach is that all factors that contribute to hydrologic losses are accounted for in the adjusted CN and Ia. There are several disadvantages to this approach. The playa volumes are accounted for as rainfall losses, rather than runoff abstractions. With this method, the effects of the playa volumes on the runoff hydrograph become dependent on the total rainfall, when in fact the playa effects are independent of the rainfall. Since losses associated with CNs are dependent on rainfall, the use of different storm frequencies or the implementation of depth-area reduction requires the user to compute different adjusted CNs to maintain the correct runoff volume, due to the playa volumes being incorporated into the CNs. These factors combine to produce peak runoff discharges that appear to be low, as shown in Figure 1.

**Initial and Uniform Losses**

For this method, an initial abstraction, including the playa volume, was computed as Ia plus the playa volume, as previously computed. The uniform loss rate was then computed by trial and error to maintain the total storm runoff (for point rainfall). Results include a hydrograph similar in shape to the adjusted CN hydrograph, but with a higher peak discharge occurring at a later time (Figure 1). The NRCS rainfall-runoff relationships used in the CN method produce loss rates that vary depending on the rainfall with the maximum loss rate occurring during
the most intense period of rainfall. For the subbasins tested, the initial and uniform loss method had higher precipitation excess at the peak of the rainfall event, resulting in higher runoff peaks.

The advantages and disadvantages to this approach are similar to those of the adjusted CN method. The hydrologic losses are accounted for as initial and uniform precipitation losses. Different storm frequencies, or the implementation of depth-area reduction, require the user to compute different initial and uniform losses to maintain the correct runoff.

Using a depth-area reduction relationship, the precipitation decreases as the watershed area increases. The CN method inherently adjusts the precipitation losses, since they are rainfall-based. However, the adjusted CN, which incorporates playa volume, must still be recomputed in order to maintain the correct runoff volume. Using the initial and uniform loss rate method, the loss functions are not inherently adjusted for depth-area reduction; therefore, the initial and uniform losses must be recomputed to account for playa volumes and changes in precipitation. As shown in Figure 2, using a CN method, the rainfall excess is greater as the drainage area increases. The use of an initial and uniform loss rate can give runoff peaks and volumes that differ considerably from the adjusted CN method, depending on the drainage area size and the storm frequency.

**Accounting for Playa Volume by Reservoir Route**

This method used the original land cover/use CN. The playa volumes were accounted for by assuming a single playa at the downstream end of the subbasins. The runoff hydrograph was routed through the playa with zero outflow until the playa volume was satisfied, then inflow equaled outflow for the remainder of the flood event. As can be seen in Figure 1, while the playa volume affects the runoff hydrograph peak, the resulting peak discharge is considerably higher than those obtained using the two methods previously discussed.

There are many advantages to this method. First, the playa volumes are modeled as runoff abstractions, rather than as rainfall abstractions. Second, the playa volumes are consistent regardless of the depth of storm precipitation or the use of the depth-area relationship. This approach is also the most physically based of the approaches tested. The disadvantage is that the development of the rainfall-runoff model is slightly more time consuming.
Figure 2. Excess rainfall vs. drainage area.
CONCLUSIONS AND RECOMMENDATIONS

A rainfall-runoff model offers flexibility in methods to account for hydrologic phenomena. The modeler must use engineering judgment to select the method that will produce the most physically based model and yield the most reasonable results.

In accounting for playa storage, the methods tested produced significantly different results. Most of the methods contain artificial adjustments that have no physical basis (i.e., artificially low CNs or artificially high loss rates). Out of the methods tested, it appears that using the natural land cover/use CN along with reservoir routing is the most representative of how playas actually function and the most accurate to account for playa volumes. Therefore, accounting for playa volumes by reservoir route is the recommended method to use for rainfall-runoff modeling in this area.

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REGIONALIZATION OF FLOOD FLOWS IN THE EASTERN SIERRAS REGION OF NEVADA AND CALIFORNIA

Wilbert O. Thomas, Jr. and Patti Sexton
Michael Baker, Jr., Inc.

INTRODUCTION

Over the past few years, a number of flood frequency analyses have been performed for flood insurance studies and design of hydraulic structures for streams in the area of Washoe County/Carson City, Nevada, within the Eastern Sierras region of Nevada and California (Figure 1). Those analyses used different hydrologic methods, including rainfall-runoff models, to determine the flood discharges. Even though the study areas are in proximity and have similar hydrologic characteristics, the results vary widely. In addition, the results are often not reasonable in comparison to stream-gaging data and the regional regression equations for the region published by the U.S. Geological Survey (USGS) (Thomas et al., 1994). An evaluation of the USGS regression equations was performed to determine whether those equations could be updated to better predict flood discharges in the Washoe County/Carson City area. The evaluation included updating station flood frequency curves, developing new regression equations, and comparing the estimated flood discharges from the new equations to those from the USGS equations.

AVAILABLE INFORMATION

The data used in our analyses consisted primarily of that used to develop the USGS regression equations for the Eastern Sierras region. Those equations were based on data at 37 gaging stations that had an average systematic record length of 31 years through the 1986 water year. Using information presently available, we added data from 50 gaging stations in Nevada and California with additional years of record through the 1994 water year. The drainage area, years of peak-discharge record available, and the 100-year (1% chance) flood discharges for the 50 gaging stations are listed in Table 1. The drainage areas ranged from 0.12 to 356 square miles. The record for those gaging stations ranged from 11 to 85 years with an average of 33 years.

Of the 50 stations, only 19 are currently active. In order to enhance our data base, peak-discharge data were obtained from the USGS for the
January 1997 flood for 18 of the 19 active stations (all except Galena Creek near Steamboat, Nevada) plus 3 discontinued stations. Of the 50 stations, 3 were omitted from our analysis because the mean basin elevations were not published, and 2 were omitted because they were outliers (Table 1). Data for the remaining 45 gaging stations were used in the regional regression analysis.

The basin and climatic characteristics evaluated as explanatory variables included drainage area, mean basin elevation, latitude, mean annual precipitation, 2-year 24-hour precipitation, 100-year 24-hour precipitation, basin shape, forest cover, and altitude index (the average of the altitudes at the 10 and 85% points along the main channel used to compute channel slope). Not enough information was available at the gaging stations to use a soils index. The 24-hour precipitation values were obtained from maps provided by the Office of Hydrology, National Weather Service.

**NEW REGRESSION EQUATIONS**

Using the expanded data set of gaging stations, updated flood-frequency curves, and the available basin and climatic characteristics, new regression equations were developed to estimate flood discharges in the study area. The equations that best fit the updated station data were those
Table 1. Gaging stations used in regression analysis.

<table>
<thead>
<tr>
<th>STATION ID</th>
<th>DESCRIPTION</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>AREA</th>
<th>Years of Record</th>
<th>Q100</th>
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<tbody>
<tr>
<td>10265200</td>
<td>Convict Creek near Mammoth Lakes, CA</td>
<td>37.607</td>
<td>118.848</td>
<td>18.20</td>
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<td>10267000</td>
<td>Rock Creek at Little Round Valley near Bishop, CA</td>
<td>37.554</td>
<td>118.684</td>
<td>35.80</td>
<td>52</td>
<td>344</td>
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<td>10267000</td>
<td>Pine Creek at Division Box near Bishop, CA</td>
<td>37.416</td>
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<td>516</td>
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<tr>
<td>10268000</td>
<td>Silver Canyon Creek near Laws, CA</td>
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<td>118.279</td>
<td>19.70</td>
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<td>9</td>
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<td>10276000</td>
<td>Big Pine Creek near Big Pine, CA</td>
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<td>39.00</td>
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<td>457</td>
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<td>10281000</td>
<td>Independence Creek near Independence, CA</td>
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<td>40.10</td>
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<td>558</td>
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<td>10283600</td>
<td>Cottonwood Creek near Plancha, CA</td>
<td>36.439</td>
<td>118.080</td>
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<td>Buckeye Creek near Bridgeport, CA</td>
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<td>10295200</td>
<td>West Walker River at Leav MD near Coleville, CA</td>
<td>38.331</td>
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<td>10304500</td>
<td>Silver Creek below Penn Creek near Markleeville, CA</td>
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<td>10308100</td>
<td>Millberry Creek at Markleeville, CA</td>
<td>38.7</td>
<td>119.783</td>
<td>5.10</td>
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<td>10308200</td>
<td>East Fork Carson River near Markleeville, CA</td>
<td>38.714</td>
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<td>276.00</td>
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<td>Bryant Creek near Gardnerville, NV</td>
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<td>Dagget Creek near Genoa, Nevada</td>
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<td>10312015</td>
<td>Adrian Valley Tributary near Weeks, NV</td>
<td>39.229</td>
<td>119.228</td>
<td>0.12</td>
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</table>
regionization of flood flows in the eastern sierras

<table>
<thead>
<tr>
<th>STATION ID</th>
<th>DESCRIPTION</th>
<th>LATITUDE</th>
<th>LONGITUDE</th>
<th>AREA</th>
<th>Years of Record</th>
<th>Q100</th>
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<tr>
<td>10335600</td>
<td>Upper Truckee River near Meyers, CA</td>
<td>38.843</td>
<td>120.024</td>
<td>33.10</td>
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<td>10336635</td>
<td>Lake Tahoe Tributary near Meeks Bay, CA</td>
<td>39.017</td>
<td>120.126</td>
<td>0.64</td>
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<td>Wood Creek near Crystal Bay, NV</td>
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<td>1.69</td>
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<td>Trout Creek near Tahoe Valley, CA</td>
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<td>10337900</td>
<td>Truckee River Tributary near Truckee, CA</td>
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<td>10340500</td>
<td>Prosser Creek below Prosser Creek Dam near Truckee, CA</td>
<td>39.373</td>
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<td>10343500</td>
<td>Sagehen Creek near Truckee, CA</td>
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<td>10347600</td>
<td>Hunter Creek near Reno, NV</td>
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<td>Franktown Creek near Carson City, NV</td>
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<td>Galena Creek near Steamboat, NV</td>
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<td>119.619</td>
<td>82.60</td>
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</tbody>
</table>

Stations 10298700, 10287210, and 10335693 were omitted from the analysis because the basin elevation was not published. Stations 10292300 and 10310400 were omitted from the analysis because they are outliers.

Based on the drainage area (Area), in square miles; mean basin elevation (Elev), in feet above mean sea level; and 2-year 24-hour precipitation (P2), in inches. The equations based on data for 45 stations for various percent-chance floods are:

\[
\begin{align*}
Q_{50\%} &= 2.6 \times \text{Area}^{0.98} \times P_2^{1.50} \times [(\text{Elev} - 4000)/1000]^{-0.28} \\
Q_{10\%} &= 53.7 \times \text{Area}^{0.90} \times P_2^{1.16} \times [(\text{Elev} - 4000)/1000]^{-1.27} \\
Q_{2}\% &= 337.2 \times \text{Area}^{0.86} \times P_2^{1.00} \times [(\text{Elev} - 4000)/1000]^{-1.87} \\
Q_{1}\% &= 644.0 \times \text{Area}^{0.84} \times P_2^{0.95} \times [(\text{Elev} - 4000)/1000]^{-2.08} \\
Q_{0.2}\% &= 2386.0 \times \text{Area}^{0.81} \times P_2^{0.86} \times [(\text{Elev} - 4000)/1000]^{-2.50}
\end{align*}
\]

Mean basin elevation was transformed by subtracting 4,000 feet and dividing by 1,000 in order to achieve more linearity in the regression equation and to minimize the intercept constant. The standard error of the 1% annual chance flood (base flood) discharge of the equation listed above is 92%. Figure 2 shows the relation between the base flood discharges (Q1%) determined using the equation listed above and the
USGS Q1% equation for the Eastern Sierras region (Thomas et al., 1994). On average, the Q1% equation predicts discharges 13% greater than the comparable USGS equation.

As shown in Figure 2, estimates of Q1% from the new and the USGS equation compare favorably for the lower discharges (small watersheds), but the new equation predicts consistently higher for the larger discharges. A paired t-test shows that the differences between the Q1% discharges predicted by each of the equations for the 45 gaging stations are not statistically significant at the 5% level of significance. However, for a significance level of 10%, the differences between Q1% estimates from the two equations are statistically significant. From an engineering standpoint, the differences in the Q1% estimates are small, and both sets of equations yield reasonable estimates of discharges in the study areas.

The regression equations were developed from gaging stations with the following basin and climatic characteristics: drainage area ranging from 0.12 to 356 square miles, mean basin elevation ranging from 5,590 to 10,500 feet above mean sea level, and 2-year 24-hour precipitation ranging from 0.7 to 4.4 inches. The equations are applicable and should be used within these ranges of explanatory variables. An analysis of the
residuals, the differences between predicted and station values, indicated the regression equations provide unbiased estimates of flood discharge. The residuals were plotted against the predicted values and all the explanatory variables to insure that the equations were unbiased with respect to the variables and the residuals were plotted against latitude and longitude to check for geographic bias. The regression equations are not applicable to watersheds with significant urbanization, or where peak discharge is regulated by dams, detention structures, or diversions.

OTHER ANALYSES

A number of other analyses were performed in an attempt to define equations that more accurately predict flood discharges in the study area. One method was based on a hybrid analysis of the gaging station records that pooled annual peak flows per square mile from all stations into one data set to define a single flood frequency curve. This approach, described by Hjalmarson and Thomas (1992), assumes independence of the annual peak flows at gaging stations in the study area. In addition to the 50 gaging stations mentioned above, indirect measurements at 19 miscellaneous sites were included in the analysis. Those measurements were made by USGS on small watersheds after extreme floods. This analysis failed to define a reasonable flood frequency curve because of the small number of extreme events. Another problem was that almost all of the extreme peak discharges per square mile have been recorded at small drainage areas. This resulted in an inverse relationship between drainage area and peak flow.

Another method explored was to regionalize the mean and standard deviation of the station flood frequency curves. The same data set of 45 gaging stations described above was used to develop regression equations for the mean and standard deviation as a function of basin and climatic characteristics. A regional skew value of zero was assumed based on the regional skew analysis performed by Thomas et al. (1994) and the regional skew map provided in Bulletin 17B (Interagency Advisory Committee on Water Data, 1982). The standard error for the base flood discharge using the equation developed with this method is significantly higher than that of the USGS or our updated equations.

The final method was to estimate the more extreme events (less than 10% annual chance) as a ratio to the 50 and 10% chance floods. Generally, regression equations for the 50 and 10% chance floods can be developed with a lower standard error because of the reduced time-sampling error for these flows. Estimates of the more extreme floods can be made for ungaged watersheds as a ratio to the regression estimates for either the 50 or 10% chance flood discharge. The standard error for the
base flood discharge based on this ratio method is significantly higher than that of the USGS or updated equations.

**Summary**

Based on our investigation, the USGS regression equations for the Eastern Sierras region and the equations resulting from our analysis both provide reasonable estimates of flood discharges for ungaged sites in the study area. The USGS equations are recommended for the study area because they are published and generally available to the hydrologic community, are included in the USGS National Flood Frequency Program (Jennings et al., 1994), and are not significantly different from the updated equations we developed. As noted earlier, different hydrologic methods are used to estimate flood discharges for ungaged sites for flood insurance studies. Regional regression equations are one of the recommended approaches (FEMA, 1995). Regional regression equations are calibrated from and therefore should be consistent with gaging-station records. Based on an extensive analysis of gaging-station records in the Eastern Sierras region, the conclusion is that any method used to estimate flood discharges for ungaged sites in the study area should be consistent with the USGS regression equations.

**References**

Hjalmarson, Hjalmar W., and Blakemore E. Thomas

Interagency Agency Advisory Committee on Water Data

Jennings, Marshall E., Wilbert O. Thomas, Jr. and Henry C. Riggs

Thomas, Blakemore E., H.W. Hjalmarson, and S.D. Waltemeyer
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Part 7

MAPPING
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INTRODUCTION

Areas subject to uncertain flow path flooding include alluvial fans, deltas, and alluvial plains. Probably most of us have experienced this concept in a braided stream. These areas are widely distributed throughout the United States and the world. While alluvial fans are more often discussed in the arid and semi-arid western part of the United States, they are also found in humid areas, including the Appalachian Mountains.

Because of a recent publication about alluvial fan flooding, this paper concentrates on that special case of uncertain flow path flooding: where we are now and paths for the future. We should recognize that how we map and manage alluvial fans will likely affect how we map and manage flood hazards in the broader context.

WHERE ARE WE?

Problems and Controversies

An alluvial fan is broadly defined as a gently sloping, fan-shaped land form created by deposition of eroded sediment. Alluvial fans are often considered attractive building sites because they have aesthetically pleasing views. The basic problem is that people have been killed and severe property damage has occurred from both water and debris flows on alluvial fans. Development on fans may be subject to more severe hazards than a normal AO Zone because of high velocity of flows and unpredictable flow paths. Because of this, Federal Emergency Management Agency (FEMA) designation as subject to alluvial fan flooding triggers restrictive regulations and major structural flood control measures may be needed before development can proceed.

The FEMA method of delineating hazard areas on an alluvial fan assumes complete uncertainty about flow path, which can understated the risk in some parts of the fan and overstate it in others. On the other hand, for riverine situations, the method of floodplain delineation assumes complete certainty of flow path. A significant number of state
and local floodplain management officials have argued neither of these assumptions is correct, and that the FEMA approach to dealing with alluvial fans is inappropriately rigid and often does not represent the actual hazards present. This point of view concludes that the modeling methods work well in some areas and not so well in others, that not all fans have the same geomorphology, not all are equally hazardous, and that land use management standards appear irrational.

For example, a home built at the bottom of a deeply incised wash on a fan could be considered subject to the same risk of flooding as a home built on an adjacent ridge on the same fan. As Dr. Stanley Shumm said at the March 1997 Arid Regions Floodplain Management Conference, "Complex problems often have simple, easy-to-understand, wrong answers." Political forces then come into play when elected officials face significant watersheds becoming undevelopable based on marginal data and management tools, and pressure to construct expensive collection and diversion facilities.

**Committee on Alluvial Fan Flooding**

As a result of these controversies, at FEMA’s request, a Committee on Alluvial Fan Flooding was established under the auspices of the National Research Council. The committee was made up of eight engineers and earth scientists: Stanley Shumm, Committee Chair, Colorado State University; Victor Baker, University of Arizona; Peggy Bowker, Nimbus Engineers (Nevada); Joseph Dixon, U.S. Army Corps of Engineers (Arizona); Thomas Dunne, University of California, Santa Barbara; Douglas Hamilton, Engineering Consultant (California).

The committee was given three tasks: (1) revise the existing definition of alluvial fan flooding, (2) develop criteria to determine if an area is subject to alluvial fan flooding, and (3) provide examples of application of the definition and criteria. The committee’s report, *Alluvial Fan Flooding*, was published in the fall of 1996.

**Definitions**

According to the committee’s report, the National Flood Insurance Program (NFIP) definition of alluvial fan flooding is "flooding occurring on the surface of an alluvial fan or similar land form which originates at the apex and is characterized by high-velocity flows, active processes of erosion, sediment transport and deposition, and unpredictable flow paths." The committee focused on alluvial fans and deliberately excluded "similar land forms." The committee’s definition is: "An alluvial fan is a sedimentary deposit located at a topographic break that is composed of..."
fluvial and/or debris flow sediments and has the shape of a fan either fully or partially extended."

Criteria

Having defined an alluvial fan, the committee then developed criteria to determine if an area is subject to alluvial fan flooding. The committee's report outlines these criteria, which boil down to determining (1) whether the area is an alluvial fan; (2) if it is a fan, whether the flow paths are stable in recent times (say in the last 10,000 years) on all or part of it; and (3) if some of the flow paths on the fan are stable and some are unstable, where the boundaries are between the stable and unstable parts.

Applications

The Committee on Alluvial Fan Flooding then analyzed six fans in the West, three in California, two in Arizona, and one in Utah, plus a group of fans in Virginia. Of these seven examples, the committee found that three were inactive, three were active, and one was partly active and partly inactive.

Then What?

Having determined that an area is an alluvial fan, whether the flow paths are stable or not, and where the boundaries are, the committee recommended that riverine techniques be used to delineate flood hazards on the stable (inactive) parts of the fan. For active parts of a fan, the committee recommended using the FEMA alluvial fan flooding methods, but with modifications. The committee concluded that the default assumption of complete flow path uncertainty is seldom appropriate. It recommended that the default assumption should be changed in using the total probability equation, based on Guidelines for Risk and Uncertainty Analysis in Water Resources Planning (U.S. Army Corps of Engineers, 1992).

What's Next?

Necessary Actions

If it affects you, study the report, Alluvial Fan Flooding. In an informal poll at the March 1997 Arid Regions Conference in Nevada, only 10% of the attendees acknowledged having done so. FEMA needs to react to the report within a reasonable time and tell state and local floodplain managers what FEMA plans to do with it. Input is needed
from states, floodplain administrators, and the Association of State Floodplain Managers, supported by its Arid Regions Committee and state chapters. We need to determine what the next steps should be, who should do the work, who should pay, opportunities for partnerships, and the ultimate goal, with intermediate objectives and a timeline. There is a recent example of state and local funding and involvement in a federal process and publication: the update of *NOAA Atlas 2, Precipitation Frequency Atlas for the Western United States*.

**Suggestions**

We need to apply the cooperative spirit of the National Oceanic and Atmospheric Administration atlas update to the present situation. FEMA should implement the committee’s recommendations, but FEMA cannot do it all. Coalitions of states and floodplain administrators might need to take the lead. Policies, guidelines, and standards may need to vary among regions or states and must address both NFIP and floodplain management issues.

We have been arguing about alluvial fans for 10 years or more. With FEMA’s help, the *Alluvial Fan Flooding* report has moved us toward a better way of delineating and managing flood hazards on fans. Let’s keep the momentum going.

**REFERENCES**

Federal Emergency Management Agency

National Research Council
IMPLEMENTATION OF THE NORTHERN AMERICAN VERTICAL DATUM OF 1988 FOR FLOOD INSURANCE STUDIES

Matthew B. Miller
Federal Emergency Management Agency

Lawrence W. Olinger
Dewberry & Davis

INTRODUCTION
The vast majority of the Flood Insurance Studies (FISs) performed for the National Flood Insurance Program (NFIP) since its inception in 1968 have used the National Geodetic Vertical Datum of 1929 (NGVD 29). However, as newer data were incorporated and as survey techniques became more accurate, it became apparent that inconsistencies existed in NGVD 1929. In 1978 the National Geodetic Survey (NGS) began development of a new vertical datum—the North American Vertical Datum of 1988 (NAVD 88). With the NGS’s conversion to NAVD 88, the Federal Emergency Management Agency (FEMA) has begun a transition to the use of this datum as well. The conversion methodology presents no problem; however, given cost constraints, the decision of when to convert a study to NAVD 88 can be a complex one.

BACKGROUND
Before the 1920s, local mean sea level was used as a datum reference and was based on the readily observed tidal cycles of mean hourly water elevations observed over a 19-year period (the National Tidal Datum Epoch). The arithmetic mean of these observations provided the level used as local mean sea level. However, there are many variables that affect the determination of local mean sea level, and it has been demonstrated since the adoption of NGVD 29 that differences between local mean sea level and NGVD 29 vary from location to location and from time to time. To assist in evaluating these local differences, geodesists have been searching for a datum definition that would more closely represent the true shape of the geoid.
During the 1920s, the federal government undertook a project to combine a series of precise leveling surveys. The network was referenced to 21 tide gages in the United States and five in Canada. The object of the network was to provide a fixed datum that was supposed to bring a consistent relationship to all vertical determinations in the United States. Initially known as the "Sea Level Datum of 1929," it provided a continental datum that eliminated the periodic changes inherent in local tidal datums. To avoid confusion over the differences in local tidal datums, the name was changed in 1973 to the "National Geodetic Vertical Datum of 1929 (NGVD 29)." Until now, NGVD 29 has been the datum of reference for the vast majority of FIS work.

As newer data were incorporated and as survey techniques became more accurate, it became apparent that inconsistencies existed in NGVD 29. For NGVD 29, it is assumed that zero NGVD is mean sea level at the 26 tide gages in the survey network. To surveyors, this produced a "warped" geoid. To remove the distortion in the network, an equipotential surface (the surface represented by a constant value of the acceleration due to gravity) needed to be defined that could be easily reproduced at any location. The National Geodetic Survey (NGS) and counterpart agencies in Mexico and Canada decided to adopt a vertical datum based on a surface closely approximating this equipotential surface.

Approval and funding to establish the new datum was received in 1978. The readjustment of the North American Vertical Control Networks is called the North American Vertical Datum of 1988, denoted as NAVD 88. The major effort to accomplish NAVD 88 was the releveling of 81,500 kilometers of existing first-order leveling lines to strengthen the network in the conterminous United States. This releveling was correlated with the North American Vertical Control Networks and adjusted using the method of least squares. The adjusted network includes about 600,000 permanent benchmarks and about 350,000 temporary benchmarks. Initially, most benchmarks established by other federal, state, or local agencies were not included in this releveling effort.

**IMPLEMENTATION OF NAVD 88 FOR FISs**

Currently, the majority of effective FISs are referenced to NGVD 29. Because some of the procedures for determining NGVD 29 and other older datums may have been unreliable, FEMA's ultimate goal is to convert all FISs to NAVD 88. However, the conversion will by necessity be gradual and driven by the opportunity to republish FISs and Flood Insurance Rate Maps (FIRMs) for other substantive reasons.
Although FEMA’s goal is to convert all FISs to NAVD 88, the decision to use NAVD 88 for a restudy cannot be an automatic one, as one might intuitively think. FEMA has decided that the use of mixed datums is impractical. One problem would be that there would be uncertainty when attempting to superimpose backwater effects from restudied flooding sources referenced to NAVD 88 onto non-restudied flooding sources referenced to an older datum, such as NGVD 29, or vice versa. Another problem is that inconsistencies of datums within FISs could lead to confusion among map users not familiar with the differing datums. Such misinterpretation could cause mistakes in flood insurance rating and floodplain management. Using mixed datums in computing flood insurance premiums could result in significant inequities to either the insured or the insurer, depending on the error (Figure 1).

The need for a systematic process for datum conversion was brought to the fore during preparation of a restudy for Escambia County, Florida. FEMA found that the difference between NGVD 29 and NAVD 88 varied by as much as 0.42 feet from one corner of the county to another (Figure 2). In some cases, conversion factors even vary significantly along a single restudied stream. This meant that for Escambia County, converting non-restudied streams, referenced to NGVD 29, to NAVD 88 would have required: 1) determining which elevation reference marks

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Correct Rating Using:

- **NGVD**: \(2 - 3 = -1\)
- **NAVD**: \(0 - 1 = -1\)

Incorrect Rating Using:

- **NGVD Lowest Floor & NAVD BFE**: \(2 - 1 = +1\)
- **NAVD Lowest Floor & NGVD BFE**: \(0 - 3 = -3\)

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Figure 1. Correct and incorrect insurance rating.
were used to develop specific cross sections used to compute the flood profile; 2) determining the conversion from NGVD 29 to NAVD 88 for each reference mark; and 3) adjusting and replotting the flood profiles accordingly. This could easily result in conversion costs that could dwarf the costs of the overall restudy being conducted.

In light of problems such as those discussed above, FEMA’s January 1995 Flood Insurance Study, Guidelines and Specifications for Study Contractors has been updated to provide project officers and study contractors more detailed guidance to allow a systematic implementation of NAVD 88 in place of NGVD 29 for FISs. The project officers and study contractors should consider the following questions in determining which datum is most appropriate:
To ensure utility of the new datum by the community, does the community have or will it soon have the ability to use NAVD 88 with its own benchmark system?

To minimize the costs of converting non-restudied streams, will less than approximately 50% and no more than approximately 20 miles of non-restudied detailed study from the effective FIS have to be converted to NAVD 88?

To minimize the costs of updating individual map panels without revised flooding information, will no more than approximately 5% of the total printed FIRM panels for the community have to be revised solely to convert non-restudied streams to NAVD 88?

For ease of conversion, which again affects costs, is the maximum difference between the conversion factors, which is defined as the difference between NAVD 88 and the effective FIS datum, within 0.1 foot for all locations within the community?

If the answers to the above four questions are “yes,” the restudy should be performed using NAVD 88. If the answer to any of the above questions is “no,” sound judgment should be used in deciding which datum to use for the restudied area, keeping in mind the costs associated with converting the effective FIS. Even if it is decided not to conduct the restudy in NAVD 88, the study contractor is still required to also submit the elevations for the elevation reference marks in NAVD 88 to facilitate future conversion of the study.

FEMA began the conversion process in 1993. Since then, approximately 300 panels or 5% of the revisions and/or restudies have used NAVD 88. This relatively small number attests to the fact that conversion between datums is not a simple task and can be costly; which datum to use for a restudy warrants careful consideration in advance of any work.
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Instead of reacting to a disastrous flood, high risk communities would save time and money by systematically updating flood studies on older floodplain maps. Recently, annual U.S. flood losses have been measured in the billions of dollars. These losses need not be a reaction to storms, but indicate the urgent need for the Federal Emergency Management Agency (FEMA) to upgrade its floodplain maps and provide National Flood Insurance Program communities with a valuable floodplain management tool. Over the last 20 years computer modeling and rainfall estimates have advanced to produce much more accurate floodplain mapping. Contrasting two 1996 restudies shows the costs of disaster mapping versus the benefits of managed floodplain mapping (Table 1).

Over the years, the 40 Des Plaines watershed communities have made poor floodplain management decisions, allowing businesses and homes to be constructed too near or within the floodplain. Development on the tributary uplands has significantly increased both runoff volume and peak flood flows. Floods in 1986 and 1987 with over $100 million in 1986 prompted the restudy of the Des Plaines River in 1987 (U.S. Army Corps of Engineers, 1996). Although the study is completed, it has yet to be approved by FEMA and no definitive remedial action has been taken. The 1996 Des Plaines flood elevations throughout the 64 mainstem miles are 2-4 feet higher than those shown in the 1981 regulatory flood study. High land values in Cook County are making reservoir construction prohibitively expensive, so alternative plans must be found.

By contrast, the five Upper Salt Creeks watershed communities, along with guidance from several federal, state, and local agencies, constructed six reservoirs in the early 1980s. These reservoirs lowered the 100-year flood elevations 1-2 feet, even after applying higher Bulletin 70 (Huff and Angel, 1989) estimates of 100-year rainfall. The Upper Salt restudy has taken a couple of years to complete.
Upper Salt Creek is a 9.5x5.5-mi rectangular drainage basin that discharges into Lower Salt Creek, then into the Des Plaines River. This highly developed suburban basin has had six major reservoirs constructed in the last 15 years. At the most downstream point of the basin, the 200-acre Busse Woods reservoir can hold 3,400 acre-feet. Together all six reservoirs impound about 5500 acre-feet of at a construction and land acquisition cost of $53 million (1983 dollars). Upper Salt had significant storms in 1954, 1957, 1972, 1982, and 1987. The 1987 event dropped 8-9 inches of rainfall in 24 hours and was used to calibrate the 1996 model. The earlier years did not have all six reservoirs online to allow for model verification. The existing FEMA flood study was completed by the State in 1978, by using TR20 and WSP2, using 1973 200-scale, 2-foot contour aerial-photographic, topographic survey (Smith, 1996).

The 670-square-mile Des Plaines river basin is 80 miles long and is oriented north to south. Flowing through 40 NFIP communities, this river had major floods in 1881, 1938, 1948, 1950, 1960, 1972, 1986, and 1987. In recent years it has frequently flooded low-lying areas. The 1986 event was several feet higher than all the preceding historical events, triggering the 1996 restudy of the Des Plaines River.

Table 1. Flood study comparisons, Des Plaines and Upper Salt Creek.

<table>
<thead>
<tr>
<th>Study Comparison</th>
<th>Upper Salt Creek Basin</th>
<th>Des Plaines River Watershed</th>
</tr>
</thead>
<tbody>
<tr>
<td>Basin Size</td>
<td>52 square miles</td>
<td>670 square miles</td>
</tr>
<tr>
<td>Land use</td>
<td>75%suburb,10%urbn,15%open</td>
<td>70%suburb, 25%urbn, 5%open</td>
</tr>
<tr>
<td>Good Floodplain Management?</td>
<td>Yes on mainstem</td>
<td>No on mainstem</td>
</tr>
<tr>
<td>1980 annual damages — pop.</td>
<td>$850K — 150K pop.</td>
<td>$5,600K — 6,300K pop.</td>
</tr>
<tr>
<td>1996 annual damages — pop.</td>
<td>$2,400K — 230K pop.</td>
<td>$21,000K — 6,500K pop.</td>
</tr>
<tr>
<td>Worst one storm damage</td>
<td>1972 @ $16 million</td>
<td>1987 @ &gt;$100 million</td>
</tr>
<tr>
<td>Number affected communities</td>
<td>5</td>
<td>40</td>
</tr>
<tr>
<td>Cause of flood increase?</td>
<td>No, dropped about 0.5-2.0 ft.</td>
<td>Yes, about 3 feet in many areas</td>
</tr>
<tr>
<td>Study Cost</td>
<td>$250,000</td>
<td>$3,100,000</td>
</tr>
<tr>
<td>Study Survey costs</td>
<td>$75,000</td>
<td>$400,000 (+IDNR survey)</td>
</tr>
<tr>
<td>Study Modeling Costs</td>
<td>$225,000</td>
<td>$2,700,000</td>
</tr>
<tr>
<td>Study Public response costs</td>
<td>$3,000</td>
<td>$30,000+ (projected)</td>
</tr>
<tr>
<td>Community challenges</td>
<td>-0-</td>
<td>At least 3</td>
</tr>
<tr>
<td>Mainstem miles</td>
<td>20 miles</td>
<td>65 miles</td>
</tr>
<tr>
<td>Tributary Miles</td>
<td>11 miles</td>
<td>-0-</td>
</tr>
<tr>
<td>Number culverts/bridges</td>
<td>110</td>
<td>100 (mainstem only)</td>
</tr>
<tr>
<td>Modeling used</td>
<td>HEC1 / HEC2 / FEQ</td>
<td>HEC1 / HEC2 / FEQ</td>
</tr>
<tr>
<td>Big storms calibrated</td>
<td>1987</td>
<td>1986</td>
</tr>
<tr>
<td># of streamgages available</td>
<td>2 mainstem</td>
<td>4 mainstem</td>
</tr>
<tr>
<td>Year started / Year completed</td>
<td>1994 / 1996 (near FEMA OK)</td>
<td>1987 / 1997 (no FEMA approval)</td>
</tr>
<tr>
<td>Agencies involved</td>
<td>IDNR</td>
<td>IDNR, FEMA, USACE, MWRD, NIPC</td>
</tr>
</tbody>
</table>
HYDROLOGIC COMPUTER MODELING APPROACHES

Generally, storm fronts travel west to east towards the Des Plaines basin and this presents an unusual design challenge to calibrate storm rainfall patterns. To solve this, an elliptical storm pattern was chosen per the suggestion of the Midwestern Climate Center's Bulletin 70 (Huff and Angel, 1989). The tributaries were modeled by the Illinois Department of Natural Resources, Division of Planning (IDNR-DOP) as a part of its ongoing floodplain feasibility studies program, designed to lessen flooding in Illinois by constructing flood control structures. Although analyzed separately, the Des Plaines tributaries were combined into one of the largest HEC-1 hydrologic models ever constructed. The 67-page Des Plaines watershed HEC-1 hydrologic input model includes seven major tributaries and the mainstem. This was accomplished to create a model that could also be used for regulatory purposes and FEMA mapping. Projected flows were about 30% higher in many locations than the 1981 regulatory model. However, the tributaries were not remapped because the HEC-2 individual models needed further refinement.

The 1996 Des Plaines 100-year flows were accepted both by the Corps of Engineers Chicago District and IDNR-DOP on April 15, 1995. By doing this, a regional skew coefficient for the four stream gages along the Des Plaines was set at -0.16 and the Corps allowed IDNR to use rainfall depth-area curve adjustments to calibrate frequency relationships for the Des Plaines hydrology. Using the rainfall depth-area curve calibration is not the traditional Corps technique employed to calibrate large models but in this case there was a reasonable calibration to the 1986 storm event at the four mainstem stream gages.

The 1981 regulatory Upper Salt Creek study land use assumptions were based on future land use projections that never came about. This land use overestimated the 100-year 1981 flood flow estimates. The 1996 restudy used existing 1995 land use with the increased Bulletin 70 rainfall of 7.5" in 24 hours. The Clark Unit hydrograph method allows for storage coefficient adjustments basin by basin, allowing the modeler to calibrate basin zones to established high waters and stream gages. The final storage coefficient held around 7.5 times the time of concentration. The stream gage on Upper Salt was located near the outlet and additional upstream high water information from 1987 event provided good HEC-2 model calibration. Basin runoff curve values held around 79 for mainly type C soils (Smith, 1996).

Salt Creek hydrologic calculations are easier to defend since the 50-square-mile basin calibrates well to the 1987 storm event, an event close to the 100-year Bulletin 70 rainfall amount. The 1986 and 1988 storms calibrated reasonably well to the Algonquin Road stream gage, matching
the peaks and general shape of the hydrographs. The initial abstract moisture conditions for these two storms were adjusted per rainfall records. The 5- to 100-year regulatory discharges were estimated using uniform Bulletin 70 rainfall distributed as defined by the Huff rainfall distributions. The Huff rainfall distributions front load (Huff 1st quartile) for more intense shorter duration rain, while backloading the rainfall (Huff 4th quartile) for longer duration storms. For the Upper Salt, the 24-hour Huff 3rd quartile was accepted as the critical duration storm, producing higher peaks than were estimated from the 1-, 3-, 6-, 12-, and 48-hour duration events (Smith, 1996). The Tom T. Hamilton and Margreth Reimer Reservoir inflow diversions were modified from today's configurations to reflect the 1987 conditions.

In Illinois many regulatory studies were undertaken in the late 1970s with little or no detailed hydrologic calculations. Approximate hydrologic methods included some stream gage calibration, yet most studies used regression equations based on average basin slope, area, and a development index. These estimates claim only 50% accuracy for the 100-year storm (although in practice seem to underestimate 100-year flows). Major Flood Insurance Study restudies since the mid to late 1980s have relied on either HEC-1 or TR20 hydrologic modeling. Combined with more stream gage data when available, the 1990s restudies have more accurate 100-year flows than earlier hydrologic regression estimates.

**Comparing 1996 Des Plaines Flood Profiles to the 1981 Regulatory Profiles**

The 1996 Des Plaines restudy was compared to the 1981 regulatory Des Plaines study by resetting the 1996 model parameters to match the 1981 parameters for the number of structures, lowering 1981 flow values, and smoothing 1981 n-values. Since the 1996 Des Plaines model base flood elevations (BFEs) have increased 2-4 feet through many highly developed communities, this careful analysis was needed to explain the increased BFE. The 1996 model has about 100 bridges modeled within the 65-mile mainstem model, whereas the 1981 regulatory HEC-2 model has only about 12 structures. About 90 structures were removed from the 1996 model, dropping the BFEs from 1.0-1.5 feet throughout the model. Next, the 1996 flows were lowered (on the average) 30% to match the 1981 100-year flows, and the BFEs dropped another foot. Finally, the 1996 n-values were dropped to match the 1981 n-values, and the BFEs dropped 1.0-1.3 feet. All three parameters, including the number of structures, 100-year flows, and the n-values, nearly equally caused the three-foot
BFE increase. Comparing the 1981 model to the 1996 HEC-2 model only highlights the relative importance of these backwater parameters.

**UPDATE EXISTING FLOODPLAIN MAPS**

Many of the Chicago area FEMA floodplain and floodway maps are more than 15 years old. Although the recent countywide digital remapping of this area appears to update the mapping significantly, there are still many waterways that need better floodplain mapping. For example, the Des Plaines 11 major tributaries were not included with the 1996 mainstem remapping. These tributaries have average annual damage greater than $1.5 million (U.S. Army Corps of Engineers, 1996). Given FEMA's 1996 annual Illinois budget of about $230,000, only a portion of one of the larger tributaries could be restudied. It will take 12 years or more just to restudy the Des Plaines tributaries at these funding levels. Other major watersheds needing further restudies include the Fox River, Kishwaukee River, Little Calumet, Poplar Creek, and Cal-Sag.

**CLIMATOLOGICAL ESTIMATES**

In 1955 Technical Publication 40 (TP40) was released as the definitive estimate for rainfall frequencies in the continental United States. For the last 10 years, the National Oceanic and Atmospheric Administration's Office of Hydrology has attempted to update TP40, drafting procedures to restudy the nation's rainfall records, but nothing has been published. However, another branch of NOAA (not under the Office of Hydrology) called the Regional Climate Centers, based mainly within universities across the country, has updated TP40 in three of its six centers. The Midwestern Climate Center's Bulletin 71 is a nine-state update to TP40 (Huff and Angel, 1992), however this document is only accepted by FEMA in Illinois and only after rigorous calibrations of existing streamgage information on small and large watersheds. FEMA should review other NOAA Climate Center TP40 updates, not only those presented by the Office of Hydrology. Updating rainfalls is important. For example, in Illinois the 100-year 24-hour rainfall has increased from 5.5 inches to 7.5 inches. The effect of two more inches of runoff volume makes many 100-year reservoirs function as 50-year reservoirs.

In the last 40 years, the evidence pointing toward higher total rainfall is becoming more obvious with each passing storm. There are two main branches of study in this area, one being the analysis of average storm total rainfall, and the other being the study only of the most severe or blockbuster storms. Some of this blockbuster storm work has been accomplished by Stan Changnon of the Midwestern Climate Center. His
phonebook-sized research paper will be published within the next few months. The Western Climate Center does not regard TP40 as accurate in part due to many recent large storm events, including a 1000+ year event that caused extensive damage. In part, now they evaluate storms using three-day volumes.

Dr. Thomas Karl, the Director of the National Climatic Data Center (NCDC), addressed Congress several months ago commenting on the increased rainfall throughout the conterminous United States (Karl, 1996). His study has concluded several trends: 1) rainfall > 2 inches increased by one more event every two years (over the last century), 2) significant increase in annual precipitation, 3) 18% increase in September-November total precipitation, and 4) extreme events are increasing while moderate daily rainfall events are decreasing. His conclusions show the need to update TP40 rainfall estimates nationwide.

CONCLUSIONS

Evaluate Parameter Accuracy and Uniformity

The most sensitive parameters incorporated in all hydrologic/hydraulic flood restudies include channel and overbank n-values, selection of "restrictive" structures, and 100-year runoff flows. The interaction of runoff parameters, although becoming more accurate, is still basin-specific and difficult to regionally predict within 30%. The science of flood forecasting needs more stream gages, rainfall gages, and two-foot contour aerial photographic topography. Climatological estimates show significant increases in rainfall as projected by TP40. Perhaps FEMA could strongly request communities within a threshold of repeat damages to provide topographic mapping of significant waterways. Accurate topography alone can be 40% of the cost to remap a floodplain. Large basins need inter-community cooperation to resolve flooding problems. Counties need to have strong floodplain regulatory agencies to help oversee large basin restudies.

Accelerate the Flood Restudy Program

FEMA should double or triple its floodplain mapping budget to accelerate the mapping program, updating all maps that are more than five years old. Increasing flood levels by 3 feet on a major Chicago area waterway, the Des Plaines restudy faces stiff community challenges resulting from poor-quality regulatory flood maps. To its credit, FEMA has pushed hard to create a digital mapping system and has implemented that effort in the Chicago area. Yet many of the digitized Chicago studies still need to be further updated. The NFIP communities with repeat
flooding problems should cost-share the burden providing better aerial photographic mapping and carefully documenting floodprone areas. Smaller basins of 10-50 square miles traversing NFIP communities can be handled by private consultants and be completed in 2-4 years. These studies are much less expensive when flood elevations are dropping due to good floodplain management. During the study process, it is important for the study contractor to meet monthly to push the study along and agree on important parameter adjustments. Remapping floodprone areas in reaction to a disaster may lengthen the restudy by 5 years and multiply the study cost by 7 times or more. Accurate maps can help prevent future floodplain development and can be used to locate flood control structures. Good floodplain management includes systematic floodplain remapping that will greatly reduce the misery of flooding.

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The hydrologic and hydraulic methods being employed by DuPage County’s Stormwater Management Division for floodplain mapping, watershed planning, and project analyses differ from traditional approaches. A continuous hydrologic simulation (precipitation-runoff) model is used with a fully dynamic flow routing model to simulate a 45-year record of flows and stages along the stream. This allows the development of frequency estimates of flows and stages at any site in the watershed. Because inconsistencies can result when traditional flood frequency analysis is applied to the results of precipitation-runoff modeling for urbanizing watersheds and/or regulated streams, a statistical approach to overcome these limitations was needed. The techniques developed by DuPage County have been under technical review by the Federal Emergency Management Agency (FEMA) and the State of Illinois. As part of the review, they have requested three floodplain mapping revision studies comparing the county’s method and FEMA’s traditionally accepted HEC-1/HEC-2 method.
METHOD DESCRIPTIONS

The methods used in this study differ significantly with respect to the hydrologic, hydraulic, and statistical analysis. The term traditional methods refers to the use of HEC-1 for hydrologic analysis, HEC-2 for hydraulic analysis, and Bulletin 17-B (U.S. Water Resources Council, 1981) or design storm techniques for the statistical analysis. DuPage County methods refer to HSPF for hydrologic analysis, FEQ for hydraulic analysis, and PVSTATS for statistical analysis. The HSPF (Hydrologic Simulation Program-FORTRAN) model was developed by Hydrocomp International, Inc. and is currently maintained by the U.S. Environmental Protection Agency. This model is used to simulate the runoff inputs needed for the hydraulic analyses by simulating continuous runoff for various land cover types for a continuous period of precipitation record. The hydraulic simulation is performed for selected events (average 3 per year) using the FEQ (Full Equations) unsteady flow model. The FEQ program was developed by Dr. Delbert Franz of Linsley, Kraeger Associates, Ltd. The U.S. Geological Survey (USGS) has verified the FEQ model and is in the process of documenting it. FEQ represents unsteady flow in channels, closed conduits and reservoirs, and is based on the numerical solution of the Saint-Venant equations describing one-dimensional flow in open channels. The statistical method used for the flood frequency analysis is the "peak-to-volume" approach (Bradley and Potter, 1992). Its premise is to estimate both the probability distribution of flood volume and a regression relationship between flood peaks (flows and stages) and flood volume. The method was developed for use with continuous simulation and is performed using a computer program called PVSTATS (Bradley and Potter, 1992). The traditional approach is to apply Bulletin 17-B flood frequency analysis to the simulated annual peaks rather than using the peak-to-volume method.

RATIONALE OF THE DUPAGE APPROACH

Traditional floodplain mapping techniques face several problems when applied to conditions in DuPage County. Implicit in the methods recommended in Bulletin 17-B are many assumptions that do not apply to most DuPage County streams. For example, storage added through various flood control projects and the county's new development detention requirements impose severe flow regulation throughout the watersheds. In Illinois, design storm methods have been implemented to address the shortcomings of Bulletin 17-B. Thus, the assumption typically used by the traditional approaches, that the 100-year rainfall produces the
100-year runoff, has also been accepted and is being used by the state. Analysis by DuPage County comparing flows produced by the design storm approach and from continuous simulation have suggested that design storms are not appropriate in DuPage County. These concerns led DuPage County to develop its HSPF/FEQ/PVSTATS approach.

Advantages of the DuPage Approach

DuPage County's hydrologic, hydraulic, and statistical procedures have several advantages. First, the continuous simulation hydrologic model utilizes six long-term precipitation gages (1949-present) to capture the effects of antecedent moisture on runoff volumes and peaks, and to account for the spatial variability of precipitation over the watershed. These factors are difficult to deal with in the design storm approach. Secondly, the effects of backwater, floodplain storage, and complex urban stream systems have a significant impact on the hydraulics of DuPage County streams. Additionally, there are several gated structures, diversions, and pumps on many of the streams. Thus, an unsteady flow model has been adopted for use in DuPage county watershed studies.

Finally, the "peak-to-volume" approach derives relationships between peak discharge and runoff volume and peak stage and runoff volume. This method eliminates design storm and steady-state assumptions; represents variable effects of backwater, floodplain storage, and flow regulation; and utilizes local historical storm data. The statistical distribution of flood volumes is less likely to have severe discontinuities often found in the distribution of peak flows in urban streams. The peak-to-volume approach also recognizes that the rating curve sometimes is poorly represented by a single line, and to compensate, the relationship between flood volumes and peak flows and stage is derived separately using locally weighted regression.

Purpose of the Comparison Study

As DuPage County developed its floodplain mapping procedures, it was hoped that the technique would be evaluated solely on its merits. The DuPage approach is a revolutionary departure from traditional methods and is considered to be state-of-the-art. Comparing the DuPage approach to traditional methods poses additional problems. As the process evolved, it became apparent that the reviewing agencies had concerns with the DuPage approach. Many of these concerns were due to unfamiliarity with the approach, the availability of qualified professionals to perform the analysis, the impact on administrative procedures, as well as technical issues. One floodplain study using the DuPage approach was completed
Comparative Study of Floodplain Mapping Techniques

and submitted to the state. The state created a steady-state model to compare the HSPF/FEQ/PVSTATS results. The floodplain/floodway boundary map developed by DuPage County was accepted but the technique was not yet approved. Before making a decision, the state requested two additional comparison studies, simulating both steady-state and dynamic models. The goal was to compare the results of the two methods, improve familiarity with the DuPage approach, and answer outstanding or unresolved questions.

**STUDY RESULTS**

As part of the comparison study, steady-state and dynamic models were developed for three watersheds—Ginger Creek, Sawmill Creek, and Upper Salt Creek.

**Ginger Creek**

Ginger Creek is an ungaged watershed with an area of 5.4 square miles. It was the original study area for implementing the DuPage approach (Bradley et al., 1996) and was submitted to the state and FEMA. No stream gage information was available for this watershed and there was limited “observed” high water information. The state developed a HEC-1/HEC-2 model to compare the results produced by the DuPage approach. The results of the two methods were quite comparable. Over the mainstem of Ginger Creek, the 100-year elevations produced by the DuPage approach were 1.7 feet lower to 2.3 feet higher than the HEC-2 results. When compared to the current FIS elevations, the DuPage approach elevation changes ranged from a 1.4-foot reduction to a 3.3-foot increase. The average difference between the two methods was less than 0.1 feet and the average absolute difference was 0.5 feet. The state accepted the map produced by DuPage County’s technique and has forwarded it to FEMA for review and acceptance. While the state gave its concurrence on the DuPage County-Ginger Creek floodplain/floodway mapping, they had concerns with the DuPage approach and have yet to approve the approach countywide. This led to the next two studies on gaged watersheds where a more conclusive calibration and verification could take place.

**Sawmill Creek**

Sawmill Creek is a gaged watershed with an area of 12.8 square miles. A continuous flow and stage gage is maintained by the USGS for the period 1985 to present. The Sawmill Creek Watershed Plan was completed and adopted in 1996. As part of that plan, a FEQ model of the
basin was developed. For this comparison, HEC-1/HEC-2 models were developed for the Sawmill Creek watershed using the FEQ land-use, cross-section, hydraulic structure, and stream network information. This insured that the models were as similar as possible. As part of the DuPage approach, 15 to 20 runoff events are used to evaluate the calibration of the FEQ model (18 for the Sawmill Creek watershed). As part of this study, these same 18 events were applied to the HEC-1/HEC-2 models. The calibrations were evaluated based on flows, stages, and volumes for 18 events recorded at the USGS gaging station. Both the DuPage and traditional methods did well in estimating the flows with each performing better than the other in 9 of the 18 events. When comparing volumes, HSPF performed better than HEC-1 on 14 of the 18 events. Flood volumes are an important component of the DuPage approach, particularly when designing flood control facilities. Since floodplain maps are based upon water surface elevations, stage is the critical point of concern. For the 18 calibration events, the HEC-2 model at the gage underestimated the stage on 10 of the 18 events while FEQ underestimated the stage on 6 of the 18 events. Deviations by the HEC-2 model results from the observed water surface elevation ranged from 1.5 feet low to 5.0 feet high while the FEQ results ranged from 2.05 feet low to 2.26 feet high. The average absolute deviation for the HEC-2 analysis was 1.2 feet and 0.91 feet for the FEQ analysis. The FEQ results fell closer to the observed stages and had a smaller range of deviations. The purpose of the calibration is to establish the validity of the hydrologic and hydraulic model and both models produced acceptable results.

Forty-five years of runoff events were run in the FEQ model to obtain the simulated runoff series for use in determining the flood frequencies. The 100-year and 50-year frequency results from PVSTATS, Bulletin 17-B analysis applied to the annual simulated peaks and HEC-1 design storm flows are shown for various locations in Table 1. The largest simulated flow for the simulation period is also shown as a point of reference. As the table shows, there are significant differences in each of the approaches at many of the locations. Overall, the PVSTATS results are consistent with the annual simulated maximum flows and are generally comparable to the design storm or Bulletin 17-B results. One benefit of the DuPage approach that can be seen in the table is the fact that the flows are variable throughout the stream system and do not produce flow discontinuities as with HEC-1. The DuPage approach more realistically mimics the stream response rather than using constant flow rates over large sections of the stream. The Sawmill comparison showed that the hydrologic and hydraulic models developed adequately represent the flow response of the stream over a wide range of flows when
Comparative Study of Floodplain Mapping Techniques

compared to gage information. The comparison of the results from the statistical methods showed that the PVSTATS method produces results that are reasonable and comparable to accepted methods.

Table 1. Comparison of flow for different frequencies.

<table>
<thead>
<tr>
<th>Location Description</th>
<th>PVSTATS Flow (cfs)</th>
<th>Bulletin 17-B Flow (cfs)</th>
<th>HEC-1 Design Storm Flow (cfs)</th>
<th>Annual Maximum Peak Simulated Event Flow (cfs)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>100-yr 50-yr</td>
<td>100-yr 50-yr</td>
<td>100-yr 50-yr</td>
<td></td>
</tr>
<tr>
<td>USGS Gage @ Argonne</td>
<td>2886 2508</td>
<td>2420 2070</td>
<td>2991 2384</td>
<td>2927</td>
</tr>
<tr>
<td>U/S Eastwood Drive</td>
<td>2627 2294</td>
<td>2220 1900</td>
<td>2991 2384</td>
<td>2652</td>
</tr>
<tr>
<td>U/S Cass Avenue</td>
<td>2166 1878</td>
<td>1690 1440</td>
<td>1621 1266</td>
<td>1969</td>
</tr>
<tr>
<td>Western Ave. X-Sect. 10</td>
<td>1155 992</td>
<td>894 748</td>
<td>649 515</td>
<td>1175</td>
</tr>
<tr>
<td>D/S Abandoned Bridge</td>
<td>1132 973</td>
<td>888 746</td>
<td>649 515</td>
<td>1141</td>
</tr>
<tr>
<td>D/S Virginia Court</td>
<td>979 834</td>
<td>1080 872</td>
<td>406 318</td>
<td>1789</td>
</tr>
<tr>
<td>86th St. Wards Creek</td>
<td>320 273</td>
<td>306 262</td>
<td>663 488</td>
<td>412</td>
</tr>
<tr>
<td>D/S Plainfield Rd. Wards Crk.</td>
<td>290 245</td>
<td>240 209</td>
<td>414 288</td>
<td>311</td>
</tr>
<tr>
<td>CGCC Berm Wards Creek</td>
<td>566 464</td>
<td>447 376</td>
<td>576 511</td>
<td>643</td>
</tr>
<tr>
<td>Carlisle Crt. Wards Creek</td>
<td>540 442</td>
<td>408 346</td>
<td>663 488</td>
<td>628</td>
</tr>
<tr>
<td>U/S Plainfield Rd. Wards Crk.</td>
<td>96 85</td>
<td>87 74</td>
<td>83 68</td>
<td>96</td>
</tr>
</tbody>
</table>

Upper Salt Creek

Upper Salt Creek is located entirely outside DuPage County, to the north in Cook County. It is tributary to Lower Salt Creek in DuPage County. The Upper Salt Creek watershed was remapped in 1996 and is currently under review by FEMA. The watershed has a flow and stage gage that has been maintained by the USGS since 1973. The tributary area at the gage is 30.5 square miles. All modeling has been completed and the analysis and evaluation of the results are underway.

SUMMARY

DuPage County's Stormwater Management Division has developed an innovative method using the hydrologic computer program HSPF, the hydraulic computer program FEQ, and the statistical computer program PVSTATS, which represents the stormwater runoff more accurately than the current technique used to create the current FEMA floodplain maps. The DuPage approach uses continuous simulation and dynamic routing
procedures and has been under technical review by FEMA and the state. The results of the comparison studies have shown that DuPage County’s innovative approach produces reasonable results.

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Bradley, A.A., and K.W. Potter

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United States Water Resources Council
Part 8
USING STRUCTURES FOR LOSS REDUCTION
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INTRODUCTION

What happens when the precipitation in a 24-hour period exceeds the stormwater control design parameters by 200%? On July 17-18, 1996, the suburban area southwest of Chicago, Illinois, was the recipient of a 24-hour summer thunderstorm. At Aurora, Illinois, 16.9 inches of precipitation was officially recorded for that storm. This rainfall occurred in an area where the 100-year, 24-hour storm event is established at eight inches over 24 hours with a third-quartile distribution recommended as a design parameter.

This case study examines the operation of the stormwater management system in the Village of Tinley Park, Illinois, which encompasses a regional retention basin and numerous stormwater control reservoirs, some of which operate as onsite and others as onstream facilities. The onsite facilities accommodate the rainfall excess produced from a specific site while the onstream reservoirs operate to control the flow of stormwater from the total tributary watershed. A precipitation map of the July 17-18, 1996, event published by the Midwest Climate Center was annotated by Lindley & Sons to illustrate both the isohyetal precipitation data and the subcatchment locations of the streams that serve various local communities in northeastern Illinois (Figure 1). The Village of Tinley Park and the Midlothian Creek watershed, which are the subject of the case study, are identified on the map.

During this storm, the Midlothian Creek uplands in the Village of Tinley Park received approximately 10 inches of precipitation between 9:00 p.m. on July 17 and 9:00 a.m. on July 18. The onstream regional retention facility (structure 32) was able to accommodate the entire volume of rainfall excess that arrived and maintain the flow in the channel downstream at rates that remained within the natural channel banks, well below previous flood stages recorded before the reservoir was constructed.
Figure 1. Precipitation map, July 17-18, 1996.
CASE STUDY

In the spring of 1975, as part of the Chicago Metropolitan River Basin Plan, a Floodwater Management Plan for the Little Calumet River was formulated and funded by the U.S. Department of Agriculture Soil Conservation Service (now the Natural Resources Conservation Service), the Chicago Metropolitan Sanitary District (now the Metropolitan Water Reclamation District of Greater Chicago), and the Illinois Department of Conservation. This plan proposed the construction of a regional onstream detention basin, designated as structure 32, to regulate the surface stormwater runoff from the uplands of Midlothian Creek, which were under extreme pressure from urbanization. The project was proposed as a multi-purpose structure to both regulate the flow of stormwater into the Little Calumet River, which had a history of frequent and damaging flood levels, and provide a recreational/open space facility for the residents of the Village of Tinley Park.

Constructed in 1978 by the Metropolitan Water Reclamation District of Greater Chicago, this regional retention basin was designed to regulate the flow of surface stormwater from a 5.87-square mile urban watershed, providing 580 acre-feet of temporary storage for surface stormwater runoff. The original design of structure 32 considered the total upstream watershed to be uncontrolled, accommodating only 5.8 inches of precipitation in 24 hours. This stormwater control facility was designed to receive flood waters above the bankfull capacity of the Midlothian Creek channel by means of a drop structure, returning the temporarily stored stormwater to the natural stream channel by pumping as soon as capacity became available in the downstream channel. The capacity provided in the upstream channel of the reservoir was sufficient to convey the 100-year storm runoff from the dominant property into the structure 32 reservoir. A limiting device was installed in the relocated and reconfigured channel to restrict the flow downstream of structure 32 to the available combined bankfull capacity of the channel and roadway crossing structures that were in existence when structure 32 was constructed. These existing roadway structures had the capacity to convey the projected runoff from the 10- to 50-year storm events, depending upon the priority factor assigned to the road to carry traffic.

A review of the watershed size and capacity available to temporarily accommodate surface stormwater demonstrated to the Village of Tinley Park that this proposed regional stormwater facility could not be expected to accommodate all of the flooding problems anticipated from major storms. It would be necessary to construct some additional facilities within the as-yet undeveloped section of the Midlothian Creek uplands that would be designed to regulate the amount of surface stormwater.
entering and being conveyed past the proposed structure 32. Consequently, the Village of Tinley Park land development regulations for the provision of utilities and roadways upon the subdivision of land into residential units also required accommodation of increased surface stormwater runoff in conformance with new state drainage statutes (Illinois Revised Statutes, 1992, Act 605, Illinois Drainage Code).

These state statutes were premised on Templeton vs. Huss, 57 Ill. 2d 134 (1974), in which the Supreme Court of Illinois ruled that both defendants—the developer and the municipality—bore responsibility for justifying any increase in water flow from the dominant estate to the servient estate. The court thereby expanded the potential liability of a municipality for wrongful approval of a plat of subdivision that results in damage to servient areas. Since this landmark decision, all Illinois governmental agencies are required to determine the impact of flood control and drainage when considering plats for land use changes. Other state and federally mandated requirements to preserve wetlands and compensate for natural detention have added to the concerns of both developers and municipalities regarding changes in land use and the effect on downstream drainage facilities.

Since the construction of structure 32, Tinley Park has rigorously enforced the requirement for installation of stormwater control structures in the formerly undeveloped 2.0 square miles of that 5.87-square mile watershed. This program has increased the ability of this regional control structure to accommodate rainfall excess from the portion of the watershed that was developed prior to the implementation of stormwater management regulations by the village. As a result of Tinley Park's stormwater control requirements, over the past 20 years a series of onsite detention ponds has been constructed within the Midlothian Creek watershed upstream of structure 32 in conjunction with the expansion of residential development (Figure 2).

Pond J, located northwest of the 175th Street and 88th Avenue intersection in Tinley Park, approximately two miles upstream of structure 32, was constructed in conjunction with the development of the surrounding residential units. This in progress expansion development project, not yet completed, did not entirely survive the impact of the July 1996 storm, suffering a breach in the control berm on the east side of pond J. However, the partial failure of this facility was completely absorbed in the onstream operation of pond H, one-half mile downstream, which functioned as designed to control surface stormwater so that no increase in water flow occurred downstream as a result of land use changes.
Figure 2. Watershed flow schematic.
Located between pond J and structure 32 and northwest of the 175th Street and 84th Avenue intersection, pond H was designed and constructed in 1973 as part of the Pheasant Chase project prior to the concept and design of structure 32. At the time of development, the landowner argued that construction of this pond was unnecessary because future construction of structure 32 would eventually provide sufficient storage to ensure that no increase in water flow would result from development of the Pheasant Chase project. The problems associated with channel capacity and limited roadway culvert capacity between the Pheasant Chase project and structure 32 were of sufficient magnitude to convince the developer of his exposure to potential damage claims from servient landowners and of the need for the pond H facilities. In fact, further development in this area resulted in the construction of ponds F and G-G, located downstream of the Pheasant Chase development, between it and structure 32.

Due to the Village of Tinley Park's foresight in requiring the provision of additional onsite stormwater control facilities as part of the land development process to augment the operation and capacity of regional structure 32, this section of Tinley Park in the Midlothian Creek uplands suffered no adverse consequences or flood damage from the July 17-18, 1996, storm. This despite the fact that rainfall from this storm exceeded the design parameters of the stormwater control structures. Debris accumulation observed at the Midlothian Creek control weir for structure 32 provided evidence that the July storm floodstage did not exceed the surface overflow elevation of this control device, and that all stormwater flow in excess of the restricted rate was directed into structure 32 and accommodated by the storage volume provided therein.

**CONCLUSION**

Based on the events of July 17-18, 1996, can one conclude that changes in land use in areas dominant to structure 32 no longer need to provide flood water controls? Emphatically not! As land use in the uplands of Midlothian Creek continues to change, stormwater runoff will increase. Therefore, each proposal for development must include a degree of stormwater management to ensure that no increased rate of stormwater flow will result from the proposed changes.

Many local governments in Illinois successfully regulate development to ensure adequate provision for the acceptable accumulation of local flood waters. Local flooding generally causes greater annual economic loss than the more dramatically publicized regional flooding events, even for storms producing runoff considered to be in excess of the one percent probability each year, or the 100-year storm event.
MEACHAM GROVE DAM AND RESERVOIR
FLOOD MITIGATION AND FLOOD CONTROL PROJECT

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INTRODUCTION

The Meacham Grove Dam and Reservoir Project is a significant element of the Lower Salt Creek Watershed Plan, implemented by DuPage County to mitigate flood damages. The DuPage County Forest Preserve District (FPD) and the DuPage County Department of Environmental Concerns (DEC) Stormwater Management Division have combined their efforts to design and construct the Meacham Grove Reservoir as the third-largest flood control facility in the DuPage County portion of the Salt Creek Watershed, located in northeastern Illinois. The FPD, as owner of the project site, administered the project. The DEC, in conjunction with the FPD, provided the hydraulic design including FEQ (Full Equations) modeling and flood control benefits analyses.

OBJECTIVES

The project objectives, which are consistent with the DuPage County Stormwater and Floodplain Ordinance, include the following:

- Mitigate downstream flood damages that occur due to the overbank flooding of Spring Brook near Lake Street (U.S. Highway 20) and Circle Avenue in Bloomingdale, and thereby reduce the damage caused by stormwater to public health, safety and property;
- Preserve and enhance existing aquatic and riparian environments and restore previously degraded areas;
- Control sedimentation and erosion of upstream drainageways;
- Promote equitable, acceptable, and legal stormwater management.
ALTERNATIVE ANALYSES AND DESIGN

The project consists of design and construction of a flood water retention reservoir and associated hydraulic structures for a flood control system to function by gravity. The former Ajax Sand and Gravel Pit located in the Meacham Grove Forest Preserve was converted to an off-line flood control reservoir to Spring Brook. Phase I of this project, which included wetlands delineation and 6 acres of mitigation, was completed in 1989, at a cost of $300,000. Phase II of the project consisted of reservoir construction earthwork and was completed in 1993, at a cost of $1.6 million. Portions of the existing construction debris landfill side slopes were also stabilized as part of the Phase II earthwork. The FPD provided the design of Phases I and II of the project in-house.

Phase III design, completed by Woodward-Clyde, consisted of analyzing the hydrology and hydraulics of the watershed and flood control system, structural and geotechnical design of structures, and preparation of permit applications and construction documents. The DEC provided the hydraulic design using the FEQ unsteady-state dynamic routing model. The FEQ model was also used to size the hydraulic structures and flood control system, including the determination of upstream and downstream flood elevations and flow bypass rates. Woodward-Clyde did the dam safety analyses, structural and geotechnical design, and the permit applications. The FPD administered the project and provided construction management and oversight.

The project site is adjacent to an environmentally sensitive wetland and hardwoods forest and therefore the project is tailored to protect the wetlands and trees. The diversion dam on the Western Tributary was constructed to provide maximum flood mitigation benefits while minimizing the impact on dense hardwood trees. Woodward-Clyde performed an alternative analysis before final project design, evaluating various dam sites and flood control structures for engineering feasibility, including hydrologic and hydraulic, and environmental impacts.

A joint permit application was submitted to the U.S. Army Corps of Engineers (USACE) Chicago District, Illinois Environmental Protection Agency (IEPA), and Illinois Department of Natural Resources/Office of Water Resources (IDNR/OWR) for development in waters of the United States and in floodways. Copies of the application were forwarded to the U.S. Fish and Wildlife Service and the Illinois Department of Conservation. A stormwater management permit was submitted to the Village of Bloomingdale, the DuPage County Department of Environmental Concerns, and Village of Roselle. On behalf of the FPD and DEC, Woodward-Clyde filed and obtained the Dam Safety Permit for the construction and maintenance of the dams with the IDNR/OWR.
The alternative analysis prior to final project design included the following:

- Review of the hydraulic structures and flood control system proposed by Woodward-Clyde and others;
- Evaluation of the location of a single dam versus two dams based on site topography, environmental impacts and hydraulic control;
- Evaluation of the locations and flood elevations to assess the impacts on existing wetlands and woodlands;
- Stage-duration and stage-storage analyses to evaluate the potential impacts of additional flooding to the wetlands and woodlands; and
- Evaluation of the construction costs of proposed hydraulic control structures.

After selection of the environmentally desirable and technically feasible alternative, Woodward-Clyde conducted geotechnical investigations to evaluate the subsurface conditions at the project site. Laboratory tests were conducted on soil samples to obtain parameters needed for the stability analyses, foundation design and construction.

The total flood water storage capacity for the project is 575 acre-feet for the project maximum design water elevation of 723.5 ft NGVD. The Meacham Grove Reservoir capacity is 444 acre-feet and the remainder of the 131 acre-feet of storage is provided in the wetlands area upstream of the main flood control dam. During the operation of the flood control facility, the reservoir is gravity fed and emptied so that no pumps are required. The main flood control dam (Dam No. 1) on Spring Brook and a diversion dam (Dam No. 2) on the western tributary were constructed to control the flow bypass rates during flood events. The floodwaters are routed into the reservoir via a labyrinth spillway located on the mainstem of Spring Brook, upstream of Dam No. 1. The reservoir is lowered to its normal pool elevation of 705 ft NGVD through a 36-inch diameter outlet conduit that functions by gravity. The diverted floodwaters are then slowly discharged back to Spring Brook near Circle Avenue (Figure 1).

**PROJECT COMPONENTS**

The Meacham Grove Dam and Reservoir operational components are:

**Dam No. 1—Main Flood Control Dam**

Dam No. 1 is an earth embankment on Spring Brook, upstream of the confluence with the western tributary. The dam is 8 feet high and has a 10-foot-wide crest with 3H:1V embankment slope. The dam crest is 275 feet long and at elevation 726.5 feet including a 3-ft freeboard above
Figure 1. Meacham Grove Dam and Reservoir flood mitigation and flood control project.
the maximum water elevation. Spring Brook base flow is maintained through a 4-foot-high by 7-foot-wide concrete box culvert. The upstream toe and face of the dam are protected against erosion from wave action using interlocking concrete blocks up to an elevation of 723.5 feet NGVD, the project design maximum water level.

**Emergency Spillway**

A 360-ft long emergency overflow spillway structure was constructed as an extension of the west abutment of the Dam No. 1. The structure consists of a sheet-pile cut-off and reinforcement wall embedded in a clay embankment with 2H:1V side slopes. The emergency spillway is an average 5 feet high and has a 10-foot-wide crest for maintenance and inspection access and as a corridor for a future recreational trail.

**Dam No. 2 (Diversion Earth Dam) and Diversion Channel**

A diversion dam (Dam No. 2) was constructed on the western tributary to divert flood waters to the wetlands reservoir behind Dam No. 1. Diversion dam is approximately 360 feet long and consists of a 5-foot-high earth embankment with 4H:1V upstream and 3H:1V downstream slopes. The dam crest is at 730.0 feet NGVD and 10 feet wide. The upstream slope of the dam is also the side slope of the diversion channel at the toe of the dam. Base flow of the western tributary is maintained through a 3-foot-high by 6-foot-wide concrete box culvert. The diversion channel lies along the upstream toe of the dam and follows the natural low ground towards the wetlands. The channel has a 12-foot-wide bottom and 0.09% longitudinal slope. The 4H:1V channel side slopes will be protected with erosion control matting and grass seeding. A concrete weir with a crest elevation of 724.5 feet NGVD was built to allow excess floodwaters to spill into the diversion channel. The channel is 500 ft. long and connected to the wetlands area upstream of Dam No. 1.

**Reservoir Spillway**

The reservoir inflow structure consists of a labyrinth weir and a concrete lined spillway with baffled block energy dissipaters. The labyrinth weir has a series of trapezoidal structures that increases the effective length of a weir without increasing the total spillway width, thereby reducing the construction cost over 40% for a linear foot of spillway compared to a broad crested weir. The relatively short width of the labyrinth weir also allowed for installation of a pre-fabricated 70-foot-long by 10-foot-wide bridge over the weir for maintenance and recreational access. The crest is 56 feet wide and at elevation 720.5 feet
NGVD. The prefabricated steel bridge was constructed over the spillway on shallow spread footings. The bridge, weir, and energy dissipater walls all have a fence on both sides to enhance public safety near the structure.

Inflow Conduit

A 150-ft long inflow conduit was constructed at the northeast corner of the reservoir to collect surface water run-off behind the houses on Foster Avenue during smaller rainfall events. The conduit consists of a 30-inch diameter reinforced concrete pipe (RCP) connected to a catch-basin at elevation 720.0 feet. The conduit discharges into the reservoir at elevation 700.0 feet, i.e., 5 feet below the normal pool elevation.

Outlet Conduit

The reservoir outlet conduit consists of a 36-inch diameter reinforced concrete pipe (RCP) located at an invert elevation of 705 feet and zero percent slope, in the southeast corner of the reservoir. Total length of the conduit is approximately 1,260 feet. The outlet conduit provides gravity drainage of floodwater temporarily stored within the MGR while maintaining a maximum normal pool depth of approximately 40 feet. At normal pool level, the reservoir (known as “Maple Lake”) covers 16 acres and provides over 4,000 lineal feet of shoreline for fishing access. The FPD stocks the lake with largemouth bass, bluegill, channel catfish, and crappie. The outlet conduit discharges into Spring Brook near Circle Avenue and has a flap gate and flared end at the discharge point.

CONCLUSION

The construction of the Meacham Grove Dam and Reservoir Project is complete except for final seeding and some permanent erosion control. During a February 1997 flood, the facilities operated successfully and prevented flooding of Lake Street, Circle Avenue, and area businesses. The project is now one of several successful components of the DuPage County’s Lower Salt Creek flood control program.

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Woodward-Clyde Consultants, Chicago, Illinois

Woodward-Clyde Consultants, Chicago, Illinois
Part 9

USING GEOGRAPHIC INFORMATION SYSTEMS
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A GIS INTERFACE TO HEC-RAS

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INTRODUCTION

The HEC-RAS River Analysis System (HEC, 1997) is a one-dimensional river modeling system designed for interactive use in a multi-tasking environment. Version 1 provided steady-flow water surface profile calculations for a river network with sub-critical, supercritical, or mixed-flow regime on computers with MS Windows® operating system. The program has been developed based on a single definition of the river geometric data for all modeling. River networks are defined by drawing, with a mouse, a schematic of the river reaches from upstream to downstream. As reaches are connected, junctions are automatically formed by the program. After the network is defined, reach and junction input data can be entered. The data editors are called by pressing the appropriate icons in the geometric data window, or reach data can be imported from HEC-2 data sets (HEC, 1990).

Cross sections are located by river, reach, and river station. Pressing the cross-section icon provides the data entry editor. Data are defined by station-elevation coordinates (up to 500). There is no maximum number of cross sections. The section data are stored in downstream order based on river-station numbers. Cross sections can be added or modified in any order. Cut, copy, and paste features are provided, along with separate expansion or contraction of the cross section’s two over banks and channel. Cross-section interpolation can create additional computational sections based on a “string model” linking adjoining sections.

HEC-RAS Version 2, provides several added capabilities including the option to import and utilize three-dimensional (3D) river reach and cross-sectional data from a data exchange file. Upon completing the hydraulic calculations, the computed profile and flow-width data can be written back to the data exchange file. This paper highlights some major new features in Version 2 and describes the general use of the data exchange file in HEC-RAS. HEC is also developing generalized procedures (macros) in Arc/Info to develop model data, in the exchange format, to export geometric model data to HEC-RAS and to import computed water surface profiles and flood boundary data back.
HEC-RAS VERSION 2.0

Version 2 completes our major goals for a new steady-flow program. The program now can model dams with gated spillways and weirs, and perform channel modifications in the style of the HEC-2 CHIMP routine. The channel modifications are defined as trapezoidal templates that are placed on the existing cross-section data to define a modified channel. The cut process produces a new channel geometry, plus cut area and volume data. Channel reach lengths and \( n \) values can be redefined for the modified reach. The modified geometry is saved in a new file. Then, under a new plan, the water-surface profiles are computed for the modified channel. The computed results can be presented in graphics and tables along with the existing-condition model results.

With support from the Federal Highway Administration, the WSPRO low-flow bridge hydraulics (FHWA, 1990) and the bridge scour computations (FHWA, 1991) have been added to the program. The culvert capability has been expanded to include high- and low-profile arches to the choices of culvert shapes. Also, the culvert routine now can compute profiles in culverts with adverse or steep slopes.

With a new data-exchange file format, the program can import and use 3D geometric data. Figure 1 shows the Geometric Data Editor with model data imported from a terrain model. The plan-form of the stream network and the cross-section locations and orientation are preserved from the terrain data. The display is not distorted; therefore, cross-section widths and the distance between sections reflect the relative spacing of the physical data. Also, background maps can be added as a backdrop in the river-reach display and photographs can be linked with model cross-sections. Sections with photos attached display a marker that can be clicked on, with the cursor, to display the photograph. This option should be helpful for bridge and culvert modeling.

DATA EXCHANGE FILE

HEC is developing a format for a general-purpose data exchange between CADD or GIS programs and its Next Generation computer programs (HEC, 1996). The goal is to facilitate data transfer between HEC models and the CADD and GIS software systems, without "adopting" any one system. Terrain data can include watershed boundaries, stream network definition, catchment area, river cross-sections, and similar model data. The initial focus has been to provide an interface with the Hydrologic Modeling System, HEC-HMS (HEC, 1995) and the River Analysis System, HEC-RAS. Data records have been defined to provide basic terrain data to these two programs and new records can be added.
Figure 1. HEC-RAS Geometric Data Screen with imported terrain data for Wailupe River, Hawaii.

The data exchange file is a formatted ASCII text file. Standard records in the file are composed of keywords and values. The use of keywords and a text-file format provides a self-documenting file which can be created or edited with a text editor, and is easily read and understood by reviewers. Records can contain a value or a set of values following the keyword. Records in the data file can be grouped into two types: file sections and objects.

File sections start with a record containing a keyword composed of the word "BEGIN" followed by the section name and a colon. For example, the file header would begin with "BEGIN HEADER:" and end with "END HEADER:". The header section can contain information like data units, DTM type, map projection, datum, etc. A stream network section would contain records describing the river reaches. One or more reaches can be included in a stream network. Other reach data could be reach and stream identification, and centerline coordinates for each reach.

Objects are sets of information starting with a record with a keyword naming the object type and ending with a record containing the keyword
END:.” For example, a reach object begins with the keyword "REACH:,” a center line begins with "CENTERLINE:" and cross sections begin with "CROSS-SECTIONS:". Comments can be added to the file using the hash character (#) at the start of an entry line. Comments are treated like blank lines when the data are imported into HEC-RAS.

HEC-RAS can read geometric data from an exchange file composed of three sections: (1) a header containing descriptions that apply to all data in the file, (2) the stream network containing reach locations and connectivity, and (3) model cross-sections containing their locations on the stream network and cross-section coordinates. The stream network section contains records defining reach endpoints and identification number (ID), plus the reach data. At a minimum, the stream network must contain at least two endpoints and one reach. Each reach is defined by a multi-record object that includes an ID, the stream centerline XYZ coordinates, and river stations. The XY values are the planar coordinates and Z is the elevation. In HEC-RAS, the elevation and river stationing are optional data in the centerline definition. River station values are assumed to be in miles for English units and kilometers for metric.

The cross-section file section contains the cross-section objects. Each cross-section must have records identifying the stream, reach and river station, and defining a 2D section cut line and a series of 3D locations on the cross-section. The cut-line object is an array of XY locations defining the cross section in plan view (see Figure 1). The cross-section object is a label "SURFACE LINE:" and the 3D coordinates, written as comma-delimited XYZ real-number triples. The section’s left and right bank stations and the downstream reach lengths can be defined with the cross sections.

HEC-RAS MODEL APPLICATION

Developing an HEC-RAS model with imported data requires starting a new project. One would open the Geometric Data editor, select Files, and then select Import GIS Data. A file browser screen appears allowing you to select the data exchange file. The program reads in the file and displays the river-reach graphic based on the imported data. The HEC-RAS program maintains the XYZ data for graphical displays and to provide output to the data exchange file. For hydraulic computations, the program translates the XYZ coordinates into 2D cross-sections. The translated data are shown in the cross-section editor. The modeler needs to provide additional data like Manning’s n, contraction and expansion coefficients, plus bank stations and reach lengths if they are not in the exchange file. The modeler also adds data defining all hydraulic
structures in the reach. Flow data and boundary conditions are required for the flow-data file. Then, the model would be ready to compute profiles. The program operation and features are the same as they are for user input data, except for the XYZ graphic, which displays the water surface in the 3D terrain model. Figure 2 is an XYZ display of the lower reach of the Wailupe River model, under flood-flow conditions.

Figure 2. HEC-RAS XYZ perspective plot of lower Wailupe River reach, Hawaii.

HEC-RAS can write an output file in the data exchange file format. In the main menu, under File, is an Export GIS Data option. Selecting this option allows you to write an exchange file with model results. In the file header section, the program writes the date and time for the output, the number of reaches, cross sections, and profiles. Version 2 allows input of a profile name (e.g., 100-year), used as the identification label.

In the cross-section file section, the program writes the cross-section identification data and the 2D coordinate pairs for the section cut line. The computed water-surface elevation is written for each cross section. Following the cross-section data, the boundary polygons for each reach are provided by 2D coordinates. A reach's boundary polygon is composed of the most upstream cross section on the reach, the endpoints...
for each cross section in the reach and the most upstream cross-section of the downstream reach(es). If the cross-section geometry defines the limit of the water-surface inundation, no adjustments are made to the polygon boundary. The floodplain boundary will be determined in the terrain model by the intercept of the water-surface plane with the river-reach geometry. However, when the water surface is limited by levees, bridges and culverts, or floodways, the polygon is defined at the water's edge for those cross sections. Then when the polygon is used in the terrain model, the HEC-RAS knowledge of where the water is within each cross section is transferred to the CADD or GIS software. The adjusted polygon boundary will limit the floodplain definition to the polygon, rather than the water's intercept with the terrain data.

CONCLUSION

The HEC-RAS Version 2 capability to read geometric data from a data exchange file is our first-stage attempt to provide a better link to GIS data. HEC has a small research work unit dedicated to developing and fielding software that can make better use of information in GIS and CADD terrain models. The program's export of water surface profile and polygons of flooded areas should facilitate the program's application for floodplain definition and mapping. Continued development will provide increased capability over the life of the research work unit.

REFERENCES

Federal Highway Administration (FHWA)

Hydrologic Engineering Center (HEC)
USING GPS FOR PROACTIVE FLOODPLAIN MANAGEMENT IN MECKLENBURG COUNTY, NORTH CAROLINA

William R. Tingle
Charlotte-Mecklenburg Storm Water Services

William C. Pruitt
Ogden Environmental and Engineering Services

David F. Maune
Dewberry & Davis

INTRODUCTION

One of the key elements needed for proactive floodplain management is a base of accurate elevation information for flood-prone structures. For flood damage models (from the Federal Emergency Management Agency or the Corps of Engineers) to accurately estimate actual or potential flood damage to each building and the community as a whole, three things must be known about each building in or near the special flood hazard area (SFHA): depth of interior flooding from a 1% annual chance (100-yr) flood; the replacement value of each building; and the area of its "footprint." The depth of interior flooding is computed from 3-D coordinates (latitude/longitude/lowest-floor elevation), lowest adjacent grade (LAG), and base flood elevation (BFE) interpolated to the nearest 0.1 ft. When a geographic information system (GIS) also includes the geocoded address of each building in an SFHA, the major tools for proactive floodplain management are available to mitigate property damage from future floods.

BENEFITS OF GPS LOCATION AND ELEVATION DATA FOR FLOOD-PRONE BUILDINGS

Hazard Identification and Risk Assessment

Flood damage models are used to accurately estimate damage to individual buildings from 100-yr and 500-yr floods, for example, and to sum the total damage to all flood-prone buildings in the community. Then, the floodplain manager can quantify the potential cost to the
community from such floods. This risk assessment helps to identify and prioritize the need for subsequent steps.

**Drainage Improvement Projects**

Cost benefits of drainage improvement projects can be accurately determined by computing the flood damage costs to the community with and without the improvements. Otherwise, it is very difficult to justify the cost of drainage improvement projects to mitigate future flood losses.

**Floodproofing Projects**

Cost benefits of floodproofing individual buildings can also be accurately computed. Highly vulnerable buildings that are candidates to be moved, elevated, or retrofitted can be identified before floods occur.

**Flood Insurance and Public Education**

GPS elevation certificates, with superior accuracy, can be mass-produced at a fraction of the cost of producing traditional certificates paid for by individual homeowners. When provided to property owners by a storm water utility along with a clear explanation of their need for flood insurance, GPS elevation certificates are ideal for marketing flood insurance to those "at risk" and those with "reduced risk" of flooding. The database of accurate building locations and elevations can also be used for other flood-related public education efforts.

**Post-Flood Assistance**

When a flood occurs, it is no longer necessary to survey every damaged building to determine its depth of flooding and the associated estimate of damage, or to endure lengthy delays for a determination of its qualification for federal assistance. By surveying only the high water marks at key locations in town, such as bridge crossings, hydrologic and hydraulic models can accurately determine the elevation of flood crests throughout the community. The GPS elevation survey data are then used to compute the depth of interior flooding for each building. The flood damage models can quickly estimate actual damage done to individual buildings, and rapid decisions can be made on whether they qualify for assistance in rebuilding to old standards or must be elevated.

**BACKGROUND AND SCOPE**

Recognizing its need to take a more proactive stance in floodplain management, Mecklenburg County Storm Water Services (MCSWS) has
undertaken an effort to implement steps outlined above. MCSWS already has a GIS in place, but one missing element was the base of information for structures in or near the existing SFHA and prone to flood damage. Based primarily on information about the benefits of using the GPS survey methodology presented at FEMA’s National Mitigation Conference in December 1995, representatives from MCSWS decided to use this method to obtain the elevation data not in its GIS. The firm of Ogden Environmental and Engineering Services Co., Inc. (Ogden), with Dewberry and Davis acting as its GPS subcontractor, was retained by MCSWS to provide the necessary engineering and survey services for the project. The overall scope of the project was to develop an ARC/INFO database of flood related elevation and valuation information, along with elevation certificates for approximately 2,200 structures along developed areas, most within the City of Charlotte, that are in or near FEMA SFHAs and prone to flooding. The digital Q3 maps available from FEMA provided horizontal SFHA limits for the project.

**TEAM MEMBER RESPONSIBILITIES**

- Mecklenburg County Storm Water Services sponsored the project, set procedures, established requirements, and provided funding.
- Ogden annotated floodplain maps with building “footprints” and addresses of all buildings within the county’s SFHAs to be surveyed. Ogden also compiled a database compatible with the existing GIS for these structures that included the following information: addresses; Flood Insurance Rate Map data, tax parcel identification; and assessed value, year of construction, and square footage on these.
- Using National Geodetic Survey (NGS) guidelines for GPS elevation surveys [5-cm accuracy], D&D surveyed the 3-dimensional coordinates and LAG for nearly 2,200 buildings, added the field surveyed/verified data to complete a geocoded ARC/INFO database, added a building description and a digital photograph, and produced color GPS elevation certificates for those buildings (Figure 1).

The GPS project was completed successfully, and both the color elevation certificates and the geocoded database of information have been delivered to MCSWS. Although no insurmountable hurdles were encountered, it is worth noting some representative difficulties addressed.

**COMPILATION OF BUILDING DATA**

The inventory of structures to be field surveyed, along with the associated information was compiled from several different sources of
### Using GPS in Mecklenburg County

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<tr>
<th>Item</th>
<th>Value</th>
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<tbody>
<tr>
<td>Street Address</td>
<td>2708 E HH 16N PT</td>
</tr>
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<td>Charlotte, NC</td>
</tr>
<tr>
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<td>17582102</td>
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<td>Easting (NAD 83 M)</td>
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<td>Elevation at Target Point (ft)</td>
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<tr>
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<tr>
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</tr>
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<td>Building Diagram Number</td>
<td>4 - Split level, wall at grade on 2 sides</td>
</tr>
<tr>
<td>Year of Construction</td>
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<tr>
<td>Elevation Datum</td>
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<tr>
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<tr>
<td>Address</td>
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</tr>
<tr>
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</tr>
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<tr>
<td></td>
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</table>

**Legend**

Special Flood Hazard Area (SFHA) with 1% or greater chance of being flooded in any given year by a "base flood" (100 year flood).

Base Flood Elevation (BFE) curve which shows the outside limits of the "base flood"

Figure 1. GPS elevation certificate.
data including 1” = 200’ flood area maps, aerial photography, county tax office maps and database records, and community flood insurance rate maps. Discrepancies in the data among the various data sources were encountered, attributable primarily to the various dates of the data sources, which spanned several years. These discrepancies translated to unanticipated effort by both office and field staff to accurately correlate the data and to ensure accurate geocoding for the structures. Other difficulties were multiple structures with the same address but different tax IDs, and questionable mapping accuracies of some floodplains.

The field crews encountered problems due to incompleteness of a network of GPS precision benchmarks, as well as environmental/topographical conditions that imposed localized limitations on the application of the GPS methodology.

**DATA ANALYSES**

Table 1 summarizes the findings on 2192 surveyed buildings initially identified as possibly being located in a SFHA.

**Lowest Adjacent Grade higher than the BFE**—Before the GPS effort, 2,192 buildings were identified as being in or very close to the SFHA. The GPS surveys indicate that 989 of the 2,192 buildings surveyed (45.1% of the total) are not floodprone because their LAGS are higher than their BFEs, and most of these are actually outside the SFHA. Possible explanations include Note 1 above and discrepancies with existing mapping sources.

**Outside the SFHA with Lowest Floor above BFE (38.1% of Total)**—Of these 989 buildings, 836 were surveyed outside the SFHA and have lowest floor elevations above the BFE.

**Outside the SFHA with Lowest Floor below BFE (1.8% of Total)**—The GPS surveys indicated that 39 buildings surveyed outside the SFHA have lowest floor elevations below the BFE. Discrepancies with existing maps are probably the major cause for this. If only horizontal criteria were used for "in/out" determinations, these homeowners would get a false sense of security (located outside the floodplain) when they actually are "at risk" and need flood insurance.

**Inside the SFHA, Lowest Floor above BFE, Pre-FIRM (23.5% of Total)**—A total of 516 pre-FIRM buildings within the SFHA have the lowest floor elevation above the BFE. Their (subsidized) pre-FIRM flood insurance rates are higher than actuarially based post-FIRM rates.
Using GPS in Mecklenburg County

Table 1. SFHA buildings, lowest floor elevations vs. BFEs.

<table>
<thead>
<tr>
<th></th>
<th>Lowest Floor Above BFE</th>
<th>Lowest Floor Below BFE</th>
<th>% Lowest Floor Below BFE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outside SFHA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>950</td>
<td>39</td>
<td>4.1%</td>
</tr>
<tr>
<td>(See Notes 1, 2, and 3)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inside SFHA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pre-FIRM construction</td>
<td>516</td>
<td>511</td>
<td>49.8%</td>
</tr>
<tr>
<td>Post-FIRM construction</td>
<td>192</td>
<td>44</td>
<td>18.6%</td>
</tr>
<tr>
<td>FIRM-year construction,</td>
<td>32</td>
<td>22</td>
<td>40.7%</td>
</tr>
<tr>
<td>or unknown date</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TOTALS</td>
<td>1,576</td>
<td>616</td>
<td>28.1%</td>
</tr>
</tbody>
</table>

1. "In/Out" determinations were based on the latitude and longitude of the front door relative to the SFHA boundary from the Q3 coverage. The remainder of the building or yard could be on the other side of the SFHA boundary.
2. Current SFHA boundaries were used. No adjustments were made due to SFHA boundary changes between the initial FIRMs and current editions.
3. No adjustments were made for city limit annexations between 08/15/78, when Charlotte’s first FIRMs were published, and 06/01/81, when Mecklenburg County’s first FIRMs were published. These dates were used for determination of pre-FIRM, post-FIRM, and FIRM-year categories.

Inside the SFHA, Lowest Floor below BFE, Pre-FIRM (23.3% of Total)—A total of 511 pre-FIRM buildings within the SFHA have lowest floor elevations below the BFE. These are the property owners that benefit from the current policy to subsidize pre-FIRM rates.

Inside the SFHA, Lowest Floor above BFE, Post-FIRM and Undetermined Construction Dates (10.2% of Total)—A total of 224 post-FIRM buildings, and those with undetermined construction dates, have lowest floor elevations equal to or higher than the BFE.

Inside the SFHA, Lowest Floor below BFE, Post-FIRM (2.0% of Total)—A total of 44 post-FIRM buildings within the SFHA have lowest floor elevations below the BFE. The main reason is that a number of buildings were built below BFE but were to be used solely for parking and storage. But many of these lower levels have been “finished off” after an occupancy permit was issued. Appropriate action will be taken. Such flood hazards may not have been identified without the GPS project.
Inside the SFHA, Undetermined Dates of Construction (1.0%)—The remaining 22 "at risk" buildings have undetermined dates of construction. Regardless of whether they are pre-FIRM or post-FIRM, their flood risk is quantifiable, and something can be done to minimize future losses.

**Conclusions and Recommendations**

Accurate location and elevation of buildings in or near the SFHA is a tremendous tool for initiating local proactive floodplain management activities in a community. GPS technology has provided the means to provide this information with speed and accuracy that was not possible until recently. Reliable Flood Insurance Studies, SFHAs, and BFEs are absolutely essential for good floodplain management. However, reliance on horizontal criteria for SFHA "in/out" determinations appears to be inaccurate in many cases.

A possible future application would be the mass production of GPS elevation certificates nationally, including reference levels (lowest floor elevations), LAGS, and BFEs, which could be batch-processed at low cost for LOMA determinations so as to avoid individual expenses and FEMA processing that further overloads the LOMA administrative system. Furthermore, if elevation data were made public, present and future homeowners would be more likely to understand their true flood risk and purchase needed insurance. Such public information would also benefit the real estate, mortgage, and insurance industries.

In 1997, Mecklenburg County understands its flood risks far better than it did one year ago. The county is now poised to move ahead utilizing accurate flood-prone structure data and 3-D ARC/INFO floodplain coverages developed as a part of the project. Completion of the GPS survey project has resulted in both near-term tangible benefits and the data necessary to support proactive floodplain management for the long term.
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DEVELOPMENT OF A GIS-BASED DYNAMIC LAND USE PLANNING MODEL:
APPLICATION TO TRAIL CREEK, NORTHWEST INDIANA

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Denver Harper
Indiana Geological Survey, Indiana University

INTRODUCTION
Identification of non-point-source pollution (NPS) in watersheds, and remediation of its impact on water quality, is often difficult because of the spatial, distributed nature of the process involved, and the fact that alternative management practices normally cannot be tested because of the cost (Engel et al., 1993). Hydrologic/water quality models, however, are increasingly being used to identify NPS pollution and to evaluate potential remediation schemes (Timm and Jolly, 1994). These models can be divided into two types: lumped parameter models, which use some type of averaging technique to assign values to parameters used for computation in the model; and distributed parameter models, which attempt to incorporate spatial variability to parameterize the model. Lumped parameterization can introduce errors into the model because it does not account for spatial variability. Distributed parameter models, on the other hand, do incorporate spatial variability during computations and thus can potentially simulate a system more accurately.

One of the main difficulties with distributive parameter modeling of large areas for sediment and nutrient sources, however, is that data requirements and computational demands increase as the area to be modeled increases. "The extreme complexity of manipulating large volumes of spatial and nonspatial (or attribute data . . . severely limits the use of distributed H/WQ models (Timm and Jolly, 1994). Thus, the
time, expertise, and cost of acquiring the data, running the model, and interpreting the results, have limited the use of these distributed parameter models to small catchments primarily for research purposes.

To solve this problem the data can be treated in a coarser manner so resolution of input data and the results become less well defined, or methods to treat the larger amount of data can be devised. Geographic information system (GIS) databases are a convenient tool for integrating and converting large amounts of spatial data and, to some extent, the limitations to the use of distributed parameter models have been lessened by interfacing GIS with the models (Cahill and others, 1993; Srivinisan and Arnold, 1993; Warwick and Haynes, 1994; Tim and Jolly, 1994).

The simplest application of GIS to spatial modeling involves use of a GIS to supply data to a separately developed model that runs independently of the GIS. Integrating these diverse data into congruent GIS layers, however, is tedious and demanding work, and spatial data almost invariably comes at a variety of scales. A second level of integration involves construction of a GIS around a pre-existing model, or development of a model on top of a pre-existing GIS database. In both cases, linkages are established using special-purpose interfaces so that the

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**Figure 1. Layout of ARCINFO/GIS-based dynamic land-use model integration.**
model can accept data from the GIS and in turn output data to the GIS for further analysis and presentation.

The third level of integration, which is the one we will describe here, involves full integration of the model with a GIS created specifically for this use. The GIS will (1) be structured specifically for use in the model; (2) store data in standardized formats; (3) analyze spatial and nonspatial data to generate input for the model; and (4) output results of modeling for graphical display and analysis (Figure 1). Interfaces will be built to provide access between the GIS database, the dynamic model, and the user. These interfaces will allow the user to browse the database, examine the input generated by the GIS, and analyze the results in graphic or tabular format so that it is accessible to the local management structure for use in developing management plans.

Although the model we will construct is not based on a thorough analysis of transport mechanisms, it will allow determination of the cumulative impact that hydrology, ecology, chemistry, and land use have on runoff and water quality within heterogeneous watersheds. Its strength lies in its congruency with GIS land coverage data and its ability to be driven by surrogate information available for many watersheds.

**Application to the Trail Creek Watershed**

The model we construct will be initially calibrated to the geologic and hydrologic conditions in the Trail Creek watershed along the southern Lake Michigan shoreline in northwestern Indiana. The Trail Creek drainage was selected because (1) its geology, climate, hydrology, and land use are similar to many watersheds around the Great Lakes; (2) it is experiencing significant environmental problems; (3) it is small enough to allow establishment of a reasonably thorough monitoring program, yet large enough that the combined effects of the hydrologic, geologic, ecologic, and social factors on watershed dynamics and water quality can be evaluated; and (4) a mechanism to facilitate cooperation among state and local planning and regulatory agencies through the Northwest Indiana Regional Planning Commission and the research team already exists.

Non-point sources have been identified as a leading water quality problem in the Trail Creek watershed. Urban non-point source pollutants include fecal material, nutrients, heavy metals and other industrial and domestic use chemicals, and organic chemicals and solids. Rural nonpoint sources include farms and livestock operations that presently account for the majority of land use in the upper watershed and as much as one-third of the sediment loading in the stream as a whole. Developing urban and suburban areas and low-density rural housing developments utilizing septic fields are also important sources, per unit area, of NPS loads.
Many of the watershed's soils are developed on sandy outwash, clay tills, glacial till, lacustrine clays, eolian dunes, and loamy alluvium that have poor filtering capacity, limited seepage, and/or proneness to ponding.

Potential point sources for pollutants in the watershed are EPA Superfund and CERCLIS sites, sewage treatment plants, landfills, and a Confined Disposal Facility for dredged materials, the water treatment plant (through back-flushing), as well as various discharge pipes into the stream operating in the watershed.

**METHODS AND IMPLEMENTATION**

We propose to address these issues through a project that will (1) create a scientifically sound inventory in a GIS of the hydrologic, geologic, ecologic, and social factors that impact the quality of water in Trail Creek; and (2) develop a dynamic land use model to identify sources of contaminants and amounts of loading, and predict how changes in land use and the application of specific remediation measures will affect the quality and quantity of stream flow in the watershed. To assure maximum utility of this plan in the highly volatile political and environmental climate of the Indiana Great Lakes Region, we will work closely with local planners and managers throughout the study to customize the prototype to their needs.

GIS coverages of the watershed will include, but not be restricted to: surface geology, aquifer systems and their relationships to recharge and discharge areas, landforms, digital elevation models, wetland areas, soils to series levels, land use/land cover, GAP analysis, stream corridor habitat units, fisheries, endangered species habitat, and jurisdictional boundaries. Coverages will be combined and the resultant maps will be analyzed to determine fundamental land use/landform subareas in the watershed. Subcatchments that are internally homogeneous and representative of the various subareas will be defined.

Determination of the extent of human impact on the watershed will be made through an interactive watershed management model that will interface the GIS coverages of the watershed with a deterministic numeric model on a PC platform. Analytical functions will be developed to calculate stream discharge and loadings of various contaminants of the subcatchments of the watershed and then applied to the whole basin. The drainage network within a watershed can be subdivided into reaches (topological links) and junctions (topological nodes), and the contributing interfluve areas can be subdivided into segments that are defined by their connection to a specific reach of stream (Figure 2). Thus, the geomorphic composition of the watershed determines the path that water and its load take through the watershed. This geomorphological approach to
discretization and water routing provides computational efficiencies over gridded distributed parameter models.

Various land coverages can be overlain onto the segment coverages, and their intersections determine the critical subareas of the watershed. Runoff of water and concentrations of various constituents will have characteristic values within the critical subareas of the watershed and these can be parameterized and described by analytic functions or statistical distributions. Depending on antecedent conditions, a particular precipitation event will produce a different set of outflows but at the scale of the contributing segment, the following loading function will hold:

\[ L_i = \int_a c_{ij} r_j \, da \]  

(1)

where \( L_i \) is the total load of constituent \( i \), \( c_{ij} \) is the concentration of constituent \( i \) in subarea \( j \) of the segment, and \( r_j \) is the runoff from area \( j \) of the segment. A simple, but physically valid approach to distributed watershed modeling involves solving equation (1) for all segments of the watershed, then routing the flows through the drainage network.
We will utilize an efficient algorithm for computing the outflows of fingertip tributaries (those with inflow from segments only) first, then calculations will be propagated down-drainage to the outlet in a manner that assures that upstream inflows of interior reaches are known. The calculation sequence is guided by Shreve's (1966) ordering system, which states that a drainage network of magnitude \( n \) has \( n \) exterior links (fingertip tributaries), \( n-1 \) interior links (2\( n-1 \) links in total), and \( n-1 \) junctions (nodes). Trail Creek has a magnitude of 99, so the watershed contains 99 exterior links and has 98 nodes. When the nodes are arranged in accordance with the value of \( u_k + u_{k+1} \) (\( u_k \) = order of converging stream) from lowest to highest, the flows are accumulated appropriately.

The routing of flood waves can be accomplished using conventional approaches (e.g. Muskingum’s method) described in Chow (1959). Runoff generation in upland subareas of the watershed can be effectively simulated using functions similar to those employed by the Stanford Watershed Model (Crawford and Linsley, 1966). In lowland subareas, runoff generation is controlled by juxtaposition of topography and the water table. The hydrologic model to be developed in this project will couple these approaches subject to water balance closure.

To insure that the model remains computationally efficient, only the most critical aspects of runoff generating mechanisms will be simulated. Therefore, model equations will be simplified, whenever possible, over those currently utilized for watershed simulation. Similarly, loadings of contaminants will be calculated following previously documented procedures (Knisel et al., 1980), but for the purposes of efficient distributed modelling, simplifications will be invoked.

The project will feature aggressive technology transfer during the final three months: (1) a fully operational model will be given to local planners and managers who have regulatory and/or programmatic responsibilities in the watershed; (2) customized interfaces and linkages will be incorporated to produce user-friendly links for easy application of the model and access to output; and (3) managers will be instructed in the use of the model and provided with technical support during its use.

**SUMMARY**

The actualistic model of watersheds that will result from this work will relate the hydrologic, geologic, ecologic, and social factors impacting the dynamics of the watershed and the quality of its water. The study will determine the impact of the various forcing factors acting over the watershed and suggest remediation that would reduce their effect on water quality. It will give various agencies a data-based framework to help them assess the problems, assign responsibilities, and implement
policies to improve water quality. Most importantly, the land use model will allow managers and planners to develop scenarios that can evaluate how any activities in the watershed will affect water quality.

The model will be calibrated to the conditions in the Trail Creek watershed, but this watershed is similar in size, geologic, hydrologic, climatic, and land use characteristics to many others around the Great Lakes. Therefore, the concepts on watershed functioning and land use management developed here can be extended to other areas with water quality problems. Also, study of this watershed will complement a similar monitoring and modeling project that will begin in spring of 1997 in the wetland watershed of The Great Marsh in the Indiana Dunes National Lakeshore. These two projects will result in hydrologic models that will be representative of most of the watersheds in the Great Lakes Basin.

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Part 10

PROTECTING AND USING FLOODPLAIN RESOURCES
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INTRODUCTION

A stream bank erosion control manual is being prepared to assist in the analysis, planning, design, and construction of stream bank erosion control measures in North Central Texas. The manual will provide procedures and design guidance for mitigation of severe erosion problems to reduce the potential for damage to public and private property and the environment. The manual preparation has been commissioned by the cities of Plano, Garland, Allen, and McKinney, some of the fastest-growing communities in Texas. The draft manual is being reviewed by city staff.

THE NATURE OF STREAMS

General

Streamflow and channel variables interact over long periods of time to form the morphology of river systems. Induced changes in any of the physical processes create rapid and significant changes to the system. Often channel morphology is influenced by streamflow and sediment regime, valley morphology, basin relief, and the nature of stream bed and bank material (Rosgen, 1996).

North Central Texas Streams

This manual addresses streams with drainage areas from 0.2 to 10 square miles that are tributary to White Rock, Rowlett, and Wilson creeks or the East Fork of the Trinity River. In that area, channels are formed in chalk or shale bedrock. Channels in the chalk are rectangular to trapezoid in shape, with bank slopes ranging from vertical to 2:1. Bank materials are silty clay. Chalk streams generally have a greater drainage
density and are relatively steep. Shale-based channels are trapezoidal with 2.5 to 3:1 bank slopes, composed of weathered shale and clay alluvium. Shale channels are more sinuous but less steep than chalk (Allen, 1985).

**STREAM BANK EROSION AND FAILURE**

**General**

The causes of stream bank erosion are varied and complex. Bank failures can be massive and sudden or occur gradually due to surface erosion. Surface erosion is caused by flowing water, seepage, overbank drainage, wave action, weathering due to wet/dry or freeze/thaw cycles and land use changes such as urbanization or deforestation.

**Erodibility**

Of all the contributors to stream bank erosion in the project area, urbanization probably is the most important. Studies have shown that urbanization accelerates erosion and channels tend to roughly double their area as the stream attempts to reach a new state of relative stability (Allen, 1985). This adjustment occurs over time, possibly as long as 50-100 years. Therefore, it is important to establish a stream bank stabilization program for newly developing areas before homeowners or public facilities incur damage from stream bank failures due to erosion.

**STREAM BANK PROTECTION AND EROSION DAMAGE MITIGATION MEASURES**

The manual presents structural and nonstructural methods of stream bank erosion mitigation for reaches of stream in existing neighborhoods and for areas that are undergoing development.

**Armor**

Channel bank armoring can be concrete lining, rock rip-rap, gabions, grass-lining, pilot channels, articulated or interlocking concrete blocks, sand-cement bag revetments, or poured-in-place concrete grid mats.

**Walls**

Sometimes walls are constructed to replace failed channel banks in areas of limited right-of-way. Walls are typically constructed of reinforced concrete, gabions, or stone. Reinforced concrete and gabion walls have some of the same advantages and disadvantages as lined channels. Stone walls are attractive but usually are restricted in height.
Other walls include bulkheads, reinforced earth, and other precast retaining wall systems.

**Grade Control Structures**

Often it is necessary to make abrupt changes in channel grade to maintain nonerosive flow conditions. This can be accomplished with check dams, drop structures, stabilizers, and channel transition structures.

**Other**

Channels and swales increase the cross-sectional area of the floodway and thereby lower velocities. Geogrids, geotextiles, and cellular confinement are proprietary systems and should be installed according to the manufacturers’ recommendations. Excellent guidance is provided by the Texas Department of Transportation for synthetic blankets and mats for slope protection and as flexible channel liners. A list of acceptable products is published annually, based on testing results.

**Soil Bioengineering Practices**

Soil bioengineering practices (SBP) combine living plant material and structural elements to prevent slope failure due to erosion. Several common SBPs discussed in the manual are live staking, wattles (also called live fascines), brush layering, and brush mattressing (also called brush matting). SBPs have several advantages, including cost and environmental compatibility (use of native and natural materials). Many SBPs require minimal equipment and are less restricted by access considerations than conventional stream bank erosion control methods.

However, there are several limitations to SBPs that can impact applications in this region. SBPs are most effective when installed during the dormant season of late fall through early spring, which may coincide with poor weather conditions. The local climate can be harsh and the area’s hot, dry summers can make it difficult to establish large SBP projects without expensive irrigation systems. Also, many SBPs are labor intensive, lack well-defined standards, specifications, and testing programs, and do not compete well with inexpensive synthetic erosion control products. Last but not least, sufficient quantities of desirable, locally adapted plant species may be difficult to obtain (Northcutt, 1995).

The use of synthetic components with SBPs is likely to increase. These materials offer advantages of strength and economy. From an engineering standpoint, synthetic products can add a greater "known" safety factor which might encourage use by engineers who may otherwise not consider SBPs due to structural failure and liability issues. Another
factor contributing to the increased use of synthetic materials is lower costs, when compared to similar natural products.

**Setbacks and Buffer Zones**

A setback is a strip of land that separates one type of land use from another, usually for protection or aesthetics. The resulting separation, also referred to as a buffer, is usually established by systematic programs involving the location of key physical or environmental components of streams and their adjoining floodplains. When used as a stream bank erosion control tool, setbacks protect adjoining developed land from damage due to slope failures, slides, and settlement.

**Stream Preservation**

One of the most effective floodplain management tools available to planners today is the preservation of our natural streams and floodplains. Preserving these areas as open space and greenbelt accomplishes the multiple goals of flood control, water quality enhancement, recreation, and often economic development. This kind of stream preservation is fairly common practice in North Central Texas communities. However, stream bank erosion can still be a problem, particularly if the watershed is urbanizing. Therefore, stabilization measures or tools like setbacks will be needed, even along streams whose channels remain natural.

**Stream Restoration**

In some areas, streams altered by humans are being returned to a natural state. This enhances habitat for fish and wildlife and provides a more pleasant setting for surrounding neighborhoods. If the restoration area is part of an urban setting, erosion protection should be incorporated with appropriate mitigation measures, including setbacks.

**SELECTING PROTECTION FOR STREAM BANKS**

**Design Criteria**

The draft manual recommends a design frequency of the 2-year flood peak discharge for typical erosion control features. This design level will typically provide protection against 70% of the 100-year storm depth based on an analysis of similar streams in a nearby community.

**Stream Classification**

All streams should be physically inspected by the design engineer accompanied by a team including a geotechnical engineer, geologist or
geomorphologist, environmental scientist, biologist, and landscape architect, depending on the size and nature of the project. The team should examine the stream’s bed and bank material and classify its soil and strata. Causes of existing erosion should be assessed, as should vegetation and habitat. A complete documentation of the field inspection should be part of the engineering study for the stream, and should include photographs and maps of critical features such as existing vertical banks. Based on the field visit and best available maps, assessments can be made of such channel features as sinuosity, channel shape, and vegetation.

Stream Hydraulic Analysis

Detailed hydraulic analysis is needed to correctly assess stream bank erosion problems. Typically, the analysis can begin with existing computer models with supplemental cross sections and updating to provide an accurate portrayal of channel velocity and tractive force in the study reach. The hydrologic analysis should be based on discharges reflecting a fully urbanized watershed. The analysis should be performed or supervised by an experienced hydraulic engineer or hydrologist.

Velocity determinations come directly from the hydraulic computer model. More detailed distributions may need to be developed across the section to accurately reflect conditions in wide flood plains or complex channels. Tractive force is a better means of assessing erosion potential than velocity, but velocity will be used in this manual until more experience with using tractive force is gained in North Central Texas.

Setback Determination

Setbacks for erosion damage mitigation should be established by plat or recorded instrument. The setback should be required on all projects in which natural streams are to be preserved or where variations from the recommendations of the manual are desired.

The following is a setback program designed for preserving natural streams in North Central Texas. It is based on the philosophy of maintainable slopes and allows the natural erosion processes to continue without threatening structures. The setback zone would extend from the toe of the natural stream bank to a point at the intersection of natural ground and a line constructed on a 4:1 slope away from the stream. Fifteen feet are added for maintenance purposes. Setbacks established for erosion control may extend beyond the limits of the regulatory floodplain.

It may be desirable to reduce the setback where stream banks consist entirely or partly of rock. In these areas, the interface of the stream bank with the top of the unweathered rock strata should be located by a
qualified geotechnical engineer or geologist. This point will be the toe of a 3:1 slope intersecting natural ground. The setback limit should be 15 feet beyond. When natural channel banks are protected in this manner, no building, fence, wall, swimming pool, or other structure should be located within the area encompassing the setback.

Erodibility Index

An erodibility index should be computed for each potential erosion site within the proposed project. Erosion sites are defined as areas of high velocity (over 5 feet per second), outside banks of meanders, steep banks (greater than 3:1) and areas of existing erosion. The index should be a function of urbanization, stream velocities, sinuosity, and channel bank material. Watersheds that are undergoing urbanization influences should be weighted by a factor of 2 unless the watershed is stable (has been urban for at least 50 years). The degree of sinuosity or meandering of the stream should be assessed and assigned a factor ranging from 1 for relatively straight streams to 3 for streams with pronounced meanders.

The effect of channel bank soils on erosion potential is quantified based on a rating ranging from 1 for rock to 4 for sands and silts. Channel velocity and tractive force are included in the erodibility index as a range from one (velocity less than 5 ft/sec) to three (more than 8 ft/sec).

The erodibility index is the sum of the indices for channel velocity, sinuosity, and bank materials, multiplied by the urbanization factor. The erodibility index will range from 3 to 20. Areas with erodibility indices of 3-8 should exhibit mild erosion; 8-12, moderate erosion; and 12-20, severe erosion potential. If the erodibility index is 8 or greater, the applicant should develop a stream bank erosion control plan.

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INTegrating fema's disaster response mission and NEPA compliance responsibilities

Pieter de Jong
Erica D. McLean
Woodward-Clyde

Introduction
Since its inception, the mission of the Federal Emergency Management Agency (FEMA) has been to provide timely assistance to communities nationwide in preparing for, mitigating against, and recovering from the certain occurrence of natural disasters. FEMA has recognized the criticality of upholding and enforcing the provisions of the National Environmental Policy Act (NEPA), Executive Orders (EO), and other federal environmental legislation that falls under the "umbrella" of NEPA; the required compliance however, is sometimes counter to FEMA's mission to facilitate a rapid response and recovery from natural disasters. Given the number and intensity of disasters occurring over the last three years, and the corresponding extent of FEMA's NEPA compliance responsibilities, there was no better circumstance for FEMA to realize a critical and far-reaching challenge of the 1990s: How to better integrate FEMA's NEPA responsibilities with its disaster assistance mission. In learning from previous disasters, and in allowing for creativity and innovation in their NEPA documentation, FEMA has initiated change in its programs and its approach to NEPA in an effort to support and expedite the NEPA process with respect to disaster assistance.

Redefining program operations
Public Assistance Program NEPA Training
As one of FEMA's most critical early disaster response programs, the Public Assistance (PA) Program is focused on providing "on-the-ground" disaster assistance to local jurisdictions, public agencies, and in some cases, private non-profit institutions. The PA Program is central to early emergency and clean-up operations such as implementing protective measures and conducting debris removal. Also provided by the PA Program is the opportunity for repair, restoration, or replacement of eligible facilities. As part of the recovery process, a damage survey
Integrating Disaster Response and Environmental Compliance

report (DSR) is completed on each potential project by a DSR inspector, whose highest priority while in the field is to document the damage that has occurred at the site and to develop a scope of work for repair. The DSR becomes the “snapshot” of the site, and represents the best early description of the site, the extent of damages, and the necessary repairs.

An evaluation to determine what level of NEPA review is required for every federally funded project. This process is conducted by an environmental reviewer at the Disaster Field Office, whose key piece of information during this review is the DSR. However, because the DSR inspector’s main purpose is to document site damage and needed repairs, information essential to determine the appropriate level of NEPA review is often not recorded on the DSR, and the environmental reviewer must make a compliance decision with what may be incomplete information. Realizing this, FEMA has authorized Woodward-Clyde to develop a NEPA training class directed specifically toward PA Program staff. One of the objectives of the training is to provide DSR Inspectors with insight into environmental review considerations and field observations that, if present, may indicate the need for detailed review later by NEPA compliance specialists. By conducting such a training class and providing DSR Inspectors with appropriate handouts, it is anticipated that the early field DSR documentation will include the information critical to determining the appropriate level of NEPA review, thus supporting FEMA’s NEPA responsibilities, while remaining focused on the original mission.

Categorical Exclusion Expansion

In general, the vast majority of DSRs that are emergency in nature or indicate repairs to return a facility to its pre-disaster condition, are statutorily excluded from NEPA review. However, those projects that can not be excluded in this manner must be reviewed under Categorical Exclusion (CATEX) criteria. CATEXs are the second level of NEPA documentation and involve actions that, as indicated through years of FEMA’s experience, do not typically result in significant environmental impacts. To implement this level of review, a proposed project must first fit the defined CATEX, and then be reviewed for potential for extraordinary circumstances. If no extraordinary circumstances exist (which are usually seen in the form of other applicable federal environmental regulations) or do exist, but can be easily addressed, then a brief administrative record is prepared and no further NEPA documentation is required. The proposed project would be subject to further NEPA evaluation by the preparation of an Environmental Assessment (EA) or an Environmental Impact Statement (EIS) if a
preliminary environmental review indicates that there are still unresolved environmental issues that could lead to significant adverse impacts.

By Final Rule promulgated in the Federal Register on February 5, 1996, FEMA revised its list of CATEXs. The revised list of 18 CATEXs reflected several years' experience on the types of actions that generally receive a finding of no significant impact (FONSI) after FEMA completes an EA. The intention of the CATEX revisions is to quicken the approval process for those classes of projects with little potential for significant adverse impacts, and to allow attention to be focused on those projects with the potential for environmental concerns. Many of the new CATEX categories address acquisition of flood-damaged homes and other small scale hazard mitigation measures that are important elements of the Section 404 Hazard Mitigation Grant Program (HMGP). As an early indication that the revisions have been effective, FEMA headquarters' NEPA compliance staff have noted that the number of EAs prepared during 1996 dropped by half after implementation of the expanded list of categorical exclusions.

Pre-disaster Programmatic Agreements

Section 106 of the National Historic Preservation Act of 1996, as amended, mandates that federally funded projects take into consideration the impacts of proposed undertakings on historic properties, and, if there are adverse effects, to mitigate against them in consultation with the State Historic Preservation Office (SHPO) and the Advisory Council on Historic Preservation. In an effort to promote efficiency in the consideration of impacts to historic properties and to reduce delay of federal assistance, programmatic agreements (PA) that effectively replace the standard Section 106 compliance outlined in 36 CFR 800 were utilized in the Midwest floods of 1993. Although successfully used, FEMA and the participating states realized that creating and implementing a PA during the often-chaotic aftermath of a disaster was difficult and time-consuming, which was counter to its original objective. In response to this, the idea of a pre-disaster programmatic agreement has come to the forefront of Section 106 compliance as it relates to disaster assistance activities.

In the pre-disaster PA, or model state agreement, the initial coordination between FEMA, the Advisory Council for Historic Preservation, the SHPO, and the participating state ensures that clear procedures for expedited review of emergency projects, non-emergency projects, and archaeological properties are established before a disaster strikes. Because the PA is standardized, it can be modified to be relevant to all types of disasters and can be applied to any state. Overall, the
benefits of having a planned, proactive procedure for cultural review in place prior to a disaster go beyond the obvious benefits of preparedness; because the PA is very mission oriented, all participants are able to stay focused on the duties they best perform. In addition, the PA delegates certain responsibilities within the historic review process to appropriate state agencies, such as the SHPO, where it is SHPO's duty to identify potential historic properties within a disaster area. The PA, then, not only provides the pre-disaster framework for completing cultural resource reviews, but also provides structure to how the reviews are completed with respect to the participating agencies.

Delegating Responsibilities to Regional Offices

Historically, FEMA has retained its NEPA compliance responsibility at the headquarters level. For example, the decision document for an EA (the FONSI), requires the signatures of the headquarters Environmental Officer and the headquarters Office of General Counsel (OGC), in addition to the Regional Director. In 1996, FEMA initiated a process to delegate much of its NEPA compliance responsibilities to the regional level. As this paper was being prepared in March 1997, seven of the 10 regional FEMA offices have filled positions for regional Environmental Officers, charged with strengthening the Region’s NEPA compliance capabilities. Following a transitional period, the Regional Offices will have full signature authority to draft FONSI s, eliminating headquarters review and approval requirements. EISs will still require the involvement and signature authority of headquarters. This change in the NEPA program operations will expedite NEPA review.

INNOVATIVE APPROACHES TO NEPA COMPLIANCE

Threatened and Endangered Species Impacts in Collier County, Florida

In addition to program changes, allowing NEPA to be innovative and creative in its application has become central to FEMA’s objective of expedited NEPA review. This is best illustrated by the NEPA documentation approach applied to a proposed project in Collier County, Florida.

A proposed HMGP project to upgrade and expand stormwater drainage within the county resulted in a project area of about 20 square miles of uplands and wetlands, which served as habitat to over 32 endangered species. As required under the Endangered Species Act, an evaluation of the potential impacts to threatened and endangered species stemming from direct construction-related impacts and indirect impacts affecting downstream water quality and quantity was required. Because
the project involves a great expanse of area, a comprehensive field investigation to evaluate the impacts would have been extremely time- and resource-intensive. To reduce these expenditures, FEMA Region IV and Woodward-Clyde developed an alternative approach.

To expedite the NEPA compliance process while continuing to meet the intent of the law and its implementing regulations, the project approach was reorganized into three phases. The first phase consisted of the collection of project area land use, vegetative cover type, and preliminary field reconnaissance data. To assist in this effort, Woodward-Clyde coordinated with the Florida Game and Freshwater Fish Commission to gather area-specific and readily available data on local land cover. Once the land cover and natural habitat within the project area were determined and mapped, the second phase was initiated. Under this phase, the land cover and habitat data were compared with habitat requirements of Collier County plant and animal species to determine whether potential threatened or endangered species occurred within the mapped project area. The third phase was the development of a coordination package that included the mapped project locations, presented the analysis of land cover, and enumerated the potentially occurring threatened and endangered species. This coordination package was sent to the State of Florida and federal natural resources trustees for review in accordance with the Endangered Species Act Section 7 coordination. Overall, the phased approach provided a less time-intensive alternative to multiple field surveys and therefore expedited the required analysis and agency review.

**Hazardous Waste and Materials Assessment at Ansonia Place, Pennsylvania**

With projects involving acquisition of structures to mitigate against future hazard damages, completion of the required NEPA review often signals the start of a new life for the residents of the acquisition. This was the case with the HMGP acquisition project submitted to FEMA by the City of Pittsburgh, Pennsylvania. Under this proposed project, approximately 22 flood-prone homes were proposed for acquisition to mitigate flooding at Ansonia Place, which was inundated by Saw Mill Run, an adjacent stream. As required under NEPA, review of potential hazardous waste and materials that may occur at the site and adjacent areas must be completed if the potential for contamination exists. Preliminary hazardous waste and materials information about the site indicated that Saw Mill Run was once declared as an open sewer by the Pennsylvania Supreme Court, and previous studies identified potentially significant chemical and biological contamination of the stream, including
acid mine drainage, untreated human waste, very high levels of coliform bacteria, and polychlorinated biphenyls (PCBs) in fish samples. This information suggested that the potential for contamination of the adjacent properties in Ansonia Place from flooding of Saw Mill Run exists, and thus raises concerns regarding potential liability to FEMA and the local applicant after property acquisition.

Instead of conducting an extensive program of investigative soil and groundwater sampling for a full complement of chemical contaminants (which represents the most conservative approach), Woodward-Clyde proposed an initial phase of site reconnaissance and records searches to evaluate the potential nature of on-site and off-site contaminant sources to determine what environmental sampling (phase two) would be appropriate. In line with this approach, a records search was conducted to determine if past uses of Ansonia Place or adjacent properties may have contributed to on-site chemical contamination. The results of the reconnaissance and data searches suggested limited potential for on-site sources of chemical contamination. However, records searches and observations in the field identified potential chemical contamination sources within the upstream reaches of Saw Mill Run that suggested potential contamination by semi-volatile organic compounds and metals. Based on the record and data searches and the field observations, the final report recommended that only a limited program of surface soil sampling and analysis for semi-volatile organics, priority metals, and PCBs was needed to fully address the issue.

**Conclusions**

The responsibility of complying with NEPA can often prove to be time- and resource-intensive, which is inconsistent with FEMA’s overall mission of providing timely response to assist communities in recovering from and mitigating against disasters. However, allowing innovative thinking to give life to new program and NEPA study approaches has enabled FEMA to meet its NEPA compliance responsibilities at an expedited pace, while observing all applicable laws, regulations, and Executive Orders. As FEMA and our communities continue to face natural hazards, it is important to realize that although the phenomenon of disasters is a fixed and perpetual aspect of our world, the methods by which we respond to disasters and consider environmental issues are not.
INTRODUCTION

The South Suburban Park and Recreation District (SSPRD) was formed in 1959 and now serves more than 130,000 residents in a 57 square-mile multi-jurisdictional suburban area south of Denver, Colorado. Over the past 20 years SSPRD has expanded its network of greenway corridors and parks by combining recreational facilities with drainageways and flood control facilities. Development of multi-use parks and greenway corridors has been facilitated by joint funding between the park district, the municipality, and the multi-jurisdictional Urban Drainage and Flood Control District. Costs are shared for capital construction as well as for maintenance of improvements.

OVERVIEW

The mission statement for the SSPRD reads “To contribute to the full and meaningful lives of our residents by providing a variety of leisure services, and improving the quality of life through stewardship of the environment, parks, trails and open space.” The District’s area includes a number of suburban Denver municipalities and unincorporated portions of three counties. Facilities include over 2,700 acres of park land at 115 locations (including developed and natural open space), 41 playgrounds, 107 miles of trails, two full-service recreation centers, a senior/community center, two indoor and five outdoor pools, a two-rink ice arena, 83 athletic fields, 61 tennis courts, a batting cage facility, three golf courses, and a miniature golf facility.

What does all this have to do with flood control? The SSPRD became the owner/caretaker for miles of drainageway corridors largely through park and open space dedications by residential developers completed as part of their platting process. Over the past 20 years SSPRD’s planners
have worked to develop a network of greenway trails that provide recreational and commuting benefits for bikers, rollerbladers, runners, and walkers. The corridors all lie within the 100-year floodplain and are also subject to frequent or nuisance flooding on an annual basis. The multi-jurisdictional Urban Drainage and Flood Control District (Drainage District) provides floodplain regulation, capital construction improvements and maintenance along all major drainageways in the Denver metropolitan area. Therefore, all designs along greenway corridors must meet UDFCD criteria. Certain projects, such as trails, crossings, and stream stabilization improvements, are eligible for construction funding assistance from the Drainage District. Once completed in accordance with District requirements, the improvements can be eligible for maintenance funding. The Drainage District utilizes the greenway trails for drainageway maintenance activities such as debris removal, vegetation management, and erosion repair. Thus the key benefits of multiple use of drainageways are

- floodplain preservation and management;
- active recreational facilities, such as trails;
- passive recreational benefits, such as open space and nature study;
- habitat and wetland preservation/enhancement;
- access for drainageway maintenance;
- shared maintenance tasks; and
- shared funding of initial construction and maintenance.

**PROJECT DEVELOPMENT GUIDELINES**

The SSPRD follows a comprehensive park/facilities and trails master plan. This document, "A Guide for Growth," was authored by a group of citizens, guided by park and recreation professionals in 1970. It created the "vision" of a park system that would provide quality services for a 57 square-mile urbanizing area.

Numerous concepts, goals, definitions, financing scenarios, and implementation strategies were established by "A Guide for Growth." The community leaders and park/recreation citizen advocates passed several bond issues, purchased or accepted land donations, implemented a public-based planning process, and then began construction of the park and recreation system.

**Public Involvement**

Early in the planning/development process, while engineers and surveyors are obtaining critical field data, park planners are contacting
local public officials and interested citizens to organize project design teams. Neighborhoods adjacent to or near the proposed trail are contacted. Notices sent to local newspapers or letters to homeowner associations are the best method of notification. On occasion, circulating flyers to a targeted area may be necessary, although other methods are preferred.

Conceptual Design

Once initial field engineering data is obtained, several site visits are conducted. Professional engineers and landscape architects/park planners proceed to design a conceptual master plan. This plan will usually contain various options regarding trailway alignment, points of access, rest areas, overlooks, parking access points, areas subject to intense flooding, and areas of critical wildlife habitat. This plan is first presented to the entire district management team, after which it is refined and presented to the elected Park Board of Directors. After this initial review, staff requests and advises the elected officials of the upcoming public planning process. Staff will also request one or two board members to join the design team, allowing active representation of the public’s elected officials.

"Open House" Concept

Interested citizens, potentially affected interests, and special interest groups are strongly encouraged to join in the planning process. SSPRD often organizes an “open house” to kick off this extended planning process.

The open house provides each potential participant the opportunity to ask questions, express concerns, react to what is being proposed, and even make suggestions to the technical experts who are responsible for developing a plan or program. The open house is an informal setting that allows for one-to-one exchanges, usually extending over several evenings and part of a weekend, between any concerned and/or interested persons and the public officials and professionals. While the potentially affected interests have the opportunity to mill around going back and forth between the displays and familiarizing themselves with the various facets of the proposed plans or plans, the open house is also productive in getting their viewpoints and perceptions communicated to the professionals.
**Master Planning for Parks**

Projects that involve capital expenditures and/or development are planned by a very specific procedure as established by SSPRD's Board of Directors:

1. The project is identified within budget parameters, public need and desirability, and with general or specific use and facility features determined.

2. Staff conducts various surveys, studies, and gathered necessary data so that an initial design phase (land use study or architectural concept) can be initiated. Board members' thoughts and input are desirable during this early planning stage. This step occurs whether the project will be designed by in-house planners or through an appointed architect or engineer selected by the Board.

3. Once the preliminary input has been gathered, the preliminary plan is developed and then submitted to the Board at a public hearing for review, revisions, and so forth.

4. Appropriate community groups, homeowners, cities, school district, etc., are contacted and input is solicited from the public. Presentations are made and written approvals obtained whenever possible.

5. If necessary, the preliminary plan is again presented to the board at a public meeting and based on citizen input and general policy considerations, whatever changes the board deems necessary are directed.

6. Once the preliminary plan is publicly approved, staff and/or the contracted architect or engineer proceed with final drawings.

7. The proposed final plan is then presented at a public board meeting, which constitutes the final hearing. If the plan is approved and adopted, the board then directs the staff to begin with the bidding process, which will lead to the commencement of construction.

During the entire planning process, the board and staff are mindful of the SSPRD's planning documents, factual data, sound design criteria, public input, and other agency approval, and of the budget parameters of the project.
PROJECT HIGHLIGHTS

The following are brief descriptions of successful multiple use projects that have been completed over the past 20 years with the joint efforts of the SSPRD, the local municipality, and the Drainage District.

South Platte Park

This park was a pioneering effort by the City of Littleton to achieve a nonstructural solution for flood control in accordance with the 1974 Water Resource Development Act. City officials, using bond funds matched by state and federal grants, acquired 630 acres of the South Platte River floodplain to be preserved for open space and habitat as an alternative to channelization by the Corps of Engineers. In partnership with the Corps, the SSPRD, and the Colorado Water Conservation Board, the citizens of Littleton overcame numerous obstacles to preserve a significant and diverse lowland riparian ecosystem. SSPRD manages the park and provides an extensive environmental education program at the Theo L. Carson Nature Center.

The Mary Carter Greenway

This greenway was named in memory of the chair and driving force behind the South Suburban Foundation, a non-profit corporation established for improving open space and recreation amenities for SSPRD residents. The greenway is an 8-mile multi-use trail and whitewater boating corridor along the South Platte River flood control channel in Arapahoe County. It forms an integral part of the central spine of the Denver metro area greenway system and is enjoyed by more than 700,000 users annually.

Multiple Use Detention Facilities

The SSPRD, the Urban Drainage District, and local municipalities combined efforts and funds to develop two significant multiple-use flood storage facilities. Park and trail development within these normally dry flood storage facilities enables recreational use during non-flood periods.

Holly Park was developed in the flood pool zone behind Holly Dam on Little Dry Creek in Arapahoe County. The 40-acre park features a playground, open space and a multi-level tennis complex, with the lowest courts at the 10-year flood elevation. The Willow Spring Open Space Park is a 122-acre natural open space within the flood pool zone behind Englewood Dam on Willow Creek in Arapahoe County. South Suburban has preserved the wetlands and wildlife habitat and, with support of
neighboring residents, has developed a peripheral trail system and is planning a nature center.

**Multiple Use Greenways**

McLaughlin Water Engineers has worked with SSPRD on the design of trails, stream crossings, and channel stabilization improvements for over 16 years. The design team has successfully completed numerous projects within challenging and often constrained floodplain/floodway corridors through innovative design and hydraulic analysis. For example, low water trail crossings are fitted with handrails that collapse under high water and debris loading to minimize upstream flood impacts. Where larger bridges cannot practically be designed to span the 100-year floodplain, a breakaway bridge design is employed to conform with “no-rise” floodplain regulations. Channel stabilization measures are often included with greenway trail designs, including check structures for gradient control and bioengineered bank protection measures. Greenway trail designs typically focus on two main objectives: no net fill within the floodplain so that the 100-year water surface profile is unaffected, and route selection that minimizes impacts to stream riparian zones and habitat. SSPRD has been fortunate to be able to share funding and maintenance with the Drainage District and the local municipality on virtually every greenway trail completed to date, which illustrates a key benefit to multiple use greenway development.

**SUMMARY**

The South Suburban Park and Recreation District is proud of its system of parks, greenways, and other recreational facilities, many of which also serve as flood control facilities and floodways. Primary elements for a successful multiple use park or greenway project include a specific planning and design process that emphasizes citizen participation; funding and involvement by groups or agencies representing special interests such as flood control, wetlands, habitat, etc.; provision for maintenance of improvements; and celebration of the completed project with recognition of the community and participating agencies for their efforts in completing “their” park or greenway.

SSPRD recently received the 1996 National Gold Medal Award for excellence in the field of parks and recreation management by the Sports Foundation, Inc. This marks the third time that the SSPRD has received this award, having previously been recognized in 1980 and 1988 as the outstanding park and recreation agency in its size classification.
This paper focuses on a greenway planning project along Mooser Creek in Tulsa, Oklahoma. It describes innovative techniques used in the project to involve citizens and to explore multi-objective management options for floodplain and watershed management. The paper also traces that community’s evolution from flooding and flood control to more nature-friendly methods of managing stormwater while also providing recreation and open space in the community.

BACKGROUND

The City of Tulsa was born 100 years ago in Indian Territory on the banks of the Arkansas River. Flooding was a persistent problem. In the city’s formative years in the 1920s, oil-boom barons and visionary leaders preserved sweeping greenways and floodplain parks. But post-war growth and sprawl reshaped that vision: floodplains were considered dumping grounds, ripe for exploitation.

Pipes and Paving

Watercourses were eagerly piped and paved. Floodplain resources were buried in concrete and crammed with development that was soon awash in frequent floods. By mid-1980, Tulsa County was included in the record books as America’s most frequently flooded community, with nine federally declared disasters in 15 years. When Tulsa’s 1984 flood left 14 dead and $183 million in damage to nearly 7,000 buildings, city leaders vowed to make flood control the community’s number-one priority.

Flood Control

In the dozen years since then, Tulsans have built scores of flood-control projects, most with the primary goal of retrofitting a drainage
system into a town largely built without one. Today, Tulsa has a comprehensive stormwater management program that since 1992 has been ranked number one in the Federal Emergency Management Agency's Community Rating System.

Tulsa has enjoyed a flood-free decade for the first time in its history, and the community's earlier ephemeral, but enduring, visions of graceful greenways are emerging again. Neighborhoods and community leaders are slowly rediscovering diminishing floodplain resources that they hope to conserve in their urbanizing region. Increasingly, leaders are exploring innovative management techniques to make the most of the waterways, vegetation, natural habitats, and native beauty that can enhance Tulsa's quality of life.

**MOOSER GREENWAY PLANNING**

A case in point is the multi-objective neighborhood planning project getting underway along Mooser Creek, a five-mile stream on Tulsa's near west side. Frequent flooding prompted calls for flood control. Leaders recognized the potential for greenway and resource protection, because much of the Mooser watershed remains undeveloped.

**Mooser Watershed**

Although the Mooser watershed is only a few miles from downtown Tulsa, perhaps half of it remains undeveloped because of rugged terrain. Development has been further limited by sparse water and sewer services. However, city service is scheduled to be extended into the basin soon, and several developments are planned. The basin includes remaining stands of bottomland and upland timber, as well as archeological resources. The creek is one of the last remaining free-flowing, naturally stable corridors in the Tulsa area. Rugged terrain, a variety of neighborhood types, and industrial encroachment present significant planning challenges.

Tulsa's mayor believed strongly that planning was needed now, to get ahead of development and try to conserve the best of the basin. But area residents and businesses had conflicting goals for the future of the watershed, and consensus seemed impossible.

It was apparent that the watershed called for multi-objective planning, and a process to make residents and businesses part and parcel of the planning, which (1) allows all interests to identify their objectives and concerns; and (2) attempts to develop alternatives that will satisfy multiple objectives versus maximizing one at the expense of others.
Planning Process

Toward that end, the mayor invited the National Park Service’s Rivers, Trails, and Conservation Assistance program (NPS/RTCA) staff to help in the planning process. The city’s goal was to include as many interested persons as possible.

Planning began last fall with a partnership among the city, NPS, and residents and businesses, assisted by a broad coalition of technical experts from the Tulsa community. The planning process is expected to take at least a year, and includes creative techniques for public involvement and community education.

NPS Involvement

Initially, the City of Tulsa handed the NPS a laundry list of potential projects to become involved with. The Mooser Creek project was chosen, because it has potential for achieving many of the goals identified in the Rivers, Trails, and Conservation Assistance Program strategic plan. RTCA’s mission is to advocate and assist community-based conservation action. One of its most important priorities is to bring people opportunities for close-to-home outdoor recreation and connections to nature. More community-based projects are needed in cities with unmet conservation and recreation needs that may be solved by promoting planning that integrates conservation, health, and economic well-being. Bottom-up strategies, consensus building, and public education are the foundations of the RTCA-style project—which had to be supported by the city before the NPS agreed to assist in any planning efforts.

Project Scoping

The variety of stakeholders within the corridor persuaded project leaders to promote greenway alternatives for the corridor that could cost-effectively reduce flood risks, while maintaining the integrity of the creek. Southwest Tulsa lacks some of the trail-related amenities found elsewhere in the city, and there is strong support from southwest Tulsa community leaders for quality-of-life improvements.

Calling All Players

A multi-objective approach to planning was needed for Mooser Creek in order to make the planning process attractive to citizens and businesses. Focusing the process on solutions to protect lives and property from flooding would have attracted the handful of residents and businesses directly affected by flooding. The RTCA goal was to involve
as many citizens, businesses, organizations, and government agencies as possible, even if they did not have a direct relationship to Mooser Creek.

Our initial step was to resolve several fundamental questions: (1) Who needs to be involved in the planning process? (2) How should they be involved? (3) At what point should they become involved? Following the identification of key people, one-on-one meetings were arranged between the city and RTCA and community leaders, business leaders, and neighborhood organizations to promote the project. The key points were:

- Explaining the merits of greenways and multi-objective management;
- Involving citizens throughout the entire planning process;
- City and RTCA roles;
- Existing funding and potential uses; and
- Providing a forum for individuals to discuss problems and opportunities.

The planning process called for the establishment of a Mooser Creek Committee, which would be divided into separate citizen and technical teams, each providing support to the other.

Committee roles and responsibilities were established, so it was clear that each would be a "working" committee with defined tasks and assignments.

Common Vision

Developing a vision was the Mooser Creek Committee's first major task. A motivational and inspiring vision statement will draw citizens and stakeholders into the process. In response to a compelling vision, people will say, "I want to be part of that!" The vision statement for Mooser Creek was developed during a public workshop and through follow-up print media. The vision shared by the Mooser Creek Committee and city leadership calls for preservation or restoration of natural conditions whenever possible. However, they recognize that existing encroachments and economic constraints may force a marriage of structural and nonstructural elements in the ultimate plan.

The Mooser Creek Vision Statement reflects multi-objective concerns indicating the communities' desires to address several problems and possibilities at one time. Besides addressing flood control, citizens want to see water quality improvements, educational and interpretive opportunities, riparian and wildlife enhancement, recreational and transportation trails opportunities, and sustainable development of the
watershed. The Mooser Creek Committee believes that development and build-out of the watershed must not compromise creek integrity.

**Community Participation**

Education on Mooser Creek resources is perhaps the most important element in successful community-based planning. Activities underway include:

- The Mooser Creek Committee has distributed a brochure on the benefits of greenways, and a newsletter introducing people to the Mooser Creek Greenway project, its planning process, and opportunities for involvement.
- The city and the NPS visited a public housing community to offer opportunities for involvement through discussion and activities to help make connections to the creek.
- The Tulsa County Conservation District is taking the lead on organizing field trips to explore Mooser Creek resources. It is establishing watershed education lesson plans in two schools, and it is assisting with the creation of a "project storefront" at a regional library.
- A National River Clean-Up allowing citizens throughout the corridor to participate in a community event.
- Stream process field trips for local engineers and planners.
- Development of General Equivalency Diploma curriculum or community college credit courses incorporating creek science, planning, and public participation theory.
- Utilizing computer video imagery to help citizens understand the range of alternatives being proposed. Based on the findings of the inventory and analysis, the Mooser Creek Committee can begin formulating goals and alternatives for public use, environmental protection and enhancement, and flood control. The committee will have to look at implementation and development, long-term management, and funding for overall project completion. Developing alternatives requires asking "What if?" Examining the range of alternatives will reveal interrelationships among the various components. One example is a trail crossing that is compatible with a highway bridge replacement. The video imagery should help answer some of these questions.
CONCLUSION

The Mooser Creek planning project represents a turning point in Tulsa’s civic life. It is a milestone on the city’s search for ways to provide public services—in this case, storm drainage, recreation, and alternate transportation—in a fashion that brings the community closer to harmony with nature. In some ways, the Mooser Creek planning has already adopted good floodplain management goals as described in *Sharing the Challenge: Floodplain Management into the 21st Century*:

- Avoiding the risks of the floodplain;
- Minimizing the impacts of those risks when they cannot be avoided;
- Mitigating the impacts of damage when it occurs; and
- Accomplishing the above in a manner that concurrently protects and enhances the natural environment.

This planning process is helping to strengthen the sense of community within the watershed, while reducing flooding problems and making the most of available resources for present and future generations. Involving the community from day one of the planning process provides an additional level of credibility for Tulsa’s efforts. The message is clear: Tulsa wants to hear from the citizens, and, to the best of the city’s ability, it is going to implement the greenway multi-objective recommendations.
Soil bioengineering works in a multifaceted world by honoring the land and connecting people with natural living resources. It is a unique technology that offers a responsible approach to land stabilization and habitat restoration, using living plant materials as the main structural component. It uses mechanical, hydrological, biological, and ecological information to develop living plant structures based on ecological principles and engineering practice. These structures are the main component of systems for erosion, sedimentation, flood control, shallow mass wasting, streambank, shoreline and slope stabilization, and land reclamation. It offers natural, effective solutions to instability throughout the watershed on cut and fill slopes, along natural and realigned streams and corridors, and in urban and rural wetland buffers. Soil bioengineering re-establishes a self-supporting, naturally beautiful, and functioning native community.

Soil bioengineering is a holistic approach accomplished through interdisciplinary teams. Projects typically are multi-objective and may require experience in wildlife and fisheries habitat, soils geology, landscape architecture, waste management, geotechnical areas, horticulture, fluvial geomorphology, biology, and soil bioengineering. Soil bioengineering considerations require careful on-site assessment, information/data review, design documents, exacting installation, and followup monitoring and evaluation, which are critical to protecting the investment in achieving a successful project. These living systems establish foundations for upland watersheds and riparian zones which, as connected systems, enhance and support a diverse aquatic, riparian and terrestrial habitat, offer food, shelter and nesting opportunities.

Such living structures as the brushlayer, live fascine, and live cribwall are applied in specific combinations and configuration on slopes and streambanks to control surface erosion, shallow mass wasting, toe erosion, and scour. Soil bioengineering considers both the mechanical/hydraulic and ecological/environmental parameters and optimization of the site before selecting the appropriate systems and plant species.

The following five case studies illustrate how soil bioengineering functions in a multifaceted world (Table 1).
<table>
<thead>
<tr>
<th>PROJECT NAME</th>
<th>LOCATION &amp; AGE</th>
<th>PROJECT TYPE</th>
<th>SYSTEMS EMPLOYED</th>
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<tr>
<td>Greenfield Road</td>
<td>Colrain, MA 1990 7 years old</td>
<td>major highway slope failures due to seeps and poor soils - stabilization &amp; restoration</td>
<td>fill brushlayers, live fascine &amp; seeding</td>
</tr>
<tr>
<td>Buffalo Bayou</td>
<td>Houston, TX 1991 6 years old</td>
<td>streambank failure - stabilization &amp; aesthetics enhancement</td>
<td>vegetated geogrid, live boom, live siltation construction, live fascine</td>
</tr>
<tr>
<td>Norton Branch</td>
<td>Sevierville, TN 1995 2 years old</td>
<td>stream realignment in fill slopes - stabilization &amp; habitat restoration</td>
<td>vegetated geogrid, seeding, habitat rock structures &amp; woody plantings</td>
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<tr>
<td>Kenai River</td>
<td>Soldotna, Alaska 1994 3 years old</td>
<td>streambank erosional failure - stabilization &amp; habitat restoration</td>
<td>live cribwall, live siltation constr., tree revetments, habitat rocks, native sods</td>
</tr>
<tr>
<td>Johnson Creek</td>
<td>Portland, Oregon 1993 4 years old</td>
<td>stream realignment - stabilization &amp; habitat restoration</td>
<td>vegetated geogrid, brushmattress, live siltation constr., live fascine</td>
</tr>
</tbody>
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**Greenfield Road Cut Slope Stabilization and Restoration**

Greenfield Road is located approximately 150 miles northeast of Boston, Massachusetts, outside the town of Colrain. The transportation route was upgraded from a simple country road to a major two-lane highway. The slope failures occurred as a result of road widening and the attendant oversteepening and/or increase in height of the highway cut slope in very unstable conditions (Gray and Sotir, 1992, 1995). Instability was exacerbated by active ground water seepage that emerged from the face of the cut. The slope, which was cut at 1.5H:1V grade, was approximately 1,200 feet long and ranged in height from 20 to 60 feet.

Local residents favored treatments that were visually non-intrusive and that blended in with the natural surroundings. A solution combining soil bioengineering and conventional engineering was eventually devised that consisted of placing a 10-foot-high rock buttress at the toe of the cut, which in turn supported a drained brushlayer fill above.

Woody plant materials used for the soil bioengineering included several willow species, including discolor and nigra; dogwood (*Cornus stolonifera*); alder (*Alnus rugosa*); and viburnum (*Viburnum dentatum*). The brushlayers have provided an opportunity for native vegetation to invade and establish itself on the slope. As a result, the process of plant succession is well underway and, after six years, the slope is stable and the project site has already assumed a natural and pleasing appearance that blends into the natural surroundings.

**Buffalo Bayou Bank Stabilization and Aesthetic Improvement**

Buffalo Bayou upstream of Sheperd Drive is the only stream of any size in Houston, Texas, that has not been channelized for flood control. The watershed of Buffalo Bayou is almost totally urbanized. Addicks Reservoir was constructed upstream to help control flooding. The combination of natural flooding and reservoir operation results in abrupt changes in water levels in the bayou coupled with prolonged periods of high water. These hydrologic conditions, combined with sandy and silty soils with little cohesion, have resulted in widespread erosion and streambank failure. The project site, located along an outside bend, is 280 feet long and its height varies from 25 to 35 feet. Over 20 feet of land had been lost due to the receding bank. A fill slope with a grade of 0.5H:1V was reconstructed upon a foundation of concrete rubble installed in a deep toe trench. The fill was constructed in lifts wrapped with geogrid. Layers of brush long enough to extend from the undisturbed soil at the back of the slope and beyond the face were placed on each
wrapped soil layer. The overall constructed height was 42 feet, with the upper half being at 0.25H:1V. Because continued seepage would have substantially reduced the factor of safety, it was necessary to install additional drainage to remove the water. The site has remained stable since construction in 1993, and the soil bioengineering installation is developing into a dense riparian buffer as native and naturalized species invade the site.

**Norton Branch Relocation, Streambank Stabilization, and Habitat Restoration**

Site preparation for a Walmart Supercenter required the relocation of a 650-foot stream reach through a deep reconstructed fill area. The fill slopes were 25 feet high and constructed at a 1H:1V grade. A Sierra slope retention system designed by Tensar was used to construct the slopes. The reinforced slopes consist of compacted soil wrapped with a geogrid material.

In an attempt to restore some of the lost riparian and aquatic habitat, rooted willows (Bankers and Streamco U.S. Department of Agriculture, Natural Resources Conservation Service hybrids) were incorporated into the first five lifts above the channel. Lifts above the willow were hydroseeded. The project was completed in the spring of 1995. Survival and growth of the willow brushlayers over the first and second growing seasons has been excellent, with growth overhanging approximately two-thirds of the streambed.

**Kenai River Habitat Restoration, Bank Stabilization, and Recreational Enhancement**

The Kenai River flows on the Kenai Peninsula approximately 75 miles south of Anchorage, Alaska. The river drains more than 2,000 sq. mi. of diverse landscape, including icefields, glaciers, lakes, mountains, and lowlands. The Kenai River is the state's premier salmon and trout stream and has a world class reputation for its trophy Chinook sport fishing.

Soldotna Creek Park attracts large numbers of fishermen and much of the bank vegetation has been destroyed. This, along with heavy foot traffic, boat wakes, and ice scour, has caused accelerated bank erosion and loss of riparian habitat. The 650-foot reach has low, 1- to 3-foot-high banks.

The project goals were to stop the accelerated bank erosion, restore riparian habitat, and improve fish habitat. After visiting the sites, conferring with Alaska Department of Fish and Game personnel, and
analyzing available information, Robbin B. Sotir & Associates designed soil bioengineering systems to meet the project goals of habitat restoration and bank stabilization. The methods included low live cribwalls, live siltation construction, live fascines, and native grass sods to stabilize the 1- to 3-foot-high banks along a 650-foot section of river bank. The woody plant materials used, with the exception of one native rose, were all willow. The cuttings were harvested and kept in refrigeration vans prior to installation. Plans, specifications, and cost estimates were produced and construction occurred during the spring of 1994.

Major flooding occurred during the fall of 1995 when discharge peaked at 42,000 cfs, a flow estimated to be in excess of a 100-year return event. Although the soil bioengineering installations were affected, damage was minimal. The willow used in the live cribwalls and live siltation construction is providing excellent overhanging cover for fish despite heavy browsing of new top growth by moose and deer.

JOHNSON CREEK RELOCATION AND RESTORATION

Johnson Creek is located in the Portland, Oregon, metropolitan area. It is highly urbanized with land uses ranging from heavy industry to low-density residential. Johnson Creek is a third-order stream with a 100-year discharge at the project site of about 4,400 cfs. A survey of Johnson Creek revealed that with few exceptions, streambanks are stable, heavily vegetated, and provide excellent riparian habitat and overhanging cover for the stream.

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

Robbin B. Sotir & Associates (RBSA) was retained by ODOT to evaluate the proposed channel design for stability and for potential impacts to aquatic and riparian ecosystems. RBSA recommended changes to the channel to improve stability, water quality, and habitat value (Sotir and Nunnally, 1995). The channel cross-section was altered by lowering floodplain berms, incorporating a sub-channel sized to convey bankfull flows, and constructing a low flow channel to concentrate flows during the summer months. A pool-riffle sequence was created by widening the
sub-channel and raising the invert by one foot in cross-over reaches and by lowering the invert one foot in outside meander sections.

The soil bioengineering systems were installed during the winter of 1993 and spring of 1994. In the early spring and before the plants had established growth, the site experienced a 1,750 cfs flood with mean velocities between 6 and 7 feet per second and maximum velocities estimated to be in excess of 10 feet per second. The soil bioengineering systems were secure, and by the end of the growing season they were providing excellent bank protection and habitat benefits.

**Conclusions**

Soil bioengineering may be effective throughout the watershed. The case histories illustrate its value in a multifaceted world, incorporating the technology in streambank and upland slope protection in the restoration of aquatic and wildlife ecosystems, as well as recreational enhancement values in a variety of environmental and climatic conditions.

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Sotir, Robbin B. and N. Nunnally
CROP TREE MANAGEMENT IN RIPARIAN ZONES*

Karen J. Sykes, Arlyn W. Perkey, and Roxane S. Palone
USDA Forest Service, Northeastern Area S&PF

INTRODUCTION
Landowners often need additional information to manage their forestlands for non-timber objectives like wildlife, recreation, aesthetic, or personal use, such as firewood. The management scenario is more complicated if floodplain and riparian lands are involved.

"Crop tree management" is a tool that can be applied both in and out of the riparian zone. Landowners and foresters are taught to pick crop trees that will accomplish stand-specific objectives and produce the benefits the landowner desires. The crop tree strategies discussed in this paper include those for managing timber, aesthetics, wildlife, fisheries, and water quality.

The riparian zone is delineated by a transition between the aquatic and terrestrial characteristics of soil, water, vegetation, and landform. These areas provide such beneficial functions as moderation of flood peaks, groundwater recharge, wildlife and fish habitat, timber and forage production, and recreation opportunities. Certain aquatic and vegetative communities are totally dependent upon riparian zones for existence.

Crop tree management in riparian zones can help with erosion and sediment control, aesthetic enhancement, timber production, improvement of wildlife and fisheries habitat, and maintenance of water quality. Proper management protects mineral soil from excess disturbance and compaction, preserves the forest floor, and prevents alteration of natural surface and subsurface waterflow paths. It also maintains vigorous and diverse vegetation, regulates stream temperature, and promotes moist soil conditions that are beneficial to soil microbes.

What is a crop tree? It is any tree the landowner retains to help reach property goals. These goals may be defined as stand-specific objectives,

* A longer version of this paper, containing additional information about crop tree management, tables of tree species according to water tolerance, and complete citations to the relevant scientific literature, is available from Karen Sykes at (304) 285-1532; e-mail: ksykes@mserve.fsl.wvnet.edu or on the web at http://www.frm.fsl.wvnet.edu/programs/watershed/ctmripar.htm.
especially if the landowner is managing the forest to produce multiple benefits. This idea is gradually becoming popular because landowners are realizing that producing high-quality timber does not have to be their main objective—their forestlands may also produce non-priced benefits, such as flowers and recreation.

What is crop tree management? It is the selection and release of desired trees by removing adjacent competing trees. Usually a crown-touching method is applied by cutting all trees that touch the crown of the selected crop tree. This is also called a four-sided release because it leaves the crop tree free to grow on all sides. Each crop tree should have at least three sides of its crown released, which allows for rapid growth.

**Figure 1.** This timber crop tree has a four-sided release.

**TIMBER CROP TREE CRITERIA AND CONSIDERATIONS**

Riparian zones can be excellent growing sites for timber crop trees because of their deep, well-drained or moderately well-drained soils with good water-holding capacities. Under these topographic and edaphic conditions, the riparian zone can produce high-quality timber provided the species selected are adapted to the moisture conditions.

The main factors to consider in managing for timber in riparian zones are flood frequency, flood duration, and high water tables. Some timber species are only marginally adapted to the conditions. For example, black
cherry may be found in riparian zones, but if drainage conditions are poor or periodic flooding occurs, its potential to produce timber is severely restricted. In fact, there is a good chance it will die.

In the Appalachian and central hardwood forest regions, high-quality timber crop trees are not usually found in riparian zones where recurrent flooding is common. Many of the tree species best adapted to these conditions are of low timber value, such as box elder. However, some very productive growing conditions can be found in riparian zones if flooding is brief, infrequent, and occurs during the dormant season.

**WILDLIFE CROP TREE CRITERIA AND CONSIDERATIONS**

Landowners need to decide what type of wildlife they want to manage: game, non-game, or a combination. Landowners are realizing they are not limited to managing the fin, feather, and fur species. Some landowners are interested in insects, such as bees, or even amphibians. A land manager must often coordinate silvicultural activities to benefit one species knowing that another may thereby be displaced. Some trade-offs may be needed. For example, a dense understory may interfere with the glide path of a flying squirrel, but may be very desirable to a deer. The crop tree species selected should provide food, shelter and/or nesting cover to satisfy the habitat requirements of the desired species.

For wildlife food production, a variety of soft and hard mast-producing species should be chosen. Trees should be dominant or co-dominant with large, healthy crowns for maximum flower production. Dens and potential den sites near water are especially valuable to certain species of wildlife. The size and location needed varies according to species. For dens or other shelter for wildlife, trees should be selected on the basis of existing or potential cavities. For example, a tree with a broken limb may form a cavity for future wildlife use.

Crop tree management can also help maintain and improve fish habitat if deciduous species are selected. Both vertebrates and invertebrates favor deciduous vegetation over conifers because the leaves are thin and easier to consume. The nearstream deciduous vegetation is the major source of food for fish and their invertebrate food source. Leaves that fall into streams add large quantities of organic material (detritus) to the water. Invertebrate populations increase and, through the food chain, result in increases in fish growth and food production.

Big, limby trees that lean out over the water will contribute to the food source for many years. When they eventually die and fall into the water, they will provide cover and habitat for fish. For a temperature-sensitive fish species, there should be a dense stand of crop trees along waterways. Trees keep streams cooler in summer and warmer in winter.
Figure 2. This white ash can provide a den for various wildlife species.

Cooler temperatures also prevent undesirable fish species from increasing. Warmer temperatures often cause the preferred species to stop reproducing. Note that the cooling effectiveness of trees decreases with increasing stream size. But if temperatures are controlled in the first-, second- and third-order streams, temperature-associated problems will be reduced downstream as well.

**Aesthetic Crop Tree Criteria and Considerations**

Species that flower in the spring or produce colorful foliage in the fall are popular with landowners, and in the riparian zone their reflections in the water add to the beauty of the landscape. Because trees grow in response to varying amounts of light, those adjacent to streams, lakes, and ponds can develop some interesting shapes. These unusual trees contribute to the attractiveness of riparian zones and often are endearing to landowners. Some landowners also retain favorite or unique trees.

Generally, landowners prefer a park-like environment near the water's edge so they can walk unimpeded by thick brush. However, this does not mean that aesthetic crop trees cannot be managed. When
relatively few crop trees per acre are given a crown-touching release, understory development is minimal.

**WATER QUALITY CROP TREE CRITERIA AND CONSIDERATIONS**

Crop trees that filter excess nutrients and pollutants provide a benefit that landowners and land managers usually do not consider. Trees require various chemical elements to live and grow. These include the gaseous elements hydrogen, oxygen, and carbon; the macro-nutrients calcium, potassium, magnesium, nickel, phosphorus, and sulfur; and the micro-nutrients boron, copper, iron, manganese, molybdenum, and zinc. The elements may come directly from rock weathering, precipitation, fixation of nitrogen from the atmosphere, decomposition of organic matter, or by being washed in or leached from agricultural practices.

Trees absorb as many nutrients as they can and accumulate them in their biomass, particularly in their woody material. Nutrient uptake into leaves and other deciduous parts of trees can be important in the short term. Nutrient uptake is most rapid in young trees and declines with increasing age. Deciduous trees have greater nutrient demands than conifers. Oaks require more nutrients, especially potassium and nitrogen,
than spruce and pine. Hardwoods along a stream course or in forested wetlands are more effective filters than conifers. This filtering process removes as much as 89% of the nutrients before they pollute waterways.

Tree species may accumulate various nutrients at different times of the year. For example, loblolly pine accumulates nitrogen all year, but takes up magnesium, phosphorus, and sulfur only in September.

Crop trees in the riparian ecosystem have a substantial capacity to control non-point nutrients. Nutrient retention by forests adjacent to agricultural land was estimated at 80% for phosphorus and 89% for nitrogen in Maryland's Rhodes River Watershed. Similar studies in North Carolina showed a reduction of 80% of the nitrogen leaving agricultural land as it passed through a riparian forest buffer. Denitrification and storage in woody vegetation account for over six times as much nitrogen removal as nitrogen output in streamflow; the same was true for phosphorus.

As trees mature or begin to die, their net annual nutrient uptake may drop. If all riparian trees mature and die at once, their effec-

**Figure 4.** Yellow-poplar filters nutrients to improve water quality.
tiveness for filtering nutrients is lost. So it is important to maintain various age classes within the zone to uphold a continuous cycle of nutrient uptake.

**TREE TOLERANCE TO HYDROLOGIC REGIMES**

The ability of different tree species to live from seedling to maturity in the various soil saturation conditions typical of riparian zones is crucial to crop tree management. Some species survive well with frequent waterlogging or flooding, but others may die. Generally, waterlogging tolerance increases with age and size up to maturity, but declines with decreasing crown position. Tolerance depends on species, growing season, age, genetics, and soil conditions. Water-tolerant species can absorb more nutrients and reportedly increase the conversion of nitrates to nitrites, but the reverse is true for intolerant species. In another example, basswood accumulates large amounts of calcium, phosphorus, and potassium in its leaves and can withstand waterlogging for most of one growing season. Yellow-poplar accumulates the same elements, but cannot stand waterlogging for over a month in the growing season.

Flooding and high water tables result in many essential elements becoming more available, depending on the chemical properties of the soil and the amount of oxygen present during flooding or waterlogging. The concentrations of sodium, manganese, aluminum, iron, nitrite, and sulfides are especially critical during waterlogging, because in high concentrations they are toxic to some tree, shrub, and plant species. For example, northern red oak seedlings are sensitive to high levels of aluminum. Once high waters return to normal, most nutrients return to pre-flood concentration levels unless excessive leaching has occurred.

The scientific literature divides trees into five categories according to their ability to withstand waterlogging:

- **Most water tolerant** trees can live from seedling to maturity in soils that are waterlogged almost continuously year after year except for short durations during droughts. These species exhibit good adventitious or secondary root growth during this period.

- **Highly water tolerant** trees can live from seedling to maturity in soils that are waterlogged for 50 to 75% of the year. Some new root development can be expected during this period. Waterlogging usually occurs during the winter, spring, and one to three months of summer.

- **Moderately water tolerant** trees can live from seedling to maturity in soils waterlogged about 50% of the time during the growing season. The root systems of these species produce few roots or are dormant during the waterlogged period.
Weakly water tolerant trees can live from seedling to maturity in soils that are temporarily waterlogged for one to four weeks.

Least water tolerant trees can live from seedling to maturity in soils that are occasionally waterlogged for a few days only.

**PUTTING IT ALL TOGETHER**

Figure 5 shows a wooded stand near a stream, with (from left to right) black walnut, sugar maple, white ash, beech, shagbark hickory, white oak, and another white ash. Black walnut is a wildlife and timber crop tree, and is least water tolerant. Sugar maple, an aesthetic and timber crop tree, is moderately water tolerant. White ash is a timber and water quality crop tree, and is also moderately water tolerant. Beech is a wildlife crop tree, and is least water tolerant. White oak is a timber, wildlife, and water quality crop tree, and is also least water tolerant. Shagbark hickory is a wildlife crop tree and is weakly water tolerant.

*Figure 5. Landowner objectives need to be considered before choosing the best crop trees.*

The crop tree selections we make are a key factor in managing a riparian zone on private non-industrial forestland. It is important to listen to landowners and obtain a clear understanding of their objectives. It is then up to us to communicate the management options that are available to landowners through the crop tree management concept.
INTRODUCTION

This paper outlines how the publication Protecting Floodplain Resources: A Guidebook for Communities (Smardon et al., 1995) was produced with the assistance of state and local officials and the Association of State Floodplain Managers (ASFPM), especially those participating in our workshop at the annual conference in Tulsa, Oklahoma, in 1994. Though the publication was produced for the Federal Interagency Floodplain Management Task Force, the key is understanding local needs of government and nongovernmental organizations and those interested in "grass roots" floodplain and natural resource management. We would like to use this forum as an opportunity for critiquing the publication. In other words, Did our development process work? Did we meet our objectives? Does it fit the intended audience? Are there other unmet needs out there in regard to natural resource management in the floodplains? Most importantly, Are there outstanding or innovative case studies that we should know about and should be communicated to others?

The topic relates to this conference's theme, Floodplain Management in a Multifaceted World, in that the publication had to anticipate different organization models. There is no one way to do floodplain and natural resource management and there are more being developed all the time. What is apparent is that different forms of partnerships of public, corporate, and nongovernmental groups are evolving. These partnerships need to collectively work out ways of inventorying, evaluating, planning, and implementing programs to protect natural resources within floodplains that simultaneously raise public consciousness and keep it salient throughout the process. This was a theme that was woven throughout the writing and production of the handbook.
PRODUCTION APPROACH

In our early deliberations about production of the guidebook, our overall concern was about types of publications and audiences. We were concerned with how many types of actors or stakeholders to target, e.g., citizens and non-governmental organizations, lenders, elected officials, and staff, as well as technical experts. We were concerned with where the emphasis of the publication should be, e.g., awareness level to collective courses of action to decisions to implementation. After two separate meetings with the Federal Interagency Floodplain Management Task Force, it was decided that this publication should be aimed at a local government, nongovernmental organization, and citizen audience and that there should be a general process or framework developed that allowed this audience to gain awareness about early organization building for the purposes of protecting natural resources in the floodplain.

A literature review was done that included general sources on multiobjective management issues, natural resources protection, recreation and aesthetics, information/mapping issues, flood control/floodplain management, citizen participation, federal government programs, state government programs, intergovernmental programs, resource protection tools, and existing case studies. This literature was annotated to some degree, but we were really looking for examples that illustrated the audience level and process orientation that we had identified earlier. Some key documents in this review are listed in the references for this paper.

KEY GUIDANCE PRINCIPLES

We then developed an outline for the publication. This outline had major sections and subsections itemized and was revised several times. This was a critical tool in itself. Many of the principles or guidance for development of the publication evolved from an Interagency Task Force meeting in December 1993. At this meeting key guidance principles included:

(1) The target audience for the publication will be community officials (appointed or elected) but the publication may be relevant to others, including citizen groups, developers, and property owners.

(2) We should find out what questions local officials have during some type of invitational workshop. In general, we should try to
produce a document that conveys a simple and forceful message—the value of multiobjective floodplain management.

(3) The publication should present information on three levels or sections. The primary level will promote awareness. The second section will list sources of information that correspond to the concepts listed in the first section and some general assessment guidance. The third level or section will present case studies that will provide some information about assessment of resources and implementation of various protection techniques.

(4) We targeted a national meeting such as the ASFPM meeting in Tulsa. Such a meeting would include many people at the local, state, and federal level whose knowledge would be especially relevant to our project.

While this strategy was unfolding Liz Meyers, J. Felleman, and R. Smardon prepared sections of the guidebook. We also were simultaneously looking for case studies. For these case studies, we needed to find projects to collect information relevant to a wide spectrum of communities. Relevant variables included region of the country, scale of project, extent of institutional overlay, extent of natural resource protection, use of citizen participation techniques, degree of local involvement and entrepreneurial activity, and creative use of maps and information sources. Potential case studies were identified for the Northeast, Southeast, West/mountain, Northwest and Southwest.

**GETTING FEEDBACK: NATIONAL SURVEY AND WORKING SESSION**

In order to get responses about the proposed outline for the guidebook and the case studies, a questionnaire was prepared. The questionnaire consisted of a cover page explaining its purpose, one page of background and information questions, and one page with a topical outline of the guidebook where respondents could rank each topic and subtopic as to its importance. This questionnaire was distributed at the Tulsa meeting of the ASFPM. It was used as a framework for a facilitation session run by Dr. Susan Senecah to get specific feedback by participants invited to a special workshop scheduled as part of the conference.

Results of the wetland questionnaires plus the facilitated session in Tulsa were used to modify the content outline once again. Final drafts of the content sections were prepared and reviewed by members of the Federal Interagency Task Force, with most review comments coming from the U.S. Environmental Protection Agency and the Federal
Emergency Management Agency. Senecah did a final grammatical/style edit with Smardon and Felleman providing content editing. Kevin Olvany, a graduate assistant, worked on additional case studies that were needed.

Final electronic copy, rough graphics, and digital copy were provided by Professor Scott Shannon for electronic duplication. This latter step was difficult as many of the printing contractors were not used to full electronic digital reproduction format as well as basic file management problems. Some 20,000 initial copies were printed in 1995 and distributed. In November 1996, a second printing of 20,000 copies was done after some minor editorial changes and introduction of a few new graphics.

**SUMMARY AND REMAINING WORK**

Some questions remain, such as:

1. Does the publication serve its intended audience?

2. Is there enough content and process to get groups beyond awareness and more toward action in protecting floodplain natural resources?


Finally, we had a difficult time finding case studies that illustrated substantial "grass roots" approaches to protection of local floodplain natural resources. There may be more potential case studies out there that deserve to be known about and even celebrated. We would like to hear about them. I have prepared a national survey initiated after the National Land Trust Rally in Burlington, Vermont, in October 1996. We would like to hear from you. Please submit any comments on the floodplain publication or case study suggestions to Richard C. Smardon, Director of the Randolph G. Pack Environmental Institute, SUNY/ESF, 1 Forestry Drive, Syracuse, NY 13210; rsmardon@mailbox.syr.edu.

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Part 11
EVALUATING ENVIRONMENTAL PROJECTS
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ECO-EASY: COST-EFFECTIVENESS AND INCREMENTAL-COST ANALYSES SOFTWARE FOR ENVIRONMENTAL PLANNING

Ridgley K. Robinson, Kenneth D. Orth, and William J. Hansen
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INTRODUCTION TO ECO-EASY SOFTWARE

The U.S. Army Corps of Engineers Institute for Water Resources (IWR) has developed procedures for conducting cost-effectiveness and incremental-cost analyses in environmental planning studies. The procedures are useful for formulating alternative plans, identifying which plans are cost effective, and conducting incremental-cost analysis. Results of the analyses help planners and decisionmakers address the question “How much environmental benefit is worth its cost?” IWR and the Corps’ Waterways Experiment Station have incorporated these procedures into a software program called ECO-EASY.

APPLICABILITY

The application of this cost-effectiveness and incremental-cost methodology is becoming widespread across the Corps’ ecosystem restoration program. Recent advancements in the form of instructional manuals and the ECO-EASY software have improved the ease and speed of the analyses for field practitioners. A recent Corps’ field application is documented as a case study involving fishery habitat improvements at Bussey Lake, Illinois.

Recent Corps’ experiences indicate that the analyses are applicable to both environmental restoration and mitigation planning; that they are useful for a wide range of sizes of problems and projects; and that they can be used to scope solutions even at the earliest stages of planning. In addition, although the analyses have thus far focused on fish and wildlife habitat and ecosystem-related studies, they should be equally useful in addressing other environmental problems such as water and air pollution and hazardous waste. Other agencies have indicated the potential

* The views expressed in this paper are those of the authors and not necessarily those of the U.S. Army Corps of Engineers or of the Department of Defense.
applicability of the procedures to a wide range of problem-solving scenarios, including the ordering of Superfund cleanup sites and transportation alternatives analysis.

**DATA REQUIREMENTS**

ECO-EASY requires three types of data: alternative solutions, and for each solution, estimates of its environmental or other nonmonetary effects (*output estimate*) and of its economic effects (*cost estimate*). “Solutions” refers to techniques for accomplishing planning objectives. Solutions may be management measures (for example, plant vegetation, install nesting boxes, or remove a leaking storage tank); plans (combinations of management measures); or programs (combinations of plans, often at a regional or national level). The user enters two types of relationships between solutions: combinability and dependency; that is, which measures can be combined with one another, and which are dependent upon others.

ECO-EASY conducts three processing functions: *formulation* of combinations, *cost-effectiveness analysis* of combinations, and *incremental-cost analysis* of cost-effective combinations. Every possible combination of solutions is derived and a total cost and total output estimate is calculated for each combination. The program then conducts cost-effectiveness analysis; first identifying the least-cost combination for every possible level of output, and then identifying the cost-effective set of combinations by screening out plans where more output could be provided by another combination at the same or less cost.

Once the cost-effective set of combinations is identified, the program calculates the incremental cost and incremental output of moving from each combination to the next larger combination. ECO-EASY also identifies the subset of the cost-effective set that would be the most efficient in production—or “best buy(s)”—as scale increases from the smallest to the largest combination.

As output, ECO-EASY provides the option to view or print matrices and their corresponding graphs for the following data sets: 1) all combinations, 2) least-cost combinations for every level of output, 3) cost-effective combinations, 4) cost-effective combinations with incremental cost per unit, and 5) set of “best buys” with incremental cost per unit. Graphs for the first three data sets plot total cost against total output for each combination; for the latter two data sets, incremental cost per unit is plotted against output in a bar graph. Graphs of ECO-EASY output are included in Figure 1. These graphs come from an application of the software to a leaking underground storage tank cleanup example described below.
Figure 1. Graphs of ECO-EASY output.
EXAMPLE APPLICATION

Planning Problem

Ten leaking underground storage tanks were identified for cleanup in a southwestern state. The funding available for cleanup was not known, so sites had to be prioritized to give the biggest cleanup benefit for the budget that would eventually be provided.

Solutions, Costs, and Outputs

Solutions at the 10 sites consisted of a variety of corrective actions, all designed to achieve 100% cleanup. Implementation costs were estimated for cleaning up each site. Cleanup benefits were measured using a point scoring system that measured the adverse effects of sites based upon proximity to groundwater tables, habitat, and other factors. Benefit scores represented the number of points that a cleanup action would reduce at a site.

Plan Formulation

All sites were combinable and none was dependent on any others being implemented first. All possible combinations of the 10 sites would formulate 1,024 alternative plans.

Plan Comparison and Screening

Fifty-six of all the plans were identified as cost-effective plans; 10 of those were identified as best-buy plans (see Figure 1). The best-buys are the range of plans that provide the best investments for achieving cleanup points—of all possible cleanup options, they provide the most cleanup per dollar invested. Note that this problem (ordering the implementation of single solutions at multiple sites without dependency or combinability constraints) is the simplest type of problem situation. The 10 best buys could be identified simply by adding additional sites by order of increasing average cost; however, the other 46 cost-effective combinations of sites would not have been identified.

Respectively, the three graphs in Figure 1 show (1) the total cost and total output of all alternative solutions for tank cleanup within the study area; (2) the total cost and total output of the subset of alternative solutions that are cost effective (that is, there are no other solutions that would provide the same or more cleanup for less cost); and (3) a bar chart of the incremental cost associated with the best buys.

The best buys are the most efficient solutions for cleaning up the leaking tanks. The height of each bar shows the unit cost of achieving the associated additional cleanup benefits. As benefits are increased, the additional units
come at a higher unit cost. These types of data help planners and decision makers decide if achieving additional benefits is worth the additional cost.

The planning methodology upon which ECO-EASY is based and instruction for using ECO-EASY Beta Version 2.6 are described in *Evaluation of Environmental Investments Procedures Manual—Interim: Cost Effectiveness and Incremental Cost Analyses* (IWR Report 95-R-1 May 1995). The program and manual expand on the earlier *Cost Effectiveness Analysis for Environmental Planning: Nine EASY Steps* (IWR Report 94-PS-2). Those reports and the case study, *Bussey Lake Demonstration Study* (IWR Report 93-R-16), are available from IWR by fax request 703-428-8435. For further technical information regarding the analyses, the ECO-EASY software, or their applicability, contact the authors at (703) 428-6217.
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A FRAMEWORK TO ASSIST WITH MULTIFACETED FLOODPLAIN INVESTMENT DECISIONS

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INTRODUCTION

Floodplains support a variety of environmental functions. Many of these services—water quality, fish and wildlife habitat, and aesthetics—do not always lend themselves to being valued in dollars. Although the results, or “outputs,” of these floodplain functions are usually not measured in dollars, they can be measured using other metrics. However, when solutions’ costs and benefits are measured in different units (for example, costs in dollars and benefits in acres of wetlands), traditional cost/benefit analysis becomes unusable and there is no rule guiding planners to an “optimal” solution. Still, decisions must be made as to what level of investment, if any, is desirable.

The U.S. Army Corps of Engineers’ Institute for Water Resources has developed a step-by-step method to bring better information to such investment decisions. This method includes plan formulation steps to assure that a range of options is considered, screening steps based upon the analytical tools of cost-effectiveness and incremental-cost analyses, and decision guidelines to assist with plan selection. Cost-effectiveness and incremental-cost analyses provide a framework for comparing the monetary costs and the nonmonetary outputs associated with alternative solutions to specific floodplain problems. The analyses make the available options and their associated tradeoffs more explicit, providing the types of information that support the decision about what level of investment is desirable and affordable, or in other words—“worth it.”

The framework requires three types of data: alternative solutions, estimates of their output, and estimates of their cost. Cost-effectiveness analysis identifies the least-cost solution for each possible level of output under consideration as well as those solutions that provide more output for less cost than others. Subsequent incremental-cost analysis reveals the increases in cost that accompany increases in output, identifying the

* The views expressed in this paper are those of the authors and not necessarily those of the U.S. Army Corps of Engineers or of the Department of Defense.
solutions that provide the greatest return in output per dollar invested, or "best buys." Application of these tools assists decisionmakers by framing the question "As we increase the scale of this solution, is each subsequent level of additional output worth its additional cost?"

**Solutions, Costs, and Outputs**

**Solutions**

"Solutions" generally refers to techniques for accomplishing planning objectives. For example, if faced with an objective to increase waterfowl habitat in the Blue River watershed, a solution might be to construct and install 50 nesting boxes along the Blue River riparian zone. Solutions may be individual *management measures* (for example, construct a levee, plant vegetation, or install nesting boxes), *plans* (various combinations of management measures), or *programs* (various combinations of plans, perhaps at the watershed, the regional, or national level).

**Costs**

Cost estimates for solutions should include both implementation costs and economic opportunity costs. Implementation costs refer to direct financial outlays for design, real estate acquisition, construction, operation, maintenance, and monitoring. The opportunity costs are any current benefits available with the existing state of the floodplain that would be foregone if the solution is implemented. For example, restoration of a river ecosystem may require that some flood damage prevention benefits derived from an existing river channel be given up. It is important that the opportunity costs of foregone benefits be accounted for and brought to the decisionmaking table. Incidental economic benefits can be treated as a negative cost for these analyses.

**Outputs**

The level to which a solution accomplishes a planning objective is measured by the solution's output estimate. Historically, environmental outputs have been expressed as changes in populations (such as waterfowl and fish counts) and in physical dimensions (such as acres of wetlands). In recent years, output estimates have been derived through environmental models such as the U.S. Fish and Wildlife Service's Habitat Evaluation Procedures (HEP), which summarize habitat quantity and quality for specific species in units called "habitat units." Models for ecosystems are in early stages of development and may be more useful across broad floodplains and at the watershed scale.
AN EXAMPLE APPLICATION

Solutions, Costs, and Outputs

In this example, four sites are proposed as restoration candidates. Different mixes of solutions are considered at each site. Cost estimates are provided for each solution at each site, and output is measured in the number of "wetlands units" estimated to result from implementing each solution. The wetlands units measure quantity and quality of wetlands; the units are based upon measurements of essential habitat variables for regional wetlands species. The solutions along with their cost and output estimates are included in Table 1.

Table 1. Wetlands restoration: solutions, costs, and outputs.

<table>
<thead>
<tr>
<th>Solution</th>
<th>Cost ($)</th>
<th>Output (wetland units)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Solution A1</strong>: Restore 200 acre wetland at Site A by installing a gated water control culvert.</td>
<td>2,050,000</td>
<td>540</td>
</tr>
<tr>
<td><strong>Solution A2</strong>: Clear existing vegetation and plant desired wetlands species at Site A.</td>
<td>125,000</td>
<td>125</td>
</tr>
<tr>
<td><strong>Solution B1</strong>: Restore 800 acre wetland at Site B by installing two gated water control culverts and planting desired wetlands species.</td>
<td>9,150,000</td>
<td>1854</td>
</tr>
<tr>
<td><strong>Solution C1</strong>: Restore 25 acre wetland at Site C by installing a culvert and building a dike around warehouse.</td>
<td>1,275,000</td>
<td>140</td>
</tr>
<tr>
<td><strong>Solution C2</strong>: Restore 30 acre wetland at Site C by installing a culvert and relocating warehouse.</td>
<td>2,750,000</td>
<td>195</td>
</tr>
<tr>
<td><strong>Solution D1</strong>: Restore 170 acre wetland at site D by installing a gated water control culvert and planting desired wetland species.</td>
<td>1,900,000</td>
<td>460</td>
</tr>
</tbody>
</table>

Plan Formulation

If we could implement any combination of the six solutions in Table 1 there would be 64 possible combinations or 64 alternative plans. However, in this example two solutions are not combinable (C1 and
C2—we can either build a dike to protect the warehouse or relocate it, but not both), and one (Solution A2) is dependent on another (Solution A1) being implemented. With these constraints, the number of valid alternative plans is reduced to 36 (Table 2).

### Table 2. All 36 restoration plans
*(shading denotes non-cost-effective plans).*

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>COST ($)</th>
<th>OUTPUT (wetland units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Restoration</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>C1</td>
<td>1,275,000</td>
<td>140</td>
</tr>
<tr>
<td>C2</td>
<td>2,150,000</td>
<td>195</td>
</tr>
<tr>
<td>D1</td>
<td>1,900,000</td>
<td>460</td>
</tr>
<tr>
<td>A1</td>
<td>2,050,000</td>
<td>540</td>
</tr>
<tr>
<td>C1+D1</td>
<td>3,175,000</td>
<td>600</td>
</tr>
<tr>
<td>C2+D1</td>
<td>4,650,000</td>
<td>855</td>
</tr>
<tr>
<td>A1+A2</td>
<td>2,175,000</td>
<td>655</td>
</tr>
<tr>
<td>A1+C1</td>
<td>3,325,000</td>
<td>680</td>
</tr>
<tr>
<td>A1+C2</td>
<td>4,800,000</td>
<td>735</td>
</tr>
<tr>
<td>A1+C1+A2</td>
<td>3,450,000</td>
<td>805</td>
</tr>
<tr>
<td>A1+C2+A2</td>
<td>4,925,000</td>
<td>950</td>
</tr>
<tr>
<td>A1+D1</td>
<td>3,950,000</td>
<td>1000</td>
</tr>
<tr>
<td>A1+D1+A2</td>
<td>4,075,000</td>
<td>1125</td>
</tr>
<tr>
<td>A1+C1+D1</td>
<td>5,255,000</td>
<td>1140</td>
</tr>
<tr>
<td>A1+C2+D1</td>
<td>5,700,000</td>
<td>1285</td>
</tr>
<tr>
<td>A1+C1+D1+</td>
<td>5,350,000</td>
<td>1265</td>
</tr>
<tr>
<td>2</td>
<td>6,825,000</td>
<td>1320</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>SOLUTION</th>
<th>COST ($)</th>
<th>OUTPUT (wetland units)</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1</td>
<td>9,150,000</td>
<td>1854</td>
</tr>
<tr>
<td>B1+C1</td>
<td>10,425,000</td>
<td>1994</td>
</tr>
<tr>
<td>B1+C2</td>
<td>11,900,000</td>
<td>2049</td>
</tr>
<tr>
<td>B1+D1</td>
<td>11,050,000</td>
<td>2314</td>
</tr>
<tr>
<td>A1+B1</td>
<td>11,200,000</td>
<td>2394</td>
</tr>
<tr>
<td>B1+C1+D1</td>
<td>12,326,000</td>
<td>2454</td>
</tr>
<tr>
<td>B1+C2+D1</td>
<td>13,800,000</td>
<td>2509</td>
</tr>
<tr>
<td>A1+A2+B1</td>
<td>11,325,000</td>
<td>2519</td>
</tr>
<tr>
<td>A1+B1+C1</td>
<td>12,475,000</td>
<td>2534</td>
</tr>
<tr>
<td>A1+B1+C2</td>
<td>13,850,000</td>
<td>2589</td>
</tr>
<tr>
<td>A1+A2+B1+C</td>
<td>12,600,000</td>
<td>2659</td>
</tr>
<tr>
<td>2</td>
<td>14,075,000</td>
<td>2714</td>
</tr>
<tr>
<td>A1+B1+D1</td>
<td>13,100,000</td>
<td>2854</td>
</tr>
<tr>
<td>2</td>
<td>13,255,000</td>
<td>2979</td>
</tr>
<tr>
<td>A1+A2+B1+</td>
<td>14,375,000</td>
<td>2994</td>
</tr>
<tr>
<td>A1+B1+C1+D</td>
<td>15,885,000</td>
<td>3049</td>
</tr>
<tr>
<td>2</td>
<td>14,500,000</td>
<td>3119</td>
</tr>
<tr>
<td>2</td>
<td>15,975,000</td>
<td>3174</td>
</tr>
</tbody>
</table>

**Cost-effectiveness Analysis**

In cost effectiveness analysis, we identify plans as cost effective if they pass two screening tests: 1) No other solution provides the same output for less cost; and 2) No other solution provides more output for the same or less cost. In our example, 12 plans (shaded on Table 2) fail to pass these tests and will be set aside. The remaining 24 cost-effective plans are carried forward for incremental-cost analysis to identify which
are the best financial investments, providing the greatest increase in output for the least increase in cost as output is increased—"best buys."

**Incremental-cost Analysis**

To identify the set of best buys, first compare all cost-effective plans to the smallest cost-effective plan, in this case, the No Restoration plan. Compute the change in cost (incremental cost) and the change in output (incremental output) between each plan and the smallest plan. Next, divide the incremental cost by the incremental output to compute the incremental cost per unit. The plan with the lowest incremental cost per unit is the best buy; it is the most efficient plan at producing output units. All plans producing less output than the best buy are set aside for the rest of the analysis. Next we compare all remaining plans to the best buy to compute the next-best buy based upon the same incremental calculations. The next-best buy is the most efficient plan at producing any level of output greater than that provided by the first-best buy. This iterative process continues until the last (largest) plan is selected. The best buys in this example are included in Table 3.

**Table 3. Five best-buy wetland restoration plans.**

<table>
<thead>
<tr>
<th>Solution</th>
<th>Cost ($ )</th>
<th>Output (wetland units)</th>
<th>Incremental Cost ($ )</th>
<th>Incremental Output (wetland units)</th>
<th>Incremental Cost per Unit ($ per wetland unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1 + A2</td>
<td>2,175,000</td>
<td>.665</td>
<td>2,175,000</td>
<td>665</td>
<td>3,270</td>
</tr>
<tr>
<td>A1 + A2 + D1</td>
<td>4,075,000</td>
<td>1,125</td>
<td>1,900,000</td>
<td>460</td>
<td>4,130</td>
</tr>
<tr>
<td>A1 + A2 + D1 + B1</td>
<td>13,225,000</td>
<td>2,979</td>
<td>9,150,000</td>
<td>1,854</td>
<td>4,940</td>
</tr>
<tr>
<td>A1 + A2 + D1 + B1 + C1</td>
<td>14,500,000</td>
<td>3,119</td>
<td>1,275,000</td>
<td>140</td>
<td>9,110</td>
</tr>
<tr>
<td>A1 + A2 + D1 + B1 + C2</td>
<td>15,975,000</td>
<td>3,174</td>
<td>1,475,000</td>
<td>55</td>
<td>26,820</td>
</tr>
</tbody>
</table>

The plans in Table 3 are the most efficient plans at producing the desired output. The first plan A1 + A2 is the most efficient plan, producing wetlands units at a cost of $3,270 per unit. The next-best buy, Plan A1 + A2 + D1, produces 460 units more than Plan A1 + A2, but the cost of producing those 460 additional units is slightly higher: $4,130 per unit. If more wetlands units are desired, the most efficient option is Plan A1 + A2 + D1 + B1, providing 1,854 additional units for $4,940 each.
Figure 1. All 36 restoration plans (squares = non-cost-effective; circles = cost-effective; stars = best buys).
The next-best buy, Plan $A_1 + A_2 + D_1 + B_1 + C_1$, provides an additional 140 wetland units at a cost of $9,110 each. The final best buy, Plan $A_1 + A_2 + D_1 + B_1 + C_2$, provides 55 additional units at $26,820 each.

**Decisionmaking Guidelines**

The decision at hand is "What level of output is worth its cost?" By implementing this plan formulation and comparison framework, we provide information to support this decision. By formulating all possible combinations of the solutions under consideration, we identify every possible level of output that could be produced. Cost-effectiveness analysis screens out combinations that do not make financial sense because we could get the same output for less cost with another plan, or could get more output for the same or less cost with another plan. Incremental-cost analysis identifies which cost-effective plans are the best financial investments as well as making the increases in output and their accompanying increases in cost explicit as we increase project scale. While cost-effectiveness and incremental-cost analyses will not necessarily identify an optimal solution, they do provide information to facilitate the selection of a solution.

The relationships identified in these analyses are highlighted by graphing the data. Figure 1 plots total cost against total output for all 36 possible plans. Non-cost-effective plans are identified by squares, the 24 cost-effective plans by circles, and the five best-buy plans by stars. Lines connecting the cost-effective plans and the best buys, respectively, are not intended to indicate a continuous range of alternative plans, but to highlight the slope (change in cost divided by change in output—equivalent to the incremental cost per unit of advancing from plan to plan) between plans. This graph makes the tradeoffs regarding cost and wetland units across all possible plans explicit to support the selection decision. This selection may also be guided by decision guidelines such as output targets (legislative requirements or regulatory standards), minimum and maximum output thresholds, maximum cost constraints, uncertainty in cost and output estimates, and by the consideration of the unintended effects of plans on other resources.
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INTRODUCTION

Throughout the nation, there is increased awareness and concern for the protection and restoration of environmental resources. Within the U.S. Army Corps of Engineers, new Congressional authorities and policy changes provide opportunities to pursue environmental initiatives. This increased emphasis on the environment, however, brings with it a need for improved techniques for evaluating and comparing environmental projects and programs.

There is almost always more than one way to address a particular problem, and typically more projects and programs waiting to be undertaken than funds available. Currently, however, there is a lack of accepted methods for assessing the effectiveness (does the project achieve its objective?) and efficiency (is it achieved in the least-cost manner?) of investments in protecting or restoring environmental resources. To address these issues, the Corps initiated the Evaluation of Environmental Investments Research Program (EEIRP) in 1993. The EEIRP, completed in 1996, provided Corps planners with methods and techniques to develop supportable environmental restoration and mitigation projects and plans and at the same time facilitate the allocation of a limited budget across many proposed projects.

TRADITIONAL PROGRAM

Historically, the U.S. Army Corps of Engineers Water Resources Development Program has been charged with improving and maintaining navigable waterways and reducing flood damage. Along with these primary missions have arisen complementary programs for generating
hydroelectric power, providing water supplies, protecting coastal shorelines, managing natural resources, and providing recreation opportunities. Individual projects typically began with an authorization by Congress to develop a plan to address a particular water resources problem. These studies were most often initiated by local interests. They included a partnership, with non-federal interests, and public participation in the planning and implementation process. And they were justified by an economic analysis, comparing both project benefits (for example a reduction in flood damage) and construction and operation costs in monetary terms. The traditional engineering projects that resulted (dams, levees, and modifications of river channels) were built with the expectation of improving the nation's material welfare, but often resulted in substantial alterations to existing watershed features and processes.

**Changing Public Values**

The Corps' water resources program has changed over the past two decades in response to changing national preferences. Watershed alterations for flood control and navigation are no longer considered a sure path to economic development. There is increased concern today for the protection and restoration of the natural services of heavily altered watersheds, many of which were related to previous Corps projects.

Since the early 1970s, the emphasis of the Corps water resources program has shifted from the construction of new projects to the improved operation of existing projects with increased concern for the environment. Today, Corps funds budgeted for the operation and maintenance exceed those for new construction. Environmental restoration is now a "high priority" mission in the Corps budgetary process, along with the more traditional missions of navigation and flood control. In addition, the Corps can participate in the modification of existing projects to restore fish and wildlife habitat.

**Evaluating Environmental Investments**

There is every reason to believe the planning approaches of the past can be adapted for evaluating environmental projects. Authorization by Congress for individual projects or programs will still be required, as will non-federal partnerships and public involvement. Limited funds will be available, and there will still be the need to answer the analytical question of how much should the fish and wildlife habitat or the watershed be altered in relation to some existing condition. However, unlike more traditional projects, many outputs of environmental restoration and mitigation cannot be measured in monetary terms.
The challenge, therefore, becomes how to select the most efficient and effective projects when they cannot all be compared in like, monetary terms. Questions addressed by the EEIRP include how to incorporate "uncertain" measures of output and differing public and institutional values into a rational and supportable evaluation and selection process.

**RESEARCH PROGRAM**

The overall objective of the EEIRP was to provide an evaluation framework, techniques, and procedures to help planners, managers, and regulators address both the site and portfolio issues; i.e., whether the recommended action is the most effective and efficient alternative for a particular location, and how to allocate limited resources among competing recommended actions. To accomplish these objectives, the research program has been divided into 10 areas, called work units. The objectives of each are summarized below.

**Determining and Describing Environmental Significance**

In many ways, this work unit is an antecedent to all the others, because the significance of the environmental resource must be determined and described before other evaluations may take place. Focussing on significant resources also makes practical sense. Narrowing a long list of resources to only the significant ones allows for a more efficient and meaningful study. The objectives were to 1) develop methods to describe and determine environmental significance; 2) evaluate the applicability of various ranking and weighting scales for prioritizing levels of significance; and 3) develop guidelines for determining significance at the local, regional, and national levels. The issue of significance is particularly critical to determining clear mitigation or restoration objectives for environmental and cultural resources.

**Determining Objectives and Measuring Outputs**

The evaluation of environmental investments requires that the planning objectives and project outputs be clearly defined and measured. How well does a proposed project contribute to environmentally significant goals? How should the project’s expected environmental outputs be measured, and are those measurement units usable and understandable? This work unit aimed to 1) provide guidance in determining appropriate goals for environmental restoration projects; 2) provide techniques for measuring outputs appropriate to those goals; and 3) identify modeling and data needs for better long-term management of ecosystems. Determination of objectives will affect the choice of
Environmental Planning Research at the Corps of Engineers

Engineering features, while better techniques for measuring outputs can be linked to the cost-effectiveness comparisons of alternative plans and the valuation techniques.

Objective Evaluation of Cultural Resources

Research here aims to establish clear objectives and output measurement techniques for cultural resources. This work unit first asks how significant a particular cultural resource is at the local, regional, or national scale. The objective is to develop quantitative and statistical procedures for cultural resources evaluation not only for a single site, but also for a national "portfolio" of sites. Again, defining objectives will influence the range of management measures, while better techniques for measuring cultural resources can be tied to cost effectiveness comparisons of alternative plans and the valuation techniques.

Engineering Environmental Investments

Environmental investments, like other projects, require that alternatives be formulated to provide a range of solutions that meet the study objectives. The effects of each alternative on the significant environmental resources are then measured. This research was intended to link engineering management measures, their components, and costs, with the environmental variables they impact. Objectives were to 1) identify approaches for environmental investments; 2) develop methods to assess the effectiveness of those approaches in providing environmental outputs; 3) develop guidance for formulating environmental projects; and 4) provide guidance on identifying the cost components of alternative restoration plans. The identification of engineering measures and costs and assessment of their efficiency is essential to comparing the cost effectiveness of alternative environmental plans.

Cost Effectiveness Analysis Techniques

The crux of the "site" question is which plan best balances the costs and environmental objectives. This research asks, "Which of the proposed management measures or combination of them is the most economically efficient for a given level of environmental output, and how much investment should be made?" The objectives were to 1) develop automated techniques for cost-effectiveness and incremental-cost evaluations; and 2) find ways to analyze multiple environmental outputs.
Monetary and Other Valuation Techniques

Traditional benefit-cost analysis requires that outputs from water resources projects be measured in monetary terms so alternatives can be compared. However, many of the goods and services produced by environmental projects cannot be readily assigned socioeconomic value, whether monetary or non-monetary. The objectives of this research were to 1) identify relevant socioeconomic values associated with environmental projects; 2) improve the linkage between environmental output measures and necessary inputs to socioeconomic evaluation; and 3) provide guidance for non-market monetary evaluation of environmental outputs and assess the appropriateness of those techniques for prioritizing projects nationally.

Incorporating Risk and Uncertainty into Environmental Evaluation

Many of the risk and uncertainty issues arising in the other work units will be addressed here. One of the central questions is which of the proposed management measures or environmental projects has the greatest likelihood of success. Other issues include uncertainty over the probability distribution of output measures, the reliability of management measures and their cost components, and confidence in output valuation. The objectives were to 1) identify components of environmental evaluation conducive to risk and uncertainty analyses; 2) develop risk and uncertainty protocols for environmental evaluation; and 3) test the protocols and develop guidance for their use.

Environmental Database and Information Management

Because this work unit deals with identification of data needed for environmental evaluation and communicating environmental information, many of the data needs that surface in other work units may be addressed here. Examples include information needs for determining significance, output measures, costs of management measures, cost effectiveness, and output valuation. The objectives of this research were to 1) develop and demonstrate a decision support methodology for evaluating environmental projects based on site and regional characteristics; 2) develop methods to communicate the results of environmental evaluations; and 3) develop methods for maintaining regional environmental databases.

Evaluation Framework

The procedures and guidance developed for the other EEIRP work units are coordinated and incorporated into the evaluation framework. This is where all the individual products are integrated to address the site
and portfolio questions and the whole trade-off evaluation process is communicated to other agencies, organizations, interest groups, and public sponsors. Through a series of representative case studies, the research aimed to 1) provide a process to identify national, regional, and local priorities; 2) identify information needs of the public, the media, decision-makers, and study participants; 3) describe trade-off processes incorporating all benefits and costs; and 4) identify processes for facilitating public involvement.

**Interagency Coordination and Program Management**

Because the EEIRP program required extensive coordination with other Corps offices, other federal, state, and local agencies, environmental groups, universities, and private contractors, an overall direction and control was necessary. This work unit ensured the successful, timely, and coordinated accomplishment of all EEIRP research components.

**EEIRP RESEARCH PRODUCTS**

A wide range of reports, software, training modules and workshops, journal and magazine articles, and publications in conference proceedings resulted from the EEIRP. The major reports are listed below. For additional information please contact William Hansen, EEIRP program manager, or the other authors at (703) 428-6217.

By the U.S. Army Corps of Engineers Institute for Water Resources, Alexandria, Virginia:


By the U.S. Army Corps of Engineers Waterways Experiment Station, Vicksburg, Mississippi:


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Part 12

INTERNATIONAL APPROACHES
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REDUCING FLOOD VULNERABILITY IN SMALL CENTRAL AMERICAN WATERSHEDS: THE LEAN RIVER PILOT PROJECT IN HONDURAS

Robert U. Murdock
Stephen O. Bender
Organization of American States

INTRODUCTION

During the last 30 years, Honduras has shown increasing vulnerability to floods. In the past they were commonly associated with major meteorological phenomena, such as Hurricane Fifi, which left 8,000 people dead and $540 million (U.S. dollars) in losses in 1974 (OAS, 1991). But current experience is that major flooding occurs more frequently and as a result of tropical depressions and even common rainstorms. For example, there were major floods in 1991, 1993 and 1996, the last of which left eight dead and immediate losses of $30 million (U.S. dollars). At the same time, many areas of the country have been subject to rapid deforestation, combined with a population increase from 1.9 million in 1961 to about 5.5 million today.

The Organization of American States (OAS), through its Unit of Sustainable Development and Environment, has assisted its member states with natural hazard management, recognizing in each case the need to implement an integrated approach that balances relief during and after natural disasters with mitigative, pre-event measures. In consideration of Honduras' present day susceptibility to floods, the OAS and the Honduran government, with financial support from the European Community, undertook a joint agreement to implement a pilot flood vulnerability reduction project in the Lean River watershed, as a means of demonstrating a low-cost, community-oriented solution stressing prevention and preparedness. Highlights of the project include a community-operated, real-time flood alert system and an in-depth analysis of flood mitigation strategies for the watershed.

PROJECT IMPLEMENTATION METHODOLOGY

The general objective of the project was to create a flood vulnerability reduction process that embraced not only local communities
and municipal authorities but also the national Honduran government. Locally, the watershed inhabitants learned about flood preparedness and response plans they could implement to reduce the effects of these events. In turn, the municipality developed a response plan to coordinate with the various communities, while the mayor and other authorities were instructed on mitigation strategies that could be employed in planning the economic and social development of the zone. At the national level, actions were contemplated that would draw attention to the need to implement flood mitigation measures in regional development activities, particularly concerning the social and economic infrastructure.

By involving the different levels of society, the project presented an integrated approach to flood vulnerability reduction, including a practical pilot experience in a small, coastal watershed to demonstrate the steps to be followed by government and community. Based on this approach, the OAS set out the following three specific project activities: (1) an analysis of the physical vulnerability of the watershed to floods, for use in development planning; (2) implementation of a real-time, community-operated flood alert system for response and evacuation; (3) elaboration of a strategy document addressing the mitigation measures necessary within the watershed, but which would, in part, be applied at the national level as an integral part of several sectors’ actions.

Three workshops were held for community training. In each, more than 50 community leaders were instructed in development and implementation of response plans, flood alert system operation, and flood forecasting. The workshops were designed and arranged by the Permanent Commission on Contingencies (COPECO), the government agency in Honduras responsible for natural hazard management and the national counterpart assigned to the project. The OAS provided technical assistance through the participation of two specialists, one who coordinated project activities locally with the COPECO, the other a hydrologist who designed the flood alert system as well as conducting the vulnerability analysis and collaborating in the identification of mitigation strategies. An indispensable element to the success of the project was the full support and participation of the local municipality in all phases.

**PROJECT IMPLEMENTATION**

**Physical Vulnerability Analysis**

The Lean River watershed is located on the north coast of Honduras, with a total area of 951 square km of which about 27% can be considered relatively flat (less than 10% grade), with the rest occupied by mountainous terrain. The Lean River has an alluvial floodplain ranging
from less than 1 km wide upstream to nearly 12 km where the river discharges to the Caribbean Sea. In 45 km (measured in a straight line), the river takes a sinusoidal, meandering path and frequently changes its course after even small floods. Mean annual rainfall ranges from about 3000 mm at the coast to 2000 mm at higher elevations, and partial records indicate that 300 to 400 mm of rainfall in 24 hours is common, occurring perhaps every two to five years along the coast (Bond, 1995).

There are a number of important tributaries that also produce serious flooding problems for residents, mainly farmers whose livelihood depends on the fertile floodplain of these waterways. Thus, the watershed population is subject to many distinct threats, such as flash floods on the tributaries having high water velocity and short durations, to floods on the Lean lasting more than two weeks in the lower lying areas. Examples of floods include Hurricane Fifi in 1974, which affected nearly all watershed communities and caused 35 deaths, dozens of houses destroyed, and incalculable agricultural and infrastructure losses. In 1993 a small tributary experienced flash flooding causing the destruction of five houses, dozens of homes inundated up to two meters, the loss of the highway bridge, and damage to the potable water system. In 1988 a landslide above a rural village formed a temporary earth dam, rupturing afterwards and releasing a huge mass of water and boulders toward the population, ultimately leaving 12 dead.

The vulnerability analysis provided the municipality and local community members with site-by-site information on flood vulnerability, for use in economic and social development planning. The analysis depended completely on field visits and interviews with the local residents, due to a lack of historical records and/or recent aerial photos. Among the findings was the fact that the watershed had experienced a large degree of deforestation in recent years, so that current estimates of forest cover range from 10% to 15% of original levels within the watershed. As a result, the river beds are rapidly filling with sediment, which reduces channel carrying capacity. Residents reported a decrease in depth in various rivers of up to four feet during the last 20 years. These factors indicate a rapidly deteriorating watershed. Given the relatively recent nature of the deforestation and erosion, it was felt that this trend would not reverse in the near future and was more likely to continue or escalate. Thus for the purposes of analyzing vulnerability of the watershed population, a determination was made to consider flood water heights of up to two meters higher than previously seen levels.

With the projected increase of two meters, each population was analyzed for current vulnerability, based on its flood history and current demographic situation, incorporating factors such as possible escape
routes and type of flood threat. The high risk communities were given a categorization of “highly vulnerable” or “significantly vulnerable,” and this information was presented as a vulnerability map and table. One of the interesting outcomes of the analysis was that some communities that historically had not been seriously affected were categorized as highly vulnerable, due to the projection of an increase in flood heights of two meters. Conveying this message to the inhabitants was a major challenge, because they have always relied on past events in deciding where to live, work, and build.

**Flood Alert System Implementation**

The objective of this activity was to provide a low-cost, community-operated alert system that would give inhabitants additional time to execute their flood response plans and especially evacuate. Thus, flood preparedness training played an integral part, and was emphasized in each of the three workshops held for community leaders. The final system utilized a network of rain and river gages interconnected by radio communication. Among the challenges encountered was the design and installation of gages simple enough for use by rural inhabitants with primary educational levels, yet adequate for the purposes of flood forecasting. In addition, it was often difficult to find willing and/or capable gage operators in the higher portions of the watershed. As for radio communication, the lack of electrical service in many sites required alternative power sources. Finally, the use of computer equipment in the forecast center was not an option. Therefore, intensive training was needed on manual data recording and analysis for flood prediction, a task to be carried out by a forecasting committee comprising mainly municipal workers with no previous experience in the subject.

For flood system design, hydrologic data was not available for the watershed. Thus an in-depth hydrologic analysis was virtually unattainable and of little use. Instead, the parameters for flood prediction were estimated using a reverse approach which “backs out” the values from known information obtained primarily from watershed residents. The process was this: (1) Interviews established that floods on the Lean appeared to cause significant damage and losses every five years, thus a conservative estimate of the two-year rainfall was chosen as the level that should trigger the flood alert dissemination, after which the rainfall curve was constructed based on data from nearby watersheds. (2) The watershed was divided into three sub-watersheds representing the upper, middle, and lower portions of the basin. (3) Concentration times for each sub-watershed were estimated from community interviews, as well as the flood travel times on the Lean between the respective sub-watershed
drainage discharge points. (4) River gages were installed on the Lean at the drainage discharge point of each of the three sub-watersheds, together with a network of rain gages over the three drainage areas. (5) By comparing the estimated concentration times of each sub-watershed with the two-year rainfall curve, precipitation levels for each sub-watershed were estimated that could cause flooding at their discharge point into the Lean River. (6) River heights indicating significant flood levels on the Lean capable of inundating downstream communities were estimated for each of the three drainage discharge points (each having its respective gage), based on topographical features and historical information.

Having established the excess rainfall values in each of the three sub-watersheds, and the river heights indicating flooding on the Lean at each of the three discharge points, forecasting guidelines could be developed based on a combination of river and rainfall readings. For example, a river gage indicating a flood at the upper sub-watershed discharge point was to be taken as a first alert for downstream communities. However, the same reading combined with an excess rainfall value in the middle sub-watershed triggers a definite alarm situation for all communities below its drainage discharge point into the Lean. That is, [High River Level - Upper Gage] + [Excess Rainfall - Middle Sub-Watershed] = [Definite Alarm - All Communities below Middle Sub-Watershed Drainage Point].

The final system design comprised three river and 25 rain gages, with a communication network of 25 radios. In actuality, project funding limited the initial number of radios to eight; priority was given to river gage sites due to their superior reliability in predicting floods. A final test of system operation was a full-scale simulation of a flood. Each of the 28 gage operators was required to take readings at constant intervals and relay them by radio to the forecast center, where the data were analyzed and compared to the established flood prediction parameters. The forecast committee accurately forecast floods at the appropriate times and locations, both on the Lean and various tributaries.

Identification of Flood Mitigation Strategies

This activity was directed primarily at the economic and social infrastructure within the Lean River valley, as a means to motivate local and national authorities to consider vulnerability reduction measures before a flood. The project covered planning and civil construction issues important to communities but frequently determined by government practices and policies, thus achieving an integrated approach focused as much on disaster prevention as on emergency response.
Based on the physical vulnerability study, a number of key infrastructure components within the watershed were identified for mitigation, in accordance with their importance to the welfare of local inhabitants as well as to the economic and social development of the area. In general, it was found that the transportation infrastructure had been built with little regard to flood vulnerability. Highway bridges, for example, were seriously undersized in terms of their free spans, relying on human-made terre plains at either extreme in order to traverse the floodplain, which frequently have been washed away during major floods. The main paved highway along Honduras' northern coast crosses directly through the middle of the Lean Floodplain in perpendicular fashion, just below the last major tributary. The entire five-kilometer stretch is built on a levee elevated two meters above the natural terrain, with meager drainage capacity, so that during floods the highway acts as a dam, backing water up and raising flood levels. Various schools as well as the municipal health center were in need of mitigation, and hundreds of private homes were considered at serious flood risk. Typically, these structures were located in or at the edge of the floodplain, built less than 50 centimeters above ground and often as little as ten.

The mitigation strategies defined in the study range from expanding existing bridge spans, to lowering highways in the floodplain to near ground level as a means of simulating natural flood behavior, to relocating stretches of key roads to higher natural elevations away from the rivers. For the social infrastructure, it was found that various buildings could be economically elevated by one to one-and-one-half meters by backfilling over the existing floors and raising walls and roof levels (because of the simple construction methods employed in many of the structures). In other cases, relocation was recommended or alternative designs suggested to elevate buildings on columns. The zoning of highly vulnerable, inhabited areas to strictly agricultural uses was strongly recommended to municipal officials, along with reforestation and the use of internationally sponsored forest management plans.

In summary, approximately 11 infrastructure components were identified and analyzed. Depending on the alternative selected, it was estimated that the vulnerability of these components, and thus that of the watershed community, could be significantly reduced with an investment between $500,000 and $1 million (U.S. dollars). The resulting study document was sent by the COPECO to appropriate government ministries responsible for infrastructure projects. Such a study is necessary, not only for implementing the mitigation strategies, but equally to motivate the incorporation of vulnerability reduction as an integral part of current national project design and implementation practices.
CONCLUSIONS AND PROJECT AFTERMATH

Flood vulnerability reduction can be achieved through a high degree of community participation, given that local inhabitants are the major stakeholders in projects of this nature. Furthermore, it is possible to include community-operated alert systems in rural flood vulnerability reduction projects as a viable, low-cost alternative to technologically advanced systems. At the national level, vulnerability reduction projects should demonstrate needed changes in infrastructure development, thus achieving an integral approach that embraces all sectors of society.

After the initial completion of the project in September 1995, heavy rains fell for more than two weeks during November of 1996 on the north coast of Honduras, causing heavy flooding in many areas, including the Lean Valley. Two of the three river gage sites did not possess radio communication equipment as per OAS recommendations, while other radios had been installed in low priority sites rather than those most critical to flood forecasting. These errors severely inhibited the effectiveness of the alert system. Nonetheless, gage operators did take the readings, and those that did have radios made reports, a fact which suggests that even with little follow-up work by the COPECO and other government agencies, the communities were enthused about the value of the system and aware of the necessity to continue using it even under difficult circumstances. A major conclusion is that projects including flood alert systems require a high degree of monitoring by the locally responsible agencies, and when possible support for these activities should be budgeted as part of local and national activities.

REFERENCES


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OPERATION OF THE NEW SOUTH WALES FLOOD POLICY

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INTRODUCTION

This paper outlines the current system of floodplain management in New South Wales (NSW), the most populous state in Australia. It has now been some 10 years since the NSW government introduced legislation and adopted a manual to assist with the implementation of the current management system, which is based on a balanced mix of responses to the flood hazard, rather than a simple works and development control response. This paper also addresses a number of key aspects where improvements to the present approach and revisions to the manual are being considered by the NSW government.

AUSTRALIAN POLITICAL FRAMEWORK

Australia has a three-tiered system of government. It has a federal government covering national issues. At the second level is a set of six states, including NSW, and two territory governments. The third level is local government, comprising locally elected and autonomous administrative units called councils. In NSW there are 177 councils. The six states were founded as separate colonies, with NSW the initial colony established in 1788. These colonies developed as discrete political entities, which in turn created councils to address and manage local issues.

In 1901, the states federated and the Constitution of the Commonwealth of Australia provided the federal government with powers to address national issues such as defence, foreign affairs, and taxation. The states retained powers in relation to the provision of services to their population, such as health, education, and transport. The provision of these services is underwritten by federal and state taxes. Local government councils retained their powers under the Constitution. They are principally charged with provision of local services, such as roads, waste disposal, and in particular, floodplain management.

With regard to floodplain management, the state government role is one of policy setting and the provision of technical and financial assistance to councils. It also provides the framework for emergency
management, response, and recovery. The federal government provides financial assistance, both in implementing floodplain management measures and in financing emergency relief during and after natural disasters.

EVOLUTION OF FLOODPLAIN MANAGEMENT POLICY IN NSW

Development on NSW floodplains proceeded with some awareness of flood hazard, but with limited reaction to its impact, from first settlement until well into the twentieth century. Historically, there have been four distinct stages in the evolution of floodplain policy.

Initial Colonisation

Since 1788 towns have been established on the fertile floodplains. Awareness of the flood hazard by the early settlers was generally offset against the more pressing demands for water, food, and transport (via rivers and ocean), and development on the floodplains proceeded in spite of the risks. Flood events, even those of great severity, had little discernible impact on nineteenth century development decisions, and the trend continued in the twentieth century. People accepted the risk of flood damage as a social and economic necessity, stoically rebuilding their lives, resources, and infrastructure after each flood event. The earliest floodplain management activity in NSW was by Governor Lachlan Macquarie in 1811. The Governor assumed the role of floodplain manager and established by decree the 5 "Macquarie" towns of Windsor, Richmond, Castlereagh, Wilberforce, and Pitt Town on land understood to be at little risk from Hawkesbury River flooding. A later proclamation in 1817 expressed the Governor's frustration that people were continuing to build houses where floodwaters came frequently.

Engineering Works

In the wake of devastating floods in 1955, the NSW government established a statewide program for subsidising councils 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.

At that time (1958) there were accepted design standards for flood works in Australia that were similar to prevailing practice in other English-speaking countries. As the expectations of communities rose, complaints increased about flooding exceeding the capacity of the works. A rising awareness of the environmental impacts of flood mitigation also
brought pressure on all levels of government for better floodplain management.

**Planning Control**

In the mid 1970s a review of floodplain management was initiated in the wake of another series of significant floods. The review highlighted the fact 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 introduced in 1977 to prevent new development on land liable to flooding and to remove existing development sited in the most hazardous situations. The policy was aimed at encouraging councils to restrict development on flood prone land. It can be briefly summarised as follows:

- no development on land inundated by 5% AEP floods which was designated as floodway;

- no development on land inundated by 1% AEP floods where flood free sites existed; and

- removal of existing development from the most hazardous floodways.

This policy approach between 1977 and 1984 was combined with continuation of the works program.

**Present Merit System**

By 1982, considerable opposition to the planning policy had mobilised. The resulting pressure from homeowners, landowners, and councils led to a thorough review of the policy, and ultimately adoption by the NSW government of a new merit-based system that is 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 requires a council to take a responsible development decision in recognition of any potential hazard of which the council should reasonably be aware. If a responsible decision is not taken, an owner or developer suffering a consequent loss due to a hazard, such as a flood, may succeed in a suit for damages on the grounds of negligence.

The ‘carrot’ involves a legislative amendment to the Local Government Act (1919), providing indemnity to councils from claims for
damages from flooding, provided they followed the principles contained in the manual. To enable implementation of this system, a detailed floodplain development manual was published by the NSW government setting out the process and principles involved in making balanced floodplain management decisions.

The floodplain management system in NSW is now a well established systematic process by which a local council committee considers the risk of flooding, the consequences of flooding, and the merits of various floodplain management options. The process has been designed to be proactive and assist the community to act now on tomorrow’s flood. The key elements are addressed as shown in Figure 1.
IMPLEMENTATION OF THE FLOODPLAIN MANAGEMENT PROCESS

The floodplain management process has developed as an orderly and sequential process. It is designed to ensure that equity of interest is addressed across the community, while preserving the ultimate responsibility of councils for managing the process.

**Steering Committee**

Best management practice now involves community input in floodplain management decisions, along with that of civil engineers, strategic planners, farmers, environmentalists, homeowners, legal advisers, and other users of the floodplain. Councils are required to form a steering committee, with all the stakeholder groups as members. Different experts in flood behaviour, emergency management, and other matters are invited to participate in committee discussions as required. The committee "steers" the remainder of the floodplain management process. Community members have proved to be invaluable in regard to local solution determination and local acceptance of plans.

**Flood Study**

The flood study consists of a detailed technical investigation of flood behaviour. It defines the flood hazard by providing information on the extent, level, and velocity of floodwaters and the distribution of flood flow, up to the possible maximum flood (PMF). The steering committee engages a state agency or a consultant to undertake the study. A report is produced based on a mathematical model, that is utilised in the floodplain management study (FMS), to estimate the impact any proposed development or floodplain management measures may have on flood behaviour.

**Floodplain Management Study**

Once the behaviour of past and future floods has been determined in the flood study, a picture of the social and environmental fabric of the floodplain is prepared in the FMS. The objective of the FMS is to show how use and occupation of the floodplain may be balanced against the risks and hazards associated with the floods. The FMS brings together facts on the management of the floodplain. The facts are used by the steering committee when comparing various management options.
management plan

A local floodplain management plan (FMP) involves the formal adoption by a council of a defined floodplain management strategy. It is based on the results of the above studies and provides a common rationale for both site specific and general development decisions.

It is essential that the local community has active involvement in the plan’s preparation. In this regard a draft document is exhibited widely within the community and amended as necessary in light of public responses prior to the council adopting a final plan.

Implementation

Implementation of a FMP involves a mix of engineering works, purchase of property, house raising, warning systems, emergency planning, environmental improvements, planning controls, etc. by the council. Significant influences, such as available funding from both council and government resources, may determine both the rate of implementation and the priority of particular actions.

Council’s adopted FMP does not finish the floodplain management process. Periodically, the plan is reassessed to take account of such factors as new flood data, possible changes in the dominant business in the area, and other issues that may not have been foreseen at the time.

Future Implications

The current NSW policy was announced in December 1984 and there was initial doubt regarding the practicality of achieving its goals. However, work commenced immediately on a manual that was released for public comment late in 1985. Indemnity legislation was enacted in 1986. Following public consultation the final manual was gazetted in February 1987. Since that time it has been actively embraced by most councils.

Revision of the manual is currently being undertaken to clarify and increase the community’s understanding of floodplain management. Issues for revision to the manual include:

• future emphasis on the need for consideration of the full range of floods, up to and including the probable maximum flood;

• inclusion of house raising as a fundable component of the implementation of a FMP;
• inclusion in the management process of local overland flooding issues rather than sole consideration of flooding from rivers breaking their banks;

• separation of floodplain management issues into "existing risk," "future risk," and "continuing risk" classes, each of which require different, if complementary solutions;

• incorporation of emergency management considerations in the development of a FMP; and

• more emphasis on positive environmental management of the floodplain.

**Conclusions**

In Australia much of our agribusiness and most of our towns and cities are located on floodplains. Exclusion of floodwater and banning of floodplain development have proved impractical. Effective floodplain management is now based on an integrated system that recognises and accommodates the social, environmental, and economic costs and benefits of development on the floodplain.

Although the floodplain development manual is to be redrafted, it is anticipated that the overall community based approach will remain the basis of floodplain management in New South Wales for many years to come.

**References**

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Part 13
THE PRACTICE OF FLOODPLAIN MANAGEMENT
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WHO IS THIS MASKED INDIVIDUAL CALLED THE FPA?

Roy D. Sedwick
Lower Colorado River Authority

INTRODUCTION
In the past year, a number of states have reduced their commitment to the National Flood Insurance Program (NFIP) and to sound floodplain management. Local governments, fighting tighter budgets and property rights movements, are seeing less support among elected officials. There is an attitude that flooding is a federal problem. Faced with decaying support for floodplain management and reeling from a devastating flood, the Lower Colorado River Authority (LCRA) began a quest to reverse this trend and to bolster local floodplain management programs.

FLOOD PROTECTION PLANNING STUDY
What type of assistance is needed by local government and which of these needs can be incorporated into a non-structural floodplain management program? To answer this, the LCRA commissioned a Flood Protection Planning Study of the NFIP activities of communities in the 10-county lower Colorado River basin. The study, completed in May 1996, used a community survey, in-depth interviews, and floodplain tour to establish the elements of a floodplain management assistance program. Through interviews with local administrators, a profile of a typical floodplain administrator (FPA) began to develop and it became apparent that the FPA holds the keys to successful local floodplain management programs.

The study focused on the local FPA, his/her concerns, and the assistance needed to effectively manage local programs. The interviews yielded a list of activities needed to improve the professional performance of the FPA. Technical assistance needs fell into six categories: program administration and permitting; maps and flood data; public awareness; floods, mitigation, and multi-objective management; Community Rating System; and non-participating and sanctioned communities.

THE FLOODPLAIN ADMINISTRATOR—KEY TO SUCCESS
Based on the face-to-face interview, the typical FPA could be young or old, male or female, greenhorn or seasoned veteran. However, some
similarities surfaced. Most did not have college degrees, in fact out of the 50 interviewed, only six had completed a four-year curriculum, and only two were registered engineers. The majority had other job responsibilities ranging from code enforcement, building inspection, planning and zoning, septic system inspection, fire marshal, emergency management coordinator, and even mayor or county judge. So many hats compete with floodplain management for the FPA's time and energy.

Only one FPA had had formal training through FEMA's Emergency Management Institute, but most had attended several one-day NFIP workshops or seminars conducted by the state coordinating agency or by the Federal Emergency Management Agency (FEMA). A major setback to this effort is the decline of state coordination, which has resulted in the loss of a statewide newsletter and the cessation of workshops and training for local governments. About 50% of the FPAs belong to professional associations and promote floodplain management through civic activities, publishing articles, and attending conferences and seminars. About 50% held some professional certification or license, mostly plumbing, sanitation, water and wastewater certifications, but none was certified as a professional floodplain manager. The average length of experience was 7 years, ranging from less than one to over 23 years.

NEEDS OF THE FLOODPLAIN ADMINISTRATOR

Formal Training and Education

Results of the survey and interview have established some priorities for advancing the professional capabilities of the FPA. The first is formal training and education. With the assistance of FEMA Region VI, the LCRA was able to bring the FEMA Floodplain Administrator Training Course to the region, resulting in formal training of 32 local administrators and FEMA has now committed to offering the course in the state at least two times per year. In addition, FEMA and the Association of State Floodplain Managers, Inc. (ASFPM) are working to develop a home study course for floodplain management while the LCRA is developing specialized workshops on floodplain management, hazard mitigation, the Community Rating System, and floodplain management for elected officials. The Texas Floodplain Management Association (TFMA) has workshops and training as part of its annual conference and ASFPM offers more opportunities at its annual meeting.

Professional Certification

Programs for professional certification have already been implemented by a number of professional organizations. In Texas, code
enforcement officials are certified by the Code Enforcement Association of Texas, while emergency management coordinators are certified through the National Coordinating Council on Emergency Management. The TFMA has a certification program for its members and the ASFPM is developing a national certification program. In Texas, the TFMA requires successful completion of a certification exam that measures the applicants’ knowledge of the basic principles of sound floodplain management as mandated by the NFIP. Over 160 people have taken the TFMA certification exam and 38 have achieved the status of Certified Floodplain Manager.

**Continuing Education**

Even veteran FPAs must continue to hone their skills as new techniques, technology, rules, regulations, and program changes sweep the profession. To meet this need for continuing education, LCRA, TFMA and FEMA are now working to develop conferences, workshops, and training seminars designed to keep the local floodplain administrator on the cutting edge of floodplain management and hazard mitigation. TFMA now requires continuing education credits or professional development hours as a condition of recertification for certified floodplain managers.

**Professional Association**

Every FPA needs to belong to a professional association dedicated to promoting the profession of floodplain management and the wise use of floodplains to reduce the loss of property damage and to save lives. Networking with fellow administrators and exposure to other successful programs tends to increase knowledge and expertise. In Texas, the TFMA is dedicated to these principles and is working to improve the status of both floodplain management and FPAs within the state. And the ASFPM strives for the same goals on the national level. The LCRA actively promotes both associations. Membership in TFMA has now reached a record high and indications are for continued growth.

**Hands-on Training**

Due to turnover there is a need for hands-on training for new floodplain administrators, especially until an opportunity opens up for a formal training session or workshop. The TFMA has formed a network of volunteers to serve as NFIP instructors and help newly hired FPAs. Members of the TFMA’s Mutual Aid Training Force, mostly veteran FPAs and engineers, will come to a community to help the FPA
implement a basic floodplain management program based on the local ordinance or court order and establish a permitting system. The LCRA makes its staff available for this important endeavor.

Information Exchange

Floodplain management is constantly changing. New programs, techniques, practices, and technology continue to develop and floods continue to test our ability to control floodwater and human encroachment. The Internet helps keep professionals abreast of these changes and new developments. FEMA has a World Wide Web site and most other federal and state agencies have at least some information available through the Internet. The LCRA has a home page and recently added real-time river and rainfall gage data. The ASFPM and TFMA are developing a home page for their activities. Both associations have a newsletter to keep FPAs informed and the LCRA has a new newsletter to promote nonstructural floodplain management in the lower basin.

Recognition of Success

Far too often, the local FPA is on the receiving end of complaints and threats as he/she attempts to enforce a local program. Sometimes even the elected officials fail to back an administrator when program decisions become controversial or political. It would be nice for FPAs to get a pat on the back and congratulations for a job well done. The TFMA tries to accomplish that through its annual Local Floodplain Administrator of the Year Award, and more awards are being developed to recognize successful projects. The ASFPM also recognizes success through its national awards and the LCRA is considering awards for basin FPAs.

Technical Assistance Needs

Program Administration and Permitting

The study revealed that many of the FPAs were doing a fairly good job of regulating development, but many had trouble producing the documentation necessary to show compliance. Some technical assistance needs are: a sample floodplain management ordinance/court order; a sample permitting system with proper forms; draft standardized floodplain management requirements for subdivision regulations; coordination of the LCRA septic tank program and non-point source pollution program with local FPAs; flood boundary overlays on current city/county maps; acquisition of computers and fax machines; a computer-based permit and recordkeeping program, especially software; a technical reference library;
and coordination with FPAs when someone applies for a LCRA meter loop or power hook-up.

Maps and Flood Data

Few FPAs are happy with the FEMA flood maps. Even communities with recent county-wide Flood Insurance Rate Maps are having problems keeping pace with rapid development. The LCRA is considering the following assistance needs: developing hydrological data for defining the 100-year floodplain around the Highland Lakes and along the Colorado River and tributaries; helping communities review hydrological and/or hydraulic data pertaining to proposed floodplain development or floodplain modifications; establishing bench marks; providing information to the local FPAs on the FEMA map amendment and map revision procedures; helping communities with technical requirements during map amendment or revision, including corporate limit changes, new incorporations, survey data, channel modifications, flood control structures, and other flood hazard mitigation projects; using GIS to produce overlays; and coordinating with FEMA and the state in setting priorities for new flood studies and limited map maintenance studies within the basin.

Public Awareness

There will always be a need to educate the public about the NFIP and the dangers of building in the floodplain. With rapid growth, families are constantly moving into new communities and most are unaware of the floodplain management building requirements, the emergency management and alerting procedures, and the dangers of a flash flood or hurricane. To facilitate local public awareness, the LCRA is considering: helping develop and distribute community floodplain management brochures and NFIP flyers; providing literature distribution racks and stocking them with appropriate NFIP brochures; establishing technical reference materials in local libraries, including flood videos; helping local governments write news articles, flood placards, and other NFIP notices; developing floodplain management information on the LCRA website; developing a speakers’ pool to address local civic and professional groups; organizing town hall meetings or public forums to discuss the NFIP; and cosponsoring workshops and seminars throughout the basin.

Floods, Mitigation, and Multi-objective Management

To assist the general public, the LCRA will continue: water well tests and cleanup assistance after floods; helping local governments establish
floodplain parks and recreation areas; providing local FPAs with information on mitigation grant programs; helping local governments draft flood hazard mitigation plans; developing hazard mitigation and multi-objective management workshops in the basin; coordinating LCRA efforts to require on-site/regional detention of stormwater and control non-point source pollution; and provide funding for mitigation projects.

**Community Rating System**

Only one community in the lower Colorado River basin participates in the Community Rating System (CRS). The LCRA is committed to expanding CRS participation and is considering: conducting CRS workshops; distributing CRS manuals, computerized application forms, and elevation certificates, and helping draft required plans; developing sample CRS plans; helping communities document CRS activities and prepare the CRS application; and seeking basinwide credit for dam safety and flood warning activities.

**Non-Participating and Sanctioned Communities**

Six of the 52 communities in the basin are not participating in the NFIP and are now sanctioned by FEMA. To reach 100% NFIP participation, the LCRA is considering meeting with the mayors and local building officials to discuss benefits of the NFIP and the effects of federal sanctions; addressing city council meetings; providing cities with NFIP applications, sample ordinances, and permit forms; and advising cities on implementing the program with existing staff and resources.

**Conclusion**

As we face declining state NFIP coordinating capability and local governments struggle to maintain an effective floodplain management program, we must first determine what constitutes effective coordination and what assistance is needed by local government. Although not all-inclusive, the results of the LCRA Flood Protection Planning Study stand as a model for states and other agencies in their development of an effective floodplain management assistance program. It is time to unmask the FPA, find the face behind the force, and provide him/her with the necessary assistance to carry floodplain management into the 21st century.
PROFESSIONAL CERTIFICATION—A WORTHY GOAL!

Roy D. Sedwick
Texas Floodplain Management Association

INTRODUCTION

For several years now, the Association of State Floodplain Managers, Inc. (ASFPM) has been discussing the advantages of implementing a national certification program for floodplain managers. Many were for it and some were against it, but everyone cast their eye on the National Coordinating Council on Emergency Management (NCCEM), a national organization with a highly successful certification program for emergency managers. There had been problems and pitfalls along the way, but many emergency management coordinators across the country now proudly display the initials "CEM" after their name, recognizing their knowledge and abilities in the field of emergency management. At long last, floodplain managers now have an opportunity to show the world that they too have the knowledge and expertise to manage the nation's floodplain and wetlands. ASFPM is nearing completion of a national certification program and on the state level, several state associations, including the Texas Floodplain Management Association (TFMA) have initiated or have plans to initiate a state floodplain manager certification program. This paper will focus on the TFMA Certified Floodplain Manager Program (CFMP) and examine its effect on the floodplain management profession.

TFMA CERTIFIED FLOODPLAIN MANAGER PROGRAM

Back in the early spring of 1996, the TFMA Board of Directors voted to proceed with development of a professional certification program for floodplain managers. Members of the Association's Professional Development/Certification Committee (PDCC) had already reviewed several professional certification programs including NCCEM's Certified Emergency Manager Program, and on the state level, certification of code enforcement officials. In Texas, code enforcement officials are certified through membership in the Code Enforcement Association of Texas (CEAT) with the exam and application process handled by the Texas Department of Health. Since many code enforcement officials also manage floodplains in Texas and the CEAT program has enjoyed major
Professional Certification—A Worthy Goal

success, it was decided that this program would be a model for TFMA’s certification program and application process. With establishment of the Certified Floodplain Manager Program, the Texas Floodplain Management Association intends to operate a statewide program for certifying floodplain managers and other professionals, recognizing the floodplain management and hazard mitigation requirements of local, state, and federal programs dealing with the National Flood Insurance Program (NFIP). The CFMP was created to raise and maintain the professional standards of those individuals who manage floodplains, wetlands, and watersheds within the State of Texas. The program is designed to certify competency with the basic principles of sound floodplain management as mandated by the NFIP.

PROGRAM GOALS

Primary Goal

The primary goal of the Certified Floodplain Manager Program is improving the knowledge and abilities of the floodplain managers in Texas. Improving NFIP knowledge and capabilities within local governments will contribute substantially towards reducing the state’s flood losses and will ensure the protection and enhancement of natural floodplain values. This primary goal will be achieved over time through encouraging self-study and attendance at training sessions; requiring continuing education as a condition for recertification; and encouraging city and county governments to require training and professional certification of local floodplain managers.

Secondary Goal

On a larger scale and in a longer time frame, a second major goal of the CFMP is increasing the prominence of floodplain management and hazard mitigation in decisionmaking by local and state officials and the general public. This goal will be achieved over time through improving the recognition of floodplain management and hazard mitigation as a specific discipline; increasing the status of floodplain managers as knowledgeable professionals in a complex profession; and promoting certification to provide greater visibility of the profession.

ELIGIBILITY AND PROGRAM REQUIREMENTS

Eligibility

Participation in the CFMP is strictly voluntary. Any person involved with the management of the state’s floodplains, wetlands, and watersheds
and who meets the credentials and requirements as established by the PDCC is welcome to apply for professional certification. It is anticipated that most applicants will be local floodplain managers, but the program is open to individuals in the private sector, state and federal government, and other agencies or organizations dealing with floodplain and other related disciplines. It is mandatory that applicants are paid up, full-time members of the Texas Floodplain Management Association.

**Program Requirements**

The initial Certified Floodplain Manager (CFM) designation will be granted upon successful completion of three basic program requirements: basic application, establishment of credentials and successfully passing the certification exam. Credentials of the applicant will address: experience (minimum of two years), education (at least high school), employment verification, references (at least three), professional association memberships (TFMA mandatory), training, and contributions to the profession. The certification exam is designed to test the applicants’ knowledge of the basic principles of sound floodplain management and the criteria of the NFIP. The pass/fail status of the certification exam will be the sole basis for the final determination to designate an applicant as a Certified Floodplain Manager.

**Recertification**

Upon completion of the above requirements, and payment of the appropriate fees, the applicant will be awarded a certificate and registered as a Certified Floodplain Manager. The certificate will remain in effect for one full year from the date of issuance. At the end of one year, each CFM must submit a modified application form for recertification. This reapplication form will be utilized to update the CFM’s credentials and employment and to document completion of the required continuing education/professional development hours. After five years of successive certification, all CFMs will be required to retest their knowledge of the NFIP as well as complete the usual requirements for recertification. Retesting is necessary to ensure that applicants have kept abreast of any changes to the NFIP brought about by legislation, rules and regulations, and administrative or policy decisions.

**Summary**

Professional certification of floodplain managers is established as a peer review process administered through the Texas Floodplain Management Association. TFMA is not establishing standards governing the conduct of
any floodplain manager or other qualified applicant, nor establishing any set procedures for work performance. The CFMP is designed to establish educational, training, and experience criteria related to floodplain management, hazard mitigation, and the NFIP and to certify that an individual applicant has met these criteria. The TFMA assumes no liability for any action or decision made by an individual Certified Floodplain Manager during the normal course of performing his or her prescribed duties and responsibilities of managing development within the identified floodplain as established by the criteria of the NFIP and mandated by their respective employer or local government agency.

CONCLUSION

The TFMA Certification Exam was offered for the first time at the Annual Texas Flood Conference held in Austin, Texas, during July 1996. Sixty-three conference participants decided to test their knowledge of the NFIP and 42 successfully passed the exam. A score of 70 was necessary to pass the exam and the average exam grade was 76. As the word spread about TFMA's certification program more and more people responded with requests to take the certification exam. TFMA was able to offer the exam at the conclusion of two offerings of the FEMA Floodplain Administrator Training Course held in the state and qualified an additional 60 plus candidates. In addition, TFMA has now developed a short NFIP Refresher Course followed by the certification exam. This course and the exam have been offered at Houston and Lubbock, resulting in an additional 40 plus individuals passing the exam. After attending the training courses and refresher courses, applicants scored a much higher average (89-90) on the certification exam. Plans are underway to offer the refresher course and exam at least two more times before a new exam is developed and offered at the next annual state conference, scheduled for June 1997.

To date, over 160 individuals have now taken the certification exam and as of mid-March, 38 applicants have successfully achieved the status of Certified Floodplain Manager. Membership in the TFMA is also on the increase and, in fact, has now reached a new record high. The numbers, both in membership and certified managers, are increasing almost on a daily basis. If you ask me if professional certification is a worthy goal, my answer is a resounding "Yes"!
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