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Water Operations Technical Support Program

Proceedings, U.S. Army Corps of Engineers Workshop on Reservoir Shoreline Erosion: A National Problem

26-30 October 1992

McAlester, OK

Prepared for Headquarters, U.S. Army Corps of Engineers

Water Operations Technical Support Program

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Hollis H. Allen, John L. Tingle, Editors
Environmental Laboratory

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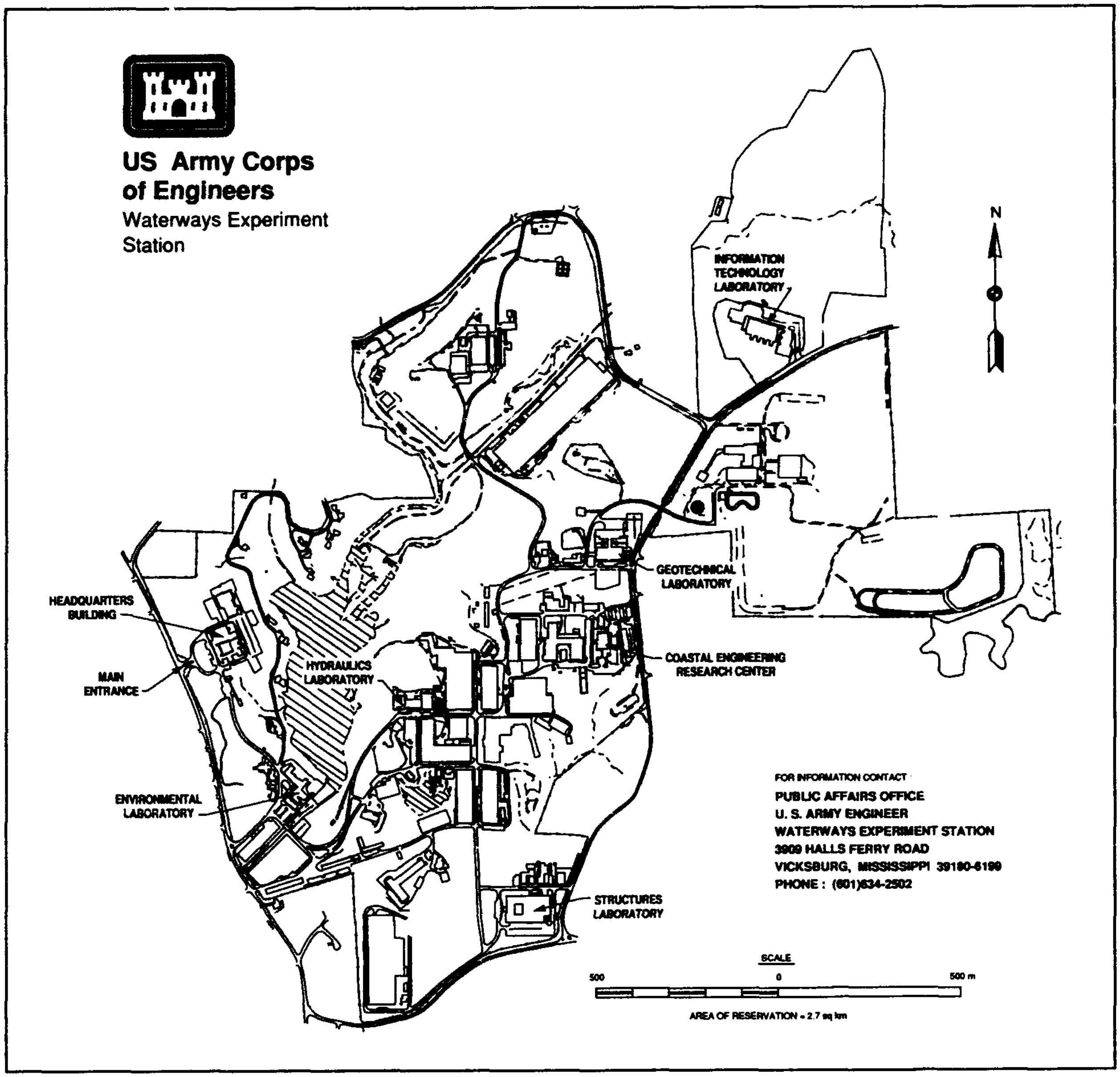
Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000



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CONTENTS

U.S. ARMY CORPS OF ENGINEERS

AGENDA FOR WORKSHOP ON RESERVOIR SHORELINE EROSION: A NATIONAL PROBLEM OCTOBER 26-30, 1992

Location: McAlester (and Lake Eufaula), OK

Monday, 26 Oct

1:00-5:00 Registration

2:30-4:30 Facilitators Meeting for Professional and WES Facilitators

4:30-5:00 Meeting for Speakers for the Tuesday Session (for location, inquire at Workshop Registration table)

5:00-6:30 Icebreaker (Casual Dress)

Tuesday, 27 Oct

Plenary Session

8:00-8:05	Workshop Convenes	Mr. Lewis Decell, Manager Environmental Resources Research and Assistance Programs, WES
8:05-8:25	Welcoming Remarks	COL Otis Williams, CDR & Dist Engineer, Tulsa District
8:25-8:45	Purpose and Scope of Workshop	Mr. Pete Juhle, HQ, U.S. Army Corps of Engineers, Washington, DC
8:45-9:25	General Perspectives on Shoreline Erosion Control	Mr. Lewis Decell

Impacts, Causes, and Control of Shoreline Erosion from Various Perspectives

9:25-9:55	Causes of Shoreline Erosion	Dr. John Reid, Geology Dept., Univ. of N. Dakota
9:55-10:15	Break	

Tuesday, 27 Oct (continued)

10:15-10:45	Shoreline Erosion Control-Engineering Considerations	Dr. Yen-Hsi Chu, Coastal Engineering Research Center, WES
10:45-11:15	Impacts of Shoreline Erosion	Mr. Joe Lyons Bureau of Reclamation
11:15-11:45	Shoreline Erosion Impacts at TVA Lakes	Mr. Don Porter, Tennessee Valley Authority
11:45-12:15	Questions and Discussion	
12:15-1:30	Lunch	

Impacts, Causes, and Control of Shoreline Erosion from Various Perspectives (continues)

1:30-1:50	U.S. Forest Service	Mr. Jim Golden, Watersheds and Air Staff
1:50-2:10	Soil Conservation Service	Mr. Gene Barkemeyer, State Conservation Engineer, Texas
2:10-2:30	State of Illinois	Mr. Gregg Good, Illinois EPA
2:30-3:10	Impacts of Shoreline Erosion in Germany	Mrs. Wendi Goldsmith, Bestmann Green Systems, Boston, Mass.
3:10-3:45	Break	

3:45-4:15	Impacts on Water Quality	Dr. Chris Zabawa, U.S. EPA
4:15-4:45	Impacts on Historical Resources	Dr. Paul Nickens, WES
4:45-5:00	Overview of Wednesday's Field Trip	Mr. Hollis Allen, WES

Tuesday Evening

6:30-8:30 Evening Social and Dinner
at Pete's Place Italian Restaurant
(Casual Dress)

Wednesday, 28 Oct

Workshop

8:00	Depart on Field Trip	
9:15-10:00	Site 1, Southport Site Riprapped Fix Berm and Willow Fix	Mr. Hollis Allen, WES, and Mr. Burl Ragland, Tulsa District Office
10:00-10:15	En route to 2nd Site	
10:15-11:00	Site 2, Ah-Du-Pah Site 2 Biotechnical Fixes With Breakwaters	Mr. Ragland
11:00-11:20	In route to 3rd Site	
11:20-11:45	Site 3, Utility Pole/Terrace Demonstration Site at Rolling Oaks	Mr. Ragland
11:45-12:30	Box Lunch at Belle Starr Park Recreation Area	
12:30-12:45	En route to 4th Site	
12:45- 1:15	Site 4, Blue Kenokee Bay Rock Jetty Fix	Mr. Ragland and Mr. John Brigham, Lake Eufaula Project
1:15-1:45	En route to 5th Site	

1:45-2:30	Site 5, Gabion Site Brooken Cove, Public Use Area	Mr. Brigham
2:30-3:00	En route to 6th Site	
3:00-4:00	Site 6, Oak Ridge Point Biotechnical Workshop Fix	Mr. Allen
4:00-5:00	En route to hotel	
7:00-8:00	**Facilitators Meeting**	

Thursday, 29 Oct

Agencies Attempts to Solve the Problem (Panel)

7:30-7:50	Corps of Engineers	Messrs. Pete Juhle and Hollis Allen
7:50-8:10	Bureau of Reclamation	Mr. Wes Green, Boise, Idaho
8:10-8:30	U.S. Forest Service	Mr. Del Skeesick, Willamette National Forest
8:30-8:50	State of Illinois	Mr. Don Roseboom, Illinois Water Survey
8:50-9:15	Break	

Concurrent Working Groups

Working groups meet, note major points of discussion, and summarize conclusions relating to *magnitude, causes, effects,* and *fixes* for the problem. Summaries will be presented as oral reports on Friday morning. Participants in working groups are encouraged to change to other working groups at designated times. Working groups are described below.

Group A - *Magnitude:* Working group focuses on how to define and measure the problem and what needs to be done; Group will consist of remote sensing and Geographical Information Systems (GIS) specialists, physical scientists, geologists, etc.

Group B - *Causes:* Working group focuses on various causes of the problem, e.g., wave action from wind and boats, ice scour, freezing and thawing, soil conditions, shore geometry and reservoir bathymetry; Group will consist of coastal engineers, geotechnical engineers, geomorphologists, etc.

Group C -*Effects:* Working group focuses on impacts of the problem, e.g., reservoir longevity, water quality, fisheries and wildlife habitat degradation, recreation, maintenance costs; Group will consist of civil engineers, water quality specialists, natural resource specialists, archaeologists, etc.

Group D -*Fixes:* Working group focuses on innovative fixes that include environmentally compatible methods, i.e., tiered gabions, groins in combination with vegetative plantings, pole/terrace combinations, breakwater and vegetation combinations, berm and vegetation combinations, etc.; Group will consist of civil engineers, coastal engineers, geotechnical engineers, biotechnical specialists, etc.

<u>Session 1:</u> 9:15-10:40

Group A - *Magnitude:*	Participants with **RED** highlighted name badges
Group B - *Causes:*	Participants with **GREEN** highlighted name badges
Group C - *Effects:*	Participants with **BLUE** highlighted name badges
Group D - *Fixes:*	Participants with **YELLOW** highlighted name badges

10:40-11:00 - Break

<u>Session 2:</u> 11:00-12:30

Group A - *Magnitude:*	Participants with **GREEN** highlighted name badges
Group B - *Causes:*	Participants with **BLUE** highlighted name badges
Group C - *Effects:*	Participants with **YELLOW** highlighted name badges
Group D - *Fixes:*	Participants with **RED** highlighted name badges

12:30-1:30 Lunch (Working Groups Continue at 1:30)

<u>Session 3:</u> 1:30-2:55

Group A - *Magnitude:*	Participants with **BLUE** highlighted name badges
Group B - *Causes:*	Participants with **YELLOW** highlighted name badges
Group C - *Effects:*	Participants with **RED** highlighted name badges
Group D - *Fixes:*	Participants with **GREEN** highlighted name badges

Concurrent Working Groups (continued)

2:55-3:15 - Break

<u>Session 4:</u> 3:15-4:45

Group A - *Magnitude:*	Participants with **YELLOW** highlighted name badges
Group B - *Causes:*	Participants with **RED** highlighted name badges
Group C - *Effects:*	Participants with **GREEN** highlighted name badges

Group D - *Fixes:* Participants with **BLUE** highlighted name badges

Friday, 30 Oct

Reports from:

8:00-8:30 Working Group A

8:30-9:00 Working Group B

9:00-9:30 Working Group C

9:30-10:00 Working Group D

10:00-10:30 Break

10:30-11:00 Discussion and Conclusions

11:00 Depart to Airport and Final Destinations

U.S. ARMY CORPS OF ENGINEERS

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RESERVOIR SHORELINE EROSION: A NATIONAL PROBLEM
OCTOBER 26-30, 1992
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PREFACE

The workshop reported herein was conducted as part of the Water Operations Technical Support (WOTS) Program. The WOTS Program is sponsored by the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is assigned to the U.S. Army Engineer Waterways Experiment Station (WES) under the purview of the Environmental Laboratory (EL). Funding was provided under Department of the Army Appropriation 96X3132, Operations and Maintenance. The WOTS Program is managed under the Environmental Resources Research and Assistance Programs (ERRAP), Mr. J. L. Decell, Manager. Ms. Carolyn B. Schneider was Assistant Manager, ERRAP, for the WOTS Program. Technical Monitors were Mr. Friedrich B. (Pete) Juhle and Mr. Rixie Hardy, HQUSACE.

Transcription of workshop video tapes and assembly of the draft manuscript were accomplished by Lewis Berger and Associates, Inc., of East Orange, NJ.

Technical editors of the proceedings were Messrs. Hollis H. Allen and John L. Tingle, Stewardship Branch (SB), EL. The overall study and organizational activities of the workshop were conducted under the general supervision of Mr. Allen, Acting Chief, SB; Mr. Roger Hamilton, Acting Chief, Natural Resources Division; and Dr. John Harrison, Director, EL. Reviews of the papers presented were provided by Mr. N. R. Oswalt, Hydraulics Laboratory, and Mr. Robert Larson, Geotechnical Laboratory.

At the time of the publication of this report, Director of the WES was Dr. Robert W. Whalin. Commander was COL Bruce K. Howard, EN.

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PROCEEDINGS, U.S. ARMY CORPS OF ENGINEERS WORKSHOP ON RESERVOIR SHORELINE EROSION: A NATIONAL PROBLEM McALESTER, OKLAHOMA, 26-30 OCTOBER 1992

WORKSHOP INTRODUCTION

The Workshop on Reservoir Shoreline Erosion: A National Problem was attended by 83 participants. Represented were eight federal agencies, four state agencies, two academic institutions, and two contractors. U.S. Army Corps of Engineers (USACE) representatives were from 13 districts, seven divisions, five USACE laboratories, and headquarters, USACE (HQUSACE). These representatives included a number of individuals associated with the Water Operations Technical Support (WOTS) program, including the Program Manager. The workshop was conducted to assess the magnitude and causes of shoreline erosion in the United States and to enumerate the ways and the degree to which it impacts natural resources and the agencies responsible for managing these resources.

An opening plenary session defined the purpose and scope of this workshop and provided a brief summary of reservoir shoreline erosion issues from the perspective of HQUSACE and the U.S. Army Engineer Waterways Experiment Station (WES). Following was a plenary session which covered impacts, causes, and control of shoreline erosion from various perspectives including those of several federal and state agencies and several disciplines.

The workshop included a field trip to Lake Eufaula to examine and discuss the application of various bank stabilization strategies by the Tulsa District, USACE, and WES. The Tulsa District pilot and test sites were executed under its operation and maintenance budget. Fixes at two sites were installed at two WES Reservoir Shoreline Erosion Control and Revegetation Training Workshops held at Lake Eufaula in 1990 and 1991. Funds and basic requirements for two other projects were provided to the Tulsa District by WES through the WOTS program. Documentation of erosion control at Lake Eufaula is included as Appendix A.

Another plenary session was a panel of agencies' attempts to solve the reservoir shoreline erosion problem. Agencies represented on the panel included USACE, the U.S. Department of the Interior Bureau of Reclamation, the U.S. Department of Agriculture Forest Service, and the state of Illinois Water Survey.

Workshop breakout sessions were held and consisted of four concurrent working groups. The working groups covered the magnitude, causes, effects, and fixes for the reservoir shoreline erosion problem. Workshop participants were divided into four groups that rotated among the four working groups, such that each participant attended each working group session. Each group discussion was facilitated by a contractor supervisor facilitator and WES co-facilitators. Each group was charged with developing a list of strategies that have been used, or are planned to be used, to address reservoir shoreline erosion and a list of research needs or issues specific to a given working group topic. Each group summarized its results in a brief oral report to the closing plenary session. The closing plenary session also included closing comments by the workshop moderator and other workshop participants.

This report was written on the basis of workshop notes, tapes, and presented papers. The proceedings are intended to provide information useful in planning further USACE and interagency efforts on this topic area.

PLENARY SESSION

The U.S. Army Corps of Engineers (USACE) Workshop on Reservoir Shoreline Erosion: A National Problem was convened by Mr. J. Lewis Decell, Manager, Environmental Resources Research and Assistance Programs at the USACE Waterways Experiment Station (WES) and Acting Chief, Natural Resources Division, Environmental Laboratory, WES. The Opening Plenary Session consisted of three talks. Welcoming remarks were provided by COL Otis Williams, Commander and District Engineer of the Tulsa District. The purpose and scope of the Workshop were presented by Mr. Friedrich B. (Pete) Juhle, hydrologist in the Engineering Division, Headquarters, USACE. Mr. Decell then presented general perspectives on shoreline erosion control. The content of these initial three talks was reproduced from video cassette recording of the presentations, including accompanying slides, and is presented in the paragraphs that follow.

Welcoming Remarks

COL Otis Williams[1]

I am very glad to be here this morning. As Lewis was indicating when I walked through the door I felt I was back at Vicksburg, because I met so many people I had run across there, Hollis, Lewis, Alfonso. The guy operating the camera and I lunched together almost every day. He and a couple of other guys named Billy Helmuth and Charlie Miller, some of those from Vicksburg may know those guys, they are all noted for telling long tales, big fish stories. I don't think anyone ever caught one as big as Billy Helmuth; if you caught one that weighed 6 lb, Billy caught one that weighed 6 lb, 2 ounces. I understand that even in retirement, Billy is excelling in catching fish, he always catches one bigger than you, and he gets up very early in the morning now and still goes out with the boat on the back of his truck. Anyway, I would like to pass on my best wishes to those folks. On the other side of the aisle, I saw folks here from the Tulsa District. We are glad to have all of you here in Oklahoma.

The Tulsa District covers southern Kansas, all of Oklahoma, and northern Texas. If you have ever been riding out in west Texas, you know it is a big area. You would really wonder whether there is any water out there, but there is a little bit of water along the Red River, and there is a lake that I have yet to get to. It is probably one of the lakes where you don't have to worry about erosion. Some people say that when there is water in it, it is a mirage.

We do have shoreline erosion within the Tulsa District. I understand that a part of your workshop is to visit Lake Eufaula. When you look at Eufaula, you see that it is really five or six lakes in one. Within the Tulsa District we have 38 lakes (multipurpose lakes); 16 of those have significant erosion problems. I was surprised to learn that in Eufaula alone, 50 miles of the shoreline is in really bad shape.

As I talked to some of the folks, they showed me some slides. I told Hollis that when I realized I had 20 minutes to talk, I could have brought some slides also. I am pretty good

[1] Commander, U.S. Army Engineer District, Tulsa.

at flipping slides. It comes from my previous training at the Pentagon. When you work in the Pentagon you frequently see a guy walking through the door with a slide tray in one hand and a checkbook in the other. Most often you never have a checkbook but you always have a slide tray; but I also could show you some of the scenes that some of the folks are showing me. Houses, patios, porches sliding off into the lake, septic tanks hanging on the edge, and then in the very next slide, you see them down in the water. So there are some significant problems that we can share here in the Tulsa District. I have not seen all of them, but I intend to see most of them and I hope that over time, that after you folks come up with some solutions to some of our problems, that you get a chance to see some of the things we have done here in the Tulsa District with WES and some of the other agencies that are here to combat the problems that we have, to combat shoreline erosion. I understand that there are over 460 lakes in the Corps and over 50 percent of them have significant or moderately significant shoreline erosion, so the problem is there to combat.

Let me tell you just a little bit more about the Tulsa District. Although we are very concerned about shoreline erosion, one of the more significant challenges is HTW-Hazardous and Toxic Waste. It is the fastest growing "industry" in the Corps of Engineers and we just happen to be at the forefront of it in the Tulsa District. We have gone from a budget of $3 million about three years ago, actually '88, to a budget of $150 million next year, and growing. I tell you that because given the problems we have with shoreline erosion, I wish that some of that growth could be targeted toward some other problems that you are facing. But as people look out there at what the priorities are, sometimes their priorities are not necessarily ours. Hopefully with some of the insights you gain from your visits and studies here that when you get back to your leaders, you can share with them some of the problems, at least some of the fixes that you have identified here, and we can get on with trying to save some of the environment.

As I told Hollis, I wouldn't talk very long, in fact, I just want to basically say that I am very happy to be here and happy that you have chosen the Eufaula area to hold your conference. I see that from the dress of many of you that you are ready to go to work, so I won't stand in your way. I am going to be here for a short while and then I am off to attend what the Corps of Engineers calls an O&M Conference. It's where they decide where some of the O&M monies are going to go, and some of that is going to be targeted toward some of the things that you are going to discuss, so hopefully we can add a little bit to your pie. With that I think I will turn it back to Hollis, unless anybody might have some questions for me. No questions? I didn't think so. I wouldn't be able to answer any of them anyway, so I will pass it off to some of the smart folk.

I know that from my days at the Waterways Experiment Station, that the number of employees is about 1,500, and over half of those are engineers and scientists. I marveled at some of the really smart people that were located at WES. The other thing I marveled at was that almost everyone there was related, or they had subsequent generations coming through the pipeline. In fact, I saw a gentleman here named Graves. I knew a Graves while I was at WES and so I asked him if he was related and he said "No, I am just a transplant from Kentucky." That's unusual because normally the track to a great career at WES is knowing somebody there, but that doesn't mean that's all that's there. They get you through the door and then you have to perform because there are some smart people there and I appreciate all of their support. I can say honestly that my three years at WES were some of the best in my life and I really enjoyed my tour there. Thank you all very much.

Purpose and Scope of Workshop

Friedrich B. Juhle[1]

My purpose here is to give you an outline of what the program here is going to be and to give you some idea as to why we are here, how we got here, and what we hope to accomplish over the course of being here. Hollis has been good enough to prepare a nice set of slides for me to flip through and hide behind while I talk. The idea of this meeting started a little less than a year ago at a IRAC meeting held in Denver, Colorado. IRAC is an acronym which stands for Interagency Research and Coordination Conference. The purpose of the IRAC is to make sure that we don't overlap on research throughout the various agencies of the federal government. In the course of attending this Conference, Lewis and I, after five o'clock, had some discussions along with a few other folks at a motel that had free drinks after five. So we got some serious talking done. In the course of those conversations, it became clear that we had really not done a very good job, at least in our perspective at that time, in addressing a very large problem. Part of the reason we hadn't done anything with that problem is that it is so large.

Shoreline erosion affects, literally, thousands and thousands of miles of Corps reservoir shorelines. We are not even talking about this waterway shoreline erosion that we have to deal with. The traditional engineering fix for dealing with shoreline erosion is to pile riprap on it, and that riprap goes for approximately $250 a linear foot, if not more. If you multiply $250 a linear foot times about 10,000 miles, then the national debt seems small by comparison. Obviously the problem is too big; therefore, we have ignored it. I don't think we need to ignore it.

In the course of the conversations we had, we decided we could solve any problem. Maybe the drinks made us pretty bold. Anyway, we decided that we could do something about it if we work together and that we had to look at the problem in a little different perspective. We recognize that there is a lot of talent in the Corps. COL Williams was suggesting a few minutes ago that the folks at WES have a great deal of talent and I certainly do not want to take anything away from that, but others have great talent also.

I was at a workshop in West Virginia not too long ago, and in the course of the workshop someone told of speaking with an old West Virginia hillbilly. The West Virginia hillbilly gave him a little bit of mountain knowledge. The basic premise of it was, I can't say it in exactly the way the hillbilly said it, but in essence, "ain't nobody as smart as everybody." That's why all of us are here, because none of us, either as individual agencies or as individual people, have the knowledge and experience and the accomplishment of all of us put together. The Corps traditionally tends to do things by itself as most agencies do. It's a natural process; we try to stay in our little worlds. This workshop is an attempt by the

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[1] Chairman, Water Quality Committee, Headquarters, U.S. Army Corps of Engineers.

Corps at least to expand beyond that and to share what we know with a lot of other agencies and have a lot of other agencies share with us what they know, so that we all can hopefully learn something from this.

The Workshop purpose - to assess the magnitude and causes of shoreline erosion in the United States and to enumerate the ways and the degree to which it impacts natural resources and the agencies responsible for management of those resources. That is, in a nutshell, why we are here. Before this workshop was held, Hollis put together a questionnaire that he sent out, Lewis will talk to you about that shortly, to get a handle on the problem. He did, to some degree, get a handle on the problem and what he found out was that the problem was much bigger than we thought.

I am especially happy to see that there are some state agencies represented here, the states really deserve a lot of credit. The federal system is set up so that everything comes down from the top and there is certainly a role for the federal system in addressing problems across the country. We have the responsibility and we probably have more resources than most states do. States are very much involved in carrying out the actual actions. The Corps has 460+ reservoirs, I think COL Williams said. We don't even know exactly how many we have. We count them every once in a while and we always get a different number. TVA has a lot of reservoirs and the Bureau of Reclamation has a lot of reservoirs, but when you count states' reservoirs, you find the states have far more reservoirs than the federal agencies combined. By comparison, however, generally the larger reservoirs belong to the federal system. Just because they are larger doesn't mean that they are any different from any of the smaller ones. They have the same kind of problems; the states have the problems of dealing with those little problems and they really deserve a lot of credit for what they have done with very limited resources. Hopefully, one of the things that will come out of this workshop is the identification of ways to enact or effect shoreline erosion protection or fixes that are very cost effective, and don't end up running up the national debt by another four or five trillion dollars. As you can see here we have Bureau of Reclamation, TVA, Environmental Protection Agency, National Park Service, Forest Service, Fish and Wildlife Service, USDA, U.S. Soil Conservation Service, and last, but certainly not least, the state agencies to accomplish these objectives.

Another thing I would like to mention is the significance of all these people we have here. We have something like 70 to 80 people here, I am not sure of the exact number. It is a very good turnout. I think that's a real reflection of change in the way we think about the environment and the way that we have become aware of how the environment affects us. We have a lot of specialists here, and the specialists we have here provide a reflection of the problem. The Corps of Engineers has specialists, we have all of these folks and a lot of others. What we don't have is anyone who covers all of these. By our nature we have become very specialized. We have become so specialized that we have taken everything apart and now we don't know how to put it back together. Basically, the environment is everything put together; it is not everything taken apart. We can't put it together independently. An ecologist cannot build an ecosystem; an engineer cannot build an ecosystem. But together, if we all work together we can come close to that. That, basically, is what environmental engineering is about.

One of the things that we really have to be aware of is that we are responsible for the water resources that we attempt to manage. We put a lot of energy and effort into their management and it is important that we manage in the best way that we can. As COL Williams said, when you come to the place with the briefcase in one hand and a checkbook in the other hand, that's fine if the checkbook has the right number on the bottom line. I see that COL Williams has come back now so we can get in a plug for the O&M Conference that he is going to attend. Perhaps he can wield a little bit of influence and get the checkbook turned in the right direction. The HTW programs have a huge amount of money in them. The O&M budget also has huge amounts of money in it (Operation and Maintenance, if you are not a Corps person that's what O&M stands for, the basic working budget of all the civil works projects in the Corps and probably in the country for whatever agency you happen to be with). If you can direct that money to accomplish more useful things than it is presently being used for, then you should work in that direction. It doesn't mean that the fences don't need to be painted and the grass doesn't need to be mowed. But perhaps the grass only needs to be cut three times a year instead of 17 times a year. We need to get some balance in that budget. There are a lot of good things that we can do for a very small investment, and I think you will learn a lot of them at this Conference if we share our experiences.

The Workshop objectives are to gain an understanding of how severe the problem is across various agencies' areas of responsibility; to explore and enumerate the causes of the problem; and to find out successful ways of measuring erosion and bank recession and ascertain the magnitude of shoreline erosion in the United States. I think there is a project that may be in this district, up on the Kansas/Nebraska border. I heard someone talking just the other day, and he mentioned the fact that this reservoir, since it's been constructed, has increased in width by almost a half mile. That's a lot of shoreline erosion in the course of a few years.

You take a reservoir project and you build it where there has never been water before and that's pretty obvious. The fact of the matter is we don't engineer the area that the water is going into, or environmentally engineer the dam. We engineer and build a dam. We put all sorts of investment into that structure and we spend a lot of time and effort in designing the structure that will confine the water, but where the water will be, we don't plan or design at all. We may go out and cut the trees and that's about the extent of it. We may install some fishery habitat before we allow the thing to fill. That's a very small amount of investment, that's where the water is, that's where the environment is that we are creating and we need to be more environmentally conscious. We need to engineer that environment a lot more than we have in the past. We also need to think differently. We have been programmed literally through our education and through our experiences to have a perception of what a shoreline looks like. I grew up on an estuary of the Chesapeake Bay; I have a very clear picture of what shorelines look like. It's a tidal-type shoreline. My tendency is to want to make all shorelines look like that. All shorelines have no business looking like that and I need to realize that. We also need to recognize that some shorelines are supposed to be eroding. We need to learn to engineer that environment to the greatest advantage for ourselves and also for the environment itself.

More objectives are to gain insight into the effects and impacts of shoreline erosion and how to ameliorate those impacts; to discuss various means and methods of correcting the problem, i.e., active and passive measures; and to elucidate innovative and cost-effective ways of dealing with the problem. I think the last objective is probably the most important. If we can find cost-effective ways of addressing shoreline erosion we can go a long way toward solving this problem of thousands of miles of shoreline that are eroding in this country. Some of those miles you will never address. You will never fix all of them and you have to understand that.

We will have a plenary session covering experiences of the researchers and practitioners who will be going through agency by agency what we have done, what we have learned, and what we know. So we will share. Later on we will also have a field trip to look at a lot of the things that have been done in the Tulsa District at Lake Eufaula. It's sort of a shopping center for innovative fixes from the Corps of Engineers. There will be an opportunity for us to see a lot of different approaches to addressing the shoreline erosion problem in a very small space of time.

I have not been to Lake Eufaula yet. Hopefully, there are some examples of fixes that didn't work. I think we need to share our mistakes. I believe mistakes are more important than our successes. It is really crazy for us to go out there and try something that doesn't work and then not tell anyone about it, because someone else is going to go out there and try the same thing and not say anything about it. That's a tremendous waste of resources. We cannot allow ourselves to do that. Here is an example of shoreline erosion from Lake Eufaula, Oklahoma. [Shows slides.]. I think we will see something like this out there. That's obviously an eroding bank that needs to be looked at for applying an appropriate fix, or for determining even if a fix is necessary.

You have color-coded name tags to identify what breakout sessions you will be attending. You will all sort of rotate through these sessions so that everyone will be able to participate in all of them. The sessions by title are Magnitude of the Problem, Causes, Effects, and Fixes. These sessions will basically try to meet for an hour and a half. You will come up with solutions or ideas and concepts to evaluate these particular issues. After that we will get together and share that information among ourselves. There will also be a process of discussion that will help us learn from each other. Hollis has written me a couple of notes here, one of which is to talk about if there are research needs, if we can identify them. You see Hollis, being a researcher, wants to find research projects for his program at WES and also, more importantly, to address the real problem. Research for research's sake is obviously not Hollis' objective nor is it the objective of the Corps of Engineers. The whole process at WES is to find useful solutions, and I think the folks there deserve a lot of credit for coming up with a lot of solutions to some real world problems. There are various programs at WES that allow them to take advantage of what they have learned, and I think we will see some of the things they have developed when we visit Lake Eufaula in the next couple of days.

Our purpose is really not to protect the environment; it is to manage it and engineer it for our own benefits. People think in snapshots of time. Our perspectives are not very real. We forget the time sequence when we think of things. We have people who say that everything has to be like it was 200 years ago before we had a country here. We can't possibly go back. Even if we never came here we couldn't go back because things would have changed in those 200 years, certainly not in the same ways, but we have to think of where we want to go and not where it is or where it was. We have to think very positively and be very forward looking and not backward looking. It is also very important that we think in a moving time frame, not in a static time frame. Lakes are not permanent fixtures. We have to think of them as not being permanent fixtures. We spend a lot of money trying to keep things as they are, we don't spend much money trying to let things go in the direction that they want to. We build boat ramps at the headwaters of lakes and they fill up with sediments. So we go in and dredge them out so they can fill back up again. It would make a lot of sense to move the boat ramp, but we don't do that because we have been going there all this time. So we keep them there and keep spending money. That's the wrong logic. We need to think; we should try to work with the environment instead of against it. That's all I have for this session at this time.

QUESTION: I wonder how one would go about changing that "wrong thinking," your term. Replacing boat docks, for example, that's really critical. Why do we fight what nature wants to do? Why don't we engineer with it and let it change as it is going to change? How do we change that wrong thinking?

MR. JUHLE: I think you have to go way down to change; it is an education process. You are probably not going to change very much the ideas of old fogies like Lew and myself. Old dogs, new tricks do not work real well. What we can do is educate our young people. We can teach them how things work and we can teach them to think in a non-linear fashion. Engineers, by nature, are linearist; everything goes from A to B to C to D and so on. We have got to find a way to teach our young engineers that things go from A to B to C and back to A again; it's a loop and it rolis. If we can get that concept into our education system, then things will change. We need to do it in our universities and also in our high schools and all the way down to our elementary schools.

QUESTION: Do you think in the Corps' case, at Headquarters, that people who make decisions will be open to thinking that is different from what the Corps has been doing in the past?

MR. JUHLE: There will always be resistance to change. By the same token, it is probably appropriate that there is some resistance to change. Otherwise, it gets a little out of control. I think there is a great willingness at Headquarters right now, at least, to consider change at almost any dimension from an environmental standpoint. I find that refreshing to be able to relay that to you.

COMMENT: It is a particular kind of change that people are really opposed to, and that's looking foolish, admitting that they have made a mistake. Your boat ramp example was really a good example. If they move the ramp, then people say, "Oh, you did something wrong." I think what was missing in the original sighting of that boat ramp was proper analysis of thosr changing conditions, over the course of years. I think that's one of the steps you could :ake to make future decision-making flow a little easier.

MR.JUHLE: I couldn't agree with you more. I think that one of the things that we fail to do is exactly what you say. We don't really analyze the whole big picture. We tend to be very focused on what our objectives are; we tend not to be realistic thinkers and to not look much further than where we are. We need to teach ourselves to look further. We really have to work at that; it's not something that happens by itself. I can get up here and preach and dance to this song and then go back and do what I always do. I have to make a real effort to go back and think about things from a much bigger perspective.

I gave you an example. I grew up on an estuary of Chesapeake Bay and I have a perception of that from when I was 10 years old. I know exactly what it looked like when I was 10 years old. But I am not 10 years old anymore. When I go back there, it doesn't look that way anymore—it's not because of any one thing that happened, it's just changing. Those changes took place because of the activities of man, some not because of man, and some changes are in response to man's activities miles away from that little estuary. That area where I grew up used to be a harbor for ocean-going sailing vessels. You can walk across it today. You can hardly get a canoe in it. That's because of erosion that took place 20 miles away. You know, the farmer that's up on the hillside in the field doesn't think he is silting up Chesapeake Bay. We need to teach our people to think in those terms.

General Perspectives on Shoreline Erosion

J. L. Decell[1]

I would like to talk to you on the general perspectives on the shoreline erosion problem as we see it. On the 13th of this month, we had invited Mr. John Elmore, Chief, Operations, Construction & Readiness Division, OCE, to this conference to make a few opening remarks. He could not attend because he is at the O&M Conference. I was in his office recently and I showed him a few of the things I am going to show you, to give him a little perspective. Our overall goal at the end of this workshop is to provide an Executive Summary Report to John which outlines the nature and the scope of the problem in the Corps and the other agencies. And there are some things we can and cannot do about it, stressing with him that we are not doing this to develop a great new program. If we do it correctly we will save on other programs, possibly, through the implementation of new and innovative methods.

Reservoir shoreline erosion is becoming more and more of a problem at Corps reservoirs and I understand it's a problem at the reservoirs managed by these other federal agencies, as well. As part of this workshop, as Pete has said, we will be hearing about what others have to say about their problems. One indication of the scope of the problem in the Corps is summarized in the surveys we did in 1990, which I will tell you a little bit about later. Basically, we don't really know how big the problem is. Quantitatively in terms of the miles of shorelines eroded and the dollar cost of the erosion, such as damage to the facilities and impacts on natural resources, we only have some estimates. Some of them are quantitative and some aren't. We have a good perspective though, I think.

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[1] Manager, Environmental Resources Research and Assistance Programs.

Why should we be concerned about shoreline erosion? There are several reasons I would like to discuss with you. Threat to government facilities and private property—eroded banks in many cases are at the back door of government facilities and private properties. We spent millions of dollars condemning some of this private property and buying it due to the erosion. The bank recession has exceeded the federal boundaries, or come so close to these facilities that they are no longer suitable for habitation. We have to do a better job of controlling the erosion earlier rather than condemning and buying property as an alternative approach. We must control the erosion so that these receding banks are not undermining recreational buildings and facilities. This costs both in terms of correcting the problem and also in terms of lost revenues from the users of these facilities.

Another result of the erosion is poor water quality. The resulting turbidity can negatively impact the aquatic food chain and ultimately affect fisheries. Then fishing becomes poor. Another impact concerns sedimentation which often covers the substrate which serves as spawning habitat. Fishery researchers have also informed us that the fluctuation zone of reservoirs often becomes an infertile ground and erosion can lead to barren nutrient-limited zones in the reservoirs. Basically, turbid water just does not appeal to the general public who enjoy our facilities for swimming, skiing, and taking part in other water-related activities. Shoreline erosion can destroy wildlife habitat. Much of this habitat would not otherwise be there if it were not for the presence of the reservoir.

Recently one of our Corps personnel was contacted by the Fish and Wildlife Service requesting assistance on erosion eating away at an island at one of our lakes in the Great Plains. The island is part of a refuge that attracts numerous shore birds, some of them threatened or endangered. We were recently told about a string of lakes in northern Illinois that have islands disappearing because of erosion, and that much of their marsh habitat is disappearing due to erosion and associated turbidity. This is just a couple of examples of many that occur across the country.

According to the National Reservoir Inundation Study done a few years ago by the National Park Service—"Perhaps the most important set of reservoir processes affecting the archaeological preservation equation are the physical erosion and deposition processes associated with any large body of water. Included in this category are the effects of wave action along the vertically fluctuating shoreline; saturation and slumping of shoreline and submerged geologic strata, and siltation from back shore runoff and stream inflow. Of these, the most destructive form of impact occurred along the fluctuating shoreline of the reservoir where the mechanical forces of wave action and near shore occurrence within the beach can drastically alter shoreline topography and any cultural resources occurring on that topography."

Obviously, this erosion destroys many archaeological and cultural resources and we must try to eliminate this from happening. We know that using traditional methods alone, such as riprapping and engineered bulkheading, can be very expensive propositions. We must seek less expensive ways of protecting these areas and use methods which protect the resources. I know that the Corps, through some of its work, has been working on ways to do this. We are going to discuss some of this today and through this week at this workshop. Eroding shorelines can contribute to reducing the design life of reservoirs or cause the

Corps or others to expend more funds on dredging than anticipated. More and more frequently we are finding examples of marinas left high and dry due to increased siltation around them. It just makes good common sense to, at least, slow the process while we can, using more cost-effective methods. The Corps cannot try to address every mile of shoreline erosion in our reservoirs. In times of limited fiscal resources, it would be impractical and probably futile to attempt to try to address them all.

The survey that we discussed was conducted in 1990 as part of the Water Operations Technical Support Program, actually the technology came out of the EWQOS Program which was completed in 1978, I believe, or 1979. We have been transferring technology from EWQOS and other research since then to the WOTS Program, which is the Water Operations Technical Support Program which is sponsoring this workshop. The impetus started with biotechnical engineering solutions to shoreline erosion, but in order to get a good perspective of the nature and scope of the erosion, we have gone beyond just looking for biotechnical approaches. We are looking for other ones on how the spectrum will lay itself out between the classical and nonclassical techniques that we might develop. At some point we will give our report to Mr. Elmore; it will cover this waterfront, no pun intended. We will focus then again on the biotechnical engineering solutions as part of that and hopefully form a team of other agencies and our sister laboratories who are here and have been working with us for several years—D.D. Davidson from our Coastal Engineering Research Center and Randy Oswalt from our Hydraulics Laboratory. That association will continue under the WOTS program.

We do direct assistance under WOTS and every year we look at what type of assistance is requested and the nature of the request. Biotechnical erosion control is one of the recurring requests from the districts for assistance under the WOTS program. Of those requests for shoreline stabilization erosion control, when you summarize the 1988-89 data and continue through the '90 and '91 data, on the assistance requests we get, are significant requests from our Corps Districts for technical assistance on shoreline stabilization and erosion control.

We did try to get a handle on it; in February 1990 we surveyed all the districts and divisions within the Corps. We sent out a questionnaire. [Shows slides.] It wasn't a scientifically designed questionnaire. The types of questions we asked were:

- How many reservoir projects does your district have?
- Which projects have shoreline erosion problems?
- For each reservoir, what is the nature of the problem?

    - Loss of private or government property,
    - Loss of government facilities,
    - Loss of archaeological/cultural resources,
    - Loss of critical fish/wildlife habitat, etc.

- For each reservoir having erosion problems, what is your estimate of shoreline miles affected, and your opinion as to severity (i.e., minor, somewhat severe, severe)?

It wasn't a scientifically designed survey, but it does give us a good idea and it gives us a start. It led to this and other workshops.

When we polled the districts, 69% responded and 31% did not. We had pretty good responses by projects, 60%. Of those that responded, those that reported erosion problems are shown here by districts, 79%, and by the projects, 58%. We knew of another four districts that had problems and another four that did not have any problems, and this accounts for the total number of districts in the Corps of Engineers. I think we were finding out something we already knew was true. We asked them whether they thought the erosion was severe, moderate, or minor. When we got to really looking at the responses, we kind of prorated the middle ground by means of some follow-up phone calls to categorize those into severe or minor, to just look at those two areas and on the degree of erosion in their minds of how bad it was. As you can see, the total is approaching those in the Corps of responding at 12,000 miles of shoreline, almost half of which they consider severe and which could take some type of major corrective action. We categorized the districts into those that had less than 100 miles, those that reported between 100 and 199 miles, and then those that had over 200 miles. Ten districts reported that they had less than 100 miles of some degree of erosion [NAO, NCB, NCE, NCS, ORP, SAC, SPK, SWL, SWG, and SWA]. Seven districts reported that theirs was between 100 and 199 miles of erosion [LMS, NCR, NPS, NPW, ORH, ORL, and SWT], about half of it was severe in all cases except NPW.

The ones that reported from 200 to somewhere in a neighborhood of 1,000 miles were: Lower Mississippi, Vicksburg [LMK]; Missouri River, Kansas [MRK]; Ohio River, Nashville [ORN]; South Atlantic, Mobile [SAM]; South Atlantic, Wilmington [SAW]; and Southwest, Forth Worth [SWF]. So you see the majority of districts in the Corps have some kind of shoreline erosion, and six here that are reporting something like 200 to 1,000 miles—pretty significant. Two hundred seventy-six reservoir projects responded and the severe, minor, no erosion report looks like this: severe - 117 or 42%; minor - 44 or 16%; and no erosion - 115 or 42%. There is as much severe erosion as there is no erosion on the 276 reservoir projects.

The types of damage or threat that are occurring throughout the whole Corps that reported are to: private homes, private properties, government structures, government property, archaeological and cultural resources sites, fish and wildlife habitat, recreational facilities and sites, and those that are related to some type of water quality degradation due to its turbidity and other factors.

We do need a better measure than miles affected. We need to look at various stretches of the shoreline, then characterize these as to the scope of the erosion and the nature of its effects on the value and uses of the reservoir. Then based on such an analysis we would be able to, hopefully, prioritize any control methods that people might have, and place them optimally where they are appropriately placed.

As I said, we cannot manage or correct every mile of shoreline erosion. Using today's technologies and remote sensing and geographic information systems, we can monitor, classify, and categorize eroding shorelines into management units that are related to treatments. Hopefully, some of these treatments would be less expensive than some of the traditional methods we have used in the past. There are cases where vegetation alone has been effective in controlling erosion and there are cases where vegetation in combination with a structure has been effective. We need a better idea of what kind of combination and what kind of treatment to use where, related to the nature of the shoreline erosion, and what type of use it's impacting in our reservoirs. A lot of the sights you will see on the field trip, fixes done here in the Tulsa District, a lot of it has been done using volunteer labor. Local groups, Boy Scouts and others come in and cooperate with the Corps district and they do the plantings of the vegetation and establish the vegetation and the zones where it is amenable to that type of solution. While we are fighting to control the erosion, we should not overlook some of the benefits that may accrue from some of the methods that are used in the treatment.

On the agenda you will see that Ms. Wendi Goldsmith is going to speak to you about some beneficial things that they have done in Germany to control erosion with vegetation, such as providing wildlife and fisheries habitat in the process. I think we can and should do similar things in our reservoirs. With proper planning and environmental design and engineering, more and more federal and state agencies are cooperating to control shoreline erosion, just like we are doing here at this workshop. Next spring at Riverton and Ocean Lake, WY, the Corps and the Bureau of Reclamation are going to be cooperating in a training workshop which focuses on low cost methods of controlling erosion with vegetation and engineering structures. We hope that this workshop this week will stimulate more interagency cooperation to reduce the impact of shoreline erosion on natural resources.

The focus that the Corps has, and will continue to have, is good stewardship of water resources. It is going to take the innovative and interdisciplinary approaches such as Pete mentioned in his opening comments. I hope the workshop will be a catalyst for this process. So let's put all our creative thinking to work when you get in those breakout sessions. I would like to thank everybody for coming, whatever distance you came, and all the brain power we have here to participate in this workshop. I think it shows there is a commitment to the stewardship of our water resources and the shorelines of our reservoirs. Thank you.

IMPACTS, CAUSES, AND CONTROL OF SHORELINE EROSION FROM VARIOUS PERSPECTIVES

MECHANISMS OF SHORELINE EROSION ALONG LAKES AND RESERVOIRS

John R. Reid[1]

Causes

Erosion of shorelines along lakes and reservoirs is a normal occurrence affecting some bodies of water more than others. The cost of loss of land is real and of concern to many private citizens and public agencies. Although most such land is allowed to erode, the most critical areas are being modified in attempts to control further erosion. But, before erosion controls can be planned, the causes of the erosion must be known. This paper is a summary of causes and how they relate to erosion along Lake Sakakawea, North Dakota (Figure 1). Erosion of shorelines can be defined by **bank-face** erosion, the removal of material along the surface exposure of a bank, or by **bank recession**, the migration of the top of the bank over time. It should be apparent that without bank-face erosion, there is no recession of the top; both are interrelated. However, because recession is an end-product of bank-face erosion, and because recession is easier to measure, most of what follows concerns the causes of bank-top recession. For a detailed discussion of measurement techniques see Gatto (1988) and Reid (1992).

The factors that determine whether or not bank recession occurs (and the magnitude of any recession) can be categorized as **activating** or **passive**. Activating factors are those that "trigger" erosion: earthquakes, waves, rain and runoff, groundwater discharge, frost thaw, ice-shove, wind, and human-caused events, such as excavation, explosions, and vehicle vibrations.

Factors: Passive

Passive factors are more subtle; they are properties, inherent in the bank material or in the geometry of the banks, that exist all or most of the time, but which cause the bank to be relatively susceptible to activating factors. Situations that promote failures include:

- A composition rich in clay, especially smectites
- Alternating layers of weak and strong beds
- Dense jointing, especially vertical
- Protection from the sun; a high moisture content
- Steep slopes
- Relatively low height
- Lack of protection from wind-driven waves
- Lack of natural or artificial riprap along beach

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- Narrow, steep beach
- Lack or sparseness of vegetation

Composition. The mineralogic composition of the banks along shores greatly affects the stability of those banks. Granite, for example, is obviously more resistant to erosion than loose quartz sand. Other than sand, perhaps the least stable bank-forming sediment is a clay or silt rich in the expandable minerals, the smectite group (montmorillonite). These clay minerals are common in the Great Plains states.

Along Lake Sakakawea the banks are composed of a variety of rock types and sediments (Figure 2). The oldest (lowest) rocks are poorly consolidated mudstones, sandstones, and lignite coal beds of Paleocene age (Sentinel Butte Formation). This bedrock is overlain by one or more tills, with or without interbedded sands and gravels, and capped by windblown silt (loess). Although the Sentinel Butte Formation has little expandable clay content, the overlying tills average 29 to 35% clay (Millsop 1985, p. 56) and much of this is of the smectite group. The presence of such a relatively high clay content makes these tills potentially unstable, especially when saturated with water.

Stratigraphy and structure. Wherever weak beds are overlain by more resistant beds there tends to be more rapid recession of the top. The best example of alternating weak and strong beds along the lake is at Station 51 (Figure 3) where the lower Horseshoe Valley fluvial sand overlies the compact upper Medicine Hill till and, in turn, is overlain by the vertically jointed upper Horseshoe Valley till. Whenever waves reach this loose sand there is rapid removal of the sediment, undercutting the overlying till. The till then fails by block sliding along joint planes. It stands to reason, then, that a combination of dense vertical jointing and underlying weak beds can lead to extensive bank recession.

Structure refers to the presence or absence of weak planes in the rock or sediment. Such planes typically are joints (fractures), both vertical and horizontal, as well as oblique. Other structures may include fault planes. As a result of Elliott's (1991) detailed analysis of fractures in each of the units at the Lake Sakakawea recession stations, it has been demonstrated that although fracture density and orientation do correlate with bank recession, other factors are more significant. However, where there are strong vertical joints parallel to a bank face, massive block failures are common. And the type of failure is controlled by the density of both vertical and horizontal fracture patterns, i.e., where both sets are of equal density the bank failure results in cubic blocks accumulating at the base.

Antecedent moisture. Moisture in bank materials can be recognized as having been introduced into the sediment during an earlier precipitation event or from the time of original deposition (antecedent), or introduced as a result of a contemporary event (rainstorm, snowmelt, etc.) A large amount of antecedent moisture can make the material weak so that an activating event of even small magnitude may trigger failure. In the northern hemisphere orientation with respect to the sun causes northerly facing banks to retain more moisture, thereby reducing their strength. At Lake Sakakawea the volume of **colluvium** (material washed and otherwise moved to the base of a steep slope) accumulating along the slopes is greatly orientation-controlled; the lowest volumes are from banks that face east and northeast. These are relatively dry because they are protected from rain-bearing winds. But other factors (height) are more important for the banks with these orientations. The north- and northwest-facing banks, however, have more colluvium largely because they are moister.

Steepness. As for the steepness factor, other factors being equal, the steeper the slope of the bank, the less stable it is. But, because banks along Lake Sakakawea are nearly all vertical, this does not explain variations in recession there.

Orientation. Steep banks are usually the result of strong waves undercutting the base. Orientation with respect to wind-driven waves is therefore the most important passive factor in accounting for bank recession. Banks that face into the strongest winds are exposed to the largest waves; in the case of Lake Sakakawea the greatest fetch is from the west, but the strongest winds that accompany high pool levels are the critical component. Two years are adequate to illustrate this factor. In both 1982 and 1983 the strongest winds during high pool levels were from the north and northwest or the south. South winds tend to precede a storm front and last several days, whereas the more northerly winds follow the passage of the front and typically last only one day. For this reason, it would be expected that south-facing banks would experience more wave erosion during high pools. The results demonstrate that southwest-facing banks undergo the most recession, supporting this assumption, whereas west-, north-, and northeast-facing banks experience the next most recession, partly supporting this assumption.

Other orientation factors that determine the effectiveness of waves include whether the site is a headland or a protected bay, and whether or not the site is downwind from an offshore island.

Bank height. The height of a bank can be a passive factor in recession. It seems reasonable to assume that higher banks are the result of more erosion. But high banks cannot occur if the land is relatively flat (low), e.g., along former stream valleys as opposed to intervalley ridges. And, although there is more recession occurring at Lake Sakakawea along banks higher than 30 ft in winter, the shortest banks are eroded far more over the warmer months. The volume of colluvium accumulating along the base of slopes is controlled by bank height, though. The higher the bank the greater the surface area over which processes can operate. Therefore, banks higher than 30 ft have three times the volume of colluvium as banks that are between 15 and 30 ft and the lowest banks have the least colluvium. It is no coincidence that winter recession values directly reflect the volume of colluvium.

Although lower banks tend to experience greater bank recession accompanying wave erosion, the higher banks undergo other types of effective erosion such that over time, the total recession of low and high banks is about the same. The annual recession, therefore, is independent of bank height along Lake Sakakawea.

Riprap. Beaches veneered with natural (or human-placed) riprap protect the banks from wave erosion by absorbing much of the wave energy before the waves reach the base of the banks. Natural riprap along the shores of Lake Sakakawea is of several types. The most common consists of accumulations of glacially deposited pebbles, cobbles, and boulders. Where such concentrations occur, though, evidence of a stonier till from which the accumulations were presumably derived is usually missing; abundance of accumulations on the beach are far greater than abundance in the till. The source of these clasts is on the top surface, not **in** the till. Local concentrations of boulders were evidently carried along the surface of the glacier and let down as the ice disappeared. So, the character of the bank material **and** the surface material have to be examined before an estimate can be made of future changes in beach composition.

The second type of riprap along Lake Sakakawea results from erosion of the Paleocene bedrock and residual concentrations of more resistant components. In places there are lag concentrations of petrified stumps and logs of *Metasequoia* trees. Many of these trees were obviously growing in swampy areas because the logs are concentrated in the lignite beds. As the coal was eroded, petrified trees accumulated along the beaches.

Other resistant components of the bedrock in places are calcareous concretions. These features are spheroidal masses up to 5 ft in diameter that are formed by groundwater moving through the mudstones and precipitating calcium carbonate around organic matter (in the case of Lake Sakakawea, usually fragments of lignite). As the mudstone is eroded the concretions end up on the beach below, forming an effective absorber of wave energy.

Finally, local concentrations of sandstone occur in the bedrock. Some of these are former stream channel sands cut into the deltaic muds. Others are distinct layers of sandstone, probably formed along floodplains or former beaches. The sandstones are hard and often form broken masses of riprap along the beaches. It is therefore important to evaluate the percentage of beach that is veneered with coarse material.

Beach geometry. Wave energy is also dependent upon the steepness and width of the beach. The gentler and wider the beach, the more wave energy is absorbed by the time waves reach the base of the banks. The usual assumption is that over time the beaches will become gentler and wider, thus stabilizing the shores. It is true that between 1986 and 1991 the beaches of Lake Sakakawea became significantly wider. But, this is only a reflection of the drought; the water levels were receding! In order to compare relevant changes from one year to the next it is necessary to measure beach widths from the same water height (or elevation along the beach). Between July 1984 and one year later the beaches along the lake averaged 31% narrower! This passive configuration indicates an increased tendency for future erosion.

Vegetation. The presence of vegetation on a bank surface may indicate that it has effectively prevented erosion or, more likely, it exists **because** there is no erosion there. If a shore is covered with prairie grass, for example, it means that erosion is not occurring there; prairie grass is ineffective against wave erosion. Even though there are a few sites along the lake where trees exist along the shores, they, too, are being eroded. The vegetation is no match against the energy of the waves on this large lake.

Factors: Activating

The factors that trigger bank erosion, in order of decreasing importance at Lake Sakakawea, are:

- Waves
- Frost thaw
- Rainsplash/runoff
- Groundwater sapping
- Lake ice shove
- Wind

These will be discussed separately, below.

Waves. Although many processes bring material to the base of banks along Lake Sakakawea, if the material is not removed the slope will become stabilized over time. The **only** process that accomplishes removal is wave erosion. And wave erosion is directly responsible only when the pool level is high enough that the waves impact the base of the banks. Ultimately then, the pool level is the critical parameter; it correlates with every passive factor.

Fluctuations of Lake Sakakawea are shown in Figure 4. The lake characteristically attains maximum level in midsummer when snowmelt from the Rockies reaches North Dakota. As water is released to provide relatively steady hydroelectric generation and sufficient depth for required downstream navigation, the pool level drops. This also makes room for any anticipated snowmelt discharge the next spring, minimizing downstream flooding. Other factors affecting the shape of the curve include heavy summer rains and, of course, the decisions by the Corps to increase or decrease discharge rates through Garrison Dam.

Wave action is greatest during summer storms when the pool levels are highest. Numerous studies have been made on the energy of waves and the resulting shore erosion. Most of these have been along ocean shores and are certainly applicable to inland shores. But lake shorelines, especially along reservoirs, need to be assessed separately. Examples of such studies include those by Buckler and Winters (1983), Carter and Guy (1983), Gatto and Doe (1983), Hands (1980), Harrison and Mellema (1984), Kachugin (1980), Koopersmith (1981), Larsen (1973), Lawson (1985), Mickelson and others (1977), Quigley and Gelinas (1976), Quigley and others (1977), Reid (1984), Sterrett (1980), and the U.S. Army Corps of Engineers (1962). For a better understanding of wave energy, the following references are recommended: Galvin (1968), Komar (1976), Miles (1957, 1959), Putnam and others (1949), Sverdrup and Munk (1946), and U.S. Army Corps of Engineers (1952, 1954).

The relationship between wave energy and resulting bank recession has been studied by many researchers; Quigley and Gelinas (1976), for example, discovered a linear relationship between historical cliff recession along Lake Erie and the breaking wave energy over a 150-year period. Sunamura (1982) concluded that the average rate of cliff erosion in Japan was linear with the frequency of waves greater than the critical wave height for that area. Our studies on Lake Sakakawea, however, suggest no statistically valid relationship between wave energy and bank recession. This is especially evident at one station, with an effective fetch of 2.5 miles, the shortest fetch calculated, and yet a cumulative bank recession of 29 ft, and a second station, with an effective fetch of 4.6 miles, but less than 10 ft of recession. This supports the conclusion that no single parameter can completely account for the erosion of a bank (Lawson 1985), but wave erosion is by far the most significant factor in bank recession.

All this ignores the impact of waves produced by boats; in many areas this is an especially significant cause of shoreline erosion and must be considered in any evaluation of erosion. On Lake Sakakawea, however, the magnitude and frequency of wind-driven waves far exceed any boat wakes.

Frost thaw. It is difficult to separate the effects of wave erosion from the other activating factors because the undercutting of the toe of a bank allows other erosional processes to become active, especially mass wasting (landsliding). In this region of the upper Great Plains, however, frost thaw failures are second only to wave erosion (Reid 1985, Reid and others 1988). In addition to the amount of water in the sediment/rock, the two aspects of frost are the depth of penetration and the number of freeze-thaw cycles. The depth of penetration depends primarily upon the surface temperature and depth of any protective snow cover. Because winter precipitation in this part of North Dakota is normally very low the snow does not effectively insulate the ground from the cold winter temperatures. The typical frost penetration begins in late October or early November. The freezing front rapidly moves downward until it reaches maximum depth in February (40 to 60 in.). By late February or early March there is both surface and bottom melting of the frost, until all frost is gone by early to mid-April.

The number of freeze-thaw cycles is more difficult to measure; a continuously recording thermistor installed at a given depth below the surface would be necessary to determine cycles at that depth. An approximation can be made by a surface thermograph to determine the number of days in which the above-ground temperatures fluctuate above and below the freezing point. During the winter of 1982-83 there were 121 such days at Riverdale, ND, at the east end of the lake.

The net result of frost action is destruction of the sediment and rock structure, such that when thawing begins the material fails rapidly. Slopes that contained the greatest percentage of moisture (north-facing), and that had the greatest surface area (highest banks), underwent the greatest amount of failure. An average of 23% of bank recession at Lake Sakakawea occurred during the "cold" season, which includes the period of thaw failures in March and April. Thaw failures are therefore very important in this region of the United States and Canada.

Rain. Rainsplash and resulting runoff are not significant activating factors of erosion at Lake Sakakawea; the slopes are nearly vertical so rain does not strike much of the surface, and there is little precipitation to begin with. At only one station was rain significant and only for one event. Several years of minor summer wave erosion had left a broad colluvium apron there. One storm event that summer (1983) produced runoff which created numerous deep gulleys in the deposit. The next summer, however, the entire deposit was removed by wave undercutting. Compared to wave erosion and thaw-failure, rain is an insignificant factor of erosion here.

Groundwater. Groundwater is not a factor in bank recession along Lake Sakakawea except for three small areas. The water table is everywhere at or below the lake level except where occasional perched water tables have formed. These perched tables are in lignite beds, resting on relatively impermeable mudstones. Where the water discharges from the lignite, spring sapping can occur which effectively undercuts the overlying material, eventually resulting in slope failures. In more humid regions of the United States the water table is higher than the lakes and groundwater discharges into (feeds) these lakes. The adjacent banks tend to be saturated at the water table contact, making them more susceptible to failure (erosion). Where springs discharge, additional erosion occurs.

In humid regions, particularly, rapid fluctuations of pool levels destabilize the banks; during high pool levels water recharges the bank material. Upon rapid drawdown the banks tend to fail because of the higher pore water pressures left in the banks. Such drawdown effects can occur in drier regions, but are not as important.

Ice shove. When lakes freeze over and later undergo cold contraction, cracks are formed into which water flows and freezes. Subsequent warming will expand the ice again, forcing the ice to buckle and/or be shoved onto the shores (Gatto 1982, Pessl 1969, Pyokari 1981, Lawson 1985). Bottom and shore sediment can be moved shoreward by this force. For this to be a significant activating factor of bank recession along Lake Sakakawea, the ice shove would have to be directed at the base of the banks. But, by the time the lake freezes, the pool level has dropped far below this level. Many lakes, however, freeze when the water level is high; weakening of the banks frequently occurs, resulting in massive bank failures in spring and summer. This can be a serious factor in shoreline erosion.

Wind. Although the wind blows strongly over Lake Sakakawea, wind erosion of the banks is minor. The reason for this is that the bank material tends to be relatively cohesive. Where loose sediment exists, mainly along the beaches and the base of the slopes, it tends to be either too coarse or too fine for easy entrainment (Bagnold 1954, p.88). If the material is entrained, little is carried up and over the typically high banks. In other words, little is **removed** from the banks, only **moved** up or down a bit. Of course, wind is the major cause of waves and, indirectly, therefore, is the prime factor of shoreline erosion.

Results

There are many erosional processes active in seasonally frozen environments such as at Lake Sakakawea (Lawson 1983, 1985). These include wave erosion, rainsplash and accompanying runoff, frost-thaw failures, and other types of mass movements (falls, topples, slides, and flows) (Figure 5). Most bank failures at Lake Sakakawea occur through mass movements rather than from surface erosion processes, but most movements are directly or indirectly the result of undercutting by waves. This part of the paper is intended to summarize the variations in bank recession rates and to discuss the factors involved in these variations at Lake Sakakawea.

Landslides

Falls. Failure by falling of material along Lake Sakakawea requires vertical or overhanging banks. Because only a very small percentage of these banks are vertical, failure by this mechanism is relatively minor. Most fail by sliding. The exception is where the Oahe Formation loess overlies actively undercut banks. Eventually, the bank is undercut enough that the loess block topples and falls. Bank top recession here is sporadic, but significant.

Planar sliding. Of the several types of bank failures at Lake Sakakawea, the most common is block sliding, due primarily to the steepness of the bank faces and to the fracture pattern of the material. The size and shape of the blocks are dependent upon the fracture density and orientation. The Paleocene bedrock fails as small irregular blocks because the fracture density is high (closely spaced) and horizontal bedding plane fractures are intersected by near-vertical fractures, reflecting regional stresses (Elliott 1991).

The Pleistocene Medicine Hill till also produces small blocks upon failure, but they tend to be much more irregular and slightly larger. The origin of the fractures in this unit appears to be upward extension of regional stresses from the underlying bedrock, glacier flow stresses, and dewatering of the till since deglaciation.

In contrast, the two upper tills (Figure 2) fail along widely spaced, long vertical fractures, resulting in large blocks and sudden rapid bank recession. Where these formations are present, total recession tends to be high. Total average recession is the lowest for the complexly fractured Medicine Hill till. The reason for this is that despite the density of the fractures, the expandable clay content tends to keep the fractures sealed. This unit is highly resistant to wave erosion.

The uppermost unit, the Oahe loess, has a dense vertical fracture pattern, due to seasonal desiccation. It is relatively resistant to failure, however, because of prairie grass root binding.

Rotational sliding. Failure along arcuate fracture surfaces leads to rotational sliding (slumping)(Varnes 1978). Such failures are often sites of high porewater pressures which reduce the strength of the bank material. Most of the bank failures along Lake Michigan were assumed to be by rotational sliding (Edil and Haas 1980). Only three known areas along Lake Sakakawea exhibit this type of failure. The first is just below Riverdale where careless use of water has created a perched water table in a lignite bed (Reid and others 1986). An extensive zone of slumping occurred sometime prior to 1983 and again in 1985.

The second area is about 1-1/2 miles west of the dam. This site has not been studied. But the third site is the largest, about 60 miles upstream. Recent investigations have indicated the existence of a buried valley, rising to the west of this site.[1] A perched water table probably forms here from time to time because of this valley and is responsible for the failure. Elsewhere around the lake the water table lies at or below the lake level; the lake serves to recharge the water table.

At other lakes, areas of perched water table discharges are particularly prone to rotational sliding. Dewatering of these sites is an effective way to increase their stability (Schuster and Krizek 1978, p.101).

Flow failures

Land failures by flowing typically accompany slumping, especially at the toe of such failures (Varnes 1978; Coates 1977). Flowing failure is therefore significant at each of the three slumping sites mentioned above. Of greater significance, however, is the fact that most thaw failure along the shores of Lake Sakakawea is by flowing. The higher the ice content, the greater the probability of such failures. Because the south-facing banks are exposed to the sun the most, these banks tend to be relatively dry. North-facing banks, on the other hand, are protected from the drying effects of the summer sun and the sublimating effects of the winter sun.

Conclusion

Shoreline erosion is a result of many factors, both passive and activating. Unless the shoreline material is ready to fail, activating factors will be ineffective. Of all the passive factors, the composition of the bank material and its orientation with respect to the wave-generating winds are most important. Of all the activating factors, wave energy is by far the most significant. In the northern regions of the United States, freeze-thaw failures are of secondary importance, whereas in more humid regions, rainsplash and runoff are more important. Regardless, each of the factors of shoreline/bank erosion should be evaluated before mitigating measures are introduced.

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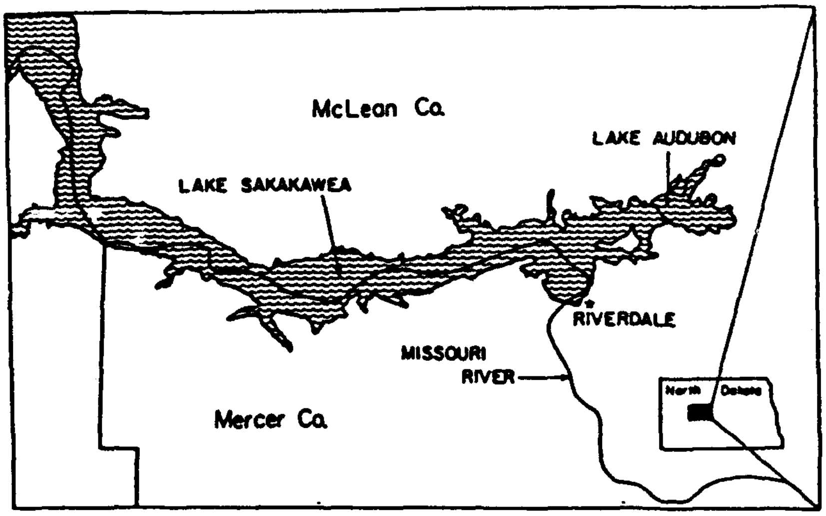

Figure 1. Location map, Lake Sakakawea, North Dakota

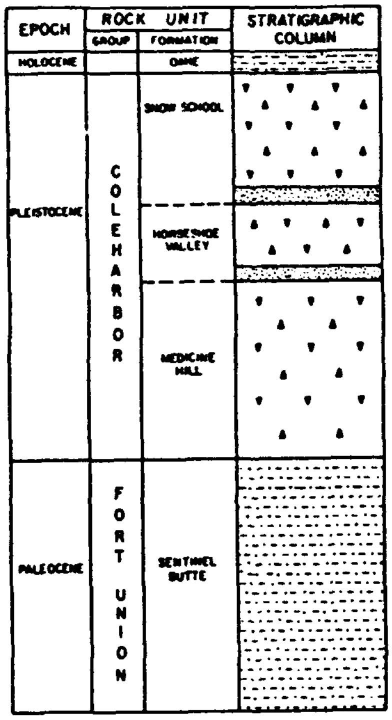

Figure 2. Geologic units present at Lake Sakakawea

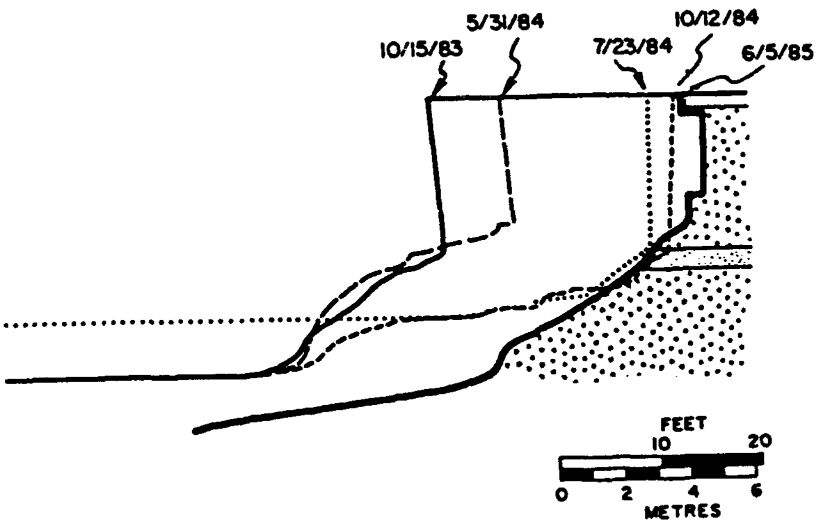

Figure 3. Bank profile changes caused by waves eroding sand beneath Horseshoe Valley Till

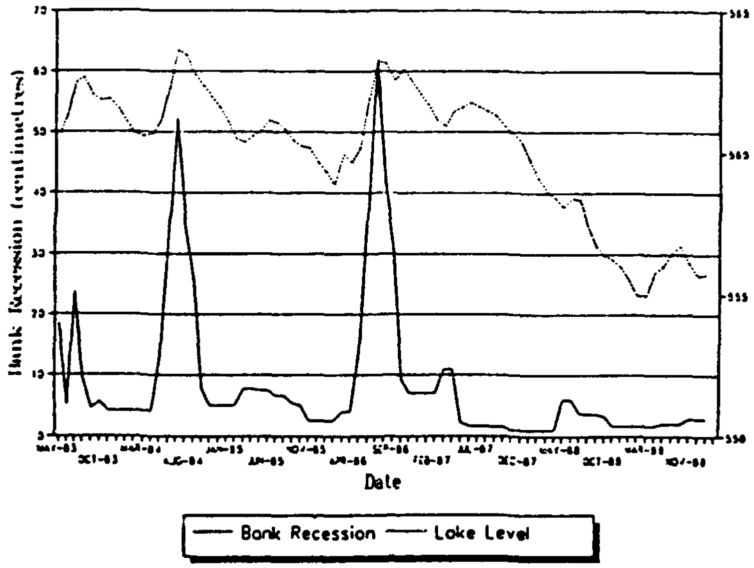

Figure 4. Average monthly pool levels and resulting bank recession

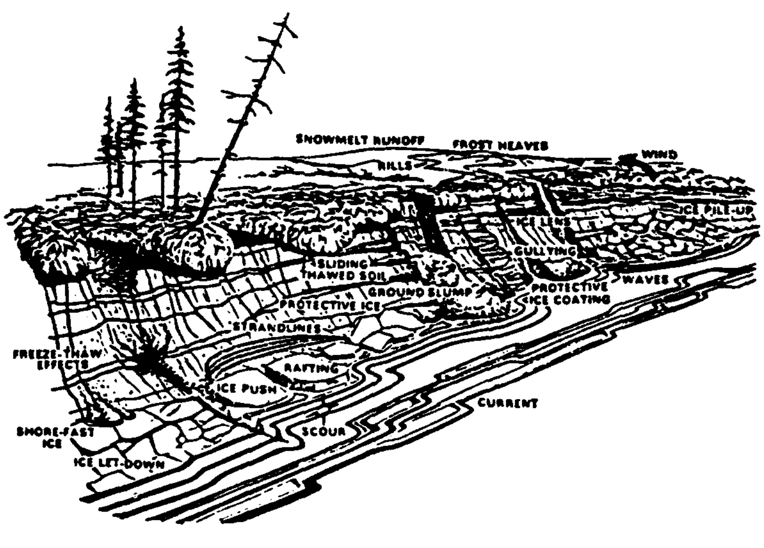

Figure 5. Erosion processes active in seasonally frozen environments
(Gatto and Doe 1983)

QUESTION: Did the bank height preclude people or vehicles from driving along the view?

DR. REID: We don't have many sites along Sakakawea where vehicles are allowed to come close to the banks; people, yes. In some places, people have really exacerbated the problem.

QUESTION: Is that something you took into account?

DR. REID: No, because compared to these other factors they were not that important.

QUESTION: From an overall viewpoint, is the high level or the low level erosion more substantial to recession?

DR. REID: All you need is one single day of a storm at high pool level and that exceeds recession from many years of erosion at low pool level.

QUESTION: Is the principal use of reservoirs you showed for flood control...irrigation?

DR. REID: For Orwell, it was flood control management, largely, and secondarily downstream water quality and fish population control management; for Sakakawea, hydroelectric, flood control, and recreation.

QUESTION: Were those Corps of Engineers facilities?

DR. REID: Yes; there are state parks all around Sakakawea, too.

COMMENT: John, I would hope there would be some time in the course of this workshop to explain how the results of your study changed the management of Orwell and the weighing of tradeoffs, specifically, erosion control versus habitat loss.

MR. ALLEN: I'm sure there will be time in the breakout sessions to discuss the secondary impacts of fixes.

DR. REID: At Orwell, our contract was to provide data on the causes and magnitude of bank erosion. However, I did provide suggestions to the St. Paul District office on how the magnitude could be reduced. They had a work session to look at this. One suggestion was to hold the pool level down for a couple of years and get some vegetation in. They said they couldn't do this. But now, they're doing it. It takes time; it's an education process.

SHORELINE EROSION CONTROL - ENGINEERING CONSIDERATIONS

Yen-hsi Chu[1]

Introduction

Protecting eroding shorelines is a major task that challenges coastal engineers the most. In the past, our efforts were devoted to erosion problems that occurred at coastlines along the Atlantic and Pacific Oceans, the Gulf coast, and the Great Lakes. In recent years, the Coastal Engineering Research Center (CERC) began to participate in shoreline erosion control projects in the "low energy" environment, such as Intracoastal Waterways, lakes, reservoirs, and coastal wetlands. We became more familiar with the problems in areas with relatively confined water bodies. Experience we gained from our practice in the "high energy" environment can be useful to efforts of controlling the shoreline erosion at reservoir and lake environments.

Between the coastal erosion problems and erosion problems of lakes and reservoirs in general, there are many similarities in causes of the problem and in physical erosion processes. This presentation will summarize the knowledge we gained, in my judgment, that might be useful to identify solutions to shoreline erosion problems occurring at lakes and reservoirs.

For a successful and effective application of an erosion control measure, it is important to know the magnitude of the force or forces that cause the erosion problems. In the lake or reservoir environment, there are many factors that will directly or indirectly influence the erosion processes. These factors, such as soil conditions, fluctuations of pool level, air temperature, vegetation, and land uses, could augment the erosion processes. Without the external forces, however, these factors alone will not present any threat to the existing shoreline.

Forces that can cause shoreline erosion whether at open coast or lakeshore are surface water waves, surface runoff, and/or groundwater seepage. Water waves induced either by winds or by boating activities are the primary force causing shoreline erosion and must be considered and understood in any successful erosion control efforts.

Waves, Wind Setups, and Wave Runups

Wave data needed for analyzing erosion processes and engineering control measures are wave height and wave period. Naturally, historical records of these data are preferred. However, site-specific wave data practically are not in existence. Direct field measurement of wave data requires relatively long-term effort for proper site characterization and can be very costly. Therefore, field wave measurement is generally not recommended. For wind

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[1] Coastal Engineering Research Center, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS 39810-6199.

wave information, a common procedure of hindcasting the wave record using historical wind data is an acceptable technical approach. Figure 1 is the nomograph used for predicting deep water-wave parameters. Methodology for predicting shallow-water waves is detailed in the Shore Protection Manual (SPM) (USAWES 1984). Once the wave information is obtained, engineers can calculate the wave runups, analyze structure stability, or size structural elements using SPM procedures. With the available wind data, engineers can also calculate wind setup, an important factor to be considered for relatively large but shallow reservoirs.

For smaller reservoirs, boat waves can play an important role in the shoreline erosion processes. Methodology for predicting waves generated by recreational boats is rather incomplete at this time. Procedures summarized by Sorensen (1986) are recommended for applications to reservoir erosion control studies.

Data Collection and Record Keeping

Wind data can be obtained from local meteorological stations. Monthly climatological data or long-term record can be retrieved from the National Climatic Data Center in Asheville, NC. Water resource data including streamflow data, topographical data, and shoreline position record can be obtained from the U. S. Geological Survey and its National Cartographic Information Center in Reston, VA. These data are always useful and sometimes important to the analysis of erosion processes and engineering erosion control measures. It is equally important to maintain a site-specific data file to include records such as photographs of eroding banks, erosion measures being implemented, shoreline positions being surveyed, and notes on significant weather events and observations.

Structural Approaches for Shoreline Stabilization

It is environmentally desirable to apply soft structure treatments such as biotechnical engineering and protective beach for shoreline erosion control. However, the effectiveness of soft structure fixes for erosion control under severe wave conditions or certain unique site configurations may be questionable. Hard structures should be considered when local waves exceed 3 to 5 ft in height. Traditional erosion control structures include fixed or floating breakwaters, bulkheads, and revetments. Each structure type has its definitive function and design considerations (SPM 1984). Innovative design of structural elements for practical purposes is always encouraged.

The primary function of a breakwater is to reflect and dissipate the incident wave energy. Its effectiveness depends on its rigidity, porosity, and structure height. A floating breakwater, in general, is not an effective wave energy dissipation device, particularly under long-period waves. However, a floating breakwater can be constructed at relatively low cost and can be easily removed from the site once its functional objectives are accomplished. It is an ideal structure used for relatively short-term protection and one which allows vegetation to grow. Floating breakwaters built of discarded automobile tires have been used for reservoir erosion control.

Revetments are designed to protect slopes. A well engineered revetment should include three basic structure elements: armor units, filter layer, and toe protection. Figure 2 is a typical design of a riprap revetment. A fabric layer is always recommended to be placed between the slope and filter and is used to wrap around the structure toe. Various types of armor units used in design include ripraps, artificial concrete units, gabions, etc. The stability criteria for the armor unit design are discussed in the SPM. It is important to note that the integrity of revetment structures also depends on the stability of the supporting foundation slopes. Many structure failures are caused by the failure of slopes rather than the failure of armor units. Therefore, proper controls of local surface runoff and groundwater seepage at the slope and minimizing wave overtopping along with an effective filter layer are important structural design considerations.

Bulkheads are vertical retaining structures designed to separate water from land mass. Various innovative bulkhead designs are documented and discussed in EM 1110-2-1614 (USACE 1984). The basic design and analysis procedure is presented in Eckert and Callender (1987). Important design considerations for bulkheads include proper protection of backfill material and scour prevention of structure toe. The loss of backfill and toe scour are two common causes of structures failure. Reducing wave overtopping by increasing the structural height and installing a splash blanket at the top of backfill are effective means to retain the backfill. In addition, proper drainage devices such as weeping holes within the backfill and toe blanket are necessary features to be included in the bulkhead design.

Figures 3 and 4, respectively, are examples of revetment and bulkhead alternatives.

Summary

It is environmentally desirable to apply soft structures for reservoir erosion control. However, situations may require a hard structure fix when the eroding force is significantly large. Successful application of hard erosion control structures requires the knowledge of common causes of structure failure and site-specific environmental data. Some essential elements for engineering design considerations are discussed benefiting non-engineer professionals. Reservoir and lake managers are encouraged to become familiar with those considerations in their efforts of shoreline erosion control.

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QUESTION: Is WES coming out with any information on geotubes?

DR. YEN-HSI: We may, but I don't know when. As this is a demonstration study, we will document all experiments. Geotubes will be one of them.

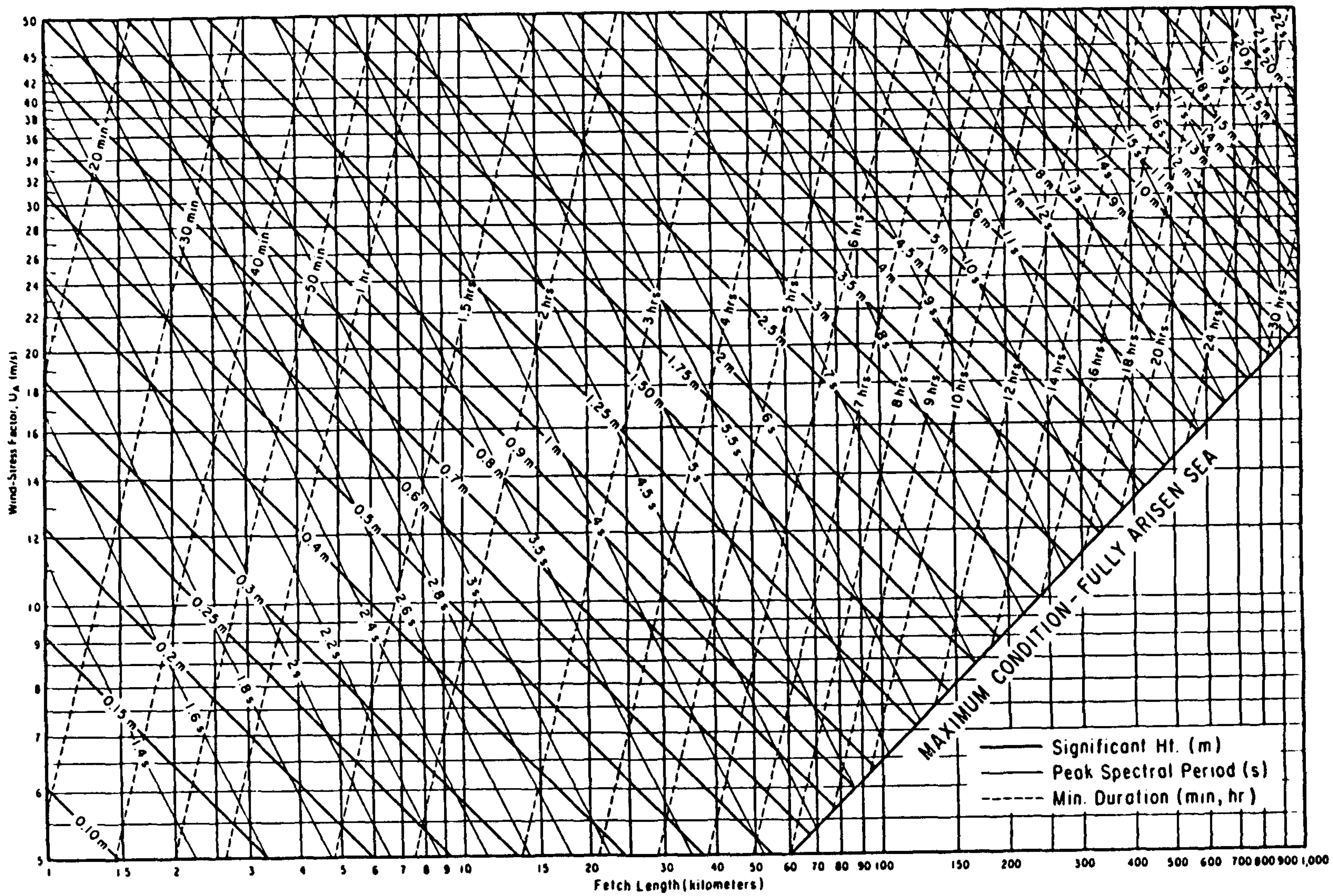

Figure 1. Nomograms of deepwater significant wave prediction curves as functions of wind speed, fetch length, and wind duration (metric units)

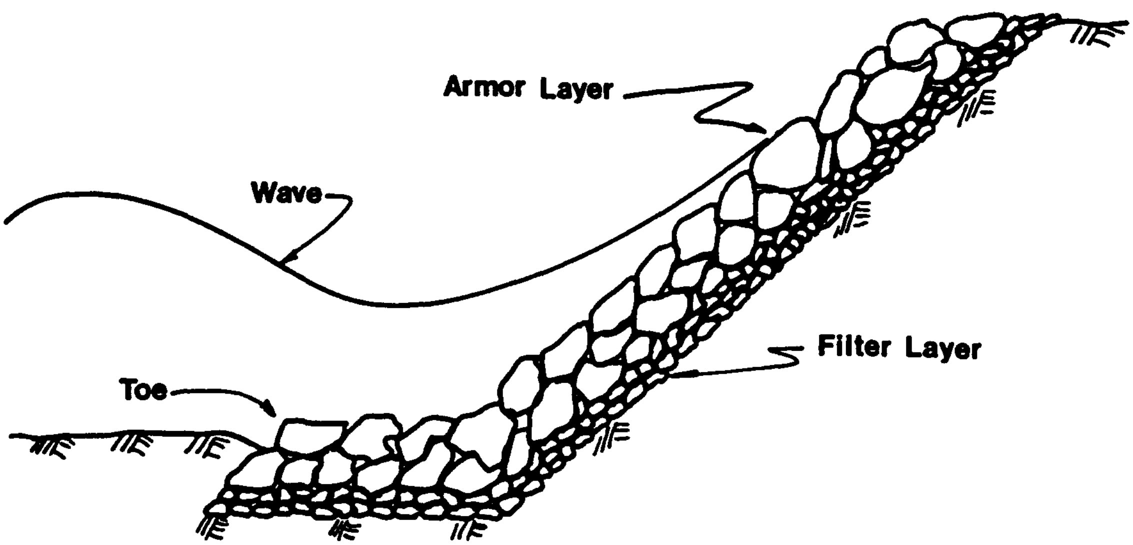

Figure 2. Typical revetment section

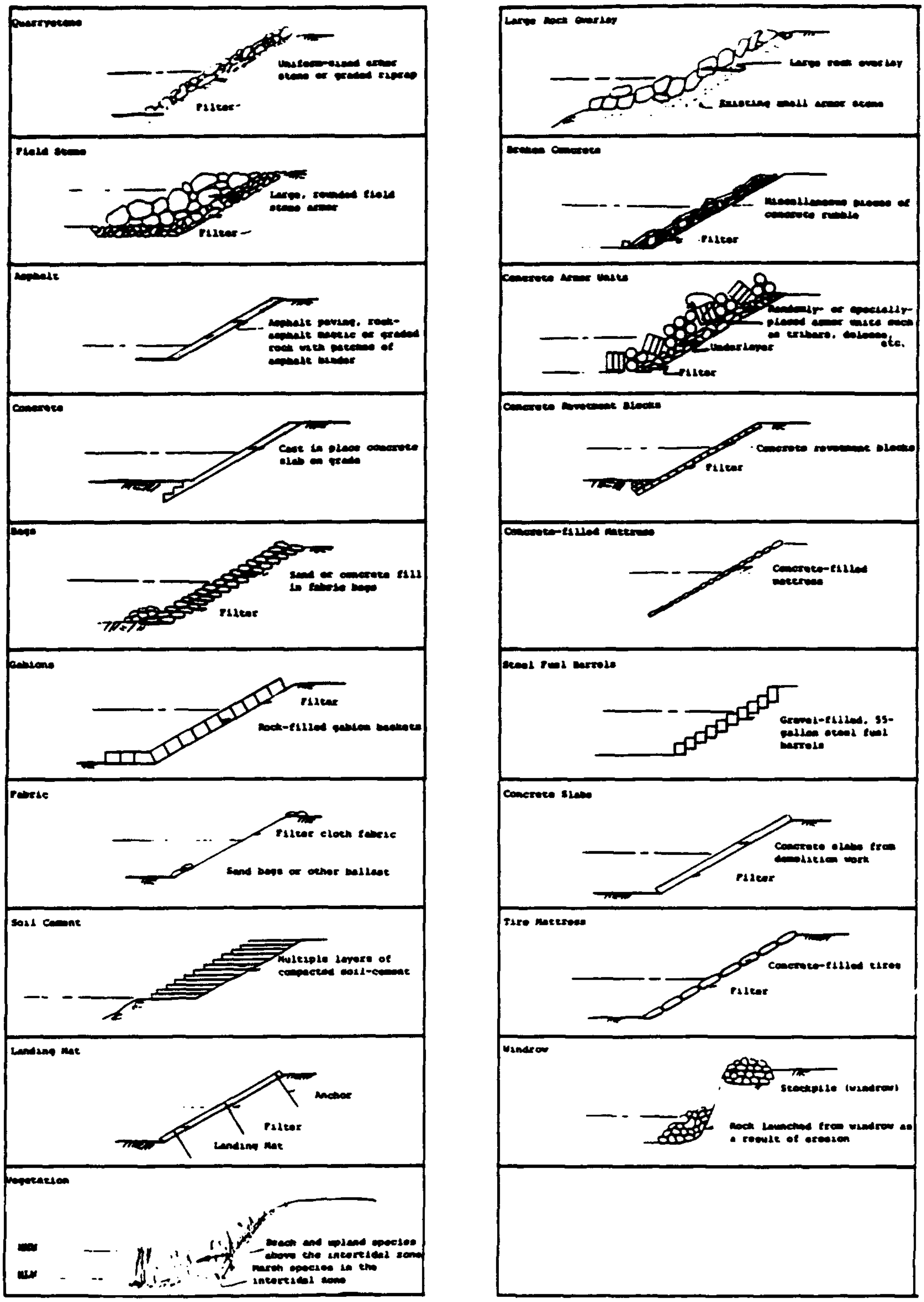

Figure 3. Revetment alternatives

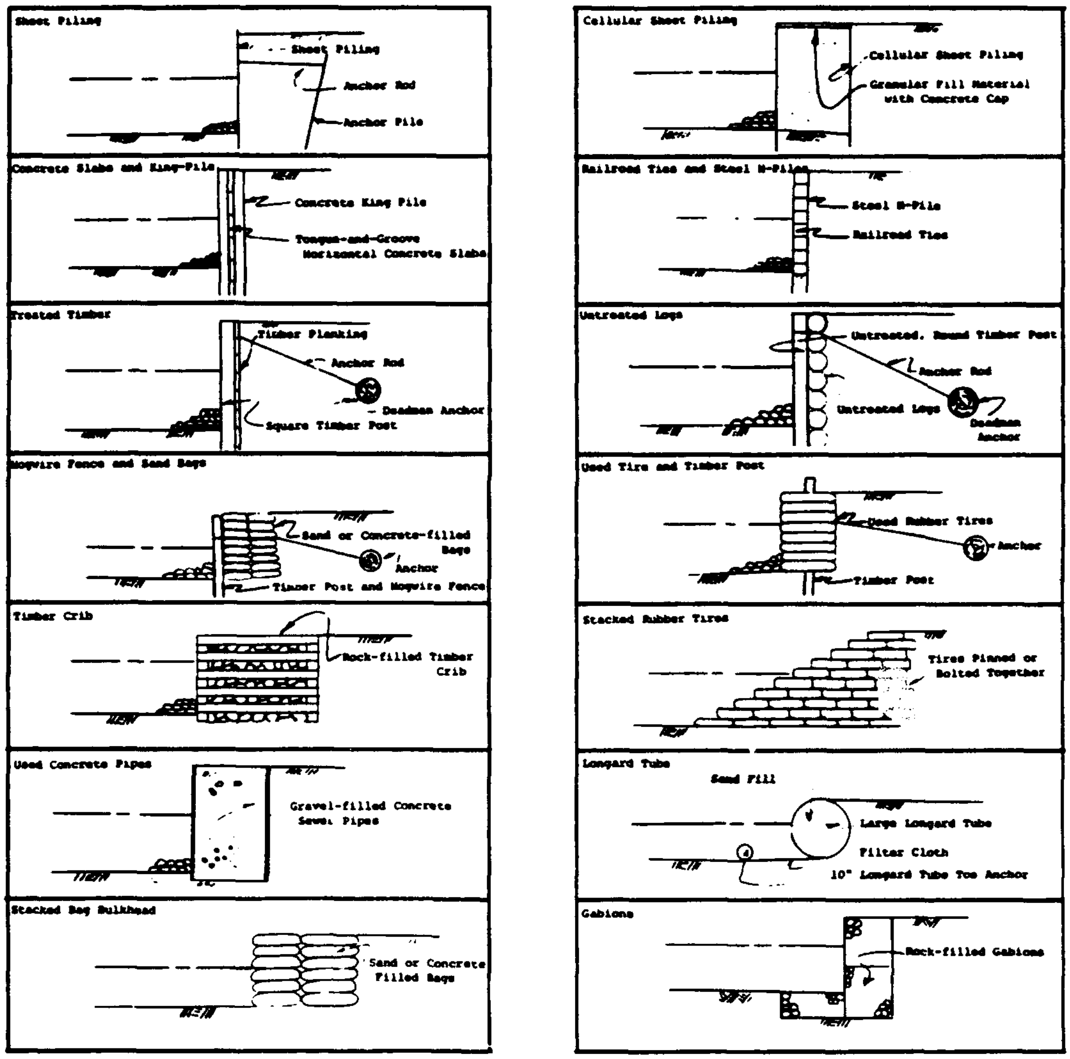

Figure 4. Bulkhead alternatives

IMPACTS OF SHORELINE EROSION AT BUREAU OF RECLAMATION FACILITIES

Joseph K. Lyons and David W. Harris[1]

Introduction

The Bureau of Reclamation (Reclamation) has the primary Federal responsibility for the development and management of water supply and hydropower projects in the 17 western states. Since 1902, 348 Reclamation reservoirs have been constructed in the western United States (Figure 1). In total, these reservoirs contain approximately 13,000 miles of shoreline, a distance nearly comparable to the Gulf Coast shoreline of the United States. Most of these reservoirs are administered through Reclamation's Operation and Maintenance program. The management of the shoreline and surrounding lands of reservoirs is coordinated through this program by Reclamation project, regional, Denver, and Washington offices.

Reclamation Programs

No special or separate program is maintained within Reclamation for shoreline erosion control. In addition to Operation and Maintenance, four other programs are established within Reclamation: (1) General Investigations, (2) Construction, (3) Other Agency, and (4) Internal Operation and Administration.

The *General Investigations Program* deals with planning studies and generally does not deal directly with operating projects.

Construction funds are used to fund construction of new projects. However, in addition to construction, this fund helps support the Research and Laboratory Services Division. Within that Division, a few studies of reservoir shoreline stability have been initiated. Erosion, causes and effects of landslides, and other topics have also been studied.

Other Agency funding is used in a myriad of activities in support of work ongoing outside of Reclamation. Although this fund source could be used for reservoir studies, such applications are not common.

Internal Operation and Administration funds are used in support of ongoing projects and are the predominant source of funding associated with reservoir facilities.

The Operations and Maintenance Program

The Reclamation Operation and Maintenance program is divided into four distinct priorities. The descriptions for the levels of priority provide for: (1) funding of critical activities which, if not performed, would prevent the operation of facilities; (2) funding of

[1] Bureau of Reclamation, Denver Office, Denver, CO.

Figure 1. The 17 western states for which the Bureau of Reclamation has the responsibility of development and management of water supply and hydropower projects. The locations of two case studies of shoreline erosion control sites are shown.

necessary activities to maintain a minimally effective level of support and operation of facilities; (3) adequate funding to provide a reasonable level of service over a sustained period of time; and (4) funds to increase the benefits associated with operating projects. Priorities are established at project office and regional office levels using these definitions.

Functional areas of concern within the Operation and Maintenance budget are existing structures, land resources management, overall program management, optimization of available resources, power program needs, administration of Reclamation Law, water management and conservation activities, water management programs, and drought contingency. Reservoir shoreline erosion problems and work activities can be addressed in a number of ways within these functional areas depending upon the priority established for the project and the availability of funding.

Impacts Associated With Reservoir Shoreline Erosion

Problems occurring as a result of shoreline erosion include: loss of property, increased sediment loads, landslide initiation, impingement on structures or cultural resources, safety issues, and many other concerns.

Shoreline erosion at Reclamation reservoirs ranges from negligible to severe and is the result of several variables at each site. Likewise, the importance of shoreline erosion control is not the same for all reservoirs. At many locations, erosion is of little significance and no structural or cultural features are threatened. Conversely, valuable farmland and archeological sites are threatened at some locations while environmental concerns are paramount at other reservoirs. In these instances, erosion control measures are necessary to protect the threatened features.

At several Reclamation reservoirs, shoreline stabilization is being implemented to control erosion and protect the adjacent resources. The following examples demonstrate the range of activities at Reclamation facilities and document the success and failure of the various treatments.

AMERICAN FALLS RESERVOIR
Minidoka Project
Burley, Idaho

Background

American Falls Dam was reconstructed in 1978 and forms a reservoir 22 miles long in the Snake River Valley in southern Idaho (Figure 1). Reservoir capacity is about 1.7 million acre feet over 58,100 acres of surface area. There are about 100 miles of shoreline at the full pool elevation.

Erosion Control Methods

The erosion problem at American Falls Reservoir is variable from site to site with the maximum rate of bank line recession measured at about 6 ft per year. A considerable amount of farmland adjacent to the reservoir is threatened by erosion. Since 1985 about 14 miles of shoreline have been protected. A similar amount of shoreline protection is anticipated in the near future. Reservoir operations have been changed during normal runoff conditions to hold the water surface elevation below the erosion control treatment level until the ice cover is diminished to prevent damage due to ice shove.

The majority of the protected shoreline has been completed using riprap dumped on a prepared slope to a depth about 10 ft below the normal reservoir elevation. This method has been effective in preventing further erosion at about 90 percent of the treated sites. The rock for this method is available locally from the abundant basalt flows near the reservoir and is a well graded, durable material. A 2- to 4-ft-thick layer of rock is applied over a geotextile material on a 3:1 slope. The slope extends about 4 ft above high water, allowing sufficient freeboard for waves generated by most storms.

Considerable earthwork may be necessary at some sites to prepare the bank line for treatment. Typical preparations include: sloping of the cliff to remove undercut material and provide fill for building a pad at the base of the cliff, building the pad and roadway to accommodate equipment used in placing riprap, and constructing the protected slope and the key trench at the bottom of the slope. Maintenance of these revetments is frequently necessary 1 to 2 yr after construction. Typical maintenance requirements include replacing rocks washed down slope either by placing additional riprap or using a long-boom excavator to pull the rock back up the slope.

Smaller, rounded rock has also been used in conjunction with wooden posts and wire mesh at two locatious on American Falls. The initial construction cost was similar to that of the mass riprap treatment but the durability of this treatment is less than mass riprap protection. No further use of this method is contemplated.

A third method involving the use of wooden posts and old automobile tires has also been attempted. This method was applied in a jetty configuration and a breakwater setting with some success in protecting the adjacent shoreline. However, these installations are subject to damage from ice shove and represent no cost savings relative to the mass riprap treatment.

AUDUBON LAKE
Garrison Diversion Unit
Missouri-Souris Projects Office
Bismarck, North Dakota

Background

Audubon Lake was created in 1953; it is a subimpoundment of Lake Sakakawea located on the Missouri River in west central North Dakota (Figure 1). Since 1956, the northern part of Audubon Lake has been managed by the North Dakota Game and Fish Department (Department) as the Audubon State Wildlife Management Area, while the southern part is administered as a National Wildlife Refuge by the Fish and Wildlife Service (Service). Audubon Lake covers approximately 18,000 acres and contains over 195 islands. Reclamation's Snake Creek Pumping Plant controls the elevation of the lake which will act as the forebay for the McClusky Canal portion of the Garrison Diversion Unit Project.

In 1967 the surface elevation of Audubon Lake reached 1,835 ft mean sea level (msl). The elevation was maintained in the 1,832- to 1,835-ft msl range until the completion of the pumping plant in 1975. The lake level was then raised by pumping to about 1,848 ft msl where it remained until 1988. As the level of Audubon Lake rose from 1,835 to 1,848 ft msl, approximately 700 acres of islands were inundated. Shoreline erosion caused an additional loss of about 100 acres of islands between 1976 and 1987 when 41 islands disappeared.

Beginning in 1988, a new operating plan for the lake was instituted. In the spring, Audubon Lake is restored from the winter level of 1,845 ft msl to an elevation of 1,847.2 ft msl. After the spring fish spawning season, the elevation of the lake is allowed to recede to the 1,846.8- to 1,847.0-ft msl range for the rest of the summer. In the fall, the lake level is lowered to about 1,845 ft msl in preparation for winter. This plan was formulated and carried out with the cooperation of the Service and the Department to sustain wildlife, fish, and recreation values while reducing the rate of erosion at the remaining islands.

Erosion of the islands within the lake threatens valuable habitat for nesting waterfowl. Because these islands are predator-free, nesting success for waterfowl is much higher there than for the surrounding area. The Service estimates that 1 acre of island habitat is equal to about 80 acres of prime upland nesting area in the Audubon Lake area.

Shoreline erosion rates on these islands have been estimated to be as much as 10 ft per year. Beginning in 1989, erosion protection measures were proposed for several islands in Audubon Lake. The erosion protection plan includes the water level management described earlier. The design of individual shoreline erosion control features had to meet biological, environmental, and engineering criteria to be considered for use at Audubon Lake. The involved agencies sought a compromise for fishery, recreation, waterfowl production, and economic considerations in preparing the pilot program for testing various engineering designs for erosion control.

Collection of the site design data for the pilot study was conducted by Reclamation. Working with a consulting engineer, Reclamation proposed the design erosion control structures which were reviewed and approved by the other agencies. Construction management and monitoring was also done by Reclamation in conjunction with personnel from the Service. To minimize disturbance to nesting waterfowl, most construction was done during the winter using the ice cover as a surface on the lake for transporting material out to the construction sites.

Erosion Control Methods

As of October 1992, eight of the most affected islands in Audubon Lake have been treated. The selected erosion control methods include: breakwaters, groins, revetments constructed of riprap, gabion baskets, cellular confinement material, articulated concrete blocks, sandbags, and sheet piling. These treatments have been applied over a range of shoreline aspects, depending upon the maximum effective fetch length for each site. Also, the offshore slope, height of the eroded bank, and the availability of material for each treatment are factors in the selection of a treatment method.

Two breakwaters have been constructed at Audubon Lake, one using modified concrete arch pipe culverts and another constructed of concrete boxes. The concrete culverts have notches in the top of the pipe to allow flow into the pipe and are installed over a filter fabric and gravel bedding. Pipe sections are connected together with steel rods to create 24-ft lengths of breakwater separated by 16-ft gaps. This design provides a waterfowl resting area in the quiet water zone on the lee side of the breakwater. Additionally, the interior of the pipe probably provides some fishery habitat and beavers have also been observed in the interior of the pipes.

The concrete box breakwaters are emplaced over filter fabric, backfilled with sand, and protected at each end with a gravel apron. Sandbags are also used beneath a surface layer of topsoil seeded with native grasses to provide protection from overtopping waves. These boxes were used as nesting areas for waterfowl during the first season following construction and the quiet water in the lee of the breakwater was used by the waterfowl broods. The gravel aprons at both breakwater installations provide a fish spawning habitat.

The groin trial was installed to interrupt the longshore current at a shoreline oriented almost due north. The prevailing northwest winds made this an ideal test case for building beach deposits with groins. The structures were fabricated from gabion baskets placed on filter fabric over a leveled subgrade. The groins are about 30 ft long and are spaced at 120-ft intervals along nearly 600 ft of shoreline. Some shoreline accretion has been observed in the lee of the groins.

The revetment treatments at the eroding island margins have provided an opportunity to evaluate the effectiveness and suitability of several methods. Except for the use of driven sheet piling, the eroding slope required regrading prior to placement of the control structure. Suitable material for riprap protection is not readily available in the work site area. Rock was hauled a distance of 60 miles for use in the riprap test site at Audubon Lake. However, from an aesthetic and waterfowl habitat standpoint, riprap is not the most desirable material for island shoreline protection at Audubon Lake.

The cellular confinement system required filter fabric placement, slope grading and compaction, placement of the cellular grid material, and filling of the cellular material with crushed rock. The articulated concrete revetment mat required filter fabric placement, slope grading and compaction, and interlocking of individual panels. Likewise, gabion mattresses required filter fabric placement, slope grading, gravel placement, gabion filling and packing, and interlocking of gabion basket. The one exception to winter construction was filling of the large sandbags used in a revetment test case. The bags were hydraulically filled in the spring after ice-out using materials stockpiled on the island during winter.

The sheet piling application was accomplished on the existing grade during the winter with equipment transported across the ice cover. The top of the sheet piling was set to match the anticipated bank sloughing behind the piling.

Riprap was piled at the ends of the sheet piling test section to prevent erosion and shoreline recession at these points.

Six more islands are scheduled for treatment in 1993 at Audubon Lake. The erosion control methods described in this paper appear to be the most suitable for use at Audubon Lake and will be applied at the sites to be treated in 1993.

Summary

The case studies described here demonstrate Reclamation's response to the impacts caused by shoreline erosion at Reclamation's reservoirs. A wide range of engineering, environmental, cultural, and biological issues can arise when shoreline erosion abatement is considered. These same issues also impact the total cost of erosion abatement as design and construction must be tailored to meet these needs. As Reclamation's role as a resource management agency expands, shoreline erosion control at agency facilities will continue to be of interest. This expanded role will continue to be reflected in Reclamation programs.

QUESTION: What kind of cost ranges are these options?

MR. LYONS: I don't have the per foot costs but they ranged from $25,000 to $35,000 per stabilization. That's why the long-term analysis is being done to see if there is a tradeoff between protecting the island or mitigating the eroded loss on upland habitat.

QUESTION: The pool is kept very stable?

MR. LYONS: The Garrison diversion unit of the project has not come on line yet but the pumping plant project allows filling of the pool to meet the design elevation of the entire project. That elevation has been backed off from a little bit during the summer because the project dimensions have also increased. In wintertime, the elevation is drawn down further to keep ice away from the islands' shores. That has been a very effective and important part of the erosion control at Lake Audubon. It has involved quite a bit of negotiation between all parties involved.

QUESTION: Does the Bureau have any monitoring program to find out how effective the erosion control has been?

MR. LYONS: There is monitoring built into the program at Lake Audubon. The first season of monitoring has just been completed.

COMMENT (DR. REID): In 1983, I compared Audubon and Sakakawea, as a preliminary stage in erosion mechanisms. As you indicated, that winter ice shove was disastrous at that time. It just weakened the banks.

MR. LYONS: That was mostly the result of maintaining the high water level year-round. Now that we've backed off from that, erosion rates have decreased dramatically.

QUESTION: What is the size of the concrete pipe you use?

MR. LYONS: It's a concrete arch pipe. I think it's about 3 ft high.

QUESTION: Has your agency done any broad estimates of shoreline loss?

MR. LYONS: No, we don't have any general information on all Bureau of Reclamation facilities. I've heard from people from many different regions and areas and they indicate that this is a broad problem that is not dealt with very much because of funding considerations. Another issue comes up in regard to cultural resources along eroding shorelines. In California, there has been work done to try to protect historic and cultural resource sites; capping with concrete or excavating them and studying them and then allowing the shoreline erosion to continue. There are a lot of issues out in Reclamation that have not been brought together in any survey.

QUESTION: Is the area around Pocatello subject to tectonic activity that has affected shoreline stability?

MR. LYONS: Keith Brooks is nere from the project.

MR. BROOKS: No, that has not bothered it at all. The main area that's active is around the Yellowstone caldera. We're far enough away that we have not had any problem and unless there is a major earthquake, we would not be affected. Then, we would be concerned with the structure, not shorelines.

QUESTION: Have you ever tried any soil cement treatment in any of your areas on the upper part of the bank?

MR. LYONS: I think we have in protecting some of our cultural resource areas, with very mixed results.

SHORELINE EROSION IMPACTS ALONG TENNESSEE VALLEY AUTHORITY RESERVOIRS

Don L. Porter[1]

Introduction

The TVA is a wholly owned government corporation which was established by Act of Congress on May 18, 1933. All powers of the corporation are vested in its three-member Board of Directors, which is appointed by the President.

The TVA Act provides TVA with the flexibility to meet its responsibilities and to adopt the methods of successful private as well as public enterprise. The Board decides upon major TVA programs and establishes organizational and administrative procedures to implement them.

From the financial standpoint, TVA programs fall into two categories. One is the power program, which is financed by the ratepayers. TVA's nonpower programs, including flood control, are funded by congressional appropriations as a part of the Federal budgetary process.

The Tennessee River watershed covers about 41,000 square miles and lies in portions of seven states - Alabama, Georgia, Kentucky, Mississippi, North Carolina, Tennessee, and Virginia. The watershed contains an estimated 42,000 miles of streams, the largest being of course the Tennessee River.

The topography of the watershed ranges from mountainous areas in the east to gently rolling in the west. The watershed is predominately rural in character with about 50 percent being forested.

TVA Reservoir System

As part of its responsibility to control destructive floodwaters in the Tennessee River watershed, TVA operates 42 dams for flood control and other purposes. The reservoir system consists of 9 dams along the Tennessee River, 32 along tributary streams, and 1 (Great Falls) located on a tributary to the Cumberland River. Great Falls was constructed by private interests for power production prior to 1933 and was acquired by TVA as a part of the purchase of the old Tenneessee Power Company. It is the only dam owned and operated by TVA outside the Tennessee River watershed.

Of the 32 tributary dams, 3 provide no useful flood control benefits since they are old (prior to 1933) power dams. Seven of the tributary dams were constructed for power

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[1] Civil Engineer, Floodplain Management, Flood Protection Section, Muscle Shoals, AL.

purposes by the Aluminum Company of America, and, by agreement, their operation is coordinated with the TVA system.

TVA reservoirs in the seven Tennessee Valley states cover more than 600,000 surface acres and have over 11,000 miles of shoreline. State and local agencies have developed public recreation areas on thousands of acres of waterfront land made available by TVA. There are 18 state parks: 3 in Alabama, 2 in Kentucky, 1 in Mississippi, and 12 in Tennessee. Counties and municipalities have some 90 public parks on TVA lake shores. Many of these are improved for boat launching, picnicking, swimming, and camping. There are some 300 boat docks, marinas, and resorts located on TVA lakes. In addition, hundreds of public access areas are scattered along the 11,000 miles of shoreline. Many of these areas have been improved with access roads, parking areas, and boat launching ramps. The unimproved shoreline of TVA lakes is generally open to the public for landing, bank fishing, hiking, camping, and hunting. In addition, the U.S. Fish and Wildlife Service operates two National Wildlife refuges and State wildlife resource agencies manage a number of wildlife and waterfowl areas. Many hundreds of miles of shoreline have also been developed for industrial, residential, or other urban purposes.

Shoreline Erosion Impacts Along TVA Reservoirs

No formal assessment of the nature and extent of shoreline erosion impacts along TVA reservoirs has been undertaken. It is, therefore, not possible to determine with specificity the economic and environmental effects of shoreline erosion along TVA reservoirs. There are, however, numerous locations where remedial measures to control the effects of shoreline erosion have been constructed by TVA, other Federal, State, or local agencies, industries, private property owners, and others. There have also been undertaken by TVA, in partnership with others, demonstration projects at selected locations to address shoreline erosion problems.

While no detailed shoreline erosion assessment has been undertaken, based on information at hand and personal observation the principal cause of shoreline erosion along TVA reservoirs is wind- and boat-driven wave action. Other contributing factors include tailwater shoreline erosion by high streamflow velocities during flood discharges, unrestricted cattle access to reservoir shorelines and tailwater areas, removal of shoreline vegetation by adjacent property owners, and impacts from rapid water level drops in tailwater areas due to turbine shutdown.

The principal categories of impacts due to shoreline erosion are (1) loss of riparian vegetation, (2) degradation of shoreline wetland areas, (3) loss of lawn areas and shade trees and damage to private docks in residential areas, (4) loss of or damage to archaeological or historical sites, (5) degradation of aquatic habitat including potential sediment damage to spawning areas, (6) damage to public recreational facilities such as boat launching ramps, picnic shelters, and camping sites, (7) loss of riparian land mass due to bank caving and sloughing, (8) damage to public water intake structures and shoreline roads, and (9) damage to or loss of campsites and cabins in tailwater areas.

Agency Response to Shoreline Erosion Problems

For many years the problem of shoreline erosion along reservoir and tailwater areas was generally neglected by TVA. It was more or less regarded as something to be expected, and problem areas were treated only if the erosion posed a threat to a TVA facility. Local government, industries, marinas, resorts, and individuals were expected to take actions on their own to solve shoreline erosion problems affecting them. These actions normally involved the placement of riprap, construction of walls, or installation of breakwaters and were permitted by the agency.

In recent years, TVA has taken a new look at the shoreline erosion problem along its reservoirs as a part of its stewardship responsibilities. The loss of or damage to archaeological or historical sites has resulted in protective measures being installed at several locations.

At other locations, TVA has worked with other agencies and property owners to implement demonstration shoreline erosion control practices intended primarily to evaluate simple low-cost techniques which could be undertaken by individual property owners.

The loss of riparian vegetation, degradation of shoreline wetland areas, loss or degradation of aquatic habitat, and water quality impacts due to shoreline erosion have resulted in the recent development of a policy proposal concerning protecting shoreline wetlands and riparian habitat management. The proposed policy is currently undergoing review by various TVA programs.

As a part of TVA's new Clean Water Initiative, strong emphasis will be placed on cleaning up sources of water pollution in the Tennessee Valley. River Action Teams will be formed to develop comprehensive watershed water quality improvement plans and projects for tributary streams where pollution sources are contributing to water quality problems in the reservoirs along the Tennessee River. Treatment of nonpoint source pollution problems such as shoreline and streambank erosion will logically be an element of such plans and projects.

QUESTION: You mentioned that a policy on streambank and shoreline erosion is under review. What is the content of the policy? You showed a number of alternative solutions that you tried, but only one seemed effective—riprap. Is that the general scope of what you found or were some alternatives effective in some locations?

MR. PORTER: Basically, the problem is we haven't done a whole lot and what we've done has been fairly piecemeal. As far as the agency taking advantage of the Corps shoreline demonstration project back in the 1970s, we opted not to participate for reasons I don't understand. Consequently, we have not done a lot of the more nontraditional, light touch treatments.

The branch-fence wave barrier was successful. We did 500 ft for a cost of about $2,500, so its economical. Its something the landowners can do themselves without a great deal of difficulty. There are several other techniques, for example, the willow-post technique.

Our problem in recent years has not been that we've not been willing to do anything. We've had a lot of ideas that have never been funded because our budget has been relatively static for the last 5 or 6 yr. A lot of TVA programs have been targeted for elimination by OMB, mine being one. We simply have not had the financial resources to attempt a significant number of these treatments. We're hoping that this situation will change with the emphasis that's being placed on the nonpoint pollution aspect in each state.

We have a new clean water initiative that has been blessed by our board. It offers the best promise of funding for doing shoreline erosion control work that we've had in the last 15 yr.

We really don't have a track record that we can draw upon. We're lucky the Corps fronts for us because you guys have done a lot more than we have in terms of shoreline erosion. Most states can't afford it.

There are places I'm familiar with where landowners have gone to SCS to develop plans for erosion control to protect eroded shoreline. It winds up with the landowner facing a cost of spending $15,000 to $20,000 to riprap a stretch of eroded shoreline to protect 2 acres of land worth $500 an acre. It is simply not cost-effective to do these kinds of things. We've got to come up with treatment methods that work reasonably well and are cost-effective to the point that they are attractive enough to hit the ground.

Its been estimated that in one tailwater reach in Hardin County along the main river that the riprap would cost $5 million to $10 million per mile. There are 110 miles of riverbank in that county. Obviously, that's not going to do it.

QUESTION: One of the earlier comments made by more than one person was that we've got to know what doesn't work, as well as what works. What about that 18-month experiment? What happened there?

MR. PORTER: That's the 18-month experiment with fibre-form mattress that we tried. That was located in the outside of a bend in a tailwater area where there were high velocities. It was adjacent to the main channel and we had a lot of wave action from barges, in particular, and pleasure craft. It was a popular water-skiing area.

The straw that broke the camel's back on that one is a barge operator came up through there one night and he decided that the bend would be a nice place to rest his barge for the night—against the mattress. He cracked it with his barge. That allowed it to be undercut and the next high water simply carried the thing away. So our message is that anything you try to do, be careful. I think it would have failed anyway from undercutting but that hastened the process. That piece right there cost $7,500 to install back in 1979.

QUESTION: You showed an example of a floating breakwater. What is that made of?

MR. PORTER: That is the floating island technique that was developed in Germany. It is made of triangles of PVC pipe, about a foot in diameter, interlocked with cables and capped at the ends, so it would float, and then connected with cables. Those triangle element links are about 8 to 10 ft. You suspend a fabric filter between them and then put water-tolerant vegetation on top of that and take it out and anchor it. Those provide enough benefits of a breakwater and enhance fisheries habitat.

QUESTION: Do you know its cost?

MR. PORTER: In gathering information for the slides, I was told that it was something we could not do a lot of because it was expensive. In comparison to riprap, I imagine it would be fairly cheap.

QUESTION: On that archaeological site you showed protected with brush-fence wave barrier, how long has protection been there? Has it worked?

MR. PORTER: Its been there over 5 yr and it's worked. It's been submerged to depths of 12 ft during flood stages without significant damage. The fence has to be well anchored. We used parallel fences 18 in. apart, packed cedar brush in between with wire on top so it wouldn't float. We have used that technique with success along streams in the Tennessee valley to help landowners. It is fairly inexpensive and it works very well.

TAKING AN ECOLOGICAL APPROACH TO RESERVOIR SHORELINE EROSION

Jim Golden[1]

Thank you for the opportunity to speak from the perspective of the Forest Service (FS) on the problems of reservoir shoreline erosion. I will present a brief example of a shoreline management problem in a National Forest, and explain an emerging strategy for developing effective, long-term solutions. The FS manages a total of 191 million acres in the National Forest System. This includes approximately 7 million acres of riparian areas amounting to over 400,000 miles of stream and shorelines. Within the National Forests we have over 3,000 reservoirs.

What is the extent of the shoreline management problem in the National Forests? We don't know! Our goal is to inventory all riparian areas, and assess condition, by 1995. But we do know that shoreline erosion is a significant problem on National Forest lands. And the effects that we see include:

- Deterioration of water quality and aesthetics
- Degraded recreational experiences
- Impacts to fisheries and wildlife habitat
- Threats to historical and cultural sites

I'd like to use an example I encountered on a recent trip in our Southern Region.

Example: Ocoee Reservoir

Location

Tennessee, National Forest (NF) Land surrounding a TVA Reservoir. The most significant reservoir management problem is the sedimentation being produced by upstream mining activities on private land. But the problem on the NF Land is associated with recreation use, and this is becoming more common throughout the NF System, as an expanding and more affluent society seeks out the Forests to fulfill recreation needs.

Situation

The recreation sites along the reservoir are not meeting our riparian area objectives. Soil is compacted and devoid of most ground cover and shrubs, and increased mortality of trees is likely, while natural revegetation is inhibited. Soil erosion is evident and affects water quality. Fish and wildlife habitat is degraded, along with the quality of the recreational experience. And it looks terrible!

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[1] Riparian and Watershed Improvement Program Manager, USDA Forest Service, Washington, DC.

Management Goals

General goals

Goals for the management of riparian areas on the National Forests are to:

- Protect the health of riparian areas by designing activities and conducting uses to prevent the degradation. Our management activities will maintain those values that are unique to riparian areas.

- Restore 75% of unsatisfactory riparian areas and wetlands by the year 2000. There are over 1 million acres in the unsatisfactory classification.

Also, to

- Continue our active research programs
- Develop demonstration areas on all NFS units
- Advise and assist private landowners in cooperation with State Foresters and the Soil Conservation Service.

Specific goals

Specific goals for these sites, in my example, would be to:

(1) Restore the health of the site, which would be indicated by:

- Productive soil condition
- Adequate vegetation to meet soil protection needs, attractive appearance, habitat, and a quality recreation experience

(2) Develop a recreation management strategy that will sustain these values. This requires the understanding of the public of the problem, acceptance that there is a need to change the current use patterns, and support for any proposed changes.

The mission of the Forest Service is characterized by the phrase: "Caring for the Land and Serving People." Recently we announced a new direction for the management of the National Forests: Ecosystem Management. This means that from now on, we will be taking an Ecological Approach to Management of the National Forests. This policy was formally adopted earlier this spring, but has evolved over the last few years as a natural consequence of balancing the demands for the uses, values, and services provided by the National Forest System. Our goal is to sustain functional ecosystems while providing for the needs of the country. Our challenge is to sustain systems that are diverse, productive, resilient to short-term stress, and able to respond to long-term change.

So how does this relate to our topic? I believe that it relates to the processes and the methods we use in choosing our solutions. Addressing the problems associated with

Reservoir Shoreline Erosion on the National Forests must consider this holistic approach. I'd like to discuss a strategy for managing the National Forests that applies also to the task at hand.

First, let's look at the definition we use for Ecosystem Management:

Ecosystem management is defined as the skillful, integrated use of ecological knowledge at various scales to produce desired resource values, products, services, and conditions in ways that also sustain the diversity and productivity of ecosystems. There are many unique values associated with shorelines that exist, and that we can create, depending on our abilities, the capabilities of the land, and the public's needs and desires.

In order to better understand and illustrate the link between shoreline improvement and ecosystem management, I would like to discuss six principles that have been proposed for use as a framework for an ecological approach to management (Burgess et al. 1992).

Principles Proposed for Ecological Approach

Sustainability

Sustained yield management of lands and resources depends on maintaining the diversity and productivity of ecosystems at multiple geographic scales.

The *key criteria* for sustainability are maintenance of:

- Biological diversity (including genetic variation)
- Viability of ecological processes
- Productivity of the soil.

Ecosystem sustainability means that the land, water, and riparian ecosystems will be managed so that the desired mix of values and resource uses are tempered to ensure that their capabilities are not compromised for future generations.

In addition to controlling erosion associated with water level fluctuations, we need to maintain stability of the shorelines by carefully managing the shoreline resources such as the soil, the native vegetation, and the air. These areas tend to be attractive for recreation use and potentially important for timber and grazing. This certainly does not mean excluding use, but that each must be managed in such a way as to maintain the unique values inherent to the shoreline environment.

At a minimum, we risk accelerating the shoreline erosion process, despite any other efforts, if we don't pay attention to managing this riparian area. At worst, we sacrifice water quality, aesthetics and recreation opportunities, cultural resources, important fish and wildlife habitat, commodity production, and all the other values that make riparian areas so valuable beyond proportion to their size.

Dynamics, complexity, and options

The natural dynamics and complexity of ecosystems mean that future conditions are not perfectly predictable and that any ecosystem offers many possible combinations of uses, values, products, and services that can vary depending on the condition and capability of the ecosystem at a point in time.

Ecosystems, at all scales, continually evolve and change over time. Fire, wind, volcanoes, floods, insect and disease infestations, and human activities constantly affect long- and short-term ecosystem structure, composition, and pattern. No alternative can produce all desired uses and values because each ecosystem has inherent opportunities and limitations based on its capabilities and resiliency requirements. Risks and uncertainty associated with our management actions are reduced if we can ensure that all biological communities are represented across the landscape.

The concept is to provide a wide range and diversity of genetic material, individual species, and communities to provide options for uncertain future conditions and needs. Consider that stabilizing the shoreline may not be enough. We can be thinking in terms of stability *and* diversity. When it's possible and reasonable, we should go beyond erosion control. Notwithstanding the fact that reservoir shorelines are a created system, we can still provide this wide range of options for the future by establishing and maintaining a variety of conditions, plants communities, and habitats. Going back to my example, the options for the future at those recreation sites will continue to diminish unless change is initiated. Also, since we lack a comprehensive understanding of some of the ecosystems that we are called upon to manage, or to "fix," we are better off if we can maintain a broad representation of species in order to ensure the widest array of future options.

Desired future conditions

Descriptions of desired future conditions (DFC) for ecosystems at various geographic scales should integrate ecological, social, and economic considerations into practical statements to guide land management activities.

National Forests are managed according to Forest Plans, mandated by the National Forest Management Act of 1976. The Plans contain direction in the form of goals and objectives for various land allocations, management standards and guidelines, and a description of the desired future condition of the Forest at some point in time. More site-specific and detailed DFC's are developed at the project planning level, usually with the watershed as the basic planning unit. DCF's are established based on ecological, social, and economic considerations. The description may include the general composition, structure, pattern, and diversity of vegetative species; the conditions applicable to other important components of the ecosystem; and the mix of public values and uses, which is the human component.

As an example, at our recreation sites on the Ocoee Lake, the DFC could include the number and species of trees, by size class, that we wish to maintain over time, and the amount of exposed mineral soil that may be acceptable. It may also include the amount of people to be accommodated daily at each site, or the type of recreation facility to be provided. DFC's may also include other expressions of scenic quality, fish or wildlife habitat parameters, etc.

The establishment of DFC's provides a common ground for people to work out differences based on end results that collectively provide for all values rather than focusing on the means to get there or on a single species. Basically, it is important to know where you're going in order to chart a course to get there. When we talk of going beyond solving shoreline erosion, we need to establish our goals for the use of the area where the water meets the land. We can establish a goal for a stable shoreline, but also provide for the other uses and values that are desirable, complementary, and within the capability of the land.

Connections and coordination

Ecosystems are connected across administrative, ownership, and jurisdictional boundaries. Cooperation with others and coordination of goals and plans are essential.

Ecosystems do not have absolute or permanent boundaries. Things move around, in, and between them over space and time. Every ecosystem is the subset of a larger one. They change and evolve in response to both people's influence and natural events. We deal frequently with overlapping or adjacent jurisdictions among government agencies and with private property owners. The effects of any management activity may go beyond our boundaries, so positive coordination and cooperation are required.

The benefits of coordination extend beyond simply avoiding litigation or bad feelings. We are finding that cooperation and the development of partnership arrangements lead to sharing of resources more efficiently toward our common objectives. In fact it requires us to examine and compare our objectives! And a synergistic relationship develops that can create momentum. Many of you are probably aware that partnerships are becoming the rule rather than the exception (in the FS), improving public relations and increasing the effectiveness of scarce federal dollars.

Integrated data and tools

Ecological classifications, inventories, data management, and analytical tools should be integrated to support management of lands and resources.

The Forest Service is currently working on integrating an ecological inventory that ties together information needs across resource areas. And it is an ambitious thought, but to truly integrate our ecological data, we need to be able to share that among all land managers.

Integrated management and research

Research should be integrated with management to continually improve the scientific basis of ecosystem management. Because ecosystems are complex and dynamic, there will always be uncertainty in our predictions of how they will respond to management. The uncertainties are greatest at the larger ecosystem scales such as watersheds and landscapes.

Given these uncertainties and new approaches envisioned in ecosystem management, it is essential that we capture information through the process of "doing" ecosystem management as well as through conventional experimental research. In other words, we must learn as we go--a process known as adaptive management.

In summary, I believe that these six principles of Ecosystem Management represent an effective, long-term strategy to solve problems such as reservoir shoreline erosion. Taking an ecological approach to managing shorelines may provide for a more holistic relation to the land beyond the shoreline, and greater benefits for those who use and value National Forest riparian areas.

I thank you for your attention, and I hope that I have provided you with a link between solving shoreline erosion problems and an ecological approach to management, and at the same time given you some insight into some exciting changes going on in the Forest Service.

Reference

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WAVE DAMAGE TO FLOODWATER RETARDING DAMS, THE SOIL CONSERVATION SERVICE PERSPECTIVE

O'Gene W. Barkemeyer, PE[1]

The Soil Conservation Service (SCS) has been constructing dams for nearly 60 yr. The largest number of these are low earth-fill dams built on private land to impound small volumes of water for livestock and other domestic uses. Generally, these experience no significant shoreline or embankment erosion damage.

In 1944 the Congress passed the first of two bills that authorized the SCS to plan, design, and construct flood prevention measures. The first, PL-534, Flood Prevention Act of 1944, and the second, PL-566, the Small Watershed Protection Act of 1953, propelled the agency into the business of constructing floodwater retarding dams. Since the late 1940's more than 10,000 of these dams have been constructed nationwide.

These floodwater retarding dams are built in cooperation with local units of government, which are responsible for obtaining all landrights and easements and performing all operations and maintenance. Most of these dams are single-purpose flood prevention and are small to intermediate in size. Water stored between runoff events is incidental to the sediment storage pool.

It is in the vicinity of the sediment pool elevation that shoreline erosion occurs on the embankment. Erosion of the reservoir shoreline is minor in nature. While erosion can occur at higher elevations on the embankment front slope during any given storm event, well-established, self-healing vegetation generally withstands the wave attacks. Routine maintenance will restore such conditions to original neat lines. However, the most persistent, long-lasting wave attack occurs within plus or minus 2 ft of the crest of the principal spillway or of the lowest ungated outlet.

The earliest low-hazard single-purpose floodwater retarding dams were constructed with limited special embankment shoreline protection. They were built with either a 3:1 vegetated front slope (predominantly Bermuda grass) or a level or gently sloping 12-ft-wide sacrificial earthen berm at or near the sediment pool elevation. In many instances neither treatment provided long-lasting protection to the dam.

The first major embankment shoreline erosion problems became an agency concern in the late 1960's, after 20 yr of operation. The approach then was centered around both treatment and prevention. Early treatment followed the same principle as early-day construction; namely, low cost, simple but with a heavy maintenance responsibility. This approach frequently called for a reconstruction and revegetation of the front slope and/or wave berm.

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In 1974 the SCS published Technical Release No. 56, "A Guide for Design and Layout of Vegetative Wave Protection for Earth Dam Embankments." This guide provided a low cost, medium height, high density, multispecie vegetation to combat wave energy generated from a 1.5- to 2.0-ft-high wave from an effective fetch length up to 2,500 ft. After a brief trial period using several different species of vegetation, the combination of common reed and switchgrass became the standard treatment as well as prevention on dams in Texas beginning in the late 1970's. This guide continues to provide a cost-effective treatment within applicable conditions. SCS in Texas limits the use of this treatment for control of wave erosion to sites on which the effective fetch is less than 1,500 ft.

The cost to repair an existing front slope using this vegetative technique is about $15 to $20 per foot, which includes reconstruction of a wave berm, plant materials, fertilization, irrigation, fencing, and labor. An average dam costs $15,000 to $25,000 to repair.

The cost to provide a new dam with a similar vegetative treatment is about $5 to $10 per linear foot of shoreline protection. An average new dam costs $7,000 to $12,000 for wave protection.

Where site conditions prohibit the successful use of common reed and switchgrass, various armor plating techniques have been employed—rock riprap and soil cement. The use of rock riprap on single-purpose floodwater retarding dams was also begun in the late 1970's. As a design consideration, SCS in Texas began experimenting in 1970 with thin layered soil cement as protection against wave damage in those parts of the state where vegetative protection could not be established and where a local source of rock was not available.

In 1983 the SCS published Technical Release No. 69, "Riprap for Slope Protection Against Wave Action." This technical release provides the design procedures and criteria for rock used as riprap protection against deepwater wave action. These procedures are intended for use with dams and reservoirs receiving SCS technical assistance. Generally, these have an effective fetch less than 10 miles and significant wave heights less than 5 ft.

The majority of single-purpose floodwater retarding dams on which rock riprap is the erosion control treatment consists of a rock blanket placed approximately 2 ft below and 4 ft above the normal pool elevation. It generally consists of dumped riprap from 3 in. to 16 in. in diameter with appropriate gradation, thickness, bedding, and filter.

The cost to repair a severely eroded front slope with rock riprap can range from $45 to $65 per linear foot. The cost to provide rock riprap slope protection on a new floodwater retarding dam will range from $30 to $50 per linear foot.

What is the magnitude of the embankment erosion problem on SCS-assisted floodwater retarding dams in the United States? It is estimated that approximately 700 dams are in need of slope repair. Based upon the Texas experience, about 75% of these will require rock riprap treatment, while the remainder can be treated with special vegetation. Again, using Texas construction costs, about $40 million are needed to repair these dams.

These floodwater retarding dams are an integral part of our nation's small watershed flood-control infrastructure. None of these dams have reached their economically evaluated life. Timely repair will not only help to provide the planned benefits, but also continue to provide flood control well into the future.

QUESTION: Regarding your use of common reedgrass or switchgrass, would that limit any inspection of your dams for slump holes, and wouldn't it encourage population of burrowing animals?

MR. BARKMEYER: As this is on the front slope, I don't see any problem with burrows. Beavers like common reedgrass, so wherever you've got water flowing, they tend to cut that and then close up the principal spillway. So you have to consider that. On dam safety, I have not observed it because most of it stays within a 4-ft vertical distance, 3 ft below and 4 ft above the water surface. Both plants are water tolerant. Switchgrass likes it on the drier side.

QUESTION: What size wave do you expect that to protect against?

MR. BARKMEYER: One to two feet. Two feet on the higher side. While our technical guide says 2,500-ft effective fetch, in Texas we've found 1,500 to 2,000 ft to be about maximum. So that goes back to a little lower wave height. I think we figured that on about a 50-mph wind, with that being more or less a perpendicular attack on the shore.

THE COSTS ASSOCIATED WITH SHORELINE EROSION ON ILLINOIS LAKES AND RESERVOIRS

Gregg Good[1]

Abstract

The State of Illinois has approximately 3,000 inland lakes and reservoirs which provide a variety of uses and benefits to its general citizenry. Unfortunately, a number of these valuable resources are degrading, in part, because of impacts associated with shoreline erosion. A Statewide Lake Needs Assessment, conducted in support of development of the Illinois Lake Management Program Act—Administrative Framework Plan, estimated shoreline erosion/stabilization costs associated with 182 lakes at $22.2 million. When extrapolated, associated costs on a statewide basis exceed $161 million. Without enhanced state and/or federal program funding, and expansion of private or locally funded control programs, future statewide erosion control costs will undoubtedly rise above the currently assessed level.

Introduction

As the State's designated water quality management agency, the Illinois Environmental Protection Agency (IEPA) has conducted a comprehensive lake management program since 1977, involving such activities as ambient and volunteer lake monitoring, technical and educational assistance, and state administration of the Federal Clean Lakes Program. State "sister" agencies, including the Illinois Departments of Conservation (IDOC), Agriculture (IDOA), Energy and Natural Resources (DENR), and Transportation-Division of Water Resources (IDOT-DWR), have also had long-standing roles in lake protection and enhancement regarding issues such as fisheries and watershed management, lake assessment and research, and dam safety investigations. The Illinois Lake Management Association (ILMA), formed in 1985, also promotes the protection and restoration of lakes and encourages support and development of local, state, and national lake and watershed management program initiatives.

After being passed into law by the Illinois General Assembly, the Illinois Lake Management Program Act became effective on January 1, 1990. The Act required the Agency to work in consultation with the agencies and organizations mentioned above, in order to develop an "Administrative Framework Plan" (AFP) (IEPA 1992a). The plan was to serve as a blueprint for the administration of enhanced State programs in public education, technical assistance, monitoring and research, and financial incentives, all of which address comprehensive lake management. The Act also required the development

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of a plan which would present the financial resources necessary to implement the above programs over a 5-yr period.

Development of the AFP required the agencies to take a closer look at the benefits lake resources provide to the Illinois economy, the causes and sources of lake-related problems, and the costs associated with improving lake resources. As part of this exercise, the effects of shoreline erosion and potential costs associated with shoreline stabilization on a statewide basis were examined.

Illinois Lake Resources

Illinois has nearly 3,000 inland lakes greater than 6 acres in size that provide for various uses such as water supply, fishing, swimming, boating, flood control, wildlife habitat, property value enhancement, and tourism. The majority of lakes (60%) are "impounded reservoirs" and are located in the lower two-thirds of the state. "Detention pond" (12%) and "glacial" (10%) lakes are primarily located in northeastern Illinois. Other types of lake resources include quarries, borrow-pits, and side-channel reservoirs.

Benefits

According to IDOC recreationally related use reports, over 90 million visitor days of recreational use occur on or near lakes annually, generating an estimated $1.78 billion to the State's economy. This represents nearly 70% of all recreational use expenditures on all Illinois waterbodies (inland lakes, rivers, streams, and Lake Michigan). The aesthetic qualities and recreational opportunities offered by lakes create demand for lakeside development of homes, campsites, hunting and fishing clubs, and marinas, all of which generate tax dollars. In addition, over 100 lakes serve nearly one million residents as public water supplies; others serve as cooling reservoirs for power plants, industrial water supplies, and flood control reservoirs (IEPA 1992a).

Sources and Causes of Pollution

Of Illinois' 36 million acres, 71% are used as cropland. Illinois annually ranks as one of the country's top two states in total corn and soybean production. Therefore, it is no surprise that "agriculture" and "in-place contaminants" (sediment and associated nutrients/ pesticides deposited primarily from agricultural areas) rank as the top two pollutant sources impacting Illinois lakes and reservoirs. Hydrologic modification, which includes shoreline erosion and stream channelization, has been identified as the third greatest source of lake pollution. Major causes of lake use impairment generated from these sources include suspended solids, siltation, nutrients, and organic enrichment/dissolved oxygen depletions (IEPA 1992b).

Lake Trends

Since 1972, Illinois stream resources have improved tremendously, primarily through point source pollution control programs initiated pursuant to the Federal Clean Water Act. Billions of federal and state construction grant dollars have been spent for the development of new or upgraded municipal wastewater treatment plants in order to meet National Pollutant Discharge Elimination System (NPDES) requirements and water quality standards. Unfortunately, Illinois lake resources have not experienced this same water quality trend. Because lakes are primarily impacted by nonpoint sources of pollution (including shoreline erosion), traditional point source control programs have had very limited impact on the majority of Illinois lakes. A trend analysis shows that water quality has declined in 21.7% of over 200 lakes assessed. Those lakes that have improved in water quality (11.8%) have generally had special in-lake restoration techniques or intensive watershed management projects implemented. The balance of Illinois lakes exhibit a fluctuating (53.8%) or stable (12.7%) trend.

Shoreline Erosion Causes, Effects, and Management

The causes, effects, and management of shoreline erosion in Illinois are, in most cases, similar to those found in other states. Factors which lead to or cause shoreline erosion include fluctuating water levels, easily erodible shoreline soil types, steep shoreline slopes, heavy visitor usage, lack or disturbance of nearshore aquatic vegetation and/or rock barriers, deep nearshore water depths, boat- and wind-induced wave action, and ice damage. All of these factors affect the rate and amount of shoreline erosion which will occur and cause problems such as shallowed nearshore water areas resulting in a loss of natural spawning habitat, uprooting and falling in of large trees, loss of valuable shoreline property, reduced lake aesthetics, and direct delivery of sediment to the lake. In impounded reservoirs, eroded materials contribute to already high turbidity and total suspended solids concentrations which inhibit light penetration and subsequent biological activity. Conversely, in good quality glacial lakes, eroded soil materials high in natural fertility contribute to increased nutrient concentrations which can subsequently lead to high algal productivity, dissolved oxygen depletion, taste and odor problems, and recreational use impairment.

The use of management techniques such as riprap with filter fabrics, seawalls, building block revetments, interlocking concrete blocks, gabions, hydroseeding, and vegetative stabilization have all been used on Illinois lakes with varying degrees of application and success. The majority of these practices are implemented with private or local funds. The only federal or state program which currently provides financial assistance for shoreline erosion protection in Illinois is the Federal Clean Lakes Program (Section 314 of the Clean Water Act). Such assistance is available only when a "comprehensive" lake restoration/protection program (e.g. shoreline erosion control in combination with several other lake management practices) is undertaken.

Statewide Costs Associated with Shoreline Erosion

One of the initial steps taken prior to the development of the Illinois Lake Management Program Act—Administrative Framework Plan was to conduct a Statewide Lake Needs Assessment. The purpose of the assessment was to quantify the existing restoration/protection needs associated with moderate to highly impacted Illinois inland lakes. A "Lake Needs Assessment Protocol" report (Cochran and Wilken 1990a) was developed for the Agency which outlined specific methodologies to estimate costs associated with typically applied lake and watershed restoration/protection practices for each of three lake size categories (0-100, 101-500, and >500 acres). Methodologies were developed for shoreline stabilization; in-lake management for aquatic vegetation and algae control; aeration/destratification; dredging, retention site development and reclamation; sediment basin development, fisheries management; and watershed protection and management. Methodologies were based on water quality information and data contained in the "Illinois Water Quality Report: 1988-1989" or "305(b)" Report (IEPA 1990), cost information collected from previously conducted Federal Clean Lakes Program projects, and telephone and written surveys to area lake managers.

Of the 413 lakes assessed in the 305(b) report, 182 (44%) were identified by the protocol report as needing additional lake and watershed restoration/protection measures implemented in order to improve or sustain beneficial lake uses (e.g. public water supply, recreation). Of the 182 lakes, 84 were directly assessed and the results were utilized to extrapolate restoration/ protection costs associated with all 182 lakes. The results of these lake assessments are reported in "Needs Assessment for Illinois Inland Lakes" (Cochran and Wilken 1990b), excerpts of which are discussed below.

Shoreline Erosion Assessment Methodology

Information compiled from completed Clean Lakes Program Phase I Diagnostic/ Feasibility studies, along with telephone and written surveys to lake contact persons, were used to determine average percentages of eroded shoreline for each of the three lake size categories. Results indicated that the following average percentages of eroded shoreline to total shoreline apply to the individual lake assessments: 17% for lakes 100 acres or less; 30% for lakes 101 to 500 acres; and 15% for lakes greater than 500 acres. The estimated percentages of eroded shoreline were extrapolated to all lakes in the 305(b) report with identified shoreline erosion problems. Length of shoreline values were obtained from "Assessment and Classification of Illinois Lakes—Volume II" (IEPA 1978). If the total length of shoreline was not known, a shoreline configuration equation was used to compute the length of shoreline in linear feet. Eighty percent (80%) of the total calculated length of eroded shoreline was multiplied by a $30 average cost per linear foot for riprap stabilization. The remaining twenty percent (20%) of eroded shoreline was assigned an $8 average cost per linear foot for vegetative stabilization in order to maintain aesthetic value and to provide riparian wildlife habitat (Cochran and Wilken 1990b).

Results

As shown in Table 1, the total estimated shoreline erosion/stabilization cost for the 182 lakes assessed as having a moderate to high impairment was $22.2 million. This represents only 3.9% of the overall estimated lake restoration/protection needs of $565.0 million. Of the eight different management principles/practices assessed, shoreline erosion had the fourth highest associated environmental impact. It was exceeded by dredging, retention site development, and reclamation ($375.5 M); watershed management ($104.5 M); and sediment basin development ($57.5 M) (Table 2).

As shown in Table 3, the costs associated with dredging, retention site development, and reclamation, in combination with watershed management, account for over 85% of the total restoration costs associated with the 182 lakes assessed. However, if these two management principles/practices were removed from the assessment, a more typical "in/near-lake" restoration/protection program found in Illinois would be represented. In such a case, shoreline erosion/stabilization represents over one-quarter (26.2%) of the total costs associated with lake rehabilitation projects (Table 4).

To reiterate, the results of this assessment as indicated above are for 182 of the 413 lakes assessed as having a moderate to high use impairment as reported in the "Illinois Water Quality Report: 1988-1989." If it is assumed that a similar percentage (44%) of all 3,000 Illinois lakes exhibited this level of impairment, an extrapolated estimation of statewide shoreline erosion costs can be made. As shown in Table 5, total shoreline erosion/stabilization costs would exceed $161 million.

It should be noted that many Illinois lakes with slight shoreline erosion impairment are gradually deteriorating and would benefit from ongoing implementation and maintenance of erosion control practices. Such activity could significantly delay or eliminate further shoreline deterioration and the need for major protection projects in future years. It should also be noted that the results of this statewide assessment are based solely on the methodologies developed and utilized for each lake. Any specific lake protection project should have an in-depth diagnostic/feasibility study performed in order to best determine the costs and needs of implementing shoreline stabilization or any other lake enhancement practice (Cochran and Wilken 1990b).

Conclusions

The costs associated with rehabilitating existing shoreline erosion problems in Illinois are enormous, and yet represent only a small portion of all restoration/protection costs required to maintain and improve the state's lakes and reservoirs. Because state and federal agency funding for shoreline erosion control is at best limited, private and local entities will continue to bear the majority of the burden of paying for shoreline stabilization programs. Without these programs, or an enhanced state or federal program, shoreline erosion will continue to be a major source of pollution contributing to an already declining lake and reservoir resource in Illinois. Total statewide shoreline erosion control costs will also continue to rise above the currently assessed level.

With passage of the Illinois Lake Management Program Act and subsequent development of the Administrative Framework Plan, the State of Illinois has taken a major step toward managing a growing natural resource concern. Even if enhanced comprehensive lake management program funding is not provided, passage of the Act has been extremely beneficial. The Act has made all state agencies identify current water quality problems, trends, needs, deficiencies, and public perceptions regarding inland lake resources. It has also provided a blueprint for what can and should be done to enhance and protect the economic, social, and aesthetic benefits derived from inland lakes by the citizens of Illinois.

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Table 1
Shoreline Erosion/Stabilization (SS) Costs (182 Lakes Surveyed)

Size	# Lakes	SS Cost	Total Rest. Cost	SS/Total Cost
0 -100	69	$640,000	$ 80,000,000	0.8%
101-500	67	$3,700,000	$115,000,000	3.2%
> 500	46	$17,900,000	$370,000,000	4.8%
TOTALS	182	$22,240,000	$565,000,000	3.9%

Table 2
Total Restoration Costs by Practice (182 Lakes Surveyed - All Practice Costs)

Practice	$ Million	%
Shoreline stab.	22.2	3.9
W/shed mng.	104.5	18.5
Algae control	3.0	0.5
Macrophyte control	1.9	0.3
Aeration/destrat.	0.2	0.0
Dredging, etc.	375.5	66.6
Sediment basins	57.5	10.2
Fisheries mng.	0.2	0.0
TOTALS	565.0	100.0

Table 3
Protection/Restoration Cost Distribution (182 Lakes Surveyed - All Practice Costs)

Practice	% of Total
Dredging, etc.	66.5
Watershed mng.	18.5
All other practices	15.0

Table 4
Total Restoration Costs by Practice (182 Lakes Surveyed - Excluding Dredging and Watershed Management Costs)

Practice	$Million	%
Shoreline stab.	22.2	26.2
Algae control	3.0	3.5
Macrophyte control	1.9	2.2
Aeration/destrat.	0.2	0.2
Sediment basins	57.5	67.7
Fisheries mng.	0.2	0.2
TOTALS	85.0	100.0

Table 5
Extrapolated Estimation of Statewide Shoreline Stabilization Costs

Category	Needs	Costs
Assessed lakes	182/413 (44%)	$ 22,240,000
Total lakes (extrapolated)	1,320/3000 (44%)	$161,300,000

BIOENGINEERING FOR SHORELINE EROSION CONTROL IN GERMANY

Wendi Goldsmith[1]

Background

The topic I have been asked to discuss is the history and development of bioengineering for shoreline management in Germany. I have an unusual perspective through work experience in Germany as well as the United States; I hope to emphasize some of the differences and similarities that seem educational and practical.

For many reasons, I believe Germany can serve as an example to follow in shoreline management. Basically, they are ahead of us. Much of Central Europe has higher population densities than our most heavily settled regions, and the history of agricultural and industrial land use is longer and more intensive. The resulting environmental impacts have generally forced Europeans to confront environmental issues earlier than in this country. Germany in particular has a strong cultural tendency for land stewardship. Forestry and wildlife management have been practiced for centuries in Germany; simultaneously America pioneered new habits in land consumption. With the strong economic growth of the latter half of this century and the Green political movement of recent decades, Germany has devoted considerable resources to study and implement management practices which address the environmental problems it faces.

In the United States, it makes a fair amount of sense to speak of protecting wilderness areas or other pristine resources; "protection" is also an understandable reaction to the rampant resource consumption of our recent past. But because virtually every square meter of land and water in their country has been altered by human activity, Germans have taken a fundamentally different approach than ours to managing environmental resources. The theme that dominates is not "protection," but rather "restoration." When managing areas altered by the human hand, the basic model of "protection" does not offer much guidance. Do we protect a degraded wetland from all change, including improvements? Do we abandon a shoreline constructed of fill to any form of development because it is already not a natural system?

Rather than focusing on "protection," Germany has identified critical shoreline functions and focused on their "restoration." They have drawn on the practice of bioengineering for much of their restoration along shorelines. Bioengineering techniques aid in the establishment of plant communities on sites where disturbance has caused instability. The practice brings together biological, ecological, and engineering concepts to produce living, functioning systems using plants, often in combination with other materials. For instance, in erosion control systems, leaves, stems, and roots shield and bind the substrate to prevent erosion. Systems can also be designed for water quality treatment, sediment accumulation, flood control, or to provide habitat on difficult sites. Eventually, bioengineered constructions become an integral part of the landscape. When living plants

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are impacted by a major force, such as flooding, or conditions are altered by sedimentation, plants can regenerate, adapt, or repair themselves.

Bioengineering as a Tool

Although it is common practice to use vegetation to prevent erosion, bioengineering addresses shoreline stability and sedimentation processes with a degree of complexity suited for difficult situations. As an alternative to riprap, gabions, or other forms of hard revetment, a well-designed live plant community improves erosion and water quality problems, supports the biological activity on the site, and gains strength and beauty over time. Plants are frequently better adapted to dynamic environmental conditions than inert, inflexible structures. In Germany, a collection of recent laws virtually forbids the construction of hard revetments on waterways due to the water quality degradation these structures produce. The land-water interface has enormous biological productivity, and many of the metabolic processes of shoreline plants and microbes are crucial to the functioning of the entire water body.

Bioengineering can facilitate new construction, such as shoreline stabilization on a new reservoir; or it can be used to compensate for changes in a natural system, such as shoreline stabilization on a lake which has developed problem levels of erosion due to increased impacts from high-energy boat wakes.

Evolution of Bioengineering Applications

The practice of using vegetation and other readily obtainable materials to stabilize land is of course very old. Many authors have written on the subject, with a growing body of literature available in English. The most common methods involve dormant cuttings of woody species which easily sprout roots and shoots: willow, alder, and dogwood are typical. Before the growing season begins, they are installed in the manner most appropriate for site conditions using such traditional techniques as constructing brush mattresses, brush layers, live wattles, and live stakes.

As plants become established, they control erosion in several ways. Leafy growth intercepts raindrops which commonly cause surface erosion. Stem material catches sediment which may be traveling down the slope surface. Roots reinforce soil into a unified substance, thereby protecting against deeper seated slope failure and slumping. Vegetation on slopes helps to improve soil moisture levels by tending to create moderate moisture regimes. Where soils are droughty, vegetation can increase infiltration of rainwater into a slope by creating root channels for water to follow, and by slowing surface flow. Over time, plants add organic matter to the soil and provide a hospitable environment for the establishment of naturally seeded woody and herbaceous plants.

Woody cutting techniques are clearly useful to stabilize steep slopes, but have fewer virtues for shoreline stabilization. On lakes, wave action is the principal cause of erosion. This mechanical force can be dealt with in two fundamentally different ways: by armoring the shoreline, or by dissipating wave energy offshore. Some shrubs will actively grow in shallow water where they can do this, but most woody species form an armor-like root structure along the edge of solid ground. As this hard edge deflects wave impacts back into the offshore area, a steep profile is developed, often undercutting the trees and shrubs. When one individual tree or shrub succumbs to old age or undercutting, it can leverage out a large root ball of soil with it, leaving an exposed section of steep shoreline. For this reason, it is often best to work with emergent aquatic vegetation: plants which root chiefly in the underwater soil while the green parts develop mainly above water--rushes, sedges, grasses, cattails, and the like. The flexible leaves and stems absorb and dissipate wave energy through their elastic deformation. Their fine fibrous root systems enclose and consolidate the soils effectively. In essence, the erosion control problem can be spread out over a larger area offshore, and handled using many individually weak plants. Bioengineering techniques are available for these herbaceous plant materials in addition to the more widespread dormant woody cutting techniques.

North Sea Coast

Northern Germany and the Netherlands have been coping with the North Sea for generations. They build dikes to fend off the storm surges which would otherwise regularly inundate miles of low-lying coastal communities. These dikes are a major feat of civil engineering, and are generally quite effective as well as costly. To protect the dike structure itself, secondary measures are employed offshore, often relying on bioengineering techniques. Naturally, there are limits beyond which vegetation cannot survive, and the stormy North Sea reaches those limits. The front edge of the secondary structures is generally a dike built of stone, behind which vegetation is used. The stone dike itself shares an important quality with bioengineered structures: it is built to be flexible, not rigid. Naturally formed columnar basalt is hand-fitted together puzzle-style without mortar. The roughly hexagonal columns are 2 to 4 ft long. When powerful waves strike, the entire structure gives a little, but very seldom breaks.

Behind this stone dike, a network of baffle structures is built to trap sediment carried by the tides. "Branch Boxes" of dead brush provide many of the same functions that live brush bioengineered systems offer. The woody materials slow water movement and filter out sediment, but instead of themselves growing, they provide shelter for coastal grasses. Spartina grasses begin to colonize the newly created mudflats, often thriving in the shelter adjacent to the Branch Boxes. Eventually the brush biodegrades; sometimes it must be replaced to continue the sedimentation process. As vegetation spreads and the water becomes shallower, sedimentation continues to increase until Branch Boxes disappear under 2 ft of new mud. This mud is dug out using a special amphibious excavator and placed above the mean high water line, creating a new level of ground higher than normal tides, and allowing more sedimentation to occur in the low spots. Eventually, a new swath of land is built up offshore, protected by a dense grass cover which can even be used for grazing. This stable land swath is the best protection for the high earth dikes behind them.

The bioengineering is aimed at increasing sedimentation and establishing vegetative cover, but this is achieved indirectly by promoting the natural processes involved, not by adding new fill and plants. These systems have been in use for a long time on many miles of the North Sea Coast.

Lakeside Bordering Wetland Dieback

Mr. Lothar Bestmann originated the idea of applying the Branch Box technique for inland lakeshores and developed methods for directly installing herbaceous material along the shoreline. Similar methods have been used on many lakes and reservoirs in Germany and elsewhere. One of the most extensive and carefully monitored projects is on Lake Havel in Berlin.

The situation on Lake Havel is typical of waters under development pressure, often creating a web of interrelated physical, chemical, and biological causes and effects which lead to spiraling wetland dieback, shoreline erosion, and water quality degradation. In response to long-term study of the underlying causes, measures were taken to protect and enhance existing wetlands and to replace or create new ones.

Prior to this approach, efforts to address shoreline erosion (rock riprap and concrete revetments) had only worsened water quality by further impoverishing the lake's biotic community. The good news: hybrid structural and bioengineered solutions solved the erosion problem and added acres of functioning wetlands to improve water quality for costs that compared favorably with standard rock and concrete construction alone.

To better understand the design and management issues on heavily developed shorelines, it is useful to study the interrelated causes and effects of shoreline wetland dieback which were identified on Lake Havel.

The physical causes are

- Waves from recreational and commercial boats cause erosion and scour of the substrate (these mechanical waves are often 10 to 100 times stronger than wind-caused waves on the same site and create a serious, often underestimated problem)
- Wave-suspended substrate abrades leaves and stems
- Drifts of garbage and tree limbs crush and cut plants
- Trampling and foot traffic crushes plants
- Woods on shoreline drop leaves and shade out herbaceous plants
- Water level fluctuations are exacerbated by stormwater from impervious surfaces

The chemical causes are

- Discharge of point source toxins
- Nonpoint source contamination from hydrocarbons, heavy metals, wastewater, fertilizers, etc.

The biological causes are

- Hypertrophic conditions lead to algae blanket formation which crushes plants
- Excess nutrient availability causes weakened, overgrown stems which tend to break (lodge)

- Attack by insects
- Biting and uprooting by handfed ducks and geese
- Reduced aquatic flora and fauna unable to perform basic functions such as denitrification

Regardless of the originally identified shoreline management issue, it is crucial to recognize the interactive physical, chemical, and biological processes, and to pay attention to the multiple roles vegetation plays. Controlling erosion and sedimentation is often the key to protecting water quality. In addition to the physical disruption caused by sediment particles themselves, many waterborne contaminants from urban and farm runoff, ranging from toxic heavy metals to excess phosphorus, adhere to sediments. Healthy vegetation filters sediments and stabilizes shorelines, and can improve water chemistry. Wetland plants support a variety of life forms and biological processes. The metabolic processes of microorganisms, and of the plants themselves, contribute to purification through nutrient uptake, breakdown of hydrocarbons, buffering pH, denitrification, oxygenation, and bacteriocidal effects.

The remaining patches of bordering wetland on Lake Havel and newly planted zones were protected in many areas using Branch Boxes. Strong wooden stakes hold the bundled fine brush in place. An apron of brush offshore protects against scour. Stone and biodegradable filter fabric often provide added strength and stability. The Branch Box barriers follow a specified elevation, typically 18 in. below mean water level, and are designed with baffled openings to allow for water circulation and animal migration through the structure. First, the stakes are pounded in place. Brush, which is readily available as a by-product of tidy German forestry practices, is placed between two parallel rows of stakes. Wire is laced over the brush, and the stakes are driven deeper one last time to cinch it all together.

These Branch Boxes provide short-term stability to help establish a dense stand of herbaceous vegetation sufficient to provide permanent shoreline protection. On sites where exposure to waves is simply too great, usually due to boat wakes, nonbiodegradable materials offer long-term wave attenuation offshore from plantings. Some of the structures used at Lake Havel include a stone berm lying on filter cloth, a flexible gabion of stone contained by a polyethylene mesh tube, a compact stone berm contained in a geosynthetic, and a Fiber Roll with a stone apron.

These Fiber Rolls are one of the materials developed by Bestmann to facilitate shoreline and streambank revegetation. The Fiber Rolls are sausage-shaped modules of densely compressed coconut fiber which has an extremely slow decomposition rate and high tensile strength, providing long-term structural protection, but also offering an excellent medium for plant growth. The slide shows young plants inserted into a Fiber Roll after it has been anchored offshore with wood stakes. [Shows slides.] The open water is very turbid, but behind the Fiber Roll, sediment has settled out, leaving clear water. Over time, sediment is deposited into and behind the Fiber Roll, providing a protected, organic-rich environment for plant expansion. As the coconut fiber biodegrades, it is replaced by sediment stabilized by living roots.

The concept of using bundled brush, also known as fascines or wattles, for erosion protection is not new. Bestmann sought to identify alternative materials which would provide similar mechanical erosion protection, and serve as a better growing medium for wetland plants. Many materials were experimented with, including natural and synthetic fibers. Synthetic fibers were not generally desirable due to their lack of cohesion, inability to absorb and retain moisture or nutrients, potential or actual wildlife entrapment, buoyancy, or the release of permanent unwanted debris in the event of partial or complete site failure. Coconut fiber was found to outperform other natural fibers, followed by heather clippings, with other fibers trailing behind. It is an interesting coincidence that around the same time, the U.S. Army Engineer Waterways Experiment Station was also independently using coconut fiber for trial shoreline plantings with successful results.

Single plants grown in coconut fiber have a dramatically increased stability and survival rate in shoreline plantings on moderately exposed sites when compared with bare-root or standard container-grown stock. The fibers, much like the plants own roots, help anchor the plantings and are not susceptible to scour and removal the way fine-grained potting materials are.

In addition to bundled cylinders of coconut fiber and single plants in fiber, various sizes and types of coconut fiber matting were used for producing reinforced wetland sods to transplant directly into shoreline areas. After many trials, two basic forms emerged: the Plant Carpet and the Plant Pallet. Both consist of a prevegetated substrate of dense coconut fiber felt encased in a woven coconut fiber wrapping. Both can be used on sites with wave action or currents too great for successful use of single plants, based on the fact that each stem and root system shelters and supports the adjacent ones, creating a *collective effect*. Plant Carpets contain a mixture of species suitable for lake and stream sites; these fully vegetated sods can be rolled up and brought to the site where they provide immediate surface protection. Plant Pallets contain stiff hollow-stemmed species which do not easily roll up, and which tolerate higher wave energies.

These forms of vegetation are often sufficient to address erosion by themselves, and may be combined with biodegradable or permanent wave attenuation structures for sites with the highest wave energies. One major advantage is that the coconut fiber makes it possible to install plantings at any time of year.

Artificial Floating Islands are bioengineering materials which offer shoreline protection, bird and fish habitat, as well as water quality functions even on sites with serious limitations to revegetation. These islands are produced in two forms, with a surface of either gravel or vegetation depending on the purpose. They float up and down on fluctuating water levels, do not take up storage volume from the reservoir, and, of course, have no problems with erosion on their plastic shorelines. Floating Islands are designed to withstand many years of UV radiation and ice. Many have been floating year-round on their anchors for nearly two decades with no maintenance.

Additional Examples

The shoreline bioengineering on the Sadenbeck Reservoir in former East Germany shows a typical installation where water levels fluctuate 6 ft or more. A Branch Box provides offshore wave attenuation. Behind this, two rows of Plant Pallets and a zone of single Plant Plugs are shown emerging from winter dormancy just after installation in March 1991. By June 1991 the site shows dense coverage of vegetation. In June 1991 water levels have dropped 6 ft, revealing the structure of the Branch Box; the plants have spread even further into the water and show no signs of stress due to water level changes.

A very dense bioengineering solution was required along the shoreline perimeter of a sand and gravel borrow pit used for Autobahn roadbed construction in Bremen. The unconsolidated glacial outwash sands interlayered with organic muck soils were impractical to stabilize using conventional engineering. In addition to the dense use of Plant Pallets, a wave-attenuation barrier of Fiber Rolls is used. This vegetated barrier has been constructed to prevent scour problems from parallel currents: the entire barrier has a sinuous shape and is broken into smaller sections by short perpendicular Fiber Roll "jetties."

Fiber Rolls form a zigzag wave attenuation barrier for salt marsh plantings near the New York City landfill. Urban debris, landfill leachate, and heavy wakes from garbage barges complicated the Spartina alterniflora restoration. In the shelter of the Fiber Rolls, single Plant Plugs grow easily. This site, implemented in collaboration with Creative Habitat Corp., is one of the early examples of a growing number of American shoreline bioengineering sites.

We are fortunate to be able to adapt methods developed in Germany and elsewhere for use in this country. From a bioengineer's standpoint, much about the regions is essentially identical: a geologically diverse landscape with erosion problems stemming from urban development, recreation, and agriculture. The ranges in climate and rainfall are similar, spanning the difficult extremes of icy winters and dry summers. The vegetation is comparable, with a high number of species native to both continents. The United States already has its own infant history of applied bioengineering: old laws required plantings of willows along the lower Mississippi, and dune grasses on Cape Cod. During the 1930's when our Soil Conservation Service was pursuing low-cost methods, Charles Kraebel investigated species and techniques for highway embankments in arid California. Although successful, his research never achieved widespread application when the economy recovered. Not until the 1980's did bioengineering again receive serious attention. Andrew Leiser, Donald Gray, Robbin Sotir, Gary Pierce, Lothar Bestmann, and other practitioners have designed and installed projects for various site conditions and generally increased public awareness of bioengineering's potential.

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QUESTION: How much inundation do the plants tolerate?

MS. GOLDSMITH: We have worked on sites where the plants were flooded for two months or more. A lot of the floodwater retention basins have long inundations. You have to get very site-specific. We've heard from a number of people that the waves on a given site are site specific. The same can be said for inundation. Different plants in different regions can tolerate different things. But there is usually something you can use.

QUESTION: Are you using native plants or exotics?

MS. GOLDSMITH: We generally use native plants. There are one or two plants we work with that are not native in the United States although its not like we're introducing something that's never been seen or heard of here before. I strongly emphasize using a variety of plant species for any given site. When we produce something in our nursery, for example, our plant carpet, it contains a minimum of four species. You can't pretend to know what one species will do best, so you use a mix of species to cover a range.

QUESTION: How do you keep the floating islands from moving downstream during a flood?

MS. GOLDSMITH: We anchor them. A 20-lb anchor will hold five or six islands in place on a lake. When you start dealing with strong currents, it's a little trickier. You have to increase the weight of the island. Some of them are tethered on shore. There are lots of ways to attach a floating island. One interesting virtue of the plastic floating islands is they don't have to be brought in the winter months. They are capable of withstanding ice. So, once you anchor them, you don't have to worry about refixing them when the season changes.

QUESTION: What type of wave environment would the floating island survive?

MS. GOLDSMITH: The floating island from a shoreline protection standpoint can withstand waves up to 4 or 5 ft in height. It starts getting to be a bumpy ride for waterfowl that are using it. There's a tradeoff there. So you've got to design a barrier structure that will address that.

SHORELINE AND STREAMBANK EROSION AS A CONTRIBUTOR OF NPS POLLUTION—AN EPA PERSPECTIVE

Christopher F. Zabawa, Ph.D.,[1] Susan Ratcliffe,[2]
and John N. Hochheimer, Ph.D.[3]

Introduction

The erosion of shorelines and streambanks can affect the quality of the nation's surface water systems in two ways. First, high levels of turbidity can result from bank erosion along rivers and streams, and from shore erosion along coastal bays and estuaries. The resulting increased rates of sediment deposition can clog stream channels and riffle pools that are used as habitat for many benthic organisms and fish. High sediment loads in coastal bays and estuaries can smother submerged aquatic vegetation, cover shellfish beds, and interfere with the ecology of wetlands and tidal flats. Second, the loss of land from streambank or shoreline erosion can result in the elimination of vital resource areas such as wetlands, riparian zones, and forested buffer strips. These areas help to maintain surface water quality by providing shade, and by filtering sediment, nutrients, and other pollutants contained in upland runoff before it reaches the surface water system.

Pollutants originating partly from shoreline and streambank erosion and partly from the destruction or degradation of streamside riparian habitat are reported by states to the U.S. Environmental Protection Agency (EPA) as among the most common causes of poor water quality in the surface water systems of the nation. EPA supports efforts such as the Clean Lakes Program, Rural Clean Water Program, and section 319 grants to implement practices at the watershed level for the protection of shorelines and streambanks that improve surface water quality and habitat.

EPA currently recognizes that nonpoint source pollution is the primary challenge to achieving good water quality in the nation's waters. The ongoing development of nonpoint pollution control programs in coastal states, as required by the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA), has given EPA the opportunity to target shorelines and streambanks for their contribution to the nonpoint source problem, and to further encourage their protection and restoration to improve surface water quality and habitat.

Assessment of the Problem

The Federal Water Pollution Control Act (commonly known as the Clean Water Act) establishes the processes that states use to assess the quality of the nation's water resources,

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and to report this information to EPA. The requirements for these processes are found in the Clean Water Act (CWA) under sections 106(e), 204(a), 305(b), 314(a), and 319(a). Continued assessment of the nation's waters by states is the principal means by which EPA, the U.S. Congress, and the American public can evaluate water quality, the progress made in maintaining or restoring water quality, and the extent to which water quality problems remain.

The National Water Quality Inventory and the State Nonpoint Source Assessments are two separate methodologies used to identify the principal pollutants in surface water systems and the likely causes or sources of these pollutants. In both cases, the data assembled by states and territories show sediment and nutrients rank high as pollutants in surface water systems across the nation. Both of these pollutants can be strongly, although not exclusively, linked to shoreline and streambank erosion and to the destruction or degradation of streamside and shoreline habitat. The actions necessary to improve the quality of surface waters must include the stabilization of eroding streambanks and shorelines, rehabilitation of stream channels, and protection or restoration of shoreline and streamside habitat.

National Water Quality Inventory

Under CWA section 305(b), states and territories monitor the quality of surface and ground waters and prepare reports every 2 yr describing the status of water quality. EPA compiles this information, along with an analysis describing the nationwide status of water quality, for a report (*The National Water Quality Inventory*) to the U.S. Congress (USEPA 1992a).

The measure of the quality of the nation's surface waters is determined by the degree to which "designated uses" are supported in rivers, lakes, and estuaries. According to the Clean Water Act, all waters of the United States must be designated for specific uses that will then be protected. Most waters are designated by states for uses that include (1) support of aquatic life and (2) contact recreation In some states, other small subsets of waters are designated for uses such as public water supplies, navigation, or industrial uses.

To protect these designated uses, states and territories establish criteria such as specific chemical concentrations or biological conditions that must be met if the designated uses are to be maintained. If these criteria are not met, then the designated uses may be impaired. The quality of the nation's waters is determined in the states by measuring the degree to which standards are met and, therefore, the degree to which the designated uses are supported (USEPA 1991).

For the 1990 National Water Quality Inventory (USEPA 1992a), states and territories were able to provide data for about one-third of the nation's river miles, for about one-half of the acreage of the nation's lakes, and for about three-fourths of the nation's estuarine waters (as measured by surface area). Of those waters that were included in the assessment, about two-thirds are fully meeting their designated uses. The rest of the assessed waters show some degree of impairment. For those waters which are categorized as "not fully supporting the designated use," information provided by the states and territories identifies the causes and sources which are contributing to the impairment of water quality.

For both causes and sources of water pollution, states and territories are encouraged to report as many categories as are necessary to describe the contributions to the impairment of designated uses for each water body. Accordingly, the tabulation of causes and sources of pollutants, which is discussed below and shown in Figures 1-3, should not be expected to add up to 100%.

Results for lakes and reservoirs

Information on 47% of the nation's 39.4 million acres of lakes and reservoirs is included in the 1990 National Water Quality Inventory. A graphic presentation of the results is shown in Figure 1. The top four pollutants reported as the most common causes of nonsupport of designated uses in assessed lakes were metals, nutrients, organics, and suspended solids. These can be controlled, in part, by better management of streambank and shoreline erosion and by protecting or restoring riparian zones and other streamside buffers to improve filtration of upland runoff before it reaches the surface water system. The second-highest reported source of pollution in assessed lakes was "Hydrologic Modification." This category includes such activities as channelization, dredging, streambank erosion, flow modification, and streambank modification.

Results for rivers and streams

Information on 36% of the nation's 1.8 million miles of rivers and streams is included in the 1990 National Water Quality Inventory. A graphic presentation of the results is shown in Figure 2. Most of the pollutants reported as the common causes of nonsupport of designated uses in assessed rivers and streams can be controlled, in part, by better management of streambanks and shorelines. Hydrologic modifications are reported as the third most common source of pollution in assessed rivers and streams.

Results for estuaries

Information on 75% of the nation's 36,000 square miles of estuarine waters is included in the 1990 National Water Quality Inventory. A graphic presentation of the results is shown in Figure 3. Again, many of the pollutants reported as the most common causes of nonsupport of designated uses in assessed estuarine waters can be controlled, in part, by better management of streambank and shorelines, particularly by protecting or restoring riparian zones and other streamside buffers. On a nationwide basis, hydrologic modifications were reported as the eighth most-common cause of nonsupport of designated uses in assessed estuarine waters. But where the contribution of shoreline sediments has been closely examined for its importance in estuarine pollution, the results have been more significant.

Chesapeake Bay Program results

The Chesapeake Bay is one coastal water body for which sufficient data exist to characterize the relative importance of shore erosion as a source of sediment and nutrients to the estuary. This characterization is the result of other studies undertaken by the U.S. Army Corps of Engineers, the states of Maryland and Virginia, and the EPA Chesapeake Bay Program. Erosion of the shores of the Chesapeake Bay above mean sea level contributes an estimated 6.9 million cubic yards of sediment per year, or 39% of the total annual sediment supply, to the Chesapeake Bay (USACE 1990; CBP 1991). Sediment and nutrient contributions from eroding banks along the Chesapeake Bay in Virginia have been determined (Ibison et al. 1990, 1992). These have been combined with the information on fastland sediment contributions to prepare an estimate of the nutrient loads for phosphorus and nitrogen to the Chesapeake Bay from fastland shore erosion (CBP 1991). The contribution of nitrogen from shore erosion on the Chesapeake Bay is estimated at 3.3 million pounds per year, which is 3.3 percent of the total nonpoint nitrogen load to the Bay. The contribution of phosphorus from shore erosion is estimated at 4.5 million pounds per year, which is approximately 46% of the total nonpoint phosphorus load to the Chesapeake Bay (CBP 1991).

Section 319 NPS assessment reports

Similar to the National Water Quality Inventory, the Clean Water Act (in section 319(a)) requires states to identify those navigable waters impacted or threatened by nonpoint sources, and to identify the pollution sources affecting those same waters. Unlike the section 305(b) reports that states have prepared biannually since 1976 as part of the National Water Quality Inventory, the section 319(a) assessment of nonpoint source pollution has only been prepared once. The data submitted by states in their nonpoint source assessments provide the most comprehensive and detailed picture to date of the nationwide scope and effects of nonpoint source pollution.[1] States identify impairment of waters in a variety of ways, ranging from extensive and rigorous chemical, physical, or biological monitoring to visual observation and evaluation of land uses in the watershed.

The results show "Hydrologic and Habitat Modification" is the third most-frequently reported contributor of nonpoint source pollution to rivers and streams (Figure 4). This category is also a frequently cited contributor of nonpoint source pollution to lakes (Figures 5). Four states—Washington, Tennessee, Idaho, and North Dakota—indicated that the streambank erosion problem accounts for more than 20% of the nonpoint source pollution in their rivers and streams. Another 22 states reported streamside and shoreline erosion accounts for less than 20% of the nonpoint source pollution. North Dakota, in particular, indicated a large nonpoint source problem from streambank erosion (USEPA 1992b).

Figures 4 and 5 show the categories of "unknown," "others," and "natural" were reported by states as additional important sources of nonpoint pollution impacting support of designated uses of rivers and lakes. Since these terms are ambiguous, it is suspected that reports of unknown, other, and natural sources of use impairment represent a significant proportion of cases where shoreline and streambank erosion is actually an important contributor to the nonpoint pollution problem.

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[1] Nonpoint source pollution generally results from land runoff, precipitation, atmospheric deposition, drainage, or seepage. Although nonpoint sources have been described in a number of ways, they are defined as sources of water pollution that do not meet the legal definition of "point source" in section 502(14) of the Clean Water Act:

> *The term "point source means any discernible, confined, and discrete conveyance, including but not limited to any pipe, ditch, channel, tunnel, conduit, well, discrete fissure, container, rolling stock, concentrated animal feeding operation, or vessel or other floating craft, from which pollutants are or may be discharged. This term does not include agricultural storm water discharges and return flows from irrigated agriculture.*

Although diffused runoff is generally treated as a nonpoint source, runoff that enters and is discharged from conveyance such as those described are point sources and subject to the permitting requirements of the Clean Water Act. In contrast, nonpoint sources are not subject to federal permits and are usually addressed through voluntary programs.

The distinction between nonpoint sources and diffuse point sources, such as storm water sewers, may be subtle and is often blurred by states in describing the effects of nonpoint sources. However, in most states, it is reasonable to conclude that nonpoint sources including certain diffuse point sources (e.g., storm water discharges) are now responsible for between one-third and two-thirds of existing and threatened impairments of the states' waters (USEPA 1992b).

Existing Programs

The quality of the nation's surface waters described in the previous section is a reflection on the conditions and activities undertaken on the lands in the watersheds. The health of the nation's rivers, streams, lakes, and estuaries depends on the use and treatment of the lands that surround them. EPA recognizes that, to meet national water quality goals, a comprehensive approach is needed that takes into account conditions within individual watersheds. To some extent, this approach requires a departure from EPA's traditional focus on regulating specific pollutants and pollutant sources. This approach also requires an alignment of traditional regulatory and nonregulatory programs to support integrated, holistic natural resource management (USEPA 1992c).

In many watersheds, EPA supports a range of activities that focus on coordinated, integrated resource management. Shoreline or streambank erosion, as a contributing factor to surface water pollution, is frequently addressed with support from EPA programs. The Chesapeake Bay Program, mentioned previously, obtains funding through EPA grants for vegetative bank stabilization along the Bay shoreline, and the tributary rivers and creeks. Several other examples from watersheds across the country are also worth mentioning.

Rural Clean Water Program

Streambank erosion has been identified as a problem in several watershed projects that EPA has helped to sponsor through the Rural Clean Water Program (RCWP). The RCWP was initiated in 1980 as an experimental effort to address agricultural NPS problems in watersheds across the country. The objectives of the RCWP were (1) to achieve improved water quality in the approved project area in the most cost-effective manner possible, (2) to assist agricultural landowners and operators to reduce agricultural NPS water pollution, and (3) to develop and test programs, policies, and procedures for the control of agricultural NPS pollution. The RCWP was administered by the USDA-ASCS in consultation with USEPA (Gale et al. 1992).

In Nebraska, a RCWP project emphasized the installation of cedar revetments for streambank stabilization in the Long Pine Creek watershed. The revetments proved to be one of the most successful and innovative practices employed in the Long Pine Creek RCWP project. In addition to reducing the sediment load in Long Pine Creek, the cedar revetments have helped the stream channel to adjust to its previous dimensions, providing a variety of benefits to trout and other aquatic life (Hermsmeyer 1991, Siefken 1992).

In Florida, one of the sources of sediment and nutrient pollution in the Taylor Creek-Nubbin Slough watershed came from cattle lounging in ditches and creeks. A RCWP project initiated in this watershed adjacent to Lake Okeechobee included fencing to keep cattle out of the waterways. As a result, native vegetation became reestablished, helping to cut down on sediment erosion from denuded banks (Stanley and Gunsalus 1991).

Streambank erosion was also identified as a contributor to water pollution in other agricultural watersheds participating in the RCWP. These included St. Albans Bay watershed in Vermont (Vermont RCWP Committee 1991) and the Snake Creek watershed in Utah (Snake Creek Local Coordinating Committee 1991).

Clean Lakes Program

Lake management for water quality improvements may include in-lake treatment techniques or watershed management practices aimed at reducing additional inputs of nutrients and other contaminants. Usually, a combination of watershed improvement to reduce pollution that enters a lake and application of in-lake restoration techniques is used to upgrade the quality of a lake or reservoir (Olem and Flock 1990, Wedepohl et al. 1990). States, often with assistance from EPA's Clean Lakes Program, have developed a wide variety of techniques to address problems affecting recreational and other important lake uses (Lapensee 1989).

Since 1975, the Clean Lakes Program has provided grants for restoration projects involving shoreline stabilization and streambank rehabilitation in several states, including: New York (Anne Lee Pond and Tivoli Lakes); Wisconsin (Bugle Lake, Lake Henry, Upper Willow Lake); Minnesota (Clearwater River Chain Watershed); Indiana (Skinner Lake); Iowa (Swan Lake), South Dakota (Lake Kampeska, Oakwood Lakes, Swan Lake); Montana (Sacajewea Park Lagoon); Nevada (Lake Tahoe); California (Lake Tahoe); and Oregon (Commonwealth Lake) (USEPA 1985, 1990, 1991a).

One notable success story comes form Utah, where a Clean Lakes grant was used to rehabilitate the Panquitch Lake drainage system. The project had several aspects, the most important of which was the restoration of streambanks of the affected tributaries. The project consisted of resloping and revegetating the streambanks, installing juniper tree revetments in highly eroded areas, building a series of gabion check dams and a sedimentation pond, and fencing approximately 7,000 linear feet of the stream to keep cattle out. The result has been a remarkable recovery (USEPA 1989). Preliminary data indicate that sediment loading has decreased 97% as a result of this and other work undertaken at Panquitch Lake. Phosphorus loading has also declined (USEPA 1989).

Section 319 CWA Funding

Although nonpoint sources of pollution are a large component of our nation's water pollution problem, diffuse sources are often harder to identify, isolate, and control than traditional point sources. Perhaps for these reasons, from the passage of the Clean Water Act in 1972 through 1987, EPA and the states focused on issuing permits to point sources, and then on inspecting, monitoring, and enforcing those permits to ensure that point sources met the Act's requirements (USEPA 1992b).

In 1987, reflecting increased awareness of the scope and diversity of nonpoint source pollution, Congress enacted section 319 of the Clean Water Act to encourage states to increase their control of nonpoint source pollution. This provision of the Clean Water Act created a three-stage national program to be implemented by the states with federal approval and assistance: (1) preparation of state Nonpoint Source Assessment Reports (discussed in a previous section, see Figures 4 and 5), (2) state development of nonpoint source management programs, and (3) implementation of the state nonpoint source management programs.

The latest Report to Congress on section 319 accomplishments (USEPA 1992b) indicates shoreline stabilization and stream rehabilitation have been identified as an integral part of watershed management plans in many states. Streambank management to reduce NPS pollution has been pursued with particular emphasis in Nevada, California, Utah, and South Dakota.

Future Strategies

In the Coastal Zone Act Reauthorization Amendments of 1990, Congress recognized that nonpoint pollution is a key factor in the continuing degradation of many coastal waters and established a new program to address this pollution (Archer 1991). Congress further recognized that the solution to nonpoint pollution lies in state and local action. In enacting the CZARA legislation, Congress called upon states to develop and implement state coastal nonpoint pollution programs.

EPA's Office of Water and the National Oceanic and Atmospheric Administration's Office of Ocean and Coastal Resources Management have developed guidance that will serve as a principal basis for new state coastal nonpoint source pollution control programs required by CZARA. The guidance specifies management measures for the following categories of nonpoint source pollution:

- Agriculture
- Forestry
- Urban areas not subject to National Pollutant Discharge Elimination System stormwater requirements (NPDES 1990).
- Marinas and recreational boating
- Hydromodification (channelization and channel modification, dams, and streambank and shoreline erosion).

In addition, broadly applicable management measures are contained in the guidance for the protection and restoration of wetlands and riparian areas, and to promote the use of vegetated treatment systems (constructed wetlands and vegetated filter strips) for all categories of nonpoint pollution.

The management measures for streambanks and shorelines are for application by states to eroding shorelines in coastal bays and to eroding streambanks in coastal rivers and creeks. The guidance adopts the viewpoint that some shorelines and streambank erosion is beneficial and need not be stabilized. For example, some amount of natural erosion has been found to be necessary to provide the sediment for beaches in coastal bays, for point bars and channel deposits in rivers, and for substrate in tidal flats and wetlands.

However, techniques involving marsh creation and vegetative bank stabilization ("soil bioengineering") are encouraged wherever shoreline and streambank erosion is determined to be a nonpoint pollution problem, and wherever these methods of stabilization will be effective against the physical processes which cause the streambank or shoreline erosion (waves, currents, runoff, groundwater seepage, etc.). In other cases, the guidance recommends the use of properly designed and constructed engineering approaches, including beach nourishment or coastal structures. The guidance further recommends that states protect shoreline features such as wetlands and streamside riparian areas that have potential for removing NPS pollutants from surface waters.

The management measure for streambanks and shorelines is considered to reflect the greatest degree of pollutant reduction that is achievable through the application of the best available nonpoint pollution control practices, technologies, processes, and siting criteria. Along with management measures for the other categories listed above, the measure will be incorporated by those states with approved Coastal Zone Management Programs into coastal nonpoint programs.

Summary

EPA recognizes stabilization of eroding streambanks and shorelines can help to reduce the quantity of sediments provided to the nation's surface water systems. Added benefits of habitat creation and nutrient reduction can be realized when stabilization is accomplished with vegetative techniques such as restoration of fringe marshes and biotechnical stabilization of eroding slopes along streambanks and shorelines. Protection of the resources in existing riparian areas and restoration of degraded riparian zones can further help to filter pollutants such as sediment and nutrients which are entering the nation's surface water systems from upland runoff. From an EPA perspective, these are some of the best tools that can be used to reduce the importance of shoreline and streambank erosion as a contributor of NPS pollution.

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QUESTION: Is section 319 applicable to the federal agencies?

DR. ZABAWA: It is my understanding that goes into the states through the regions. As the speaker from Illinois discussed, it can't be given to individuals to support cost share, but it can go toward demonstration projects. I think that in many cases the states put together a basket of effort that does include involvement of federal agencies. I know that in the State of Maryland, the state which I am familiar with, that is the case.

QUESTION: Can funding from another federal agency be used as part of a state's cost share for a 319 grant when the state and the federal agency are working together on the same problem?

DR. ZABAWA: In that case, I believe, yes.

COMMENT (DR. ZABAWA): If you are interested in following the progress of the rewrite of this technical guidance, "Best Available Technologies for Non-Point Source Control," we also have our bimonthly nonpoint source newsletter, "Non-Point Source Newsnotes," which is available free of charge. It's also carried on a computerized bulletin board that is supported by the EPA nonpoint source program. And we also have copies available here for distribution.

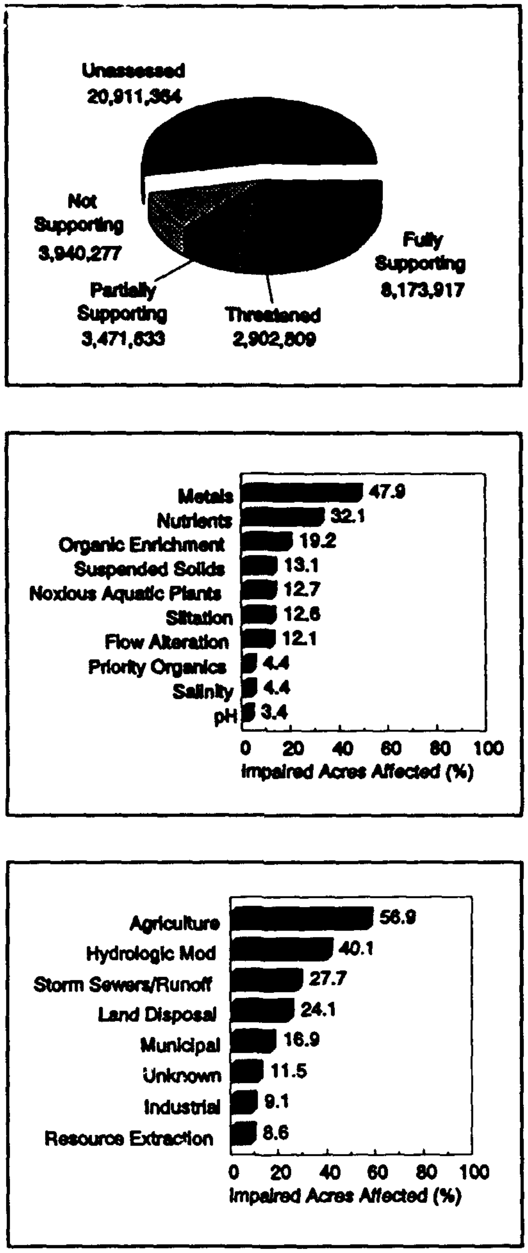


Figure 1. Summary results of the 1990 National Water Quality Inventory for lakes and reservoirs (not including the Great Lakes), as reported to EPA by the states (USEPA 1992a)

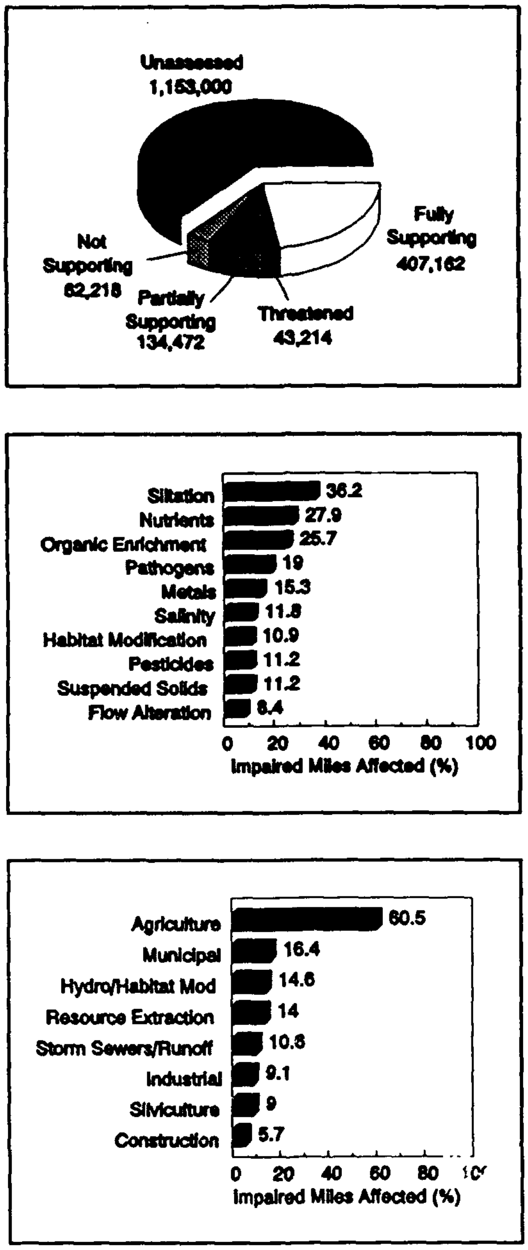
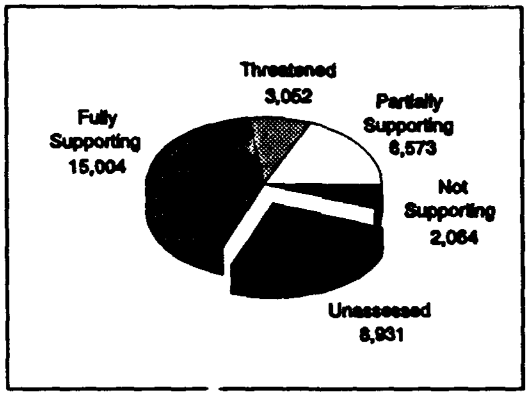
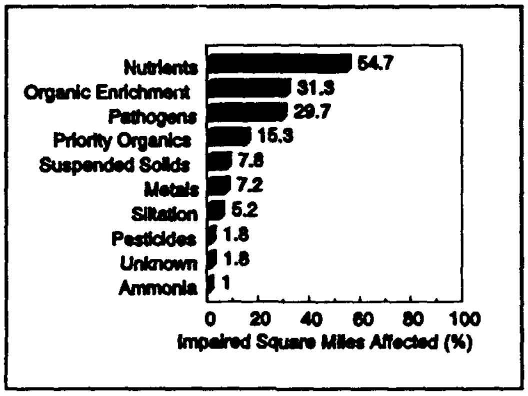


Figure 2. Summary results of the 1990 National Water Quality Inventory for rivers and streams, as reported to EPA by the states (USEPA 1992a)





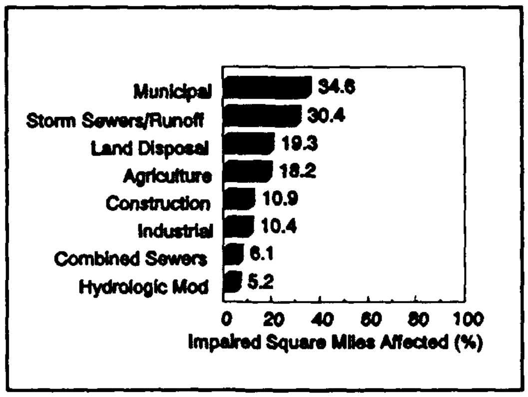


Figure 3. Summary results of the Water Quality Inventory for estuaries, as reported to EPA by the (USEPA 1992a)

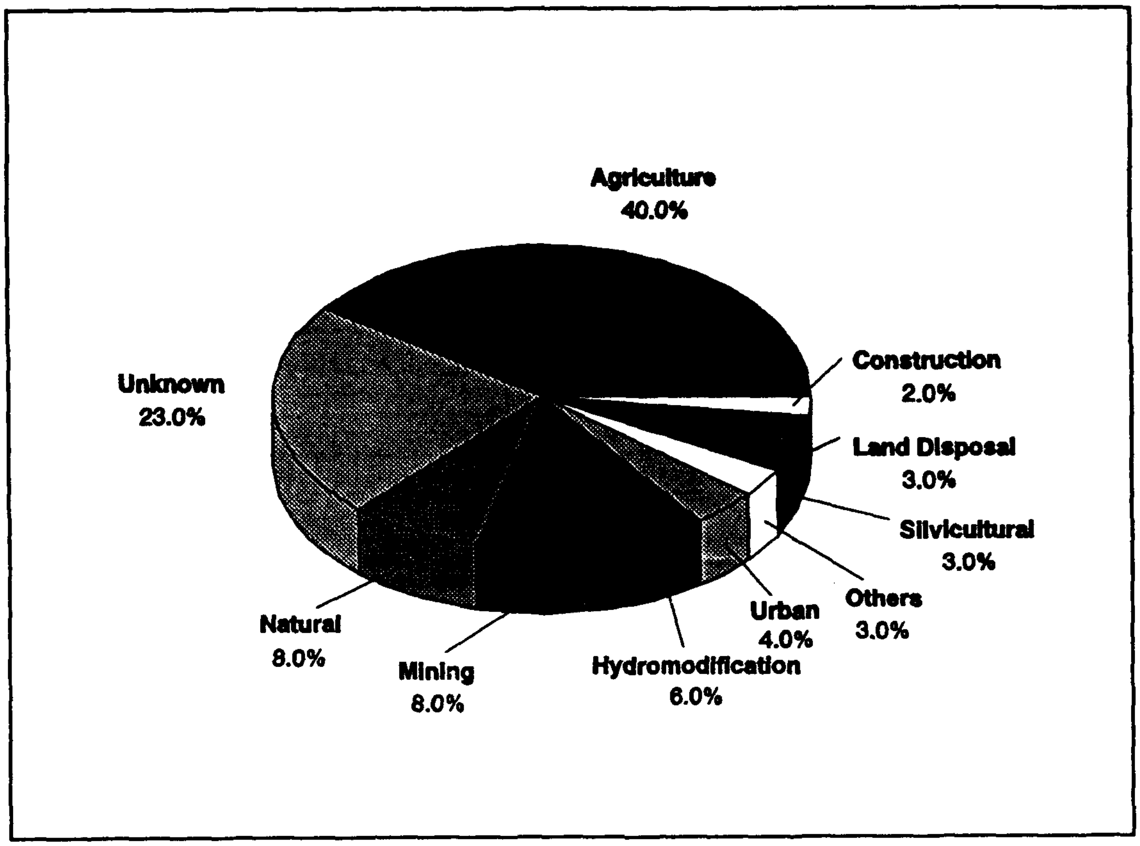


Figure 4. Sources of nonpoint pollution impacting support of designated uses in rivers, as reported to EPA by the states (USEPA 1992b)

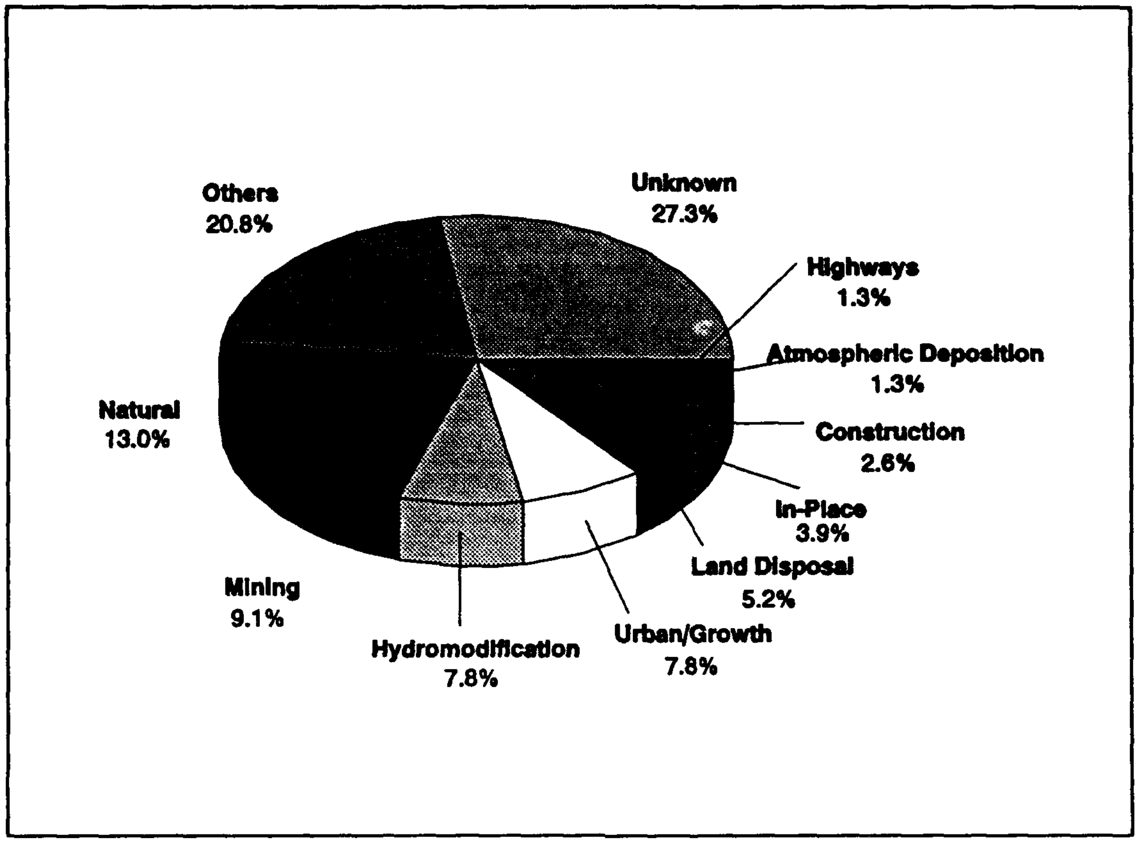


Figure 5. Sources of nonpoint pollution impacting support of designated uses in lakes, as reported to EPA by the states (USEPA 1992b)

IMPACTS ON CULTURAL RESOURCES FROM RESERVOIR SHORELINE EROSION AND BANK RECESSION

Paul R. Nickens, Ph.D.[1]

Introduction

Construction and operation of reservoirs by various federal and state agencies and other proponents have created significant adverse effects for archeological and historical resource properties. Initially, these impacts primarily involve those associated with construction activities and subsequent inundation. Following reservoir filling, impacts to cultural resources come from various sources associated with natural processes and use of the adjacent land. Adequate mitigation of impacts to cultural resources at reservoir projects over the years has ranged from none at all for some older projects to only partial mitigation efforts at others.

Various factors have limited mitigation efforts, including a lack of adequate protective legislation at the time of project authorization and construction or simply insufficient funding and time for satisfactory resource identification, evaluation, and data recovery efforts. Moreover, the nature of the resource base itself can be a hindrance (significant portions of the earlier prehistoric/historic record may be buried and therefore not easily observed) and important improvements in the methods and techniques of identifying and studying cultural resources have occurred over the past 50 or so years. Significant changes in approaches for managing and protecting these resources have also taken place in the past few decades.

The consequence of this situation for today's resource managers is that significant portions of the once extant cultural resource record still remain at many, if not most, operating reservoir projects. Among the ongoing impacts that threaten cultural resources at these projects, those associated with shoreline erosion and bank recession are easily the most prevalent and most damaging to the resource base. Unfortunately, the full extent of the problem is not known. Presently, for example, identifying with any degree of certainty how many archeological and historical sites actually exist at reservoir projects around the country nor how many are being eroded is not possible.

A recent survey of U.S. Army Corps of Engineers Districts assessed the scope and nature of shoreline erosion problems at Corps reservoir projects (Allen and Wade 1991). Based on the results of a Corps-wide questionnaire, it was determined that nearly 60 percent of the total reservoir projects reported on (161 out of 276) have shoreline erosion problems. Included in the sample projects are an estimated 10,000 miles of eroding shoreline, half of which can be classified as severe. Importantly, about one-half of those projects with shoreline erosion problems include deterioration of archeological and historical sites in the

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overall situation. Here again, the actual degree of impact cannot be determined. However, the Omaha District did report that 525 cultural resource sites were endangered by shoreline erosion. Based on this information and other observations, an assumption that several thousand cultural resource sites are presently eroding at Corps reservoirs alone would not be unreasonable. The number of sites that have already been completely lost is unknown.

This paper undertakes an overview of the factors related to impacts on cultural resource properties located at or adjacent to reservoir shorelines. A brief review of ways to protect and preserve eroding cultural sites is included, along with some comments regarding future directions and investigative needs.

Background

Before reservoir shoreline erosion impacts on cultural resource sites are examined, characteristics of both the reservoir setting and the resource base are reviewed.

The reservoir setting

Dams and reservoir projects generally fall into two major categories: storage and run-of-river. Both types are commonly multipurpose and usually part of a multireservoir system. Storage reservoirs adjust the river's natural flow patterns and maintain sufficient capacity to regulate streamflows on a seasonal basis according to water use. Examples of these uses include power production, irrigation, and recreation. Storage also helps regulate flows, reducing potentially damaging downstream floods.

Run-of-river projects usually have limited storage, allowing water to pass the dam at about the same rate it enters the reservoir. These projects also provide power generation, but are principally used to enhance navigation by maintaining sufficient navigation depth over rapids and other obstacles.

The shorelines of both types of reservoirs are subject to erosion, although the intensity and sources of erosion vary greatly, not only among projects but also at specific locations along the shoreline at a given project. Shorelines of reservoirs are subject to a number of forces contributing to their stability, and frequently undergo significant changes throughout the life of a project. The causes and actual mechanisms of erosion and bank recession are covered by other presentations in the workshop and need not be detailed here. (A good summary of shoreline erosion causes and impacts can be found in Lawson (1985)).

Characteristics of shoreline cultural resource sites

Much like today's population, early historic and prehistoric peoples tended to concentrate their settlements in river valleys. This high settlement density was predicated on the availability of a permanent water source, abundant floral and faunal resources, arable land, and transportation corridors. Site types varied widely throughout the cultural sequences in the various culture regions around the country, but often large permanent villages were established along the major river drainages. Typically, these sites were situated on the first terrace above river floodplain--a location that often places the resource in the greatest zone of impact following construction and filling of a reservoir.

Because these sites are numerous and often quite extensive (deeply stratified and multicomponent in nature), mitigation of reservoir-related impacts can be an immense and costly undertaking, if done properly. At the Bureau of Reclamation's Dolores River Project in southwestern Colorado nearly 20 million dollars was spent during the 1980's on mitigation of impacts to cultural resources. Nearly a quarter of this amount was for long-term curation of excavated materials.

Unfortunately, many of the large reservoirs along major drainages, such as the Columbia, Colorado, and Missouri Rivers, were completed between the 1940's and the mid-1960's when comprehensive management of the resource base was in its infancy. This time frame incorporated the era of "salvage archeology" which, as the name implies, basically involved saving that part of the overall resource base that could be salvaged given extremely limited personnel and funding. This approach has been succinctly summarized by Adams (1973), who observed that between 1946 and 1957, some 310 reservoirs were surveyed and over 9,000 archeological and historical sites were recorded. While these figures are at first glance impressive, the simple calculation of an average of only 29 sites per reservoir indicates that most or all of these surveys were only done at a reconnaissance level. Salvage excavations concentrated primarily on the larger more impressive sites which were to be inundated. Today, erosion and bank recession at many of these early reservoirs have extended the shoreline to areas that were not "cleared."

A review of the results of this earlier work indicates that a significant number of the cultural resource sites at many reservoir projects were not identified or impending impacts were only partially mitigated at many sites. In many instances, these sites are the ones that are today eroding into the reservoirs. There are also many reservoirs constructed in the past 25 years for which insufficient cultural resources baseline data also exist. As an example, a 1989 archeological survey in the northwestern part of the country documented over 160 previously unknown prehistoric sites in only a portion of the total drawdown zone at a reservoir which has been in operation since 1971 (Draper 1990). The integrity of these resources has suffered greatly as a result of over 20 years of annual drawdowns. In other instances, the results of previous cultural resource surveys may be inadequate today for planning needs because shoreline erosion has greatly modified the database, removing some known sites while exposing others for the first time.

Reservoir Impacts on Cultural Resources

The construction and operation of reservoirs include a wide range of potential impacts to cultural resource sites, ranging from full inundation (and possible long-term preservation) to others of a more devastating nature. In order to investigate these impacts, a multiagency (National Park Service, Bureau of Reclamation, and Corps of Engineers) 5-yr research effort was completed in 1980 (Lenihan et al. 1981). This effort, known as the National Reservoir Inundation Study (NRIS), examined reservoir-related impacts on cultural resources from several angles, one of which was the effects of shoreline erosion and bank recession. Much of the following discussion is taken from the original NRIS study and a recent summarization of the overall effort (Ware 1989), supplemented by other data sources and the author's own field observations.

To facilitate analysis of the various reservoir-related impacts which might affect cultural resources, the NRIS subdivided a typical reservoir impoundment into five impact zones, the most critical of which are the conservation pool, the fluctuation or drawdown zone, and the backshore zone. For the purposes of this workshop, we will concentrate on the area comprising the fluctuation zone.

The NRIS also identified three categories of processes that affect the preservation of cultural resources in reservoirs and waterways: (1) mechanical or physical, (2) biochemical, and (3) human and other processes. Mechanical processes include the physical erosion and deposition processes associated with a large body of water. In reservoirs, wave action is the most important mechanical impact on cultural resources. Wind-generated waves are the most common, but destructive waves can also be generated by power boat wakes and tectonic disturbances.

On run-of-river pools, navigation-related impacts have also been shown to have great potential for creating considerable erosion of cultural resources located on the banks (Gramann 1981). Several types of impacts were identified that contribute to bank erosion and potential loss of resources including barge traffic, pool manipulation, recreational use, structural aids such as wing dams and levees, and mooring of barges near shorelines.

The chemical and biological environment of a reservoir is of primary concern for the differential preservation and destruction of inundated cultural materials. These processes are particularly critical in the fluctuation zone. Changes in rock art sites located on geologic strata near the waterline serve as a good example of these impacts. Such impacts can include chemical changes leading to deterioration of the stone matrix, growth of algae, deposition of resource-obscuring silt or calcium deposits (the ubiquitous reservoir "bathtub ring"), or simply deterioration of pigments used to create the aboriginal artwork.

The final set of processes, human and other, includes the various consequences of human activities, ranging from dam construction to cultural site vandalism, and impacts associated with changes in land use following dam construction and reservoir impoundment. While these impacts may primarily occur in the backshore zone, many activities take place near the waterline that increase the possibility for erosion or destruction of cultural resources. An example is the opportunity for easy access to cultural sites by boat, when prior to reservoir filling access had been difficult.

Another way to categorize reservoir shoreline impacts to cultural resources is in terms of primary and secondary impacts. Put another way, there are a number of secondary impacts which are created or made possible due to the presence and activity of a primary impact such as shoreline erosion and bank recession. In most cases, these secondary impacts exacerbate the situation and hasten the loss of both the substrate and resources. Some of these secondary impacts include burrowing of animals and birds in the exposed vertical cutbank which further contribute to bank instability, undercutting and subsequent falling of large trees, vandalism of exposed cultural artifacts and features, and wind or solar erosion of exposed artifacts, particularly items of bone.

Impacts on Cultural Resources in the Fluctuation Zone

In the search for evidence of damage or destruction to cultural resources located along the shoreline of a reservoir, it is necessary to go beyond examination of only the erosion occurring at the waterline and look, rather, at the total fluctuation zone. In some instances, this may be only a 1- or 2-ft zone; in other cases, the fluctuation zone may include a 150-ft drawdown.

Normally, the fluctuation zone is determined by operational considerations, although special circumstances can greatly alter these procedures. Recent examples of significant changes in normal operating drawdown procedures include the drought-caused drawdowns along the Middle Missouri River and the intentional drawdowns currently taking place and possibly proposed for the future along the Lower Snake and Columbia Rivers. Other special drawdowns have occurred in conjunction with compliance with the Dam Safety Act or other modifications of the dam structures. At the other end of the spectrum, some conservation pools may actually be raised in the future. Such might be the case, for example, if generating units are added at dams where the original construction plans included block-outs for additional units.

One of the most critical current data gaps is associated with identifying, evaluating, and preventing erosion impacts to sites situated in drawdown zones. This includes those impacts that occur during both drawdown and filling episodes. Loss of sites due to mass failures along a cut bank is easily measured. Slower, more gradual loss of cultural sites due to fluctuating water levels is much more difficult to visualize and measure, although this type of erosion may be even more damaging since it affects a larger area of a site's surface.

Within the shoreline fluctuation zone of most reservoirs, virtually all categories of the impacts discussed above are intensified, with mechanical hydrological impacts constituting the greatest threat to cultural resources. The NRIS concluded that wave action in this zone created the most serious impact to sites. The nature and extent of these impacts is influenced by four variable conditions:

- The nature and extent of erosion and deposition impacts to cultural resources will be determined by a number of characteristics, including reservoir size, depth, and orientation, hydrological characteristics of the watershed local climatic regime, and the operating characteristics of the reservoir.

- Location of the cultural resource site relative to reservoir fetch and prevailing wind patterns.

- The geological and environmental context at the site (especially the slope and erosion resistance of the geomorphological substrate).

- The character and erosion resistance of the cultural deposits themselves.

In addition to the high-energy impacts of waves in the fluctuation zone, frequent wetting and drying of cultural deposits on the shoreline poses a significant threat to a wide variety of cultural materials (e.g. bone, pollen, and other organic items).

Although mechanical impacts are most prevalent in the fluctuation zone, the potential for biochemical impacts is also greater than in any other reservoir zone. Biochemical activity is accelerated in the shallow waters of the reservoir littoral zone because of higher light, dissolved oxygen levels, and ambient temperatures. These conditions will support more organisms that may cause deterioration of perishable cultural materials. Similarly, the potential for human and faunal impacts is greatest in the fluctuation zone because of increased activity along the reservoir shoreline.

Control of Shoreline Erosion Impacts to Cultural Resources

Approaches

Three broadly defined approaches are commonly used for mitigating adverse impacts to cultural resource sites. They include steps to simply *avoid* impacts to a resource site, mitigation of unavoidable impacts through *data recovery*, and implementation of specific measures designed to ensure long-term *in-place preservation*. As they apply to cultural resources and shoreline erosion or bank recession, the characteristics of each approach can be summarized as follows:

Avoidance. Simple avoidance of the effects of an impact can be the easiest, quickest, and cheapest of the approaches. However, simply avoiding impacts to a cultural resource site by changing project features is no guarantee that it will be preserved for the future. Of more consequence for the types of impacts under discussion here is that once a reservoir has been put into operation there is little if anything that can be done to merely avoid shoreline impacts. Other impacts related to operation of the reservoir, e.g. recreation areas, roads, etc., can usually be avoided through redesign efforts.

Data recovery. Data recovery as a mitigation procedure has a long history at reservoirs, going back to the salvage effort during the early days of reservoir construction. In some cases, where the resource is severely endangered, it is not practical to preserve a property in place, and if time is running out, recovery of the remaining data may well be the most viable option. Before selecting a site for data recovery, however, a careful assessment of the site's significance and vulnerability to loss should be completed.

On the negative side, data recovery can be expensive, if done properly, and long-term curation of recovered materials and data is a critical concern. Another set of issues that may have a bearing on the decision to excavate certain sites is that related to the provisions of the Native American Graves Protection and Repatriation Act of 1990. This act includes provisions restricting data recovery of Native American human remains and associated artifacts.

Because of the fragility of the archeological record and its diminished state, it is also generally accepted that if a site can be practically preserved in place, it should be. In other words, proper management of an important cultural resource property should include mitigative data recovery only as a last resort.

In-place preservation. Protection and long-term preservation of a cultural resource site involves application of a structural or nonstructural technology or technique designed to prevent or to mitigate the adverse effects of either natural or cultural processes. Although local conditions vary widely, reservoir shorelines and drawdown zones have traditionally combined to create a significant problem with regard to in-place preservation of resources. This is due, in large part, to the severity of the impact, the general difficulty associated with controlling such impacts, and the repetitive nature of the processes. These factors create an environment in which monitoring and maintenance of the protective strategy must be considered since the erosion pattern will continue to be a hazard to the resource site.

In the past few years, several agencies have increased their efforts in cultural site protection and preservation, especially the Corps of Engineers which funded a multiyear research and development effort to identify appropriate technologies for cultural site protection (e.g. Nickens 1991; U.S. Army Corps of Engineers 1992). Much of this Corps effort has been directed toward identification of reservoir shoreline impacts (Ebert et al. 1989), evaluating site protection needs (Thorne 1988), and implementing various strategies to protect endangered resources at reservoir projects (Grosser 1991).

Not surprisingly, much of the technology used to protect cultural resource sites from eroding shorelines derives from engineering solutions to such problems. However, some modifications in the application may be necessary given the fragile condition of the resource. Cultural resource managers should be aware of some basic references concerning the numerous shore protection features available for consideration (e.g. U.S. Army Corps of Engineers 1981a, 1981b, Coastal Engineering Research Center 1984, Henderson and Shields 1984, and Allen and Klimas 1986).

Examples of shoreline protection projects

Several examples of attempts to protect cultural resource sites from the effects of shoreline erosion and bank recession can be found around the country. Even so, only a very small percentage of the total number of sites being eroded along reservoir shores have been treated in this manner. Three cases are briefly discussed below to indicate the scope of the problem, and a few of the solutions which have been implemented.

Whistling Elk Site, Lake Sharpe, SD. This archeological site is located on the Missouri River, south of the town of Pierre. Wave action and fluctuating water levels of the reservoir were eroding up to an estimated 2.3 m of bankline per year. Three protection alternatives were evaluated, including excavation (three subalternatives) and three engineering features (bank sloping, flexible concrete revetment, and riprap) (U.S. Army Corps of Engineers 1987). Excavation of the site was estimated to cost between $2 million and $22 million, depending on the amount of the site excavated. The solution chosen was dumped riprap over approximately 830 linear ft of bank at a cost of $126,850.

Site 23HE260, Harry S. Truman Lake, MO. The archeological site was being impacted by periodic inundation and sheet erosion. Also, a campground was proposed for a nearby location which would have increased human-caused impacts to the shoreline site. The protection method selected was intentional burial of the site surface to protect it from the lake waters and human intrusions (Grosser 1992). A 2-in. layer of gravel was spread over the site, followed by a 4-in. layer of fill. Seeding of the area was planned; however, native vegetation rapidly covered the area to provide a substantial ground cover. A fence and signs will be placed to further protect the site surface from artifact collectors and all-terrain vehicles. The cost of the site protection effort in this case was $5900.

Archeological Sites, Voyageurs National Park, MN. Several archeological sites at this park are experiencing erosion at the shoreline due to elevated lake levels resulting from dam construction in the early 20th century. Two sites, Clyde Creek and Sweetnose Island sites, were initially selected for bank stabilization activities (Lynott 1989). Standard bank stabilization techniques (sediment fill, filter fabric, riprap, and vegetation) were used to control the shoreline erosion at each site. As with the above examples, in-place preservation was significantly cheaper than projected costs for data recovery. At the Clyde Creek site, for example, the bank stabilization was accomplished for about $22,000. Excavation and curation of materials for only a 50 percent sample of the eroding portions of the site was about $45,000.

Protection and long-term preservation of cultural resources being impacted by shoreline erosion may not always be the cheapest mitigation avenue as in the examples given here. However, in-place preservation should always be considered as an equally viable alternative to other options. As noted previously, if feasible, in-place preservation is the preferred alternative for resource protection.

Conclusions

Shoreline erosion and bank recession at reservoirs across the country clearly constitute a serious and ongoing threat to cultural resource properties. The magnitude of this impact is not known since there are few cases where an adequate database is available. An adequate database, in this case, should include not only an accurate picture of the site distribution, but also a detailed evaluation of the current condition of the resources and a understanding of the types and intensity of the erosion impacts. Compilation and analysis of the required data should involve an interdisciplinary effort and have an integrating mechanism, such as a geographic information system.

Once the database is developed, it will be possible to address vulnerability of individual sites on a case-by-case basis, and then design reservoir-wide effective resource protection programs. When dealing with impacts generated by erosion processes, a key element of the protection program is the need for monitoring. Monitoring of changing conditions is critical, both for unprotected sites and those where a protection technology has been applied since it is possible that some maintenance will be required to ensure continued success.

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AGENCIES ATTEMPTS TO SOLVE THE PROBLEM (PANEL)

CORPS OF ENGINEERS' ATTEMPTS TO SOLVE RESERVOIR SHORELINE EROSION PROBLEMS USING INNOVATIVE APPROACHES

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The U.S. Army Corps of Engineers (CE) has over 460 reservoirs in the United States. It is estimated that over half have shoreline erosion problems (Allen and Wade 1991). On 276 of these projects, about 5,400 miles were estimated as having severe erosion with another 5,100 miles rated as having minor to moderate erosion (Allen and Wade 1991). Some of the types of damage reported on these 276 projects include: (1) damage to or destruction of homesites and property, both private and government; (2) fish and wildlife habitat degradation; (3) damage to and destruction of archeological and cultural resources; and (4) water quality degradation (Allen and Wade 1991).

The CE has historically attempted to address the erosion problem by designed revetments made from graded gravel and stone, often underlaid by a geotextile. Other revetments have consisted of articulated concrete blocks or asphalt. These methods have been fairly successful because the Corps has been working with these materials over a number of years and has been improving their design specifications.

Erosion control with these methods, however, is fairly expensive and has some environmental and recreational disadvantages. From an environmental perspective, riprapped revetment takes a long time to be covered with vegetation and does not provide shoreline habitat needed by many fishes and wildlife. From a recreational viewpoint, it is difficult to imagine that people enjoy pulling a boat up to riprap risking the chance of scouring their boat or that they enjoy traversing the riprap to reach the top of the bank or vice versa.

The CE, as a general rule, is trying to incorporate environmental engineering features into almost every facet of its construction, operations, and maintenance activities and it is trying to do this less expensively. Several research programs and customer assistance programs managed by the U.S. Army Engineer Waterways Experiment Station (WES) have spearheaded efforts to find more environmentally acceptable and less expensive erosion control methods.

The Environmental Water Quality and Operational Studies (EWQOS) Program at WES had a research task within it entitled "Revegetation of Reservoir Shorelines." This work focused on two primary things: (1) revegetating reservoir shorelines with plants that can survive within the drawdown zone, i.e., survive not only flooding, but drying; and (2) plants that can be used in combination with low-cost materials and structures that can

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be used to control erosion while providing other benefits. The latter is referenced as bioengineering or biotechnical methods.

The EWQOS Program produced several reports that help us to know more about the kinds of vegetation that can be used on reservoir shorelines and how to use that vegetation (Whitlow and Harris 1979; Comes and McCreary 1986; Hoffman et al. 1986; Lester et al. 1986; and Allen and Klimas 1986). For example, one experiment demonstrated that reed canary grass can withstand up to eight weeks of flooding in the drawdown zone of Lake Oahe, South Dakota (Hoffman et al. 1986). These results encouraged the South Dakota Game, Fish, and Parks Department to drill-seed this on a shore of the reservoir and noted that the grass served as valuable spawning habitat for northern pike (Allen and Klimas 1986).[1]

Another effort in the EWQOS Program was to find suitable ways of combining vegetation with low-cost building materials and structures. At Lake Wallula, near Walla Walla, WA, in the Walla Walla District of the CE, a biotechnical method was used where live willow branches were interwoven with hog-wire fence and rows of fence were installed along an unstable bank. Within a few months, the bank was covered with willow and was stabilized (Comes and McCreary 1986).

The Water Operations Technical Support (WOTS) Program managed by WES is an outgrowth of the technology produced by the EWQOS Program. This program is designed to give technical support and counsel to CE Districts and Divisions. In the case of shoreline erosion control, WES has provided these organizations with assistance on how to employ vegetation along with low-cost structures or materials. Through this program, WES can provide interdisciplinary expertise from its various laboratories, such as ecologists and geotechnical, coastal, and hydraulic engineers. In many instances, the program can help.

A WOTS team was asked to provide assistance at Lake Winnebigoshish, Minnesota, a CE project, but much of the land surrounding the project is managed by the U.S. Forest Service. Here, shoreline erosion was contributing to sedimentation of Walleye Pike spawning beds. Gravel beds were being covered with sediment. Recommendations urged the use of flood-tolerant vegetation in combination with a rock toe at the base of shorelines.

Another instance of the CE participating with other agencies occurred in the Omaha District. At Branched Oak Reservoir, a CE-built reservoir near Lincoln, NB, the Omaha District requested WOTS assistance to help them control erosion on land managed by the Nebraska Game and Parks Commission. Here, shoreline was being eroded next to a recreation area and the above agency was looking for cost-effective ways of controlling the erosion. The WOTS team designed a floating pole breakwater and both CE and state

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[1] Even though this grass is considered to be a noxious weed in some localities because of its characteristic to form monotypic stands, it was already naturalized in the reservoir at the time of planting and is not considered to be a pest in the area referenced. Other agencies with whom the CE is cooperating and some examples appear below.

personnel built the breakwater and then installed some biotechnical treatments shoreward of the breakwater.

The biotechnical treatments consisted of brush matting and wattling combinations made from live willow branches (Figures 1 and 2). These combinations were installed after shaving the bank to a slope with an acceptable angle. The matting consists of a 4- to 8-in. layer of live willow branches secured to the bank by tie-wires and stakes. At the lower edge of the matting, there is a cylindrical-shaped bundle of live willow 8 to 10 in. in diameter. Actually, the cylinder is formed by staking together several cigar-shaped bundles of willow branches called wattling. After a few months of growth through one growing season, the brush matting and wattling treatments were doing a superb job of stabilizing the shore.

Another promising biotechnical treatment at Branched Oak Lake was the use of willow cuttings inserted into cut slits of a 2-in.-thick geotextile made of coconut fibers with a rubberized backing. This treatment was applied without the protection of a breakwater. Several 50-ft lengths of 6-ft-wide geotextile were placed along the shoreline next to the toe of a 10-ft-tall cutbank. The edges of the geotextile were buried in the substrate and it was covered with the aid of handtools. The geotextile continues to become filled with sediment from wave action. Its many fibers provide an ideal growth medium for roots that become quickly attached to the fibers. It only takes a few weeks for willow cuttings to start sprouting. Omaha District personnel have been monitoring this treatment over the last couple of growing seasons and report that the treatment is quite promising even without the protection of a breakwater. With the protection of a breakwater, results would be even better.

The WOTS Program also sponsors tutorial workshops for CE personnel. Other agency personnel can attend on a space-available basis. Workshops have been held for the last 6 yr at CE district project locations (two at Carlyle Lake, Illinois, St. Louis District; one at Papio/Salt Creek Project, Omaha District; two at Lake Eufaula, Oklahoma, Tulsa District; and one at Orwell Lake, Minnesota, St. Paul District). At these workshops, tutorial information covering shoreline erosion causes and control methods have encouraged districts to go back to their own projects and try innovative methods of low-cost shoreline protection.

Examples of using WOTS workshop information can be seen at several CE projects and even some non-CE projects, where other agencies have applied the information. A couple of noteworthy examples occur in the Kansas City and Tulsa Districts. Kansas City District personnel used the brush matting and wattling combination at two projects within their District, Wilson and Long Branch Lakes, Kansas. The installation at Wilson Lake was used behind a rock berm placed just slightly offshore while the lake was at its multipurpose pool. Even though the willow used in the installations suffered initially after a severe drought that has persisted the last 3 to 4 yr, the willow is still alive and is starting to spread after recent precipitation and rise in the pool.[1] Tulsa District personnel have used a rock berm almost up next to a 30- to 40-ft escarpment with live, willow cuttings packed in ditches

[1] Personal Communication, October 1992, Mr. Michael Watkins, Kansas City District, Corps of Engineers.

behind the berm along with rows of willow cuttings and randomly placed cuttings. This was done at a cost savings of one-fourth the cost of riprapped revetment, which was applied to a similar shoreline reach just next to the one using the berm and willow cuttings, a biotechnical treatment.[1]

Another research program managed by WES is the Environmental Impact Research Program (EIRP). This program had a recent research task in it entitled, "Biotechnical Approaches for Shoreline Revegetation." This task was initiated in 1988 and was just completed in September 1992. A report on the task will be forthcoming within the next few months. This task focused on low-cost methods of shoreline erosion control using combinations of vegetation and low-cost construction materials or wave breakwaters.

This research effort had demonstration sites scattered around the country at four different sites: Dorena Lake, Oregon, near Eugene; Lake Sharpe, South Dakota, near Pierre; Holmes Lake, Nebraska, near Lincoln; and John H. Kerr Lake, near Clarksville, Virginia. With the cooperation of the U.S. Forest Service, the USDA Soil Conservation Service, Southern Tier Consulting, and others, the CE was able to demonstrate some cost-effective techniques of shoreline erosion control using biotechnical methods.

Only one site example, Lake Sharpe, South Dakota, will be discussed at this workshop due to a lack of time. This reservoir is on the Missouri River, just downstream of Pierre. The site where a demonstration was installed is next to DeGrey Public Use Area. There, wind-driven waves from a 2- to 3-mile fetch and ice scour were causing shoreline erosion that produced a 3-ft-high escarpment. A log breakwater (Figure 3) made of debris existing at the site and a wetland were used to heal the eroding bank. After the bank was shaved, the breakwater was constructed about 30 ft offshore and wetland grasses, bulrushes, and cattail were planted shoreward of the breakwater. Sediment was quickly seen trapped behind the breakwater and a slack-water zone was created. The breakwater dampened waves while concurrently acting as an ice deflector for melted and moving ice during spring thaws. Ice rode up on the breakwater; thus, there was a zone behind the breakwater that was conducive for plant establishment. The combination of a low-cost breakwater and wetland has helped heal the eroded bank over the last 3 yr.

The Repair, Evaluation, Maintenance and Rehabilitation (REMR) Program is the last program to be discussed and is also managed by WES. It has a research work unit in it entitled, "Cost-effective Shoreline Erosion Control Techniques for Reservoirs." It was initiated in October 1991 and is capitalizing on work done in the EIRP, mentioned above, but it is also addressing some other low-cost innovative methods of shoreline erosion control, such as some used in Germany consisting of low-cost breakwaters and wetlands.

In the REMR Program, just as we did in the EIRP Program, we will be cooperating with other federal and state agencies. We will have a joint project with the U.S. Forest Service at Hills Creek Lake, Oregon, and we hope to have a joint project with the Bureau of Reclamation at Ocean Lake, Wyoming. The REMR work will ultimately produce a

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[1] Personal Communication, 1992, Mr. Burl Ragland, Tulsa District, Corps of Engineers.

decision and design criteria guidance report and a report for giving critical success factors for shoreline erosion control.

In conclusion, you can see that the Corps of Engineers, along with other cooperating agencies, are trying some innovative techniques for shoreline erosion control. Our focus is on techniques that are both cost-effective and have some other beneficial uses in addition to erosion control, such as fish and wildlife habitat improvement and water-quality enhancement. It would do us well as a society and as government stewards of the lands and waters entrusted to us to continue to seek less expensive and more environmentally compatible ways of controlling reservoir shoreline erosion.

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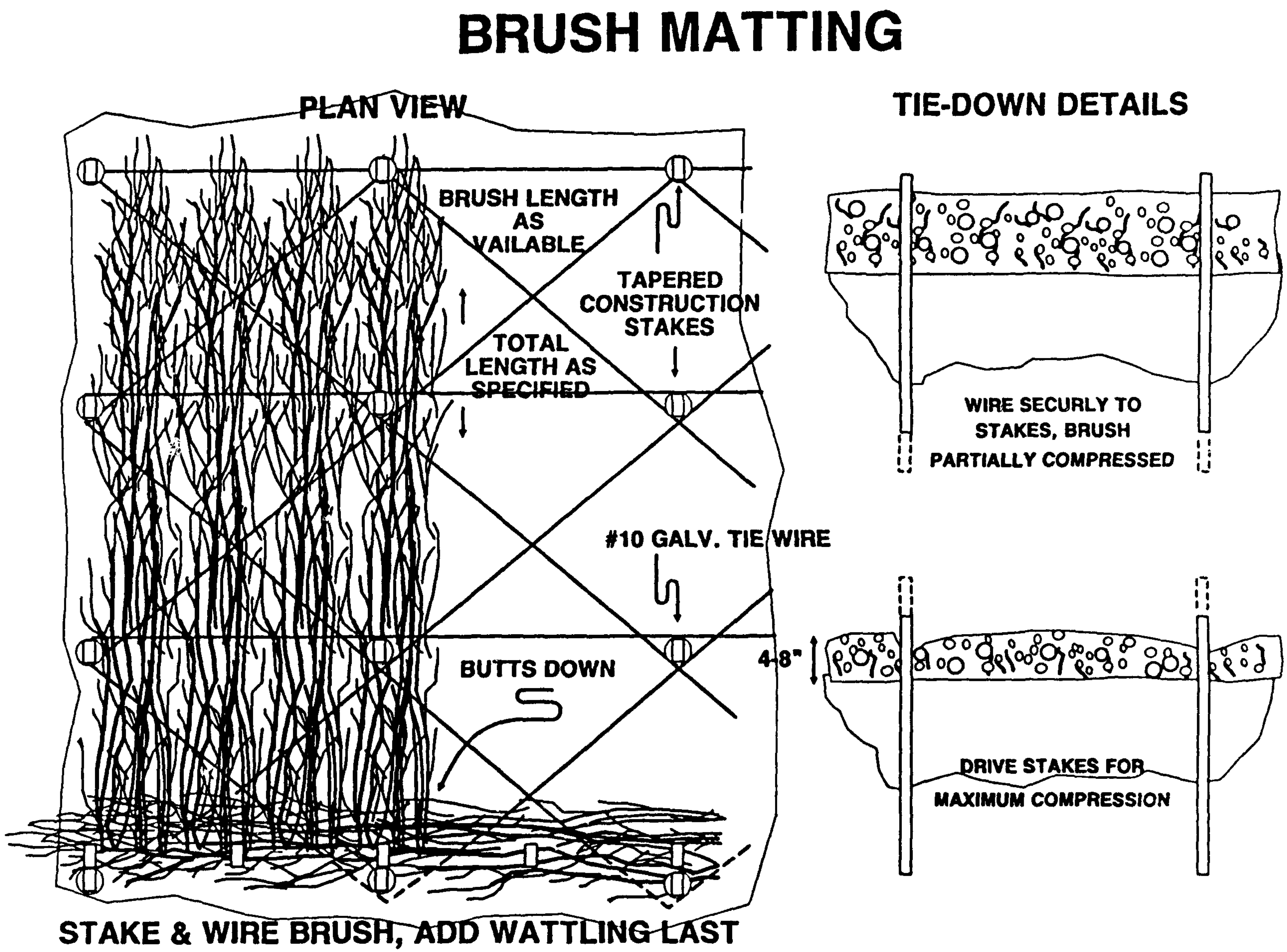

Figure 1. Plan view and tie-down details (profile view) of brush matting biotechnical treatment

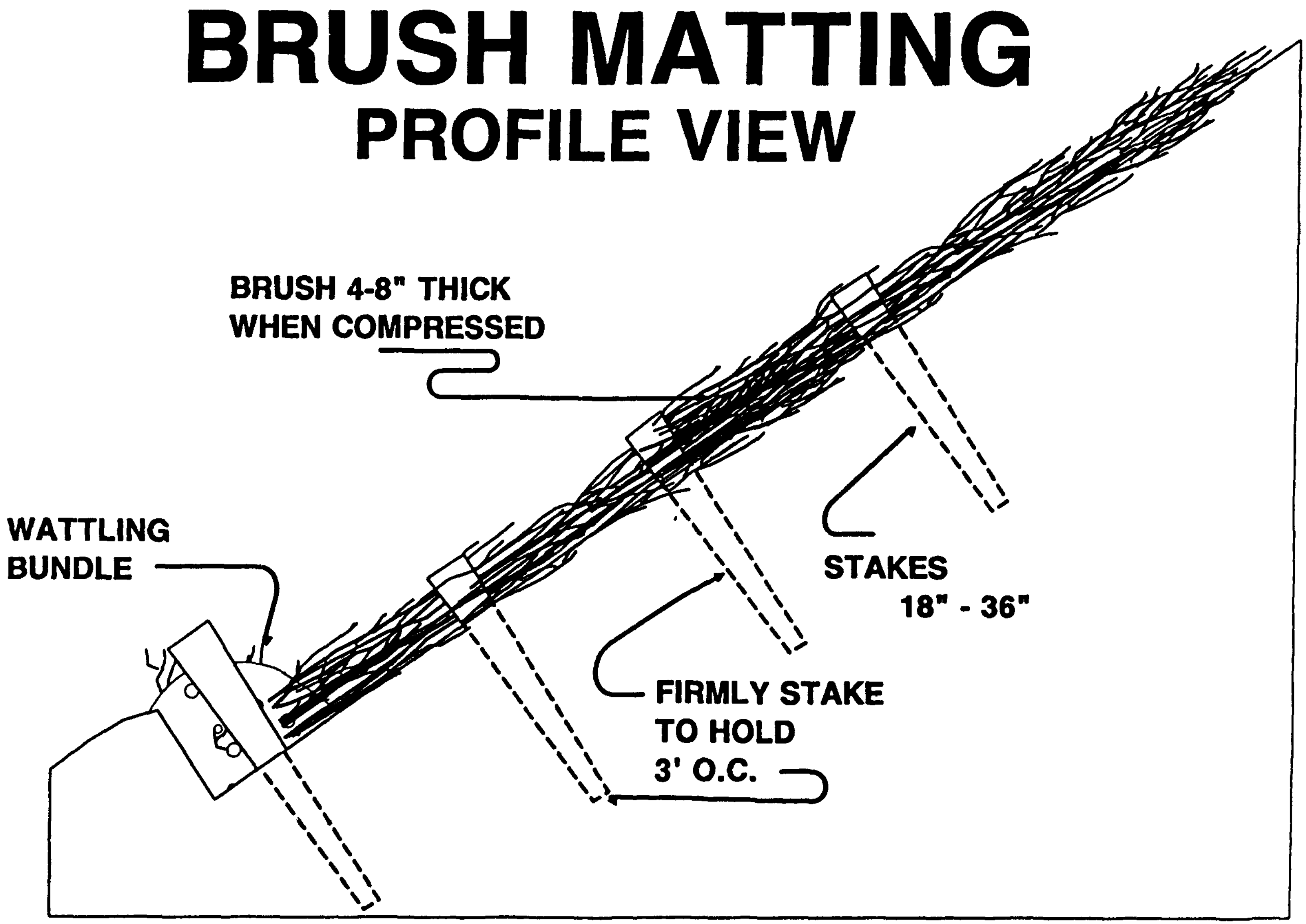

Figure 2. Profile view of brush matting biotechnical treatment. Note wattling bundle at toe of matting

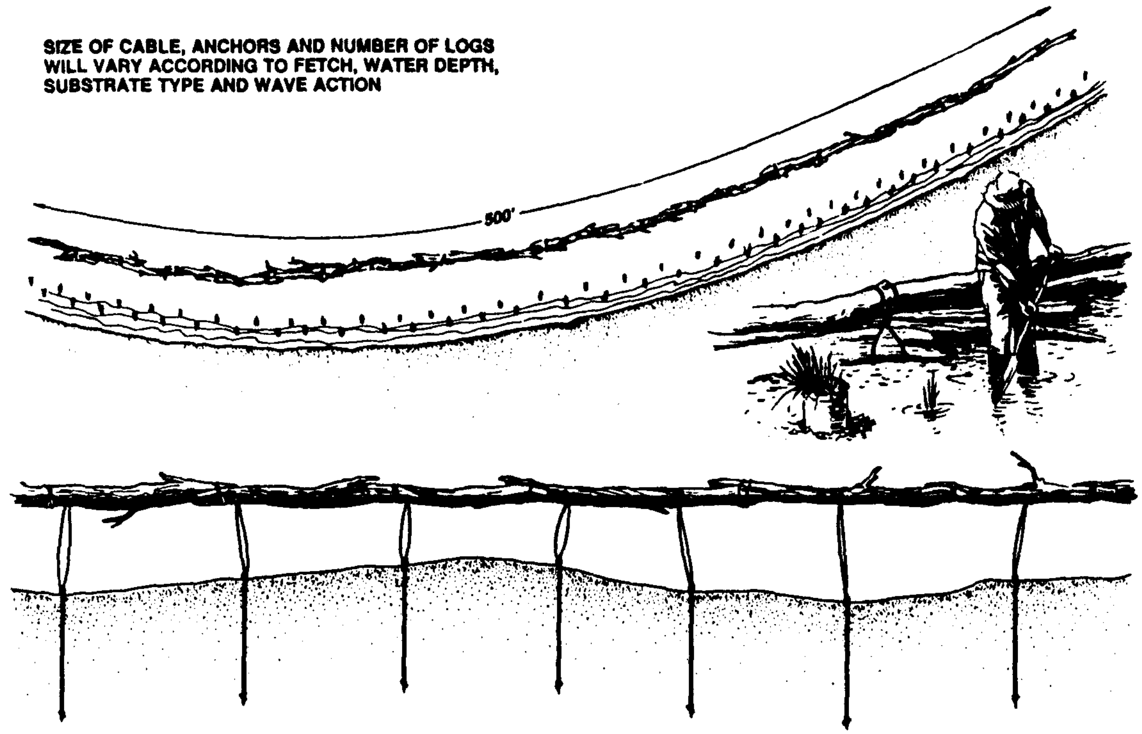

Figure 3. Plan (top) and profile (bottom) views of log breakwater used at Lake Sharpe, South Dakota. Note wetland vegetation planted shoreward of breakwater

PLANTING TECHNIQUES FOR VEGETATING SHORELINES AND RIPARIAN AREAS

J. Chris Hoag,[1] Harold Short,[2] and Wes Green[3]

Abstract

The Aberdeen Plant Materials Center in cooperation with the Bureau of Reclamation found the following woody riparian species effective in shoreline protection and revegetation of eroded stream channels: Coyote Willow (*Salix exigua),* Laurel Willow (*Salix pentandra),* Prairie Willow *(Salix humilis),* 'Siouxland' Eastern Cottonwood *(Populus deltoides),* 'Imperial' Carolina Poplar (*Populus canadensis),* and Robust Poplar (*Populus robusta*). A small power auger was the most effective planting method on shorelines without riprap. "The Stinger," a backhoe attachment, was the most successful method on rock riprapped shorelines. Hormones, fungicides, and fertilizer did not necessarily enhance survival and establishment. Long cuttings with large diameters planted into the midsummer water table gave the highest success rate.

Introduction

The Minidoka Project office of the USDI, Bureau of Reclamation (USBR) is located in Burley, ID, about 80 miles west of Pocatello. Its area of responsibility is the Snake River drainage in southeastern Idaho and western Wyoming. The Minidoka Project operates 8 separate reservoirs and 2 power plants. It provides full or supplemental supply irrigation water for about 1.2 million acres. The American Falls Reservoir is the largest reservoir in the system and is the keystone of the project.

The Plant Materials Center (PMC) at Aberdeen, ID is one of 26 PMCs in the United States run by the USDA, Soil Conservation Service. Even though we are located in Idaho, our service area includes southern Idaho, southeastern Oregon, the northeast tip of California, most of Nevada, and Utah. The Aberdeen PMC was established in 1939 to assemble, test, and release plant materials for conservation uses; determine techniques for their successful use; provide for their commercial increase; and promote the use of plant materials needed to meet the objectives and priorities of the National Conservation Program.

The Minidoka Project had tested various structural and vegetative methods for reducing shoreline erosion around American Falls Reservoir in the past with varied success. The vegetative methods indicated great potential in areas with a short fetch, so it was decided to expand the testing to areas with more severe conditions. In order to more fully

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research these methods, the USBR contacted the Aberdeen PMC and entered into an agreement with them to develop a vegetative solution to reduce shoreline erosion.

Problem

American Falls Reservoir was built on the Snake River in 1926 to store irrigation water for farmers and ranchers downstream of the dam. The reservoir's capacity is 1,670,000 acre-ft. The elevation of the reservoir is about 4,350 ft. The annual precipitation for this area is 8 to 10 in. Idaho Power has a hydroelectric plant downstream of the dam for power generation. The general operation of the reservoir is based on the irrigation needs of the water-right owners below the dam. Drawdown starts in early summer and continues into the fall until the end of the irrigation season, which is usually in October. The water level in the reservoir decreases continuously over the course of the summer according to irrigation water demand downstream. The reservoir is refilled during winter and spring.

The main problem at American Falls Reservoir is that much of the shoreline soils are clay and sand. Much of the shoreline has been eroded into 20- to 40-ft vertical cliffs. Wind-driven waves during the spring refill and summer drawdown slam against the vertical cliffs causing massive undercutting and sloughing. In some cases, the shoreline has retreated hundreds of feet with the loss of many acres of valuable farmland. The general rule of thumb has been that 3 to 5 ft of shoreline is lost each year.

Social, political, and economic reasons have prompted USBR to come up with some method of controlling this erosion. The best structural method to date is to armor the shoreline with geotextile sheet and rock riprap. Considering that the reservoir has about 60 miles of shoreline that needs some treatment, the cost of riprapping the shoreline at $20 to $25 per linear foot is prohibitively expensive. Additional methods of protecting the eroding shorelines must be found.

In 1986, the Aberdeen PMC put together a research project to study methods of establishing vegetation to protect the shoreline of American Falls Reservoir. The objectives of the study were to (1) test various plants for their erosion-controlling ability along the shorelines (including unprotected stretches and stretches partially or fully protected by structures), (2) improve low cost, high volume planting techniques, (3) ensure low maintenance costs, and (4) maintain or improve wildlife and fish habitat needs, as well as aesthetic values.

The study is composed of two parts. The initial study was started in 1986 and lasted approximately 2 yr. Based on information on cutting size and planting methods developed in this initial study, the second phase of the study was radically changed. The techniques and species that were developed in the first 2 yr of the study were refined and built upon to better handle the wave undercutting and ice problems that plagued the first phase.

Materials and Methods

Background

Since the 1950's, the Minidoka Project has been testing various methods, both structural and vegetative, to reduce the shoreline erosion on American Falls Reservoir. The first method was to use rock picked off of agricultural fields and pushed over the sides of the cliffs. This method was ineffective because the waves tended to move the small rock and continue to erode the cliffs. Then railroad rails were pounded into the reservoir bed and old automobile tires piled on the rails to a height of 6 to 8 ft. The rails and tires were placed about 1 to 2 ft apart, assuming that wave energy would be reduced as it passed through the tires before it hit the banks. This method did not work very well because the wave energy was not significantly reduced. USBR also tried a tire mattress made of old automobile tires tied together and placed on the shoreline in front of the cliff. They hoped that the tire mattress would reduce wave energy and catch sediment before the waves hit the cliffs. This worked so well that the mattress was totally buried by sediment in a couple of years and the erosion problem started again. After the tire mattress, the USBR tried a method called post and wire. This method used railroad rails pounded into the bed, galvanized wire tied to the rails, and rock riprap piled between the wire and the cliffs. This method was very successful, but also extremely expensive and difficult to repair. Finally, the preferred method currently in use is shaping the upper bank, dropping the soil down to the base of the cliff, dozing a road along the base, laying geotextile over the slope, and covering the geotextile with large rock.

The Minidoka Project also tried using Brittle Willow (*Salix fragilis*) for shoreline protection. The project started planting cuttings in the 1950's. A large bulldozer with two ripper teeth was driven along the base of the cliffs and short cuttings were placed in the resulting trenches and soil packed around them. The problem with this procedure was that the cuttings were too short. Not only did the wave action tend to destroy the plantings by undercutting, but ice froze around the bases and as the water level in the reservoir continued to rise, it pulled the cuttings out of the ground.

This project was designed to expand the USBR's experiments with Brittle Willows and to discover ways to enhance the structural methods that have been used around the reservoir. Initially, the PMC decided to look at different species of willows and different growth forms.

The Aberdeen PMC has been testing riparian woody species since 1982. A large planting of various windbreak species was established in 1982. It contains, among other things, about 70 different riparian accessions.

An initial evaluation willow planting was established in 1984 at the PMC. It includes about 30 different accessions of willows. These accessions were collected from native stands throughout the Aberdeen PMC service area and from PMCs in North Dakota, Montana, Washington, and Michigan. From these two initial trials, 15 different accessions were selected for advanced testing (Table 1).

Site

American Falls Reservoir is an extremely harsh site because of three major limiting factors. The first is the soil. It is made up of clays and silty clays intermixed with layers of sand. It is very compacted and has almost no organic matter or soil nutrients. This makes root penetration very difficult. In addition, as the soils dry out during drawdown, the sand, shattered clay, and silts fill up the planting hole as fast as the drill instrument is removed.

Another major limiting factor is the lack of natural vegetation. Few species are available at the reservoir to establish, spread, and protect the shoreline. These species are normally found only in protected areas that have extra water seepage from springs or summer irrigation water that drains underground from the fields above the reservoir.

The last major limiting factor is the irrigation drawdown of the water stored in the reservoir. From the start of the irrigation season in mid-April to the end of the irrigation season in late October, the water in the reservoir is drawn down to as low as 10 percent (or less) of its capacity. This means that willows planted along the shore in the spring are 1,000 ft or more from water by the end of the irrigation season. After the irrigation season, the reservoir begins to refill, and the last 10 vertical ft of the reservoir normally fills by March or April. This means that willows planted at the base of the shoreline are inundated just before they break bud and may stay inundated until June or July.

American Falls Reservoir lies generally southwest to northeast. Prevailing winds are from the southwest and are most active in the early spring. Test plots were established on five different beaches around the reservoir. Of the five beaches, three beaches are unprotected and face east, west, and south. The unprotected beaches are bounded by vertical cliffs at the high-water line, and fairly uniform slopes drop away from the cliffs at 3 to 5 percent. The other two beaches have existing structures, such as rail and wire, rail and tire, rock riprap, and tire mattresses. The PMC planted willows in front of these structures to slow down the wave energy before it hits the structures. These structures generally extend 40 to 60 ft out from the cliffs. One beach faces east and the other faces west.

Test design

The test plots were set up in randomized, replicated complete blocks. Initially, each block contained all of the accessions in a test and extended out from the cliff at three different inundation levels. At each inundation level, treatments were randomized. Each combination of inundation level, accession, and treatment was replicated three times. The accessions were planted with five members spaced 1 ft apart in a "W" arrangement. This allowed not only an adaptation test, but was also thought to provide the best protection possible for the shoreline. As the survivability of the different accessions became established, the W arrangement was supplemented by various other arrangements based on the individual growth types of the accessions. For all succeeding tests, accessions were planted in five groups of four individuals randomly arranged in the various segments of the block.

Generally, we tried to use the natural growing habits of the willows when designing the layout of the tests. Creeping-type willows with their flexible stems and extensive root systems, shrub-type willows with shorter stature and somewhat flexible stems, and tree-type willows with large roots and trunks were planted in association with each other in a way that wave energy would be reduced as it passed through each successive type before it impacted the cliff or structure.

Test methods

Initially, to improve low-cost, efficient, successful planting techniques, five different factors were examined. They were: (1) planting methods, (2) cutting diameter, (3) cutting length, (4) planting depth, and (5) planting supplements. To test these factors, five different accessions were used that grew on different areas of the reservoir as native or naturalized species, or are species widely used and well adapted to the area. In subsequent years, after determining which factors improved willow establishment, other factors such as stored versus fresh cuttings and additional species were examined.

Planting methods. Seven treatments were tested: Direct insertion by hand, direct insertion by pounding with a small sledgehammer onto a special shock-absorbing cover, a 1.5-in.-diam hand auger, and 1-in.-diam planting bar. In subsequent years, a 3-in.-diam, two-person power auger, a 3-in.-diam, towable one-person power auger, and "The Stinger" were tested. The compacted nature of the clay soils meant an aggressive method was needed to get the cuttings into the ground.

Cutting diameter. Cutting diameter varied greatly by species. Six classes of diameters were established: 0.125 to 0.25, 0.25 to 0.5, 0.5 to 0.75, 0.75 to 1.0 in., 1.0 to 1.5 in., and greater than 1.5 in. All diameter classes were represented by all the accessions tested except the Dwarf Blue Arctic and the Sandbar Willows, which rarely get bigger than 0.25 to 0.5 in. In subsequent years, "dormant stump" plantings were made where the cutting diameters ranged from 2 to 8 in. in diameter.

Cutting length. Cutting length also varied greatly by species and source. The majority of the first plantings were 18 in. long. Specific tests were made of 1-, 2-, and 3-ft lengths. Generally, only about 6 to 10 in. of the cutting protruded from the soil after planting. Subsequent years' tests were made of 8- to 12-ft lengths. This was to ensure that enough stem protruded above the ground after planting so that the tops were above the high waterline.

Planting depth. Planting depth varied with the planting method. The cuttings were placed so that at least one to three buds were above ground level. Generally, where possible, two-thirds of the cutting was placed into the ground. Direct insertion by hand was the shallowest method, about 3 to 6 in., with a few cuttings going as deep as 8 to 10 in. The hand auger and bar generally put the cuttings down approximately 12 in. The power augers put the cuttings down to a depth of 24 to 34 in. depending on the compacted soil layers. With an extension, the one-person towable auger could go deeper than 36 in. "The Stinger" is a new attachment for a backhoe for planting in rock riprap. It can punch holes through large rock riprap as deep as 7 ft.

Planting supplements. Planting supplements were examined to see if they would enhance survival and rapid establishment which would in turn decrease the total cost per plant. About 50 g of Ozmacote 19-6-12 time-release fertilizer was placed 3 in. below the cutting in a hand-augured hole and covered with a layer of soil. Two treatments, fertilizer and no fertilizer, were applied to each of four different accessions. Four treatments, rooting hormone, fungicide, rooting hormone and fungicide, and no treatment, were also tested. The rooting hormone was 0.1 percent Indole-3-Butyric acid. The fungicide was 4.0 percent Thiram. They were applied as dry powder dips or as liquid dips just prior to planting according to the manufacturer's recommendations. In addition, soaking the stored cuttings for 24 to 48 hr in tap water before planting versus planting dry cuttings was tested.

Adaptation trial. Over 14 different accessions from Washington, Oregon, Montana, Utah, Idaho, North Dakota, and Michigan were tested to examine their range of adaptability. These cuttings were arranged in rows that contained 10 cuttings of a single accession with each accession randomly replicated three times along the beach. The cuttings were planted in rows at a 45-deg angle to the cliff. The rows were 2 ft apart and the cuttings were 3 ft apart within the row.

Stored versus fresh cuttings. Large-diameter cuttings were harvested from dormant plants in late winter. The cuttings were then placed in a walk-in cooler that was set at 35 to 39 °F. The cutting date was documented. Large-diameter fresh cuttings were harvested within 20 hr of planting. Both stored and fresh cuttings were harvested from the same parent plant. All cuttings were 1.5 in. or larger. All cuttings were planted 26 to 34 in. deep. After planting, 2 to 6 ft of the stem protruded above the ground.

Results and Discussion

Initially, of the first four planting methods that were tested, direct insertion by hand was the most successful. It was followed closely by the hand auger and the planting bar. The direct insertion by pounding tended to shatter the tops of the cutting, even though a special metal pipe cover with a piece of rubber belting was placed in the top to absorb some of the force generated by the sledgehammer. This method was used only once and was discontinued.

Close contact between the surface of the cutting and soil was identified as a critical element to cutting establishment. Removal of extra soil from the hole led to problems with air pockets and lightly compacted soil when backfilled after planting the cutting. Because willow and poplar cuttings have root primordia all along the stem, the better soil is packed around the stem or the closer the hole diameter is to the stem diameter, the better the establishment success.

For the most part, the first four planting methods rarely placed the cuttings any deeper than 12 to 14 in. Excellent sprouting success was obtained the first summer with these methods. However, by the following summer, after a normal windy spring with abundant wave action, most of the cuttings had either been ripped out of the soil entirely or the soil was washed away from the roots down to about 8 to 10 in. It was apparent that the cuttings had grown a good root system over the initial summer growing season with some of the roots measuring over 26 ft long. However, for cuttings to survive at the reservoir, it was apparent they were going to have to be planted much deeper.

The Aberdeen PMC has been researching different species of willows and poplars, planting supplements, and planting techniques since about 1986. Through this research, especially on the shoreline of American Falls Reservoir, we have determined that large unrooted cuttings of willows and poplars when planted with good stem-to-soil contact will root and sprout quite readily. We have experimented with cuttings that are from 1 to 8 in. in diameter and 4 to 15 ft in length and had excellent establishment success.

The best sprouting success was achieved when the cuttings were larger than 0.5 in. in diameter. In subsequent years, it became apparent that cuttings no less than 1 in. and preferably larger than 1.5 in. in diameter produced the best sprouting success. "Dormant stumps" with a diameter of 3 to 8 in. were also used. Dormant stumps appear to have a much better supply of stored energy than the smaller diameter cuttings, so they can survive a longer sprouting period. They also can withstand much greater wave velocities than can the smaller diameter cuttings.

The 18-in. length of the initial cuttings was determined to be much too small after the first 2 yr. This was because they (1) could not be planted deep enough to keep the waves from washing them out, (2) could not be planted deep enough to reach the midsummer water table, and (3) would be totally inundated during initial bud break, not to mention late spring and early summer growing periods.

After determining that larger cuttings would increase the establishment success, power augers were tested. It was clear that the other methods, even though they were fast and efficient, were not going to get the cuttings deep enough to allow them to survive on American Falls Reservoir. Tractor-mounted power augers or any other vehicle-mounted equipment could not be used at the reservoir because of the soils. If the soils were the least bit wet, any heavy piece of equipment would mire down in a very short time. Handheld power augers, in the size necessary to get through some of the hardpan areas, were too large and cumbersome to efficiently plant large numbers of cuttings with a reasonably sized planting crew. The towable auger was an attempt to increase the number of cuttings that could be planted over long distances and with a reasonably sized crew. Both power augers had establishment rates that were equal to the hand augers.

The Stinger was designed and built to continue and improve the power auger success. In addition, it could plant cuttings right into rock riprap to better stabilize the rock, allow the cutting to be above the ice layer, and improve the aesthetics of the riprap.

The Stinger can plant 3- to 5-in. diameter and 5- to 7-ft long willow and poplar cuttings directly into rock riprap. This tool was built to fit on the back of a backhoe in place of the bucket. The shaft is a cold-roll round steel bar 8 ft long. The total length for punching holes is 7 ft. The business end of the bar is pointed and hardfaced with electric welding rod and 4 in. in diameter. The mainframe that attaches to the backhoe was manufactured from 3/4-in. steel plate. The mainframe is designed to allow the bar to move back and forth. This movement will allow a hole to be punched almost perpendicular to a vertical bank.

The Stinger was designed to be heavy enough to punch a hole down through the large rock riprap and into the soil underneath. Generally, the soil underneath is moist to wet when the willow and poplar cuttings are being planted. Once the Stinger goes through the rock, there is not much resistance from the soil.

Cutting lengths of 8 to 12 ft had excellent sprouting success because of two factors. First, the cuttings could be planted 32 to 84 in. deep, and second, they extended 3 to 5 ft above the high water. The major problem was ice. In a normal year, USBR endeavors to not fill the last 10 vertical ft of the reservoir because of the thick ice sheet that forms on the surface. When the ice does form, it freezes around the trunks of the trees and shrubs established along the shoreline and will actually pull them out of the ground. In addition to freezing around the stems, willows planted in front of structures encountered severe damage along the stems from ice chunks that were floating on the surface after breakup. The wind-driven waves would smash them against the willows, which could not give enough because they were planted too close to the structures.

In the planting supplement trial, we could find no clear-cut advantage to using fertilizer, rooting hormones, or fungicides when the cuttings were part of a high-volume, high-intensity riparian planting program. Untreated cuttings had as high or higher establishment success when compared to those that were treated. Data on soaking are not clear-cut in our studies. However, when one reviews the literature with its numerous references to the benefits of soaking, it should be encouraged as a standard practice.

In the stored versus fresh trial, we found that there was no significant difference between cuttings that were harvested in the dormant season and stored in a cooler until summer and fresh cuttings that were harvested the day before the plantings. The storage option provides more flexibility with harvesting, site preparation, and planting than the fresh cut option.

Recommendations

We recommend that, wherever possible, cuttings be at least 1 in. or greater in diameter. They should be long enough to reach the midsummer water table. This is to ensure the cuttings have ample water to sprout. It also puts the majority of the roots below most of the root systems of competing vegetation. The cuttings should also be high enough above ground level to be above the inundation level and to avoid shading from weeds and grass. If erosion control is an objective, the cuttings must be tall enough to intersect wave action. In high-volume, high-intensity planting programs, the use of fertilizer, rooting hormone, and fungicide does not necessarily increase the establishment success to a point where these practices will repay the extra effort and cost associated with them.

The post and wire protection that was installed at two locations on American Falls Reservoir was in response to the public's request for an erosion control method that would utilize small rocks that were picked out of agricultural fields adjacent to the reservoir.

Initial construction costs were about equal to rock riprap. As time goes on, the durability of the wire is questionable as stress points have failed and repair is difficult. In addition, rounded rock is required versus angular rock normally used in riprap. After using this method, the conclusion is that it is not durable or flexible enough to use on large scale.

The post and tire protection was also tried on two different points around the reservoir. One site was a jetty structure and the other was in front of the reservoir cliffs. The jetty site has worked well by piling up the sands and silts behind it and providing protection to a section of shoreline behind it. The other site has slowed erosion rate, but not stopped it. This site has now been riprapped behind the post and tire section. The post and tire method allowed too much wave energy between the tires so cliff erosion continued, only on a smaller scale. Another problem was that the tires had to be continually replaced because the old ones would disappear into the clay base. This method has been discontinued.

The present method in use is rock riprap with geotextile sheet underneath. This method is installed in August and September when the reservoir is at least 12 to 15 ft below high water. The construction is started with a long-boom excavator that slopes the clifftop back to remove any undercut material and to provide fill at the base of the cliff for a building pad. Then a large dozer builds a pad wide enough to accommodate 10-wheel dump trucks, usually about 10 to 12 ft. The slope on the pad is smoothed and compacted by a small dozer. The top of the pad is 4 ft above the highwater mark which allows sufficient freeboard for most storms. A key trench (3 ft x 3 ft) is dug with a small excavator. The key trench allows additional protection against undercutting. Next, a nonwoven geotextile material (ARMCO 1120 or equivalent) is laid on the slope in place of gravel. The geotextile is 60% cheaper than gravel. Finally, rock riprap is end-dumped onto the fabric and pushed as necessary with a small cat to get a layer of 2 to 4 ft. The rock around American Falls Reservoir is difficult to find because the lake area is lacustrine in nature with basalt flows that surface in specific areas. Quarries have been found on the west side of the lake where well-graded material from 6 in. to 5 ft plus is blasted out of the basalt flows.

Table 1
Species Selected for Advanced Testing from Two Initial Trials at the Aberdeen PMC

Accession	Scientific Name	Common name	Source
9005049	Salix pentandra	Laurel Willow	Michigan
9047349	Salix vitellini	Golden Willow	North Dakota
9044859	Salix alba	White Willow	North Dakota
9053849	Salix fragilis	Brittle Willow	Idaho
9020059	Salix drummondiana	Drummond Willow	Washington
9020121	Salix lemonii	Lemon Willow	Washington
9020100	Salix rigida var. mackenziana	Mackenzie Willow	Washington
303584	Salix humulis	Prairie Willow	North Dakota
9026075	Salix exigua	Sandbar Willow	Montana
9020099	Salix exigua	Sandbar Willow	Washington
9044861	Salix exigua	Sandbar Willow	Idaho
9031690	Populus robusta	Robust Poplar	North Dakota
9031688	Populus deltoides	'Siouxland' Cottonwood	North Dakota
432347	Populus x canadensis (deltoides x nigra)	'Imperial' Carolina Poplar	Michigan
9005050	Salix purpurea nana	Dwarf Blue Artic Willow	Michigan

QUESTION: What period of time...season...in planting the willows did you get the best survival?

MR. GREEN: We cut them dormant then plant them in the Spring. This creates a problem because the water is up pretty high at that time. We do get a good establishment because the reservoir is high, getting ready for irrigation. The water table is also high. When we draw down by summer they tend to hold on their own.

QUESTION: Do you plant them before the new growth shows?

MR. GREEN: Yes. We also found that if we want to adjust the size of the plant, if we want it to grow with a big ball on top, we scrape off the buds along the base. So, we can control the shape of the tree by taking the buds off it as they start to sprout.

QUESTION: How far away from the site are you getting your willows?

MR. GREEN: Michigan...New Mexico...anywhere we can. Really, a lot of our reservoir area of American Falls, particularly the upper island area, is a very vegetated area. It has a lot of willows naturally growing. So, we're getting a lot of cuttings in and around the reservoir. We have some other reservoirs in the same project that have good willow establishment, and we get our cuttings from there.

BLUE RIVER AND DORENA RESERVOIR EROSION CONTROL VEGETATION SURVIVAL TESTS

Delbert G. Skeesick[1] and Michael C. Sheehan[2]

Introduction

Construction by U.S. Army Corps of Engineers of flood control/power generation reservoirs in western Oregon in the 1950's and 1960's changed sections of 13 streams from lotic to lentic environments. In the Willamette River basin, 34,515 acres of reservoirs are covered at high pool, but the area shrinks to 13,240 acres during the late summer and fall. Thus, up to 21,275 acres of reservoir slopes are exposed during the late fall and winter. In February, refilling begins so the reservoirs can reach full pool by late May, the start of the recreation season.

During construction, drawdown zones were cleared of vegetation, leaving only low stumps. Post-clearing volunteer vegetation typically was not water-tolerant and generally died out following the first inundation. Thus, reservoir slopes became destabilized and extensive downslope movement of soils occurred. Unprotected high-pool banklines have eroded, causing chronic turbidity as well as unsightly escarpments.

Since five of these reservoirs occur within the boundaries of the Willamette National Forest, responsibility for management of shoreline area has been a shared responsibility of the Forest and the U.S. Army Corps of Engineers, Upper Willamette Valley Project office.

Beginning with the construction of Blue River Reservoir in 1969, there have been sporadic attempts to establish terrestrial vegetation in reservoir drawdown zones to stabilize soils and reduce turbidity (Dyrness 1970, Skeesick 1983, Skeesick and Sheehan 1992, and Swanson 1974).

Over the years since construction, a few species of water-tolerant terrestrial vegetation have invaded the reservoir drawdown zones. In a few places this natural colonization has been augmented by trial planting of species suspected to be tolerant of inundation. From observing the areas where vegetation was successful, certain benefits become evident (Table 1).

Different types of vegetation serve different roles in the drawdown zone (Table 2).

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Study Area

The presentation describes the results of two trial plantations at Blue River Reservoir and one at Dorena Reservoir. These reservoirs are on low elevation tributaries of the Willamette River near Eugene, OR. Both are U.S. Army Corps of Engineers flood control reservoirs.

Blue River Reservoir is 1,420 surface acres and begins drawdown in mid-July to augment Willamette River flows. Test vegetation has the shortest inundation period of any of the Willamette basin reservoirs.

Dorena Reservoir is 1,840 acres and is maintained at nearly full pool until early September for recreation. Test vegetation has inundation periods equal to the longest that would be experienced in any Willamette basin reservoir.

Climate

The area receives approximately 47 in. of precipitation annually, most of which falls between November and April. Air temperatures are moderate, with summer highs rarely exceeding 90 °F and daily fluctuations of 25 °F are in the norm. Winter temperatures may drop below 20 °F occasionally but temperatures between 30 °F and 50 °F are typical. Light snow is common but rarely persists. Last spring frost occurs in early April and first fall frost is in mid-October.

Blue River Studies

Beginning in 1971, the Willamette National Forest established test plantations of terrestrial vegetation thought to be water-tolerant in Blue River Reservoir. The early testing was a cooperative effort with the U.S. Department of Agriculture Plant Material Center at Corvallis, OR.

Although the studies being reported were carried on independently, they each included a variety of tree, shrub, and herbaceous species. Plant sources, method of planting, timing of planting, and assessment of results varied too much for there to be analytical comparisons, but each demonstrated enough success to warrant continued testing as well as field application.

Results, Blue River Reservoir, 1971

The 1971-72 trials included 14 grasses, 10 legumes, 13 forbes, 5 shrubs, and 4 tree species. Establishment was from rooted plants, cuttings, plugs, or seedlings, depending upon species and availability. Of the 46 species tried, four remain viable after 21 years (1992 observations).

Columbia sedge (*Carex aperta*) persists strongly over the entire depth range planted (0 ft to -50 ft) and the plugs planted have coalesced into a solid row 4 ft to 5 ft wide. This species is an unqualified success.

Slough sedge (*Carex obnupta*) has spread extensively laterally from the original planting in the shoreward area (less than -25 ft) but has disappeared in the deeper zone (-25 ft to -50 ft). This species is a qualified success and has the desired ability to spread extensively.

Baldcypress (*Taxodium distichum*) persists over the entire depth zone originally planted (0 ft to -50 ft). Overall tree survival is approximately 75 percent with trees in less than 15-ft depth actually emergent and growing throughout the summer. Nearshore trees are in excess of 20 ft tall, four in DBH (Diameter Breast Height) with branches to 6 ft in length, but those planted near the 50-ft depth have barely increased in height or width. This species is an unqualified success both from the standpoint of survival and the dense, bushy lower branches that provide juvenile fish cover and dissipate wave energy.

A few silky dogwood (*Cornus amomum*) persist at depths less than 20 ft, but are nonexistent beyond that. The hedged condition of the remaining plants along with deer tracks near the remaining plants suggest that heavy browsing may play a significant role in keeping the plants from surviving better. Although this planting cannot be judged successful, it demonstrates some inundation tolerance and may warrant further testing where browsing is not a factor.

All other species tested must be considered failures either from lack of tolerance to inundation or inability to compete with invading plants (mainly reed canary-grass, *Phalaris canariensis*).

Results, Blue River Reservoir, 1988-89

The 1988-89 trials included 10 shrubs and seven tree species. Establishment again was rooted plants or cuttings, depending upon the species. All of the tree and shrub species demonstrated good survival after one inundation (Table 3).

Although one inundation may not be a sufficient challenge to test long-term response/survival of all species, initial results appear encouraging for several species and corroborate previous observations/tests. In particular, the baldcypress survival rate appeared similar to the 1971 test, supporting the previous evaluation.

Of the species tested for the first time, green ash (*Fraxinus pennsylvanica*) at 90 percent survival, Douglas spirea (*Spirea douglasii*) at 83 percent survival, and rigid willow (*Salix rigidia* var. MacKenzieana) at 92 percent appear particularly promising.

Dorena Studies

April 1989 study design

The study design included th. ؛ basic treatments, with six replications. Within each replication, there were six subtreatment types using a total of ten plant species or varieties.

Within each treatment set, woody vegetation was used to create horizontal wattling, diagonal wattling, and willow matting. Within each replication, each woody subtreatment rotated through each of three elevational zones (0 to -2 ft, -2 to -4 ft, and -4 to -6 ft below maximum conservation pool level). These zones were between elevations 832 and 826 msl.

Herbaceous vegetation was used in either plant rolls, single plants as plugs, or in an alternating pattern of rolls and plugs at approximately 1-ft intervals from elevation 820 above msl to 826 above msl.

November 1989 study design

The study design included planting ten cultivars of willow at three depth intervals with six replications at each depth interval. The November 1989 plantings were incorporated to test the assumption that root development would occur over winter and some spring sprouting would occur before the plants were inundated the first time, enhancing survivability.

The herbaceous study included the same four species used earlier to test the hypothesis that fall planting would provide a period for root development and soil stabilization before the plants were inundated the first time.

Individual plugs of each species were planted in groups of three, between the rows planted in spring 1989.

Vegetative sources

Test vegetation came from local sources and the Soil Conservation Service Plant Material Center at Corvallis, OR (Table 4).

Wattlings

Wattlings were constructed of Scouler and Sitka willow in approximately 10-ft lengths, with a nominal 6-in. diameter. Bundles were tied with hemp twine at 18-in. intervals and averaged about 2.5 lb per linear foot. Wattlings were placed in 4- to 6-in. deep trenches and secured with opposing tapered stakes at approximately 4-ft intervals.

Willow mattings

Matting consisted of Scouler/Sitka willow whips placed at right angles to the shoreline contours. Approximately 1.7 lb of willow stems per square foot produced a mat of about 4-in. thickness. Then the site was covered with poultry wire and the wire secured with stakes spaced on 4-ft centers. At the downslope edge of each matting, a horizontal wattle was positioned to prevent wave action from undercutting the lower edge of the mat. The mat was covered with soil to fill voids and partially bury willow whips.

Herbaceous plants

Herbaceous plants were delivered to the site as large clumps of sod. These large clumps were divided into individual plants about 3 by 3 in. and stockpiled for use as individual plugs or for use in producing plant rolls.

Plant rolls

Plant rolls were soil-filled burlap tubes, each containing five plant plugs. A sheet of burlap 40 by 72 in. was doubled lengthwise, placed in a 5-in. by 5-in. by 6-ft trough, and topsoil was added to fill the trough. Five herbaceous plants of the same species were embedded in the soil. The edges of the burlap were gathered together and rolled into a tight seam which was then secured with hog rings.

Water regime

The reservoir maximum conservation pool level is at elevation 832 above msl in the western foothills of the Cascade Mountains. The reservoir typically fills by the end of May. To meet recreation needs, the reservoir is maintained as near full as possible until September 1, when the next drawdown cycle begins. Because Dorena is primarily a flood-control reservoir it is evacuated to minimum conservation pool by mid-November and, except for temporary fluctuations, remains so until mid-February. A heavy rain in late April 1990 caused earlier than scheduled pool filling that year, and a heavy rain in mid-May 1991 caused a 3+ ft surcharge (Figure 1).

Since the reservoir filling depends mostly upon late winter and spring rainfall, rather than snowmelt, the spring hydrograph is quite variable and on some years, the reservoir does not become completely full; however, for each of the three inundations which occurred during the study period, maximum conservation pool level was reached.

Installation

April 1989 installation

Baker Bay project site was the location of all efforts in April 1989. Preparing the sites for installation of the wattlings and plant rolls required very extensive hand trenching. A total of 2,680 linear ft of wattling was installed in the project.

Preparing the sites for matting required scalping and stockpiling a 2-in. layer of the surface from the site to provide a relatively smooth bed. Each brush matting was covered by poultry netting and securely staked. Each matting was then covered by a combination of local materials and sandy loam from up-reservoir sources. A total of 4,623 sq ft of project area was treated with matting. Each of the herbaceous subtreatments used one of three planting regimes emplaced in April 1989:

- all plants in rows of plugs
- all plants in rows of rolls
- alternating rows of plugs and rolls

Regardless of planting regime, each herbaceous row was composed of five individuals of each of the four herbaceous species used. The order of species was held constant throughout the study site to aid in identification.

To accommodate the plant rolls, a trench about 6 in. deep was excavated on contour. The plant roll was laid in place and the trench was backfilled and compacted so the crowns of the plants were barely exposed. Forty plant rolls of each species were utilized.

The plugs were planted in individual holes dug at approximately 1-ft intervals. After placing the plug in the hole, excavated material was used to backfill the hole. Compaction of material left only the crown of the plug exposed.

The lowermost herbaceous subtreatments became inundated almost immediately, but the willow subtreatments nearer high pool were exposed for as long as 3 weeks. The exposed area was heavily irrigated on a biweekly basis to minimize initial drying.

November 1989 installation

Willow species/varieties available for testing included specific accessions from the U.S. Department of Agriculture Plant Materials Center, Corvallis, OR, as well as local species that had demonstrated survival in nearby lakes or reservoirs (refer to Table 4). Full-length whips of each willow cultivar were brought to the Baker Bay project site where project personnel reduced them to 12-in. cuttings. The upper ends of the cuttings of each species were dipped in a unique color paint to minimize chance for error in planting and to aid in identification during later evaluation.

The cuttings were then planted vertically in a standard array in the easterly one-half of each of the brush matting subtreatments installed in April 1989 (Figure 2). Twenty-five cuttings of each cultivar were planted in each subtreatment. Individual cuttings were left with approximately 3 in. exposed for sprouting. Care was taken not to disrupt the wire cover holding the matting in place.

The fall 1989 herbaceous plantings at Baker Bay project site were sets of three plugs of each species using the same sequence as employed in the earlier plantings. Individual planting spots were dug in the spaces between the spring planted rows.

Biotechnical Treatment Results

Wattles

Evaluation criteria. The following criteria were used in evaluating the effectiveness of the wattles:

Buried	Ground level on both sides is at or above the level of the wattling.
Successful	Top of the wattling is at or above ground level; upslope soil is in contact with the wattle, and the elevation of downslope soil is less than that of the upslope soil.
Partially Successful	Top of wattling is above ground level; upslope soil is in contact with the wattle, but there is little difference in elevation of upslope or downslope soil; or the wattle binding twine has failed, causing the wattle to lose effectiveness.
Failed	Most of wattle is at or above ground level, or broken twine has permitted wattle expansion and large-scale movement of soil material through the wattle. There is little difference between soil level on either side of the wattle.
Displaced	Wattling bundle is completely missing or the few remaining willow stems lack structural character.

To evaluate the effects of slope, the linear footage of wattling within each subtreatment was lumped into one of three slope classes irrespective of its elevational position. Each slope class was approximately equal in total length of wattles.

Horizontal wattling. After the first inundation most of the horizontal wattles were judged to be successful or buried (Table 5). In succeeding years, the percentage that were buried changed very little, but there was a gradual shift from successful toward only partly successful, or failed or absent (Figures 3 and 4).

Within the slope classes tested, horizontal wattles were considerably more effective (successful or partly successful) on the steeper slopes. Slope did not appear to affect in-place failure or displacement rates (Figure 5).

Diagonal wattling. After the first inundation, most diagonal wattles were evaluated as partly successful, with the percent successful and percent buried about equal (Table 5, Figures 6 and 7). After the second inundation, more of the diagonal wattlings had become buried. Following a third inundation, there was a moderate shift toward being less successful or buried.

The diagonal wattles were more successful or partly successful on the steeper slopes (Figure 8). More gentle slopes led to a higher percentage of total length of wattles buried. Failure or displacement showed little relationship to slope of the treatment area.

At the shallower wattling treatments, irrespective of the type of wattle, there was some evidence of pioneering by local herbaceous species, but most was directly associated with the wattling bundle. The soil between wattlings remained essentially bare except where there was pre-existing reed canarygrass.

Willow matting

Evaluation criteria. Willow matting was judged according to how well the structure collected and stored sediment to embed the willow stems, how well the wire mesh retained its function, and how well the site was stabilized.

Embeddedness. After one inundation only about 40% of the treatments were judged to be 50% or more embedded (Figure 9). However, there was a gradual increase in success, so after the third inundation, 56% of treatments were more than 50% embedded.

Wire mesh durability. After the first inundation, the mesh was essentially 100 percent effective, and after two inundations all subtreatments were over 50% intact and nearly three quarters were completely intact. After the third inundation, only one-third were essentially intact and most wire was failing due to corrosion (Figure 10).

Site stabilization. The site protection provided by the willow stems and the sediment retention provided a site acceptable to pioneering species (Figures 11 and 12). Consequently, after the second inundation, a large variety of species invaded the mats (Table 6). As expected, the reed canarygrass was the primary invader of the shallower water treatments, but at least 15 different species of native vegetation were identified.

Willow cutting survival

The spring 1989 installation of mats and wattles presumed that long-term success would be enhanced by sprouting of the whips used. However, that did not occur.

In contrast, the fall 1989 plantings as cuttings demonstrated considerable sprouting ability, some of which was tempered by depth during inundation (Figure 13).

For all of the ten willow species tested as cuttings, there was a demonstrated decrease in survival with increased depth. Arroyo (*Salix lasiolepis*), Hooker (S. *hookeriana*), erect (S. *ligulifolia*), and Sitka (S. *sitchensis*) were the willows possessing the greatest rates of survival in the 0 to -2 ft below maximum conservation pool level. Only Fish Lake Pacific (S. *lasiandra*) and Hooker willows exhibited notable survival rates at -2 to -4 ft below maximum conservation pool level. At depths greater than -4 ft below maximum conservation pool, no species demonstrated perceptible tolerance to extended inundation.

Although ungulates, beaver, and Canada geese are abundant in the Dorena Reservoir area there was little, if any, evidence of use of the willow sprouts. Some trampling by the public may have occurred, and a few dead cuttings may have been inadvertently broken off as the samplers collected the first period data. The fact that over 91% of the individual cuttings were in place after the third inundation demonstrates that in situ mortality, rather than displacement, was the predominant cause of loss.

Herbaceous plantings

Evaluation criteria. Evaluation of the results of the herbaceous plantings is based upon three different factors. Planting efficiency addresses the percentage of the plants that can be found at sampling time regardless of whether they are alive or dead. Survival is a measure of the proportion of live plants among all plants found at sampling time. Vigor represents a subjective assessment of the condition of the surviving plants.

Planting efficiency. The spring 1989 herbaceous plantings included individual plants and plant rolls to evaluate the relative effectiveness of the two planting techniques. After one inundation, only 25 of 780 (3.2%) of plants secured in burlap rolls were missing. During that same period 418 of 720 (58.1%) of those planted as individual plugs were missing. Most were washed away but some may have been buried; however, the exact numbers could not be determined without jeopardizing the site. After the third inundation, 479 of 780 plants (61.4%) in burlap rolls were missing while 527 of 720 (73.2%) individual plants as plugs could not be found. Analysis by species indicates that for all herbaceous species, plants in rolls were still more identifiable than those planted as individual plugs (Table 7 and Figure 14). After three inundations, between 32 and 54% of the plants in rolls were still available for assessing survival/vigor while only 15 to 36% of the individuals planted as plugs could be found.

Burlap fabric integrity deteriorated significantly during the first inundation. However, where left undisturbed, the plant rolls were still functional in retaining sediment at the end of the study.

The fall 1989 plug planting, on the other hand, had phenomenally low loss after one inundation with only 6 of 828 (0.7%) missing after one inundation. After the second inundation, 496 plants were found for a 40.1 percent loss during that period. The lower loss rate of this subtreatment (i.e., 0.7% vs 58.1%) after one inundation was not unexpected. The spring 1989 herbaceous plantings, especially the plant rolls, had stabilized the site very well. Also, the plants had five months in which soil immediately surrounding the plug could resettle, and the plants could begin root development before their initial exposure to wave action.

The net effectiveness of 26.8 percent for individual plants and 38.6 percent for plants in rolls should be considered as minimums. General observations over the project period suggest that plant rolls were quite effective in trapping soil particles, but the individual plugs considerably less so (Figure 15). Thus, many of the "missing" plants in rolls are probably buried.

Survival. The spring 1989 herbaceous plantings demonstrated greatly different survival rates between species (Figures 16 and 17). Columbia sedge demonstrated the best survival and reed canarygrass survived well, while bulrush survival was marginal and slough sedge was a near total failure.

Poor growing periods in 1990 had an adverse effect on the herbaceous plants and caused observers to under-record the number of live plants of each species. Due to a slightly cooler spring, plants had not begun to grow, and an early April storm period raised the reservoir level prematurely, inundating the site, so no meaningful data could be collected before the herbaceous plants were inundated. Then in the fall, the reservoir evacuation was slowed, providing fewer growing days. Both reed canarygrass and Columbia sedge responded by appearing dead in fall 1990, but then resprouted in 1991. That phenomenon was observed in both the plug and burlap roll treatments, reinforcing the veracity of the response.

Planting in burlap rolls substantially increased survival of Columbia sedge (from 26% to 41%) over the three inundation periods. Reed canarygrass and bulrush barely responded, and slough sedge was unresponsive to either planting technique.

The fall 1989 plants demonstrated very high first-inundation survival with the exception of slough sedge. After the second inundation, slough sedge suffered total mortality and the bulrush survival dropped substantially (Figure 18). Columbia sedge maintained a very high rate of survival, while reed canarygrass demonstrated only a fairly small decline.

Vigor. Comparisons of vigor of the spring 1989 plantings can only be done within the species because of the inherent differences in growth rates and growth periods between species.

No objective criteria could be developed so the observations are subjective. However, all the ratings were done by a single observer with no previous exposure to the project, minimizing any bias. A *substantial proportion* of the reed canarygrass survivors were rated moderate to robust in both treatments (Figures 19 and 20). Columbia sedge vigor appeared to benefit somewhat from the burlap roll treatment with a lower percent rated as weak, a somewhat higher percent rated as moderate, and robust plants were only found in the plant rolls. The few bulrush that survived three inundations were mainly rated weak, with only a few judged to be moderately vigorous, and only within the plant rolls. Slough sedge mortality was nearly 100 percent and the few live plants were very weak.

The fall 1989 herbaceous plantings demonstrated similar patterns except there was a lower percentage of dead reed canarygrass and Columbia sedge (Figure 21).

Discussion and Conclusions

Biotechnical treatments

Evaluation of the biotechnical treatments at Baker Bay project site included effectiveness in preventing escarpment reformation, durability, and installation considerations.

Escarpment prevention. In each of the six replications, each willow subtreatment occupied the 0 to -2-ft depth range once. This coincided with the area that previously had a short wave-caused escarpment. Final evaluation after three inundations indicated that the brush matting subtreatment was much more effective in preventing escarpment reformation than either diagonal or horizontal wattle subtreatment (Figures 22 and 23). Mattings offered partial or full protection over 80 percent of their total length while diagonal wattles offered 68 percent and horizontal wattles only 55 percent of their total lengths, partially or fully protected. Only 35 percent of the diagonal and none of the horizontal wattles offered full protection to the bank upon which they had been installed.

Durability. Using wattle condition and matting embeddedness as measures of resistance to erosion, the increased effectiveness of mattings as a technique for shoreline stabilization becomes evident. The matting embeddedness actually increased slightly over time (refer to Figure 10) while both types of wattles showed deteriorating trends over the test period (refer to Table 5). The stability of the matting is not expected to deteriorate because extensive volunteer plant invasion has occurred wherever matting protected the high pool bankline.

The wattles had already begun to seriously deteriorate after one inundation and suffered further severe deterioration during the second period. By the end of the third period, several wattles had disintegrated and floated away. A stake count during the cleanup accounted for over 75 percent of the original stakes holding the wattles and mats in place. Stakes examined showed no deterioration, indicating that they would have remained functional several more years. The willow stems also retained most of their integrity and could have been functional for several more years. The majority of wattle failure appeared to result from rapid deterioration of the hemp twine.

Regardless of the biotechnical method, the rate of invasion of native plants increased with proximity to maximum conservation pool elevation. However, willow mattings exhibited a greater rate of recruitment with these pioneers more evenly dispersed than in either wattle type across all test plot elevations (Figures 24 and 25). Recruitment in wattle areas tended to occur on or adjacent to the structural elements, leaving the intervening spaces essentially exposed.

Installation considerations. Each of the methods installed covered approximately the same area of treated shoreline. This lends itself to a comparison of investment per plot for each structural method. On the average, 145 lb of willow stems were used for each horizontal wattle treatment while 171 lb of willow stems were used in each diagonal wattle plot. The matting plots, however, required an average of 437 lb of willow stems for each plot.

The number of stakes used varied as well with the structural method used. Horizontal and diagonal wattles used approximately 29 and 34 stakes per plot, respectively, while the matting plots needed only about 20 stakes each. Labor, regardless of subtreatment considered, was basically equivalent.

Willow cuttings

Evaluation of the fall 1989 willow cuttings included overall survival and survival as a function of depth below maximum conservation pool level.

Overall survival. Several species of willow from the Soil Conservation Service Plant Material Center demonstrated some capability to endure prolonged periods of inundation (erect, Hooker, and arroyo). Of the locally collected varieties, only Lookout Point Pacific, Fish Lake Pacific, and coyote willow from Blue River Reservoir survived very well.

Survival by depth. Only Fish Lake Pacific and Hooker willow from SCS PMC demonstrated tolerance when planted at elevations -2 to -4 ft below maximum conservation pool level.

The varieties all started very well, with all but Lookout Point and Blue River Pacific willows sprouting in excess of 90 percent prior to inundation. After the first inundation, all but two species had survival rates exceeding 50 percent in shallow water, and all species had at least token survival in the deeper water areas. The somewhat delayed drawdown in fall 1990 and related shorter growth period followed by the second inundation took its toll, and few survived at the -4 to -6 ft below maximum conservation pool level.

General observations of vigor led the sampler to believe the following: (1) that the survivors in the 0 to -2-ft zone would survive over a long period; (2) some of the survivors in the -2 to -4-ft zone would survive, but that all those in -4 to -6 ft would expire following the next inundation.

Herbaceous plantings

The evaluation of herbaceous plantings considered planting technique comparisons, between species survival comparisons, and planting season comparisons.

Planting techniques. The low loss of plants in burlap rolls (3.2%) compared to individual plants as plugs (58.1%) demonstrated the burlap rolls to be extremely effective in preventing the plant from being washed away the first year. However, over the next two inundations, 58% more of the plants in rolls disappeared, while only an additional 15% of the individual plants as plugs disappeared. Considering lack of evidence of heavy erosion in the roll subtreatments and no broken or disarranged plant rolls, we conclude that the most probable loss was due to burial as the plant rolls effectively trapped downslope soil movement.

The cost is a major disadvantage of using burlap rolls despite their better initial performance. It proved time-consuming to construct the plant rolls (about five per person-hour), more difficult to move them to the planting site, more work to prepare the site (a trench vs individual holes), and the cost of the burlap.

The higher retention rate of the fall plug plantings on sites stabilized by the burlap rolls installed previously is additional evidence of the ability of burlap rolls to aid in shoreline stabilizing efforts.

Once first-year losses are eliminated, planting technique only seemed to be an important factor with Columbia sedge and bulrush (Figure 26). Columbia sedge plants in rolls demonstrated an increased survival/retention rate of about 15 percent. This may be important because Columbia sedge is slow to develop from the initial plug. Bulrush survival/retention rate was also enhanced when planted as rolls because bulrush as plugs tended to lose surrounding soil and almost become bare-root stock.

Combining plant retention, survival, cost, and stabilization leads to the conclusion that planting in burlap rolls is more effective but less efficient so generally applicable only where plug retention would be at an unacceptably low level, or where increased bank stability is an essential part of the project.

Herbaceous species survival. Direct species comparisons leave no doubt that after two or more inundations, only reed canarygrass and Columbia sedge are demonstrating worthwhile survival and vigor.

Slough sedge demonstrated practically no tolerance to inundation at the -6 to -12 ft level (Figure 27). Unpublished information from Blue River Reservoir where slough sedge was successfully introduced in 1971 suggests slough sedge can grow to a depth of -35 ft below maximum conservation pool as long as it has 75 to 90 growing days per year. Unfortunately at Dorena Reservoir, only about 40 to 60 growing days are available. Bulrush had some tolerance the first year, but faded badly in subsequent years.

Planting season. Improved survival of fall-planted plugs was apparent once displaced plants were accounted for. Fall-planted Columbia sedge showed about a 10% increase in survival and the fall-planted reed canarygrass had about a 5% increase in survival (refer to Figures 14 and 18).

Vigor. For both spring and fall planting the large majority of even the more successful species were rated weak to moderate in vigor (refer to Figures 19, 20, and 21), suggesting the tolerance limit of these four species has been reached under this water level management regime.

Miscellaneous Observations

During the course of the project, but not as a part of the study design, some items were noted that may be helpful for future projects.

Kellogg sedge (*Carex lenticularis*): At one site with cobble soil, approximately 500 plugs were planted to -10 ft below maximum pool level. After one inundation, 457 plugs were still in place (91%) and all were alive and expected to survive.

Bulrush. Bulrush roots excess to study needs were planted in several areas in and adjacent to the project in depths less than 6 ft below maximum conservation pool level. A number of these plants demonstrated vigorous growth documenting the validity of establishing bulrush via root clumps. Their vigorous growth in the shallower water suggests that the species has significant value where shallow water planting areas are available.

Summary

At the Baker Bay project site, six biotechnical methodologies were tested. The willow mattings were most effective at stabilization. Neither wattling regime was effective over the time span of the study.

Herbaceous plantings in rolls were retained at a higher rate than plant plugs and offered increased soil stability. The fall plantings persisted at a higher rate than those planted in the spring. Survival rates of the persistent individuals did not depend on planting season.

Four species of willow as cuttings survived well at depths less than 2 ft below maximum conservation pool level. A separate species shows moderate tolerance to depths less than 4 ft below maximum conservation pool level. No species displayed viability at depths greater than 4 ft below maximum conservation pool level.

Reed canarygrass and Columbia sedge exhibited much higher survival rates in the herbaceous plots than either slough sedge or bulrush.

Early trials at Blue River Reservoir demonstrated that one tree species and two herbaceous had significant survival capability under that drawdown regime.

Later experiments verified the results of earlier tests and also documented that one additional tree species and three shrub species had high survival rates.

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Table 1
Benefits of Revegetation

1. Reduces shoreline erosion
2. Improves fish habitat
3. Increases wildlife use
4. Increases fish production
5. Improves visual quality
6. Improves boating safety

Table 2
Functional Role of Vegetation

Trees	Shrubs	Herbaceous Plants
Wave energy dissipation	Wave energy dissipation	Soil stabilization
Fish cover	Juvenile fish cover	Juvenile fish cover
Raptor perches	Periphyton substrate	Invertebrate food source
Wildlife forage	Wildlife browse	

Table 3
Tree and Shrub Trials at Blue River Reservoir, 1988-89

Species	Maximum Depth	Percent Survival (post-submergence)
TREES		
Maple	10	34
Honey locust	10	33
Green ash	25	90
European white birch	25	46
Mountain alder	15	36
Baldcypress	60	91
SHRUBS		
Redosier dogwood	40	50
Douglas spirea	50	83
Pacific willow	50	63
Rigid willow	50	92
Purple willow	50	85
Erect willow	50	43
Columbia willow	50	54
Hooker willow	50	65
Sitka willow	50	24
Scouler willow	50	47

Table 4
Vegetation Used at Baker Bay Project Site, Dorena Reservoir Inundation Tolerance Test

Common Name	Scientific	Source
Columbia R. willow	*Salix fluviatilis*	SCS Plant Material Center
Cottet willow	*S. cotteti*	" " " "
Sitka willow	*S. sitchensis*	" " " "
Arroyo willow	*S. lasiolepis*	" " " "
Hooker willow	*S. hookeriana*	" " " "
Erect willow	*S. ligulifolia*	" " " "
Fish Lake Pacific willow	*S. lasiandra*	Fish Lake, Linn Co., OR
Coyote willow	*S. exigua*	Blue River Res., Lane Co., OR
Blue R. Pacific willow	*S. lasiandra*	Blue River Res., Lane Co., OR
Lookout Pt Pacific willow	*S. lasiandra*	Lookout Pt. Res., Lane Co., OR
Bulrush	*Scirpus validus*	Fern Ridge Res., Lane Co., OR
Columbia sedge	*Carex aperta*	Cougar Reservoir, Lane Co., OR
Slough sedge	*C. obnupta*	Dorena Reservoir, Lane Co., OR
Reed canarygrass	*Phalaris arundinacea*	Dorena Reservoir, Lane Co., OR

Table 5
Wattling Effectiveness Rating in Percent of Length in a Given Condition After First, Second, and Third Inundations

Evaluation Period	Partly Buried	Successful	Successful	Failed	Displaced
Horizontal					
Fall 1989	24.9	39.5	18.5	17.1	0.0
1990	26.2	16.6	28.3	28.9	0.0
1991	19.7	3.2	30.0	21.9	25.2
Diagonal					
Fall 1989	23.7	26.2	44.9	5.2	10.0
1990	50.8	14.1	15.0	20.1	0.0
1991	41.3	1.9	23.5	24.4	8.9

Table 6
Species Invading Willow Matting Subtreatments After Two Inundations

Abundant		Sparse	
Common Name	**Scientific Name**	**Common Name**	**Scientific Name**
Geyer's onion	*Melica geyeri*	Chain speedwell	*Veronica catenata*
Am. wintercress	*Barbarea orthocera*	Forget-me-not	*Myosotis discolor*
Water foxtail	*Alopecuris geniculatus*	Little western cardamine	*Cardamine oligosperma* var. *oligosperma*
Reed canarygrass	*Phalaris arundinacea*		
Water chickweed	*Montia fontana*	Spring whitlow grass	*Draba verna* var. *boerhaavii*
Common spikerush	*Eleocharis palustris*		
Annual bluegrass	*Poa annua*	Inflated sedge	*Carex vesicaria*
Sticky chickweed	*Stellaria jamesiana*		
Delicate spikerush	*Eleocharis bella*	Unknown sedge	*Carex* sp.

Table 7
Fate of Herbaceous Plants at the Baker Bay Project Site

Species	Techniques	No. of Plants Trans-planted	No. of Plants Found in Nov 1991	% Found	No. of Plants Alve in Nov 1991	Percent Survival in Nov 1991
SPRING 1989 PLANTINGS						
Reed canarygrass	Plugs	176	62	35	30	48.4
	Rolls	195	77	39	38	49.4
Slough sedge	Plugs	180	27	15	0	0.0
	Rolls	195	63	32	1	1.6
Columbia sedge	Plugs	184	66	36	48	72.7
	Rolls	195	106	54	79	74.5
Bulrush	Plugs	180	40	22	0	0
	Rolls	195	70	36	6	8.6
FALL 1989 PLANTINGS						
Reed canarygrass	Plugs	207	153	74	97	63.4
Slough sedge	Plugs	207	80	39	0	0.0
Columbia sedge	Plugs	207	143	69	122	85.3
Bulrush	Plugs	207	116	56	9	7.8

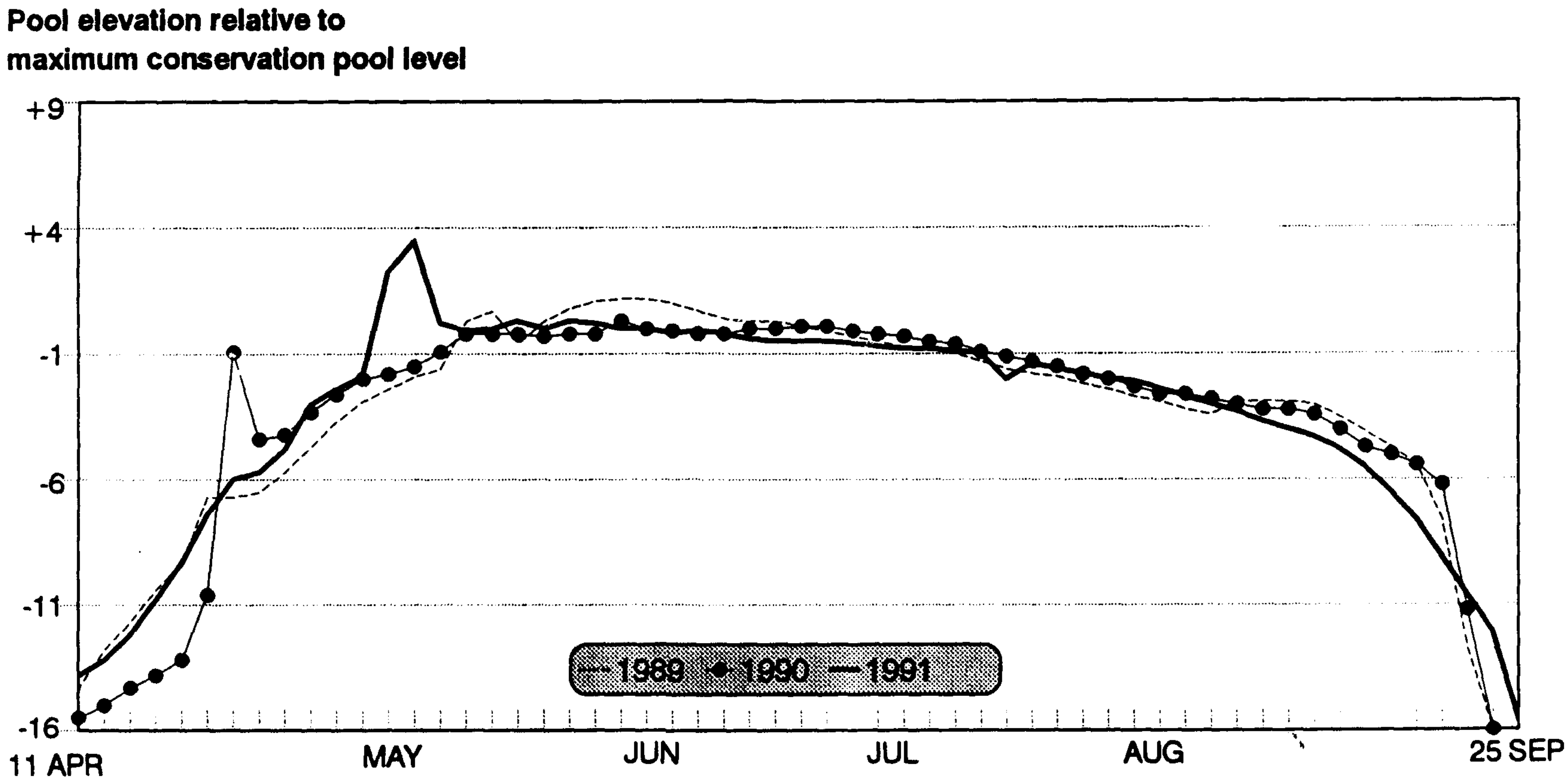

Figure 1. A comparison of Dorena Reservoir pool elevations within the project sites during the three periods of inundation

AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	AA-Erect
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	BB-Hooker
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	CC-Coyote
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	DD-Lookout Point Pacific
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	EE-Columbia River
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	FF-Blue River Pacific
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	GG-Fish Lake Pacific
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	HH-Cottet willow
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	II-Sitka willow
AA	BB	CC	DD	EE	FF	GG	HH	I I	JJ	JJ-Arroyo willow
A	B	C	D	E	F	G	H	I	J	

Figure 2. Standard array of willow cuttings planted in matting subtreatments, Baker Bay project site

Figure 3. Baker Bay project site, horizontal wattles before initial inundation

Figure 4. Baker Bay project site, horizontal wattles after three inundations

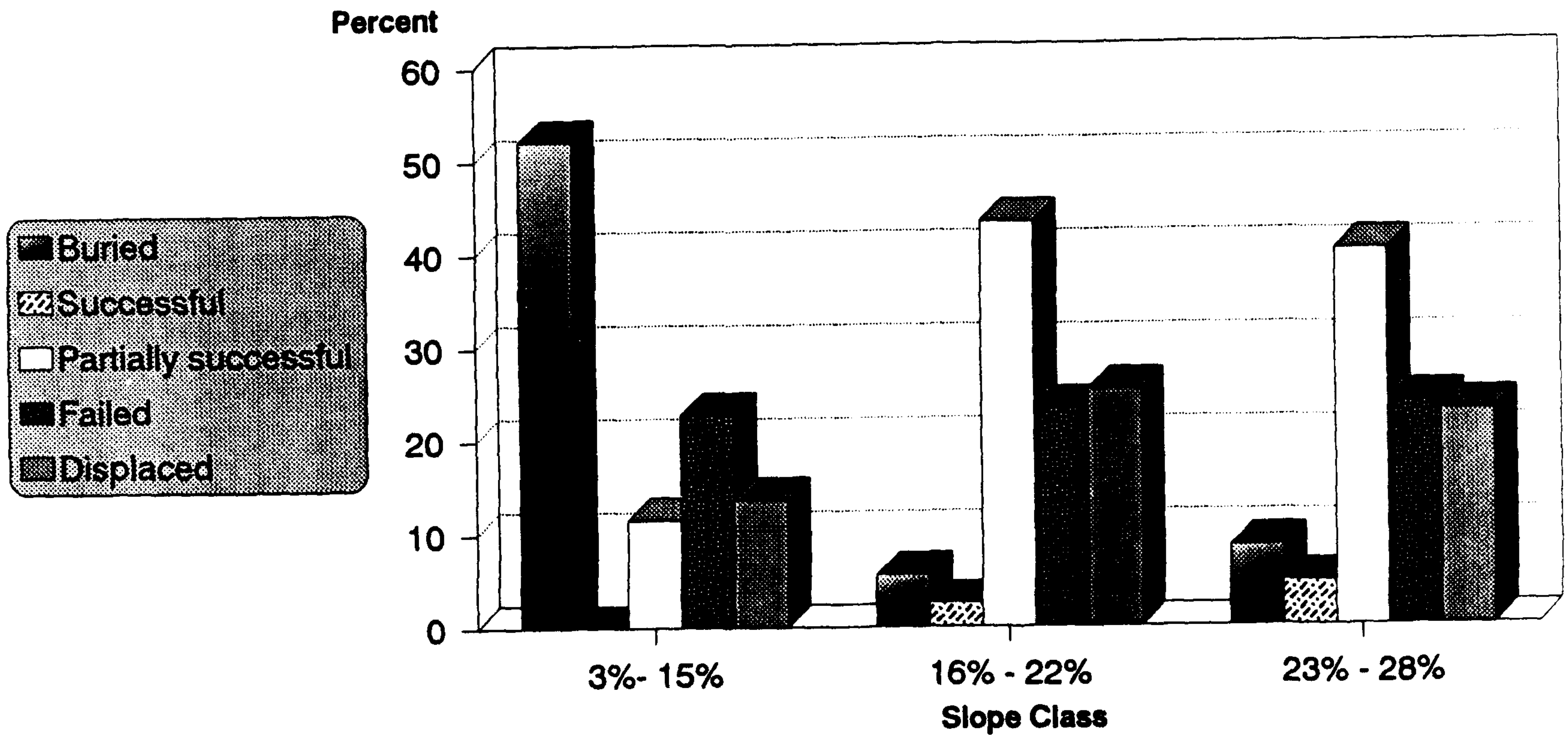

Figure 5. *Success of horizontal wattles after three inundations as a function of slope*

Figure 6. Baker Bay project site, diagonal wattles before inundation

Figure 7. Baker Bay project site, diagonal wattles after two inundations

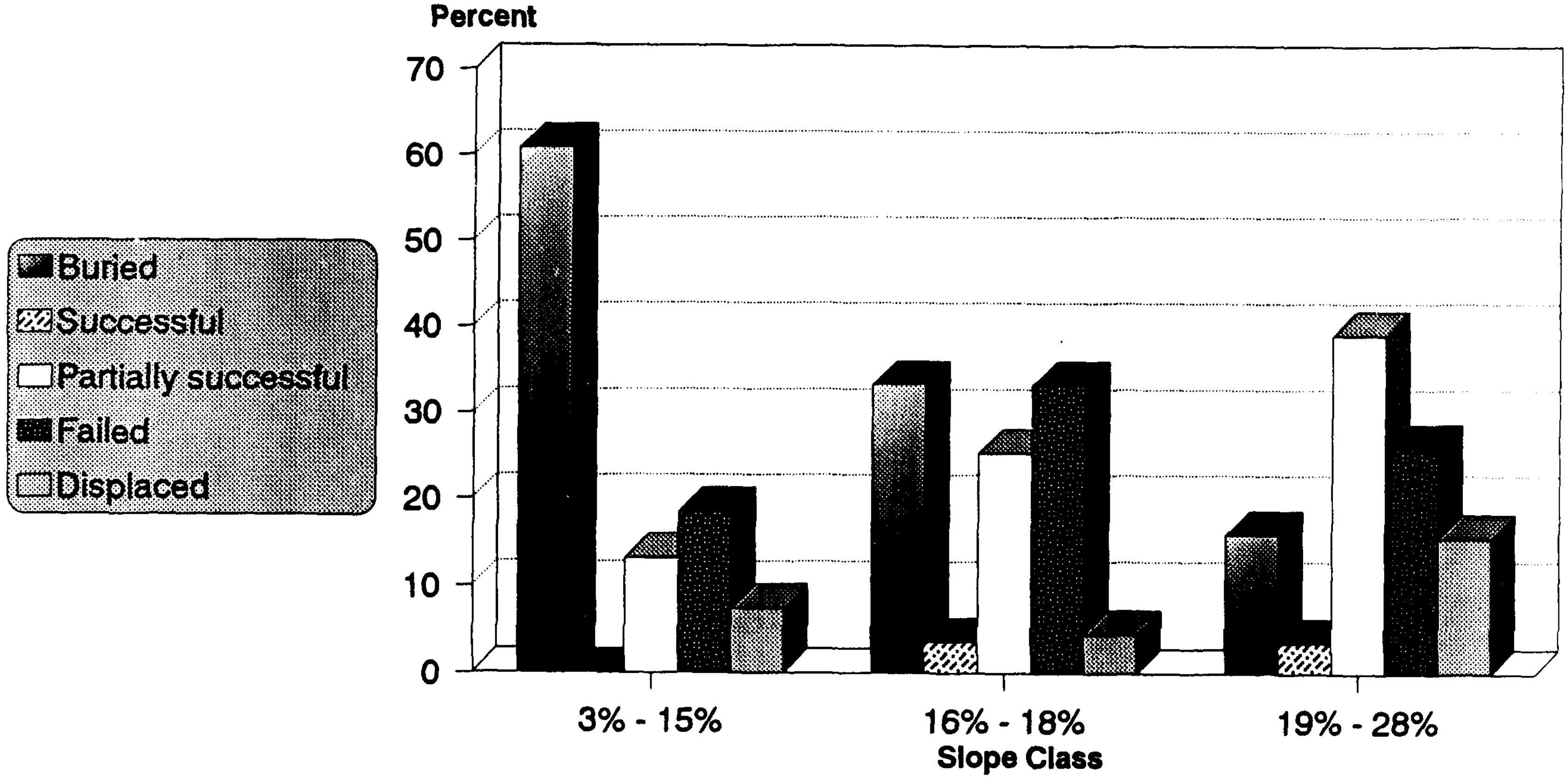

Figure 8. Success of diagonal wattles after three inundations as a function of slope

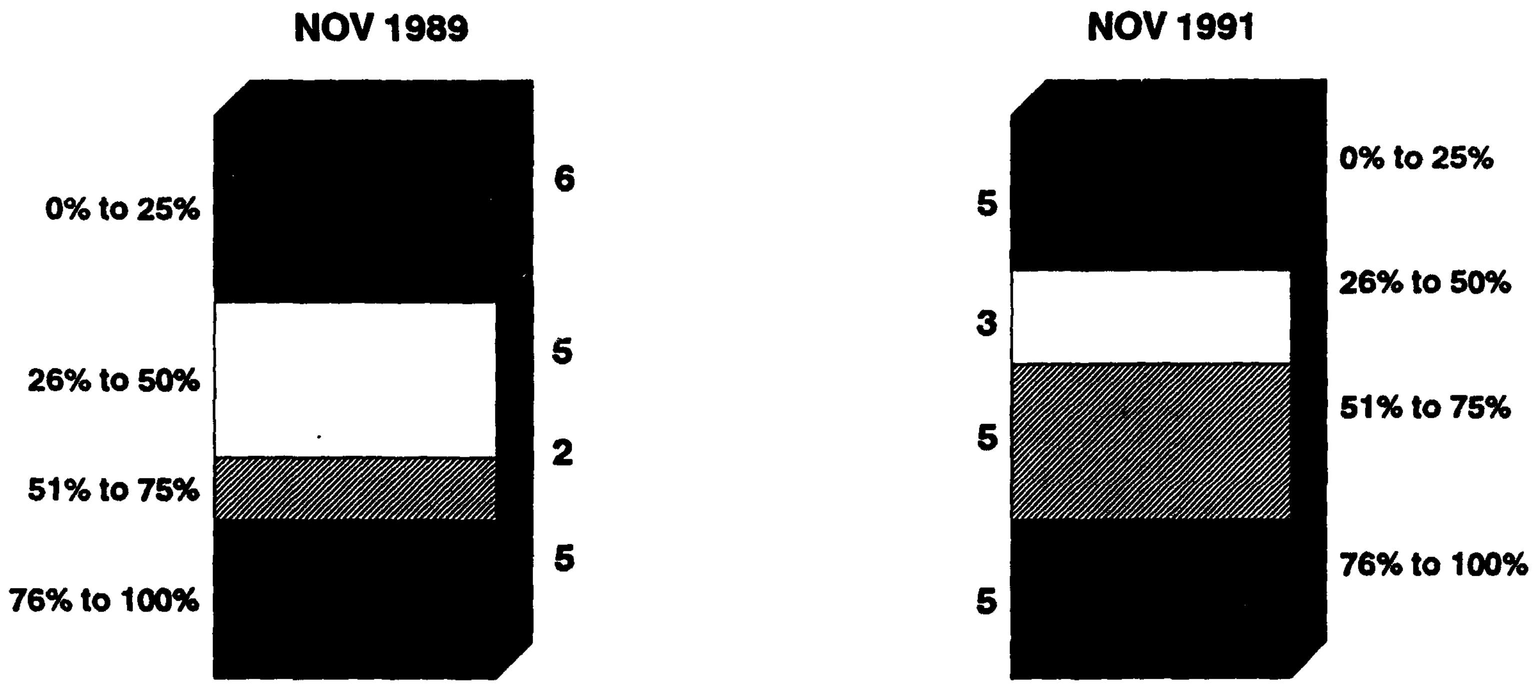

Figure 9. Number of mats possessing similar percentages of embedded surface area, fall 1989 and fall 1991

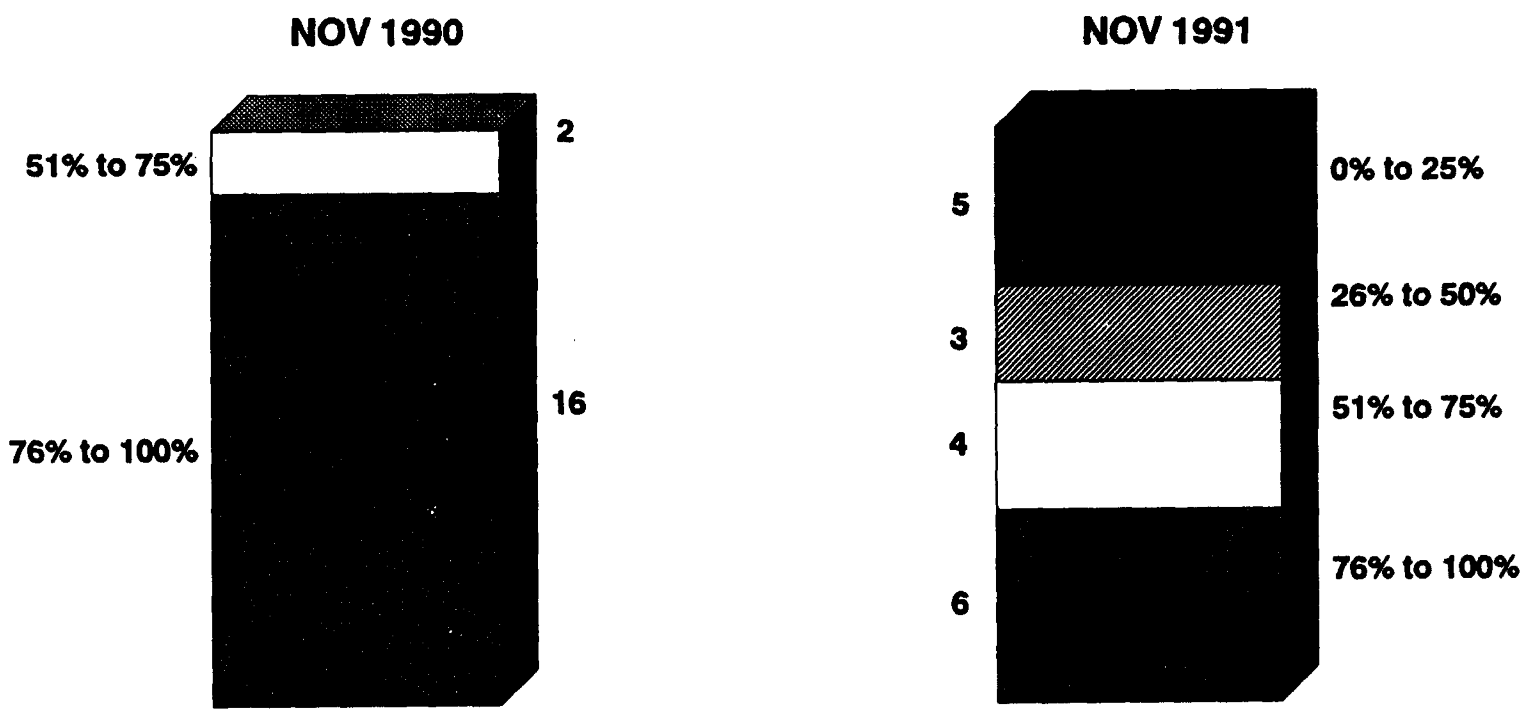

Figure 10. Number of mats possessing similar percentages of functional wire mesh, fall 1990 and fall 1991

Figure 11. Baker Bay project site, willow matting before inundation. Note mat covered by soil

Figure 12. Baker Bay project site, willow matting after three inundations. Note the mat is intact and functional although toe wattle has disappeared

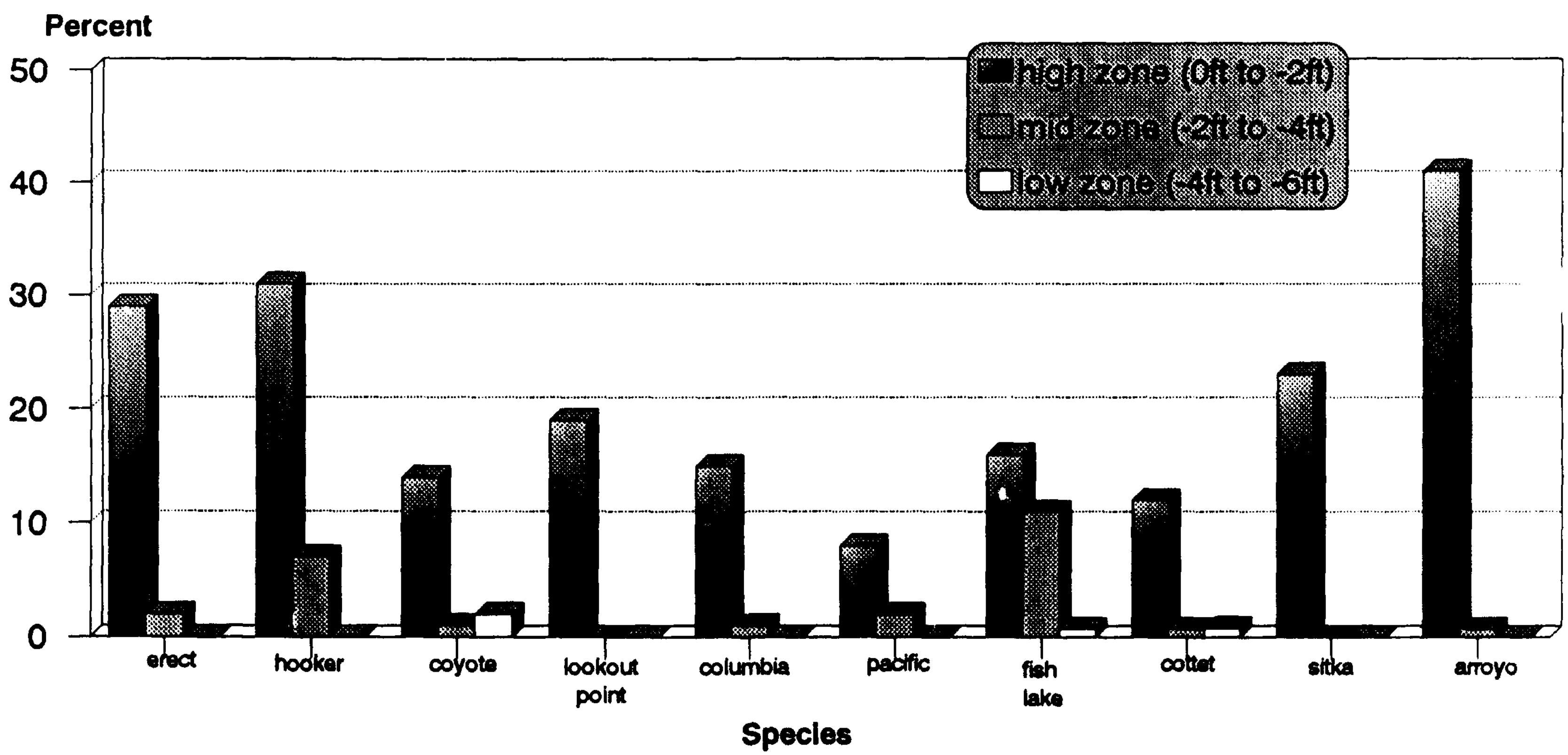

Figure 13. Survival of willow cuttings as a function of elevation below maximum conservation pool level after two inundations, Nov 1991

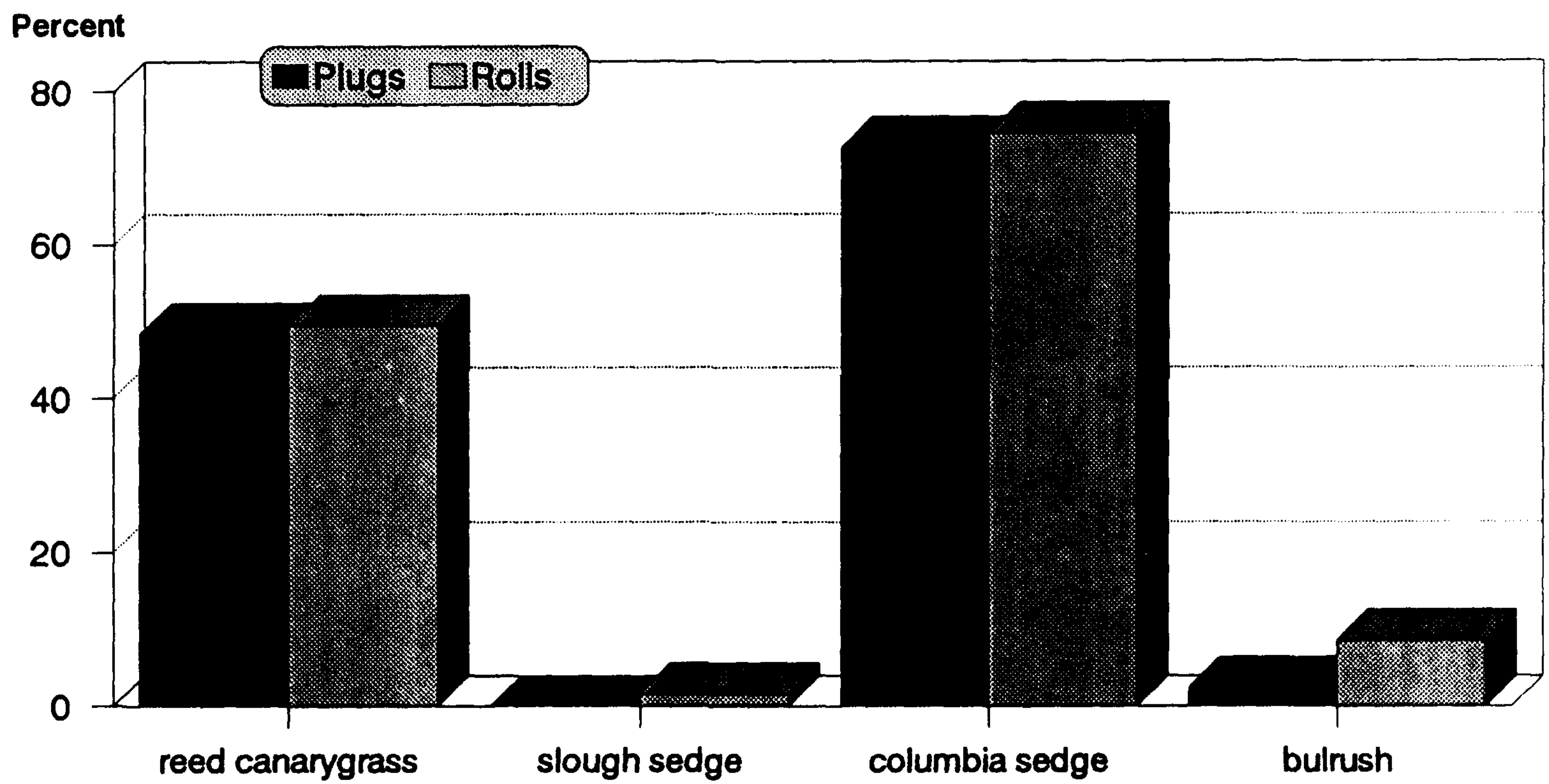

Figure 14. Survival by planting techniques based on percent of plants identifiable after three periods of inundation, spring 1989 planting

Figure 15. Dorena Reservoir, bulrush vigor after first inundation. Note that plant rolls are buried

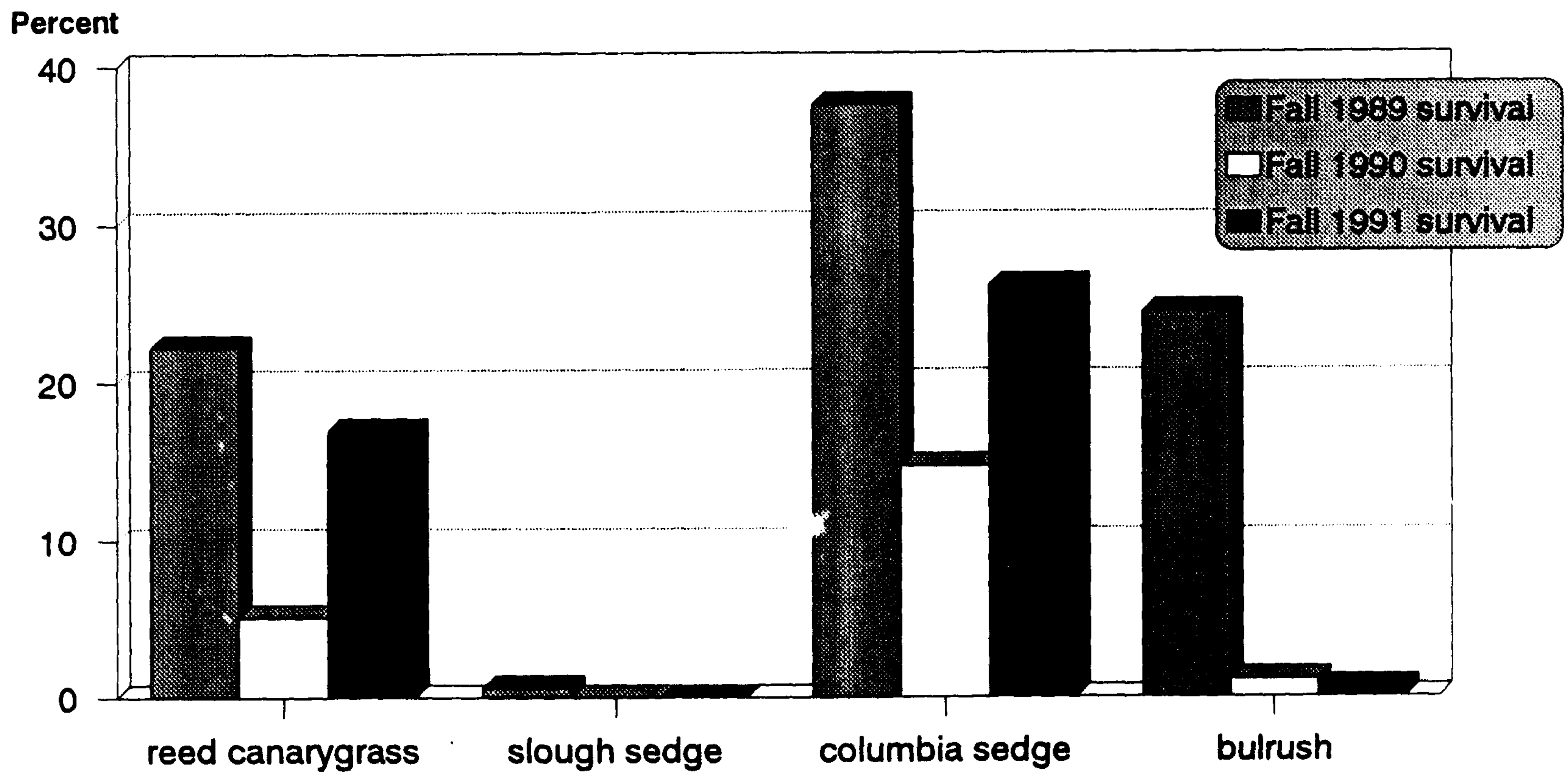

Figure 16. Survival of four herbaceous species as a function of the total population planted as individual plugs in spring 1989

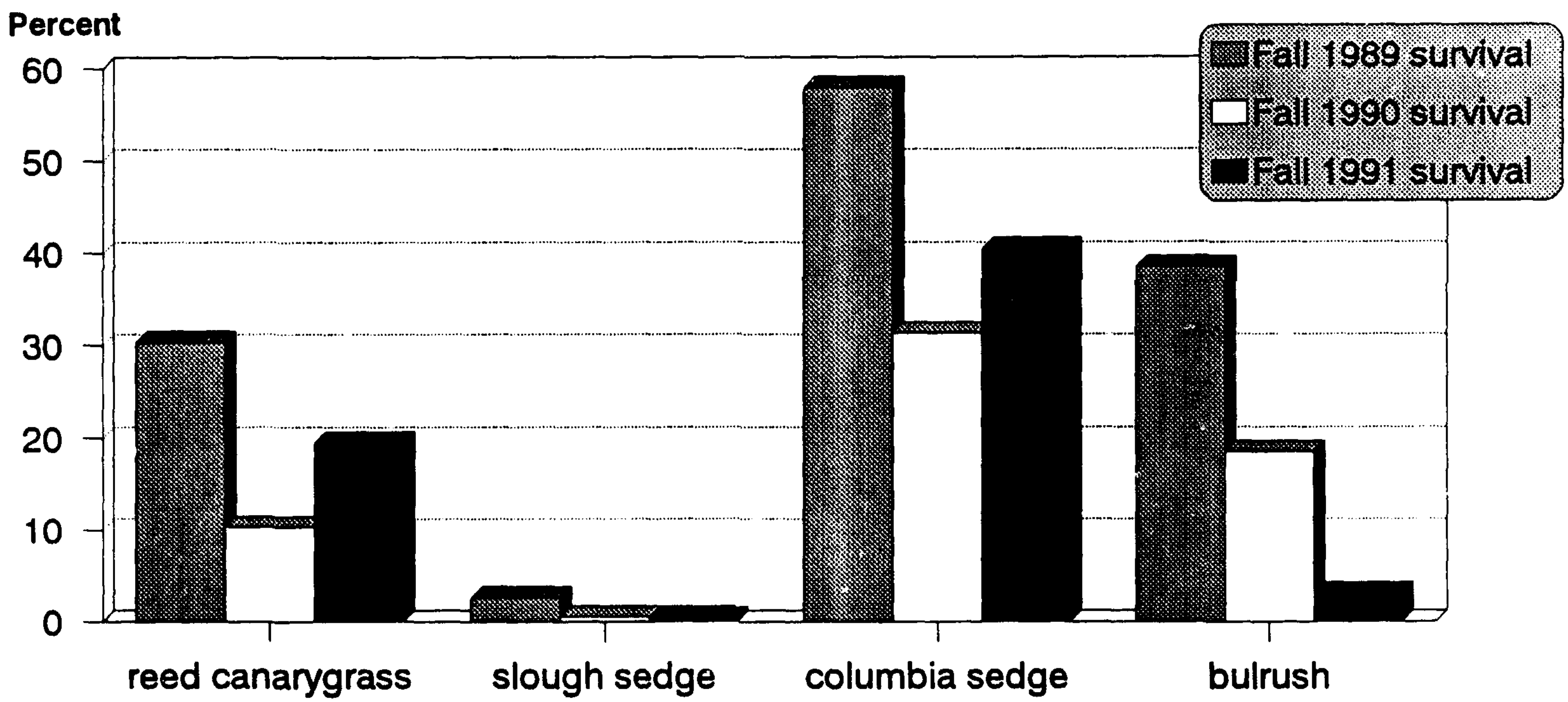

Figure 17. Survival of four species as a function of the total population planted as rolls in spring 1989

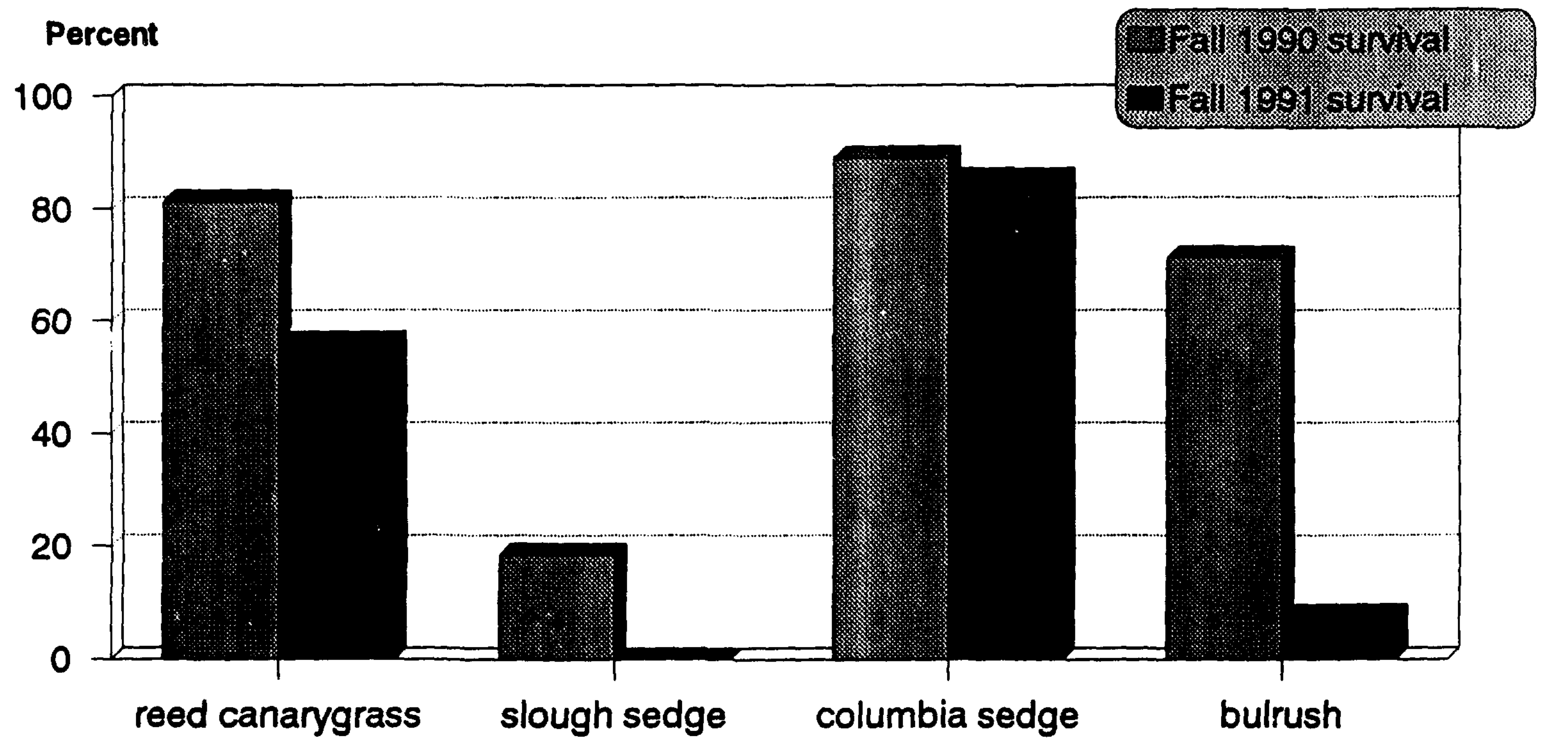

Figure 18. Survival of fall 1989 plantings as a function of plants still visible (dead and alive) in fall of 1990 and fall of 1991

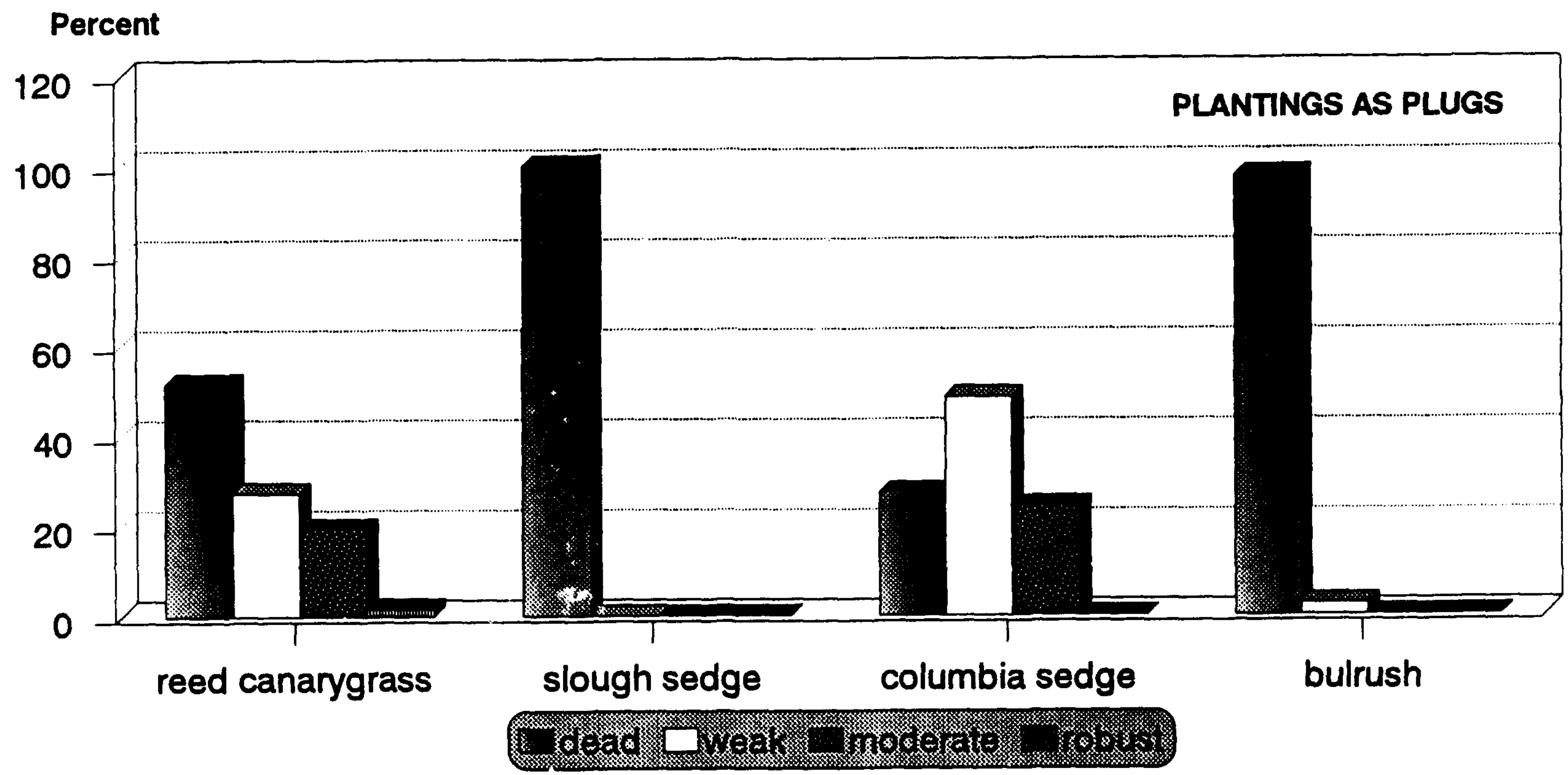

Figure 19. Spring 1989 herbaceous plantings as plugs identifiable after three inundations

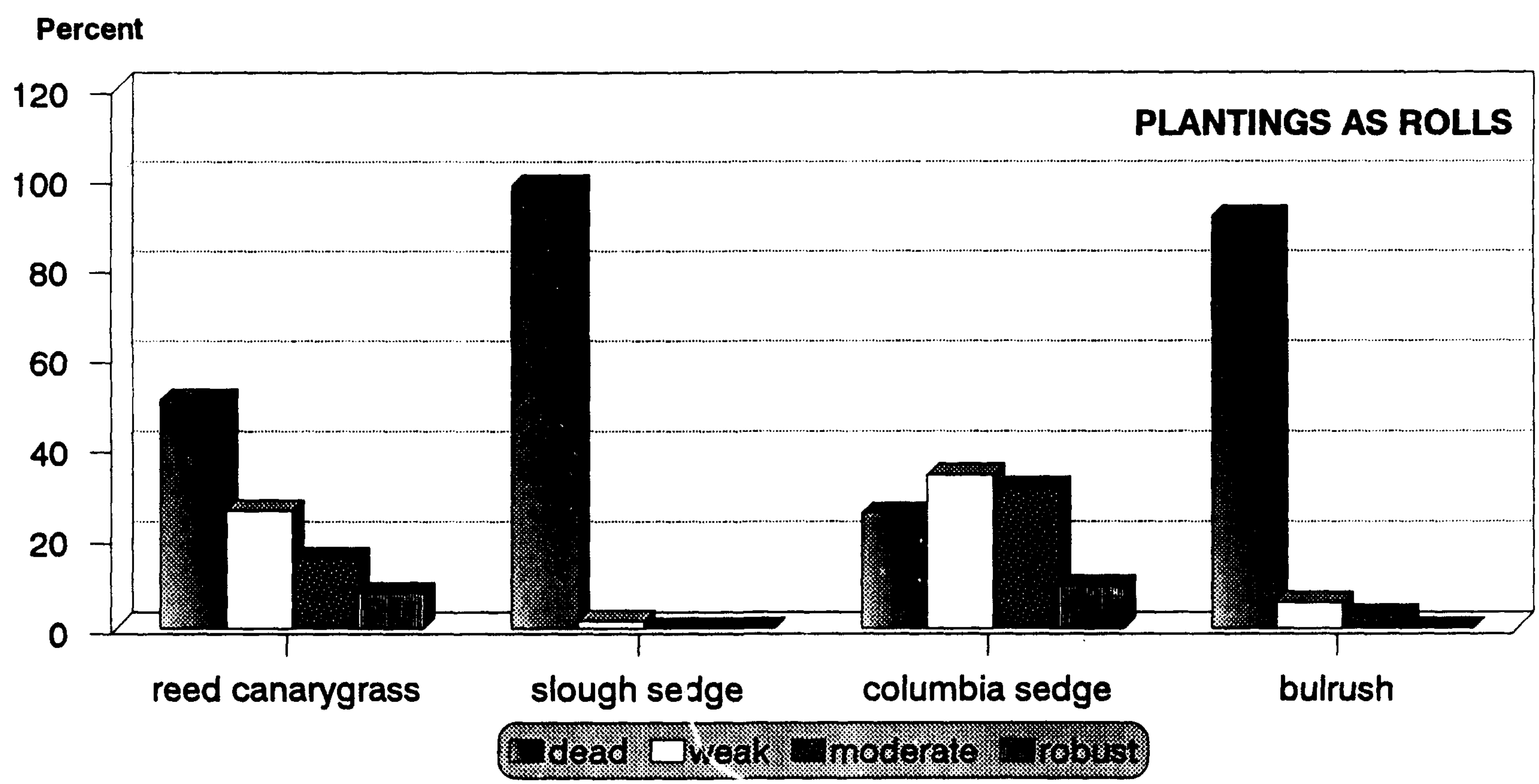

Figure 20. Spring 1989 herbaceous plantings as rolls identifiable after three inundations

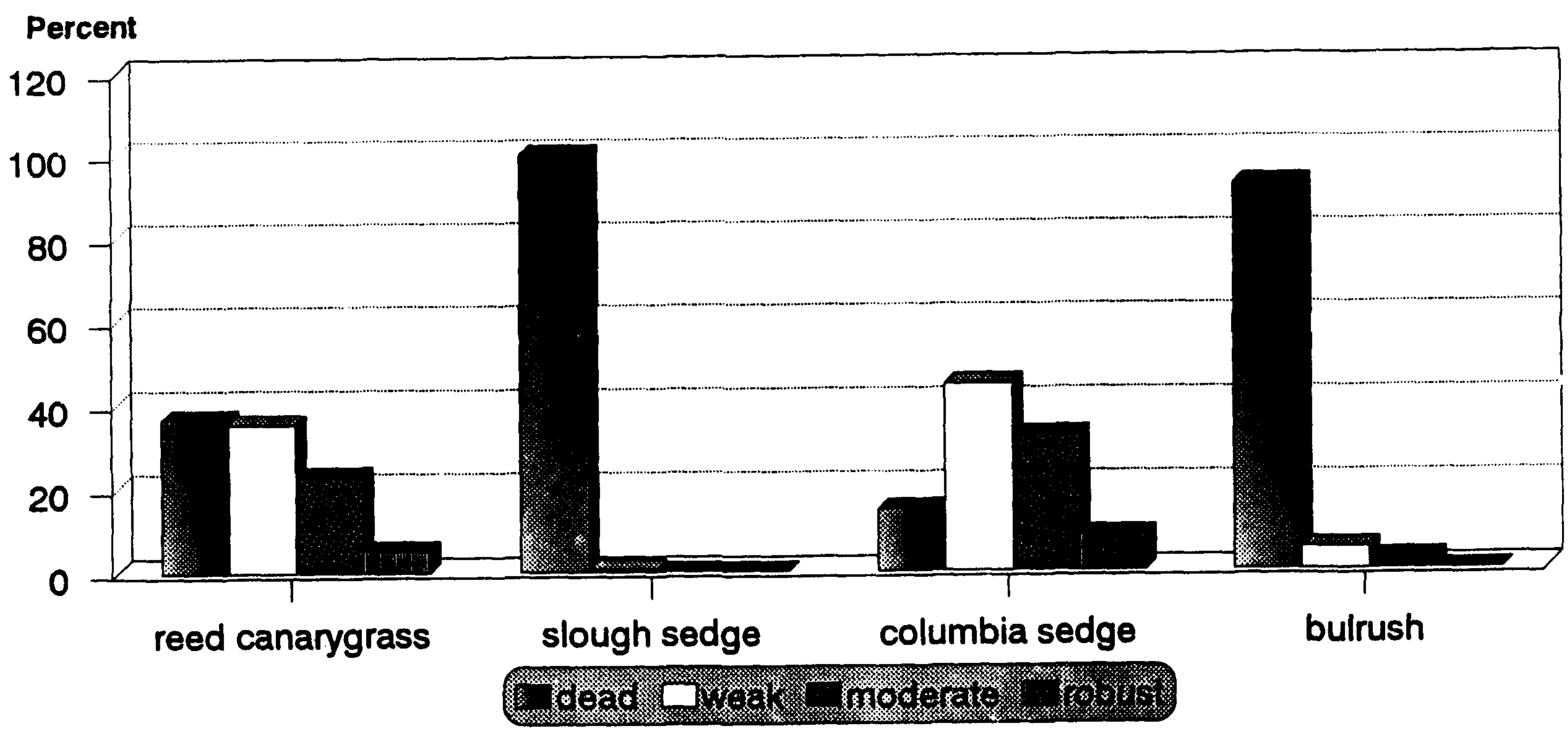

Figure 21. Relative vigor of fall 1989 herbaceous plantings identifiable after two inundations. All herbaceous plantings in fall 1989 were individual plugs

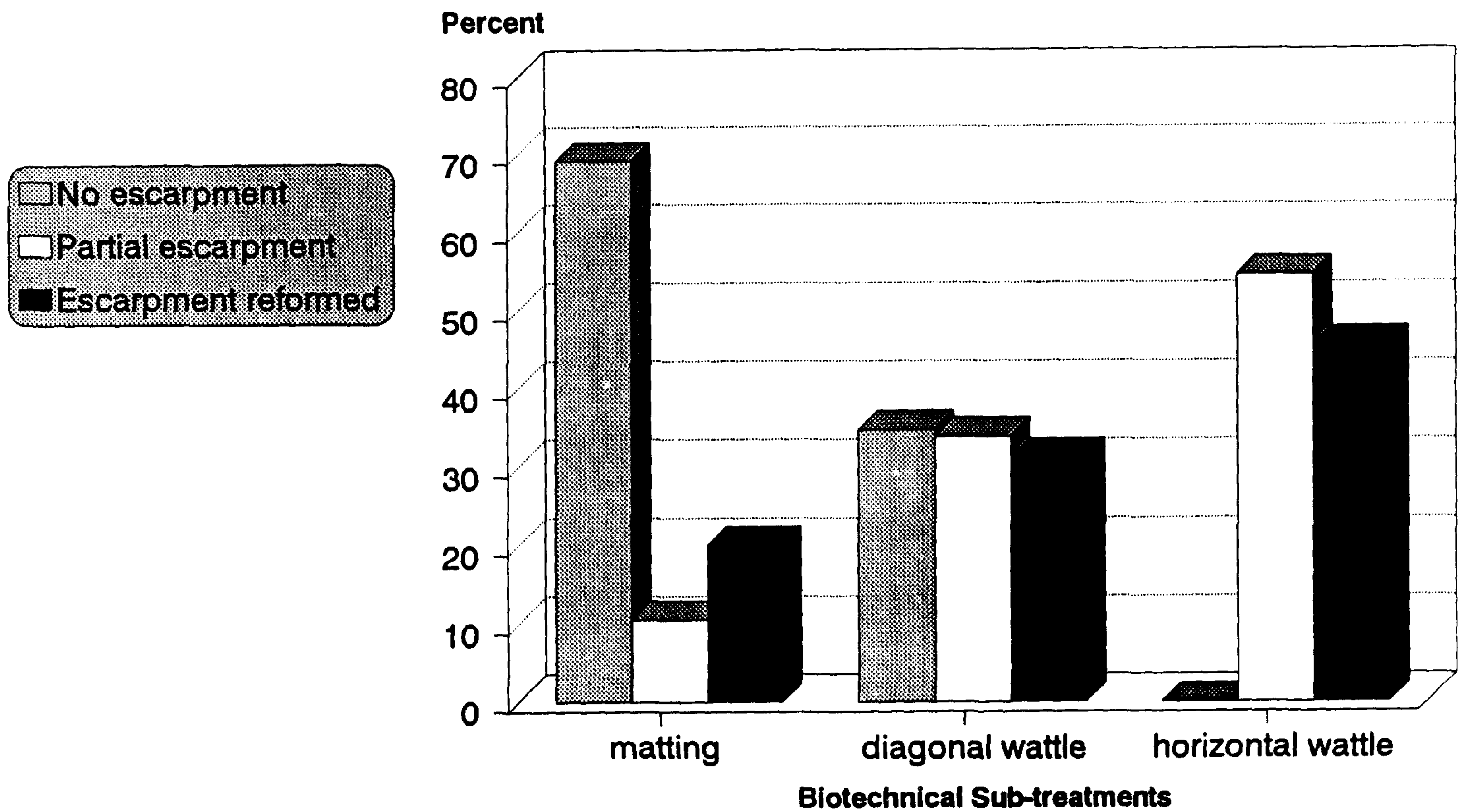

Figure 22. Resistance to escarpment reformation by three types of biotechnical structures. Values in percent of linear feet in contact with maximum conservation pool shoreline, Nov 1991

Figure 23. Baker Bay project site escarpment reformation in left foreground (horizontal wattling treatment) and no scarp behind center stake (matting treatment)

Figure 24. Baker Bay project site willow matting after three inundations. Note that center left and lower right mats are heavily invaded

Figure 25. Baker Bay project site, barren wattles after three inundations (lower right and middle left). Note matting in center is heavily invaded and stabilized by reed canarygrass

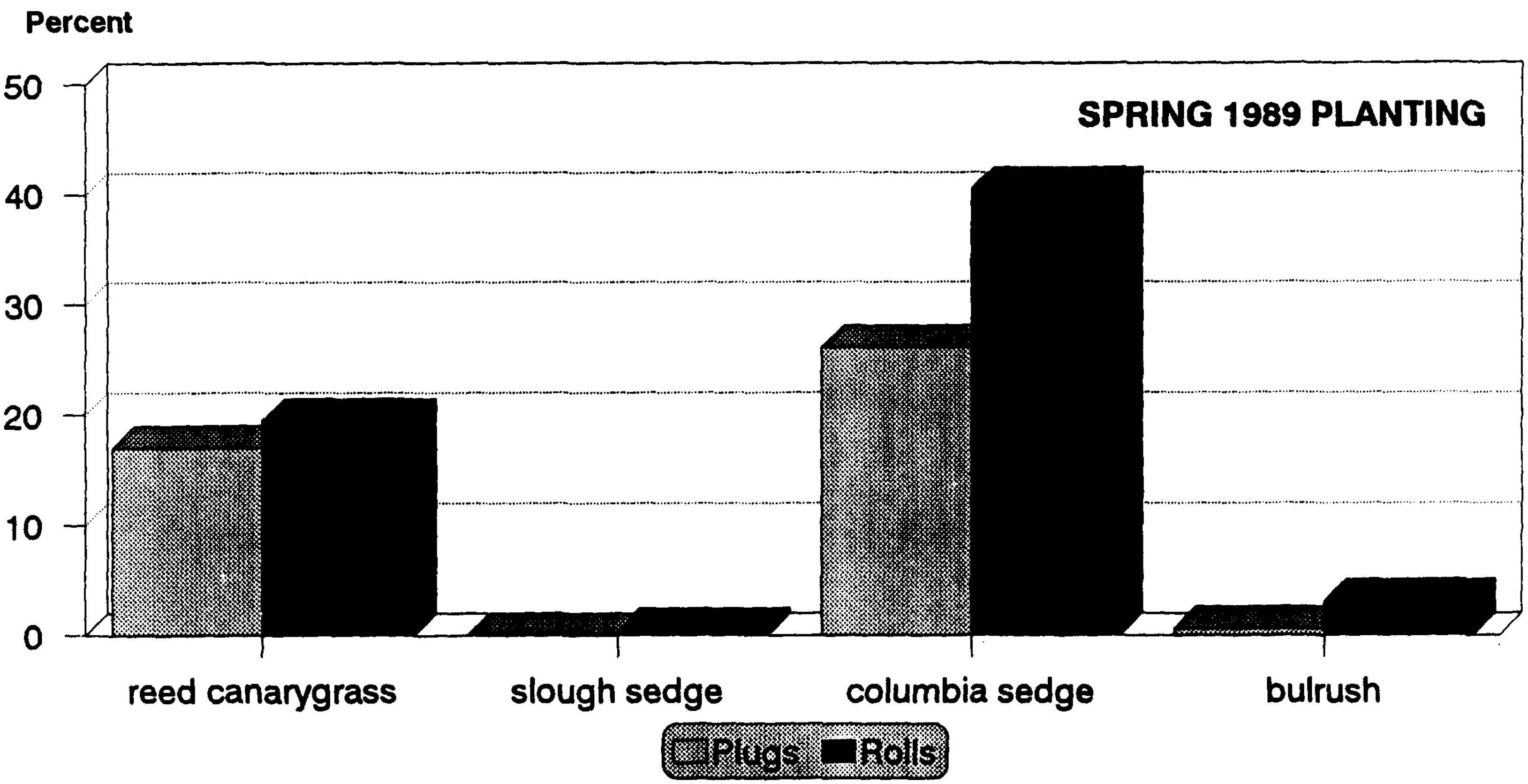

Figure 26. Survival as a function of planting technique and the total population originally planted. Above observations, Nov 1991

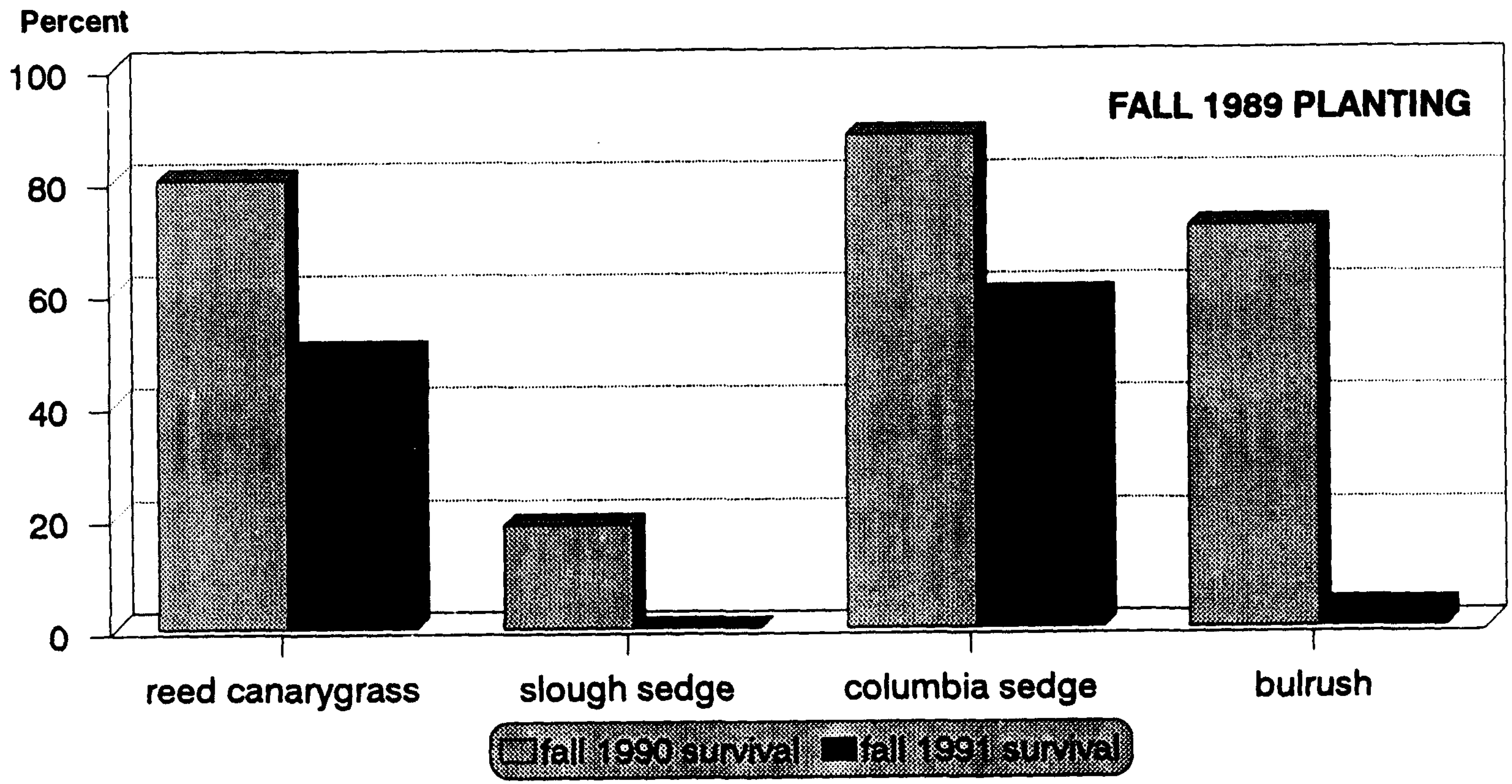

Figure 27. Comparative survival as a function of the original population planted in Nov 1989. All herbaceous plantings in fall 1989 were individual plugs

BREAKWATER INSTALLATION AND VEGETATIVE STABILIZATION IN ILLINOIS

Don Roseboom[1]

The major water quality problem of the Illinois River is the nonpoint pollution problem of sedimentation. There are 53 backwater lakes along the Illinois River with a combined surface area of 5,187,000 acres. These backwater lakes have had such severe sedimentation that many are only broad shallow wetlands. Examples are Weis Lake and Sawmill Lake with volume losses of 86 percent and 91 percent, respectively. It is believed that over 20,000 acres of backwater lakes have been lost. Recent sedimentation studies have indicated an increase in the rate of sedimentation between 1960 and 1980 in Peoria Lake (Demissie and Bhowmik 1986).

Corresponding with the increase of sedimentation has been a decrease in the amount of aquatic vegetation, which supports fishery and waterfowl resources. While the filled backwater lakes have been called wetlands, aquatic vegetation is extremely limited so that wave action constantly resuspended sediment. While highly turbid waters adversely affect many species of plants, even emergent species such as arrowhead are absent from most of the filled backwater lakes. As in Chesapeake Bay with the increased sedimentation and loss of aquatic vegetation, sport and commercial fisheries declined, particularly centracid species. Numbers of waterfowl migrating through the Illinois River valley dropped precipitously also (Mills et al. 1966).

Field Test Design

With Sport Fish Restoration funds from the Illinois Department of Conservation, the Non-Point Pollution Control Program of the Water Quality Section began a 3-yr project to test methods of aquatic revegetation and their effects on gamefish populations. Three areas of experimentation were established in a bay of lower Peoria Lake (Figure 1). This bay lies just downriver from the delta of Ten Mile Creek. One area is a control area without any type of revegetation attempted. The third area would have revegetation behind a tire breakwater (Figure 2). All revegetation methods were low-cost approaches which could be utilized over a large area.

During 1986, baseline data were established on all three areas. Aquatic plantings were attempted in both areas to be revegetated. Laboratory studies had found even weighted tubers of arrowhead and sago pondweed would pull loose from the fluid sediments from wave action in no time. The plant tubers were therefore placed deep into the sediment so that the developing root system would be in a more cohesive sediment layer.

All plant beds required grazing protection from waterfowl during initial spring growth. Orchard netting was placed around all plant beds. All plant beds were uprooted

[1] Illinois State Water Survey.

with the exception of one site behind a 40-ft floating log. This bed regrew during spring of 1987.

Revegetation and the tire breakwater

During the winter of 1986-87, a 700-ft-long tire breakwater was constructed in 112 modules and transported to the bay area. During May 1987, the 25-ton breakwater was towed into the bay from the delta of 10 Mile Creek. The breakwater was held in place by nine steel pilings. The pilings were 11 ft long and 5 in. in diameter. A gasoline water pump and nozzle were used to jet the pilings 11 ft into the sediment. The breakwater was attached to the pilings with 18-ft lengths of 3/8-in.-diam chain. With such construction, the breakwater has survived the ice of two winters.

In June 1987, arrowhead plantings were again made in the two areas of vegetation. Orchard netting was again required to prevent overgrazing of the developing plant stems by waterfowl. In the vegetated area without breakwater protection, only the bed of vegetation behind the floating log survived to flower in August.

All beds of arrowhead behind the breakwater survived to flowering in August. The plants died back rapidly in September after flowering. The breakwater was left in place through the winter of 1987-88. All the 1987 plant beds regrew more densely in 1988. New beds of arrowhead were established behind the breakwater in 1988. Sago pondweed was also planted with the arrowhead beds. Sago plants were visible through August 1988.

Gamefish response to revegetation and the breakwater

By the fall of 1988 and spring of 1989, the number of fish species in the area of the revegetated breakwater area was double the number of species in the untreated control area. The number and weight of all fish in the breakwater area were quadruple the number and weight of all fish in the control area. The control area fish numbers were similar to the breakwater area before revegetation and breakwater installation.

During the May 1989 fish survey, bluegill and channel catfish exceeded all other fish in the control area in both numbers and weight. While bluegill were never found in the control area, they did become numerous in the breakwater area. The vegetated area served as shelter and forage base for young channel catfish and striped bass.

Waterfowl grazing

Both second year and newly established beds of arrowhead flowered behind the breakwater in August 1987. Orchard netting was removed after flowering to determine the effects of grazing on the beds. Even though arrowhead is not considered to be a prime waterfowl food source, the effects of grazing were immediately apparent. While openings in the orchard netting below the water surface allowed carp into some plant beds, the activity of rough fish did not compare with the grazing of waterfowl and aquatic rodents.

None of the aquatic beds had protective netting until June 1989. The broods of both mallard and geese young around the breakwater required the establishment of protective fencing around the remaining plant beds. Waterfowl seem to prefer the vegetated areas, which are separated from the predators on mainland. Protective fencing was placed around the vegetative beds early in 1990. In this manner, recovery of fish and second year plants can be determined. The major problem in conducting this field trial was a major reason for revegetation - the limited supply of wetland plants for migrating waterfowl in the Illinois River valley.

The floating tire breakwater has demonstrated the effectiveness of aquatic vegetation and underwater habitat to increase gamefish populations. However, F-55-R also illustrated the difficulty in protecting revegetation plots from the wildlife which graze upon the vegetation. Methods must be developed to reduce grazing pressures on newly established vegetation or to increase the rate of vegetative growth.

Floating Island Breakwaters

Seven islands have been constructed and vegetated at the Woodford County Conservation Area by May 1992. Four islands consist of two 10-ft modules of cedar rafting (Figure 3a). One island consists of three 8-ft modules of recycled plastic in the form of 5-in. x 5-in. x 8-ft Ecowood (Figure 3b). Two islands consist of 16-ft cedar pole rafting (Figure 3c). All three types of island breakwaters are shown in Figure 4.

Soil is placed within the alternate spacing between the cedar poles or Ecowood timbers. The soil is contained by layers of erosion-control geofabric and chainlink fence bottom.

During 1991 module construction, chains were used to bind the cedar poles together, but wave action caused them to wear through the cedar poles. In 1992, 1/2-in. wire rope was used to bind the 10-ft cedar modules and the 8-ft Ecowood modules. The wire rope tightened the timbers and helped prevent wave action abrasion. Both methods required complete construction on land and transport to the site, which increased the effort and cost. The cedar poles were obtained free from a local utility company which replaces their old poles. The cost of materials for construction was approximately $160 for a 10-ft cedar module ($16/ft), $300 for an 8-ft Ecowood module ($37.50/ft), and $130 for a 16-ft cedar island ($8.13/ft).

The 16-ft cedar pole design was the most efficient for construction materials and durability under wave action. The long, single space maximizes material use and wave reduction over a large area. Two 16-ft cedar poles, 24 in. in diameter, are spaced apart with 6-ft poles to form a single space. The larger cedar poles allow wider and deeper pockets with a bottom layer of chainlink fence and a top layer of erosion-control geofabric. This space is 3 ft deep compared to less than 2 ft on the other modules, and thus helps reduce wave action below the surface while increasing area for root growth and fish habitat. The cedar poles are joined with 8-ft 5/8-in. rebar through holes with metal sleeves, to prevent wave action abrasion. This design was assembled in the water, which enabled easy movement of the large cedar poles.

Modules are towed to the site, secured in place with 13-ft 4-in.-diam steel pilings and filled with sediment from the site. Cedar poles over 30 ft could be more efficient to form an extended breakwater if delivery to the site is possible.

The floating islands were planted in April through May with wild rice seeds, arrowleaf tubers, and transplants of local bulrush and arrowleaf plants. The tubers, seeds, and transplants were all planted in the sediment with an excelsior cover to hold them in place until root development.

In May the arrowleaf tubers and wild rice seeds showed rapid growth, approximately 3 weeks faster than the local arrowleaf on the shoreline. They also flowered in June, 1 month earlier than the arrowleaf plantings in lake sediment behind the breakwater during 1987-89.

The arrowleaf and bulrush transplants adapted well to the floating islands. The bulrush formed dense, 60-in. stands by mid-June and provided an extra windbreak.

Mallard ducks utilized the floating islands for nesting in June, resulting in minor vegetation damage for nest construction. After the nesting period, the arrowleaf on this module resprouted into a healthy stand of plants.

Grazing Controls

A timer-controlled sonic cannon, which is powered by propane was tested in August. The noise produced by the cannon was startling to human ears within 300 yd of the floating island site. Further testing will be done on an area under heavy grazing pressure by waterfowl in September.

A small, battery-powered electric fence is being tested for effectiveness in keeping waterfowl out of one island module. So far it has been effective, with no waterfowl use being observed.

A larger, battery-powered electric fence is being tested for effectiveness in reversing effects of heavy grazing by Canada geese on newly established arrowleaf, via transplants and other aquatic plants in a 20-ft-square area on dredge material islands in the Woodford County Conservation Area. Continual maintenance was required to ensure a strong shock potential.

Willow Post Bank Stabilization

Erosion along Court Creek (near Galesburg) has been reduced significantly, thanks to a cooperative project between the Water Survey and the Illinois Department of Conservation. The erosion-control methods that have been tested have the potential for application in many other streams because of their success and economy.

The erosion control project began more than 3 yr ago with funding from Illinois Department of Conservation's Watershed Planning Program. Naturally steep slopes in the Court Creek watershed, high rates of runoff, detrimental land management practices, and channelization of the stream had all contributed to severe bank erosion problems.

Vegetative Protection Most Effective

The most effective erosion control was obtained by the vegetative method: the "planting" of willow posts - large, dormant cuttings of willow logs. In this method, 12-ft posts are driven into holes placed along the streambank by a Caterpillar excavator with a metal ram. The willow posts are placed about 4 ft apart in five offset rows. The posts regrew root systems and branches, stabilized the banks, and deflected the streamflow. The method is being used on about 1,200 ft of bank in each of five areas along Court Creek.

The willow posts have stopped all bank erosion since April 1987. The willows withstood beavers, bugs, ice floes, and extremely high flows caused by stream channelization. In June 1992, 4 in. of rain fell in 30 square miles of the watershed in only 1 hr. The creek rose 7 ft in 2 hr, but despite the high flow there was no erosion whatsoever at the sites protected by the willows.

The willow post techniques have proved to be the most cost-effective, at about $5 per foot of streambank. Riprap is two-and-a-half times more expensive, largely because of the cost of obtaining the material and hauling it to the site.

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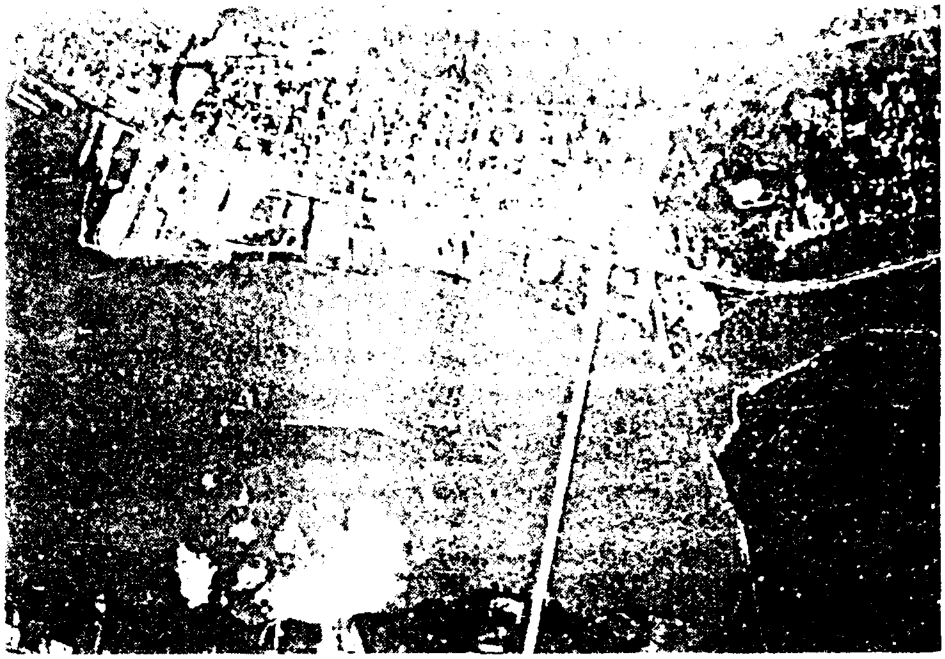


Figure 1. Aerial view of Lower Peoria Lake. Study site is located in the bay at lower right-hand corner of photo (north is to the right)

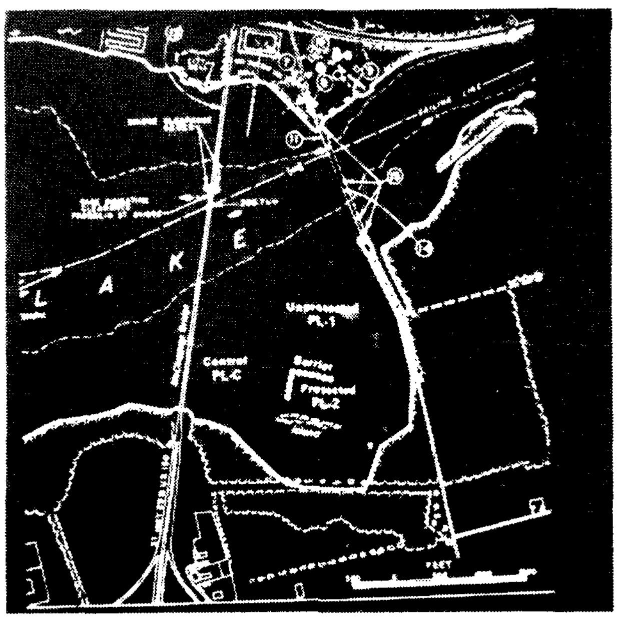
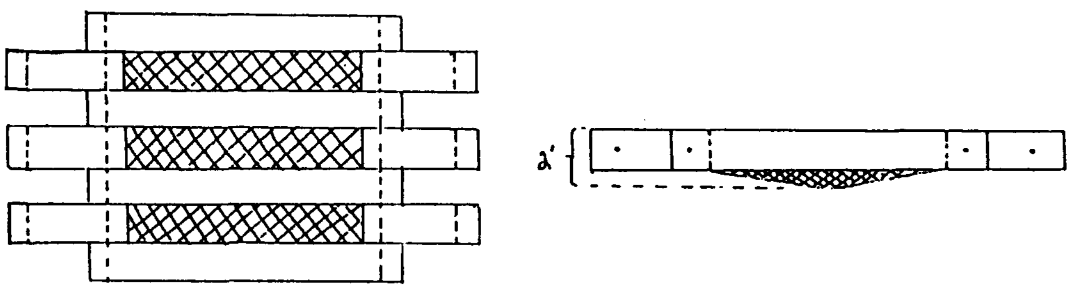
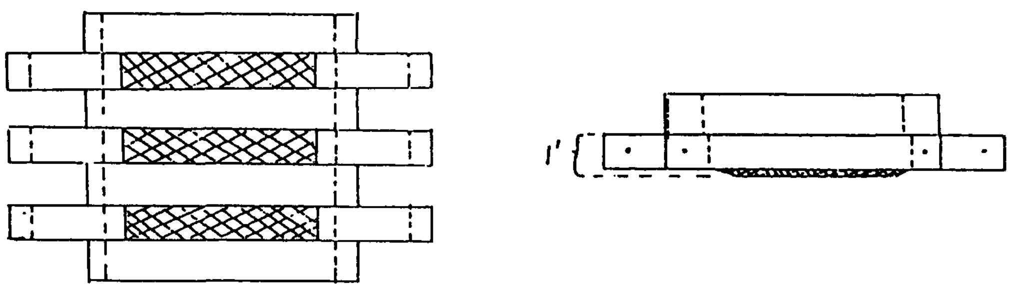


Figure 2. Schematic of study site showing planting areas and control area. Station PL-1 was planted without wave protection. Station PL-2 was planted behind a floating tire breakwater. PL-C is a control area without plantings or wave protection

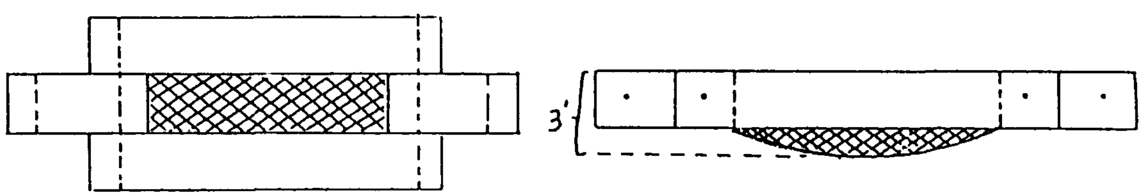
PLAN VIEW CROSS-SECTION



3A Cedar Module: 10 ft.



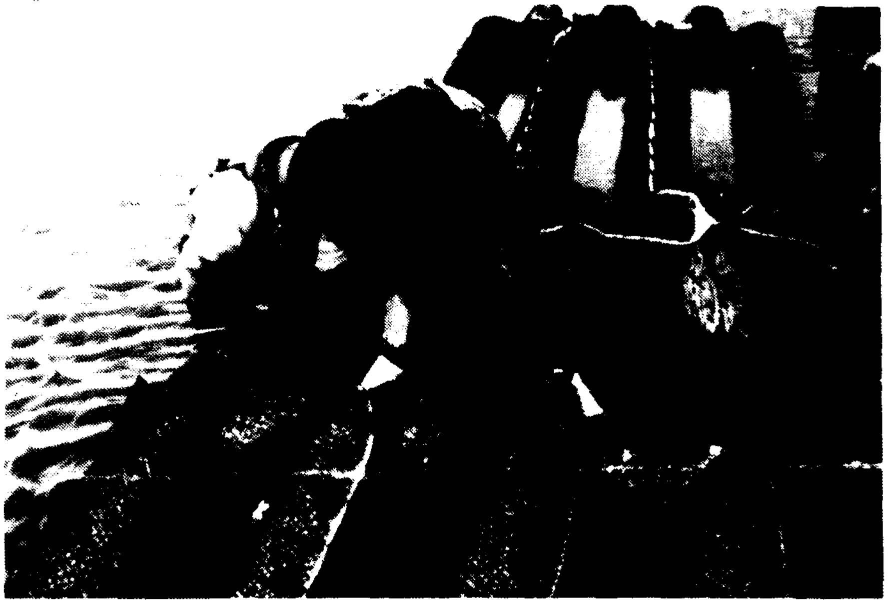
3B Ecowood Module: 8 ft.

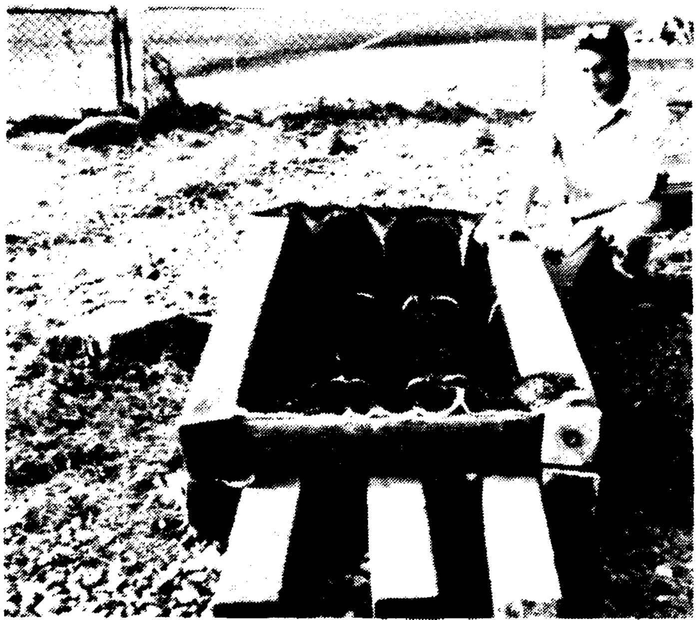


3C Cedar Island 16 ft.

Figure 3. Diagrams of three floating island designs

10-ft cedar module





8-ft recycled
plastic-Ecowood module

16-ft cedar island

Figure 4. Three floating island designs

CONCURRENT WORKING GROUPS' SUMMARY REPORTS

Overview

The purpose of the working group sessions was to provide an open forum for focused discussion of four topic areas (1) magnitude of the problem, (2) causes of the problem, (3) effects of the problem, and (4) fixes. The focus of each topic area working group was on participants' experience and approaches to assessing and controlling reservoir shoreline erosion and on related issues, needs, and data gaps.

The four working groups met concurrently during four separate sessions, such that all workshop participants could attend all four working groups. Each group discussion was facilitated by contractors from Louis Berger & Associates, Inc., and co-facilitated by WES personnel.

Results of each working group are summarized in the four subsections which follow. These group summaries were prepared from notes, lists, and tape recordings of the working group sessions.

SUMMARY REPORT OF WORKING GROUP ON MAGNITUDE OF SHORELINE EROSION

The working group on the magnitude of the problem focused on the following: how reservoir shoreline erosion problem areas are identified, measured, and prioritized; difficulties encountered in identifying and portraying reservoir shoreline erosion; ideal or suggested approaches to the problem of reservoir shoreline erosion; and information gaps and needs. The summary report of this working group is organized by these topic areas.

Problem Identification, Measurement, and Prioritization

Input from agency staff, landowners, or reservoir users is a typical way that shoreline erosion problems are brought to the attention of reservoir managers. In certain cases, the affected party brings the problem to the attention of an elected official (e.g., congressional representative who then notifies the agency). The problems reported may be a direct result, e.g., property damage, or an indirect result, e.g., sediment plumes or other evidence of resource degradation of the shoreline erosion. Several reservoir managers discussed systematic approaches to identifying reservoir shoreline erosion. These included annual surveys by boat of the reservoir shoreline or of landslides along the shoreline. Reservoir shoreline erosion has also been detected through reservoir cross-sections and profiles, siltation surveys, and aerial photographic interpretation.

Problem Measurement

Several of the techniques that can identify shoreline erosion are also used, in some cases, to measure the erosion or rate of shoreline (bank) recession. Included are reservoir cross-section and profile surveys, siltation surveys, and aerial photographic interpretation.

Michael Corkran (CESWT-PL-R) provided a 15- to 20-min demonstration on the use of computer-aided mapping as a tool for measuring bank recession at 262 sites on Lake Eufaula over the period 1968 to 1989. Aerial photographs were the basis for the mapping, and the bluff crest as traced from the photographs was used as the indicator of bank recession.

A stereo tracer was used to record the bluff crest lines into a digital format. Coordinates for the mapping were obtained from state plane base maps. Students from the University of Oklahoma were responsible for much of the effort in setting up the program. The product developed to date is a computer visualization tool which illustrates the sequence of bank recession at the sites over time. Ground control for the earlier photography was reported to be a problem because of a lack of identifiable benchmarks.

Several individuals reported having used a global positioning system (GPS) as a surveying tool. The general consensus of those familiar with GPS was that it is not yet accurate enough for application in measuring bank recession.

The use of tagged nails as ground reference markers for measuring bank recession was also discussed. One individual reported the experience of nails having been removed or repositioned to the extent that this technique could not be relied upon.

Problem Prioritization

This portion of the discussion centered on how resource managers prioritize allocating resources to remedy a variety of reservoir shoreline erosion problems. A common theme was that the problems that get addressed are generally those being pressed by elected officials, landowners, or user groups.

Several resource managers noted that in the absence of political pressure, they placed priority for fixing reservoir shoreline erosion on protecting those resources or uses valued most by their agency. For Corps of Engineers reservoirs, it was noted that the Corps mandate gives flood control and navigation the highest priority followed by water supply and hydropower (non-federal uses) and recreation. The various uses are expressed as pools, or water levels, maintained to meet the use need. It was noted that maintaining the flood control pool produced fluctuating water levels that contribute to shoreline erosion. Threats to the integrity of the impoundment structure are given high priority by various agencies. Meanwhile, the Tennessee Valley Authority considers erosion as a greater threat to hydropower than to flood storage.

Regulatory or statutory mandates were also cited as forces which affect prioritization. For example, when cultural resources are threatened or damaged by reservoir shoreline erosion, then their National Register status or the presence of human remains becomes the overriding factor relative to the actual severity of the erosion. From the perspective of the U.S. Environmental Protection Agency and state water resource agencies, priority is on maintaining or attaining the water's designated use or water quality standard. When the use or standard is threatened or violated from sediment eroding from shorelines, then remedying the shoreline erosion takes priority.

Several resource managers noted that priorities are frequently given to problems that they are confident can be fixed. Similarly, it was mentioned that the estimated cost of fixing several problems is a factor in prioritizing which problems are to be fixed first.

Difficulties Encountered

There was general agreement in each of the sessions that defining the problem is difficult. For example, should the problem be measured based on the severity of the erosion or the severity of damage or both. One of the more succinct definitions posed was that reservoir shoreline erosion is a problem when it is not acceptable to someone. This definition acknowledged the general consensus that erosion is a natural process and that all shoreline erosion cannot be fixed. However, certain individuals took issue with this definition noting that it excluded situations in which people are not affected or aware of the erosion.

A common theme noted by resource managers was that they are addressing reservoir shoreline erosion in a reactive mode for a variety of reasons. One of the reasons noted was that higher levels in the chain of command are more responsive to political pressure than to engineering or scientific rationale. Some mentioned the lack of measures to convey the severity of the problem to higher levels. Another reason noted was that of resource limitations. Specifically, Corps Districts operate under a certain contract ceiling. This influences not only what gets fixed (what problems can be fixed within the ceiling) but also influences the amount contractors bid to do the work (they are aware of the ceiling and price accordingly). Those in the Bureau of Reclamation noted that irrigators do not pay to fix shoreline erosion unless it is a component of their water cost rate. Others cited the general rural location of reservoirs as reason for a lack of attention to reservoir shoreline erosion from higher administrative levels or the general public.

Those from the Corps of Engineers mentioned a lack of jurisdiction over non-Corps lands surrounding reservoirs as an impediment to addressing reservoir shoreline erosion. There is a lack of control over what private landowners may do to accelerate shoreline erosion.

Another common difficulty encountered is how to measure the severity of the erosion. In particular, where sediment pollution is a problem, it is difficult to discern the portion from eroded shorelines from other sediment sources (e.g., inflows, overland flow, etc.).

Finally, there was comment that the division between disciplines (e.g., scientists vs engineers) impedes addressing the problem. Although scientists in the session acknowledged that the education process has improved the environmental sensitivity of engineers, and engineers acknowledged that scientists have become more practical, the conclusion of these discussions was that there are still cross-discipline barriers. Further, these barriers manifest themselves, in particular, in determining fixes.

Suggested Approaches to the Problem

Discussions on this topic included what participants mentioned or suggested as ideal approaches to the problem and, where noted, what drawbacks other participants saw to these approaches.

There was a consensus that the problem would be better addressed in a proactive rather than reactive mode. In other words, resource managers would prefer to prioritize based on scientific criteria and then plan engineering solutions. It was generally felt that a holistic approach to the problem, such as that enunciated in U.S. Forest Service policy, would facilitate a proactive approach.

It was suggested by several participants that more systematic monitoring of reservoirs be done. Recognizing resource limitations, it was noted that systematic monitoring could be as simple as having agency staff take a measurement on any visit to a reservoir. Several suggested adding this task to rangers job descriptions. However, it was countered that the existing workload does not permit an added task.

It was also felt that the problem could not be successfully approached without more public awareness and participation. The U.S. Forest Service representatives noted use of water education teams which focus on improving water management awareness at the high school and college levels. A program of citizen monitoring was suggested as a solution to the problem of limited resources. It was felt that as participants, landowners, users, and other interested citizens would become better stewards of the reservoir resources.

Distinguishing perception from fact was mentioned as a drawback of citizen monitoring based on observations rather than measurement.

There was consensus that geographic information systems (GIS) based on remotely sensed data have application in identifying and measuring shoreline erosion. GIS was viewed more as a tool for measuring chronic erosion problems as opposed to problems caused by a particular event. It was cautioned that users of GIS need to understand the magnitude of error inherent in the process (e.g., level of resolution, skewing, scaling, etc.). One particular application of GIS suggested was a means to measure land use change vs bank recession. This was seen as an aid to anticipating potential real estate requirements (i.e., condemnation) prior to property development which increases land values.

Having a model of a reservoir's shoreline processes, based on such factors as wind direction and speed, pool level, and soil types, was viewed as an ideal tool for managing the reservoir. One application of the model would be to predict the effect of altering the reservoir pool level through drawdown. Such a model would largely be reservoir-specific. It was also cautioned that it is sometimes difficult to correlate cause and effect.

Information Gaps/Needs

Several participants noted the need for standard methods to define and measure reservoir shoreline erosion and its effects, as well as standard thresholds to determine when to act and standard approaches to evaluate appropriate fixes. It was felt that a standardized approach would give resource managers an objective method for prioritizing the allocation of resources to remedy the erosion and for communicating the severity of the problem to higher administrative levels. One specific information gap commonly noted was the proportion of sediment eroded from a reservoir shoreline to the total sediment load to that reservoir. This information could provide a standard measure of the problem.

There was also a commonly stated need for systematic monitoring of reservoir shoreline and water and habitat quality. A related need, and a first step to systematic monitoring, would be a comprehensive resource inventory that would provide a baseline for measuring reservoir shoreline erosion and its effects.

Another generally stated need was having the capability to predict the rate of bank recession, i.e., correlate causes and effects. More specifically, having the capability to predict when and where equilibrium (angle of repose) will be reached, would help determine where, when, or if remedial action should be taken.

Finally, there w... a consensus that more interagency and public/user involvement is needed in addressing reservoir shoreline erosion. It was felt that public involvement and education could improve an understanding that erosion is a natural process and that fixes sometimes fail. More interagency involvement, it was noted, could result in more and better use o. available information including resource maps and photography, techniques, and materials.

SUMMARY REPORT OF WORKING GROUP ON CAUSES OF SHORELINE EROSION

The focus of this working group was various causes of erosion. The guiding question was: How can we better understand the causes for reservoir shoreline erosion, such that reservoir managers and engineers can install erosion control measures and fixes more effectively?

Part of the session examined present approaches and policies for understanding causes of erosion. Based on the experience of the participants, the functionality and appropriateness of such current approaches was examined. Data gaps were identified. Suggestions were made for new or modified plan and agendas that agencies or individual reservoir managers could consider to better understand the causes of erosion.

Types of Causes

The list of the types of causes and related factors identified by the participants fell into two main groups:

Natural causes and factors

- Waves
- Ice scour
- Freezing and thawing
- Soil conditions
- Shore geometry
- Rain/runoff
- Groundwater hydrology
- Wind
- Currents
- Topography
- Floating debris (trees)
- Fires

Human causes and factors

- Reservoir operation (drawdown, etc.)
- Boat wakes (recreational boats and barges)
- Land use (forest, agriculture, urban development)
- Construction
- Beach use
- Motorcycles/recreational vehicles
- Trails (trampling)
- Livestock
- Negligence/vandalism
- "Property value enhancement"
- Insufficient enforcement
- Politics

Causes for reservoir shoreline erosion were considered and well understood in general. The relative significance of causes of erosion cannot be ranked easily, since it varies considerably between individual reservoirs and depends on a broad variety of site-specific factors. Below, the major types of causes will be summarized reflecting the experiences and views of the participants.

Natural causes and factors

Wind-generated waves are the predominant cause for erosion in large reservoirs. The magnitude of erosion and the most vulnerable parts of the shoreline are determined in part by factors such as the prevailing wind direction, fetch, duration of wind, wind speed, soil conditions, and the shoreline geometry. Ice scour and erosion from freezing and thawing of the soil is a common cause in colder regions of the country.

The degree of erosion from runoff from rainwater is determined by the intensity of periodic rainfalls, particularly in drainage basins with fine-grained soils. Trees that are transported into reservoirs by floodwater or that fall into the reservoir when the shoreline recedes may themselves cause erosion by being constantly pushed against the shore by waves.

Another less common natural cause is fires adjacent to reservoirs that burn the vegetation thereby exposing the soil to erosive processes. Naturally, fires are more likely in dry regions of the country such as California.

Human causes and factors

The most important human cause mentioned for reservoir shoreline erosion is the operational practice of the reservoir itself. Erosion commonly occurs during drawdown. While the degree of drawdown varies depending on physical parameters such as soil condition and reservoir bathymetry, the speed with which reservoirs are drained can affect the erosion rate. However, it was also recognized that reservoirs such as flood control reservoirs are built for a specific purpose which requires drawdown in order for the reservoir to function for what it was designed.

The second most important human cause for erosion mentioned was waves generated by boat wakes. Boat wakes are relatively more important in smaller reservoirs where shorter fetches limit the effect of erosion by wind-driven waves. The degree of the effect of boat wakes depends on the size and speed of the boat (recreational boat/barge) and the density of boat traffic. Speed limits for boaters exist but may be ignored because they are not always enforced.

Other human causes are the use of beaches. It is not uncommon that beach-goers and hikers leave marked paths to the beach and along the shoreline and trample the shoreline-protecting vegetation in the process. Also motorcycles and other recreational vehicles were mentioned as destroying vegetation. Cross-country motorcyclists like to ride particularly up and down the soft slopes along the shoreline. Also, children have been observed sliding down the soft sandy slopes moving the soil down with them. Aside from exacerbating shoreline erosion, this can also be dangerous; just recently a child died in Oklahoma when an over-steepened bank caved in during such activities.

Beach-goers typically do not like riprap. In a more unusual story, one participant observed that beach-goers removed rocks from a riprap wall on one location to create easier access to the beach and then piled up the rocks on an adjacent location like a monument. In other cases, erosion is caused by vandalism.

Property owners can contribute to shoreline erosion through a variety of actions. Vegetation along the shore is removed in order to improve the view across the water and to destroy habitats for rodents and other animals that are considered a nuisance. Grass is mowed as part of landscaping activities. The shoreline is covered with fill in order to enlarge the usable property, sometime beyond the property boundary. Several of these activities are carried out for "property value enhancement" purposes, particularly when a sale of the property is pending. In other instances, shoreline protection measures are removed out of negligence or out of lack of knowledge of their importance.

Changes in the land use of the area surrounding the reservoir may speed up or slow down erosion. Forest with trees and shrubs surrounding the reservoir reduces erosion the most. Barren soil of agricultural fields surrounding the reservoir can increase the erosion rates. Tall trees reduce the wind speeds acting on the water surface and thereby reduce the size of waves, particularly at smaller reservoirs. The loose soil and the root system soak up some of the runoff during rainstorms. Excess runoff from agricultural fields (and open construction sites) may rush into the reservoir, potentially causing erosion in the process near the drainage channels. Urban developments may increase the amount of storm-water runoff if large paved areas prevent infiltration of some or all of the water into the ground.

Livestock may add to shoreline erosion if they are allowed to trample and graze protective vegetation adjacent to the shoreline.

Indirectly, politics was mentioned as another human cause, as sometimes decisions of how to operate reservoirs and how and where to deal with specific shoreline erosion problems are handled by elected officials.

General Issues and Main Ideas

The second part of this working group's sessions focused on suggestions for better understanding the causes of erosion.

Data gaps

It was the opinion of the participants that data gaps about the causes for shoreline erosion in general do not exist. However, available data for individual reservoirs may be insufficient. A meaningful strategy for handling shoreline erosion for a specific reservoir should be based on a meaningful database. Given that erosional events (such as erosion caused by wind-generated waves) are random events, an objective pattern of erosion in a particular reservoir may not emerge without many years of data and observations. Valuable observations by individual reservoir managers may be lost when they leave their position, unless it is recorded in a manner that is easy to understand for successors and other personnel working on shoreline erosion. It was suggested that, if not already in place, each reservoir manager should keep a well-organized and easily accessible data and observation archive. The information stored in this archive does not need to be expensive to obtain, but it should be recorded in a continuous manner. Such archive could include:

- Visual observations (by managers and other individuals);
- Measurements (e.g. water level, wind direction, and velocity);
- Photographs of erosion damage, dated on the back;
- Video-recording of erosion in progress, for example during a stormy day;
- Research results obtained by outside researchers. Copies of the data and the final reports should be obtained from these researchers for the reservoir archive.

The location of all information (visual observations, measurements, photos, video, etc.) should be recorded on a detailed map.

Gaps in the understanding of the fundamental physical processes at work at a specific reservoir could be reduced by encouraging academic investigations. Such investigations would typically be free of charge or available for a minimal amount for some financial support for a graduate student and, concurrently, further the education of a young scientist.

Develop a cost-effective National methodology

Guidelines could be prepared by agencies for reservoir managers in order to close existing data gaps and develop data and observation archives at individual reservoirs, as discussed above.

The agencies could also work as "relay stations" for information obtained by individual reservoir managers. Such technology transfer could be done in the form of regular newsletters that include practices, successes, failures, and other activities in regards to shoreline erosion. This newsletter could also include a list of recent publications (and may be the summary of such publications) dealing with research on reservoir erosion and fixes.

Communication

Dealing effectively with shoreline erosion partly depends on communication, information transfer, and education. More communication should take place between agencies, from agencies to individual reservoir managers, between individual reservoir managers, and between reservoir managers and the public that utilizes or is affected by the reservoir.

The form of communication should vary and be pragmatic. The participants considered workshops such as this workshop very effective for the exchange of information and experiences. Some participants stated that there should be more workshops to bring in other audiences that are in contact with shoreline reservoir erosion as well. In some instances, general brochures could be produced by agencies for educating the public on the "Do"s and "Don't"s in regards to shoreline erosion.

Multidisciplinary monitoring of key erosion areas

Key erosion areas at individual reservoirs should be monitored regularly in a multidisciplinary manner. The disciplines should include:

- Hydraulics
- Geotechnical
- Environmental
- Fish/Wildlife Biology
- Recreational resources
- Operation and Maintenance (O & M)

The reason for such monitoring would be to:

- Enhance the understanding of the site-specific causes for erosion;
- Be able to prioritize erosion sites based on their urgency and degree of erosion reduction with a fix; and
- Be able to determine the best cost-effective fixes designed to further prevent or reduce erosion over long-term periods.

Allocate available funds most effectively

Erosion is a problem in many reservoirs. Erosion leads to a loss in property and thereby costs money. However, funds to counter erosion are very limited. Reservoir managers have three basic options of how to counter erosion:

- Buy the land
- Fix erosion
- Prevent erosion

The choice or the mix of choices will vary at individual sites within individual reservoirs. For each site, choices should be evaluated and the most cost-effective approach should be chosen. The focus of the choice should be long-term. It was believed by many participants that all too often the choice is a reactive short-term fix. More emphasis should be placed to think ahead, take into consideration the dynamics of the erosion process at a particular erosion site, and evaluate also long-term preventive maintenance which could well be the most cost-effective choice.

The suggestion to evaluate the use of available funds for optimal cost-effectiveness pertains both to reservoir managers as well as to budget directors of agencies since the choices for erosion control by reservoir managers are usually predetermined by budget allocations.

Some of the examples for preventive measures include walkways to reduce trampling, temporary beach closings to let vegetation regrow, targeted public education, adequate enforcement of existing preventive measures, and others.

Innovative and experimental approaches

Some participants have successfully tried approaches as fixes and preventive maintenance that were both new and cost-effective. One example was the use of large hay bales that one participant emplaced along several erosion sites at the cost of about $1.20/foot; after five years 60% of his hay bales were still intact. Helpful in his case was the availability of the hay bales which were supplied free of charge by a local farmer as part of a deal.

The point of this example is to show that aside from the traditional ways and means to counter erosion other possibilities exist that can result in equal or better protection for a lower price. Reservoir managers should be encouraged to use more creativity and experimental approaches, which include being allowed to make some mistakes. At the same time, lead agencies through budgets and operational guidelines should allow reservoir managers to evaluate different and innovative approaches.

Other sources of help for shoreline erosion control may be the general public. Along many coastal beaches, citizen groups participate in beach cleanup days, organized as enjoyable social events, and in some parts of the country the "Adopt-a-Highway" program has been successful. Similarly, social "Beach-Erosion-Control-Days" and "Adopt-a-Shoreline" programs may be successful if organized appropriately. Aside from physically planting some willows, for example, these citizens could in the process become messengers for the responsible use of the reservoir for recreational use.

Again, an important element of trying new and innovative approaches is to share the approach and their success (or failure) with other interested members. Such technology transfer could be part of a newsletter discussed above.

Evaluate reservoir operation practices

The reservoir operation and erosion stemming from the operation of the reservoir may be examined and reevaluated. Some participants stated that often the operational procedures for reservoirs are many decades old. A re-evaluation of the reservoir operation may find that some changes could be made that would reduce erosion without jeopardizing the mandate for these reservoirs.

Summary

While the causes are in general well-understood, several constructive suggestions were made by the participants to enhance the response to reservoir shoreline erosion which ultimately could lead to a reduction in erosion with the same available financial resources.

SUMMARY REPORT OF WORKING GROUP ON EFFECTS ON SHORELINE EROSION

Widespread Impact

The working group examining the effects and impacts of reservoir shoreline erosion focused on those impacts that the project and resource managers attending the workshop were actually witnessing and addressing as part of their jobs. Because the workshop participants were drawn from a diversified group of resource managers, it was evident that few, if any, of the potential impacts voiced during the workshop were not of direct concern to some resource manager. Initially it was thought that it would be possible to gauge the significance of these impacts as either major or minor. However, it was quickly realized that such qualitative ratings were largely dependent on individual resource responsibilities. Rating the significance of the various impacts was abandoned. During each of the workshop sessions, several participants emphasized the fact that not all instances of erosion, even where severe, warrant corrective action.

During the discussions, a *data gap* was evident—the impact of shoreline erosion on the overall water quality and aquatic resources of reservoirs. Obviously, shoreline erosion processes contribute to the total sediment load in the water column. However, the magnitude of that contribution when compared to the total watershed input is likely to vary widely among different reservoirs with the observed differences dependent on numerous individual landscape characteristics, system configurations, and management practices. For the vast majority of reservoir systems, there is little or no data as to the actual contribution of shoreline erosion to the overall sedimentation budget or water quality characteristics including turbidity, nutrient budgets, or pesticide loadings. This data gap is transferred to impact analyses of shoreline erosion on fisheries, fishery reproduction, benthos, aquatic resources, and food webs. Low pool conditions, which offer a wide expanse of unvegetated soils, generate the greatest impacts via water quality degradation to the aquatic biology and species diversity. The resuspension of bottom sediments, originally derived from shoreline erosion events, was also cited as a possible impact vector.

For those managers responsible for a reservoir project, shoreline erosion directly impacts the Operation and Maintenance Budgets (O & M) of the individual projects. If any direct action is taken to resolve an erosion event, either by the introduction of a fix or via land acquisition, the funding necessary to complete that work is taken directly from the individual O&M budgets without augmentation from higher funding levels. Recently, a reservoir system had to reallocate $450,000 from it's O&M budget to pay for the acquisition of an eight-unit apartment complex. This action necessitated cancellation of several planned elements at the reservoir and caused a severe cutback in many maintenance activities. Dealing with shoreline erosion not only effects the allocation of funding, but manpower allocations as well. In many cases, the litigation activity and the manpower commitment necessary to determine the appropriate response are much more expensive than subsequent corrective actions.

Effects Discussed

Table 1 provides a comprehensive list of effects mentioned in each of the sessions. Elaboration of certain of these items follows.

Loss of the purpose

Shoreline erosion events have the potential to adversely alter or remove key project elements including structural and recreational features. Where erosion degrades a recreational facility, there is the potential for a decrease in public utilization.

Cultural resources

An overview of the effects of shoreline erosion on Cultural Resources is presented as part of the formal papers contained in these proceedings. It was noted that the management of shoreline erosion impacts on Native American Tribal Lands may have to be resolved in a different manner than for other lands.

Damage to and loss of private and public property

There appears to be no national estimates as to the yearly monetary losses attributable to reservoir shoreline erosion, but the workshop consensus is that the loss is in the millions of dollars per year. It has been governmental policy that damage to private property via shoreline erosion is "an act of God" and not the responsibility of project management. Many private landowners have installed "fixes" with private funds. Where the erosion is severe, some reservoir managers have elected to install "fixes" as part of their overall maintenance functions. Managing shoreline erosion of public property is the direct responsibility of the individual project managers.

Where long-term analyses and future predictions of shoreline erosion have been conducted, the magnitude of the monetary loss is relatively extreme.

Public relations with adjacent landowners

Where moderate to severe erosion is occurring on private lands, the relationship between the private landowners and the resource managers is strained. Frequently, these relations are worsened by outside government agencies supporting the contention that project management is legally responsible for the erosion events.

Boundary disputes

With eroding shorelines, some project managers have experienced boundary disputes with some landowners which can affect public access control and landowner rights.

Reservoir management practices

If the erosion is severe or where there is public criticism, project managers may be pressured to change water level management practices or reduce the hydropower generation. In some reservoir systems, necessary management practices generate secondary impacts that are exacerbated by erosion processes including severe dust generation during low pool conditions.

Political pressures and inquires

Such actions can occur at the local or the Congressional level. The impetus for such inquiries originates with adjacent landowners who are experiencing some level of erosion. Regardless of the resolution of the discussions, it is very rare that the funding necessary to correct the erosion will be forthcoming. If any corrective action is taken, the funding is derived from the individual O&M budgets. Occasionally, negative publicity can stop a construction project.

Tax base loss

Where lots have been lost to tax rolls, there is a decrease in the taxable land. However, due to the rise in land values attributable to construction of the reservoir, the validity of this impact was questioned.

Mineral rights

In some cases, landowners have pushed for access to deeded mineral rights even after the land has become submerged. The search for minerals in an aquatic environment has the potential to generate numerous adverse impacts to the aquatic ecology of any reservoir.

Forced land acquisition

Under some circumstances, the solution to severe erosion problems has been land acquisition. Besides the direct loss of private property, land acquisition may be required to maintain public access or buffer zones. The Corps has developed such access guidelines; however, the cost for new land acquisition surrounding an existing reservoir is generally high because of inflated land prices of the surrounding shoreline. Any litigation activities can greatly increase the "true" acquisition cost. The cost for the land acquisition comes from the O & M Budgets of the individual projects, and not from a higher level of funding.

Installation of erosion corrective measures

Certain project elements, facilities, and infrastructures must be protected from shoreline erosion and require the installation of shoreline protection as part of the initial construction or as subsequent "fixes." The installation of "fixes" at other noncritical locations is at the discretion of project management.

In most cases, the installation of a fix is more economical and practical than the abandonment or relocation of a facility or of infrastructure. The relocation of any facility is difficult and expensive with the "true" cost including funding to provide full access to the new facility—new roads, new parking areas, etc. Where recreation facilities have been established, there is strong public pressure to maintain the facilities in those same locations. Abandonment of recreational facilities is politically difficult as many local economies are largely dependent on the recreational resources provided by reservoir systems.

Infrastructure protection or replacement

Shoreline erosion, particularly tailwater events, may require either the protection of existing infrastructure or in extreme cases the replacement of existing bridge, roads and utility line or crossings. Funding for such projects is derived from existing O&M budgets.

Sediment deposition

Sediment loading from shoreline erosion contributes to the overall sediment load in the water column. Under certain circumstances, the depositional patterns of sediments can block access to recreational facilities such as boat ramps and marinas. Funding to remove these sediments may either be public or private.

Some concern as to the impact of sediment loading on hydropower generation and turbine wear was expressed.

Loss of farmland, crops, and timber

No monetary estimates of these impacts are available on a national basis, but the consensus is that the loss is in the millions of dollars per year.

Reservoir capacity loss

The impact of shoreline erosion on reducing the overall reservoir storage capacity and project life is likely of greatest importance in a small reservoir system. Because of the likelihood that a significant proportion of the sediment will be deposited in the storage pool, the operational flood storage capacity may not remain the same.

Decrease in forecasting capabilities

A concern was voiced that shoreline erosion coupled with sedimentation events decreases forecasting capabilities and the accuracy of flood storage calculations. As sedimentation is constantly occurring in the basins, most reservoir managers do not possess accurate topographic mapping on which to make forecasting calculations.

Public safety

Unstable shorelines with high steep bluffs can pose public safety concerns. Unauthorized excavations into these slopes, especially digging for archaeological artifacts, is not uncommon. Undercutting of slopes can be a danger to people, livestock, vehicles, and any facility located above the undercut. Falls have occurred and facilities such as campsites have been quickly lost. Timber wash and debris from the eroding shoreline pose a hazard to recreational boating.

Visual/aesthetic impacts

There is a public perception and expectation of what constitutes an "appropriate" shoreline landscape. Brochures describing recreation uses of specific reservoirs illustrate the high pool condition with stable shorelines. Managers are frequently chastised for "allowing" low pool conditions or for "permitting" unsightly shoreline erosion to occur. Although there can be pressure on the project management to comply with the public perception of "appropriateness," the consensus of the workshop was that stable bare banks should not be viewed as a problem.

Water quality degradation

Soil erosion from the surrounding shoreline will contribute to the overall sediment load in the water column and the water's turbidity. Turbidity levels are generally greatest during the low pool condition when there are wide expanses of bare soil. Water quality degradation adversely affects the fishery resources, species composition, and fishery reproduction. Highly turbid waters decrease the recreational attractiveness.

Several members of the workshop cited other vectors derived from shoreline erosion processes that would lead to a degradation of water quality including increased nutrient loadings, pesticide transfer, and pollutant releases.

Wetlands

Erosion processes can lead either to degradation of existing wetlands through soil removal or burial, or these same processes can lead to the creation of new wetlands.

Habitat loss and wildlife impacts

Erosion events can lead to shoreline loss, slope failure, and a complete loss of beach and upland habitats. Shoreline erosion of avian nesting islands, especially those supporting waterfowl and shorebirds, was cited as a major impact occurring in some reservoir systems. These island habitats generally support few predators and breeding success is many times higher than on mainland shorelines. The loss of shoreline trees that support cavity nesting by wood ducks was cited as an impact.

Fishery resources

Where erosion events and currents are generating uniform lake bottom topography without features, there is the potential for severe degradation of the fishery habitat. One biologist described such conditions as desertlike. Clearly, the fishery resource and species diversity are strongly influenced by management practices. Low pool conditions result in increased turbidity and when combined with low oxygen conditions are especially stressful to many fish species.

Rare and endangered species

For rare and endangered species, the chief concern expressed centered on maintaining the present species diversity in tailwater streams, particularly those supporting rare and endangered mollusks. The loss of shoreline nesting sites for endangered raptors was also cited as a potential impact.

Aquatic weeds

In some reservoir systems, the shallow waters at erosion sites are ideal for the colonization of nuisance aquatics. These nuisance aquatics generate recreational management problems and can adversely affect the aquatic ecology and aquatic species diversity.

Riparian habitat loss

Erosion impacts in tailwater ecosystems can cause considerable loss of riparian habitats. These riparian habitats support a wide array of wildlife and have the real potential to support rare and endangered species. Loss of marketable timber was also cited as an impact.

Impact of fixes

Hard fixes may be viewed as eyesores, can restrict public access, and may result in permanent loss of desirable habitats including beaches. Certain hard fixes can result in the creation of undesirable habitats that can support high rodent populations. Other hard fixes can create favorable habitat including important fishery, benthos, and aquatic habitats. Vegetative fixes will increase habitat values. Occasionally fixes fail and must be re-engineered. Cultural resources are particularly sensitive to poorly engineered fixes. Several managers emphasized that once you buy into a riprap fix, some periodic maintenance of the riprap will be required.

Habitat improvement

Shoreline erosion can result in the creation or the improvement of certain habitats. The steep bare banks offer excellent swallow denning areas and turtle nesting sites, dead trees may provide nesting cavities, and the submerged fallen trees improve the fishery habitat. In many cases, shoreline erosion results in beach creation and sandbar habitat which provides valuable resting and foraging areas, especially for shorebirds during high pool conditions.

Dredging

Several managers indicated that sediment loadings derived from reservoir shoreline erosion may increase dredging requirements for tailwater navigation channels and boating facilities.

Table 1
Summary of Effects Discussed During Working Group Sessions

EFFECTS ON RESOURCES
- NATURAL RESOURCES
  - Wetland Areas
  - Critical Habitat - on shore and off shore (Flora and Fauna)
  - Loss of Biodiversity
  - Endangered Species
- CULTURAL RESOURCES
  - Archaeological Sites
  - Historical Sites, including Cemeteries
  - Native American Interests
- EARTH RESOURCES
  - Scientifically - Important Geology/Geomorphology
  - Mineral Rights

PROJECT-RELATED EFFECTS (i.e. Operations)
- SEDIMENTATION
- WATER QUALITY - Turbidity
- AIR QUALITY
- BOUNDARY CONTROL AND LAND ACQUISITION
- LOSS OF STRUCTURES
- TRANSPORTATION EFFECTS - Features, Access, Circulation Visual/Aesthetic
- PUBLIC SAFETY - Banks, Turbidity, Debris (floating and stumps)
- NAVIGATION - Dredging
- POLITICAL IMPACTS ON PROJECT OPERATION
- RESERVOIR CAPACITY (Flood Control vs Conservation Pool)
- RESERVOIR LONGEVITY (Life)
- RECREATION - Loss of Visitor Use Days - less Revenue
- HTW
- DOWNSTREAM
- RE-ALLOCATION OF MANPOWER AND DOLLARS

OFF PROJECT EFFECTS
- IMPACTS ON THE PUBLIC
  - Public Perceptions of Agency
  - Loss of Private Land
  - Changes in Land Values
  - Change in Local Tax Base
  - Change in Community Economic Potential

POSITIVE EFFECTS
- CREATION OF NATURAL BEACHES, WETLANDS, SHORELINE HABITAT, TREE FALL DOES CREATE GOOD FISH HABITAT
- SCIENTIFIC - Exposure of Data
  - Archaeology
  - Geology/Soils
  - Paleontology
- WORKSHOPS/EMPLOYMENT (Government and Contractors)

NEGATIVE EFFECTS OF THE FIXES
- RIPRAP - Safety, Visual, Boat Landings, Habitat for Undesirable Animals
- Public Perceptions - Failures
- Public Access can be restricted
- Sometimes sends erosion elsewhere
- Maintenance

SUMMARY REPORT OF WORKING GROUP ON FIXES FOR SHORELINE EROSION

The working group on "Fixes" was charged to focus on innovative fixes that would include environmentally compatible methods, i.e., tiered gabions, groins in combination with vegetative plantings, pole/terrace combinations, breakwater and vegetation combinations, berm and vegetation combinations, etc. Discussions included types of methods, experience and plans, advantages and disadvantages, successes and failures, and needs for data and research.

Inasmuch as the presentations at the plenary session of the Workshop and the observed fixes on the field trip covered a vast number of traditional and new fixes, each of this group's sessions generally started slowly with the expression and discussion of general considerations rather than specific fixes. General considerations which were consistently mentioned were:

- *The type of treatment (fix) should be relative to what is to be accomplished and the erosion situation at that particular time.* Is the fix to be permanent or temporary? Is it to restore the shoreline to previous conditions or is it to maintain or stabilize present condition? Does it have to consider special emphasis, such as archaeology sites?

- *Most fixes are site specific, thus it is important to understand each site's characteristics.* What are the forcing functions: waves, flow, etc..., realizing that all the deterioration factors mentioned by the plenary session presenters on causes are or can be important? Physical site conditions mentioned were soil type, bank and offshore slopes, water depth, effective fetch, wind magnitude and direction, sedimentation process, local currents, overland flow, and water level changes.

- *Open communication/coordination/participation at all levels of the project is very important.* Everyone from financing, permitting, and scheduling to operation and maintenance needs to be informed because each area of concern has an effect on the project. Also, a better understanding of the whole project by all involved deters resistance. Communication means not only informing people of what is going on, but educating them as to the why and why nots of the project.

- *Legal liabilities.* Some participants were concerned about the legal aspects of using volunteer labor and/or whether to post or not post warning signs.

- *Better coordination among agencies on long-term approaches (fixes).* Since specific long-term fixes may affect, or overlap into, the responsibilities of several agencies, all of them should be asked to participate or at least be kept informed of proposed actions.

- *Mindset of higher authorities to new and innovative concepts and ideas.* Some people were concerned that maybe there should be a policy change or special programs set up to make the trying of new concepts easier or at least reduce the "red tape" involved. Others were concerned that there was too much planning and not enough action when innovative fixes were proposed.

- *Recreational access.* Some fixes cut off public access from the landside whereas others limit access from the water. These should be considered at the beginning of the project and appropriate provisions made, depending on the purpose of the project.

- *Water conservation versus vegetative transpiration.* In some cases, especially Bureau of Reclamation reservoirs where water usage is critical, plants may take up water needed for other purposes.

Specific fix discussions and descriptions were often mixed with general considerations and were compiled into classification of fixes, such as location (land, interface, and water) and type (hard, soft, and combined). Nonmaterial fixes such as changing operation procedures and buying of the land were also discussed. A listing of specific fixes is given in Table 1 (no priorities). Needs for data, research, and monitoring of field sites and needs met by the Workshop were discussed and are summarized in Table 2.

Table 1
Reservoir Shoreline Erosion Fixes

Traditional and Structural Fixes
Riprap, small and large, with mineral and geotextile filters
Hand-fitted stone
Articulated concrete blocks
Terraced rock
Riprapped low berm
Soil cement
Other revetment
Bank grading
Beach fill
Sandbags with geotextile filter
Wave berm
Bulkheads: piling, fence with bags, cribwalls
Fixed breakwater
Rubble-mound breakwater
Floating breakwaters
Some combinations of traditional and biotechnical
Other Hard Fixes
Tire mattresses
Tire revetment with silt
Gabions with geotextile filter
Gabion rock mat with soil and vegetation
Geogrid
Gunite with planting gaps
Soil cement with planting gaps
Interlocking concrete blocks
Cement bags with rebar and geotextile filter
Fabri-form
Miscellaneous surplus materials
Cabled log slope protection
Post and tire breakwater
Post and fence breakwater
Fence with rockfill
Wisconsin "lunker"
Slotted concrete with top plantings
Concrete box with top plantings
Gabion breakwater and groin
Geotubes
Rock jetty
Floating log breakwater
Floating tire breakwater
Floating islands
Biotechnical Fixes
Tall trees on terrace to protect high banks
Reforestation belts
Coconut fiber carpet
Brush matting
Imported fill soil for plant medium

Table 1
(Continued)

Brush trench
Wattling
Brush dike
Hay bales
Coconut fiber fascines
German inclosed branch box
Plant plugs
Plant rolls with herbaceous plantings
Live stakes and poles (deep set)
Dormant season planting
Hydroseeding
Herbaceous plants
Sedges
Grasses
Woody plants
Willow
Alder
Bald cypress (extreme water tolerance)
Nonmaterial Alternatives
Reservoir construction clearing practices
Operational changes (pool level schedules)
Acquire threatened land

Table 2
Reservoir Shoreline Erosion Program

Needs:

- Monitoring
- Technology transfer
- Transportable floating breakwater
- Life expectancy of components; functional life of fixes
- Risk assessment methodology applied to shoreline erosion fixes
- Plant materials research for flood tolerant species (Federal and private sources)
- Mooring forces for breakwater in shallow water and anchors
- Energy environment in reservoirs

Data Gaps:

- Native or acceptable planting list for district or region
- Soil-sensitivity of planting species
- Plant handling and storage techniques
- Planting methods/depths
- Propagation techniques
- Legal liability of unprotected bank and fixes

Needs Met:

- Availability of:
  - Small-diameter, round hay baler (Ford-New Holland)
  - "Spider" - articulated backhoe
  - Portable hydraulic stake driver made in Sweden
- Tulsa District provided sites for focused discussions

CLOSING PLENARY SESSION

The Closing Plenary Session consisted of acknowledgements by Mr. Hollis Allen (Workshop Coordinator), Working Group summary reports by various WES facilitators, and closing comments. The acknowledgements and closing comments were reproduced from tape recordings and are presented below. The tape recording of the summary reports was referred to in preparing the Working Group Summary Reports contained in the previous section. As such, the summary reports presented at the Workshop were not reproduced for these proceedings.

Acknowledgements

I started this endeavor about a year or so ago and I think we would all have to agree that we got a lot out of this conference, at least I did. We owe that to Pete [Juhle] and Lewis Decell. Let's give Pete and Lewis a big hand.

I would also like to take this time before we bring this meeting to a close to thank those that have had a big hand in this workshop because without these folks this workshop would not have been possible. I would like to thank, first, those who helped us host this workshop. I think we all have to agree that we have a good laboratory right here at Lake Eufaula with so many different bank situations and so many different fixes. I think its incredible that they've tried to do so many different things. I would like to thank Loren Mason and his staff in the Natural Resources Branch. I would like to thank Everett Laney who works with Loren who helped set up the logistics and the vans and everything. I would like to thank Burl Ragland of the Tulsa District Engineering Division who got this field trip organized. I would like to thank John Brigham and his staff. I'd like to thank all those WES facilitators who worked so late last night getting the notes together and that includes Dr. Yen-hsi Chu, Mark Graves, Jim Leech, David Abraham, D.D. Davidson, Bob Larson, Buck Taylor, Randy Oswalt, and Paul Nickens. I think you all have met those folk at the various sessions yesterday and you will hear from some of them just shortly.

And last, and certainly not least, are those folks on my team that helped us, John Tingle, Alfonso Vasquez, and Cherry Cox. Cherry worked very late last night on the summary slides and we appreciate that, Cherry. Without these folks, this workshop would not have been possible. And of course, Louis Berger's folks, who led the session yesterday with facilitation and we certainly appreciate those — Larry Pesesky and his team. So I hope I haven't left anybody out. There is always a risk of leaving somebody out and my apologies if I did that, but there seems there are many folks behind the scenes. And so I along with Pete and Lewis, I'm sure, appreciate all that support.

Well, without further ado, today's a reference session that will recap the issues and things we've seen on the field trips and in the session yesterday. From my observations, everybody was busy going at it yesterday; everywhere I went everybody was busy and into it and seemed to be enjoying themselves. So we're going to hear from the WES facilitators today and we're going to try and give you a summary of what was said in their sessions.

Closing Comments

MR. ALLEN: The common themes I have been hearing here are more interagency cooperation, more communication up and down the ladder, more public involvement. I think it would be important if we would have workshops of this nature in the future to possibly bring in some private groups like the American Sport Fisheries Institute, representatives of Bass Unlimited, etc. just to get some of these grassroots organizations that want to correct shoreline erosion involved. Also, let us get our public affairs people more involved in this. Let's get the word out to the public. In retrospect I thought of having TV coverage down here; that probably would have been a good idea. Loren and I talked just a few minutes ago of having something put out through the public affairs people of the Tulsa District in the newspapers and such. So we do need to spread the word.

MR. GOOD: As one of the few state agency people here, hearing so many times the idea of communicating, I just want to share with you the names of some of the organizations we work with and have learned from just as I have learned from people who I have met here. I have learned more about the Corps and the TVA. I know the TVA people know how to play poker. I had to come to McAlester, Oklahoma, to meet my Corps person from Illinois. These Conferences are great. There are three things I want to share with you. A lot of states have State Lake Associations that you can get information from. Most of those lake associations belong to an organization called the North American Lake Management Society. I learned more about large reservoirs here than I ever thought I would. I quite frankly didn't know how we could talk about shoreline erosion for three days.

MR. SKEESICK: I think a number of you have a number of personnel who in the future will be doing more of this kind of work that we have been talking about this past week. I would challenge you to identify those people who are the more technically oriented people, and that they get a chance to participate in the week-long workshop that Hollis and his folks are talking about putting on in the spring. I think that that's a very helpful thing that you can take back, that you get to utilize on your home turf, as well. There was a gentleman from Illinois who spoke here, it's fun for me to get back here and see what a real lake looks like. I am amazed to think that if you take all the lakes I have got you can put them in one bay at Eufaula and still have room for all the houseboats. So Hollis, I really have to congratulate you folks, you have put on a workshop that has been organized to the ultimate. In fact, there has not been any little thing that you have left unattended, so I congratulate and thank you very much for inviting me.

MR. DELUCCHI: I might add something to what these other two folks said. Coming from other agencies and having you folks from the Corps of Engineers share your expertise with us is very appreciated. So at great expense I have prepared this trophy. It's called the Hollis Allen Award for 1992. It is for Interagency Exchange and Cooperation, and I would like to present that to Hollis. You should have it for about a month and then pass it around WES so that everybody gets a chance to use it, because I think that WES has had a great part in providing technical expertise. I would like to add, too, that if you have not been in contact with our plant material centers you are missing some good information and some good plant materials, oftentimes, free. Also, if you are not working with some of the Soil Conservation Commissions and Districts, they can take care of a lot of the off-site things for you so that you won't be getting a lot of that sediment into your reservoir. Thank you very much for giving me the opportunity for meeting you folks and sharing with you.

MR. ALLEN: I would like to recognize Mr. Larry Gatto from our Cold Regions Research Engineering Laboratory. He also has done a lot of work on ice and frozen soil problems with reservoir erosion and I hope I have pointed out that this week. That's why Larry is here to share his expertise.

MR. GATTO: We have heard several people already say it, but I think it is important before we depart that something solid be done regarding what do we do next year regarding bringing everybody together again, maybe not for a four-day workshop but for a one-day workshop and continue this interagency cooperation and involvement. Because if we walk away from here and nothing is solved and is in place, it is very likely that this has all just been talk. As a group, let's agree upon where the next meeting will be, who the next chairman will be. It should not always fall upon WES. It should be a shared responsibility. I think that's important that we as a group agree that there will be a somewhat shorter one, if that's appropriate, but there will be one somewhere and that there will be a chairman who will volunteer, or whatever. I don't think it is appropriate for a nonoperating outfit to be a chairman for the future ones because that's where the problems are, in the operating elements. But if no one volunteers, I would be willing to put on something. New England is a bit out of the way; it's not centrally located. So for many reasons, I don't think New England is the best spot. But if no one else volunteers, I would be willing to do it, because I think it is that important.

MR. ALLEN: I think it is timely that question was brought up, because I think a lot of people have anticipated it. For instance, under the WOTS program, I asked Pete [Juhle] if he thought we should have another one of these. Pete definitely thinks there needs to be another workshop like this and he is willing to sponsor it. He said, all you have to do is come to us and we will be willing to sponsor it under the WOTS program. That may be a vehicle, or like you say Larry, maybe another agency would be willing to do that.

MR. GREEN: I think that the Bureau had indicated that they would sponsor one in Pocatello to look at the American Falls work that we have done. I can see that after being here this week, that we can't exclude these other agencies. State agencies and other agencies have got a lot of input. I think if we do have this workshop next spring, I will tentatively volunteer until I can sum it up with our project people. I think that would be a good location. We can co-sponsor it with the Soil Conservation Service since we do have that plant material center right close. We can show some of the work that the Soil Conservation Service has been doing in our area, and maybe we can have representatives from some of the other plant material centers and they can show some of this in their particular locale, like the Southwest and the Southeast. Tentatively we will try to set something up.

MR. ALLEN: You all have heard of other workshops that we have had in the past. They have been more tutorial in nature actually, where we do get into causes of the problem and so on, and then some traditional engineering fixes and then we spend the last couple of days focusing on biotechnical fixes. There is one coming up next spring that WES has mentioned here that will primarily be in cooperation with the Bureau of Reclamation because they are willing to put up half the bucks, but that's not to exclude other agencies. We traditionally include other agencies in those kinds of workshop. I have to confess, it has been primarily on a space available basis. This workshop has taken on a bigger scope in terms of the overall magnitude of the problem, causes, effects, fixes, etc. and involves everybody from natural resource people, archaeologists, engineers, ecologists, everybody. You can see it's everybody's problem. There may be two kinds of workshops here. There may be a tutorial that you have been thinking of Wes, or there may be this kind of workshop and I think that's what Pete is referring to. What's the feeling of the group? Do you think an annual workshop of this nature needs to be conducted, or maybe every other year or longer? Any discussions on that? Larry feels annually.

MR. GATTO: Moving it around, Hollis, would be beneficial.

MR. ALLEN: That's what we have done with our tutorial. At workshops we have gone to different regions. The next one will be in the inter-mountain region. Either in Wyoming or Idaho. I don't think that has been pinned down yet. There are specific needs in specific regions that require different plans, different fixes, etc.

MR. SKEESICK: I think all of us have concluded at one time or another during this workshop that we need more support from our highest levels. In other words, primarily Washington, D.C. I would think that at some point or another, we need to consider having one of these workshops very near Washington, D.C. because those folks have a great deal of things tugging on them. Having to fly across the nation for a couple of hours or even a day is a bit of a drag on them. I would guess that at some point in time we could actually have one of the installations fairly near Washington, D.C. where we can get some of those senior folks from back there out for a day or so to see what we are up to. I believe very strongly in visualization, and even though your Colonel was here, he didn't see anything; he heard, but he didn't see anything. I believe that if we could show them something on one of the reservoirs on the East Coast, we can pick up a lot of support for what we are doing.

MR. ALLEN: Many of you don't know this, there was another concurrent conference going on within the Southwestern Division which required the attendance of all the Project Managers in the Southwestern Division. Colonel Williams was at that conference, as well. That conference also went around this lake and observed these fixes that we observed. Colonel Williams, I am sure, did go on that tour. He has also requested a follow-up briefing by his staff on this conference. So, it indeed does attract his attention and, of course, he works for the Chief of Engineers and I am sure that he will be talking to him about this. So it will get some higher level visibility, but your point is well taken. There are some reservoirs in the East close to Washington that may lend themselves to this kind of workshop.

MR. WACHSMUTH: I would like to thank you for getting me out here from out West. I really appreciate it. This is my second time to McAlester and I really learned a lot. Something we touched on at one of the workshops yesterday is this: WES putting together a quarterly newsletter, regarding erosion control problems. We could write to WES and you could mail out a quarterly newsletter to folks that are interested in it so that we could find out what is going on around the country, such as problems encountered and successes for controlling erosion.

MR. ALLEN: That may be a possibility. The WOTS program does have an information transfer bulletin and I will take that comment back and we will see; I can't commit to that obviously, if not quarterly, at least some periodical update would be appropriate.

MR. DUNNE: As far as soft fixes are concerned, I think there is a real need for those soft fixes to have construction details generated, specifications generated, and material specifications generated. A lot of things are being disseminated word of mouth; there is very little paper trail, and it's very hard to bid. If you are doing construction plans without materials specs, some of the things you are using, you can't bid them. The coconut fiber-rolls: I don't think there is a material spec for that product in the country right now. I couldn't put in a construction plan because there is no material spec for that and there is no paper trail. Maybe there should be a compilation of the techniques that are used in the soft engineering.

MR. ALLEN: I think there is a gap there between the research and the actual construction part of it. I know Bestmann has material specifications; they have those in Germany, I assure you of that. Some of these specs are really not specs. They are more general guidelines and need to be put into more detail specs.

QUESTION: How many years do you think there will be before there is a green version of the Shore Protection Manual?

MR. ALLEN: Boy, that's a tough question. Anybody from CERC want to answer that?

COMMENT: I think before the year 2000. I see it coming just like in Germany where there is required green along streambanks and reservoir shorelines. I think that is something that will go along side by side with the blue version.

MR. DELUCCHI: The Soil Conservation Service is putting an effort on this fix approach, too, so maybe we can work closely together. There is information we can share with you to speed up the process of getting this information out in the field. We are in the process of putting together chapters specifically on this in our engineering manual.

MR. ALLEN: We at WES have or are doing some work with the SCS on some of these reservoir shoreline plantings with their plant material centers. I think what you are alluding to are the wetlands guidelines or the wetlands engineering manuals.

MR. DELUCCHI: I think it's Chapter 13 of our engineering manual. Someone then added, I think Hollis said some kind of performance standards need to be passed out. A lot is known about these fixes but people in the field don't have a lot of confidence in knowing when to use a particular fix at a particular site. I think that needs to be worked on.

MR. ALLEN: I think that's a research or data gap. Unless any of you have anything else, I would like to again convey my gratitude to all of you for coming here and showing the enthusiasm you have demonstrated here this week. I really think that your attendance is a tribute to you as really good land resource managers, planners, and stewards of our land and our water resources. I applaud you and thank you!!

APPENDIX A
DOCUMENTATION OF EROSION CONTROL PROGRAM ON EUFAULA LAKE, OK

DOCUMENTATION OF EROSION CONTROL PROGRAM ON EUFAULA LAKE, OK

BURL D. RAGLAND[1]

[1] TULSA DISTRICT, CORPS OF ENGINEERS.

I. Background

Shoreline erosion has been and is a problem of many Corps lakes. Conservative real estate policies in place when a large segment of the lake was constructed, coupled with the erosion of the shoreline, has led to erosion beyond the Government property line and onto private property. In some instances, this erosion has threatened residents and the damaged property (a second taking) has had to be purchased. Such is the case at Eufaula Lake which is located in Eastern Oklahoma. This large lake has some 660+ miles of shoreline of which 50+ miles are eroding. Of this, some 22 miles of shoreline is serious enough to need protection or some type of stabilization.

The information provided herein is intended to make a record of the efforts expended at Eufaula in order to evaluate various erosion control techniques that have been or are being tested. The purpose of these test sections is to determine the most economical erosion control method for different conditions. Additional information concerning these tests can be obtained from Mr. Burl Ragland, CESWT-EC-TO (918-581-6641), Mr. John Brigham, CESWT-OE (918-799-5843), or Mr. Kevin Weber, CESWT-EC-TO (918-581-6641).

II. Initial Efforts

Under our O&M program, we were able to execute a pilot project in 1986. Five areas were studied and a structural solution was determined necessary in two of these areas—Southport and Beavers Lodge. We expended approximately $400,000 to stabilize approximately one-half mile of shoreline where public property was endangered. The specifics of each step is covered below.

1. Beavers Lodge

The location of Beavers Lodge is shown in enclosure 1. The specifics for the construction project follow:

Length = ±420 ft
Top el = 597.0 ft msl
Bottom el = ±585 ft msl
Protection: 18-in. riprap on 6-in. bedding on filter cloth with 15-ft-wide rock toe
Cost: $82,402 (excludes E&D and S&A) ($196 per foot)

Since completion, the owner of the private property has established a very good stand of grass above the riprap section. No significant problems have occurred at this site.

2. Southport

The location of Southport is shown in enclosure 1. The specifics for the construction project follow:

Length = ±970 ft
Top el = 597.0 ft msl
Bottom el = ±585 ft msl
Protection: 27-in. riprap on 9-in. bedding on filter cloth with 15-ft-wide toe to el 589
Cost: $243,000 (excludes E&D and S&A) ($253 per foot)

This project has two significant problems. First, the surface runoff in the initial design was allowed to run down the slope over the mulched and seeded surface. Very large eroded areas occurred which required regrading a segment of the slope and adding bermuda mulch sod. Had the surface water been controlled, this may have been avoided.

The second problem occurred at the west end of the riprap section. Here, wave action eroded the slope for some 140 ft. This led to a follow-up fix which is part of Section IV of this report.

III. Lake Survey

In 1989 a survey was made of the entire lake. In preparation for that survey, a series of potential shoreline erosion "fixes" were developed to aid in selecting the right fix for the lake conditions. The nine potential fixes together with estimated cost are included as enclosure 2.

The survey identified some 22+ miles of the shoreline needed to be protected or stabilized. The estimated cost to perform this work was $10.2 million. The survey was developed into a decision document and submitted through higher authority requesting approval to proceed with this project. After evaluating this document for approximately one year, approval was withheld and guidance was to address each area as problems developed.

IV. Test Sites

One of the outcomes from the survey of the entire lake was the need to test some of the low-cost fixes designed/selected for Lake Eufaula. The section that seemed to hold the most promise was the fix No. 6 or "Brooks Fix" which was named after the civil engineer who developed the series of fixes. This fix used a 4- to 5-ft-high rock dike with a bottom el of ±585 (conservation pool) which would form a foothold for the high, steep slopes. Willows would be added behind the rock dike to let the vegetation complete the stabilization process.

Several different erosion control methods have been tested. A brief discussion of each is provided below.

1. Southport Extension

As a result of the continued erosion at the west end of the original Southport site, an additional ±140 ft of riprap was added to that end. The riprap was purchased, equipment was rented, and personnel from the Eufaula Resident office placed the riprap and bedding.

An unexpected windfall from this process was an excess of 27-in. riprap. A decision was made by the project manager to stockpile this material at the base of the adjacent eroded area to provide a test section for fix No. 6. The specifics for this construction follow:

Length = ±140 ft
Top el = 597.0 ft msl
Bottom el = ±585 ft msl
Protection: 27-in. riprap on 9-in. bedding with 15-ft-wide toe to el ±589. (No filter cloth)
Cost: See next section for combined cost of this as Southport Test Section.

Recent high lake levels have caused some additional erosion on the west end of this extension. This highlights the need to use stepdown erosion control at end of project until protection is no longer required. (One of the conclusions from the survey work on the lake was the need to have about 100 ft of vegetative plantings at each end of riprap sections to control minor erosion that plague all riprap projects.)

2. Southport Test Section

This is the most important test section currently being evaluated on Lake Eufaula. This low-cost, no-maintenance erosion-control method combines the traditional and environmental esthetic methods to allow the bank to stabilize on its natural slope. The 4-ft-high rock dike provides protection from waves for about 80% of the time which allows the vegetation behind the dike to grow. As the high banks fail and develop their natural angle of repose, soil fills in behind the rock dike.

To date, this been subjected to several floods and the section appears to be stabilizing. The specifics for this site follow:

Length = ±300 ft
Height = 4 to 5 ft
Bottom el = ±485 ft msl
Top width = 8 to 10 ft
Size riprap = 27 in. (excess from Southport Extension)
Bedding: 6 to 9 in. placed on sand beach (Riprap was dumped on top. Bedding served as roadbed for riprap placement.)
Cost: $37,400 for this plus Southport Extension. (Estimated cost for this by contract is $60/ft).

3. Sandy Bass Bay

The location of Sandy Bass Bay is shown in enclosure 1. This area was chosen as a test site to protect a 200-yr-old Indian burial site being damaged by erosion. A section similar to that of the Southport Test Section was chosen. This work was performed by Purchase Order. The section ultimately developed into one with two dike heights. The 4- to 5-ft segment extends in front of the burial site while a 2-ft segment extended from the beach out to the start of the higher dike. Therefore, this site is being evaluated to determine the difference in protection between the 2-ft- and 4-ft-high dikes.

The WES Reservoir Shoreline Erosion Control and Revegetation Workshop (Hollis H. Allen) was held at Lake Eufaula in 1990 and this area was chosen as the workshop site. (See section V.) The specifics for this site follow:

Length = ±100 of ±2 and ±100 of ±4 ft
Height = ±2 and ±4 ft
Bottom el = -55 msl
Top width = ±10 ft
Rock: 2 ft of bedding placed in lake with 27-in. riprap placed on top.
Cost: Approx $10,000

4. Rolling Oaks

The location of this project is shown in enclosure 1. This area was also chosen as a test site to protect an archeological site that was being damaged by erosion. This is a sandy area adjacent to a very popular beach area that receives heavy public use. The test section selected for this test site consisted of a rock dike up top up to approx el ±589 with telephone poles anchored to provide wave protection for another 3 to 4 ft above the top of rock dike on the slope of the bank. This work was accomplished by Purchase Order early in 1992. The specifics of the project include:

Length of rock dike = ±310 ft
Approx length of telephone poles = 4 rows of 120 ft
Rock dike:
    Bottom el = ±585 ft msl
    Top el = ±589 ft msl
Rock size: 270-in. riprap on crushed rock
Cost: $24,000

This project has experienced damage when the lake level exceeded el 489 in the summer of 1992. Some of the anchor cables loosened when the waves hit them allowing for some movement and minor erosion. More emphasis needs to be placed in getting anchors to directly pull down on the logs before they will work beneficially. Also, need to specify soil fill with more binder (medium clay) in future jobs.

5. Blue Kenokee Bay

The location of this project is shown in enclosure 1. This area was chosen as a test site to evaluate the impact of a rock dike extending out into the lake. This point is on the west side of a bay that had in the past been protected from wave action by a point that now has mostly been eroded away. The dike extends from the existing eroded vertical bluff about 100 ft into the lake in a southeasterly direction. This section ends in about 5 ft of water. Section 404 permit was obtained for this test site. The specifics for the site follow:

Length: 150 ft
Height: 5 to 8 ft
Width: 10 ft (top width)
Rock: 27-in. riprap on 6-in. of crushed stone
Cost: $19,300 (Purchase Order)

This site is working extremely well. In the first 6 months after completion sand has filled in and created a nice beach below the conservation pool plus built up sand up to and overtopping the rock above the conservation pool. If resources were available to start vegetation in this area, the improvement would continue.

6. Ogden Cove

The location of Ogden Cove is shown in enclosure 1. This area was chosen to complement the Blue Kenokee Bay site. This point would and does represent the opposite point that protects inland bays. The dike extends southwest from the eroded point about 100 ft into the lake. The prevailing wind hits this dike almost head-on. The preconstruction expectations for this site were low. The site may function much better during the winter periods when the wind is not out of the southwest. The specifics of the site follow:

Length = 150 ft
Height = 5 to 8 ft
Top el = 588 ft msl
Top width = 10 ft
Rock: 27-in. riprap on 6 in. of crushed stone
Cost: $18,400

Since completion, this site has experienced some erosion at the bluff. Additional crushed stone and riprap should have been used to blanket this tie-in point since wave action is hitting this dike almost head-on.

V. WES Training Projects

WES has held two Reservoir Shoreline Erosion Control and Revegetation Training Workshops on Eufaula Lake. A brief discussion of these two sites is presented below.

1. Sandy Bass Bay

The WES Workshop was held at this site in 1990. The workshop was held just before the rock dike was installed at this site to protect the archeological site.

Most of the plants at this site were destroyed by vandals. The few remaining plants are surviving and multiplying. For example, one bulrush plant was found in 1991 and was doing well. This summer (1992) that plant had multiplied until there were about 50 plants in that area. (Think what might have been without vandalism.)

2. Oak Ridge Point

The 1991 WES Workshop was held at Oak Ridge Point (see enclosure 1 for location). Switch grass, bulrush, and willows were planted at this site. Also, a coconut fiber roll was used as a water break and a planting medium. The most significant single finding from this effort is the protection provided by a willow mat that was placed on an eroding bank. The lake has been very high for most of 1992 and the bank just past the protection has eroded back several feet. The segment with the willow mat has only minor erosion. This protection and results are significant.

VI. WES Projects

The WES, represented by Mr. Hollis Allen, selected Lake Eufaula to test two methods of controlling erosion currently being used in Germany. Funds and basic requirements for these test sections were provided to the Tulsa District who developed the plans and specifications and awarded a Purchase Order contract to construct the projects.

1. Au-Du-Pah, Site No. 1 (Coconut Fiber Rolls)

This site was selected by WES (Hollis Allen) to construct a water break consisting of stacking three coconut fiber rolls between 4-in. posts. For this test, 1-ft-high gabions were placed in front of the water break to ensure that the water break would be stable.

Behind the water break, plants that can live in water and out of water were selected and planted. The intent is to develop a wetland that would fill in and provide the "toe" or stable point in order to stabilize the slope.

The construction is underway at the time this report is being drafted. Specific data follow:

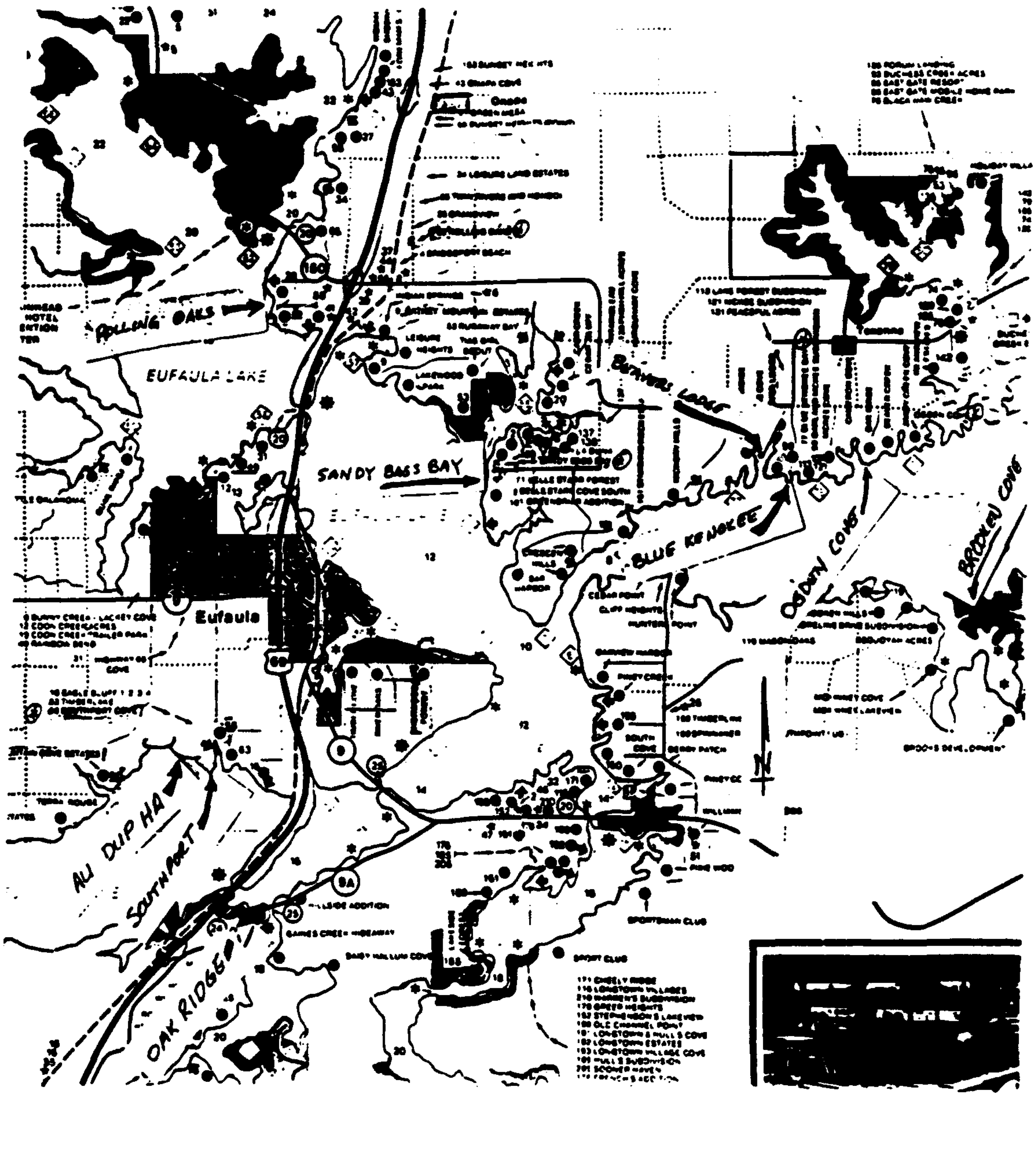
Length = 120 ft (coconut fiber roll) + 42 (additional) ft of gabions
Height = 2 ft
Materials: 3 coconut fiber rolls (2 on bottom and 1 on top), 4-in. treated wood post, galvanized wire, and coconut fiber mat under roll
Plantings: Several (cattails, bulrush, etc.) plus two 50-ft-long by 5-ft-wide preplanted coconut fiber mats behind breakwater

2. Au-Du-Pah, Site No. 2 (Dead Limb Test)

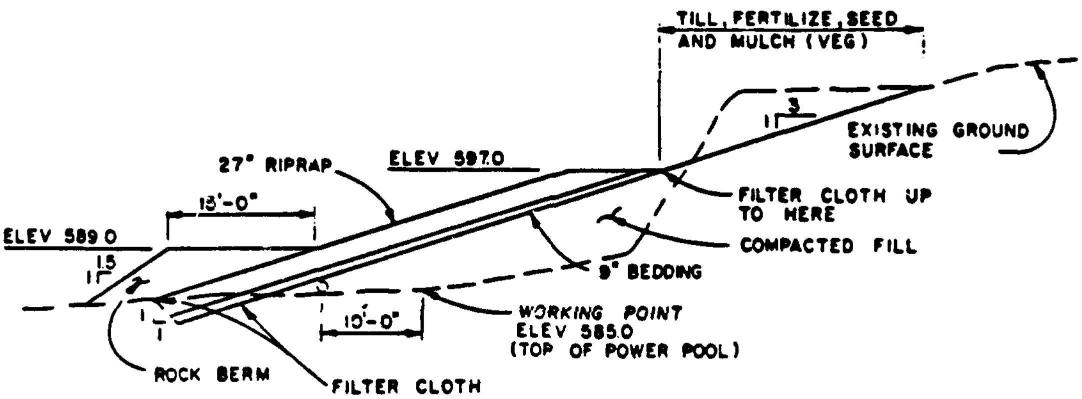
This site was selected by WES (Hollis Allen) to construct a breakwater from bundled dead limbs anchored between posts. The breakwater will be constructed by placing four bundles (two layers), each bundle approx 12 in. in diameter, between 4-in. posts driven into the lake bottom to be 2 in. apart on 3-in. centers. Galvanized wire will be laced between the post and the post driven down further to cinch in the bundles. The area behind the breakwater will be planted similar to the planting at the coconut fiber roll site.

Specific data for this site:

Length = 120 ft (dead limb) + 36 ft of gabions
Height = 2 ft (dead limb segment)
Materials: 4 dead limb bundles (2 on bottom and 2 on top), 4-in. treated wood post, galvanized wire, with coconut fiber mat and dead limbs under rolls on bottom
Plantings: Several (cattails, bulrush, etc.) plus two 50-ft-long by 5-ft wide preplanted coconut fiber mats behind breakwater.
Cost: (for both sites)
  Const contract (PO) = approx $17,000
  Coconut rolls = 18 20-ft rolls, approx $9.20/lin. ft
  Coconut mats = 250 ft x 5 ft, approx $6.00/sq yd
  Gabions = $915
  Posts = $652
  Rock for gabions = $450
  S&A costs = ±$1,500

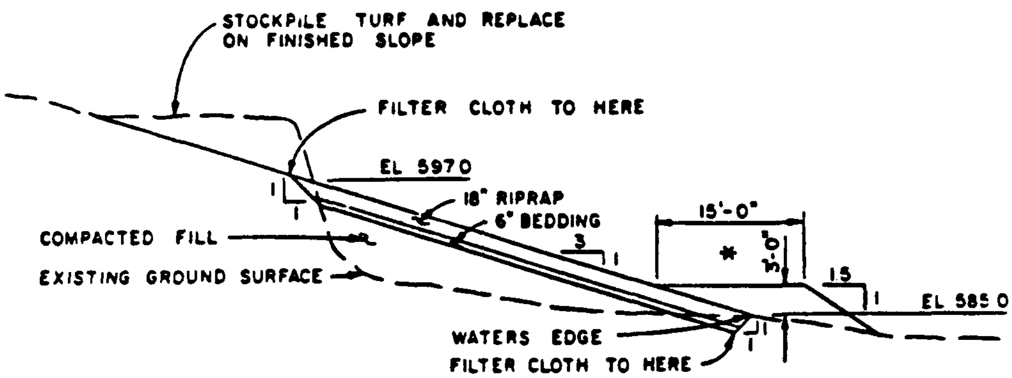


Site Map
(Encl 1)



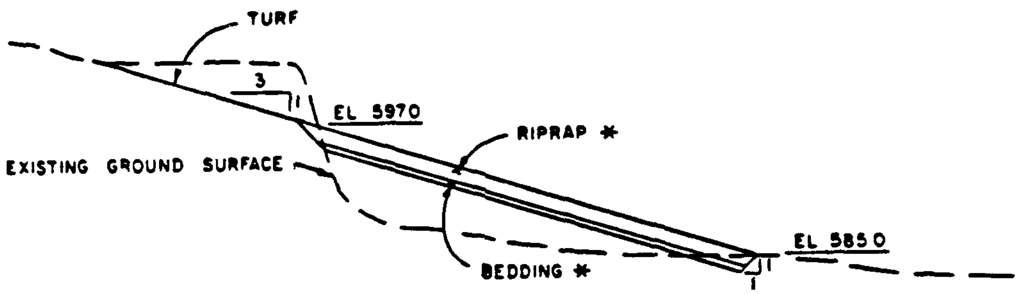
FIX NO. 1	HIGH ENERGY W/ PVT STR (SOUTHPORT)	SCALE: NONE	SHEET NO. 1 OF 9

Potential "Fixes"
(Encl 2)



* NOTE:
CONSTRUCT ROCK BERM AS SHOWN 3 FEET ABOVE TOE OF RIPRAP BERM SHALL BE PLACED ON NATURAL OR CUT SURFACE BEYOND TOE OF RIPRAP ROCK SHALL BE 18" RIPRAP MATERIAL.

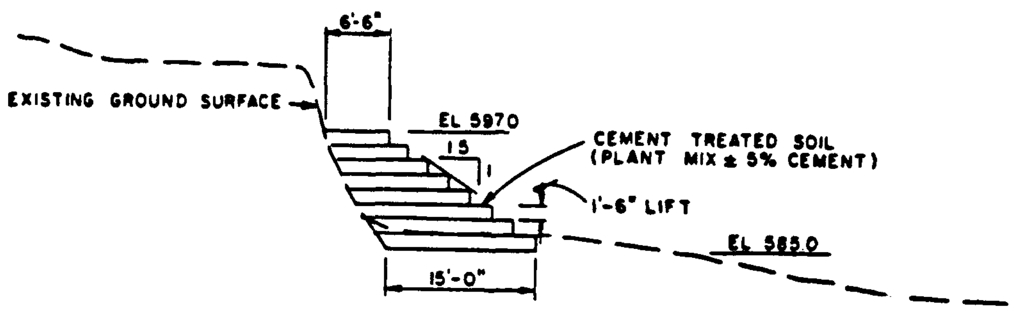
FIX NO. 2	LOW ENERGY W/ PVT. STR. (BEAVER'S LODGE)	SCALE: NONE	SHEET NO. 2 OF 9



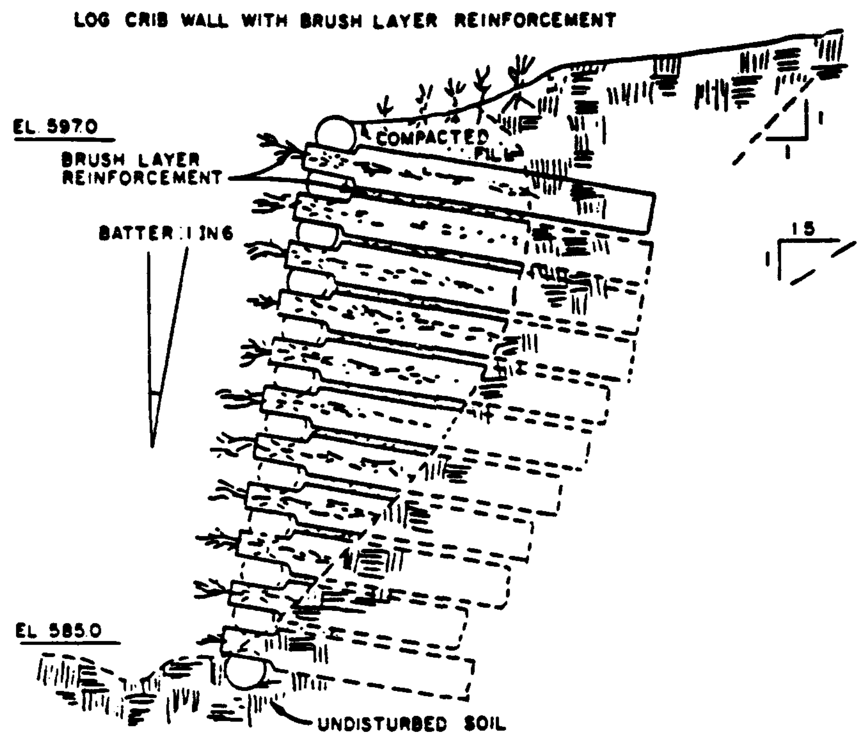
* THICKNESS & SIZE ACCORDING TO OLD EUFAULA LAKE HIGHWAY SLOPE PROTECTION CRITERIA

(A) 18" RIPRAP W/ 6" BEDDING
(B) 24" RIPRAP W/ 6" BEDDING

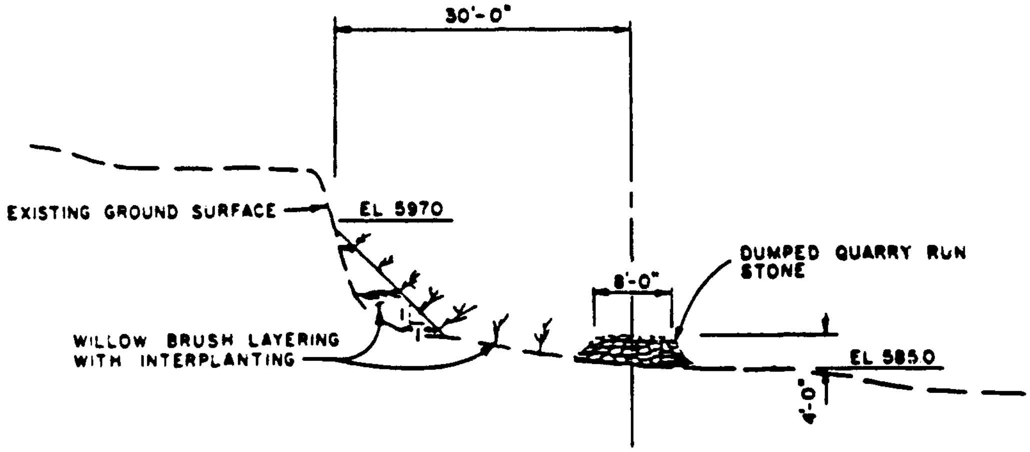
FIX NO. 3	HIGH PERCENTAGE, EXPECT SOME ANNUAL MAINTAINANCE	SCALE: NONE	SHEET NO 3 OF 9



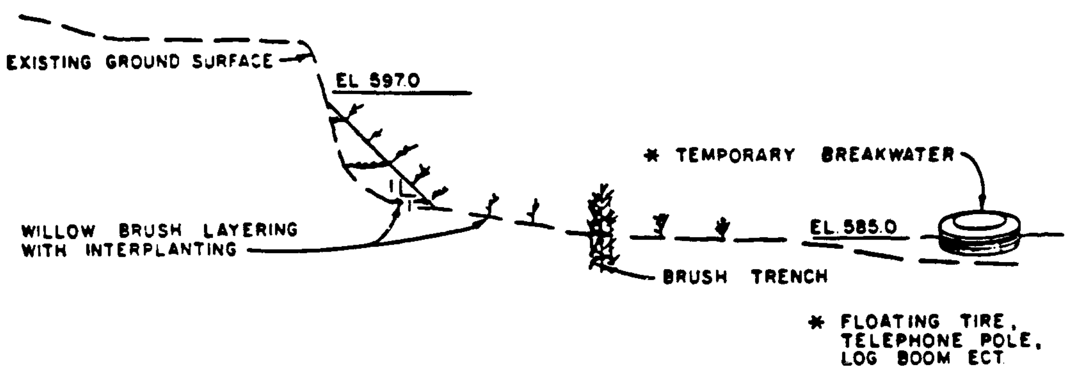
FIX NO. 4	HIGH PERCENTAGE, NO ROCK	SCALE: NONE	SHEET NO. 4 OF 9



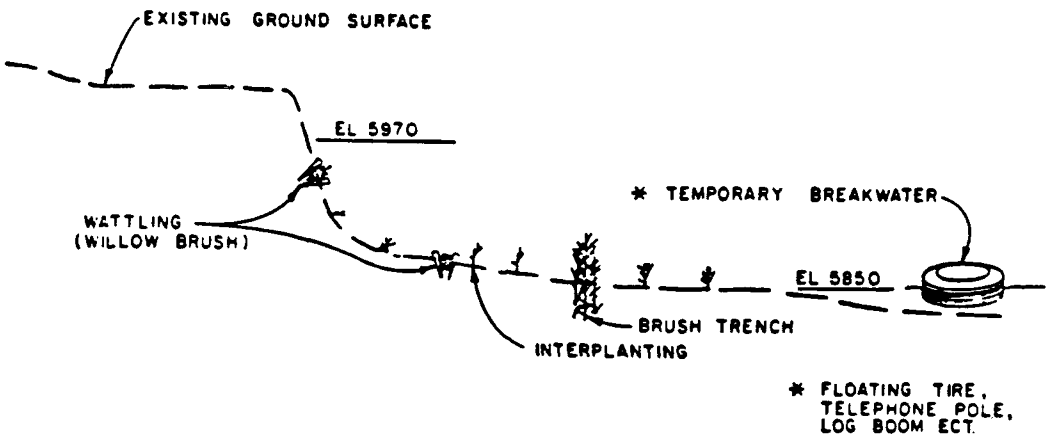
FIX NO. 5	NO ROCK	SCALE: NONE	SHEET NO. 5 OF 9



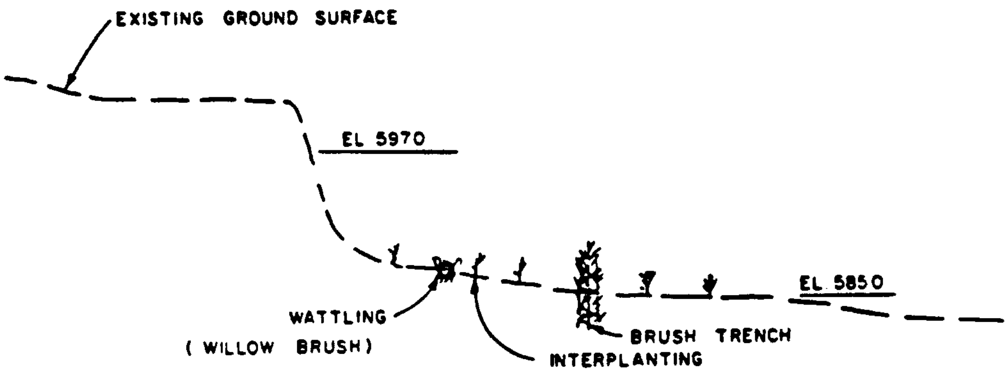
FIX NO. 6	VEG., EARTHWORK, & ROCK	SCALE: NONE	SHEET NO. 6 OF 9



FIX NO. 7	VEG., EARTHWORK, & TEMP. BREAKWATER	SCALE: NONE	SHEET NO. 7 OF 9



		SCALE:	SHEET NO
FIX NO. 8	VEG.& TEMP. BREAKWATER	NONE	8 OF 9



FIX NO. 9	VEG., LOW ENERGY ONLY	SCALE: NONE	SHEET NO. 9 OF 9

DISPOSITION FORM

OFFICE SYMBOL: CESWT-EC-C

SUBJECT: SLOPE PROTECTION & REPAIR LAKE SHORE LINE EROSION CONTROL

TO: CESWT-EC-PT Att. Burl Ragland

FROM: CH. COST ENGR. BR

DATE: 19 APR 89

CMT 1 GAGE/7237

The unit costs for each of the 9 different methods of erosion control appear to be reasonable, although a 15% contingency should be applied in order to compensate for the unknowns (access, preparation of area, size of units and quantities of each unit required). Therefore, the unit cost should be increased as shown below. If you have any questions, please call.

Larry Gage
Acting Chief, Cost
Engineering Branch

FIX NO.	UNIT COST per linear foot	ACTUAL UNIT COST (with contingencies) per linear foot
1	$220	$253
2	$170	$196
3A	$110	$127
3B	$148	$170
4	$ 83	$ 89
5	$166	$191
"BROOK'S FIX"	$ 56	$ 64
7	$ 35	$ 40
8	$ 29	$ 33
9	$ 17	$ 20

APPENDIX B

BIOGRAPHICAL INFORMATION FOR WORKSHOP SPEAKERS

INTERAGENCY WORKSHOP
RESERVOIR SHORELINE EROSION:
A NATIONAL PROBLEM

BIOGRAPHIC INFORMATION
FOR
WORKSHOP SPEAKERS

Hollis H. Allen

Mr. Allen is a Botanist in the Environmental Laboratory of the U.S. Army Engineer Waterways Experiment Station (WES). His primary professional interests include restoration ecology, applied ecology, wildlife biology, and botany. Mr. Allen has 23 years experience in ecology and related sciences at the WES and as a combat engineer in the U.S. Army Reserve. Mr. Allen conducts ongoing research into testing techniques for reclaiming dredged material by revegetating and developing it for wildlife habitat; revegetating reservoir and streambank shorelines using biotechnical methods; integrated natural resource management on Corps of Engineers and Department of Defense lands; determining the effects of natural and man-induced activities on the environment; and revegetation of military training areas. Mr. Allen has a B.S. degree in Forestry from Oklahoma State University and an M.S. degree in Forest Ecology from Oregon State University, and has completed postgraduate studies at Colorado State University. He holds memberships in the Ecological Society of America, the Society of Restoration Ecology, the Society of Wetland Scientists, the Alpha Zeta Society, and the Phi Sigma Society.

O'Gene W. Barkemeyer

Mr. Barkemeyer is the USDA Soil Conservation Service State Conservation Engineer for Texas. Mr. Barkemeyer holds a B.S. degree in Agricultural Engineering from the Texas A&M University, and he has completed postgraduate study at the University of Texas and at Utah State University. Mr. Barkemeyer, who has served with the Soil Conservation Service since 1963, has held the posts of Area Engineer, Design Engineer, Engineering Field Specialist, Soil Mechanics Engineer, Assistant State Conservation Engineer, and State Conservation Engineer. Mr. Barkemeyer is a Licensed Professional Engineer in both Texas and Tennessee. He is a member of the National and Texas Societies of Professional Engineers, the American Society of Agricultural Engineers, Soil and Water Conservation Society, the National Association of Conservation Districts, and the Organization of Professional Employees in the Department of Agriculture.

John H. Brigham

Mr. Brigham began his career with the Corps of Engineers in the Materials Lab at Fort Sill, Oklahoma. Since that time, he has worked in the Construction and Operations Divisions of the Tulsa District. Except for a 1-yr tour in the District Office, all of his assignments have been at field offices. Although Mr. Brigham has considerable office engineering experience in Military and Civil Works Construction, most of his career time has been spent at Eufaula Lake. He served first as Reservoir Manager/Supervisory Ranger, then Project Manager, and finally as Resident Manager of the Eufaula/Wister Resident Office when he was selected for that position in 1990.

Yen-hsi Chu

Dr. Yen-hsi Chu is Chief of the Engineering Applications Unit of the U.S. Army Engineer Waterways Experiment Station's Coastal Engineering Research Center in Vicksburg, Mississippi. Dr. Chu received a B.S. degree from the Cheng-Kung University in Taiwan, an M.S. degree from the University of Iowa, and an ScD from the Massachusetts Institute of Technology. Before he joined the Corps of Engineers in 1983, Dr. Chu taught fluid mechanics, water resources, hydraulics, and coastal engineering at the University of New Hampshire. He is a registered professional engineer and practiced engineering consulting services in Massachusetts and Wisconsin.

Lewis Decell

Mr. Decell received his B.S. degree in Civil Engineering from Mississippi State University; he has completed graduate studies at the University of Michigan and the Massachusetts Institute of Technology and received his M.S. in Environmental Engineering Sciences from the University of Florida.

Mr. Decell is currently Manager, Environmental Resources Research and Assistance Programs at the Waterways Experiment Station. His responsibilities include management of the following Corps of Engineers programs:

Water Quality Research Program
Water Operations Technical Support Program
Aquatic Plant Control Research Program
Natural Resources Research Program
Natural Resources Technical Support Program

For the past 6 months, Mr. Decell has also been serving as Acting Chief, Natural Resources Division, Environmental Laboratory, WES, which he organized and formed during a recent WES reorganization.

Mr. Decell serves on numerous review committees for federal and state agencies and has authored over 50 publications and articles. He serves on the Corps Committee on Water Quality and the Federal Interagency Steering Committee for Water Quality and Ecology.

Mr. Decell is a Registered Professional Engineer; a member of the National Society of Professional Engineers, the American Water Resources Association, and numerous state and regional society chapters in which he is active.

Jim Golden

A native of New Jersey, Jim Golden has spent the last 20 years in Oregon before moving to Washington, D.C. in May 1992. Mr. Golden received a B.S. in Forestry and Wildlife from Rutgers University in 1972 and studied Forest Ecology and Silviculture at the University of Washington Graduate School in 1981-82. Mr. Golden has worked in a a variety of Forest Service positions and locations, as a silviculturist, a recreation manager, and recently as a District Ranger for the 300,000-acre Wallowa Valley Ranger District on the Wallowa-Whitman National Forest in northeast Oregon.

Wendi Goldsmith

Ms. Goldsmith is Principal of Bestmann Green Systems, Inc., a Boston-based firm offering products and services in bioengineering for erosion control, water quality, and habitat restoration. She has experience in all phases of project design and implementation for wetlands, lakes, rivers, and tidal areas. Ms. Goldsmith is a regular speaker on shoreline revegetation techniques and water resource management for academic and professional audiences. Ms. Goldsmith holds a B.S. degree in Geology and Environmental Studies from Yale University and an M.S. in Landscape Design and Planning from the Conway School. She received her bioengineering training in Germany as an apprentice under Mr. Lothar Bestmann.

Gregg Good

Mr. Good is the Supervisor of the Illinois Environmental Protection Agency's (IEPA) Lakes Program, located within the Planning Section, Division of Water Pollution Control. Mr. Good is a native of Wisconsin and attended the University of Wisconsin - Stevens Point where he earned his B.S. degree in Soil Science. He first moved to Illinois in 1983 when he was employed by several central Illinois Soil and Water Conservation Districts. In 1985, Mr. Good began his career with IEPA working in the Non-point Source Management Program which included conducting implementation and assistance programs dealing with such areas as agricultural and urban runoff, hydrologic modification, construction erosion control, resource extraction, and livestock waste management. In addition to authoring a number of Agency reports, Gregg was the primary author of the state's Non-point Source Assessment and Management Program reports required under the auspices of Section 319 of the Federal Clean Water Act. Mr. Good became Supervisor of the Agency's Lakes Program in 1989, where he oversees implementation of several programs including the Ambient and Volunteer Lake Monitoring Programs, Lake Water Quality Assessment Program and state administration of the Federal Clean Lakes Program (Section 314 of the Federal Clean Water Act). As required by passage of the Illinois Lake Management

Program Act (P.A. 86-939) in 1990, Mr. Good coordinated development and authored the ""Illinois Lake Management Program Act—Administrative Framework Plan." The plan offers feasible and cost-effective recommendations for implementation of enhanced state programs in the area of comprehensive lake management.

Wes Green

Mr. Green is a Management Agronomist with the Bureau of Reclamation working in the areas of erosion control, revegetation and vegetation management for wildlife enhancement and development including wetlands. In addition, Mr. Green is a Regional Pest Management specialist with emphasis in irrigation reservoirs, distribution and drainage systems and rights-of-ways and anadromous fish passage and protection facilities. Mr. Green was graduated from the University of New Mexico and has completed postgraduate work at West Texas State University. In his 23 years with the U.S. Bureau of Reclamation, Mr. Green has served as fish and wildlife biologist, land management specialist, and pest management specialist.

Friedrich B. (Pete) Juhle

Mr. Juhle is a hydrologist in the Engineering Division at the Headquarters, U.S. Army Corps of Engineers. He is responsible for development of policy and guidance for water-quality and water-control matters throughout the Corps. Pete is chairman of the Corps committee on water quality, has a B.S. degree from the University of Maryland, and has over 25 years experience in water quality and water control with the Corps.

Joe Lyons

Mr. Lyons has worked in the Sedimentation Section of the Bureau of Reclamation since 1986 and has been involved in impact assessment of Reclamation Projects on fish and wildlife resources, sediment data collection and analysis, and reservoir sediment surveys. Also, he developed the Plan of Study for the island erosion investigations at Audubon National Wildlife Refuge in North Dakota. Prior to working for Reclamation, Mr. Lyons was employed with the U.S. Fish and Wildlife Service, providing hydrologic assistance to biologists in the areas of water management, geomorphology, and water quality. A native of Colorado, Mr. Lyons received a B.S. degree in Watershed Sciences from Colorado State University and an M.S. degree in Hydrology from Oregon State University.

Paul R. Nickens

Dr. Paul R. Nickens is a research archeologist in the Environmental Laboratory of the U.S. Army Engineer Waterways Experiment Station where he has worked since 1988. He received his Ph.D. in Anthropology at the University of Colorado-Boulder. Dr. Nickens is a member of numerous honorary and professional societies and has authored or co-authored over 150 technical reports, papers, journal articles, and books on North American archeology and cultural site protection and preservation. As an archeologist, Dr. Nickens' interests in reservoir shoreline erosion are focused on identifying impacts to cultural resource sites and in identifying and evaluating technologies and strategies for mitigating those impacts. He has worked on archeological site preservation throughout the U.S., dealing with many natural and cultural impacts to archeological sites. Dr. Nickens has worked most extensively in the Rocky Mountain West region, especially in the Four Corners area.

Don L. Porter

Mr. Porter is a Civil Engineer with the Tennessee Valley Authority's Division of Water Resources. He has worked for TVA for 16 years in the area of floodplain management and flood damage prevention. Prior to joining TVA, Mr. Porter served as Assistant City Engineer for Knoxville, Tennessee, during the period 1974-1976. he received his B.S. degree in Civil Engineering from the University of Tennessee.

Burl D. Ragland

Mr. Ragland has a B.S. in Civil Engineering from Oklahoma University and an M.S. in Civil Engineering from Oklahoma State University. He is a registered engineer in the state of Oklahoma and an active member of the American Society of Civil Engineers. Mr. Ragland has worked for the Corps of Engineers since 1963 and has spent most of that time working in the Tulsa District. Currently he is Chief of the Civil Works Section of the Technical Management Branch, Engineering-Construction Division. Mr. Ragland has been involved with the Erosion Control Program at Lake Eufaula for the last 4 years and has attended the Reservoir Shoreline Erosion Control and Revegetation Workshop Training sponsored by the U.S. Army Engineer Waterways Experiment Station.

John R. Reid

Dr. Reid is a native of Massachusetts. He has a B.S. degree in geology from Tufts University and M.S. and Ph.D. degrees in geology from the University of Michigan. Dr. Reid has served as a professor in the Geology and Geological Engineering department of the University of North Dakota since 1961. He has an interest in glaciers and has studied them in Greenland, Alaska, Canada, Washington (state), Norway, Scotland, New Zealand, and Antarctica. Dr. Reid's work in the area of shoreline erosion dates to work with the U.S. Army's Cold Regions Research and Engineering Laboratory in 1980. In research begun in 1983 on Lake Sakakawea, North Dakota, Dr. Reid directed the master's theses of three students, and out of these studies came publications which define erosion processes, measure these processes, and develop predictive capabilities of them.

Donald Roseboom

Mr. Roseboom has been employed at the Illinois State Water Survey for 17 years. He manages the Non-point Pollution Control Program in the Office of Water Quality Management. He has directed projects on streambank stabilization and habitat restoration for the Illinois Department of Conservation and local Soil and Water Conservation Districts.

Delbert G. Skeesick

Mr. Skeesick has been employed with the U.S. Forest Service since 1978. He currently holds the position of Fish Program Manager for the Willamette National Forest. Originally from Minnesota, Mr. Skeesick earned an A.A. Degree in Science form Los Angeles Valley Junior College in 1959, a B.S. in Fisheries from Humbolt State College in 1961, and an M.S. in Fisheries from Humbolt State College in 1963, and is a Doctoral Candidate at Oregon State University. Mr. Skeesick has worked for the Minnesota Department of Natural Resources in the area of warmwater game fish reproduction; for the Oregon Fish Commission on anadromous fish inventories, and habitat protection, estuarine fisheries, and threatened and endangered desert fishes; for the Bureau of Land Management on assessing the effects of timber harvest on Oregon fish and wildlife; and for the U.S. Forest Service on timber harvest assessment, riparian protection, fish stock assessment, aquatic ecosystem restoration, warmwater fish management, threatened fish species protection, and reservoir shoreline erosion control technology development. Mr. Skeesick is past President of the Oregon Chapter of the American Fisheries Society, past President of the Pacific Fisheries Biologists, and the organizer/chair of the Salvelinus Confluentous Conservation Society.

Colonel Otis Williams

COL Otis Williams assumed command of the Tulsa District, U.S. Army Corps of Engineers, on July 14, 1992. As Commander, COL Williams is responsible for Corps water resources development activities in southern Kansas, northern Texas, and the entire state of Oklahoma. He also supervises Corps design and construction support of Army and Air Force installations in Oklahoma and northern Texas.

COL Williams came to Tulsa District form the Pentagon where he was Joint Requirements Planner, the Joint Staff. Earlier, he was Chief of the Evaluation and Standardization Division at the U.S. Army Engineer School, Fort Belvoir, VA. During a previous Pentagon assignment, COL Williams was Engineer Staff Officer in the Office of the Assistant Chief of Engineers.

Formerly, COL Williams was Research and Development Coordinator, Waterways Experiment Station, Vicksburg, MS, and assistant professor of Military Science, Jackson State University, Jackson, MS.

COL Williams is a former Commander of the 30th Engineer Battalion at Fort Belvoir. In Germany, he was Commander of the 227th Topographic Planning and Control Detachment and Operations and Executive Officer of the 249th Engineer Battalion.

Other assignments included duty with the 43rd Engineer Battalion, Fort Benning, GA, and the 809th Engineer Battalion in Thailand.

COL Williams' military awards include the Legion of Merit with Oak Leaf Cluster, Defense Meritorious Service Medal, Meritorious Service Medal with Oak Leaf Cluster, and the Army Commendation with two Oak Leaf Clusters.

He was commissioned in 1968 in the Corps of Engineers through the ROTC program at South Carolina State College, Orangeburg, SC, where he earned a B.S. degree in Civil Engineering Technology. He received his M.S. degree in Education Administration and Supervision from Jackson State University, Jackson, MS, and pursued additional graduate studies in Facilities Engineering Management at Arizona State University, Tempe, AZ.

COL Williams is also a a graduate of the National War College, Fort McNair, Washington, D.C. Additional military education includes the Engineer Officer Basic and Advanced Courses, Command and General Staff College, and various other advanced engineering courses.

Chris Zabawa

Chris Zabawa holds B.S. and M.S. Degrees in geology from The Johns Hopkins University, and a Ph.D. in geology from the University of South Carolina. Dr. Zabawa has worked for many years in the Maryland Department of Natural Resources, where he directed shore erosion control projects which included treatment with constructed wetlands and vegetative bank stabilization techniques. He also coordinated Maryland's contributions to the *Chesapeake Bay Shoreline Erosion Study*, which was recently completed by the Baltimore and the Norfolk Districts of the U.S. Army Corps of Engineers. Dr. Zabawa has published numerous papers on suspended sediment transport and shore erosion in the Chesapeake Bay estuary. Currently, Dr. Zabawa is working in the EPA Office of Water, Assessment and Watershed Protection Division, Non-point Source Control Branch. His responsibilities are to develop and implement national guidance to control nonpoint sources of pollution in the coastal zone under the Coastal Zone Act Reauthorization Amendments of 1990. His specialty areas are Hydromodification and Wetlands.

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13. ABSTRACT *(Maximum 200 words)*

A Workshop on Reservoir Shoreline Erosion: A National Problem was held by the U.S. Army Corps of Engineers at McAlester, OK on 26-30 October 1992. Representatives from federal and state agencies, academic institutions, and contractors attended. The workshop was conducted to assess the magnitude and causes of shoreline erosion in the United States and to enumerate the ways and the degree to which it impacts natural resources and the agencies responsible for managing these resources. Papers presented at this workshop are included in this report.

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