One in a Series of Reports to FEMA on Future Research Needs in Dam Safety

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Report on Specialty Workshop #1: Plant & Animal Impacts on Earthen Dams

Acknowledgements

The project proposal and scope of work were developed and submitted by Dr. B. Dan Marks, affiliate (private sector) member of the ICODS Subcommittee for Dam Safety Research. The steering committee which organized the Workshop on Plant and Animal Penetrations on Dams included the following members:

Dr. B. Dan Marks, (chair); S & ME, Inc.;

Dr. Bruce Tschantz, University of Tennessee;

Dave K. Woodward, North Carolina State University;

Charles Clevenger, Mississippi Dam Safety Program

William Bouley, US Bureau of Reclamation

Susan Sorrell and Sarah Mayfield of the Association of State Dam Safety Officials served as administrative and research staff. Dr. Tschantz was assisted in his bibliographical research by University of Tennessee graduate students Chad R. Wagner, James W. Jetton, Jr., and D. Cody Conley.

PROJECT SPONSOR

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Introduction and Scope of Project

The research project associated with plant and animal penetrations of earthfilled dams was proposed through the Interagancy Committee on Dam Safety (ICODS) Subcommittee on Dam Safety Research. The project was subsequently submitted through ICODS for funding by the Federal Emergency Management Agency (FEMA). The project was funded by FEMA with a contract administered through the Association of State Dam Safety Officials.

The Steering Committee for the Plant and Animal Penetrations of Earthfilled Dams Project was comprised of representatives from ASDSO, academia, private practice, state agencies, and federal agencies.

The scope of work or purpose of the research project as set forth in the agreement between FEMA and ASDSO was to identify dam safety state-of-practice issues and research needs relative to plant and animal penetrations of earthfilled dams. The purpose of this project was to be accomplished through the achievement of five objectives, which include the following tasks:

1. Conduct literature searches and surveys to determine state-of-practice issues and research needs.

2. Organize and conduct an invited-participant state-of-practice and research needs workshop.

3. Publish a proceedings of the presentations made at the workshop.

4. Publish a project report to be submitted through ICODS to FEMA.

The workshop on Plant and Animal Penetrations of Earthfilled Dams was conducted November 30-December 2, 1999 at the University of Tennessee Conference Center in Knoxville, Tennessee. The workshop was a successful undertaking that opened communications between the dam safety and wildlife communities.

Executive Summary of Project

Item 1. Summary of Data Collection Process and Workshop

Pre-Workshop Data Collection

The data collection process was identified early on as the key to successfully completing the project. Some of the questions asked in the initial stages included:

1. What is known about the impacts of plants and animals on dams?

2. What kinds of policies or procedures are being followed by regulatory agencies (state or federal) for dealing with plants and animals on dams?

3. How can the gaps in knowledge or technology that prevent dam owners or regulators from developing effective methods to control plant and animal damage to dams be identified and addressed?

In order to collect as much information as possible on this topic, several literature reviews and surveys were completed. ASDSO Information Specialist Sarah Mayfield conducted a search for sources of information on plant or animal impacts on dams. The resulting bibliography included references from the following sources: the American Society of Civil Engineers (internet database), the Association of State Dam Safety Officials (newsletter articles and conference proceedings), the Canadian Dam Safety Association (conference proceedings), and several state and federal agencies (technical notes/fact sheets/guidelines).

In addition, Dr. Bruce Tschantz of the University of Tennessee and Dave Woodward of North Carolina State University undertook independent searches of university databases and other sources of information on plant and animal impacts on dams. Dr. Tschantz compiled a significant number of references from some of the same sources listed above, as well as from the National Technical Advisory Service (NTIS) and the National Performance of Dams Program (NPDP). His bibliography includes references on the general physiology and character of woody plants, documented case histories of problems attributed to woody plants on dams, as well as current research activities involving the effects of woody plants on dam safety.

Mr. Woodward consulted Water Resources Abstracts and the Agricola Database, as well as the sources used by Dr. Tschantz. His bibliography includes references on the habits of burrowing animals; case studies of animal-caused damage to embankments and spillways; agency practices for preventing, controlling and repairing such damage; and related research activities.

In addition to the bibliographic searches, a large number of dam safety specialists were given the opportunity to contribute to the "body of knowledge". Surveys were developed to extract information from different groups, asking them to describe their experiences with plants and animals on dams. Primarily, the committee wanted

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Item 1. Summary of Data Collection Process and Workshop

to know the following:

- *What types of policies or operating procedures are being utilized by regulators facing problems with the management of plants or animals on dams, and, if no policy or procedure exists, then what recommendations are regulators making to dam owners concerning such problems?*
- *What legal, financial, environmental or other constraints apply to the resolution of impacts made by plants and animals on dams.*

In addition, the survey respondents were asked to supply the following:

- *Documented evidence where plant or animal impacts have negatively impacted the operation of a dam, or contributed to its failure, and*
- *References to research projects or discussions already completed or underway regarding the effects of plants or animals on dams.*

Surveys were distributed to all state dam safety regulatory staffs, all federal agencies with dam safety responsibility (through their ICODS representatives), and to several dam owners and consultants (through the ASDSO Affiliate Advisory Committee). Responses were received from 48 states, 11 federal agencies, and four representatives of the private sector. The detailed survey response data was compiled and can be viewed in sections One and Two of the attached workshop proceedings.

Key results of the surveys include the following:

- *All state dam safety officials consider trees and plant growth on dams to be a safety problem. Further, both state and federal officials generally agree that trees in particular have no place on dams.*
- *The problem most commonly noted by state officials is that trees, woody vegetation, briars, and vines on dams interfere with effective safety inspections.*
- *Twenty four of the 48 responding states do have either a formal policy or operating procedure for addressing tree and woody plant growth issues. Of the remaining 24 states that do not have a formal policy or procedure, the range of recommended procedures to dam owners varies widely.*
- *The greatest constraint to having unwanted trees and plants removed and repairing a structure infested with roots is the limited financial capacity of the dam owner. The second most listed constraint was environmental regulations, such as limitations on the use of herbicides, or the prohibition of burning vegetation.*
- *Twenty-nine states have documented evidence where vegetation on dams has either caused dam failure or negatively affected their safe operation.*
- *The most severe problem impacting the integrity of dams caused by animals is the burrowing into*

Executive Summary of Project

Item 1. Summary of Data Collection Process and Workshop

embankments by muskrats, beavers, and woodchucks. The next most significant problem is clogging, or the obstruction of hydraulic structures and spillways.

- *The seepage and piping caused by such burrowing or tunneling activities by animals have resulted in documented dam failures.*
- *For animals the most successful abatement method, cited by at least 40 states and nine federal agencies, is trapping (including live trapping and relocation of the animals). Additional procedures cited include habitat alteration, exclusion (such as fencing and filters), hunting, and toxicants.*
- *Controlling vegetation and animal populations on or near dams can be an expensive and time-consuming activity, but the cost of control methods pales in comparison to the potential cost of repairing neglected dams that have been damaged by plant and animal penetrations.*

Literature Review

The literature review yielded several references on federal and state practices, policies, and procedures for dealing with trees and vegetation, but few research reports.

The literature search yielded documentation of numerous cases of animals causing damage to embankments and spillways, and various procedures for dealing with the problem, but little in the way of research.

Workshop Results

Another component of the project, the Specialty Workshop on Plant and Animal Penetrations on Dams, fulfilled an objective of the original project scope of work, and was designed to complete the data collection process. The steering committee's goal was to bring together a group of experts with experience in all aspects of the issue for more in-depth, face-to-face discussions. The participants included state and federal regulators, dam owners, academics, and private industry representatives. All had either had direct experience dealing with the impacts of plants and animals on dams, had researched the issues, or were developing potential solutions to the known problems. In addition to the broad range of expertise, the participants also represented all regions of the U.S., ensuring that all types of animals, vegetation, climates, and structures were included in the study.

The workshop was held November 30 to December 2, 1999 in Knoxville, Tennessee. The twenty-two invited participants each made a 30-60 minute presentation summarizing their experiences or research relating to plant or animal impacts on dams.

Key findings from the workshop include the following:

- *All types of dams (large, small, earthen, and concrete), and their appurtenant structures are vulnerable to safety problems caused by plants and animals.*

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Item 1. Summary of Data Collection Process and Workshop

- *While all dam safety regulatory agencies are aware of the problems associated with plant and animal penetrations on dams, some can take a stronger enforcement stand on prevention and elimination, while others are more limited by financial, environmental, or legal constraints.*
- *Tools, technology and methods are available to help regulators and owners identify, prevent and mitigate problems with plants and animals on dams. Information on the most effective tools should be compiled and distributed to those responsible for the safety of the dams.*
- *The impacts of vegetation on dams and the effectiveness of treatments to inhibit the growth of plant roots on dams are the two areas where further research is most needed. Not enough scientific information is available to determine what the acceptable level (amount, size) of vegetation on dams should be; and more facts are needed about how the currently recommended damage mitigation and repair methods work.*

Executive Summary of Project

Item 2. What is the State of Practice?

In the years since this issue was first studied, dam safety regulators (and some dam owners) have become more educated about the safety problems caused by animals and vegetation on dams. Not only is there more knowledge, but also more agreement about the need to prevent and repair damage caused by plants and animals on dams. Specifically, dam safety officials and experts agree that vegetation and animals need to be managed and controlled on both existing and new dams for these important reasons:

(1) Woody plants and dense vegetation (and in some cases, animals) hinder effective dam inspections; and

(2) Tree roots and animal burrowing can cause serious structural instability or hydraulic problems with dams, which could lead to dam failure.

However, the "state of practice" is somewhat fragmented and inconsistent among the responsible parties. On the regulatory side, a significant range of differences exists among state and federal agencies with respect to treating the plant and animal problems. Some state agencies have no official policy on the issue and treat each case individually, while other states, and almost all federal agencies have a "zero tolerance" rule, especially with respect to large trees on dams. Most state policies on vegetation fall somewhere in the middle, allowing certain levels of vegetation (i.e. shrubs or small trees only), or requiring the cutting of live trees but allowing tree stumps to remain, etc. Policies on the treatment of animal impacts are mostly inconsistent.

Regarding vegetation/animal management and control, several factors seem to contribute to the fragmentation of the current state of practice. One is that the diversity of problems, and the types of plants and animals that cause them, seems to widen by the day. Climate and geography determine what types of trees will grow and what types of animals will invade dams in different parts of the country. For example, while beavers and muskrats seem to cause problems everywhere, animals such as crayfish, armadillos, and gopher tortoises would only be a concern in very specific areas. Additionally, geological factors such as soil types and conditions, and groundwater levels will result in different growth patterns of tree roots.

Finally many dam owners and state regulators are unaware of what resources are available to help with these problems. Better communication between organizations would for instance, allow owners to take advantage of USDA programs to help deter or remove animals that cause property damage, or to follow research on herbicides being conducted by the US Bureau of Reclamation. State regulators would also benefit by learning what damage prevention and repair methods have been tried successfully by other state programs.

Executive Summary of Project

Item 3. What are the Future Research or Development Needs?

Summary of Research Needs:

It was concluded that through studying case histories and conducting field studies, vital information on the impacts of trees and other vegetation on dams could be collected. This information is needed to help regulators determine what (if any) vegetation should be allowed on or near dams.

The second area of research relates to the treatment of roots. Workshop participants learned about chemical/herbicide treatments that are being used by the USBR to deaden roots, as well as some barrier substances that can be used to prevent root growth into unacceptable areas. Studies of these and other possible methods of root control are needed to determine what works and what doesn't.

Summary of Development Needs:

Several areas for future development were identified by the group. The first is characterized by education. Tools are needed for educating dam owners and engineers on how to spot problems caused by plant and animal penetrations, how to prevent these problems from occurring, and how to mitigate (or repair) existing problems. Specific ideas include the development of a booklet for dam owners with information on why plants and animals should be kept off dams, how to remove and manage animals and plant growth, and a list of resources for aiding owners with these types of problems. Both a manual and a training seminar have been proposed which would provide dam owners and engineers with design guidelines for preventing plant and animal problems on dams, and maintenance guidelines for removing or mitigating existing problems.

It was also determined that a booklet is also needed to train regulators and staff, especially dam inspectors, how to identify animal and vegetation problems that threaten the safety of a dam.

The experts propose that tools and methods for repairing animal burrows on dams be analyzed for their effectiveness in different situations, and that new tools and methods be developed where needed.

Finally, the experts determined that collaboration with other groups (such as federal wildlife agencies) that have research programs in place should be a part of this development process.

Results

Item 1. Literature Review and Current Research

Woody Vegetation

Few citations to woody-plant-related research were identified by any of the three groups surveyed. The reference most often cited was the *University of Tennessee Tree Growth Report* (Tschantz, 1988). The Corps of Engineers referred to the technical report series, *Repair-Evaluation-Maintenance-Rehabilitation (REMR)* on research conducted at the Waterways Experiment Station.

The literature review yielded several references on federal and state practices, policies, and procedures for dealing with trees and vegetation, but few research reports.

Workshop presentations on current research in this area included *Biobarrier: A Long-Term Root Control System,* by William Hawkins; *Control Methods for Woody Vegetation*, by David Sisneros; and *Engineered to Fail? Tree Root Management on Dams*, by Dr. Kim Coder.

Animal Impacts

Those surveyed referred to numerous instances where animals affected the safe operation of dams and/or caused dam failure. Few knew of any research in this area. The following documents/studies were among those mentioned:

- *Hegdal, Paul L. and Harbour, A.J.,* Prevention and Control of Animal Damage to Hydraulic Structures, *U.S. Bureau of Reclamation and U.S. Department of Agriculture, 1991.*
- *Hygnstrom, Scott; Timm, R.M. and Larson, Gary E. (eds),* Prevention and Control of Wildlife Damage, Nebraska Cooperative Extension Service, *University of Nebraska and U.S. Dept of Agriculture, 1994.*
- *Tschantz, Bruce A. and Weaver, Jess D.,* Tree Growth on Earthen Dams: A Survey of State Policy and Practice, *1988.*
- *unspecified research by the USACE Waterways Experiment Station*
- *Oklahoma Bulletin No. OK210-0-3,* Evaluation of Beaver Control Trials *(1989)*
- *Haggard, David W. and Dominick, Max D.,* Evaluation of Beaver Guards on Restricted Flow Risers of SCS-Assisted Floodwater Retarding Structures in Oklahoma, *USDA/SCS, 1989.*

The literature search yielded documentation of numerous cases of animals causing damage to embankments and spillways, and various procedures for dealing with the problem, but little in the way of research.

Reports on current research in the field were presented at the workshop by Matthew Barner (The Use of Ground-Penetrating Radar, Electrical Resistivity, and Streaming Potential to Assess Damage by Burrowing Animals to Three Selected Portions of Earthen Levees Near Dayton, Ohio) and Jim Miller (Wildlife Damage to Earthen Dams, Dikes, Levees, and Related Structures).

Results

Item 2. Workshop Issues Development and Prioritization

In the interest of collecting as many ideas as possible, but yet, preparing a workable list of possible topics, a special process was developed and used in the workshop. This process was a variation of the Strategic Planning Process known as MetaPlan developed by the IBM Corporation (see Appendix 3 for an explanation of the process).

Question to Resolve

The question developed for attendees to address:

What are needed developments to feel comfortable when dealing with woody vegetation and animals associated with dams?

The question is intended to be specific to the desired outcome, but somewhat vague so as to not influence input into predetermined categories.

Prioritizing the Categories

Individuals are asked to define their own priority (importance) for the categories using a multi-vote. All votes are counted for each category. This voting creates a typical Pareto distribution of the categories.

Participants were also asked to rank difficulty. This is an estimate as to how difficult items in a any particular category may be. Difficult may mean expensive, technically challenging, complex, or any context, which the participant chooses for any given category. In this case each participant gives EACH category a score of 0 to 10, with 0 being easy and 10 being very difficult. Scores are then averaged. Final results for importance and difficulty are shown in the table below.

Table 1 - Categories, Items and Scores

Category	Importance # (From 1-25)	Difficulty (Avg) (from 1-10)
A DESIGN GUIDELINES	7	4.25
1. Determine design prevention measures		
2. A buffer zone minimum of 30 ft for deep rooted vegetation		
3. Develop an engineering guide to establish barrier system		
4. Allowable proximity of desert trees to dams		
5. Different animals in different parts of U.S.		
6. Do not limit discussion to "woody" vegetation		
B P&A MANAGEMENT OR CONTROL	14	5.33
1. Determine mitigated measures		
2. Kudzu, how to get rid of it		
3. Develop animal damage control techniques for aquatic vs. land animals		
4. Recommended repair methods for deep animal burrows		
5. Habitat alteration		
6. Other dam upgrades with tree removal		
7. Tree stump removal methodology		

Results

Item 2. Workshop Issues Development and Prioritization

Category	Importance #	Difficulty (Avg)
C RESEARCH & DEVELOPMENT	25	6.66
1. What are the interactions between plant/tree development and the phreatic surface?		
2. Rate of root decay		
3. Burrow data		
4. Tree root data		
5. Research of root development pre & post treatment of control methods		
6. How do different tree species roots develop on dam slopes		
7. Establish more definitive guidelines/technology on tree root penetration		
8. Develop barrier methods for targeted animals		
9. Research vegetation that might act as animal repellent		
10. Research to determine methods to keep animals out of earthfilled dams		
11. Best method for removing animals from dams		
12. Brush root growth limits (understanding of)		
13. Impacts of plants & animals on weak zones such as cracks		
14. Growth limits		
15. Acceptable size of root left in a dam		
D INFORMATION RESOURCES	19	4.5
1. A concise, well illustrated bulletin or handbook for field use by inspectors, that is weatherproof and practical.		
2. What to look for re P & A.....		
3. Determine extent of general problem		
4. ASDSO session on P & A penetration issues		
Expand reference sources/network for up to date information, e.g. herbicides, wildlife damage, soil renovation techniques, etc.		
5. Determine species of concern across U.S.		
6. State inservice training involving other disciplines, and expertise from a variety of sources, e.g. state DNR, CES, others		
7. Explain current technology for non-scientists regarding control methods for trees/animals		
8. Provide technical training relative to plant/animal dam Penetrations		
9. Establish tech transfer mechanisms (e.g. the web)		
10. Need to look at levee experience		
11. Establish database structure		
12. What lessons can be learned about trees/animals on dams from Europe & Asia?		
13. Dam failure case histories		
14. Send NPDP your slides for posterity		
15. State of riser and drain dam design		
E OPERATION & MAINTENANCE	6	4
1. More frequent inspection schedule for animal burrowing		
2. Recommendation for frequency of mowing dam embankments		
3. Recommendation for frequency (minimum) of inspections (periodic) by owner or owner's representive		

Results

Item 2. Workshop Issues Development and Prioritization

Category	Importance #	Difficulty (Avg)
F. FUNDING	2	5.72
1. Money for funding remediation/repair		
G. VALUE ENGINEERING	1	6
1. Develop cost models for P & A mitigation		
2. Evaluate cost impact of P & A on dams		
3. Value engineering methods for deep burrow repair (what is least expensive & beneficial repair method)		
H. INDUSTRY PRODUCTS	1	3
1. More input from industry products		
2. Pesticides, p&a		
3. Materials that are non-penetrable by animals		
4. Chemical limits		
I. INTERORGANIZATIONAL COOPERATION	1	6
1. Cooperative efforts between private/state groups to assist in dam repairs		
2. A trust relationship between owners and dam safety officials		
3. Develop cooperative relationship between USDA state extension & ASDSO		
J END USER AWARENESS	22	6.5
1. Owner belief in proactive rodent and woody vegetation control		
2. We need to develop effective awareness/education tools for owners about the problems and management of plants/animals on trees		
3. Develop owner maintenance manual		
4. Develop dam owner guidelines for plant (tree) damage control		
5. Develop dam owner guidelines for animal damage control assistance		
6. Develop an owner guide for dealing with P & A		
7. Develop cases/proof tools - why p&a are bad		
8. Develop guidelines for removal of woody vegetation from dams, for owners		
9. Owner responsibility		
10. Mention that problems associated with animals and trees are recurring, not onetime problems		
11. Develop method for educating dam owners of the need to keep woody vegetation off dams		
12. Develop method for educating dam owners of the need to keep burrowing animals out of dams		
13. Develop information pamphlet for chemical removal of woody vegetation on dams for dam owners		
K. POLICY & REGS	7	8
1. Uniform policy across states		
2. Policy for removal of animals		
3. Policy for repairing areas where animals have been removed		
4. Policy for repairing areas where trees have been removed		
5. Existing dams policy: Remove all trees and bushes		

Results

Item 2. Workshop Issues Development and Prioritization

Category	Importance #	Difficulty (Avg)
6. New dams policy: No trees or bushes! Ever! Period.		
7. Establish a criteria for size & method of removal of vegetation on dams		
8. Use of IPM/BMP		
9. Regulatory guidance: EPA, FW, DS		
10. Determine where important in dam safety and maintenance		
L. INVESTIGATIVE TECHNIQUES	10	7
1. An accurate method of mapping burrow systems		
2. Better ways to detect leakage from plants/animal penetrations		
3. Means to animal location/presence		
4. Investigate barrier methods		
M. PUBLIC RELATIONS	6	5
1. PR stuff to give public		
2. Language understood by all		
3. Being responsible to animal rights		
4. Acceptable public animal control		
5. Guidelines for dealing with "anti"s		
N. LEGAL ISSUES	2	8
1. Animal/plant caused failure liability		
2. Publicize danger of plant/animal penetrations relative to dam safety		
3. Liability		
4. Owner liability regarding A&P damage leading to dam failure		

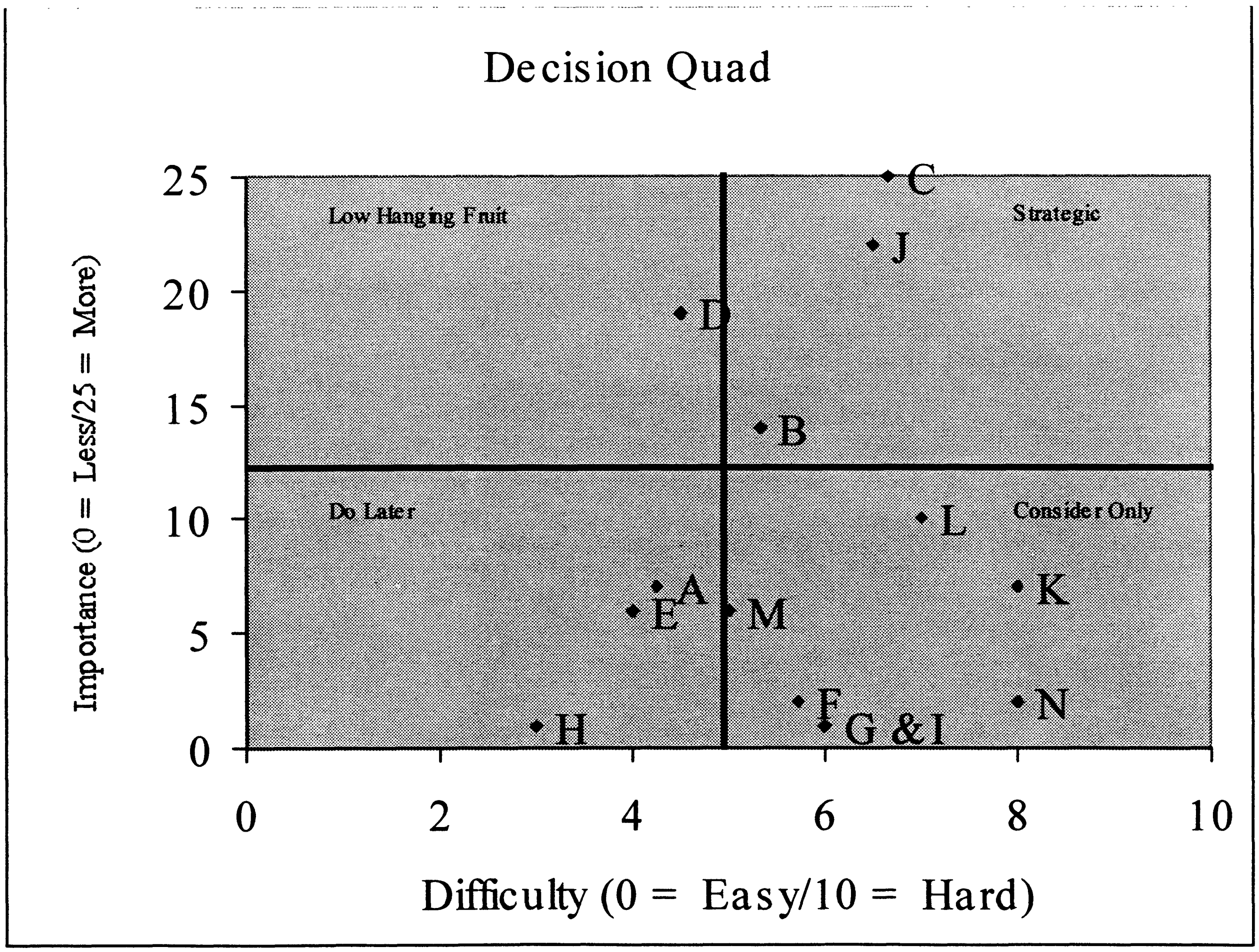
Using both types of data, a "decision quad" of the data was produced. The quad is formed by four quadrants in the data, each of which is given a descriptive name.

Quad : Easy and important : Low Hanging Fruit

Hard and important: Strategic Items

Easy but less important: Do later .

Hard and less important: Consider



Results

Item 3. Topics Developed for Future Research and Development Projects

Based on the issues developed and subsequently prioritized, workshop participants were askedto submit siggested research and development projects. Below is a sample of the form used by the participants to record their project ideas. Following the sample are copies of the completed forms as submitted by the workshop participants. The ideas therein constitute the research and development "deliverables" resulting from the workshop.

Survey on Research Pertaining to
Animal and Vegetative Impacts on Earthen Dams

1. Title/Description of Research Item:

____

2. Description
   A. Why is this a priority research item?

   ____

   B. What is the expected outcome?

   ____

3. Project Tasks and Needs
   A. What tasks are to be done?

   ____

   B. How is the problem to be solved?

   ____

4. Project Lead and Contact
   A. Who is working in this area?

   ____

   B. Who might be able to lead the project?

   ____

   C. Who are good candidates to complete the work?

   ____

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Root Longevity Pre/Post Development Following Various Control Methods

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

Based on presentations it seems that very little is known on what happens to roots on trees/brush on dams that have had some type of control conducted on them. Do roots of treated plants pose a problem to dams if not removed, covered with soil? The research item would give information regarding decay rates, (void development, soil types, PH) of roots following treatment.

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

Specific dams and sites could be located containing various types of dediduous, evergreen and shrubs/trees. Current controls could be applied to this vegetation and then monitored over a period of years. The observation period would need to be over a prolonged period of time based on soil types, rainfall and geographic location. It is possible that chemical agents other than herbicides could be added to the treated trees/brush to accelerate the decaying process. Labeled trees and brush could then be periodically unearthed to determine rates of decay. This work could potentially be conducted away from dam sites in small case studies which would mimic actual sites.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

I don't know of anyone working in this area. Dr. Marks would probably be able to lead this project.

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Plant and Animal Problems with Dams Booklet

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

Very important to educate dam owners about problems with penetrations and why we need to prevent and mitigate them. A booklet I can give to John Q. Dam-owner which clearly defines the problem, liabilities and corrective measures.

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

Current state-of-practice must be defined. Broad, general policies need to be developed, i.e. trees on dams are unacceptable. Research areas must be defined. A booklet or web-based document should be developed and made available.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

ASDSO, in conjunction with the BuRec and NRCS and private sector experts. A cross-agency workgroup.

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Research and Development – Allowable Proximity of Trees to Dams

2. Description

   A. Why is this a priority research item?
   B. What is the expected outcome?

Dam failures have been attributed to tree impacts at dams.

3. Project Tasks and Needs

   A. What tasks are to be done?
   B. How is the problem to be solved?

Evaluate actual impacts of trees (various species) adjacent to both water storage dams and flood control (dry) dams. Research needs to include field investigations, compilation of case histories, and recommendations developed from research.

4. Project Lead and Contact

   A. Who is working in this area?
   B. Who might be able to lead the project?
   C. Who are good candidates to complete the work?

Recommend large organization such as ASDSO or federal agency research this in cooperation with all having interest in dam safety.

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Development of Procedures for Repair of Animal Burrows in Dams

2. Description

   A. Why is this a priority research item?
   B. What is the expected outcome?

Dam failures have been attributed to animal burrows.

3. Project Tasks and Needs

   A. What tasks are to be done?
   B. How is the problem to be solved?

Evaluate different impacts by animals known to burrow on dams. Repair procedures to be developed for specific animal impacts, i.e., beaver dams, ground squirrel burrows. Procedures may require dam owner to determine site-specific impacts before selecting repair method.

4. Project Lead and Contact

   A. Who is working in this area?
   B. Who might be able to lead the project?
   C. Who are good candidates to complete the work?

Large organization involved with dam safety such as ASDSO.

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Manual for Minimizing Negative Impacts of Vegetation and Animals on Earth Embankment Dams

2. Description

   A. Why is this a priority research item?
   B. What is the expected outcome?

Write manual which 1) provides design guidelines for preventing or minimizing the occurrence of vegetative and animal problems, and 2) provides maintenance guidelines for removing and mitigating the impacts of existing problems due to vegetation and animals.

3. Project Tasks and Needs

   A. What tasks are to be done?
   B. How is the problem to be solved?

- Determine extent of problem (plants and animals)
- Determine current methods for dealing with problems
- Write manual and publish
- Provide training

4. Project Lead and Contact

   A. Who is working in this area?

   B. Who might be able to lead the project?

   C. Who are good candidates to complete the work?

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

ASDSO Regional Training Seminars "Plant and Animal Penetrations of Earthen Dams"

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

This topic categorized as a strategic activity that with some difficulty can be accomplished with or by use of the workshop manual to be developed from workshop. Engineer and owner awareness will be the desired outcome.

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

Proposals will be developed to present both regional and specialty training seminars to be sponsored through ASDSO.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

Dr. B. Dan Marks, S & ME, Inc.

Dr. Bruce Tschantz, UTK

David K. Woodward, NCSU

Charles Clevenger, MS

Dr. Nale Nolte, USDA-APHIS

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Develop Two Types of Owner Brochures for States:

1. Why keep trees and brush off dams?

2. How to remove and manage trees and brush on dams.

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

The dam owner needs information, and the state dam safety field people need reinforcement about why trees and brush have no place on dams. Also guidance on removing, managing and preventing such growth in order to help inspectors and to prevent potential failures.

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

- Review and compile existing literature,, state survey data, failure cases, state and federal procedures/policies to give rationale, basis.
- Develop a tri-fold, slick, colored brochure for states to give to owners. Allow space on manual for a given state to stamp their contact names, telephone numbers, address, etc. for obtaining additional information.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

B. Tschantz, University of Tennessee, (trees/plants); with a couple of state officials and consultants assisting. (C. Clevenger, D. Marks)

D. Woodward, NCSU (Also suggest a parallel set of brochures on animals.)

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Research Practice Manual on Use of Chemicals, Bio-barriers in Dam Applications

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

This product technique, which seems to be well-established for gen landscaping applications, has apparent promise for controlling trees/brush on earthen dams and at various other appurtenant structures associated with all types of dams. Such controls could eliminate potential tree & brush problems on dams.

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

- Review current literature on all available barrier products, techniques and applications in all types of protection situations.
- Document successful existing dam application prototypes (re: Bill Hawkins note re: a Montana dam use of Bio-barrier)
- Determine dam feasibility, assess application potential, recommend any further testing (field/laboratory)
- Develop a state-of-art report on current technology, constraints (cost, environmental, etc.), matrix of products/applications.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

Seek matching funds from Bio-barrier (Nashville) and other similar industry reps.

B. Tschantz, Univ of Tennessee, P.I., perhaps in cooperation with people from NRCS and US FS.

Also with Tom Renckly with Maricopa County FCD

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Effects Trees and Other Woody Vegetation Have on Earthen Dams, or "Trees Are No Friends to Dams"

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

To educate dam owners, engineers and government officials on the damaging effects tree roots and woody vegetation have on dams, especially earthen dams.

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

Specialized study on actual dams showing what effects tree roots have, how far into the dam do they penetrate, what effects the phreatic line has on roots. Do the study on an actual dam. Find some dam owners with these problems and get them to let a study be made on the inside of the dam.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

Dr. Bruce Tschantz, UT Knoxville

Dr. Dan Marks, S & ME

Also, a parallel on animals with Dave Woodward, NCSU, and Dr. Dan Marks, S & ME

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Collaborate with Ongoing Animal Damage Issues, Research and Operations

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

- Similarity of problems in other areas
- Reducing redundancy in addressing questions

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

Identify who is working on these problems. Ensure researchers are aware of concerns/needs of dam specialists.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

National Wildlife Center, Dick Curnow, Director (970/266-6000)

Wildlife Services – Regional offices

Raleigh, NC – Eastern Region: Gary Larson

Denver, CO – Western Region: Mike Worthen

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Handbook (weather-proof) for Dam Inspectors and Staff

2. Description

A. Why is this a priority research item?
B. What is the expected outcome?

Concise, basic technical information with illustrations which can be used to identify vegetative and animal problems or threats to dam safety and maintenance.

3. Project Tasks and Needs

A. What tasks are to be done?
B. How is the problem to be solved?

Involve engineering expertise, soils, vegetative, wildlife, and safety in developing current research knowledge and translating this into an extension type of handbook for use by dam inspectors and staff. Fact Sheet with more specific details can then be developed for use to address problems identified.

4. Project Lead and Contact

A. Who is working in this area?
B. Who might be able to lead the project?
C. Who are good candidates to complete the work?

ASDSO/Dam and wildlife services, state land grant university researchers.

We recommend that a state cooperative extension service specialist be contracted with to do this work.

Contact: James E. Miller, National Program Leader, Fish and Wildlife, USDA-CSREES/NRE, Rm 829 Aerospace Center, AG Box 2210, Washington, DC, 20250-2210

Results

Item 3. Topics Developed for Future Research and Development Projects

1. Title/Description of Research Item:

Guidelines/Awareness Document for Dam Owners

2. Description

    A. Why is this a priority research item?
    B. What is the expected outcome?

Concise, practical information written in non-technical language which would help landowners identify plant and animal threats or hazards and a list of state or federal agencies to contact for more information about specific problems.

3. Project Tasks and Needs

    A. What tasks are to be done?
    B. How is the problem to be solved?

Assembling known information and developing appropriate review to produce final document for dissemination and use by dam owners/community leaders and the public.

4. Project Lead and Contact

    A. Who is working in this area?
    B. Who might be able to lead the project?
    C. Who are good candidates to complete the work?

ASDSO/Dam and wildlife services, state land grant university researchers, state cooperative extension services

Contact: James E. Miller, National Program Leader, Fish and Wildlife, USDA-CSREES/NRE, Rm 829 Aerospace Center, AG Box 2210, Washington, DC, 20250-2210

Results

Item 4. Specialty Workshop Proceedings

Proceedings Table of Contents

The following is a compendium of papers presented at the Specialty Workshop on Animal and Vegetative Impacts on Earthen Dams. Papers are in the order of presentation.

Overview of Issues and Policies Involving Woody Plant Penetrations of Earthfilled Dams
9 - 10 am Tuesday, November 30, 1999

Bruce A. Tschantz, P.E.
Professor of Civil and Environmental Engineering
University of Tennessee, Knoxville 37996

Most dam safety engineers, including state and federal officials, consultants, and other experts involved with dam safety, agree that when trees and woody plants are allowed to grow on earthen dams, they can cause several problems relating to interference with safety inspections, safe operation, or even dam failure. However, engineers and dam safety experts are not in agreement about the best way to handle tree growth problems such as preventing or controlling growth, removing, and repairing safety-related damages caused by trees. This presentation will summarize the recent ASDSO state and federal (ICODS representatives) survey results from dam safety officials about their problems, practices and policies involving woody plant and tree growth on dams. State and federal agency attitudes will be summarized for the following tree and woody plant topics and issues:

- Types of dam safety problems caused by trees and other woody plants
- Policies and operating procedures or programs for addressing and removal of trees and woody growth from dams
- Recommendations by states and federal agencies where no formal policies or procedures exist for dealing with trees and woody plants on dams
- Legal, financial, environmental constraints to controlling unwanted vegetation
- Documented evidence of failures, accidents, incidences and operational problems linked to vegetative growth
- Current and past research efforts to understand and deal with effects of vegetation on dam safety
- Example remediation procedures, costs, contract specifications and photographs resulting from tree-caused repairs.

ASDSO Survey

In June 1999, ASDSO mailed out survey questionnaires relating to the above issues to all state dam safety representatives and ICODS agency representatives. The questionnaire contained two parts: Part I contained 7 questions relating to tree and woody plant-caused dam safety issues and Part II contained 5 questions relating to animal impacts on dam safety. Questions 1, 2, 5, and 6 on trees and woody plants were the same questions sent out by the author to the states in 1988 for comparison. This paper and presentation only addresses the tree and woody plant part issues.

The states and ICODS representatives were asked to respond, with comments, to the following 12 Parts I and II survey questions:

Part I: Trees and Woody Plants on Dams

1. Do you consider vegetative growth on earthen dams to be a problem for your organization? Comments:

2. Does your agency have a specific policy or operating procedures addressing the removal of trees/vegetation from earthen dams? Please provide a copy of your policy, and/or describe your operating procedures.

3. If your organization has no set policy or procedures, what do you recommend?

4. What legal, financial, environmental, or other constraints apply when your organization attempts to deal with problems caused by unwanted vegetation?

5. Do you have any documented evidence where vegetation has negatively affected the safe operation or have been linked to the failure of earth dams?

Comment and give examples, if available.

6. Are you aware of current or past research or documented discussions regarding the effects of unwanted vegetation on dam safety? Please list or attach known references.

7. If tree removal from earth dams is authorized by your organization, would you please provide available data for examples of procedures, costs, contract specifications, and photographs of rehabilitated dams?

Part II: Animal Impacts on Dams

8. What types of animals cause problems on earthen dams for your organization? Please describe the problems.

9. How do you deal with each species?

10. What legal, financial, environmental, or other constraints or issues arise when your organization attempts to deal with problems caused by animals on dams?

11. Do you have any documented evidence where animals have affected the safe operation or have been linked to the failure of earth dams? Comment and give examples if available.

12. Are you aware of current or past research or public discussions regarding the effects of burrowing animals on dam safety? Please list or attach known references.

Survey Results

Survey replies were received by October 8, 1999 from all states except Alabama and Delaware and from all ICODS representatives. Alabama indicated that there was no one available in that state for answering the questions and Delaware offered no survey response. Table 1 summarizes the state responses to woody plant questions 1, 2, 5 and 6 with comparative1988 state survey results shown. Table 2 summarizes responses to the remaining 3 woody plant questions, 3, 4 and 5. Detailed state responses and comments are available as a separate appendix.

State survey responses indicated that trees and woody plants are considered a problem in 48 of the 48 responding states. Of the 48 responding states, 24 noted that they have formal policies and/or operating procedures for addressing tree and woody plant growth issues and 24 states indicated that they didn't have formal policies or procedures. However, 16 of the states that don't have formal policies or procedures either evaluate each dam on a case-by-case basis, require owners to remove vegetation for inspection, or use other means for dealing with plant problems.

Other than a few references to the 1988 Tschantz and Weaver Tree Growth report (1988), only 1 or 2 other citations for tree or woody plant-related research were identified by the states.

The states had considerable response and comment regarding the question 4 reference to constraints to effective management of trees and woody plants on dams. Thirteen states cited financial limitations by owners, 10 referred to environmental and permitting requirements, 6 indicated legal issues, 5 esthetics, 2 endangered species, and 4 states cited other constraints.

Only 3 states (Massachusetts, Missouri, and Virginia) provided any cost information for removing trees or rehabilitating vegetated dams. Most states either indicated that they didn't have the data or that the owner or his consultant would have that information. Virginia reported that, while costs can be nominal, extensive tree growth situations where grubbing is required, $10,000 to $20,000 is common and that at one dam, the tree-clearing cost was about $40,000. Missouri reported that such costs can range from $1000 to $10,000 depending on how badly the dam is overgrown with trees.

Twenty-nine states indicated documented evidence where vegetation on dams has either caused dam failure or has negatively affected their safe operation. Sixteen states had no documented evidence and 5 states had no response. Several states provided photos and information on tree-caused failures or dam safety problems. Colorado furnished a PowerPoint photo presentation of an Air Force Academy dam failure in May 1999.

Table 3 summarizes 11 responses received from the Bureau of Reclamation, Corps of Engineers (3 divisions), Department of Energy (2 organizations), Mine Safety and

State	Consider Woody Vegetation a Problem?		Policies Concerning Woody Vegetation?		Documented Woody Vegetation Failures?		Aware of Reasearch?	
	1988		1988		1988		1988	
Alabama	Yes	NR	No C	NR	Yes C	NR	No	NR
Alaska	Yes C	Yes C	Yes C	No	No	No	No	No
Arizona	Yes C	Yes C	No	No C	No	No C	Yes C	No C
Arkansas	Yes C	Yes C	Yes C	Yes C	No	No	No	Yes C
California	Yes C	Yes	Yes C	No C	Yes C	No	No	No
Colorado	Yes C	Yes	Yes C	No	Yes C	Yes C	Yes C	Yes C
Connecticut	Yes C	Yes C	Yes C	Yes C	Yes	Yes C	Yes C	Yes C
Delaware	Yes C	NR	No	NR	No	NR	No	NR
Florida	No	Yes C	No	No	No	Yes C	No	No C
Georgia	Yes C	Yes C	Yes C	Yes C	Yes C	Yes C	No	No
Hawaii	No C	Yes C	No C	Yes C	No	No C	No	No C
Idaho	Yes C	Yes C	Yes C	Yes C	Yes C	Yes	Yes	No
Illinois	Yes C	Yes C	Yes C	No	Yes C	Yes C	Yes C	No
Indiana	Yes C	Yes C	Yes C	No C	Yes C	No C	No	No
Iowa	Yes	Yes C	No C	Yes C	No	No	No	No
Kansas	Yes C	Yes C	Yes C	No C	Yes C	Yes C	Yes C	No
Kentucky	Yes C	Yes	Yes C	Yes C	Yes C	No	No	Yes C
Louisiana	Yes C	Yes C	Yes C	Yes	No	No	No	No
Maine	Yes C	Yes	No C	No	No C	No	No	No
Maryland	Yes C	Yes	Yes C	Yes C	Yes C	No	Yes C	Yes C
Massachusetts	Yes C	Yes C	Yes C	Yes C	Yes C	Yes C	Yes C	No C
Michigan	Yes C	Yes C	Yes C	No	Yes C	Yes C	Yes C	Yes C
Minnesota	Yes	Yes	No	No	No	No	Yes C	No
Mississippi	Yes C	Yes C	No C	No C	No	Yes C	No	Yes C
Missouri	Yes C	Yes	Yes C	No	Yes C	Yes C	No	No
Montana	Yes	Yes C	No C	No C	No	No	No	No
Nebraska	Yes C	Yes C	Yes C	No	No C	Yes C	No	No
Nevada	Yes C	Yes	Yes C	Yes C	Yes C	Yes C	No	No
New Hampshire	Yes C	Yes C	Yes C	Yes C	No	No	Yes C	No
New Jersey	Yes C	Yes	Yes C	Yes C	No	No	No	No
New Mexico	Yes C	Yes	Yes C	Yes C	Yes C	Yes C	No	No
New York	Yes C	Yes C	Yes C	Yes C	Yes C	No C	Yes C	No
North Carolina	Yes C	Yes C	Yes C	Yes	No	Yes C	Yes C	No C
North Dakota	Yes C	Yes C	No C	No	No	Yes C	Yes C	No
Ohio	Yes	Yes C	Yes C	Yes C	Yes C	Yes C	Yes C	No
Oklahoma	Yes C	Yes	No	Yes C	Yes	Yes C	Yes C	No
Oregon	Yes C	Yes C	Yes C	No C	No	Yes	No	No
Pennsylvania	Yes C	Yes C	Yes C	Yes C	No C	Yes C	Yes C	Yes C
Rhode Island	Yes C	Yes C	No C	No C	No	No	No	No
South Carolina	Yes	Yes	Yes C	Yes C	Yes C	No C	No	No
South Dakota	Yes C	Yes C	Yes C	No C	Yes C	Yes C	No C	Yes C
Tennessee	Yes	Yes C	Yes C	Yes C	No	Yes C	No	No
Texas	Yes C	Yes	Yes C	No C	No C	Yes C	Yes C	No
Utah	Yes C	Yes	Yes C	Yes C	No C	Yes C	No	No
Vermont	Yes	Yes C	No C	No	Yes C	Yes C	No	No
Virginia	Yes C	Yes C	Yes C	No C	No C	Yes C	Yes C	Yes C
Washington	Yes C	Yes C	Yes C	Yes C	No C	Yes C	No	No
West Virginia	Yes	Yes	Yes	Yes C	Yes C	Yes C	Yes C	No
Wisconsin	Yes C	Yes C	Yes C	Yes C	Yes	Yes C	Yes C	No
Wyoming	Yes C	Yes C	No C	No	No C	Yes C	No C	Yes C

C - Comment furnished; NR - No response to questions

Table 1. 1988 & 1999 State Survey Responses for Woody Growths on Dams as of 10/08/99

State	Recommendations, Policy/Procedures? 1988*		Constraints To Policy? 1988*		Data Available On Costs? 1988*	
Alabama		NR		NR		NR
Alaska		Yes C		No		No
Arizona		Yes C		Yes C		No C
Arkansas		Yes C		No		No
California		Yes C		No C		No C
Colorado		Yes C		Yes C		No C
Connecticut		Yes C		Yes C		No C
Delaware		NR		NR		NR
Florida		Yes C		No C		No C
Georgia		No		No		No C
Hawaii		Yes C		Yes C		No C
Idaho		No		Yes C		No
Illinois		Yes C		No C		No
Indiana		Yes C		Yes C		No
Iowa		No		No		No
Kansas		Yes C		No C		No
Kentucky		Yes C		Yes C		No
Louisiana		No		Yes C		No
Maine		Yes C		No C		No
Maryland		No		No		No
Massachusetts		Yes C		No C		Yes C
Michigan		No		No C		No C
Minnesota		Yes C		No C		No
Mississippi		No		Yes C		No
Missouri		Yes C		No C		Yes C
Montana		Yes C		No C		No C
Nebraska		Yes C		Yes C		No C
Nevada		Yes C		No C		No
New Hampshire		Yes C		Yes C		No
New Jersey		No		No C		No
New Mexico		No		No C		No
New York		Yes C		No C		No
North Carolina		Yes C		Yes C		No
North Dakota		Yes C		No C		No
Ohio		No		No		No
Oklahoma		Yes C		Yes C		No C
Oregon		Yes C		Yes C		No
Pennsylvania		No		Yes C		No
Rhode Island		Yes C		No C		No
South Carolina		Yes C		No C		No
South Dakota		No		No C		No
Tennessee		No		Yes C		No
Texas		No		No C		No
Utah		No		No C		No C
Vermont		No		No C		No
Virginia		Yes C		No C		Yes C
Washington		No		Yes C		No C
West Virginia		No		No C		No
Wisconsin		Yes C		No		No C
Wyoming		Yes C		No C		No

C- Comment furnished; NR - No response to questions
*No 1988 data available for comparison

Table 2. 1999 State Survey Responses for Woody Growths on Dams as of 10/08/99

Organization	Do You Consider Woody Plants a Problem?	Do You Have Policy and Procedures on Dealing with Woody Vegetation?	Do You Have Recommended Procedures If No Policy?	What Legal, Financial , Environmental Or Other Constraints Apply To Issue?	Any Documented Evidence Of Woody Plants Causing Safety Problems or Failure?	Aware of Current or Past Research Related To Plants on Dams?	Any Available Data on Procedures, Costs, Contract Specs, or Inform. On Rahab. Dams?
BOR	Yes	Yes C		Comment	No C	Yes C	No C
COE/MV	Yes C	Yes C		Comment	Yes C	Yes C	No C
COE/SW	Yes	Yes C		Comment	No	Yes C	No C
COE/SW2	Yes C	No C	Yes C	Comment	No C	No	No C
DOE/ORNL	Yes C	No	Yes C	Comment	No	Yes C	Yes C
DOE/SRS	Yes	No C	Yes C	Comment	No	No C	No C
MSHA	Yes	No C	No C	No Comment	No	Yes C	No
NPS	Yes	Yes C		Comment	Yes C	Yes C	Yes C
NRC	Yes	No C	Yes C	Comment	No	No	No
TVA	Yes C	Yes C		Comment	No	No C	No
USDA	Yes C	Yes C		Comment	No C	Yes C	Yes C

C - Comment furnished

Table 3. 1999 ICODS Representatives Survey Responses for Woody Growths on Dams as of 10/08/99

Health Administration, National Park Service, Nuclear Regulatory Commission, TVA, and U. S. Department of Agriculture (NRCS). Detailed ICODS agency responses and comments are available as a separate appendix.

Generally speaking, the federal ICODS agency representatives that responded to the survey consider woody plants and trees to be a problem for dams. Most agencies have written procedures for dealing with trees and woody plants and those who don't (i.e., DOE and National Park Service) either use other federal agency procedures or make recommendations to licensees (i.e., NRC). Several states and agencies referred to Technical Notes 705 published by the USDA/SCS (1981) for their procedures.

Only the USDA/NRCS referred to documented cases where dam failure has been determined to be caused solely by trees, but noted that trees have masked other more serious seepage problems, which went undetected.

The Federal agencies had very little to offer in the way of references to current or past research regarding the effects of tree and plant growth on dam safety. The Corps referred to recent work at the Waterways Experiment Station. Reference was made to the Repair-Evaluation-Maintenance-Rehabilitation (REMR) Technical Report series for applicable research. The USDA/NRCS referred to the 1950's research work done at the ARS Hydraulics Laboratory in Stillwater, Oklahoma, on Flow in Vegetative Channels, which could have application to some emergency spillways.

A recent study, sponsored by ASDSO/FEMA, was completed in September 1999, by students at the University of Tennessee for the Steering Committee on Plant and Animal Penetration of Earthen Dams, to research the available literature body on woody plant effects on dam safety. Several types of sources and searches were inventoried, including ASDSO conference and workshop proceedings, ASCE technical journals and articles, USCOLD, direct email and telephone contacts of selected federal and state agency officials, universities, research laboratories and other data bases accessible through the National Technical Advisory Service (NTIS) and National Performance of Dams Program (NPDP). Copies of this bibliographic study, *Bibliography on the Effects of Woody Vegetation on Dams,* will be presented to workshop participants.

While only a few references were found on recent or current research of tree and plant effects on dam safety, several references about federal and state practices, policies and procedures for dealing with trees and vegetation were cited. Because some additional state and federal survey information has been received since this study was completed, the bibliographic summary will be updated in early 2000. The ASDSO workshop participants will be asked to help in this updating by reviewing this bibliography and providing additional information for each of these topical areas:

- woody plant physiology,
- documented examples of woody plant-caused dam failures, operation and maintenance problems,
- case histories related to tree-caused dam failures,
- current and past federal, international and other research activities,

- federal, state, international, and other organizational policies and practices for preventing and remediating woody plant problems, and
- federal, state or private cost documentation for removing or controlling trees and woody plants.

A companion PowerPoint summary presentation entitled, *Current Policies Toward Woody Plant and Tree Penetrations on Dams,* will be made available to all workshop participants.

Soil Conservation Service (SCS), U. S. Department of Agriculture, Technical Note 705 - Operations and Maintenance Alternatives for Removing Trees from Dams, South Technical Center, Fort Worth, April 1, 1981, 8 pp.

Tschantz, B. A. and Weaver, J. D., Tree Growth on Earthen Dams: A Survey of State Policy and Practice, University of Tennessee, Civil Engineering Report, November 1988, 36 pp. + Appdc. A & B.

CURRENT POLICIES TOWARD WOODY PLANT AND TREE PENETRATIONS ON DAMS

ADSO/FEMA WORKSHOP
ON
PLANT AND ANIMAL PENETRATIONS
OF EARTHFILL DAMS

KNOXVILLE, TENNESSEE

NOVEMBER 30 - DECEMBER 2, 1999

Workshop Poster Tree

2

CITED PROBLEMS CAUSED BY TREES AND OTHER WOODY PLANTS ON DAMS

- Overturning or uprooting cause large voids and reduce freeboard; reduce x-section for maintaining stability
- Decaying roots of dead trees cause seepage paths and piping problems
- Interferes with effective dam surveillance, inspection and maintenance for seepage, cracking, sinkholes, slumping, settlement, deflection, and other signs stress
- Discourages desirable vegetative cover and causes embankment erosion
- Obstructs emergency spillway capacity
- Falling trees may cause damage to spillways and outlet facilities
- Clogs embankment underdrain systems
- Cracks, uplifts or displaces concrete structures and other facilities
- Induces local scouring during overtopping
- Provides cover for burrowing animals
- Loosens compacted soil
- May tend to wedge open joints and cracks in foundation rock along abutment groins and toe of embankment and increase leakage potential

3

CITED BENEFITS OF TREES ON DAMS

- Embankment stabilization
- Esthetic and environmental qualities
- Livestock cover
- Reduced toe seepage
- Indicator of slope instability

4

TYPES OF WOODY PLANTS OF CONCERN

- Trees: Shallow (<3 ft.) - or deep-rooted (>3 ft.)
- Bushes and shrubs
- Vines - Kudzu and other
- Cacti, desert broom, sagebrush and other desert plants

5

1999 SURVEY QUESTIONS

- Do you consider vegetative growth on earthen dams to be a problem for your organization?
- Does your agency have a specific policy or operating procedures addressing tree growth or removal of trees/vegetation from earthen dams?
- If your organization has no set policy or procedures, what do you recommend?
- What legal, financial, environmental, or other constraints apply when your organization attempts to deal with problems caused by unwanted vegetation?
- Do you have any documented evidence where vegetation has negatively affected the safe-operation or have been linked to the failure of earthen dams? Comment and give examples, if available.

6

1999 SURVEY QUESTIONS (CONT.)

- Are you aware of current or past research or documented discussions regarding the effects of unwanted vegetation on dam safety? Please list or attach known references.
- If tree removal from earth dams is authorized by your organization, would you please provide available examples of procedures, costs, contract specifications, and photographs of rehabilitated dams?

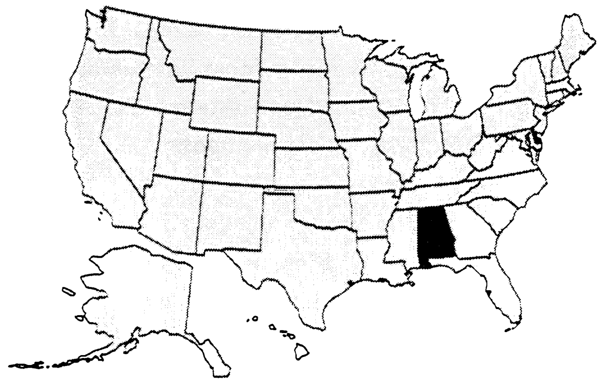
7

1999 SURVEY RESPONDENTS

- 50 STATES
- ICODS REPRESENTATIVES (USBuRec, COE/MV, COE/SW2, DOE/ORNL, DOE/Savannah River Site, MSHA, NPS, NRC, TVA & USDA/NRCS)
- OTHERS

8

STATE SURVEY FINDINGS

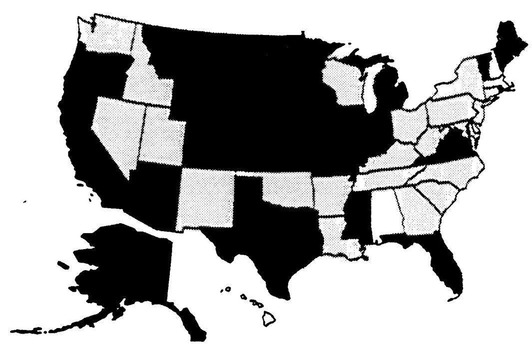


Q#1: Do you consider vegetative growth on earthen dams to be a problem in your state?

☐ Yes (48)
■ No response (2)

9

STATE SURVEY FINDINGS



Q#2 Does your state have a specific policy or operating procedure for tree growth and removal from earthen dams?

☐ Yes (24)
■ No (24)
☐ No response (2)

10

SCHOOLS OF THOUGHT ON DEALING WITH TREES AND VEGETATION ON DAMS

EXISTING DAMS:

- Distinguish between "small" trees and "large" trees
- Remove all trees, stumps, & roots from dam embankment
- Cut trees to ground level, but leave stumps and roots
- Cut trees, remove stumps, but leave roots
- Case-by-case basis
- Breach or remove dam
- Do nothing

NEW DAMS:

- Establish effective ground cover and hope for the best in continual maintenance
- Use vegetative barriers such as bio-barriers or silvicides/herbicides/chemical treatment

11

States Indicating a Formal Policy	Policy or Operating Procedure for Growth & Removal of Trees & Vegetation from Earthen Dams
ID, MA, NH, NV, NJ, NM	Trees have no place on dams or near toe and abutment; general statement
OH	Remove all trees and stumps, but roots may be left
LA, NC	Remove all trees, stumps and roots
AR, CT, GA, HI, MD, OK, SC, TN, UT, WI, WV	Remove all trees, leave the root systems of "small" trees; remove the root system of "large" trees
	Leave all "large" trees; remove all "small" trees
KY, NY, PA, WA	Treat on case-by-case basis (see all above); usually under direction of a qualified P. E.
Total = 24	

States Indicating Having A Specific Policy Or Operation Procedures Addressing Tree Growth and Removal of Trees From Earthen Dams

12

STATE SURVEY FINDINGS

Q#3: If your organization has no set policy or procedures, what do you recommend?

13

States	Recommended Procedures for Dealing With Growth & Removal of Trees & Vegetation from Earthen Dams
CA, IL, MN, MS, MT, RI	No specific written policy, but educate owner and make suggestions to remove; may recommend that a qualified engineer be retained
AZ, ME, TX	Evaluate on case-by-case basis; "dam must be adequately maintained"
AK, CO, KS, IN, MI, MO, NE, ND, OR, SD, VT, VA, WY	No written policy, but require owners to remove certain sizes or all trees & vegetation that hinder inspection; may require qualified engineer be retained; may depend on dam hazard category
IA	No policy
FL	Other
Total = 24	

Recommendations by States Having No Specific Policy Or Operating Procedures For Tree Growth and Removal of Trees From Earthen Dams

14

STATE SURVEY FINDINGS

Q#4: What legal, financial, environmental, or other constraints apply when your organization attempts to deal with problems caused by unwanted vegetation?

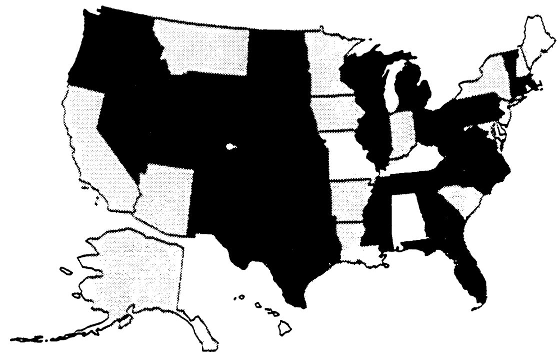
15

TREE REMOVAL POLICY CONSTRAINTS

- Financial limitations by owners (13 states)
- Environmental/Permits (10 states)
- Legal issues (6 states)
- Esthetics (5 states)
- Threatened/endangered species issues (2 states)
- Media (1 state)
- Other (1 state)
- Sentimental

16

STATE SURVEY FINDINGS



Q#5: Do you have documented evidence where vegetation has caused dam safety problems?

- Yes (29)
- No (16)
- No response (5)

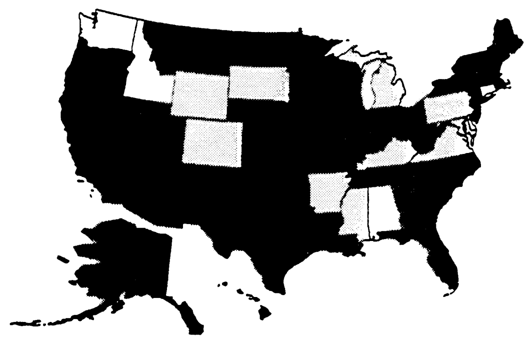
17

CATEGORICAL EXAMPLES OF CASES WHERE TREE GROWTH HAS AFFECTED SAFE OPERATION OR HAS BEEN LINKED TO DAM FAILURE

- CONTRIBUTED TO DAM FAILURE
- HINDERED INSPECTIONS
- CAUSED INTERNAL EROSION & PIPING PROBLEMS
- CLOGGED DRAINS
- PREVENTED PROTECTIVE VEGETATIVE COVER
- CAUSED VARIOUS TYPES OF DAMAGE FROM UPROOTING
- CAUSED SPILLWAY OR HYDRAULIC PROBLEMS
- CONTRIBUTED TO ANIMAL-CAUSED PROBLEMS
- CONTRIBUTED TO OTHER DAM SAFETY PROBLEMS

18

STATE SURVEY FINDINGS



Q#6: *Are you aware of current or past research on effects of vegetation on dam safety?*

- ☐ Yes (11)
- ■ Not aware (35)
- ☐ No response (4)

19

LISTED RESEARCH OR DISCUSSIONS ABOUT EFFECTS OF VEGETATION ON DAM SAFETY

8 states: Tschantz' & Weaver's November 1988 study, "Tree Growth on Earthen Dams: A Survey of State Policy and Practice"

1 state: Bold & Batcheler's 1997 ASDSO Conference paper, "Vegetation Control on Earthen Embankment Dams"

1 state: Texas' Website: Limited discussion vegetation & animal control in Texas' Guidelines for Operation & Maintenance of Dams
http://www.tnrcc.state.tx.us/water/quantity/flood/dam.html

1 state: ⊵SCS (NCRS) Engin. Series No. 705, April 1981 manual: "Operation & Maintenance Alternatives for Removing Trees from Dams"

20

STATE SURVEY FINDINGS

Q#7: If tree removal from earth dams is authorized by your organization, please attach available data or examples of procedures, costs, contract specifications, and photographs of rehabilitated dams.

21

TREE AND PLANT REMOVAL COST FACTORS

- Density and distribution of woody plant
- Type and species
- Extent and type of root system
- Size
- Site access
- Location of vegetation (i. e., crest, u/s, or d/s faces, groins, near outlet or drain facilities, rip-rap areas, structural walls or slabs)
- Normal lake level and potential fluctuations
- Type and slope of embankment or dam
- Disposal methods allowed
- Permit for environmental compliance requirements
- Extent and type of removal methods
  - Tree cutting
  - Stump & root removal (grubbing, excavation, grinding or chemical treatment)
  - Backfill, compaction & filter requirements
- Required engineering services

22

Organization	Do You Consider Woody Plants a Problem?	Do You Have Policy and Procedures on Dealing with Woody Vegetation?	Do You Have Recommended Procedures If No Policy?	What Legal, Financial, Environmental Or Other Constraints Apply To Issue?	Any Documented Evidence Of Woody Plants Causing Safety Problems or Failure?	Aware of Current or Past Research Related To Plants on Dams?	Any Available Data on Procedures, Costs, Contract Specs, or Inform. On Rahab. Dams?
BOR	Yes	Yes C		Comment	No C	Yes C	No C
COE/MV	Yes C	Yes C		Comment	Yes C	Yes C	No C
COE/SW	Yes	Yes C		Comment	No	Yes C	No C
COE/SW2	Yes C	No C	Yes C	Comment	No C	No	No C
DOE/ORNL	Yes C	No	Yes C	Comment	No	Yes C	Yes C
DOE/SRS	Yes	No C	Yes C	Comment	No	No C	No C
MSHA	Yes	No C	No C	No Comment	No	Yes C	No
NPS	Yes	Yes C		Comment	Yes C	Yes C	Yes C
NRC	Yes	No C	Yes C	Comment	No	No	No
TVA	Yes C	Yes C		Comment	No	No C	No
USDA	Yes C	Yes C		Comment	No C	Yes C	Yes C

C - Comment furnished

Table 3. 1999 ICODS Representatives Survey Responses for Woody Growths on Dams as of 10/08/99

23

USDA COMMENTS ON WOODY GROWTH ON DAMS

"Yes, trees are a problem. Removing trees from earthen dams is a continual challenge, especially in a state like Oklahoma that has over 2000 flood control dams. There are 3 basic challenges:

1. Educating landowners and watershed sponsors that trees on dams can result in potential serious problems in the future.

2. Obtaining funding for removing trees.

3. Practicing effective techniques for cost-effective methods for removing trees."

-Larry Caldwell, NRCS

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EXAMPLE FEDERAL AGENCY POLICIES & PROCEDURES FOR WOODY PLANTS ON DAMS

USBR - Has several related publications:

- Irrigation Operation and Maintenance - Herbicides (Bull. 52, Apr-Jun 1965)
- Water Operation and Maintenance - Weed Disposal (Bull. 97, Sep. 1976)
- Water Operation and Maintenance - Criteria for Removal of Trees, (Bull. 143), Mar. 1988)
- Water Operation and Maintenance - Guidelines for Removal of Trees and Other Vegetative Growth from Earth Dams...... (Bull. 150, Dec. 1989)
- Standing Operating Procedures Guide for Dams, Reservoirs, and Power Facilities - Maintenance & Inspection (Aug. 1996)
- Field Examination Guidelines - Appdx. B, Removal of Trees and Other Vegetative Growth from Earth Dams, Dikes ... , 1991

-Bill Bouley, USBR 25

FEDERAL POLICIES & PROCEDURES (CONT.)

USCOE:

- Repair-Evaluation-Maintenance-Rehabilitation (REMR) Technical Reports: T.Notes EI-M-1.4 (Levee Vegetation Mgt.; EI-M-1.3 (Vegetation and Struct. Integr. on Levees); EI-M-1.5 (Effects of Vegetation on the Structural Integrity of Sandy Levees)
- Policy Statement Regarding Tree Growth on Hydraulic Structures, Omaha District, May 1980
- Tech Manual EM 1110-2-301 (Policy)

-Tony Young, COE/MV

NPS:

- NPS Directives (NPS-40 & 87-4), TADS self-paced training modules, and other references to USBR manuals, incl. Operation and Maintenance Guidelines for Small Dams - incl. Trees & Vegetation, Animal burrows (Memo dated Aug 10, 1983)

-Charles Karpowicz, NPS 26

FEDERAL POLICIES & PROCEDURES (CONT.)

TVA:

TVA's guideline is that the slopes and 50 ft. below the slopes should be cut frequently enough to limit grass height to 6-10 inches and eliminate growth of trees, bushes, vines, etc. In areas where this is not possible TVA manages those sites on a case-by-case basis.

-James Varner/James Coulson, TVA

USDA/NRCS:

- Technical Note - Operations and Maintenance Alternatives for Removing Trees from Dams (SCS/USDA Engineering Note 705), April 1, 1981
- Technical Notes - Control of Trees and Brush on Dams (ENGIN.-OK-8), Stillwater, Okla., April 5, 1988

-Larry Caldwell, NCRS

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LISTED RESEARCH OR DISCUSSIONS ABOUT EFFECTS OF VEGETATION ON DAM SAFETY

- Review of Corps of Engineers Design for Rehabilitation of the Perimeter Dikes Around Cross Lake, Minn., James Duncan, Report to St. Paul Distr., July 14, 1999
- Waterways Experiment Station research (contact Milton Myers or Buck Taylor)
- TP-61: Flow in Vegetative Channels, ARS Hydraulics Laboratory, Stillwater, OK (1950's)

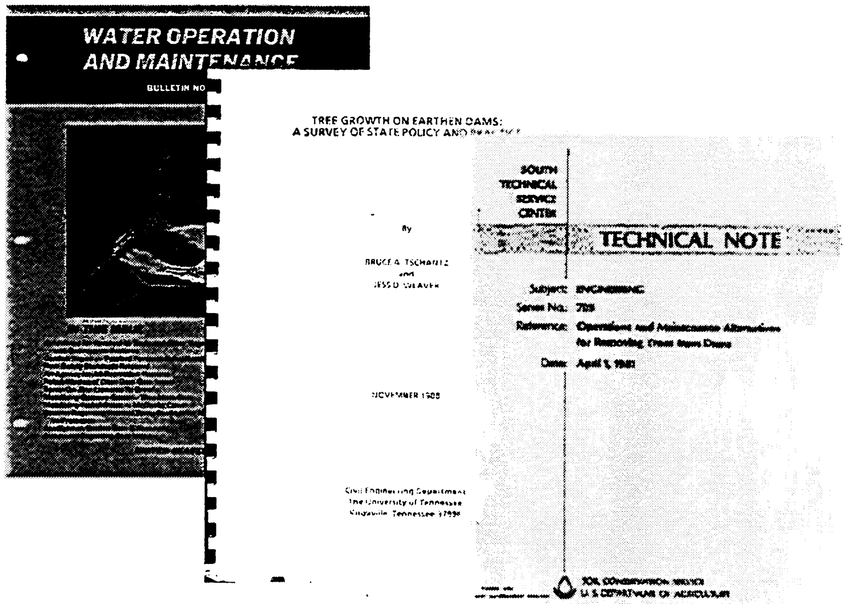
28

QUESTIONS?

29

The perfect, maintenance-free vegetation solution. . . .

30



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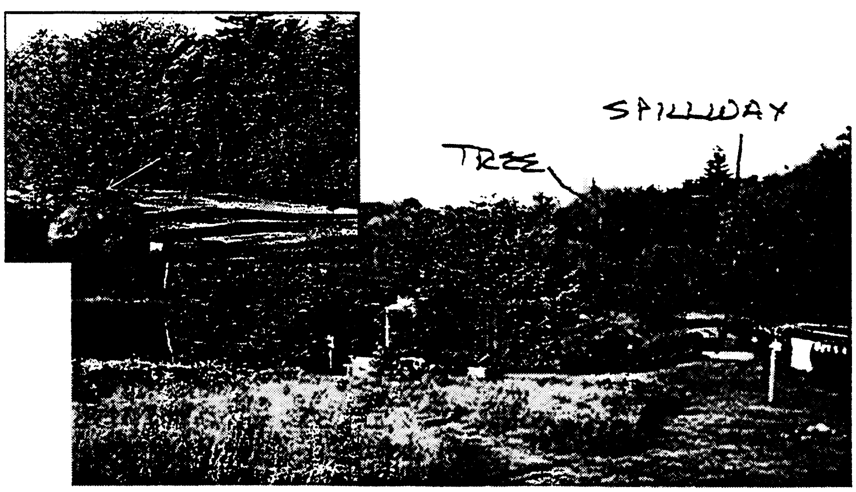
Elizabeth O'Grady's Tree



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Saving Elizabeth O'Grady's Tree.......

You may recall that from our limited telephone discussion on June 28, 1993 that we reached the following qualified conclusion. If all conditions concerning the tree and its location were as I described them to you, you felt that since the State of New Hampshire has in place a program of annual dam inspections for which Ms. O'Grady pays a fifty ($50.00) dollar annual inspection fee, it was logical to ask the State to consider the aesthetic value of the tree and allow it to remain in place, but to continue to monitor the dam with annual inspections for any problems which may be caused by allowing the tree to remain in place.

I would like to represent at the hearing on June 21st, that you have reviewed the enclosed letters and photographs, and although you have not visually inspected the dam in person, you feel that the tree should be allowed to remain given annual inspections by the State. If it is possible that in your professional capacity you could place this recommendation in writing to Ms. O'Grady, with any stated qualifications concerning the lack of an onsite visit etc., we would appreciate it, and be willing to pay you the appropriate fee for your time. Quite simply, we feel that the single pine tree is not a risk to the integrity of the structure of the dam, and we'd like to try and save it from arbitrary destruction.

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TOCCOA FALLS FAILURE NOVEMBER 1977

34

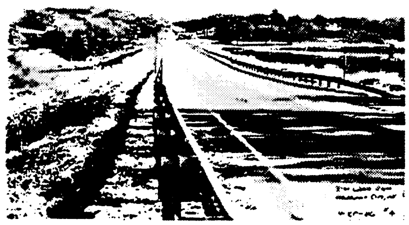
SERIOUS PROBLEMS FROM UPROOTING

35

SIGN OF SLOW SLUMPING

36

ZOO LAKE DAM, OKLA



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APPENDICES

State and ICODS Survey Results: Animal and Vegetative Impacts on Dams

(October 8, 1999)

Compiled by

Sarah Mayfield, ASDSO, Lexington, Ky.
and
Bruce Tschantz, University of Tennessee, Knoxville, Tn.

For

ASDSO/FEMA Workshop on Plant and Animal Penetrations of Earthfilled Dams
November 30 - December 2, 1999

UT Conference Center
University of Tennessee
Knoxville, Tennessee

A. ASDSO Survey Questions for States and ICODS

B. Detailed State Survey Question Responses and Comments

C. Detailed ICODS Survey Question Responses and Comments

A. ASDSO State and ICODS Dam Safety Survey Questions: Animal and Vegetative Impacts on Dams

Part I: Trees and Woody Plants on Dams

1. Do you consider vegetative growth on earthen dams to be a problem for your organization? Comments:

2. Does your agency have a specific policy or operating procedures addressing the removal of trees/vegetation from earthen dams? Please provide a copy of your policy, and/or describe your operating procedures.

3. If your organization has no set policy or procedures, what do you recommend?

4. What legal, financial, environmental, or other constraints apply when your organization attempts to deal with problems caused by unwanted vegetation?

5. Do you have any documented evidence where vegetation has negatively affected the safe operation or have been linked to the failure of earth dams?

Comment and give examples, if available.

6. Are you aware of current or past research or documented discussions regarding the effects of unwanted vegetation on dam safety? Please list or attach known references.

7. If tree removal from earth dams is authorized by your organization, would you please provide available data for examples of procedures, costs, contract specifications, and photographs of rehabilitated dams?

Part II: Animal Impacts on Dams

8. What types of animals cause problems on earthen dams for your organization? Please describe the problems.

9. How do you deal with each species?

10. What legal, financial, environmental, or other constraints or issues arise when your organization attempts to deal with problems caused by animals on dams?

11. Do you have any documented evidence where animals have affected the safe operation or have been linked to the failure of earth dams? Comment and give examples if available.

12. Are you aware of current or past research or public discussions regarding the effects of burrowing animals on dam safety? Please list or attach known references.

B. ASDSO State Representatives Survey Responses and Comments
Animal and Vegetative Impacts on Dams
(Received as of 10/8/99)

Part I: Vegetation on Dams

1. Do you consider vegetative growth on earthen dams to be a problem for your organization?

Y	AK, AZ, AR, CA, CO, CT, FL, GA, HI, ID, IL, IN, IA, KS, KY, LA, ME, MD, MA, MI, MN, MS, MO, MT, NE, NV, NH, NJ, NM, NY, NC, ND, OH, OK, OR, PA, RI, SC, SD, TN, TX, UT, VT, VA, WA, WV, WI, WY
N	PR
NR	AL, DE

Y-Yes; N - No; NR - No response

Comments:

AL: According to the listed ASDSO contact, Leslie Durham, Alabama does not have a Safe Dams program of any kind, and is not sure why she is even listed as a contact. This person has no comment on the question.

AK: Due to long days during the growing season, vegetation grows up rapidly and inhibits visual inspections. However, I do not have any records of specific performance incidents that are known to be caused by vegetation.

AZ: Arizona considers deep rooted vegetation to be a problem for dams under jurisdiction.

AR: After inspections we send report to owner to remove from dam.

CT: The CT DEP Dam Safety program does consider woody vegetation growing on earthen dam embankments to be problematic.

FL: Trees must be cut unless mature, and mature trees must be topped. Grassing is required. Vegetation must not block inspection.

GA: Vegetative growth on earthen dams is a problem for our program. During the annual inspections performed each year, we will find some dams that have inappropriate vegetation. This would include trees, brush, kudzu, and other growth on the dam. Georgia Acts and Rules address appropriate vegetation on dams. The biggest problem is when a dam is reclassified from Category II to Category I it is likely that the dam will have trees, brush, weeds, etc.

HI: Yes, vegetation overgrowth on earthen dams in Hawaii is a huge problem. Many of the plantations have reduced their maintenance staff due to a downturn in the economy resulting in vegetative overgrowth on their dams.

ID: Can be if not controlled. IDWR requires removal of large woody growth. Encourage seeding with grasses or grains to control surface erosion.

IL: We believe that trees and other deep-rooted vegetation cause long term problems for earthen dams. Brush and weeds on dams makes them difficult to inspect and provides cover for animal burrows. A well-maintained and mowed grass cover provides excellent erosion control and inspection capability.

IN: Woody growth is a problem.

IA: Tree, brush or excessive weed growth on embankments or sparsely vegetated embankment are a concern for the dams that this agency owns as well as the dams that we regulate. Decaying tree roots can create voids through an embankment, trees blown over or simply falling over can weaken embankments or reduce the crest width. Excessive tree, brush or weed growth can hamper thorough inspection and hide problems. Sparsely vegetated embankments can allow surface erosion.

KS: The growth of woody vegetation prevents the thorough inspection of the dam and can pose a risk to the earthen embankment. It can also pose a risk to the inspector. On the other side of the coin a dam can have little or no cover. This is an unacceptable condition also, as severe erosion damage tends to occur.

LA: Louisiana has a significant number of our earthen embankments with trees growing on them. Louisiana's climate and fertile soil fosters rapid growth of grass, brush, and trees.

MA: Trees and other woody vegetation are serious problems. The vegetation makes inspecting difficult and most dams in Mass have trees growing on them. The conservation commissions in the State do not like it when we order tree removal from dams. They consider the trees as part of scenic vistas and they believe the trees stabilize the dams. The estimated cost of tree removal is 50 to 100 million dollars.

MI: Yes, a nearly universal problem. It is sometimes tough to convince a dam owner that the beautiful trees he/she planted 30 years ago are a threat to his dam embankment.

MS: Trees, woody vegetation, vines, briars, etc. keep grass from growing, thereby contributing to erosion. Tree roots have been known to contribute to dam failures also. When a tree on a dam blows over the rootball leaves a large hole.

MT: The usual vegetative growth is trees and brush.

NH: Yes. The presence of trees and brush is the most common deficiency cited in response to dam safety inspections.

NY: I'm answering from the point of view of a state regulatory agency.

NC: The State of North Carolina requires low-growing grasses, such as Fescues, Bermuda, or Centipede grass types. High-growing vegetation such as trees, bushes, brush, sericea lespedeza, weeping lovegrass, and crown vetch are not permitted.

ND: Trees are the major vegetative growth problem.

OH: Large trees, dense brush, and crown vetch are big problems for dams that we periodically inspect.

OR: The problem is two-fold, with separate consequences:

- Low shrubs, dense undergrowth – makes viewing ground surface and getting access to embankment slopes for inspection very difficult. Impact on earthen dam from these type root systems may be slight to none; however, burrowing animals often use the under story for habitat and protection from natural predators. (See Part II.)
- Large trees or invasive phreatophytes – the root systems can cause significant damage to embankments by providing seepage pathways or can result in a sudden breach of the dam if the tree is blown over during a storm.

PA: It is one of the primary maintenance headaches for dam owners. From time to time the removal of tree growth on dams can be controversial. However, on new dams it's much easier to deal with.

RI: Please note that all responses are based on my experience during the last six months.

SD: Many owners do not want to remove trees.

TN: We do not consider appropriate vegetation such as Bermuda grass or tall fescue to be a problem. Inappropriate vegetation such as honeysuckle, brush and briars, and trees are not allowed to remain on the dam.

UT: Problems:
1. Habitat for burrowing animals
2. Dies and leaves piping channels
3. Makes inspection difficult
4. Can blow over and root wad breach crest

VT: Roots damage embankment. Provides cover for burrowing animals, makes inspection difficult and may conceal defects.

VA: This can be either too much or too little. Too much usually involves undesirable plants, shrubs, or trees. A significant number of dams have an on-going problem with one or the other. Trees and other excessive vegetative growth is probably the single biggest problem we have with dams. In most cases, it is simply a matter of the owner not recognizing the importance of their control until, over the years, the trees grow to such a size that they have become unmanageable.

Some dams lack sufficient vegetation. The lack of a dense, low growing grass cover has resulted in sheet, rill, and gully erosion on several dams.

WA: Four negative impacts of uncontrolled vegetative growth:
1. Hampers visual inspection of dam embankment for seepage, slides, etc.
2. Tree roots can intercept seepage line within dam.
3. Blowdown of large trees can leave large void in dam, lead to slope failure.
4. Supports burrowing animal habitat.

WI: Many of the dams we inspect have excessive growth of woody vegetation.

WY: Most lay people think trees are good to have on dams. Dams also commonly have heavy brush which owners generally do not feel the need to control, which makes inspections difficult.

2. Does your agency have a specific policy or operating procedures addressing tree growth and removal of trees/vegetation from earthen dams?

Y	AR, CT, GA, HI, ID, KY, LA, MD, MA, NV, NH, NJ, NM, NY, NC, OH, OK, PA, PR, SC, TN, UT, WA, WV, WI
N	AK, AZ, CA, CO, FL, IL, IN, IA, KS, ME, MI, MN, MS, MO, MT, NE, ND, OR, RI, SD, TX, VT, VA, WY
NR	AL, DE

Y-Yes; N - No; NR - No response

AZ: Arizona does not have a specific written policy.

AR: See attached rules and regs., Subtitle VIII – 706.3 and 706.4.

CA: No. We provide dam owners with the attached suggestions on vegetation control.

CT: General "tree-on-dam" policy:
a) By regulation, no woody vegetation is allowed on dams or within 25' of an embankment toe.
b) Trees greater than 6" must have stumps (and roots) removed. (See enclosed specifications.)

GA: The Safe Dams Act has a section that references vegetation. It states that dams shall be protected from surface erosion by appropriate vegetation on some other type of surface. Examples of appropriate vegetation such as fescue and Bermuda are given. The Act also states that inappropriate vegetation such as trees should be removed after consultation with the Safe Dams Program. Hedges and small shrubs may be allowed if they do not interfere with the maintenance and operation of the dam. This same information is also contained in the Rules for Dam Safety.

The following rule of thumb is applied with respect to the removal of trees. If the trunk is less than 8 inches in diameter then the tree can be cut and the stump left. Otherwise, the entire stump must be cleared and grubbed.

HI: See attached sheet on Criteria for the Removal of Trees, Vegetative Growth and Rodent Burrows from Earth Dams

ID: One of the routine maintenance items that's required to be performed, periodically.

IN: We have practices, but not a written policy or guidelines.

IA: There is no written policy on tree/vegetation removal from dams.

KS: The only specific requirement is the permit condition that states the dam will be maintained in a manner satisfactory to the Chief Engineer. Trees on dams is not satisfactory maintenance.

KY: We evaluate every site where vegetation is a problem on a case-by-case basis. Where practicable we have trees and other brushy vegetation removed. In some few cases, this would have required the removal of many, large trees, which we were afraid would have caused serious problems in itself.

LA: All trees, brush, shrubs, and other woody growth must be removed from earthen dams (See attached specifications.)

MD: See Attachment A.

MA: Standard language in all of our reports calls for removal of all trees and woody vegetation in the vicinity of the dam and spillway.

MI: We have no specific policy or written procedures. Tree removal is considered a maintenance item, for which a permit is not required. If the impoundment is drawn down significantly in order to remove the trees, then a permit would be required. We have a fact sheet on removal of trees and brush on our homepage.

MS: Nothing written. Office policy is to cut level with the ground anything 6" or less. Everything else must have the stump and roots removed. We do not require 6" or less to remove stump and roots.

MO: We have no formal written policy.

MN: No specific policy or procedures

MT: Nothing in writing, removal of trees especially before they are larger than 2 inches in diameter is a lot less work than when they are larger. Larger trees require the roots to be grubbed out. Small brush or willows are allowed in certain areas to provide wildlife habitat if it does not obstruct viewing structures or operations of the dam.

NV: Nothing specific other than the guidelines I had sent you earlier where we outline what to look for when expecting dams and of course vegetation growth is a part of the inspection. I would estimate that 80% of our dam inspections find that the dam needs to be cleared of vegetation.

NH: State statute indicates that it is the duty of every dam owner to maintain his/her structure such that it does not become a "dam in disrepair" (essentially, this is a structure that is incapable of performing the tasks of withholding or releasing impounded waters safely).

NJ: All woody vegetation must be removed from embankment dams. The department has no specific procedures for this removal. The department requires that a New Jersey licensed professional engineer develop the specific tree removal plan for each case. The department does use published guidelines (i.e. Bulletin No. 143, Bureau of Reclamation, SCS Technical Note 705) as a reference.

NM: Our agency views trees and other "woody type" vegetation (i.e. thick, heavy brush) to be detrimental to the safe operation of a dam. Native grass and very small brushy vegetation is usually acceptable because it generally protects from erosion. However, all vegetation must be monitored carefully to assure that rodent infestation does not also become a problem.

NY: Trees and brush are not permitted on earth dams. See Section 9.4 of "Guidelines for Design of Dams" (Guidelines).

NC: Please see attached.

OH: We have a fact sheet addressing trees and brush on dams. The fact sheet can be found on our web site at the following address: www.dnr.state.oh.us/odnr/water/
Click on Publications, Fact Sheets, 28 Dam Safety: Trees and Brush

OK: We recommend all trees to be removed by flush cutting. If there are a large number of old trees, we recommend a filter blanket be installed and additional fill to stabilize the filter.

OR: No, Oregon Dam Safety does not have a specific written policy.

PA: See attached fact sheet. Every new permit we issue contains a special condition prohibiting woody growth and requiring mowable groundcover.

PR: Yes. Our policy is that trees on the embankment should be cut at about six feet high, without killing them to avoid roots enlargement.

RI: RI does not have a policy for tree removal.

SC: Our policy is to have the vegetation cut so that an adequate inspection can be made. For old (pre-law) dams that were overgrown with trees at the time the inspection program started, we have allowed healthy trees more than 6" in diameter at ground level to remain on the dam as long as the tree is upright. Trees less than 6" in diameter must be cut, with trees of hardwood variety having their stumps treated to prevent regrowth. If the owner elects to remove trees larger than 6", he must pull stumps and fill holes.

SD: No specific policy, we generally recommend remove all trees and root systems of those 4 inches diameter or larger.

TN: All trees larger than 4 inches in diameter shall be cut and the stumps grubbed out. Smaller trees may either be cut at ground level or be removed from the dam.

TX: No written regulation or operating procedure. Texas has a general rule, §299.2(c), which states: *Dams and associated facilities must be adequately maintained throughout their lives, ... If abandoned at any time, a dam must be removed or breached in a manner to eliminate any hazard to life and property downstream.*

UT: Yes – See attachment.

VA: Not a specific policy. We do have a FACT SHEET (No. 3, copy attached) which we use as a guide when working with owners and engineers.

WA: Yes. Operating procedures. Evaluate on a case-by-case basis. If vegetation hampers inspection, has roots that could intercept the phreatic surface, is large enough to topple, and/or supports burrowing animal habit, it must be removed. If vegetation is sparse, and doesn't meet any of the above problems, then it can remain in some cases.

WV: 17.2.a. Removal of Trees and Tree Roots - All trees shall be removed from the embankment and abutment areas, unless otherwise approved by the director based upon site-specific conditions. Small trees with a base diameter of four (4) inches or less may be removed without removing the root system unless specific problems with the root system are evident. Larger trees may require special care in removal. The director may require the removal of root systems of large trees if the potential for seepage along the root system exists. If removal of root systems requires extensive excavation of the embankment, the removal shall be considered a major repair requiring a complete application for a certificate of approval.

WI: We have a standard paragraph that we put in all reports where woody vegetation is an identified problem that reads as follows..."Tree removal is important for a number of reasons. Tree root systems have been know to penetrate concrete and masonry structures, causing damage. Trees can topple over in a severe storm taking with them a portion of the earthen embankment. Trees grow old, die and topple over and/or leave their root system in the embankment to rot and provide a path for seepage. Tree roots have also proven to be attractive to burrowing animals for use as homes. All of these things lead to the same end, a risk of failure. By eliminating the trees from the embankment you reduce the risk of failure caused by tree growth. In most cases, we require removal of the tree and root systems down to one inch in diameter.

WY: Nothing in current regs or law. See #3.

3. If your organization has no set policy or procedures, what do you recommend?

AK: Regular clearing of brush to facilitate inspections

AZ: Arizona usually evaluates each dam and hazard potential on an individual basis. However, we typically recommend that owners remove deep rooted vegetation. We especially recommend this if the diameter of the trunk is larger than 1 to 2 inches, and the dam is High Hazard. We also require removal of vegetation as needed to allow visual inspection of the embankment. Trees smaller than 2 inches in diameter are typically accepted by cutting the trunk at the ground surface. Larger trees and vegetation usually require removal of the root ball and filling the hole with compacted fill materials.

On several low hazard dams, large trees have been in place for years and have not been removed and repaired; typically, we do not see that a significant safety benefit would be gained by removal and repair. Usually, the tree removal would affect a major portion of the embankment.

AR: See above.

CA: We have guidelines for the control of vegetation on dams. The owner is directed on a case by case basis to abate particular vegetation. The reason for the abatement is explained and the desired goal explained. The means and methods are left to the owner.

CO: We order the dam owner to remove trees and brush from the dam slopes, crest, and toe to prevent deep-rooted systems from weakening the embankment and to facilitate visual inspection of the dam.

CT: See #2 above.

FL: See comments above.

HI: See attached sheet on Criteria for the Removal of Trees, Vegetative Growth, and Rodent Burrows from Earth Dams.

IL: See attachment.

- Trees – remove the tree and as much of the root system as possible; place compacted clay soil in the excavated area; cover with top soil, and seed the area with grass.
- Brush & Weeds – mow, burn, or scrape as appropriate; fill eroded areas; seed the area with grass

IN: We recommend grass vegetation that is mowed several times a year. Any woody vegetation should be removed.

IA: The department recommends that dam embankments be kept clear of trees and brush and that a vigorous stand of suitable grasses be maintained on the dam. If trees or brush do become established on an embankment, we recommend that they be removed and that an appropriate vegetative cover be re-established. We also recommend that the larger roots be grubbed out.

KS: The promotion of the growth of grasses (native mixes tend to be more maintenance free) and the removal of all trees from the dam.

KY: Trees of less than about 4 inches in caliper should be removed and the embankment repaired. Large trees should be left in place, but watched carefully. If any indication of problems arise, the removal of such trees should be treated as a major structural activity. The lake level should be reduced before removal begins. Trees of intermediate size would need to be evaluated to see if they should be handled as one of these extremes or at some point in between.

ME: Take each case on its merits. Generally remove all shrubs and trees including root structures.

MA: I am taking every opportunity to educate dam owners and environmental regulators to the point that trees do not belong on dams.

MI: We typically recommend removal of trees and brush. We also recommend stump removal, with precautions depending on the condition of the earth embankment, seepage conditions, etc. Staff use professional judgement on some earth embankments, with the possibility of trees being allowed on the embankment, where the embankment is massive, or on certain low hazard dams.

MN: We recommend removal of trees and brush and weeks from dams.

MS: Same as #2.

MO: We require dam owners to remove all trees from the dam and any other type of vegetation that hinders the visual inspection of the dam (i.e., briars, thick brush). We generally promote the development of a good grass cover on the dam. In removing trees, we ask for them to be cut off as close to the top of the ground as possible. We prefer this to pushing the trees over and pulling up the roots.

MT: See above.

NE:

a. Cutting of trees and treating stumps to prevent regrowth.
b. Periodic mowing when needed to control weedy growth that is inhibiting the growth of grasses.
c. Controlled burning (where permitted) to control residue accumulation when it interferes with proper inspection.

NV: Depending on the size of the growth. For small rabbit brush, greasewood etc. we want it removed completely. For small willows (up to a few inches in diameter) and similar vegetation, we also want it removed from the embankment. Large trees, i.e. cottonwoods etc., if it is possible to completely remove the tree and trunk and backfill root system with structural fill, then we would like to have the tree removed. Otherwise, we would like to have the tree limbs trimmed back so that high winds can't blow it over, thus causing a possible breach of the dam.

NH: Generally, all trees and brush on or within 10 to 25 feet (depending upon the structure affected) of all structures are required to be removed.

NJ: See 1 & 2.

NY: We recommend tree and brush removal, and establishment and maintenance of a low vegetative cover. There are a few reference documents we use.

NC: See item #2.

ND: Brush and trees along embankments should be completely removed, including their root systems, since decaying tree roots may become passageways for water through the embankment.

OK: See #2.

OR: We recommend that a good cover of grass or similar carpet-type vegetation be cultivated on embankment slopes, and work to dissuade owners from allowing any vegetation to grow to heights greater than one foot (12").

RI: We recommend removal of all vegetation. However, if larger trees are present on the embankment, we recommend that the owner retain a qualified engineer to determine which trees can be removed without damaging the embankment.

SC: See #2.

TX: All brush and trees with a trunk diameter of approximately 4 inches or less should be cut from the entire dam. Care should be taken to avoid damage to the structure. The larger trees should be properly trimmed to allow the penetration of sunlight to the dam, and help encourage the establishment of a good, protective grass cover. The larger trees and associated root systems should only be removed from the embankment under the supervision of a licensed engineer experienced in dam design, construction and maintenance. However, all trees and brush should be removed from the spillways to allow the unobstructed passage of floodwaters.

VT: Cut brush less than 4" DBH. Cut trees over 4" DBH with qualified supervision and remove roots. Mow at least annually.

VA: See Item 2.

WI: See above.

WY: We tell owners of High and Significant hazard dams to remove trees and brush (bluff). Low hazard dams, we recommend that owner remove them.

4. What legal, financial, environmental, or other constraints apply when your organization attempts to deal with problems caused by unwanted vegetation?

AK: No comment

AZ: Arizona finds that we must always deal with dam owners who have limited financial capabilities. We also encounter problems with environmental permits being required for larger projects. On smaller maintenance issues there are concerns about Threatened and Endangered Species. Each situation is unique. We do believe that most of these problems are minimized by active, annual maintenance by the dam owners and believe that we should be diligent in following up on this.

AR: None – rules control.

CA: See the answer to #3. The owner often cites as reasons for delays in abatement, the constraints presented by legal, financial, environmental, and other processes. It remains the owner's responsibility to perform the abatement.

CO: We try to be reasonable when issuing orders, but the safety of the dam and the downstream lives and property is paramount. If the legal, financial, environmental, or other constraints are significant, the dam owner has the choice of abandoning the dam to preserve the trees.

CT: Constraints are "dam" specific. Generally, dam owners just plain do not want to cut trees, particularly if they have planted ornamental trees/shrubs on their dam.

FL: Removal is the dam owner's responsibility.

GA: None

HI: The Department conducts an inspection of the dam accompanied by the irrigation manager. During the inspection, if vegetative overgrowth and large trees are observed on the top and embankments of the dam, the irrigation manager is advised:

Proper maintenance of dams and appurtenant structures requires the periodic removal of all undesirable vegetation within the defined areas. If not removed, the effect of this growth may be detrimental to the safe operation of the features and can also lead to structural failure.

The Criteria for the Removal of Trees, Vegetative Cover and Rodent Burrows from Earth Dams is given to the irrigation manager. A reasonable time is given for him to remove the vegetation overgrowth and trees. If they are not removed, a notice of deficiency is sent to him and the State Attorney General will begin legal proceedings. A majority of the dam owners comply before the notice of deficiency is issued.

ID: Impose reservoir (operating level) restrictions until removal work performed.

IL: Primarily it is only a reluctance to do the necessary work.

IN: Financial constraints apply; many people say they cannot afford the expense of removing large woody vegetation and the repair to the structure that may be needed in order to get roots out of the structure. Additionally, there are environmentally-inclined individuals who seem to think that the more woody vegetation on a structure, the better things are.

IA: None known

KS: The main restriction tends to be financial. Most owners understand the need for satisfactory vegetation and often see the problems related to too much or too little growth, but time and money restrict their response.

KY: If this means "what constraints would be acceptable reasons for a dam owner <u>not</u> to remove trees from dams", there are no such constraints. We would, of course, work with an owner to minimize the financial burden, as long as this in no way prolonged a threat to the public. Owners also would have the right to contest our directives to perform such maintenance through both administrative and judicial appeals

LA: If deficiencies are found in a dam during inspection, including unwanted vegetation, the Assistant Secretary, Public Works & Intermodal Transportation is empowered to request the owner of the dam to perform the remedial work (LA R.S. 38:24). The right of the state to take over a dam in the event of an emergency is stated in LA R.S. 38:26B.

ME: Untested as yet. Legally nothing in Maine law specifically states that dam owners should remove vegetation.

MD: None I am aware of.

MA: . We have little legal power to force removal. We usually end up doing battle with the owner and environmentalists. Not enough money around, some of this work could cost $3,000 to $6,000

MI: We are not sure that there are any legal constraints. Financial constraints are, of course, of concern to the dam owners. Environmental constraints may limit the application of certain herbicides that may be considered for application, especially near watercourses. Also, one effective control method in many instances, that is definitely not encouraged here, is quick burning of the vegetation. Done properly, it does very little damage to root structures, but it can be risky under windy conditions that often occur in Michigan, and there is considerable concern regarding air quality consequences.

MN: Opposition viewpoints:

- Expensive to remove
- The trees provide aesthetic benefit.

MS: Primarily financial, on the part of the dam owner.

MO: When dams have not been maintained for several years, the vegetation can quickly get out of control. This can result in a lot of hard work for the owners to regain control. Hiring someone to do this work can be quite expensive for the owners.

MT: None so far. Usually getting the dam owner motivated to accomplish the needed annual maintenance is the main problem.

NE:

a. Cost (financial) is a big factor, especially on privately owned dams.
b. Environmental (burning prohibited) is sometimes a factor.
c. Some owners of private dams intentionally plant trees to provide shade and improve the looks of the dam. These owners can be reluctant to remove the trees.

NV: In ridding a dam of vegetation, typically, the dam owner will burn it off; however, sometimes the owner wants to use a herbicide, which is fine, and we would normally steer the owner to the Dept. of Agriculture or perhaps our sister agency, Environmental Protection to get names of appropriate herbicides.

NH: DES issues documents (administrative orders, letters of deficiency and notices of inspection) to dam owners related to addressing these types of deficiencies at dams. In some cases, it is necessary to enlist legal assistance to perform enforcement functions.

NJ: No constraints apply. The State of New Jersey considers the safety of the dam structure to be of primary importance.

NM: In some cases there has been some environmental concern in regards to using herbicides to control vegetation.

NY: Many parties find trees aesthetically pleasing and object to their removal. Owners would rather not spend the money on removal and on proper maintenance. Vegetation removal and maintenance can be at odds with wetland protection.

NC: The North Carolina Dam Safety Program has broad statutory and regulatory authority to require the removal of trees from dams. Costs are to be incurred by the owner.

ND: The usual constraint is that the brush and trees are of such a mature age. Trees that are of the greatest maturity have a more extensive root system. Therefore, greater effort (excavation) is required for the removal. The greater effort creates a greater financial constraint. In some cases, the financial constraint is the only existing constraint.

OK: If there is a problem with tree removal, we require the owner to provide a statement from a registered professional engineer that the trees will not cause a problem on the dam. !!!

OR: In the situation of a recalcitrant owner, a Proposed Order (legal process) can be initiated by Dam Safety to correct the situation if determined to be an immediate threat to the integrity of the structure. However, this approach is rather lengthy and can be expensive when staff time, materials, and attorney fees (hearings officer) are included in the costs of preparation for a contested case hearing. Also, a variable amount of "bad press" is generated any time Big Brother issues an order against a poor, downtrodden citizen or insolvent municipality.

PA: Sometimes the removal of unwanted vegetation can be a financial problem above and beyond normal maintenance costs. The environmental impact of removing large stands of trees sometimes makes it more difficult to get dam owners to remove the trees.

PR: None.

RI: Legally, RI is not allowed to require tree removal; we can only make recommendations. Environmentally, there is an exemption in the governing regulations (Wetlands Regulations) which allows removal of vegetation for dam safety maintenance

SC: Oftentimes, the owner will not voluntarily cut or remove the vegetation, and the only course of action is to start legal action against him. But legal help is limited and must be saved for the most extreme cases. This means that only a few owners can be forced to do something.

SD: We have a small dam where the embankment is ½ "state owned" and ½ "private owned". The state started to remove trees and vegetation, but the private owner did not allow any tree removal on his half.

TN: We deal with problems caused by unwanted vegetation based on the law and we do not have any constraints.

TX: Environmental issues arise when dams are located in parks or environmentally sensitive areas, especially when endangered/threatened species habitat is involved * which also then brings in legal constraints. Private dam owners provide financial constraints for not removing undesirable vegetation.

UT: The biggest problem is complaints from neighbors about aesthetics.

VT: Too many dams, not enough money.

VA: Dam safety concerns on vegetation often conflict with other perceived benefits of the vegetation. Examples – aesthetics, low or no maintenance.

WA:

- Legal - Our statutes allow us to require changes in maintenance as needed to protect lives and property.
- Financial - This can be a problem, but ultimately the owner just bear the costs of maintenance.
- Environmental - This too can pose a major hurdle, but ultimately in Washington, public safety takes precedence over environmental concerns. We usually work with the owner and the environmental agency to resolve any concerns with vegetation.

WV: Financial capability of the owner is often an issue. Some owners use livestock to control vegetation which can create an associated problem with overgrazing and related damage to the embankment cover.

WY: (See enclosed newspaper articles.) Since there is nothing in current regs or laws, we have to wait until we have an emergency situation before we can force action.

5. Do you have any documented evidence where vegetation has negatively affected the safe operation or have been linked to the failure of earth dams? Comment and give examples, if available.

Y	CO, CT, FL, GA, ID, IL, KS, MA, MI, MS, NE, NV, NM, NC, ND, OH, OK, OR, PA, SD, TN, TX, UT, VT, VA, WA, WV, WI, WY
N	AK, AZ, AR, CA, HI, IN, IA, LA, ME, MN, MT, NH, NJ, NY, PR, RI, SC
NR	AL, DE, KY, MD, MO

Y-Yes; N - No; NR - No response

AZ: Arizona does not have any specific documentation.

CO: See the Powerpoint presentation attachment.

CT: I cannot readily document where vegetation (trees) has directly lead to a dam failure. However, we have observed a number of dams where tree roots have displaced masonry dam components. We have also many times visited dams which were nearly completely obscured by tree and brush growth, which made inspection impossible.

FL: Since safe operation includes the ability to inspect, yes. Failures tend to wash away the evidence. Nearly every inspection we or the operator performs discovers nuisance vegetation.

GA: We have a couple of cases where trees were blown over in severe storms/tornadoes. As the tree fell it took a portion of the dam with it. No failures have occurred that we are aware of at this time.

HI: I do not have any documented evidence where vegetation has negatively affected the safe operation of the dam.

IL:

- Johnston City Lake Dam – NPDP Incident No. 8101
- Sudduth Lake Dam – NPDP Incident No. 8201
- Rice Lake Dam – NPDP Incident No. 9201

IN: I don't have documented evidence, but one dam failure comes to mind where I suspect that the failure was caused by unvegetated footpaths that were worn into the embankment.

KS: A small dam was reported to have failed in a tornado when a large tree was uprooted. Some inspections have found erosion linked to the lack of vegetation, but no failures documented.

MA: I have personal knowledge of one failure and several piping situations around root systems

MI: We have several documented dams where trees have damaged dam appurtenances, such as spillways or other structures. Examples would be where trees destroy spillway walls or wingwalls, or where they have toppled and contributed to the reduction of embankment cross section. We also have documented a case where a mature tree growing at the water's edge on a dam embankment was causing a serious threat to the dam. The tree was leaning at an extreme angle. Its root mass was uplifting the earth around it. Had it toppled over, the uprooted area would have reduced normal freeboard to zero. This incident was included in Dr. Tschantz' presentation on vegetation at the Albuquerque ASDSO annual conference.

MS: We have pictures of problems caused by trees.

MO: We have found dams where leakage has developed through decayed root systems of trees. Unfortunately, that has been several years ago and I do not recall the name of the dams where this was a problem.

NE: About 20 years ago, linden trees were planted on the crest of a privately-owned dam to improve the looks of the dam. Linden trees were selected by the owner because they are supposed to be "shallow-rooted". The roots of a few of these trees were recently investigated. The tap roots extended a long ways downstream, through the dam's internal sand drain system.

NV: It wasn't long after I had ordered the removal of greasewood and rabbit brush off an earthen dam that it developed a piping problem and the structure had a clear-sky failure. The owner asked me if I thought the removal of the vegetation contributed to the failure. I told him no, that the structure was built around the turn of the century with little or no compaction and little or no quality control and had seepage problems for years.

I can't think of any negative aspect to the removal of vegetation unless it is grass cover. Grass cover can provide good slope stability – especially to steep sloped faces.

NM: Indirectly yes. Heavy vegetation on a dam provided habitat for burrowing rodents on a normally dry flood control dam. A significant flood event in the watershed caused water to be impounded behind the dam. Water found its way into holes dug by the rodents and the dam failed by piping.

NY: Maybe, but would require extensive file search.

NC: There is documented evidence that trees have contributed to failures of dams in North Carolina from seepage along roots as well as from being blown over during heavy winds.

ND: The only example is vegetation that has negatively affected the safe operation of the dam. Some dams do have trees very close to outlet structures. The trees may be the cause of structural movement or seepage, as examples of the negative effects.

OH: Miller's Farm Pond Dam - Overtopping flow toppled a tree on the dam, which accelerated the development of the breach.

OK: We had some pictures of old dams that have failed and tree roots are in the failure area. That documentation is hard to find with the files in the shape they are in since the bombing. We are in the process of getting them in order.

OR: Please allow time until the end of July for requested documentation.

PA: We have documented evidence where vegetation has negatively affected the ability to properly inspect dams. We have no recollection of specific instances where failure to remove vegetation was linked to dam failure

SC: I have no documented evidence, but common sense tells me vegetation has contributed to dam failures.

SD: Have seen several <u>large</u> toppled trees with exposed root balls reducing cross-section of embankment, and a breached dam (probably piping) with the breach section full of tree roots.

TN: Enclosed are pictures that document these facts.

TX: We have seen instances where excessive tree growth in spillways has prevented sufficient conveyance of floodwaters by restricting the flow path and collecting debris. Large trees growing adjacent to headwall/conduit outfalls have caused structural damage to the headwall or conduit. Trees in the direct path of conduit outfalls also restrict discharges. There have been instances where large trees have been uprooted by high winds and/or turbulent floodwaters; the uprooted trees, which also take out a chunk of the dam, have contributed to failure of the earthen embankment.

UT: A lot of dams have this problem.

VT: Many uninspectable.

VA:

Chandler's Mill Pond Dam (VA19311)	-See attached write-up.
Small unnamed dam in Henrico County	-no data available
Small unnamed dam in Henry County	-no data available
Marshall Creek Dam (VA19309)	-Dam overtopped and failed in '97 or '98. No other data available

(All four of the above were attributed to trees on embankments.)

WA: I am personally aware of dams where a blow-down of a large tree on an embankment has reduced the thickness of the dam to a point where safety was compromised. I am also aware of one dam where blackberry vines and brush completely obscured a major slope failure on the downstream slope. Finally, I am aware of cases where tree roots have penetrated the low level outlet pipe, compromising its safety.

WV: Tree roots at the Lake Washington Dam in Wood County may have contributed to a concrete chute undermining failure. Roots apparently circumvented the concrete core wall at one abutment and allowed seepage flow to undermine the spillway in that area.

WI: We had a case where a dam with good grass cover overtopped for a period of hours. The turf stood up well except where the water flowed around trees. At these locations the flow concentrated and accelerated the embankment erosion. Unfortunately, at this time I cannot located these photos of others where tree roots were found in the failed portion of an embankment.

WY: See photo enclosed.

6. Are you aware of current or past research or documented discussions regarding the effects of unwanted vegetation on dam safety? Please list or attach known references.

Y	AR, CO, CT, KY, MD, MI, MS, PA, SD, VA, WY
N	AK, AZ, CA, FL, GA, HI, IL, IN, IA, KS, LA, ME, MA, MN, MO, MT, NE, NV, NH, NJ, NM, NY, NC, ND, OH, OK, OR, PR, RI, SC, TN, TX, UT, VT, WI, WV
NR	AL, DE, ID, WA

Y-Yes; N - No; NR - No response

AZ: Arizona does not know of any specific references.

AR: Heard by word of other regulators.

CO: Only what's in the FEMA dam safety manual.

CT: The only document I know of is "Tree Growth on Earthen Dams: A Survey of State Policy and Practice", by Bruce A. Tschantz and Jess D. Weaver, dated 11/98, published by the Civil Engineering Dept. of the University of Tennessee.

FL: Only standard practice

HI: I am not aware of current or past research on the effects of unwanted vegetation on dam safety.

KY: I have seen some, and we may even have copies, but I don't know what they are.

MD: Dr. Tschantz paper only.

MA: No I am not, but I have some interesting correspondence I would be willing to share.

MI: None other than Dr. Tschantz's previous work.

MS: Dr. Bruce Tschantz's "Tree Growth on Earthen Dams: A Survey of State Policy and Practice".

NC: "Tree Growth on Earthen Dams: A Survey of State Policy and Practice", Nov. 1988, Bruce A. Tschantz & Jess D. Weaver

OH: Not aware of any

OR: Not specifically. However, we are very interested in such references, as they would be invaluable as testimony in our contested case hearing(s).

PA: We have a documented discussion regarding the effects of unwanted vegetation in a 1997 ASDSO annual conference technical paper ("Vegetation Control on Earthen Embankment Dams", Thomas Bold and Norman Batcheler)

SD: Bruce Tschantz – "Tree Growth on Embankment Dams"

TX: Only bits and pieces. Our manual entitled Guidelines for Operation and Maintenance of Dams in Texas contains a limited discussion on vegetation and animal control. The manual is available on our website * http://www.tnrcc.state.tx.us/water/quantity/flood/dam.html

VA:
Tree Growth on Earthen Dams: A Survey of State Policy and Practice, University of Tennessee, Tschantz & Weaver, November 1988.
Operation & Maintenance Alternatives for Removing Trees from Dams, Soil Conservation Service (now NRCS), South Technical Service Center, Engineering Series No. 705, April 1, 1981.

WY: Only Bruce's last report

7. If tree removal from earth dams is authorized by your organization, would you please provide available data for examples of procedures, costs, contract specifications, and photographs of rehabilitated dams?

AK: Not specifically authorized

AZ: Arizona does not have specific written information. One of the dams which we required removal and replacement of deep rooted species was handled verbally and by field inspection. The original species were removed and the holes were backfilled with compacted fill materials.

AR: See Subtitle VIII. No costs available.

CA: Abatement of trees from embankments is initiated at the sapling size. While delays caused by factors in #4 may result in tree sizes of several inches of diameter by the time abatement occurs, the removal is considered maintenance and applications are not required.

CO Not applicable (we don't authorize removal...that's the owner's job).

CT: Upon entreaty, yes, but not today.

FL: Since we require the operator to bear responsibility, we don't have these specifics. Photos may be available, but not readily.

GA: The only information we have is on the policy regarding the removal (i.e. over 8 inches must be cleared and grubbed). If needed, I could probably give you a before and after set of pictures for a couple of dams.

HI: Tree removals are done by the dam owners under advisement by the Department. I do not have any data on the costs for removal of trees.

IN: No such information available.

IA: None available

KS: None available.

LA: Addressed in question no. 2.

ME: No data available.

MD: See Attachment B.

MA: We are trying to develop this data . I can say that tree removal, including removal of root mass and recompacting could run from $1,000. to $6,000.

MI: Procedures may include mechanical removal and stump grinding, cutting, or application of herbicides. Again, we do not regulate the removal, as it is considered a maintenance item.

MS: No available data for transmitting.

MO: The usual procedure is to cut the trees down with a chainsaw as close to the top of the dam as possible and remove it from the dam. The costs are directly related to how badly the dam is overgrown and can range from $1000 to as high as $10,000 in some instances.

MN: None available

MT: None, usually included in the routine maintenance required. As said earlier, clipping small trees is much cheaper than cutting and grubbing roots of large trees.

NE: Tree removal is an option but do not have any data or examples.

NH: Depending upon the size and location of the trees to be removed, DES sometimes requires that the root system be excavated. In general, however, we recommend that trees be cut just below the ground surface, covered with an adequate depth of loam and seeded.

NJ: See attached.

NM: No data available.

NY: Same as #5 above.

NC: Not available at this time.

ND: Data is not available.

OK: Will find pictures and send.

OR: Cannot allocate sufficient time for assembly of request until the end of July 1999.

PA: Our dam safety program generally requires removal of the most significant portion of root systems and backfilling with an inverted filter. We have no specific examples, references regarding costs, or readily available photographs.

PR: Is not authorized.

RI: None other than as noted above.

TX: Not available. Consultants perform the work.

UT: Not available – We require that the root wad be removed and the area backfilled and compacted for large trees.

VA: We (the State) do not have specific authorization to remove trees. We have required it, however, as a condition for full certification for several dams, e.g. VA00380, VA13714, VA09519, VA08713. Costs typically are very nominal but if tree growth is extensive and especially if grubbing is required, $10,000 to $20,000 is common. One dam (VA13714) reportedly required about $40,000 in clearing costs.

WV: Not available

WI: We do not have standard specification for tree removal. I will look for an example of a rehabilitated embankment.

WA: The procedure for tree removal is site specific. Typically, trees are cut off to the ground surface. If the tree is greater than 6 inches diameter, the roots and stump are removed and replaced with compacted earth. Smaller tree stumps may be left in place, depending on the thickness of the embankment section.

Part II: Animal Impacts on Dams

8. What types of animals cause problems on earthen dams for your organization?

AK: No specific incidents known.

AZ: Arizona has problems with ants, gophers, squirrels, badgers and martins. These insects and animals dig burrows, both in undisturbed sections of earth embankments and along areas in embankments loosened by transverse and longitudinal cracks. These voids lead to potential failures due to piping through voids in embankments.

AR: Burrowing animals. Possibility of piping. When we see, advise owner to get rid of animal, recompact soil in burrow and sod.

CA:
Burrowing mammals – increased seepage
Burrowing mammals – piping
Burrowing mammals – loosening of compacted fill
Burrowing mammals – food source for predatory mammals which enlarge burrows
Cattle – reworking of rain soaked embankment
Cattle – initiation of erosion paths
We provide dam owners with the attached suggestions on Muskrat Control.

CO: Burrowing animals such as groundhogs, gophers, beavers, and muskrats create the biggest problems by causing damage and seepage paths within the dam. Damage from livestock is also significant, because of accelerated erosion of the slopes and loss of cross section or freeboard.

CT: Connecticut has been "blessed" with an (over) abundance of beavers, which has caused many problems with plugged and back watered spillway structures, conduits, etc. In addition, muskrats and woodchucks have periodically caused problems by burrowing into earthen dams.

FL: Gopher tortoises. They dig long (35 ft. and more) tunnels into embankments 18" in diameter.

GA: Beavers, muskrats, and other burrowing animals. The beavers tend to block spillways and burrow into the embankment material. Most common problem we see is where burrows have been created at the waterline. These will eventually slough or slide causing minor problems with the slope.

Beavers can also back water up from downstream onto the downstream slope. This adversely impacts drain outlets, slope maintenance, etc. It should also be noted that overgrown upstream slopes provide excellent cover for beavers and muskrats. Rip-rapped slopes seem to have less problems with burrowing animals.

HI: The Department will operate and maintain a flood control levee. I did a recent inspection of the levee and discovered rat burrows on the downstream embankment of the levee. If the burrows go through the embankment, this would allow water to seep through the burrows and cause possible settlement and instability of the structure.

ID: Muskrats, gophers, badgers, woodchucks

IL: Groundhog, ground squirrel, crawdad, muskrat, fox, (snakes, mice – minimal problems)

IN: Groundhogs burrowing into the structure, beavers blocking spillway inlets with debris, cattle grazing the embankment.

IA: Muskrats and gophers will burrow into dam embankments. Beavers will plug spillway inlets. It has also been reported to me that snapping turtles will burrow into embankment.

KS:

- Cattle by trails which can reduce freeboard, create erosion channels and damage appurtenant structures.
- Beavers by obstructing spillways, burrowing into dams, creating paths on dam.
- Muskrats by burrowing action.
- Crawfish have been suspected in some piping incidents as they were found in the cavities, but we are uncertain if the crawfish were the agents to forming the cavities

KY: We see mostly groundhogs and muskrats. The problems they cause are the extensive system of burrows they dig in the embankment.

LA: Nutria and armadillos frequently dig for food in a small number of our earthen dams.

ME: Beavers and humans block spillways. Coons, woodchucks and porcupines bore into earth walls. Otters and muskrats undermine walls.

MD: Beavers - clog spillway; groundhog - burrowing into dam

MA: Beavers and muskrats mostly. Flooding of downstream toes of dams, raising impoundment levels beyond which the dams were designed for.

MI:

- Beavers—plugging spillways, burrowing into embankments, creating paths over the embankment, damming tailwater to increase water level on downstream toe/slope of embankment.
- Muskrats and woodchucks—burrowing into embankments.
- Livestock—contributing to erosion of embankments.

- Insects—Mosquitoes, black flies, wood ticks and deer ticks all inhabit Michigan in excessive numbers. These are annoying nuisances to dam inspectors. Deer ticks carry the threat of Lyme disease.
- Man—vandals seem to have a preoccupation with unauthorized placement or removal of stoplogs, unauthorized manipulation of gates, placement of debris in spillways, riding ORV's up and down slopes.

MN: Muskrats and groundhogs dig holes that cause seepage.

MS: Beaver primarily. Tunnels and dens in the dam erode out, causing failures or near failures.

MO: Muskrats, beavers, groundhogs. Muskrats and groundhogs like to burrow into the dam. Beavers tend to block flow through the spillway structures.

MT: Gophers and muskrats are the main problem. Holes on the top and downstream face are usually caused by gophers. Holes at the water line are usually caused by muskrats, especially if cattails and brush are allowed to build up.

NE:
Beavers – Build dams around risers and in outlet channels. Also can build dens inside dam embankments.

Muskrats – Create burrows and dens inside dam embankments.

Badgers – Burrows.

Prairie dogs – Create "towns" consisting of interconnected burrows and tunnels in embankments and in auxiliary (emergency) spillways.

NV:
- Beavers - by building dams in our spillway channels
- Muskrats, prairie dogs and other rodents - by digging holes in the embankment and causing seepage paths through the dam
- Cows - by trampling up and down the faces of the dam thereby reducing the effective width of the dam and lessening the phreatic surface distance and corresponding seepage paths.

NH: Ground hogs - burrows. Beavers - pathways, erosion, clogging of outlets/spillways and felling trees onto structures. Farm animals (cows, pigs) - pathways, erosion.

NJ: All burrowing animals, specifically groundhogs and muskrats. These creatures shorten potential seepage paths which could result in a piping failure on a typical embankment dam.

NM: Usually gophers.

NY: Hydraulic obstruction – beaver. Burrowing – woodchuck, muskrat. Foot trails – livestock, beaver, muskrat, etc.

NC:
1. Beavers: Clog riser pipes and open-channel emergency spillways
2. Muskrats: Burrow dens in dams with an extensive network of burrow holes in upstream slope and crest of dam. (Caused dam failure – Boyd Lake Dam, Richmond County, NC)
3. Groundhogs: Same as muskrats except burrow holes are on downstream slope and crest of dam.
4. Snakes: Be careful of them during inspections. Copperhead, rattlesnakes, water moccasins and coral snakes are in NC.
5. Ticks (insects): Lyme disease & Rocky Mountain spotted fever. Staff members have contracted both these diseases in NC during dam inspections.

ND: Gophers and beavers. Gophers burrow into the embankment. Beavers build dams that cause backwater at outlets, especially for low-level outlets.

OH: Groundhog and muskrat burrows weaken embankments and can serve as pathways for seepage. Beavers may plug the spillway and raise the pool level.

OK: Beavers, badgers, and gophers. all burrow into the embankment. We recommend traps or poison bait where acceptable.

OR:
Western Oregon:

- Nutria, muskrat, beaver and two-legged, red-necked, half-witted vandals

Eastern Oregon:

- Prairie dogs, ground squirrels, badgers, coyote and two-legged, red-necked, half-witted vandals

PA: Beavers, muskrats, groundhogs. Problems described on attached fact sheet.

PR: Cows and horses, which are illegally allowed to graze at a couple of embankment dams. Is not a big problem but they help increase erosion of the embankment.

RI: None to my knowledge. Most of the embankments have been so overgrown with vegetation, a complete visual inspection could not be performed.

SC: Muskrats – create tunnels near the water line
Beavers – plug risers and build dams in emergency spillways

SD: Beaver/Muskrats – Dens and burrows on embankment; Livestock (cattle, sheep, horses) – Overgrazing of grass cover and erosion damage (cattle trails)

TN: Muskrats and beavers, and to a lesser extent groundhogs. Animal holes. Beavers also build beaver dams that block spillway inlets.

TX: Beavers and nutria are the most destructive animals for earthen dams. Beavers and nutria construct tunnels and dens within earthen embankments, leading to seepage paths and large voids within the dam. The tunnels and dens can be extensive and greatly weaken the dam. As time passes, the roof of the tunnels or dens tends to collapse (often the crest of the dam). We have incidents where dams have failed as the result of higher lake levels allowing water to flow through the tunnels or dens and cause internal erosion and subsequent breaching of the dam.

Gophers and related rodents construct burrows all over dams. Alligators, badgers, and muskrats also perform burrowing activities. These tunnels are usually not too extensive, but repairs must be performed to preserve the integrity of the structure.

Wild hogs and armadillos cause extensive surface disturbance by rooting, scratching and digging on dams. Cattle have been observed to cause very extensive damage to earthen dams by eating down the protective grasses and causing erosion with their extensive trails network.

Alligators and snakes may hinder inspections of certain areas on a dam. Occasional angry cattle, horses and dogs also cause access problems for inspectors.

Fire ants have become a big problem for inspectors in a large portion of the state by having to watch every step taken to ensure your foot or hand is not placed on or near a mound. Fire ants are attracted to electrical components, and their congregation in these areas has attributed to component malfunction. We have also observed a few instances where small embankment failure was attributed to the extensive network of ant tunnels and soil movement * when the lake reaches higher levels, the water pressure and soil saturation contributed to structural failure of the earthen dam.

UT:
1. Beavers – block spillways
2. Pot Guts (gophers)
3. Muskrats
4. Badgers
5. Squirrels
6. Cattle, sheep, horses – leave trails on dam slopes

VT:
1. Beavers in spillways
2. Muskrats build extensive burrows in embankments.

VA:
- Beavers – block spillways and back water up into outlet pipes.
- Groundhog, muskrat – burrowing, creating voids & water channels that may lead to piping or embankment sloughing.
- Grazing animals – over-grazing reduces vegetation to a level where it cannot provide stability to surface soils. Sheet, rill and gully erosion results.
- Voles or moles were reported as causing a problem at one dam by "softening" part of the crest of the dam.

WA: Beavers, mountain beavers, muskrat, moles. Beavers can plug spillways with debris. Other animals burrow in the dam just above the normal high water line. When the pool is elevated during a flood, water can flow into the burrows and initiate a piping failure. Also, burrows can intercept the phreatic surface within embankment and shorten seepage path.

WV: Groundhog burrows on embankments, muskrat holes on the upstream face, beavers blocking spillways, mice burrowing into internal drain outlet pipes..

WI: Muskrats, woodchucks and beavers. The first two burrow, causing seepage problems. Beavers block outlets with the potential for overtopping the dam.

WY: Gophers, prairie dogs, ground squirrels, badgers and muskrats.

9. How do you deal with each species?

AZ: Arizona allows each dam owner to deal with his particular problem on an individual basis. We believe that animals are typically removed by poison bait. In some areas of the state where there may be concern about T & E species, we have been told the State Game and Fish Department will provide assistance in identification of animals and trapping and relocation of T & E species.

AR: All the same with us.

CA: The owner is directed on a case by case basis to abate animal damage. The reason for the abatement is explained and the desired goal explained. The means and methods are left to the owner.

CO: We order the owner to remove the animals. The owner generally contacts the Division of Wildlife or a licensed pest control agency to either trap or exterminate burrowing animals. Livestock control is most effectively accomplished by fencing.

CT: a) In the case of beavers we kill them, trap them, and/or ask them to leave and move to an abutting state (they seem to favor Massachusetts, by the way).

b) i) Seriously, we actually do trap and eradicate beavers, but we also have been incorporating anti-beaver fencing at several state-owned dams.

ii) Muskrats and woodchucks are normally trapped or killed.

FL: Require relocation.

GA: We advise the owner of the dam to remove the burrowing animals from the dam area. How they do that is up to them. Trapping seems to be ineffective and has several disadvantages. Beavers are currently considered a nuisance animal in Georgia and can be killed without a permit. However, local laws pertaining to the use of guns may prevent the killing of the beavers. Some of our owners have found this out the hard way.

HI: We will install rat traps to trap the animals and humanely destroy them. If we are not able to trap them, then we will use rat poison to exterminate them.

ID: Recommend dam owner eradicate, as necessary. Removing growth also eliminates their cover, reveals where burrows are located.

IL:
Groundhog & muskrat – See attachment.
Fox – Similar to groundhog for appropriate actions.
Crawdad – Provide toe drainage to minimize their preferred environment – in some cases lime stabilization of the downstream face of the embankment has been necessary.
Ground squirrel, snake, mice – Keep the embankment maintained.

IN: We recommend hunting or trapping in compliance with state regulations.

IA: Trapping, relocating, shooting, and poisoning animals have been used by a variety of dam owners in Iowa. The method of control would be up to the individual dam owner, as long as it's legal.

KS: The owner must deal with each. On most you remove the animal, its habitat and food source, and it leaves.

KY: We require the dam owner to fill in the burrows and to prevent the animals from returning. Some owners trap the animals, others eradicate them by other means.

LA: Louisiana uses traps to remove the animals.

ME: We don't deal with them. Owners have variously shot and poisoned them.

MD: Require owner to hire trapper, etc.

MA: We usually get a permit from Fisheries and Wildlife for removal of the species and a permit from the conservation commission for removal of the beaver dams and lodges

MI:

- Beavers—either trap or otherwise remove; hunt them; declare war on them and fight the battle daily.
- Muskrats and woodchucks—some owners have placed wire/steel fencing on the embankment face to deter burrowing; hunt, trap or otherwise remove them; follow them around and repair any burrows.
- Livestock—fence or otherwise prohibit them from traffic on the slopes.
- Insects—use insect repellent and avoid areas if possible.
- Man—Large boulders or other secure fencing; security devices on stoplogs slots or gates.

MN: We don't try to remove the animals, they are too hard to eradicate. We repair the holes.

MS: We get the dam owner to trap and remove the beaver.

MO: We require the owners to remove them from the lake and dam. This involves live trapping techniques or obtaining a permit from the Fish and Game Program to trap or shoot the animals.

MT: Poison

NE: Dam owners are responsible for removing the animals. Trapping is the most common method and sometimes poisons are used, if allowed.

NV: We simply tell the owner to monitor the rodent holes and eradicate the animals if necessary.

NH: Ground hogs - eradicate animal and fill/compact burrows.
Beavers - trap and relocate or eradicate animal, and repair erosion damage with new soil, install trash racks and clear away debris.
Farm animals- relocate to alternate pasture/land areas

NJ: The burrows are filled. Animals are at times trapped and relocated.

NM: Usually poison bait.

NY: Recommend removal of beaver work, repair of burrows and trails. Recommend trapping out or shooting of rodents, fencing out livestock. Some experiments with "beaver tubes", etc., to thwart beaver activity.

NC: We encourage owners to get rid of beavers, muskrats, and groundhogs in legal ways be trapping (or killing with appropriate permit).

ND: Gopher holes are refilled or covered. Beaver dams are removed. In both cases, the hope is the disruption will drive the animals away.

OH: Groundhogs can be controlled by using fumigants or by shooting. Muskrats can be discouraged from burrowing by a riprap and filter layer, wire fencing laid flat against the slope, and eliminating aquatic vegetation along the shoreline. Muskrats and beavers can be trapped

OK: By the recommendation of the US Fish and Wildlife Service Animal Damage Control Section.

OR: Trapping (both live and lethal), poison bait, hunting, or alternative control such as preventative armoring with riprap, gravel, etc.

PA: We defer the problem of elimination or removal to the owner, who consults with the state game commission for the recommended course of action. (See fact sheet.)

PR: The owner of the dam contacts the animal's owner and removes the animals and provides a fence to the embankment to avoid the entrance of these animals.

RI: N/A

SC: By trapping and removal from the area. (Not always successful.)

SD: Recommend fencing for livestock and some dams the beaver/muskrats have been removed.

TN: Fill the holes with clay. The upstream slope can be protected with riprap. These animals can be eliminated by smoke bombing and trapping.

TX: We recommend that the burrowing animals and soil disturbing animals be removed from the dam and vicinity, either by trapping and relocation or other means. Fire ants may be eradicated temporarily with chemical treatments. Any destruction caused by animals should be appropriately repaired, based on the extent of damage.

UT:
1. Beavers – trap and relocate
2. Pot Guts – poison with treated grains
3. Muskrats – attempt to poison/drain habitat
4. Badgers – trap or shoot
5. Squirrels - poison
6. Stock – fence dam

VT:
1. Beaverproofing pipes, stone beds around outlets.
2. Stone facing embankments above waterline.

VA: Case by case.

WA: Typically, the responsibility for controlling the animals is up to the owner. We have them work with our state Fish and Wildlife Department to either trap or kill the animals.

WV: Trap, relocate animals. Fill in burrows with compacted material or remove obstructions placed by beavers.

WI: Repair the damage. Owners can get permits to trap or shoot nuisance beaver.

WY: Usually poison (except for muskrats which they will try to trap), but prairie dogs may soon be protected species.

10. What legal, financial, environmental, or other constraints or issues arise when your organization attempts to deal with problems caused by animals on dams?

AZ: Arizona has only had to deal with those issues discussed in the comments to question #9 above.

AR: None

CA: The owner often cites as reasons for delays in abatement, the constraints presented by legal, financial, environmental, and other processes. It remains the owner's responsibility to perform the abatement.

CO: The dam owners must deal with environmental issues pertaining to trapping or exterminating animals, with the assistance or guidance of the local wildlife agencies. The issue of livestock control has a mostly financial impact on dam owners, who generally hate to see all that grass unavailable for their animals. The owner must choose how he wants the dam used, for water storage (or flood control) or for pasture. He generally can't have both.

CT: Animal eradication is also problematic, due to regulatory constraints in terms of trapping and hunting. (i.e., time of year, proximity to residences, method of trapping, types of traps, etc). Occasionally, "special" out-of-season trapping permission is granted by the DEP wildlife division in severe situations of beaver infestation.

FL: We require relocation and repair.

GA: See comments above.

HI: There are no problems since everyone detests rats because they are a health hazard to the residents the flood control levee is protecting.

ID: Objections: Bureau of Land Management – loss of wildlife habitat

IL: Primarily it is only the reluctance to do the necessary work.

IN: We really haven't run into any.

IA: Trapping, shooting or otherwise destroying the animals would need be done in accordance with current laws and regulations.

KS: None at this time.

KY: Nothing major. The biggest problem is the persistence of the varmints.

LA: None

ME: We merely tell the owner to get rid of them.

MD: None I'm aware of.

MA: Since they changed the trapping laws to "HAVE A HEART TRAPS ONLY" the beaver and muskrat populations have grown exponentially out of control. Very controversial at this time.

MI: Financial constraints are of concern to dam owners. Environmental constraints may include special nuisance permits for trapping or removal of beaver and muskrats.

MN: No legal constraints. Cost is a problem.

MS: Financial, for the dam owner.

MO: Permits have to be obtained from the Department of Conservation Fish and Game Program to legally remove animals out of season.

MT: None so far, getting the owner motivated to do the work is a problem sometimes.

NE:
a. It is difficult to find trappers if the value of the animal pelts is low.
b. Special trapping permits are required if the animals are not "in-season".
c. Before prairie dogs can be removed, studies of black-footed ferret populations in the area have to be conducted.

NV: I haven't run into any problems other than actually trying to get rid of the rodents.

NH: See #4.

NJ: The State of New Jersey, Department of Environmental Protection does not deal directly with this problem. It is the responsibility of the individual dam owner to ensure that all local, state, and federal laws are obeyed when removing burrowing pests.

NM: As a regulatory agency, it is our responsibility to advise the owner to have the animals removed. It is up to the owner to deal with any legal, financial or environmental issues that may arise.

NY: Widespread beaver population leaves no transfer locations for "trap & transfer".

NC: Potentially, organizations such as "People for the Ethical Treatment of Animals" (PETA) could raise concerns for removal.

ND: The main constraint is that most dams are isolated from human habitation and are not frequently monitored by caretakers. Of course, financial constraints always exist.

OK: None so far.

OR: Many of the same previously described in No. 4, above, except that with animals the perceived brutality by Big Brother against our helpless furry friends is more pronounced, and the reaction much more severe than with vegetation.

PA: None

PR: None

RI: N/A

SC: Our problem is often in getting the owner to take the necessary action. If he won't do so voluntarily, we have no option but to initiate legal action against him. As with the problem with vegetation, legal help is limited, and must be rationed for the most extreme cases.

SD: Many dams are for livestock water and owner does not see the problem.

TN: Trapping is supposed to be done per the regulations of the Tennessee Wildlife Resources Agency

TX: Fur-bearing animals, such as beaver and nutria, are regulated by the state Parks and Wildlife Department, and permits must be obtained for relocation. Everyone hates fire ants.

UT: None that are significant except getting owners convinced they are a problem

VT: Financial mostly for cost of stone.

VA: Some landowners have allowed their cattle to overgraze.

WA: Fish and Wildlife Department has regulations on killing or trapping animals.

WV: Trap, relocate animals. Fill in burrows with compacted material or remove obstructions placed by beavers.

WY: Biggest problem now is just recurrence but endangered species act could be a future problem

11. Do you have any documented evidence where animals have affected the safe operation or have been linked to the failure of earth dams? Comment and give examples, if available.

Y	CA, CT, FL, GA, ID, IL, IA, KY, MA, MI, MS, MO, NE, NH, NC, OH, OK, OR, PA, SD, TN, TX, UT, VA, WY
N	AZ, AR, CO, HI, IN, KS, LA, ME, MN, MT, NJ, NY, ND, PR, RI, VT, WV, WI

AZ: Arizona does not have specific documentation.

CA: The following uncontrolled releases of water have been caused by burrowing mammals:

Mud Lake Dam, No. 129-5	1932
Rye Grass Swale Dam, No.150	1932
Kelley & Greiner Dam, No.133	1939

Kelley & Greiner Dam, No.133	1947
Horse Lake Dam. No. 245	1952
Pete's Valley Dam, No. 1256	1959
Gerber Dam, No. 261	1969
Foote #3 Dam, No. 428-2	1975
Nine Springs Dam, No. 1245	1980
Mud Lake Dam, No. 129-5	1982
Mud Lake Dam, No. 129-5	1993
Rye Grass Swale Dam, No.150	1995
Nine Springs Dam, No. 1245	1996

CT: Yes, we do have one such documented problem where an earthen embankment was riddled with woodchuck burrows and subsequently significant soil movement occurred. (Further details are available when time permits me to dig out related materials and also to file an "incident report" with M. McCann.)

FL: We have discovered many (hundreds) of gopher tortoise burrows. We don't know of any failures caused by them.

GA: We have one example where beavers failed a dam. Casey Lake Dam was listed as a Category II (low hazard) dam when we got an emergency response call on the dam. After further review, it was reclassified to Category I (high hazard). The dens built by the beavers went well into the dam and were a direct cause of the dam to fail. I did not respond to this situation so I do not have the full details readily available. If you need additional clarification, please let me know. Lake Lonnie Dam in Henry County failed in 1990 where animals had burrowed into the upstream slope in several locations. When the lake level rose as a result of a prolonged rain storm, the water blew out the downstream slope. One 5 year old girl was nearly killed in this failure.

HI: I do not have any documented evidence that animals have affected the safe operation of a dam.

ID: Frazier Dam failed, in part due to animal burrows (their activity).

IL: See references for vegetative problems.

IA: We believe that an earthen dam in eastern Iowa failed in 1986 because of rodent burrows. The dam failed during a storm when the elevated head on the embankment created flow directly through burrow ridden embankment or the burrows allowed embankment saturation to the point where it became unstable.

KY: We had pretty strong circumstantial evidence on one dam that developed major piping in an area of the dam that we had detected animal burrows, which we directed the owner to fill. We know that they were filled at least surficially, but suspect that the owner did little more than that.

MD: Beavers routinely place branches, logs, etc. in spillways. Coupled with lack of maintenance by owner causes reduced spillway capacity.

MA: Overtopping and flooding of Roadways yes!!

MI: We probably have dozens of photos documenting spillway restrictions caused by beaver debris. We have one documented failure, the US-10 flooding in Midland County.

MN: Not available

MS: We have had several dams to fail or nearly fail because of beaver activity.

MO: We have several tailings dams that have chronic problems with beavers building dams in spillway channels and thereby significantly reducing the spillway capacity. We have an earth dam that overtopped due to beavers totally blocking the open channel spillway for the dam.

NE:
a. Beavers and muskrats built large dens inside a dam embankment. The upstream half of the dam had to be excavated and rebuilt.
b. On several dams, beavers have completely dammed up and blocked off riser inlets.

NV: Nothing documented. But there does seem to be a trend between dams that are in poor condition with excessive seepage that have heavy vegetation and rodent action. It seems that the more vegetation there is on a dam, the greater the habitat area for rodents and corresponding rodent holes.

NH: On more than one occasion, dams have been overtopped in areas where beavers have lowered crest elevations with transverse pathways.

NM: See No. 5 above.

NY: Same as #5 above.

NC:
1. Beavers clogging spillways caused overtopping failures.
2. Muskrats (and possibly groundhogs) caused failure of Boyd Lake Dam, Richmond County.

OH: Crawford Fitting Company Pond Dam - A muskrat hole penetrated the embankment and allowed lake water to seep through the dam.

Pischieri Pond Dam - Dam was breached because of piping created by animal burrows.

Crown City Mining Pond No. 024 Dam - Dam failed by overtopping due to plugging of the spillway by beavers.

OK: Several small farm ponds have been lost due to gophers or beavers.

OR: Please allow time until the end of July 1999 for requested documentation.

PA: Documented evidence is limited to occasions where beavers have blocked spillways and outlets and have adversely affected the safe operation of dams. However, we don't readily recall specific incidents that have led to failure.

RI: No documented evidence of which I am aware.

SC: No documented evidence

SD: Have seen several large slides (both upstream and downstream slopes) due to animal burrows.

TN: Almost certainly caused failure of Mary's Creek #8 Dam in Shelby County. Pipe developed between muskrat holes on the upstream slope and groundhog hole on the downstream slope.

TX: Yes, see response to #8 above.
Harris Back Lake Dam, TX 4877, failed from internal erosion through beaver dens.
Willow Lake Dam, TX 3541, failed partly from fire ant tunnels.

UT: Wales Reservoir failed in 1983 due to piping through badger holes.

VA: No known failures. We have generally been able to address the problem before it got to that point on regulated dams.

The owner of one dam (VA11306) had to lower the pool when the embankment became overgrazed to the point that it was considered to be compromising the safety of the dam.

WV: None documented that affected operation or caused a failure.

WI: Nothing comes to mind at this time

WY: We had one case where a significant hazard dam was found to have a large badger hole and shortly thereafter the dam almost failed (piping) at the same place the hole had been noted

12. Are you aware of current or past research or public discussions regarding the effects of burrowing animals on dam safety? Please list or attach known references.

Y	AR, CO, GA, KY, MI, MS, OK, TX, VA
N	AZ, CA, CT, FL, HI, ID, IL, IN, IA, KS, LA, ME, MD, MA, MN, MO, MT, NE, NV, NH, NJ, NM, NY, NC, OH, OR, PA, PR, RI, SC, TN, UT, VT, WA, WI, WY

AZ: Arizona is not aware of specific references.

AR: Yes, from other regulators.

CO: Only what's in the FEMA dam safety manual.

CT: No, I am not – but there must be tons of them.

FL: No, but the danger is obvious. If a burrow were to reach a wet zone, failure would be nearly certain.

GA: 1984 SE Regional Dam Safety Conference in Mississippi

HI: I am not aware of current or past research regarding the effects of burrowing animals on dam safety.

KY: Same as #6.

MI: No known references other than informal discussions at ASDSO workshops and conferences, and at dam safety workshops sponsored by us.

MN: Not aware of any

MS: The SCS has done some research in this area.

OK: I remember some discussions or presentations at past ASDSO meetings.

OR: No. However, we are very interested in such references, complete with success rates for the many approaches for rodent control that may exist.

TX: We have produced a 2-page information sheet entitled *Animal Burrows and Lodges* for dam owner benefit. The document is located on our website -- http://www.tnrcc.state.tx.us/water/quantity/flood/dam.html

VA: We have a FACT SHEET (No. 4 attached).

WV: None beyond Dr. Tschantz's and ASDSO publications.

C. ICODS Agency Representatives Survey Responses and Comments
Animal and Vegetative Impacts on Dams
(Received as of 9/2//99)

ICODS Representatives: BOR, (Bill Bouley), **COE/MV** (Tony Young), **COE/SW** (Willis Walker), **COE/SW2** (Tommy Schmidt), **DOE/Oak Ridge National Lab** (David Buhaly), **DOE/Savannah River Site** (Perry Dukes), **MSHA** (Kelvin Wu), **NPS** (Charles Karpowicz), **NRC** (Daniel Rom), **TVA** (James Varner/James Coulson), **USDA/NRCS** (Larry Caldwell)

Part I: Vegetation on Dams

1. Do you consider vegetative (woody) growth on earthen dams to be a problem for dams under your organization's jurisdiction?

Y	BOR, COE/MV, COE/SW, COE/SW2, DOE/ORNL, DOE/SRS, MSHA, NPS, NRC, TVA, USDA
N	

Comments:

COE/MV: It would be if uncontrolled. We do not allow woody vegetation to grow on our dams. It is a greater problem on some levees constructed by the Federal Government and turned over to local interests to maintain. Woody vegetation is not always controlled as it should be on some of these levees.

COE/SW2: If it is allowed to become excessive the embankment them becomes impossible to inspect adequately for signs of distress, cracking, movement, and/or seepage.

DOE/ORNL: Following guidance per "engineering guidelines for the evaluation of hydroprojects Federal Energy Regulatory Commission Office Of Hydropower Licensing April 1991", ORNL removes saplings/trees and controls vegetation on its impoundment on an annual basis to ensure their structural integrity.

TVA: Vegetation with root systems could result in piping problems, grass and other vegetation can hinder visual inspections.

USDA: Yes! Removing trees from earthen embankments is a continual challenge, especially in a state like Oklahoma that has over 2000 flood control dams. There are three basic challenges:
- Educating landowners and watershed sponsors that trees on earthen embankments can result in potential serious problems in the future.
- Obtaining funding for removal of trees.
- Practicing effective techniques for cost-effective methods of removal of trees.

See page 2 of the enclosed Oklahoma MRCS Tech Note No. 8 (Control Trees and Brush on Dams) for a discussion of potential problems caused by trees growing on dams.

2. Does your agency have a specific policy or operating procedures addressing tree growth and removal of trees/vegetation from earthen dams?

Y	BOR, COE/MV, COE/SW, NPS, TVA, USDA
N	DOE/ORNL, DOE/SRS, MSHA, NRC

BOR: Yes, we have guidelines regarding clearance zones. Initially, they were more stringent, but toned down by 1989 to establish a 25 foot clearance zone from concrete structures, and the groins and toe of embankment dams. The depth of removal for root systems is not specific to size of the roots. Allowances are made for shallow rooted cacti on steep slopes.

COE/MV: See EM 1110-2-301 for Corps policy.

COE/SW: The Corps policy is no trees. I don't know of a manual that describes how to remove trees.

COE/SW2: We do not have a written policy.

DOE/ORNL: Not applicable.

DOE/SRS: There is no specific written policy. Operating procedures limit vegetation to a maximum height of 18 inches. In the early 90's, large vegetation/trees were removed from all site dams. Since that time mowing has been sufficient.

MSHA: No written policy. Practice is to request that trees be removed if hamper inspection or if there is concern that roots could provide seepage paths.

NPS: Attachments to be faxed.

NRC: No - case by case basis.

TVA: YES, as a guideline the slopes and 50' below the slopes should be cut frequently enough to limit grass height to 6-10 inches and eliminate growth of trees, bushes, vines, etc. In areas where this is not possible we manage those sites on a case by case basis.

USDA: Oklahoma NRCS policy on removal of trees and brush on dams is contained in Oklahoma Engineering Tech Note No. 8 (Control of Trees and Brush on Dams) dated April 5, 1998. (copy enclosed). Due to the ever changing availability of chemicals, the specific chemicals for site specific projects must be reviewed with current chemical label directions.

3. If your organization has no set policy or procedures, what do you recommend?

COE/MVD: N/A

COE/SW2: We recommend that the grass on the dams be mowed several times a year to prevent excessive growth and to prevent the spread and growth of trees.

DOE/ORNL: As noted in answer 1 above, ORNL follows guidance from the Federal Energy Regulatory Commission (FERC) and uses maintenance forces to annually remove excess vegetation from its impoundments.

DOE/SRS: Mowing two to four times per year. Hand work (weedeater) is required around instrumentation and in wet areas where mowers would rut the surface.

MSHA: (Legal) I guess we have to be prepared to defend our position that the trees present a safety problem.

NPS: National Park Service has same standards as Bureau of Reclamation.

NRC: Specific recommendations are made to licensees following routine inspections.

USDA: Not applicable (see 2 above).

4. What legal, financial, environmental, or other constraints apply when your organization attempts to deal with problems caused by unwanted vegetation?

BOR: All work has to be in compliance with the national Environmental Policy Act and the Endangered Species Act prior to initiating work activities.

COE/MV: Limited funding and environmental concerns are common obstacles to vegetation removal.

COE/SW:: Certain non-federal levees with woody vegetation do not qualify under public laws that allow federal reconstruction if they fail due to a flood. Consequently to remain qualified, many of the levee boards have vegetation removed improperly by merely cutting trees, which actually causes a higher risk of failure. Trees once established have to be removed properly and levee boards often can't afford that cost. A comprehensive policy that focuses on levees, levee maintenance, and support of levee districts should be considered.

COE/SW2: No specific constraints have been encountered recently because we have worked this problem for many years and have long standing procedures in place.
DOE/ORNL: ORNL spends approximately $15,000 annually removing excess vegetation and controlling burrowing animals on its impoundments. ORNL is compliant with all applicable federal, state, and local regulations implementing the maintenance actions.

DOE/SRS: None. We own and operate the Federal dams on Federal land. Any significant removal in connection with construction would be addressed in construction environmental documentation.

NPS: Because of various factors, individual park managers typically decide on how they'll manage their own dams or monitor non-NPS dams affecting the National Park System. There hasn't been an executive level correspondence from the Washington Office for some time instructing the field on their requirements including outstanding deficient dams, NPS or non-NPS. Normally higher priority facilities than dams take available funding. Also, perceived higher priority programs like environmental compliance, historic preservation, disruption of visitor services, etc. may override the safe operation and maintenance of impoundment structures.

NRC: Potential license violation if vegetation remains untreated.

TVA: Spraying of vegetation with chemicals requires close environmental considerations.

USDA: Local watershed project sponsors are responsible for operation and maintenance of the dams throughout the project life. Obtaining funding for maintenance is a continual challenge. Oklahoma Conservation Commission provides guidance and some financial support for project sponsors (primarily conservation districts) each year. They also provide limited staff (for specialized watershed technicians) and equipment (siphons and pumps to lower water levels in reservoirs with plugged principal spillways), remote video camera for inspecting interior of principal spillways, and a mower that can cut brush and other vegetation on steep embankment slopes.

5. Do you have any documented evidence where vegetation has negatively affected the safe operation or have been linked to the failure of earth dams? Comment and give examples, if available.

Y	COE/MV, NPS
N	BOR, COE/SW, COE/SW2, DOE/ORNL, DOE/SRS, MSHA, NRC, TVA, USDA

BOR: None to date. At Hyrum Dam, burrowing animals were found to be protected from predators by large trees and brush growing on the dam in 1987. Vegetation removal has commenced before the onset of problems.

COE/MV: Two non-Federal earth dams located in the St. Louis District and two non-Corps levees located in the Vicksburg District failed due to woody vegetation. In both non-Federal dam cases, roots and root channels were found in the side walls of the breach, and pre-failure photos show extensive trees and vegetation on the embankments.

COE/SW2: Since we do not have excessive vegetative growth on our dams, we have had no documented problems.

DOE/ORNL: Not applicable.

DOE/SRS: No specific documentation.

NPS: Several minor size, LOW Hazard potential dams at NPS Delaware Water Gap National Recreation Area, NJ/PA. Many other instances but don't have time to lookup.

USDA: We have no documented cases where failure of an embankment has been determined to be caused solely by trees on embankments. However, trees have masked more serious seepage problems that would have been less expensive to repair had the problem been identified earlier. Trees on dams inevitably result in higher maintenance cost of the dam after significant emergency spillway flows, or other appurtenance repairs.

6. Are you aware of current or past research or documented discussions regarding the effects of unwanted vegetation on dam safety? Please list or attach known references.

Y	BOR, COE/MV, COE/SW, DOE/ORNL, MSHA, NPS, USDA
N	COE/SW2, DOE/SRS, NRC, TVA

BOR: *Trees – Structure and Function*, by Martin H. Zimmermann and Claud L. Brown summarized the form and extent of tree roots. See attached.

COE/MV: Waterways Experiment Station has recently done research. Suggest contacting Milton Myers or Buck Taylor for information. Also, go on line to http://www.dep.state.pa.us then to subjects/dam safety and flood protection/fact sheets for information on vegetation and burrowing animals.

COE/SW: Yes. A research paper on the damage to levees from root systems used to be available from the Waterways Experiment Station.

DOE/ORNL: Yes. (FERC guidance noted in answer 1 above)

DOE/SRS: No specific documentation.

MSHA: Stan & Tara did some digging on this issue for Unimin site.

NPS: I have copy of Corps paper.

TVA: None that we have documented. We had failure, resulting from piping along a low level sluice tunnel, of a small low hazard dam where roots from trees growing in the toe were identified but not thought to have contributed to the failure.

USDA: The only related research I am aware of that could be related to dam safety is the research that has been conducted at the ARS Hydraulics Laboratory, Stillwater, OK. This is a location where TP-61, Flow in Vegetative Channels, was done in the 1950's. There is still one of the original natural channels that has been allowed to grow into trees and brush naturally that, I understand, has had infrequent tests to evaluate the flow through these natural channels. This could possibly be correlated with restriction of flow in emergency spillways.

7. If tree removal from earth dams is authorized by your organization, would you please provide available data for examples of procedures, costs, contract

specifications, and photographs of rehabilitated dams?

BOR: This is generally performed as routine maintenance on our dams by the operating entities.

COE/MV: A project may soon be underway in St. Paul District at Pine River Dam. Contact David Rydeen for additional information.

COE/SW: The practice within SWD is to prevent the establishing of trees on earth dams by removal of all saplings.

COE/SW2: We generally remove trees growing on our dams before they get too big. We therefor do not have a detailed procedure for removing them. Whenever trees are removed, the root are excavated and the resulting hole backfilled with compacted soil.

DOE/ORNL: The cost is approximately $15,000 annually. There are no procedures or specifications. Pictures are shown in a report that will be sent to you entitled "Formal Inspection Report, White Oak Dam State Highway 95 Oak Ridge, Tennessee LMER Agreement 74b-99414v Release X-04, September 25, 1998".

DOE/SRS: May be able to provide before and after pictures.

MSHA: Don't have this info.

NPS: This agency has done tree removal with the assistance of Bureau of Reclamation, but it would take several weeks to work up information.

NRC: N/A

TVA: NONE

USDA: I suggest this information be obtained from Oklahoma Conservation Commission, contact Dan Sebert, telephone (405) 521-4818. Note he has been provided with a copy of this survey and will probably be submitting a separate reply.

Part II: Animal Impacts on Dams

8. What types of animals cause problems on earthen dams for your organization?

BOR: Since we are a water resource agency, we published the *Prevention and Control of Animal Damage to Hydraulic Structures* in April 1991 with the Department of Agriculture Animal and Plant Health Inspection Service.

COE/MV: Gophers, beavers, muskrats, and groundhogs mostly on levees. Also, see the online reference in paragraph 6 above.

COE/SW: Any animal that burrows.

COE/SW2: Armadillos and beavers.

DOE/ORNL: Ground hogs, muskrats

DOE/SRS:

- Ants nesting on embankments is a continuing but minor problem.
- Feral hogs root on the embankments and surrounding areas, damaging grass cover.
- Beavers attempt to block spillways, especially on the smaller dams.

MSHA: Have seen only limited evidence of rodent holes.

NPS: Muskrats - damage/burrow holes upstream face of dam

Groundhogs - damage/burrow holes on downstream face

Beavers - obstruct waterways

"California squirrels" - numerous burrow holes in dams

NRC: Rodents - burrow problems

TVA: Not a large problem. However when found they are removed. Groundhogs are typically the only animals that cause problems.

USDA: Beavers are by far the largest problem associated with maintenance of earthen embankments across Oklahoma. The beavers cause major problems by plugging principal spillway inlets, submerging principal spillway outlets, and burrowing into the embankment.

9. How do you deal with each species?

BOR: The publication in question 8 describes strategies to eradicate various burrowing rodents and other mammals. Reptile burrowing, such as alligators, is not addressed.

COE/MV: Extermination or relocation.

COE/SW: Keep vegetation mowed regularly to eliminate ground cover for animals.

COE/SW2: I do not know how we control armadillos but the beavers are trapped and removed.

DOE/ORNL: Tennessee wildlife resource agency officials capture the animals and relocate them to safe areas. engineering controls like rip-rap over the embankments reduce the occurrence of burrows.

DOE/SRS:

- Ants are controlled by routine application of insecticides.
- There is a site-wide hog removal program which includes areas near dams.
- During periods of their highest beaver activity, more regular inspection and removal are required.

MSHA: Case-by-case; no policy or practice

NPS: Typically trapping & relocating away from dam.

NRC: Eradication as proposed by licensee and approved by NRC.

TVA: Remove them.

USDA: The Oklahoma conservation Commission has a cooperative agreement with the Oklahoma Animal Damage Control who send state trappers to remove beaver upon request. There have also been attempts at trying different "beaver guard" designs for flood control dams. See the enclosed report on evaluation of various beaver control trials dated December 15, 1989. Also enclosed in information on beaver control methods and damage prevention developed by Fish and Wildlife Service and article on "Electrical Devices to Help Contain Beavers" for information.

10. What legal, financial, environmental, or other constraints or issues arise when your organization attempts to deal with problems caused by animals on dams?

BOR: Same legal constraints as described with vegetation removal.

COE/MV: Has not been a significant problem. Could become a problem depending on location and means of control.

COE/SW: None

COE/SW2: None that I know of.

DOE/ORNL: Refer to answer to question number 4 above.

DOE/SRS: None special.

MSHA: No experience

NPS: See item four above.

NRC: Potential license violation for failure to treat problem.

TVA: Not aware of any.

USDA: Again, Dan Sebert, Oklahoma conservation Commission, should be contacted for first-hand experience. To my knowledge, primary constraints involve a source of funding for areas with continual problems and access to adjacent landowners (outside the original easement area) where beaver's work has an adverse impact on the dams.

11. Do you have any documented evidence where animals have affected the safe operation or have been linked to the failure of earth dams? Comment and give examples, if available.

Y	BOR, NPS, USDA
N	COE/MV, COE/SW, COE/SW2, DOE/ORNL, DOE/SRS, MSHA, NRC, TVA

BOR: We are aware of past failures where animals may have been a contributing cause, but not on Reclamation dams.

COE/MV: Has not been a significant problem. Could become a problem depending on location and means of control.

NPS: See item five above.

USDA: Plugging of principal spillways by beavers have filled the detention pools of several flood control dams. Then when large storms occur, emergency spillways flow more frequently and for longer duration than they were designed causing significant damage and costly repairs. To my knowledge, we do not have a site-specific example where beavers have directly resulted in failure of a dam, but they certainly have increased maintenance costs significantly.

12. Are you aware of current or past research or public discussions regarding the effects of burrowing animals on dam safety? No. Please list or attach known references.

Y	COE/MV, DOE/ORNL, USDA
N	COE/SW, COE/SW2, DOE/SRS, MSHA, NPS, NRC, TVA

BOR: I am not aware of research or public discussions regarding these effects.

COE/MV: See the online reference in paragraph 6 above.

DOE/ORNL: Refer to answer to question number 6 above.

NPS: Nothing that ASDSO doesn't already have on record from their proceedings

USDA: None, other than the documents mentioned in Number 9 above.

A Survey of ASDSO/ICODS Representatives on Animal Damage To Earthfilled Dams and Appurtenances[1]

by

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Abstract: As preparation for the ASDSO/FEMA sponsored "Workshop On Plant and Animal Penetrations of Earthfilled Dams"held November 30 - December 2, 1999, a survey questionnaire was sent to ASDSO and ICODS representatives in June 1999 to determine, from a national perspective, the current problems and policies relating to plant and animal impacts on earthen dams. The results of the plant survey were reported elsewhere in the proceedings of the workshop (Tschantz 1999). This paper summarizes a series of questions relating to the kinds of animals and the types of impacts effected on earthen dams and other water control structures in addition to reviewing current state and federal issues and policies to dam owners/caretakers in dealing with problems caused by animals. The survey revealed that some of the most severe problems, such as seepage and piping (leading to documented dam failures) was caused by muskrats, beavers, and woodchucks (including marmots) burrowing into embankments. For example, problems with beavers were cited by 32 of the 48 state ASDSO representatives in addition to several ICODS member organizations. The majority of states with beaver problems (78%) specifically mentioned that the "clogging" and "obstruction of hydraulic structures" (restricted flow risers) and spillways often resulted in overtopping of embankment crests with subsequent dam failures. Other animal species causing significant problems included livestock, nutria, badgers, gophers, ground squirrels, prairie dogs, armadillos, and humans (vandals). The most successful abatement method cited, by at least 40 states and 9 ICODS agencies, was "trapping" (including live-trapping and relocation). Additional procedures attempted included: habitat alteration, exclusion (fencing, rip-rap, filters, concrete walls, etc.); shooting (including hunting); and toxicants (including fumigants, repellents and poison). Information on a companion study to produce a bibliography on the impacts of animals on earthfilled dams and appurtenances is updated.

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[1] Presentation and Proceedings: ASDSO/FEMA Specialty Workshop on "Plant and Animal Penetrations of Earthfilled Dams", November 30-December 2, 1999, Univ. of Tennessee Conf. Center, Knoxville, TN.

Introduction

The types of impacts that animals (including humans) inflict on earthfilled dams, levees, restricted flow risers, principal and emergency spillways, and other types of floodwater retarding structures are almost as varied as the species that cause the effects. With continuing constriction, fragmentation and, most importantly, direct loss of animal habitats by the encroachment of human activities throughout the United States, many wildlife species attempt to adapt by using earthen dams and embankments as foraging and den sites. The efficient and effective functioning of these water retaining structures is often reduced and can be totally compromised by these animals and their effects to the point of endangering human life and economics downstream if not addressed by appropriate abatement and remedial procedures.

The primary purpose of this paper is to summarize the results of a survey questionnaire distributed in June 1999 by the Association of State Dam Safety Officials (ASDSO) to member representatives in each state, the Affiliate Member Advisory Committee of ASDSO, and to federal agency representatives of the Interagency Committee on Dam Safety (ICODS). Additionally, a review of current management policies and issues concerning animal penetrations and abatement procedures is discussed.

Methods

The questionnaire consisted of two parts; the first part contained 7 questions related to the impact and policy issues of trees and other vegetative growth occurring on earthen dams was initially developed in 1988 and re-issued currently for comparative purposes (Tschantz & Weaver 1988, Tschantz 1999). The second part of the questionnaire was comprised of 5 new questions relating to animals burrowing into, foraging on or otherwise impacting the safe operation and maintenance of earthen dams and associated appurtenances such as spillways and flow risers. Information was gathered to determine:

(1) Question #8 – the types (species) of animals and their impacts on earthen dam operation and safety;
(2) Question #9 – existing policies and abatement procedures to deal with these problems;
(3) Question #10 – legal, financial and/or environmental constraints to controlling the animals and their impacts;
(4) Question #11 – identification of site-specific, animal-caused, earthen dam failures; and finally,
(5) Question #12 – any knowledge of past or current research activities and documented references.

Each state ASDSO representative, affiliate advisory member, and ICODS delegate was sent a questionnaire. A single reminder request was sent to non-respondents. Results were tabulated as of November 20, 1999 and a PowerPoint presentation was made to attendees at the Knoxville workshop.

Results and Discussion

With the exception of Alabama and Delaware, survey replies were received from 48 states and Puerto Rico ASDSO representatives in addition to 4 ASDSO Affiliate Advisory and 11 ICODS representatives. Many of the answers to Questions 9, 10,11, and 12 (above) were in comment form. A verbatim copy of the survey results may be obtained from ASDSO upon request. For purposes of summarizing and reporting the survey results, some answers have been consolidated and/or abbreviated to fit table columns as needed. Portions of some comments have been reproduced to illustrate a particular viewpoint and to facilitate discussion.

State ASDSO Representative Survey Response

Individual species accounts have been developed based on the information supplied by each state ASDSO response to question #'s 8–12 on the survey form augmented with information obtained from a variety of sources including private, state and federal agency publications related to animal impacts on earthen dams. Table 1 summarizes the state responses by animal type with 7 of the more commonly reported species, including a livestock ("ls") group comprised of cows, horses, sheep, pigs, goats, etc., arrayed in descending order of occurrence with "other species; damage comments" noted in the adjacent column. Table 2 details the state responses on the methods that dam owners/managers have utilized to attempt abatement procedures for problem animals and impacts.

<u>Muskrats</u>: The muskrat ("mu" – Table 1) was listed as the most common species of problem animal impacting the integrity of water retention structures by 34 of 48 (70%) state ASDSO representatives. The principal effect this species has on earthen dams is the extensive tunneling in the construction of dens. Detection of this species is sometimes difficult because entrances to the tunnels are often located just below the water surface along overgrown shorelines. It is known that as water levels rise during periods of high water, muskrats extend their tunnels upward into the interior of the dam to maintain the nest chamber above the waterline. The muskrat is a prolific species with females having up to 6 litters of 6 young each per year (Hegdal and Harbour, 1991; Miller 1994). This mammal probably occurs in most states (and watersheds) throughout the country. Abatement procedures reported by ASDSO representatives included: trapping, shooting,

poison, installation of stone rip-rap, metal fencing laid on upstream slopes, and habitat alteration through reduction of cattail plantings and overgrown bank vegetation.

Beaver: Thirty-two of 48 (67%) state ASDSO representatives reported problems with beavers ("be" - Table 1). Twenty-five respondents mentioned specifically that beavers "blocked principal and emergency spillways" resulting in overtopping during heavy rains in addition to burrowing into earthen embankments or flooding downstream toe areas with tailwater dams. Several state representatives (i.e. CT, GA, MS, NC, NH, NY, PA, and SC) reported beaver activities had "clogged" and "blocked hydraulic structures" commonly referred to as riser outlets.

Blocked riser orifices were reported to be especially problematic at low level units and on those situated in close proximity to the upstream face of the dam. At these sites beavers piled mud and other debris underwater against the face of the structure until inlet openings and trash racks finally were covered. Studies conducted since the mid-1970's in AL, MS, OK, and TX by USDA-NRCS (previously SCS) in attempts to develop a "beaver-proof" riser guard have had mixed results (L. Caldwell, OK USDA/NRCS, pers. commun.). Two designs have showed promise: the first incorporated the use of elbow shaped corrugated metal pipes (CMP) extending into deep water off of the inlet tower while the second design used aluminum grates to completely enclose and isolate trash racks from access by beavers (Reynolds 1976, Anonymous 1984, Haggard and Dominick 1989)

Currently, two economical methods have been used to aid in keeping beavers from blocking riser towers (J. Pelley, OK Cons. Comm., pers. commun.). The first method involves affixing 10 cm X 10 cm (4" X 4") pieces of hog pen panel with bolts or wire to the standard trash rack frame protecting inlet openings. A backup method to ensure water flow through the structure has been to replace the standard manhole cover on top of the riser tower with a "beehive" grate. This cast iron dome permits drainage during high water events even if beavers block the lower orifice(s). The sloping surface of the cone-shaped dome apparently prohibits beaver placed debris from completely obstructing the slotted openings.

It has been found that the deeper the water in which the riser initially is constructed, the greater the protection from the impact of beaver activity over extended periods (Anonymous 1984). Because of their large size (up to 54 kg), beavers construct large diameter (0.5+ m) tunnels and often excavate large underground chambers within earthen embankments for den sites. The potential for internal erosion, seepage, and piping leading to subsequent failure of the structure is always of concern.

Abatement procedures for beaver and their "construction activities" listed by state ASDSO representatives included removal of the animals (both lethal and non-lethal methods) and an array of cultural and habitat alteration techniques (Table 2). A number of states continue to discourage beaver occupancy at a particular site by repeatedly removing beaver debris from riser inlets and spillway structures. This time-consuming and expensive method rarely cause beaver to leave for any length of time. Similarly, experimentation by several states and agencies with various "beaver-proof" drain pipes and exclusionary fencing, while often having short-term success, usually re-quires prohibitive installation and/or maintenance costs over large areas and long term periods. All these methods allow the problem animals to remain in the area to continue embankment degradation from tunneling activities that could, in turn, lead to failure of the structure through seepage and piping events.

The one method for abatement of recurring beaver problems that has been proven efficient and effective through the years has been to intensively trap and remove the problem animals either by kill or live-trap methods (Hill 1976, Woodward 1983, Huffstatler 1990). A trapping effort lasting up to two weeks the first year to remove the majority of beavers present, including breeding adults, followed by "clean-up" of any remaining animals the second year is the recommended procedure (Hill 1976). Huffstatler (1990) stated "beaver costs (and efforts) associated with a systematic trapping program are insignificant compared to repairing or replacing beaver damaged flood water retaining structures."

Woodchucks or Groundhogs (including marmots): Woodchucks and marmots ("wo" – Table 1) were listed by 24 of 48 (50%) states as causing burrowing problems on downstream and levee embankment slopes. Marmots (known as "rock chucks" in western states) prefer rip-rap sites. The main concern with these animals and the other burrowing species mentioned below, is that tunnels dug into the upstream slope (e.g. by muskrat, nutria and beaver) will contact burrows dug by woodchucks (groundhogs) on the downstream slope of the embankment. If this occurs, a geophysical phenomenon called "piping" can result with complete loss of water through the eroded earthen structure. Extensive tunneling and den construction can also result in the formation of seepage pathways, internal erosion, collapse of surface soils, and wash out of dam crests during high water events. Abatement procedures for woodchucks listed by ASDSO personnel included trapping, shooting, toxicants, and fumigants.

Livestock (cows, horses, sheep, pigs, goats, etc.): The column marked "ls" denotes a livestock group of animals including cows, horses, sheep, pigs, and goats which were identified as problems in 12 of 48 (25%) states (Table 1). In Puerto Rico, the livestock group was the only animal type reported causing problems on earthen dam slopes. The livestock group was reported from mostly western states to forage and root on grassy slopes reducing protective vegetation and resulting in: trampling, sloughing and erosion of embankment slopes; creation of erosion-prone foot trails; loss of effective width of the dam crest (freeboard), and reduction in the phreatic surface distance. Respondents from several western states installed fencing to restrict problem livestock access to dam slopes. The overgrazing of erosion prone slopes was also discouraged.

Gophers: Pocket gophers ("go" – Table 1) were listed by 11 of 48 (23%) state respondents from the western United States as causing problems on embankment and levee slopes. This group of burrowing rodents belongs to the family Geomyidae and ranges in size from 36 cm (14 inches) in length and up to 500 g (20 ounces) in weight. Gophers dig extensive tunnels foraging on both surface forbs and underground root structures of herbaceous plants. Not only does the tunnel system weaken the integrity of dam embankments but gophers are preyed upon by larger predators, such as coyotes and badgers, that attempt to dig them out of their tunnel system, thereby enlarging surface holes and contributing to additional erosion, seepage, and piping problems. Abatement methods include a range of legal toxicants that are placed underground, fumigants, and trapping (Hegdal and Harbour 1991).

Badgers: Eight of 48 (17%) western state ASDSO representatives reported that badgers ("ba" – Table 1) were a problem around dams. Specifically, badgers were said to dig some den burrows but, more importantly, badgers excavate smaller mammals such as gophers, ground squirrels, prairie dogs, and other small rodents for food. Although shooting and trapping can be used for control in some instances, best abatement methods include control of the prey species on which this predator feeds.

Ground Squirrels: Ground squirrels ("gs" – Table 1) were reported by 6 of 48 (13%) states and were the seventh most numerous "type" of problem animal around dams and levees. This is a widely dispersed group of rodents comprised of 17 species found in over 27 states. Although varying in size, some of these species can reach 50 cm (20 inches) in length and up to 1000g (2.5 lbs.) (Hegdal and Harbour 1991). The extensive tunnels constructed by this, for the most part, colonial group of rodents, have been determined to cause increased seepage and potential piping problems in both dam and levee (canal) slopes, especially after high water events from heavy rains. As with gophers, dense populations of ground squirrels attract predators, such as the aforementioned badger, which, in turn, open up tunnel entrances in attempting to dig out the ground squirrel. Abatement methods include toxicants, fumigants, trapping, and shooting.

"Other" Species:

Inspection Problems: The following brief accounts represent miscellaneous animal species or groups of animals listed by either state ASDSO or ICODS representatives on the survey returns. The term "other" should not be construed as representing a species of lesser importance to the safety and protection of human life and property or to the proper functioning and maintenance of water control structures. For example, if the vegetation on embankment slopes has not been maintained in a short grass cover and is overgrown with impenetrable trees, brush, and weeds, inspection personnel may not be able to perform as complete an inspection as necessary to ensure the integrity of the structure because of worries about snakes (especially venomous species), insects (mosquitoes, flies, and fire ants) or even the presence of ticks, which may carry Rocky Mountain Spotted Fever and Lyme's disease. In fact, this example was mentioned by the states of IL, MI, NC, and TX and ICODS DOE/SRS in listing problems with these animal groups, in particular. The RI representative stated that the types of animals causing problems to dams in that state were "None to my knowledge. Most of the embankments have been so overgrown with vegetation, a complete visual inspection could not be performed."

Prairie Dogs: Prairie dogs were reported to be problems on dams (embankments and emergency spillway slopes) in NE, NV, OR, and WY (Table 1). These colonial rodents can weigh up to 1.7 kg (4 lbs.). Of the 4 species found in several western states, the black-tailed prairie dog is the most widespread occurring in the Great Plains region from MT to TX. The ASDSO representative from WY commented that control efforts may have to be curtailed as the future existence of the federally endangered black footed ferret is closely tied to that of the prairie dog on which it feeds. In addition to gophers and ground squirrels, prairie dogs also form a part of many other predators' food chains, including the badger.

Armadillos: The armadillo was listed only by the states of LA and TX and ICODS COE-SW2 (see Table 3) as being a problem. However, as this species continues to expand its current range from TX to FL and north to SC, KS, and MO, additional impacts on water retaining embankments may become more common in the future. This species can weigh up to 8 kg (17 lbs.) and prefers to dig dens, averaging 20 cm (8 in) in width and up to 5 m (15 ft) in length, in sand or loam soils (Hegdal and Harbour 1991). It also digs small surface holes in its nightly search for food, which consists primarily of invertebrates. Local control of this animal involves habitat alteration and exclusion, trapping, and shooting.

Nutria: The nutria is another example of an animal that, historically, has been known to damage crops and infrastructure in many coastal states but, as in the previous species, was listed only by LA and TX as being a problem on dams and levees. In fact, the TX comment was "beaver and nutria are the most destructive animals for earthen dams...we have incidents where dams have failed as the result of higher lake levels allowing water to flow through the tunnels or dens and cause internal erosion and subsequent breaching of the dam." Currently found in at least 20 states, the nutria can reach 9 kg (20 lbs.) in weight. Nutria are very prolific producing 2 litters a year with up to 9 young per litter. Each female becomes capable of breeding at 6 months of age (Willner 1982). Trapping for the fur market can help in some situations by maintaining populations below levels that cause extensive damage to dam and canal banks (Kinler, et al. 1987). However, additional abatement procedures including vegetation control on embankments, use of toxicants, and shooting may have to be employed to control overabundant local populations of problem animals (Hegdal and Harbour 1991).

Rats, Mice, Voles and Moles: This group of small burrowing mammals was listed by several states, including HI, IL, VA, WA, and WV, as causing problems on earthen dams and other types of embankments. None of these species was directly implicated in dam failures. These small mammals, however, are attracted to brushy, overgrown and unmanaged vegetation growing on slopes for use as food sources (seeds and succulents), nest sites and cover from predators. In fact, 12 of 48 state ASDSO representatives completing Part 1 of the questionnaire dealing with the impacts of plant penetration and reported by Tschantz (1999) in the "Workshop Proceedings", specifically mentioned that "excess vegetative growth": (1) hampered visual inspections, (2) provided cover for animal burrows, and (3) provided protection (to prey) from natural predators. Several state representatives indicated that these small mammals had "softened up" dam crests leading to increased erosion, others believed dense populations of these prey species tended to attract larger mammalian predators, such as badgers, coyotes, and foxes. Regular and thorough maintenance of embankment slopes should aid in prevention or remedial abatement of such problems.

Humans: The survey returns from ME, MI, and OR mentioned problems with human vandals impacting the integrity and safety of earthen dams and related water control structures. The respondent from MI summarized the types of problems encountered stating "...vandals seem to have a pre-occupation with unauthorized placement or removal of stoplogs, unauthorized manipulation of gates, placement of debris in spillways, and riding ORV's up and down slopes."

Reptiles: The only problem animal species the FL survey return documented was the existence of: "Gopher tortoises. They dig long (35 ft and more, 18 inches in diameter) tunnels into embankments." Stated abatement procedure for this federally listed, endangered reptile was stated as: "re-location." The ASDSO representative from IA related that snapping turtles had been reported "burrowing into embankments." In this particular instance, personal experience of the senior author has often noted that this species of turtle is commonly found in bank depressions and excavations made by other animals, such as beavers, rather than the turtles' initially having made the holes. The TX state survey return listed the alligator as a problem species by its underwater burrowing into embankments to construct dens and as a "hindrance" during dam inspections.

Crayfish: The crayfish ("crawdad") was listed as a problem animal by the IL state ASDSO representative. Abatement procedures included: "provide toe drainage to minimize their preferred environment – in some cases lime stabilization of the downstream face of the embankment has been necessary." The survey return from KS stated: "crawfish have been suspected in some piping incidents as they were found in the cavities, but we are uncertain if the crawfish were the agents to forming the cavities."

Summary of Abatement Procedures

Although abatement techniques have been outlined for many of the species accounts discussed previously and comprise the data set used in Table 2, the following responses by individual state ASDSO representatives were selected to represent "interesting" or "common sense" answers to Question # 9: "How do you deal with each species."

CA – "The owner is directed on a case by case basis to abate animal damage. The reason for the abatement is explained and the desired goal explained. The means and methods are left to the owner."

IA – "Trapping, relocating, shooting, and poisoning animals have been used by a variety of dam owners in IA. The method of control would be up to the individual dam owner, as long as it's legal."

MN – "We don't try to remove the animals, they are too hard to eradicate. We repair the holes."

PA – "We defer the problem of elimination or removal to the owner, who consults with the state game commission for the recommended course of action."

TX – "We recommend that the burrowing animals and soil disturbing animals be removed from the dam and vicinity, either by trapping and relocation or other means. Fire ants may be eradicated temporarily with chemical treatments. Any destruction caused by animals should be appropriately repaired, based on the extent of damage."

Summary of ASDSO and ICODS Responses to Question # 10

Question # 10, asked: "What legal, financial, or environmental constraints or issues arise when your organization attempts to deal with problems caused by animals on dams." Responses from 46 state ASDSO representatives resulted in 13 (28%) that stated "none." Most of the state and ICODS (Table 3) responses indicated that "animal control must be done in accordance with current laws and regulations." Of the remaining comments, the following, listed in alphabetical order by state, have been reproduced verbatim to illustrate different viewpoints:

CA – "The owner often cites as reasons for delays in abatement, the constraints presented by legal, financial, environmental, and other processes. It remains the owner's responsibility to perform the abatement."

CO – "The dam owners must deal with environmental issues pertaining to trapping or exterminating animals, with the assistance or guidance of the local wildlife agencies. The issue of livestock control has a mostly financial impact on dam owners, who generally hate to see all that grass unavailable for their animals. The owner must choose how he wants the dam used, for water storage (or flood control) or for pasture. He generally can't have both."

CT – "Animal eradication is also problematic, due to regulatory constraints in terms of trapping and hunting (i.e. time of year, proximity to residences, method of trapping, types of traps, etc.). Occasionally, 'special' out-of-season trapping permission is granted by the DEP wildlife division in severe situations of beaver infestation."

IL – "Primarily it is only the reluctance to do the necessary work."

KY – "Nothing major. The biggest problem is the persistence of the varmints."

MA – "Since they changed the trapping laws to 'HAV-A-HART' only, the beaver and muskrat populations have grown exponentially out of control. Very controversial at this time."

MT – "None so far, getting the owner motivated to do the work is a problem sometimes."

NC – "Potentially, organizations such as 'People for the Ethical Treatment of Animals' (PETA) could raise concerns for removal."

ND – "The main constraint is that most dams are isolated from human habitation and are not frequently monitored by caretakers..."

NE – "It is difficult to find trappers if the value of the animal pelts is low."

NJ & NM – "It is the responsibility of the individual dam owner to ensure that all local, state, and federal laws are obeyed when removing burrowing pests."

NY – "Widespread beaver populations leaves no transfer locations for 'trap and transfer'."

SC – "Our problem is often in getting the owner to take the necessary action. If he won't do so voluntarily, we have no option but to initiate legal action against him. As with the problem with vegetation, legal help is limited, and must be rationed for the most extreme cases."

WY – "Biggest problem now is just recurrence but the Endangered Species Act could be a future problem."

In addition to the states of IL, MT, and SC quoted above, 3 additional states cited troubles in convincing dam owners they "have a problem" or in motivating them to perform needed animal control and remedial repairs. A total of 6 states mentioned that special re-location, nuisance and/or "out-of-season" trapping permits from appropriate authorities were needed for animal control. Lastly, a total of 7 states reported that dam owners cited "financial constraints" as a reason for delaying necessary work. From the number and diversity of comments received on this question, it is apparent that there exists a need for increased communication, with an emphasis on education, between agencies assigned to monitor both the safety of dams and the owners and/or managers of the structures.

Summary of ASDSO and ICODS Responses to Question # 11

Answers to Question # 11, "Do you have any documented evidence where animals have affected the safe operation or have been linked to the failure of earth dams?" were received from 25 (60%) of the 42 states that responded in some way to this question. A total of 16 states provided evidence of 1 or more dam failures. None of the 11 ICODS agencies reported any dam failures from animal activity on their lands (Table 3). The following alphabetical listing of states has been compiled, together with the reason for the dam's failure:

CA – Records indicated that "uncontrolled releases" of water occurred from 1932 – 1996 from 7 different earth dams with multiple animal problems at Mud Lake (3), Rye Grass Swale Dam (2), Kelley & Greiner Dam (2), and Nine Springs Dam (2).

CT – A failure was documented "where an earthen embankment was riddled with woodchuck burrows and subsequently significant soil movement occurred."

GA – Casey Lake Dam was lost due to "...beaver dens that went well into the dam and were a direct cause of the dam to fail."

IA – An earthen dam failed in "eastern IA in 1986 because of rodent burrows."

ID – Frazier Dam failed, "...in part due to animal burrows (their activity)."

KY – "We had pretty strong circumstantial evidence on one dam that developed major piping in an area of the dam that we had detected animal burrows, which we directed the owner to fill. We know they were filled surficially, but suspect that the owner did little more than that."

MI – "...we have one documented failure, the US–10 flooding in Midland County" (by beaver).

MO – "We have several tailings dams that have chronic problems with beavers building dams in spillway channels and thereby significantly reducing the spillway capacity. We have an earth dam that overtopped due to beavers totally blocking the open channel spillway for the dam."

MS – "We have had several dams to fail or nearly fail because of beaver activity."

NC – "Beavers clogging spillways caused overtopping failures..."

OH – (1) Crawford Fitting Company Pond Dam from muskrat, (2) Pischieri Pond Dam from piping caused by animal burrows, and (3) Crown City Mining Pond No. 024 Dam by overtopping due to plugging of the spillway by beavers.

OK – "...several small farm ponds have been lost due to gophers or beavers."

TN – "Almost certainly caused failure of Mary's Creek #8 Dam in Shelby County. Pipe developed between muskrat holes on the upstream slope and groundhog hole on the downstream slope."

TX – (1) Harris Back Lake Dam, TX 4877, failed from internal erosion through beaver dens, (2) Willow Lake Dam, TX 3541, failed partly from fire ant tunnels.

UT – "Wales Reservoir failed in 1983 due to piping through badger holes."

WY – "We had one case where a significant hazard dam was found to have a large badger hole and shortly thereafter the dam almost failed (piping) at the same place the hole had been noted."

The remaining 25 state ASDSO representatives listed many instances of safety problems due primarily from beaver, muskrat, and woodchuck activity on dam embankments or in associated risers and spillway structures.

Summary of ASDSO and ICODS Responses to Question # 12

Question # 12 asked "Are you aware of current or past research or public discussions regarding the effects of burrowing animals on dam safety? Please list or attach known references." Only 9 of 45 (20%) state ASDSO and 3 ICODS (Table 3) representatives answered Question # 12 in the affirmative. Of the 9 states answering "yes", only TX and VA provided references. TX referenced a 2 page information sheet entitled "Animal Burrows and Lodges" that was produced by the Texas Natural Resource Conservation Commission and was available over the internet. The state of VA attached a 2 page "Dam Safety Fact Sheet No. 4 – Rodent Control on Earthfilled Dams" which briefly described groundhog, muskrat, and beaver abatement procedures. The ICODS COE/MV representative referenced the fact sheet, "Burrowing Animals and Dams", produced by the PA Department of Environmental Protection and obtainable over the internet. The DOE/ORNL ICODS representative follows guidance per "engineering guidelines for the evaluation of hydroprojects FERC (Federal Energy Regulatory Commission) Office of Hydropower Licensing April 1991". The third federal ICODS agency that responded, USDA/NRCS, referenced two reports: (1) a 1989 status report on the testing of various riser beaver guards which previously has been discussed in the beaver section; and (2) a brief article on "Electrical Devices to Help Contain Beavers" written by B. DeVille of the Samuel Roberts Noble Foundation, Ardmore, OK.

Update on Bibliography of Animal Impacts on Earthen Dams

Efforts are continuing on a companion study to search and assemble the available literature relating to animal impacts on earthfilled dams and appurtenances. Many state departments of environmental protection have brief "fact sheets" on animal impacts and abatement procedures. These references are located in the ASDSO library along with ASDSO sponsored workshops and annual meeting proceedings, in addition to other references that have been accessed to provide an initial database for a "working bibliography" on this topic. However, additional sources are now being researched including the National Technical Advisory Service (NTIS) and the National Performance of Dams Program (NPDP). Other databases will also be accessed through the university library and the Internet. The final product will be produced and distributed in the near future with the guidance of ASDSO.

Literature Cited

Anonymous. 1984. Report of coordination and evaluation of beaver guard devices to prevent plugging of principal spillway risers. South National Technical Center, Fort Worth, TX. 9 pp. + Appdc. 1– 18.

Haggard, D. W. and M. D. Dominick. 1989. Evaluation of beaver guards on restricted flow risers of SCS assisted floodwater retarding structures in Oklahoma. USDA-SCS, Stillwater, OK. OK Bull. No. OK210-0-3.

Hegdal, P. L. and A. J. Harbour. 1991. Prevention and control of animal damage to hydraulic structures. U.S. Government Printing Office, Denver, CO. 102pp.

Hill, E.P. 1976. Control methods for nuisance beaver in the southeastern United States. Proc. Vertebr. Pest Conf. 7:85–98.

Huffstatler, H. G. 1990. An evaluation of trapping for beaver control on floodwater retarding structures. USDA:SCS, Jackson, MS. 21 pp.

Kinler, N. W., G. Linscombe and P. R. Ramsey. 1987. Nutria. Pages 326–343. *in* Wild Furbearer Management and Conservation in North America. M. Novak, J. A. Baker, M. E. Obbard, and B. Malloch, eds. Ontario Trappers Association, Ontario, Canada.

Miller, J. E. and G. K. Yarrow. 1994. Beaver. Pages B1–B11 *in* Prevention and Control of Wildlife Damage. S. E. Hygnstromm, R. M. Timm, and G. E. Larson, eds. Univ. of Nebraska Cooperative Extension. Lincoln, NE.

Reynolds, R. E. and J. C. Lewis. 1976. Evaluating beaver guards on restricted flow risers of flood control impoundments. Proc. Annu. Conf. Southeast Assoc. Fish and Widl. Agencies. 30:455–462.

Tschantz, B. A. and J. D. Weaver. 1988. Tree growth on earthen dams: a survey of state policy and practice. Univ. of Tennessee, Civil Engineering Report, 36 pp. + Appdc. A & B.

Tschantz, B. A. 1999. Overview of Issues and Policies Involving Woody Plant Penetrations of Earthfilled Dams. Presentation and Proceedings, ASDSO/FEMA Specialty Workshop on Plant and Animal Penetrations on Dams. ASDSO, Knoxville, TN. 8 pp.

Willner, G. R. 1982. Nutria. Pages 1059–1076 *in* J. A. Chapman and G. A. Feldhamer, eds. Wild Mammals of North America: biology, management, and economics. Johns Hopkins Univ. Press, Baltimore, MD.

Woodward, D. K. 1983. Beaver management in the southeastern United States: a review and update. Proc. East. Wildl. Damage Control Conf. 1:163–165.

State	mu[1]	be	wo	ls	go	ba	gs	"Other Species"; Comments re: damage, etc.
Alabama								No Response
Alaska								"no specific incidents known"
Arizona					x	x	x	"ants", marten
Arkansas								"burrowing animals"
California	x			x				publication provided on muskrat control
Colorado	x	x	x	x	x			
Connecticut	x	x	x					
Delaware								No Response
Florida								"gopher tortoise burrows 18 in. dia. X 35 ft. long"
Georgia	x	x						waterline burrows cause slope sloughing & sliding
Hawaii								"rat burrows in flood control levees"
Idaho	x		x		x	x		
Illinois	x		x				x	crayfish, fox, snakes, mice
Indiana		x	x	x				
Iowa	x	x			x			"embankment burrowing by snapping turtles"
Kansas	x	x		x				crayfish(? - see text)
Kentucky	x		x					
Louisiana								armadillo, nutria
Maine	x	x	x					human vandals; raccoon, porcupine, otter
Maryland		x	x					
Massachusetts	x	x						"beaver flooding of downstream toes..."
Michigan	x	x	x	x				human vandals; insp. problems w/ insects and ticks
Minnesota	x		x					
Mississippi		x						
Missouri	x	x	x					
Montana	x				x			
Nebraska	x	x				x		prairie dogs create "towns" on slopes & aux. spillway
Nevada	x	x		x				prairie dogs, "other rodents"
New Hampshire		x	x	x				"beavers fell trees onto structures"
New Jersey	x		x					"burrowing mammals"
New Mexico					x			"usually gophers"
New York	x	x	x	x				
North Carolina	x	x	x					insp. problems with snakes and ticks
North Dakota		x			x			beaver dams cause backwater at low outlets
Ohio	x	x	x					"burrows weaken embankments"
Oklahoma		x			x	x		
Oregon	x	x				x	x	human vandals; coyote, nutria, prairie dogs
Pennsylvania	x	x	x					"see attached fact sheet" (text discussion)
Rhode Island								"none [no problems] to my knowledge"
South Carolina	x	x						
South Dakota	x	x		x				livestock overgrazing = erosion
Tennessee	x	x	x					
Texas	x	x		x	x	x	x	alligator, armadillo, fire ant, wild hog, nutria, snake
Utah	x	x		x	x	x	x	livestock leave trails on dam slopes
Vermont	x	x						overgrazing leads to "sheet, rill and gully" loss
Virginia	x	x	x	x				mole
Washington	x	x						mole, mountain beavers
West Virginia	x	x	x					"mice burrowing into internal drain outlet pipes"
Wisconsin	x	x	x					
Wyoming	x				x	x	x	prairie dogs

Table 1. Species of animals causing problems in earthen dam structures identified by state ASDSO representatives in a 1999 survey ([1] mu = muskrat; be = beaver; wo = woodchuck, including marmots; ls = livestock; go = gophers, ba = badgers, gs = ground squirrels).

State	"How do you deal with each species"
Alabama	No Response To Questionnaire
Alaska	no answer
Arizona	landowner handles problem, poison baits, live trap & re-locate T& E species
Arkansas	"all the same with us"
California	case by case abatement; means & methods left to landowner
Colorado	fence out livestock, hire licensed PCO or DNR to remove problem animals
Connecticut	trap, anti-beaver fencing
Delaware	No Response To Questionnaire
Florida	live trap & re-locate
Georgia	case by case abatement; means & methods left to landowner
Hawaii	poison baits, trap
Idaho	case by case abatement; means & methods left to landowner
Illinois	trap, maintain embankments, provide toe drainage for crayfish abatement
Indiana	trap, shooting (including hunting)
Iowa	case by case abatement; means & methods left to landowner, poison bait, trap
Kansas	case by case abatement; means & methods left to landowner
Kentucky	trap, fill burrows
Louisiana	trap
Maine	poison baits, shooting (including hunting)
Maryland	trap
Massachusetts	hire licensed PCO to remove problem animals
Michigan	shooting (including hunting), trap, fill burrows, fence out livestock & humans
Minnesota	fill burrows
Mississippi	trap
Missouri	trap, live trap & re-locate
Montana	poison baits
Nebraska	case by case abatement; means & methods left to landowner, poison bait, trap
Nevada	case by case abatement; means & methods left to landowner
New Hampshire	fill/compact burrows, eradicate woodchucks & beavers or re-locate, trash racks
New Jersey	fill burrows, live trap & re-locate
New Mexico	poison baits
New York	fence out livestock, trap and shoot rodents, some use of 'beaver tubes'
North Carolina	trap
North Dakota	fill gopher burrows, remove beaver dams
Ohio	fumigants, shooting (including hunting), trap, rip-rap for muskrats
Oklahoma	control of problem animals by 'USF&WS Animal Damage Control Section'
Oregon	poison baits, trap, live trap & re-locate, hunting, habitat alteration
Pennsylvania	case by case abatement; means & methods left to landowner
Rhode Island	N/A
South Carolina	trap
South Dakota	fence out livestock, removal of beaver dams
Tennessee	trap, smoke bombs, fill burrows
Texas	trap, live-trap & re-locate, chemicals for fire ants
Utah	poison bait, trap, live trap & re-locate, fence livestock, drain habitat (muskrats)
Vermont	beaver proofing pipes, stone rip-rap on embankments and outlets
Virginia	case by case abatement; means & methods left to landowner
Washington	case by case abatement; means & methods left to landowner
West Virginia	fill burrows, clean up after beavers, live trap & re-locate
Wisconsin	repair damage, trap or shoot nuisance beaver
Wyoming	poison baits, trap muskrats, concern over future prairie dog protection (?)

Table 2. 1999 state ASDSO representative survey recommendations for abatement of animal impacts on earthen dam structures and other appurtenances.

Organization	What types of animals cause problems on earthen dams for your organization?	How do you deal with each species?	What legal, financial, environmental, or other constraints apply to issue?	Any documented evidence where animals have affected safe operation or caused dam failure?	Any knowledge of past research on or the effects of animals on dam safety? (please attach references)
BOR (US Bureau of Reclamation)	see reference: BOR/USDA-APHIS, 1991 publication by Hegdal and Harbour	see publication at left	"all work complies with Nat'l Environ. Policy & Endangered Species Acts"	"...not on BOR dams..."	"No" (but see publication referenced at left)
COE/MV (US Army Corps of Engineers - MS Valley)	muskrats, beavers, groundhogs, and gophers	"extermination or relocation"	"... not a significant problem..." (at this time)	"No"	"see text re: Summary of Question # 12"
COE/SW (US Army Corps of Engineers - SW1)	"any animal that burrows"	"...vegetation mowed regularly to eliminate cover for animals"	"none"	"No"	"No"
COE/SW (US Army Corps of Engineers - SW2)	armadillos and beavers	"...beavers are trapped and removed"	"none that I know of"	"No"	"No"
DOE/ORNL (US Dept. of Energy - Oak Ridge National Lab.)	muskrats and groundhogs	"...TN Wildlife trap and relocate problem animals; rip-rap also used"	"ORNL is compliant with all applicable fed., state, and local regulations"	"No"	"see text re: Summary of Question # 12"
DOE/SRS (US Dept. of Energy -Savannah River)	fire ants, feral hogs, and beavers	"...insecticides for ants, trap and remove hogs and beavers"	"none special"	"No"	"No"
MSHA (Mine Safety & Health Administration)	"have seen only limited evidence of rodent holes"	"case by case, no policy or practice"	"no experience"	"No"	"No"
NPS (National Park Service)	muskrats, beavers, groundhogs, and ground squirrels	"trap and relocate"	"...individual park managers decide on management..."	apparently not from animals	"No"
NRC (US Nuclear Regulatory Commission)	"rodents - burrow problems"	"eradication as proposed by licensee and approved by NRC"	"...potential license violation for failure to treat problem..."	"No"	"No"
TVA (Tennessee Valley Authority)	"groundhogs, not a large problem"	"remove them"	"not aware of any"	"No"	"No"
USDA/NRCS (Natural Resources Conservation Service)	"beavers, by far, are the largest problem in Oklahoma"	"...beaver are removed; also beaver guard designs for risers..."; see text	"...funding and access to adjacent landowner properties..."	"...no failures from beavers...but increased maintenance..."	"see text re: Summary of Question # 12"

Table 3. 1999 ICODS representative survey responses concerning animal types, abatement, impacts, etc. on earthen dam structures.

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National Performance of Dams Program

Martin W. McCann, Jr.[1]

Abstract

After years in development, the National Performance of Dams Program (NPDP) was kicked off at the 1994 Association of State Dam Safety Officials (ASDSO) conference in Boston. The NPDP is designed to put dam engineering and dam safety in a position where the lessons learned from the in-service performance of dams, as it relates to their design and operation, can be more efficiently chronicled and translated into improved design and safety standards and public policy.

Introduction

Engineers have long been in the business of learning from the in-service performance of structures and systems they design. Prior to the development and use of engineering analysis and design tools, builders relied on trial-and-error experiences to construct safe structures. Unfortunately, some lessons are learned only as a result of system failures. Although the capability of engineering tools to predict structure behavior prior to construction has steadily improved, engineers continue to rely heavily on direct observation of in-service performance to verify design and analysis methods.

The construction and operation of dams is a classic example in civil engineering where trial, success, and error have played a major role in the development of dam engineering. While dams have been constructed and operated to serve water resource needs for at least 5000 years (Jansen, 1980), there remains today as much as ever, a focus on improving dam engineering, operation, and safety through the verification of methods of engineering analysis, testing of new design and construction methods, and the improvement of codes and standards.

From time to time, dam engineers have compiled data on dam failures and incidents (Engineering News, 1902; Babb and Mermel, 1968; Middlebrooks, 1975; USCOLD, 1975, 1988) in an effort to learn from past experience. However, at no time has an attempt been made to establish a national capability to systematically collect and archive information on the performance of dams. The purpose of the NPDP is to do exactly this.

As the information age advances, it is important that engineers, owners and regulators be in a position to assess the condition of dams and to predict future

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trends. The National Inventory of Dams (NID) has established a standard for federal, state and private sector cooperation in developing an up-to-date, useful and readily available source of information on the number and location of dams in the U.S. In this same spirit, the NPDP creates an information track that requires these same partners to report, archive and disseminate data on the performance of dams.

The foundation for the NPDP partnership was laid by the Center on the Performance of Dams at Stanford University (Center), ASDSO and the Federal Emergency Management Agency (FEMA). Unique features of the program include:

- a goal to achieve 100 percent reporting of dam incidents,
- real-time notification of dam incident occurrences,
- a special library devoted to the performance of dams, and
- utilization of the Internet to facilitate information exchange and access to NPDP resources.

Resources developed by the NPDP will benefit the engineer, policy maker, and the public by:

- maintaining an archive that provides resources to learn from the in-service performance of dams;
- gathering data to aid in the identification of pre-cursory signs of distress at dams,
- making information available that measures the value and need for dam safety programs, and
- providing a realistic perspective of the risks associated with dams and their operations.

The NPDP is a proactive effort of the dam safety profession to build an information network that will elevate dam safety to a level commensurate with other disciplines involving the health and safety of the public (e.g., medical, law enforcement, transportation, air travel) where information resources make it possible to measure the value of effective engineering standards and public policy.

NPDP Organization

The NPDP is a broad-based, cooperative program involving all segments of the dam safety community. The NPDP infrastructure consists of the:

- Executive Committee
- Center on the Performance of Dams

Executive Committee - The program is managed by an Executive Committee whose members represent all segments of the dam safety community in the U.S. and Canada (see the adjacent table). It's primary responsibility is to establish the goals and scope of the program and to oversee its implementation.

Executive Committee
Chairman - Director, Center on the Performance of Dams, Stanford University
Association of State Dam Safety Officials (2)[1]
Canadian Dam Safety Association and Canadian Committee on Large Dams (1)
Federal Emergency Management Agency (1)
U.S. Interagency Committee on Dam Safety (1)
Private Dam Owners (2)
Engineering Firms (2)
U.S. Committee on Large Dams (1)
[1]The number in parenthesis indicates the number of seats on the committee.

Center on the Performance of Dams -The secretariat and archive for the NPDP is located at the Center on the Performance of Dams (Center) at Stanford University. Stanford University is located in Palo Alto, California, approximately 30 miles south of San Francisco. The Center is an inter-disciplinary group sponsored by the School of Engineering and created as a result of an ongoing project supported by the Federal Emergency Management Agency (FEMA). The author is the Director of the Center and Chairman of the NPDP Executive Committee.

<u>Reporting Dam Incidents</u>

An important part in setting up the NPDP concerned the establishment of a standard for reporting dam incidents. To meet this need, the *Guidelines for Reporting the Performance of Dams* (NPDP, 1994 were developed by a working group of engineers from ASDSO and Stanford. The *Guidelines* address such issues as the events that are considered reportable dam incidents, how should an incident be documented and where is the information sent.

What is a Dam Incident? - One of the major issues addressed in the Guidelines is the definition of a dam incident. A dam incident is an event of engineering interest that provides insight to the structural and operational integrity of dams. This definition includes obvious events involving dam failure and uncontrolled release of the reservoir. However, limiting dam incidents to failures is far to narrow of a characterization which only focuses on extreme instances of unsatisfactory performance. Experience suggests the investigation of failures alone does not always provide the needed benefits and insights that are often hoped for because the failure often destroys critical evidence (Carper, 1987). Consequently, the results of failure investigations are not always conclusive. Leonards (1982) suggests there are valuable lessons that can be learned by observing the in-service performance of a facility and the wide range of load/performance (response) scenarios that it experiences.

Defining dam incidents as events of engineering interest accommodates a broad range of events. It includes events involving:

- the performance of a dam (satisfactory or unsatisfactory, anticipated or unanticipated) during periods of extreme loading such as produced by a nearby seismic event or a large inflow flood,
- misoperation resulting in uncontrolled release from a reservoir,
- implementation of an emergency action plan,
- signs of distress that are indicative of a potential loss of structural/operational integrity of a dam or its appurtenant structures,
- extreme deterioration of concrete, steel or timber structures that jeopardizes their structural integrity and safety, and
- dam safety modifications that are required to satisfy regulatory requirements and repairs to remedy damage caused by a dam incident.

As indicated above, the definition of dam incidents includes events that involve not only unsatisfactory performance. For example, if a dam experiences earthquake ground motion that is equal to or greater than its seismic design basis, this event provides quantitative insight to the "true" structural integrity of the dam and its appurtenant structures. Systematic documentation and evaluation of events of this type, as well as those that involve failures or other levels of unsatisfactory performance, provides an experience database with which quantitative assessments can be performed and valuable insights derived. The Guidelines provide specific guidance to determine if a dam incident has occurred. In most cases it is relatively easy for the engineer to determine if an event is a dam incident.

<u>Reporting Process</u>

Another purpose of the *Guidelines* was to define a straightforward process for reporting dam incidents. The process, illustrated in Figure 1, consists of four steps. They are:

1. Determine if a dam incident has occurred.

2. Prepare a Dam Incident Notification (DIN)

3. Prepare a Dam Incident Documentation Report (DIDR)

4. Prepare a Dam Incident Follow-up Report (DIFR)

Figure 1 Steps involved in reporting dam incidents.

In the first step the engineer determines if a dam incident has occurred. The *Guidelines* identify the events that are considered dam incidents. If an incident has occurred, a Dam Incident Notification is completed. The DIN is a simple, one-page form that is used to identify the dam, the type of incident and any preliminary information that may be available on damage that occurred. The DIN can be completed and mailed to the Center or on the NPDP web page. Next, the DIDR is used to document what happened during the incident, the damage to the dam or appurtenant structures, downstream damage and the as-built design characteristics of the dam. The DIFR documents activities following an incident such as the results of investigations into the cause of an incident, repairs, design changes, etc.

<u>Center On the Performance of Dams</u>

When a Dam Incident Report is prepared, it is sent to the Center at Stanford. The Center serves as the archive and database for the NPDP. The Center's role is to store and manage information on the performance of dams and to make it available to dam safety professionals.

The Center consists of a library, a research and library staff, and a database information system. In addition to its activities as a technical resource for dam engineers and others, the Center will also be involved in dam safety and dam-engineering research. The library and research staff will process dam incident reports as they are received, conduct studies to identify trends in the performance of dams, and evaluate the factors involved in dam incidents. The library staff will respond to requests for information and identification of available references. A database information system will provide easy search capability of the library holdings and basic information on dam incidents.

NPDP Resources

The foundation of the NPDP resources is the special library at the Center on the Performance of Dams. The library maintains a collection of NPDP Dam Incident Reports, as well as records of historic dam incidents pre-dating the program. The library currently holds nearly 6000 documents including newspaper and magazine articles, videotapes, slides and photographs, dam inspection reports and engineering studies of notable dam failures. In addition to the NPDP library, the program resources include:

- NPDP Directory of Dams
- Incident Database
- Reference Database

NPDP Directory of Dams - the inventory is a database of existing or retired dams in the U.S. and Canada for whom incidents have been reported.

Incident Database - this is the master database of dam incidents on file at the NPDP archive. It provides basic summary information about an incident, including a brief narrative.

Reference Database - this database lists all documents on file in the NPDP library. Documents can be identified through a keyword search, dam name or ID number, or document type (i.e., videotape).

NPDP Resource Access

An important role of the Center is to make information on the performance of dams available to dam engineering and dam safety professionals. This dissemination will be carried out in two formats. In the future, the dam engineering professional will be able to actively access the Center's archive on the Internet. As a library, documents will be available for reproduction or loan. As the resources of the Center expand, online computer access will make it possible to conduct searches, report dam incidents and make information requests. At this time engineers can access the NPDP resources by:

1. Mail, telephone, or fax request

2. E-mail to the NPDP (npdp@ce.stanford.edu)

3. Personal visit and access to the archive at Stanford

For the professional who merely wants to stay abreast of the status of dams in the U.S., the Center will distribute two publications to the dam engineering community. They are a newsletter and an annual report. The newsletter will provide an update on the Center's activities, reports of significant events, study reports and other topics related to the performance of dams. The annual report will provide a statistical summary of the yearly and cumulative number and type of dam incidents that were reported to the Center. As information is accumulated, evaluations of trends in the number and type of incidents will be performed. The purpose of these publications is to make information readily available to the dam safety professional on the performance of dams.

<u>1996 Report</u>

Calender 1996 was the second full year of operation for the NPDP. Since the kickoff in September 1994 a total of approximately 1600 Dam Incident Notifications have been submitted to the program. Figure 2 shows the cumulative submittal of notifications. Many of the incidents that have been reported are historical events. In 1996 a total of 300 notifications were submitted which identified 368 incidents, many of which occurred in 1996 (i.e., we are seeing more real time reporting). Figure 3 shows the monthly submittal of notifications.

A breakdown of the dam incidents reported to the NPDP in 1996 is provided in Table 1 (note not all of these events occurred in 1996). The table identifies the number of dam failures (events involving uncontrolled release of the reservoir), the number of notifications reported as a result of periodic dam inspections, and a breakdown of incidents by type.

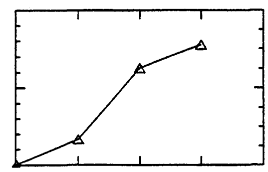

2000
1000
0
1993
1994
1995
1996
1997
Year
Number

Figure 2 Cumulative contribution of Dam Incident Notifications since 1994.

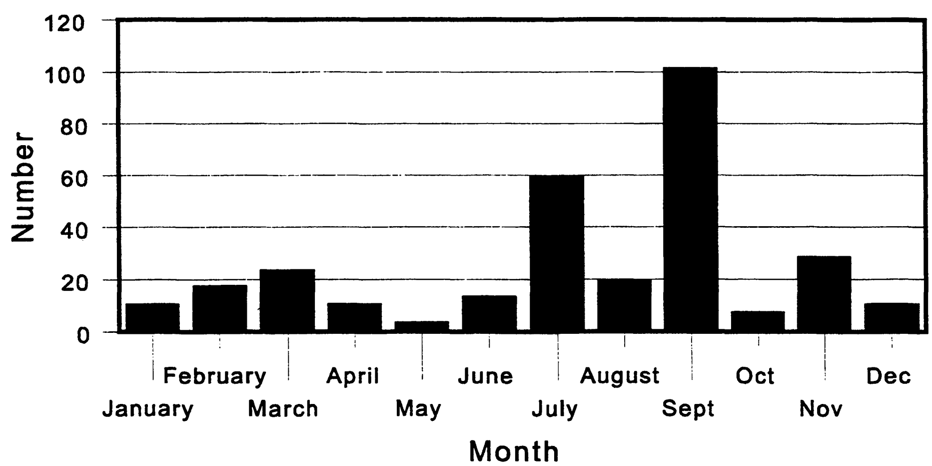
Figure 3 Monthly submittal of Dam Incident Notifications in 1996.

<u>On a Par With Comparable Programs</u>

An important part of the NPDP is to establish an information resource for engineers. This resource will be a valuable tool to address specific technical problems and to summarize the state of dams in the U.S. The biggest impact may be felt in the public policy arena where dam safety programs compete with other health and safety issues for limited resources. The NPDP will provide public-policy

Table 1
Summary of Dam Incident Notifications Submitted in 1996

Category	Number/Percent
Dam Failures	38
Periodic Inspections	27
Incidents by type:	



Flood	35.3%
Seepage/Piping	14.4
Deterioration	7.9
Operations	1.6
Dam Safety Modifications	6.0
Inadequate Spillway	6.5
Reservoir Incidents	1.4
Other	26.9

makers with information on the performance of dams that is comparable to data that is made available by professionals in other public-health and safety fields. For example, it is clear that information on such issues as public health (e.g., the rise in tuberculosis cases or the increase in the number of HIV-positive individuals), domestic and industrial safety, and crime helps to focus the attention of public officials. As a whole, the public and elected representatives have become accustomed to having statistical information that characterizes the critical issues of our time. While numbers alone do not tell the whole story, they are often the fundamental, hard information that is needed to clearly define an issue. With the creation of the NPDP, dam engineers will be able to facilitate the policy making process with information that characterizes the safety of dams, trends in performance related to aging and deterioration, and public safety.

Concluding Remarks

By its nature the NPDP is a dynamic undertaking. The constant inflow of Dam Incident Reports and the lessons learned from this data will provide an ever changing view of the state of the nation's dams. As the average age of dams increases, the ability to monitor such key barometers as:

- the occurrence of dam incidents,
- costs of modifications and repairs to dam owners,
- fraction of dam inspections that uncover unsatisfactory conditions, and
- the impact of dam incidents on the public (e.g., personal injury, property damage)

will become a vital part of dam safety practice.

Appendix

Babb, A.O. and T.W. Mermel, "Catalog of Dam Disasters, Failures and Accidents," U.S. Bureau of Reclamation, Department of the Interior, Washington, D.C., 1968.

Engineering News, "A Classified Review of Dam and Reservoir Failures in the United States," Vol. XLVIII, No. 25, June 19, 1902.

Jansen, R. B., Dams and Public Safety, U.S. Department of the Interior, Water and Power Resources Service, 1980.

Leonards, G.A. "Investigation of Failures," American Society of Civil Engineers, Journal of the Geotechnical Engineering Division, Volume 108, No. GT2, February 1982.

Middlebrooks, T.A., Earth Dam Practice in the United States," American Society of Civil Engineers, Centennial Volume, Paper No. 2620, New York, New York, 1975.

National Performance Dams Program, "Guidelines For Reporting the Performance of Dams," Prepared by the Association of State Dam Safety Officials and Stanford University, August, 1994.

U.S. Committee on Large Dams, Lessons From Dam Incidents, USA, American Society of Civil Engineers, New York, New York, 1975.

U.S. Committee on Large Dams, Lessons From Dam Incidents, USA, American Society of Civil Engineers, New York, New York, 1988.

ASDSO/FEMA Workshop on
Plant & Animal Penetrations of Earthfilled Dams

National Performance of Dams Program

Program Overview

Presented by
Martin W. McCann, Jr.
National Performance of Dams Program

University of Tennessee
Knoxville, TN
November 30, 1999

http://npdp.stanford.edu NPDP

Agenda

- What is the NPDP?
- Background
- NPDP Information Model
- NPDP Digital Library Development

http://npdp.stanford.edu NPDP

What is the NPDP?

- National effort to retrieve, archive and disseminate information on the performance of dams.
- 'Public Library' Model - there when you need it.
- A place where, with little effort or $$ you can gather information to address technical, policy and public safety or risk issues.

http://npdp.stanford.edu NPDP

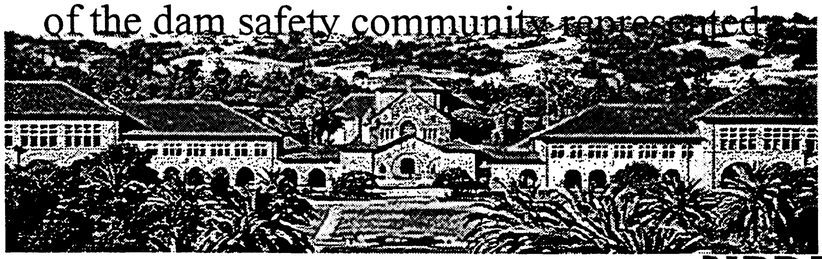
Background

- NPDP - started as part of an effort to support dam engineering and safety
- Building on the tradition of learning from past performance (USCOLD/ICOLD)
- Formalizing the retrieval and archiving of dam performance data
- Utilizing the Internet to maximize access to data and information on dams

http://npdp.stanford.edu NPDP

Program Operations

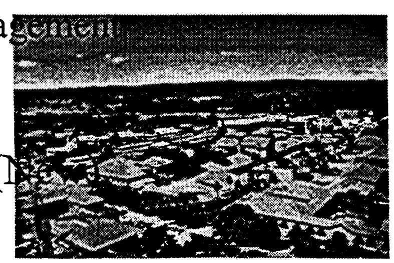
- Started & headquartered at Stanford University
- Program Director and staff
- NPDP Executive Committee - all segments of the dam safety community represented



http://npdp.stanford.edu NPDP

Program Activities

1. Program Administration
2. NPDP Operations
   - Dam Incident Processing
   - Data entry/archive management
   - User support
3. Database Development (
4. Data Analysis/Research



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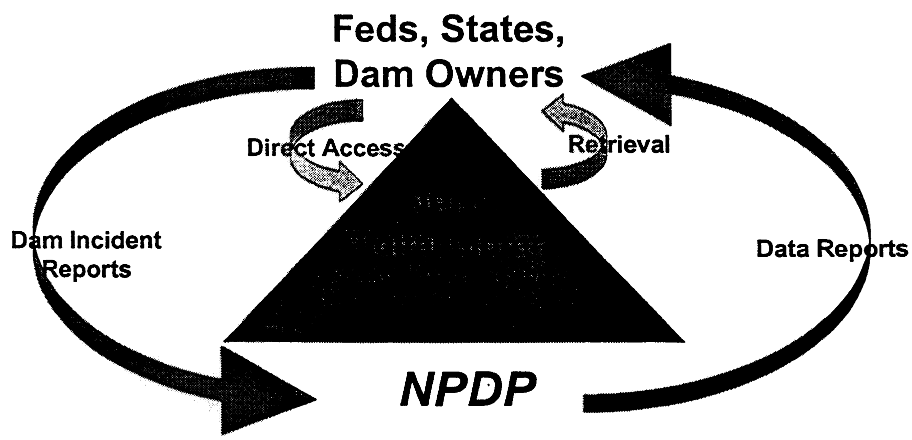
NPDP Information Model



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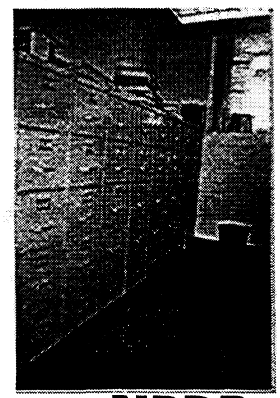
NPDP Data Reports

- Purpose - establish standard data evaluations that provides a consistent level of information on dams and dam performance
- Content
  - State of dams in the U.S.
  - Dam performance/condition evaluation system
- Distribution by e-mail, web publication

http://npdp.stanford.edu NPDP

Digital Library Development

- Develop a web-based digital library
- Four primary elements
  - Dams Directory
  - Performance/Incident Database
  - Bibliographic database
  - Digital Archive



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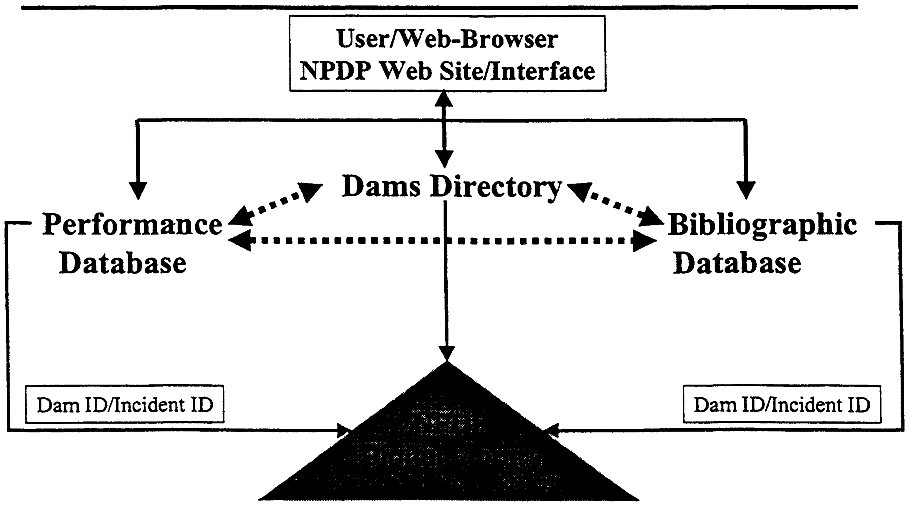
NPDP

NPDP Information System



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NPDP

NPDP Database Elements

- Dams Directory - Inventory of all dams, past, present (NID) & future
  - systems and components
  - history (i.e., spillway modifications, etc.)
- Dam Performance - Master incident table
  - basic data (date, type, consequence, summary)
  - failure modes & effects concepts to document dam/component performance

http://npdp.stanford.edu NPDP

NPDP Database Elements (cont.)

- Bibliographic - bibliographic database of NPDP documents
  - searchable by author, keyword, etc
  - linked to other databases by Dam ID and Incident ID

NPDP Case Files

http://npdp.stanford.edu NPDP

Wildlife Damage to Earthen Dams, Dikes, Levees, and Related Structures

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ABSTRACT:

The damage caused by burrowing animals to earthen dams, dikes, levees, and related structures can threaten both the reliability and integrity of the structure. There are a number of mammal species throughout the United States which, because of the damage they cause to such structures, must be either prevented from becoming established or, once established, controlled and damage-monitored to allow for appropriate repair to the structure to prevent further damage or breaching of the structure. Many of these mammal species and their establishment in water control or management structures are partially dependent on appropriate vegetation for use as food and/or cover, or as den construction and water control structure breaching materials. Therefore, earthen dams, dikes, levees, and related structures must be monitored regularly to allow for appropriate control or removal of vegetation and burrowing animals, and repaired as needed to protect the integrity of the structure. Failure to monitor and control both inappropriate vegetative cover and burrowing animals on such structures will ultimately result in either breach of such structures which threaten the safety of people, cause significant damage to people's property, and pose significant liability potential; or significant costs associated with repair and maintaining the integrity of the structure.

The principal focus of this presentation was to: help attendees at this workshop to improve their capability to identify burrowing mammal "signs" in and adjacent to earthen water control structures; recognize the types of vegetation which provide food and cover for such mammals; recognize the tools, sources of assistance, and educational information available which can be utilized to either prevent or control these mammals; encourage the use of appropriate existing educational and technical assistance; contribute to the development of useful educational materials which can be used by dam safety officials and their staffs and by landowners responsible for management of these structures (to be of assistance to them in monitoring for evidence of burrowing mammal damage); and how to employ available prevention and control methods to avoid future burrowing mammal damage to these structures. Slides of the major wildlife species causing damage to such structures, examples of damage they cause, and visual "signs" to look for are utilized in the presentation to assist participants.

Presented at ASDSO/FEMA Workshop, November 30, 1999, University of Tennessee Conference Center, Knoxville, TN.

WILDLIFE SERVICES ACTIVITIES TO PREVENT ANIMAL PENETRATION TO EARTHEN DAMS

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Abstract: Wildlife Services provides federal leadership to manage a diverse array of problems incurred through the activities of a variety of animal species. Examples of the diversity of work performed by Wildlife Services to protect earthen dams are presented. The processes of reducing wildlife damage is described; including identifying the problem (examples of damage to earthen structures by selected species), possible approaches to alleviate problems (brief overview of methods), developing a strategy, implementing a program and monitoring. Means to contact Wildlife Services regional and state offices, and the National Wildlife Research Center are provided.

INTRODUCTION

Wildlife Services provides federal leadership to manage a diverse array of problems incurred through the activities of a variety of animal species. Activities include numerous projects to reduce negative impacts of animals to earthen dam embankments across the United States. Often assistance consists of providing guidance regarding possible measures that will discourage animals from encroaching onto or penetrating into earthen structures. Wildlife

Services, working with concerned persons or agencies, also develops cooperative programs to provide more direct assistance to reduce problems. This paper presents examples of the diversity of work performed by Wildlife Services to protect earthen structures and the processes necessary to implement appropriate measures to reduce damage inflicted by animals.

Burrowing to create nests or beneath-ground runways is the most common type of damage to dams. Herbivorous animals also penetrate dams to forage on plant materials, and carnivores dig up dams to reach prey species. Penetrations by these animals directly impact the integrity of the dams and subsequently these activities lead to increased erosion problems. Animals also damage vegetation on dams or along waterways which ultimately leads to the indirect negative impact of erosion. Gnawing or pecking by animals also damages wooden supports or materials in electrical monitoring devices, such as wires, caulking and installation.

EXAMPLES OF WILDLIFE SERVICES' COLLABORATING ACTIVITIES

Wildlife Services has responded to problems posed by dam penetration through burrowing or obstruction of overflow causing dam failures. These problems, if not addressed, eventually cause erosion with the potential for an eventual dam collapse and loss of water. Generally, specialists are requested to remove a few burrowing animals from a small dam to stop an ongoing problem. Cost to repair dams after animal removal can range from several hundred dollars to several thousand, depending on how much time elapses before the problem is noticed or a response is taken. Wildlife Services also has collaborated with other agencies on large projects to protect more extensive dams or levees used to hold municipal water sources or serve as flood control structures.

Wildlife Services reports similar efforts to assist on small cooperative projects across several states. Nebraska reports working to solve problems induced by beaver and muskrat. Beaver and nutria are the most frequent culprits in Louisiana, though muskrats also can cause burrowing problems. Specialists also have responded to reduce burrowing damage inflicted by beaver, nutria and muskrat in Mississippi. A Mississippi specialist reported an incident in which a dam was riddled with beaver burrows to the extent it became a hazard for the property owner's dairy cattle to cross the levee. Oregon specialists have responded to similar problems. Beaver damage is the most common but they also have responded to problems induced by nutria, muskrat and marmot. California reports requests to address problems associated with ground squirrels as well as problems with beaver, muskrat and nutria. The most significant burrowing problems in Tennessee are inflicted by muskrats and voles, with woodchuck and skunks also causing substantial damage.

Wildlife Services personnel also have participated in larger-scale multi-year collaborative efforts with municipalities or other government agencies. Wildlife Services assisted the Massachusetts Metropolitan District Commission after their engineers located seepage at the base of a Quabbin Reservoir dike (Boston water supply). Extensive burrowing by meadow voles was determined to have caused the seepage.

At the request of the New York Power Authority in Lewiston, New York Wildlife Services conducted a control program from 1995 through 1997 to reduce potential structural damage caused by woodchucks on an eight kilometer earthen impoundment structure. Wildlife Services also provided wildlife damage management services to the United States Corps of Engineers for the protection of earthen levees near Lewiston, Idaho. The levees along the confluence of the Snake and Clearwater Rivers served not only as flood control structures, but as a green-belt parkway for the local community. The Corps determined that marmot burrows had penetrated far enough into the structure to pose a potential threat. However, the public appreciated the presence of wildlife along the green-belt and enjoyed the antics of the Yellow-bellied marmots. A program was initiated to lower but not eliminate marmot populations in an effort to reduce the extensive burrowing while maintaining wildlife for public view.

Wildlife Services also has undertaken collaborative efforts to address damage to earthen structures by wildlife other than burrowing rodents. Connecticut Wildlife Services assisted in planning a Canada goose control program to protect the Groton Connecticut water supply reservoir. Prior to this program grazing geese had destroyed the cover vegetation causing erosion on the earthen dams; repairs costs approximately $280,000. Tennessee has responded to complaints of damage inflicted to water monitoring devices. Rats and muskrats have gnawed through wiring and black vultures have damaged control equipment and removed caulking. Oregon specialists report complaints of badgers digging into earthen structures, presumably to retrieve prey, which reduces structural integrity and leads to erosion. Specialists also reported an isolated instance where a black bear was repeatedly digging into and damaging an earthen dam.

REDUCING WILDLIFE DAMAGE

Several steps need to be considered to implement a successful program to reduce wildlife impacts on earthen structures. First, determine whether a problem exists or whether there is likely to be a problem. Second, if there is a problem, evaluate possible approaches and select feasible options. Third, develop a strategy to incorporate the selected options into a program. The fourth step is to implement the program, and the fifth is to monitor the consequences of the program.

Identify the Problem

The first step is to assess the cause and magnitude of a problem. The presence of wildlife does not necessarily equate to negative impacts, though awareness can enable early detection of damage and permit a quick response before damage becomes excessive. Visual sightings of wildlife can be rather rare, thus species generally need to be identified through activity indicators. Generally, extensive burrowing activities are obvious and the burrow itself is a good indicator of the animal inflicting the damage. Less extensive burrowing, however, may be less obvious and require close and regular monitoring to be detected. Species that inflict non-burrowing damage need to be identified by other traits, but unless the damage is extensive it is unlikely to be considered a problem; and if the damage is extensive, the indicators are probably obvious.

Traits associated with animals recognized for inflicting damage to earthen dams or levees are reviewed below as summarized from selected sources (Hegdal and Harbour, 1991; Hygnstrom et al., 1994).

Armadillo (*Dasypus novemcinctus*). Characteristic signs of armadillo activity are shallow holes (2.5 to 7.6-cm deep; 7.6 to 12.5-cm wide) created as they root and dig for food. Several rather large burrows (17 to 20-cm diameter; 4 to 5-m length) may be dug to provide shelter, which are large enough to damage small dams and canal banks. Armadillos can also make burrows in riprap areas similar to those created by rockchucks.

Badgers (*Taxidea taxus*). Most badger damage occurs while they dig for rodents. Therefore, evidence for badger presence is invariably accompanied by signs of high rodent activity. Typical holes dug in pursuit of prey are generally shallow and approximately 30-cm in diameter. Often their digging can greatly enlarge holes of burrowing rodents, which may cause washouts or weaken canal banks and small earthen dams. Female badgers dig longer burrows (1.5 to 9-m) with an enlarged chamber below the surface (60 to 90-cm) in which to give birth. Dens usually have a single, often elliptical entrance, typically marked by a mound of soil in front. Badger activity around hydraulic structures, though sporadic, can be severe.

Beaver (*Castor canadensis*). Identifying beaver is generally not difficult. Indicators include their dams; plugged culverts, bridges, or drain pipes resulting in flooding; conical shaped stumps with large wood chips at the base; girdled trees; or lodges and burrows in ponds, reservoir levees and dams. In large watersheds, it can be difficult to locate bank dens. However, the limbs, cuttings, and debris around such areas as well as dams along tributaries usually helps to identify their location. Damage can be a direct result of burrowing in dams or along levees. Beaver dams across spillways can result in flooding, failure of the spillway, or failure of the entire structure. Beaver activity in and around canals, culverts drain pipes, flood channels, and bridges can render the structures inoperable. The removal of sticks, logs, debris, and accumulated mud can be extremely difficult. Even limited beaver activity can disrupt normal stream flow, and clog drainage or emergency flood channels.

Canada goose (*Branta* spp.). Canada geese are often visible along waterways and the aesthetics of small numbers are deemed desirable by the public. Animal numbers, however, can rapidly increase if the birds are left undisturbed. Waterfowl damage to earthen structures is generally limited to destroying vegetation which may lead to erosion problems. Other animals, particular livestock, also may over-graze or trample vegetation on dams or levees. Prime indicators of geese are direct sightings, and large flocks will deposit considerable feces in areas they frequent.

Coyotes (*Canis latrans*). Coyote damage to earthen structures is similar to that incurred by badgers. Dens dug along canal banks can be a potential threat to the integrity of the canal, as they can be quite large and deep (1 to 15-m) with several openings. Most coyote digging in pursuit of rodents is not as deep or persistent as that of badgers.

Ground squirrels (*Spermophilus* spp.). Ground squirrels keep their burrows open. Burrows of solitary species tend to be scattered and inconspicuous. Burrows of colonial ground squirrels resemble those of prairie dogs, including the presence of mounds. Burrow design varies with the species, soil type, habitat, and climate. Depth may range as deep as 3-m. Diameter varies with body size of the species and may range from 5 to 25-cm. When colonial ground squirrels are present, they are usually visible above ground during their active periods. Some species can reach population densities as high as 250 individuals per hectare.

Ground squirrel activity can seriously damage canals and can be a threat to the integrity of small dams. Their burrows weaken ditch banks, cause water loss by seepage and piping through the bank, and can result in complete loss or washout of the canal bank. The potential for damage is higher when storms or other surges cause changes in water levels in the canal. In addition, the presence of ground squirrels increases the likelihood of badger activity. Ground squirrels also can alter vegetation composition along canal banks, and their mounds provide seed-beds for invading annual weeds.

Muskrat (*Ondatra zibethicus*). Damage caused by muskrats is primarily due to their burrowing activity. Burrowing activity, however, may not be evident until serious damage has occurred. Burrowing may be detected by walking along the bank's edge when the water is clear and looking for trails from just beneath the water surface to as deep as 3-m. If no burrow entrances are evident, muskrat activity may be evident by droppings along the bank or on logs or other structures which a muskrat can easily climb. Muskrat burrows can be exposed by reducing the water level approximately 1-m.

Norway rats (*Rattus norvegicus*). Rats can damage the banks of irrigation canals and levees. More commonly, damage associated with rats and other commensal rodents is caused by their gnawing on wiring or pipes.

Nutria (*Myocastor coypus*). Burrowing is the most commonly reported damage caused by nutria. Burrows range from a simple, short tunnel with one entrance to complex systems with several tunnels and entrances at different levels. Though not common, tunnels as long as 46-m have been reported. The diameter of chambers within the burrow system range in size from 30-cm to 1-m. Nutria tunnel systems have permeated levees so extensively that water flowed unobstructed from one side to the other, necessitating complete reconstruction of the earthen structure.

Nutria and their burrows can often be sighted during visual inspections of sites. Crawl outs, slides, trails and exposed entrances to burrows often have distinctive tracks indicating nutria. The hind foot, 13-cm long, has four webbed toes and a free outer toe. A drag mark left by the tail is often evident between the footprints. Droppings also may be found floating in the water, along trails, or at feeding sites. Nutria fecal matter is dark green to almost black in color, cylindrical, and approximately 5-cm long and 1.3-cm in diameter. Additionally, each dropping usually has deep parallel grooves along its entire length.

Pocket gopher (*Geomys* spp., *Pappogeomys* spp., *Thomomys* spp.). Pocket gopher tunnels in ditch banks and earthen dams can weaken these structures, causing water loss by seepage and piping through a bank or the complete loss or washout of a canal bank. A single burrow system may contain 180-m of tunnels. Though solitary animals, pocket gopher densities can be high. Densities of 40 to 50 animals per hectare are common for *Thomomys*, but densities can reach as high as 150 animals per hectare. *Geomys* populations are generally much less dense (20/hectare). Pocket gopher activity can be distinguished from that of other burrowing mammals by distinctive mounds (fan- or kidney-shaped) mounds and plugged burrow entrances. The rate of mound building is variable, but may reach as high as 70 mounds per month. Mound building by a single pocket gopher has been estimated to bring as much as 2 metric tons of soil to the surface annually.

Prairie dogs (*Cynomys* spp). Prairie dogs can cause severe damage to ditch banks and small earthen dams. They probably do not threaten the integrity of large dams, but may interfere with foot drains or other structures in larger earthen dams. Prairie dog towns have multiple entrances that lead to tunnels 1 to 2-m deep and about 5-m in length. Prairie dogs construct crater- and dome-shaped mounds up to 60-cm high and 3-m in diameter.

Prairie dogs are active above ground during the day and sightings are common.

Voles (*Microtus* spp.). Vole activity is readily identified by the animals' extensive surface runway systems and numerous burrow openings. Voles are only a problem to hydraulic structures when populations are very high, and then only small berms and small canal banks are probably threatened.

Woodchucks, marmots, rockchucks, groundhogs (*Marmota* spp.). Marmot activity is relatively easy to identify as they can often be seen sunning themselves during the day. The yellow-bellied marmot or rockchuck (*Marmota flaviventris*) is the primary concern around hydraulic structures because they readily occupy riprap and their populations can be high along canals with steep banks in areas with sharp turns and fast-moving currents..

Preventive Measures

The most appropriate approach to reduce animal damage needs to reflect the overall objectives of the manager, as well as the conditions of the specific problem. All techniques are not feasible or appropriate for all situations. No action may be the appropriate action if the problem is relatively minor. A few preliminary considerations will increase the success of a program. Check on the legal ramifications for any action selected, and ascertain that the action will not be potentially hazardous to non-target species, in particular to endangered or threatened species. An effective approach will require familiarity with the behavioral traits and biology of the target species. Assess how the environmental conditions of the site will effect the selected method and the consequences of the action to the environment. Determine whether the selected methods will achieve an acceptable degree of protection, and whether the situation warrants the anticipated expense. Public attitudes also need to be considered when selecting an approach.

Reducing damage to earthen structures requires that either animals are encouraged to avoid the structures or for the animals to be physically removed from the area. Physical deterrents, repellents, frightening devices and habitat modification are possible techniques to discourage animals from a targeted area. Non-lethal removal usually involves live-trapping the animal and transporting it to an alternative location. Lethal removal or population reduction can be accomplished through kill-traps, toxicants or through shooting. A brief overview of these techniques as they may pertain to protecting hydraulic structures is summarized from Hegdal and Harbour (1991), and Nolte and Otto (1996).

Physical Deterrents. Physical deterrents impede animal access to specific resources. Deterrents vary from minor efforts to extensive construction projects. The most feasible approach depends on several economic, physical and biological factors. Fencing often has limited use for protecting hydraulic structures, because of the expense and impracticality of installation. The species and behavioral characteristics of the animal(s) inflicting the damage will dictate the necessary physical traits of a deterrent. Concrete-lined canals provide excellent protection from some rodents (e.g., ground squirrels, pocket gopher) but are expensive and they are not completely immune. Barriers, such as concrete walls or impervious soil walls incorporated in a canal bank, have demonstrated some efficacy. Barriers installed around culverts and drain pipes can impede beaver access and slow plugging of these devices. Fencing can be effective to impede armadillos from entering critical areas near hydraulic structures. However, the tops of fences need to be slanted outward (40 degree angle) and the bottoms buried, because armadillos can climb and they often burrow deep.

Repellents. At present, there are no feasible registered repellents to inhibit wildlife from burrowing into earthen structures. A few products may serve to inhibit waterfowl from extensively damaging vegetation planted on dams and levees.

Frightening Devices. Visual displays or noises that serve to alarm or appear threatening can be installed to frighten wildlife from resources. Animals are generally wary of any unfamiliar sound or sight, but they become less wary with time unless the noise or vision is paired with a negative reinforcer. Familiarity of wildlife to frightening devices can be minimized by installing or operating the devices only during periods when resources are most susceptible to damage. Devices, however, need to be used immediately after the onset of damage. Established movements and behaviors are much more difficult to disrupt than are newly forming behavioral patterns.

Efficacy of products can usually be increased by alternating techniques or use patterns. Sporadic displays or devices that are activated by an animal's presence are more effective than permanent or routine displays. Visual displays combined with noisemakers are generally more effective than either technique implemented alone. For example, sirens and strobe lights activated at irregular intervals are more effective than either a constant visual display or loud noises generated at fixed intervals. Supplementing these techniques with occasional lethal measures (e.g., shooting) further enhances their continued efficacy. Properly trained dogs confined within the boundaries of the protected resources are very effective at frightening wildlife.

Habitat Modification. Animals are attracted to areas because of the availability of food sources or cover types; altering these characteristics can reduce their presence. Herbicides applied to remove edible vegetation or create bare ground will reduce pocket gopher activity. Eliminating dense grass cover and weeds also discourages voles and other small rodents, while prairie dogs prefer to avoid areas with tall vegetation. Nutria will not frequent areas where their food source and cover have been removed. Likewise, muskrats avoid areas where aquatic vegetation and other edible plants have been eliminated. Controlling rodents on which badgers and coyotes prey will prevent digging in pursuit of prey by these species. This is especially important on small earthen dams and canals. Proper vegetation management along canals, including removal of brush, mowing, and planting low grasses, will discourage coyotes from selecting canal banks for den sites. Armadillo activity also can be reduced by removing cover and by using insecticides to reduce the populations of invertebrates that constitute their food supply.

Trapping. Trapping can be an effective means to remove animals. The objectives of a trapping program will dictate the type and size of traps that should be utilized. In developing a trapping program several factors need to be considered, including the behavioral and biological characteristics of the target animal, ease of access to the trap site, experience and skill of the trapper, non-target animals in the vicinity, cost effectiveness, state and federal laws and regulations, as well as other specific site considerations. Trap and release programs can be effective when specific individuals need to be removed. However, appropriate release sites need to be identified prior to capture. Euthanasia procedures and equipment also need to be ready before a program is implemented.

State and Federal laws and regulations govern the treatment of wildlife. Prior to implementing a trapping program, check with the proper authorities to ensure that your program is legal. Generally, a state's Department of Wildlife is an appropriate place to contact for information and guidance on trapping regulations.

Toxicants. Toxicants can be an effective means of quickly reducing high populations of some problem animals, or of maintaining acceptable densities. Generally, they are most applicable where existing or potential damage problems are related to population density. However, they may also be appropriate for treating areas with limited access or where other approaches have proven ineffective.

Toxicants are generally classified within one of three categories depending on their mode of action. Acute toxicants are ingested and are most often lethal soon after a single encounter. Chronic toxicants are also ingested, but are not immediately lethal. Fumigants are lethal gases which are injected into the burrows of targeted species. The most applicable approach will be directed by the overall objectives and any restrictions regulating toxicants that apply to a specific situation.

Toxicants pose a potential hazard to the operator and other humans, as well as to non-target species. Therefore, extreme caution needs to be exercised in handling, storing, and applying toxicants, and in disposing of waste materials. The applicator assumes responsibility to ensure that all legal and safety concerns are met prior to using a toxicant. For use of some products, applicators must pass examinations and be certified by their state pesticide regulatory authority. Federal and state registrations certify that it is legal to use the product according to the conditions and restrictions stipulated on the approved label. Registration does not necessarily guarantee the availability or the efficacy of a product.

Shooting. Shooting to control populations of small rodents (e.g., pocket gopher, voles) is impractical. Shooting to reduce populations of larger rodents (e.g., beaver, muskrats, nutria, prairie dogs, woodchucks) is generally not cost effective and primarily used as a follow-up method after other control efforts have already reduced populations. Some control, however, may be achieved by encouraging sport hunters to target specified problem areas. Shooting can be an effective means to remove individual problem badgers. Shooting is generally considered an impractical or cost prohibitive means to protect hydraulic structures from damage by coyotes or armadillos. Sine states regulate many of these species as game or furbearers, special licenses are generally required for shooting or trapping.

Strategy

Project personnel need to develop a strategy to implement selected approaches to reduce wildlife impacts. This strategy may incorporate several methods at once, or utilize one method to stop the damage and another to limit future problems. Inquire among experts within the field if you need additional information or are unsure of specific requirements. Acquire training, licenses, or expertise in handling equipment or chemicals. Identify and obtain any required equipment, personnel, resources, and safety equipment necessary for the program.

Implementation

Though it may require time and effort, implementing the program should be straightforward, provided the prior steps were thoroughly covered. However, unanticipated problems or concerns may require modified or alternative strategies. In that case, repeat the decision process incorporating the new information.

Monitoring

Continued monitoring of the program is a particularly important activity. Determine whether the desired goals are being achieved and whether there are any unexpected negative consequences. Continue to evaluate the program until the resource is no longer vulnerable, or conditions warrant terminating the program.

CONTACTING WILDLIFE SERVICES

Wildlife Services provides technical and operational assistance to reduce conflicts between people and wildlife. Assistance is managed within most states through the eastern and western regional offices, or through the individual state offices (Appendix 1). Research to develop practical methods to resolve problems caused by the interaction of wild animals and society is conducted at the National Wildlife Research Center. The Center is located in Fort Collins, Colorado and can be contacted at 970-266-6000. Information pertaining to the Wildlife Services and the National Wildlife Research Center also can be obtained from their web sites, http://www.aphis.usda.gov/ws/info.html and http://www.aphis.usda.gov/ws/nwrc/about.htm, respectively.

Assistance or information regarding wildlife damage issues also can be obtained through other sources, such as extension agencies, United States Fish and Wildlife Service, State wildlife and fish management agencies, local animal control agencies and private pest control operators. Public telephone directories list local government offices and private pest control operators.

LITERATURE CITED

Hegdal, P.L., and A.J. Harbour. 1991. Prevention and Control of Animal Damage to Hydraulic Structures. U.S. Government Printing Office. Denver, Colorado.

Hygnstromm, S.E., R.M. Timm, and G.E. Larson. 1994. Prevention and Control of Wildlife Damage. University of Nebraska Cooperative Extenstion. Lincoln, Nebraska.

Nolte, D.L. and I.J. otto. 1996. Materials and Supplies for Management of Wildlife Damage to Trees. Technical report 9624-2808-MTDC. Missoula, Montana: USDA Forest Service, Missoula Technology and Development Center.

Appendix 1. Directory for Wildlife Services offices.

Washington Office: William H. Clay, Acting Deputy Administer; Room 1624 South Agriculture Building, Washington D.C. 2050; Telephone (202) 720-2054; Facsimile (202) 690-0053

Eastern Region: Gary E. Larson, Regional Director; Venture II, Centennial Campus, 920 Main Campus Drive, Suite 200, Raleigh, North Carolina 27606; Telephone (919) 716-5632; Facsimile (919) 716-5659

Western Region: Michael Worthen, Regional Director; 12345 West Alameda Parkway, Suite 204, Lakewood, Colorado 80228; Telephone (303) 969-6565; Facsimile (303) 969-6578

National Wildlife Research Center: Richard D. Curnow, Director; 4101 LaPorte Avenue, Fort Collins, Colorado 80521; Telephone (970) 266-6000; Facsimile (970) 266-6032

Alabama: Frank Boyd, State Director; Room 118, Extension Hall, Auburn University, Alabama 36849; Telephone (334) 844-5670; Facsimile (334) 844-5321

Alaska: J. Gary Oldenburg, State Director; 720 O'Leary Street, Northwest Olympia, Washington 98502; Telephone (360) 753-9884; Facsimile (360) 753-9466

Arizona: Steve Fairaizl, State Director; 2224 West Desert Cove Avenue, Suite 209, Phoenix, Arizona 85029; Telephone (602) 870-2081; Facsimile (602) 870-2951

Arkansas: Thurman W. Booth, State Director; 55 Post Office Building, 600 W. Capitol Avenue, Little Rock, Arkansas 72201; Telephone (501) 324-5382; Facsimile (501) 324-7135

California: Gary Simmons, State Director; P.O. Box 255348, Sacramento, California 95865; Telephone (916) 979-2675; Facsimile (916) 979-2680

Colorado: Craig C. Coolahan, State Director; 12345 West Alameda Parkway, Suite 210, Lakewood, Colorado 80228; Telephone (303) 969-5775; Facsimile (303) 969-5798

Connecticut: Laura Henze, State Director; 463 West Street, Amherst, Massachusetts 01002; Telephone (413) 253-2403; Facsimile (413) 253-7577

Delaware: Les Terry, State Director; 2530 Riva Road, Suite 312, Annapolis, Maryland 21401; Telephone (410) 269-0057; Facsimile (410) 269-0258

District of Columbia: Les Terry, State Director; 2530 Riva Road, Suite 312, Annapolis, Maryland 21401; Telephone (410) 269-0057; Facsimile (410) 269-0258

Florida:	Bernice Constantine, State Director; 2820 East University Avenue, Gainesville, Florida 32641; Telephone (352) 377-5556; Facsimile (352) 377-5559
Georgia:	Douglas Hall, State Director; School of Forest Resources, University of Georgia, Athens, Georgia 30602; Telephone (706) 546-2020; Facsimile (706) 546-2004
Hawaii:	J. Gary Oldenburg, State Director; 720 O'Leary Street, Northwest Olympia, Washington 98502; Telephone (360) 753-9884; Facsimile (360) 753-9466
Idaho:	Mark Collinge, State Director; 9134 West Blackeagle Drive, Boise, Idaho 83709; Telephone (208) 378-5077; Facsimile (208) 378-5349
Illinois:	Kirk Gustad, State Director; 2869 Via Verde Drive, Springfield, Illinois 62703; Telephone (217) 241-6700; Facsimile (217) 241-6702
Indiana:	Judy Loven, State Director; Purdue University, 1158 Entomology Hall, Room B-14, West Lafayette, Indiana 47907; Telephone (765) 494-6229; Facsimile (765) 494-9475
Iowa:	Ed Hartin, State Director; 2407 Industrial Drive, Columbia, Missouri 65202; Telephone (573) 446-1862; Facsimile (573) 446-1942
Kansas:	Jim Luchsinger, State Director; 5940 South 58th Street, P.O. Box 81866, Lincoln Nebraska 68501; Telephone (402) 434-2340; Facsimile (402) 434-2330
Kentucky:	Kenneth Garner, State Director; 441 Donelson Pike, Suite 340, Nashville, Tennessee 37214; Telephone (615) 736-5506; Facsimile (615) 736-2768
Louisiana:	Dwight LeBlanc, State Director; P.O. Box 589, Port Allen, Louisiana 70767; Telephone (225) 389-0229; Facsimile (225) 389-0228
Maine:	Edwin Butler, State Director; Capital West Business Center, 81 Leighton Road, Suite 12, Augusta, Maine 04330; Telephone (207) 622-8263; Facsimile (207) 622-5760
Maryland:	Les Terry, State Director; 2530 Riva Road, Suite 312, Annapolis, Maryland 21401; Telephone (410) 269-0057; Facsimile (410) 269-0258
Massachusetts:	Laura Henze, State Director; 463 West Street, Amherst, Massachusetts 01002; Telephone (413) 253-2403; Facsimile (413) 253-7577
Michigan:	Peter Butchko, State Director; 2803 Jolly Road, Suite 160, Okemos, Michigan 48864; Telephone (517) 336-1928; Facsimile (517) 336-1934

Minnesota:	Ed Hartin, State Director; 2407 Industrial Drive, Columbia, Missouri 65202; Telephone (573) 446-1862; Facsimile (573) 446-1942
Mississippi:	Kris Godwin, State Director; P.O. Drawer FW, Mississippi State, Mississippi 39762; Telephone (601) 325-3014; Facsimile (601) 325-3690
Missouri:	Ed Hartin, State Director; 2407 Industrial Drive, Columbia, Missouri 65202; Telephone (573) 446-1862; Facsimile (573) 446-1942
Montana:	Larry L. Handegard, State Director; P.O. Box 1938, Billings, Montana 59103; Telephone (406) 657-6464; Facsimile (406) 657-6110
Nebraska:	Jim Luchsinger, State Director; 5940 South 58th Street, P.O. Box 81866, Lincoln Nebraska 68501; Telephone (402) 434-2340; Facsimile (402) 434-2330
Nevada:	Robert Beach, State Director; 4600 Kietzke Lane, Building O-260, Reno, Nevada 89502; Telephone (702) 784-5081; Facsimile (702) 784-5874
New Hampshire:	Dennis Slate, State Director; 59 Chenell Drive, Suite 7, Concord New Hampshire 03301; Telephone (603) 223-6832; Facsimile (603) 229-1951
New Jersey:	Janet Bucknall, State Director; 140-C Locust Grove Road, Pittstown, New Jersey 08867; Telephone (908) 735-5654; Facsimile (908) 735-4513
New Mexico:	Alex Lara, State Director; 2113 Osuna Road, NE, Suite B, Albuquerque, New Mexico 87113; Telephone (505) 346-2640; Facsimile (505) 346-2627
New York:	Richard Chipman, State Director; 1930 Route 9, Castleton, New York 12033; Telephone (518) 477-4837; Facsimile (518) 477-4899
North Carolina:	Jon F. Heisterberg, State Director; 6213 East Angus Drive, Raleigh, North Carolina 27613; Telephone (919) 856-4124; Facsimile (919) 782-4159
North Dakota:	Phil Mastrangelo, State Director; 2110 Miriam Circle, Suite A, Bismarck, North Dakota 58501; Telephone (701) 250-4405; Facsimile (701) 250-4408
Ohio:	Andrew Montoney, State Director; Federal Building, Room 622, 200 North High Street, Columbus, Ohio 43215; Telephone (614) 469-5681; Facsimile (614) 469-2912
Oklahoma:	John Steuber, State Director; 2800 North Lincoln Boulevard, Oklahoma City, Oklahoma 73105; Telephone (405) 521-4039; Facsimile (405) 525-5951
Oregon:	David Williams, State Director; 6135 Northeast 80th, Suite A8, Portland, Oregon 97218; Telephone (503) 326-2346; Facsimile (503) 326-2367
Pacific Islands:	J. Gary Oldenburg, State Director; 720 O'Leary Street, Northwest Olympia,

	Washington 98502; Telephone (360) 753-9884; Facsimile (360) 753-9466
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Rhode Island:	Laura Henze, State Director; 463 West Street, Amherst, Massachusetts 01002; Telephone (413) 253-2403; Facsimile (413) 253-7577
South Carolina:	Robert Hudson, State Director; 400 Northeast Drive, Suite L, Columbia, South Carolina 29203; Telephone (803) 786-9455; Facsimile (803) 786-9472
South Dakota:	Phil Mastrangelo, State Director; 2110 Miriam Circle, Suite A, Bismarck, North Dakota 58501; Telephone (701) 250-4405; Facsimile (701) 250-4408
Tennessee:	Kenneth Garner, State Director; 441 Donelson Pike, Suite 340, Nashville, Tennessee 37214; Telephone (615) 736-5506; Facsimile (615) 736-2768
Texas:	Gary Nunley, State Director; P.O. Box 100410, San Antonio, Texas 78201; Telephone (210) 472-5451; Facsimile (210) 472-5446
Utah:	Mike Bodenchuck, State Director; P.O. Box 26976, Salt Lake City, Utah 84126; Telephone (801) 975-3315; Facsimile (801) 975-3320
Vermont:	Dennis Slate, State Director; 59 Chenell Drive, Suite 7, Concord New Hampshire 03301; Telephone (603) 223-6832; Facsimile (603) 229-1951
Virginia:	Martin Lowney, State Director; P.O. Box 130, Moseley, Virginia 23120; Telephone (804) 739-7739; Facsimile (804) 739-7738
Virgin Islands:	Frank Boyd, State Director; Room 118, Extension Hall, Auburn University, Alabama 36849; Telephone (334) 844-5670; Facsimile (334) 844-5321
Washington:	J. Gary Oldenburg, State Director; 720 O'Leary Street, Northwest Olympia, Washington 98502; Telephone (360) 753-9884; Facsimile (360) 753-9466
West Virginia:	William Bonwell, State Director; 730 Yokum Street, Elkins, West Virginia 26241; Telephone (304) 636-1785; Facsimile (304) 636-5397
Wisconsin:	John Maestrelli, State Director; 750 Windsor Street, Room 101, Sun Prairie, Wisconsin 53590; Telephone (608) 837-2727; Facsimile (608) 837-6754
Wyoming:	Richard Phillips, State Director; P.O. Box 59, Casper, Wyoming 82602; Telephone (307) 261-5336; Facsimile (307) 261-5996

Engineered To Fail?
Tree Root Management on Dams

by Dr. Kim D. Coder, Professor of Forest Resources,
University of Georgia, Athens, GA, USA

Invited Abstract:

Many structures invite tree root invasion and degradation of function by concentrating tree-essential resources and making these resources readily available. Tree roots are opportunistic and genetically aggressive in seeking and controlling resource spaces. As a consequence of tree root survival and growth, the physical, chemical, and biological structure of the soil matrix is modified. Tree roots require; soil pore volume for growth and holding of essential resources (water, oxygen, elements, biological partners, etc.); structural support of roots and resistance of forces generated on above-ground components; and, soil surface area for element availability and transformations, gas and water exchange, and mineralization area for organic material.

The soil / tree interface, adjacent pore spaces, and neighboring soil solids provide a chemically, biologically, and mechanically active zone where the tree affects, and is effected by, the environment. Tree roots respond in genetically predetermined ways to the availability of resources. Root systems are designed to capture and hold essential resources while defending themselves. The most critical resources that must be balanced for proper root growth are soil oxygen availability, water contents, and pore space size. These resources can be manipulated to constrain root colonization and growth. Soil successional processes, and associated root shedding and decay can geometrically increase available resource space for tree growth over time.

Over several growing seasons, tree roots can generate significant hydraulic forces with elongation and radial expansion. These forces applied to soil volumes eventually generate additional pore space as well as multiple-sized channels through soil materials. Root growth barriers and protection techniques must be used in designing and maintaining dams to assure structural integrity against the biological onslaughts of woody roots. This presentation will concentrate on: the foundations of how tree roots elongate and expand; tree root growth, death and decay; essential resources required or controlled; and, a variety of design features and tools to prevent tree root degradation of dam integrity.

Note: All the handouts and papers presented at the presentation are available at WEB site = www.forestry.uga.edu/efr under the "Community Forestry" section and the "**Tree Root Growth Control Series.**" Individual titles by the author include: Methods for Root Control, Root Control Barriers, Root Growth Requirements and Limitations, Selected Literature: Root Control Methods, Soil Constraints on Root Growth, and Tree Roots and Infrastructure Damage.

Trees in Embankment Dams

By
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North Carolina Department of Environment
And Natural Resources
November 5, 1999

"I think that I shall never see a poem as lovely as a tree..." - Joyce Kilmer

When Joyce Kilmer wrote her celebrated poetry, she likely did not have trees that had become established on dams in mind. The growth of trees on dams has been an issue in the area of dam safety for an extended period of time. Trees and ornamental bushes on dams provide aesthetic scenery, and a shady place to sit and "wet a hook." From a dam safety perspective, however, trees can be very detrimental to the safety of a dam. Experience-based evidence and anecdotal information suggest the following:

- Trees (and bushes), as they mature, develop extensive root systems that can provide preferred paths of seepage through dams. Also, roots can damage structures in dams, such as pipes or concrete spillways. Root intrusions into pipes or pipe joints can cause soil loss through such penetrations. Tree roots can also cause cracking in concrete structures resulting in soil loss or uplifting of a spillway slab which would permit water to flow beneath the slab.
- Trees can be uprooted during heavy winds or ice storms, causing a large soil mass to be taken from the embankment.
- Trees, like all living organisms, eventually die. Some die from blight, disease, or adverse environmental conditions, such as air pollution; some die from competition with other types of trees or vegetation; and some die simply from old age. Once dead, the root systems begin to decay within the soil matrix. The decaying of roots can create a greater potential for seepage along the root systems and allow for uprooting more easily during wind or ice storms.
- Trees, bushes and brush provide excellent cover for animal habitat, particularly for burrowing animals. Animal burrows in the upstream and downstream slopes of an embankment dam may lead to connectivity of burrows through which water can flow during rainfall events. This can lead to erosional failure of a dam.
- Trees, bushes and brush deter the establishment of a good grass cover. Competition for sunlight, moisture and nutrients in the soil is often won by trees and brush. This prevents the establishment of a good grass cover on an embankment dam. Studies have shown that a good stand of grass provides excellent erosion protection during overtopping.
- Trees, bushes and brush in a spillway channel can obstruct flows and reduce the hydraulic capacity of the spillway. Also, localized increases in velocity result from flow obstructions, such as trees, thereby increasing erosion of soil materials from around such obstructions when flow discharges through a channel or over the top of a dam littered with trees.
- Excessive growth of trees, bushes or brush can inhibit a thorough inspection of a dam. This is an extremely important consideration, as such growth may prevent early detection of a problem that could lead to failure of a dam.

With these considerations in mind, it is hoped that sufficient evidence may lead to development of a policy for requiring the removal of trees on existing embankment dams and preventing the establishment of trees on new embankment dams.

MISSISSIPPI EARTHEN DAMS AND THE BEAVER

"*BEAVERS AND EARTHEN DAMS DON'T MIX*"

Presented by

Charles E. Clevenger, P. E. / P.L.S.
Chief, Division of Dam Safety
Office of Land & Water Resources
Mississippi Department of Environmental Quality
Jackson, Mississippi

For

ASDSO / FEMA WORKSHOP
on
PLANT AND ANIMAL PENETRATION OF EARTH-FILLED DAMS

at

UNIVERSITY OF TENNESSEE CONFERENCE CENTER
Knoxville, Tennessee
November 30 - December 2, 1999

According to an article published in February 1998, in the Mississippi Forestry & Wildlife News at Mississippi State University, "*Beaver are not a problem in Mississippi.*" They are not a problem unless they are on your land or in your Earthen Dam!

Life as a beaver is not all sapling dinners and swimming parties. Beavers are very controversial. Part of the controversy about beaver is the damage these animals cause by flooding crop land, destroying timber and BURROWING INTO DAMS.

Many dam owners don't realize they have a beaver problem until it is too late. Some of the common signs of the presence of Beaver are gnawed or cut trees on or near the dam and lake; burrows below the normal water line, sunken or collapsed areas on the crest and slopes of the dam; pathways across the dam; and an unusual lowering of the water level in the lake.

Beavers dig tunnels and dens in dams which affects the structural integrity of the dam. In Mississippi, we find most beaver tunnel entrances are from 1- 4 feet below normal water level in the lake. The beaver tunnel from below the water line into the dam and then up and horizontal to the area they excavate for a den. The den is located under the crest of the dam. The den can be from 6 - 10 feet in diameter and several feet in height. The floor of the den is usually around 1 foot above the normal water level in the lake. The beavers don't necessarily make one tunnel. Some of their tunnel systems can become quite extensive. The more tunneling inside the dam, the more weaken the dam. We have seen many cases where the roof of the dens have collapsed leaving a large hole in the crest of the dams and sometimes the upstream slope. Over time, with the constant movement of the water in-and-out of the tunnels, one may eventually erode through the downstream slope. This can lead to a dam failure.

There have been several dam failures due to beaver activity in the dams. One particular failure occurred in Southern Hinds County a few years ago. We got a call one morning from a woman saying when she went to work yesterday, she had a nice lake behind her house. When she came home that afternoon, she had a mud hole. We investigated and found the dam was completely riddled with beaver dens and tunnels. The only reason the dam had not failed before was that the beaver had been able to repair the breach before the dam failed. This time it was just too much for them. The dam was in such bad shape the beaver had moved out and were living in the banks of the lake.

Another incident occurred in DeSoto County, near the Tennessee line. We received a call on a Sunday night that water was gushing from a hole approximately 1 foot in diameter on the downstream slope of a dam. This was during a heavy rainfall. The hole was aimed at a house approximately 200 feet downstream. Fortunately, the dam owner was able to lower the water level in the lake by cutting a relief ditch. The next day, with the water level down, we found numerous beaver tunnel entrances in the dam. One was under a tree on the upstream slope. The tunnel had, over time, eroded through the dam and almost caused the dam to fail.

Burrows and dens are just part of the problems related to beaver activity in dams. The sound of running water triggers the urge to stop the flow. Many dams in Mississippi have had their spillway riser completely blocked by beaver who just had to stop the sound of running water. They can be very ingenious in their efforts to stop-up riser pipes. Not only can they stop small leaks in dams, they can dam up spillways when water starts flowing over them.

According to a report entitled "*An Evaluation of Trapping For Beaver Control On Floodwater Retarding Structures*," published in June 1990, by the USDA Soil Conservation Service in Jackson, Mississippi, trapping is the best method of removing beaver from an area. Conibear traps do the job very well, but should be used with extreme caution! Professional trappers should be employed.

Many other methods have been tried to get rid of beavers. Alligators have been tried, but that did not work. It was easier for the alligators to catch turtles, snakes and fish than to catch and eat beaver. Also, people in subdivisions are reluctant to having alligators in their lakes. Gator like small dogs and cats, also. Chemical birth control was tried without success. The beaver were simply not interest in taking the pill. So, the best method remains the professional trappers.

In conclusion, Beaver and earthen dams don't mix. If you must have beaver in your lakes then measures to keep them out of your dam must be taken. Wave action protection, such as rip-rap or interlocking concrete blocks, extending 4 to 6 feet vertical below normal water level will help to stop beaver from tunneling into the dam.

In Mississippi, we recommend owners of dams classified as high hazard to get rid of the beaver in their lakes and dams, dig out the tunnels and dens, then backfill with well compacted material. If they are reluctant, we ask them, "How much liability insurance do you have?" Dam owners may be held liable for damages, and loss of life, downstream should their dam fail because of their negligence.

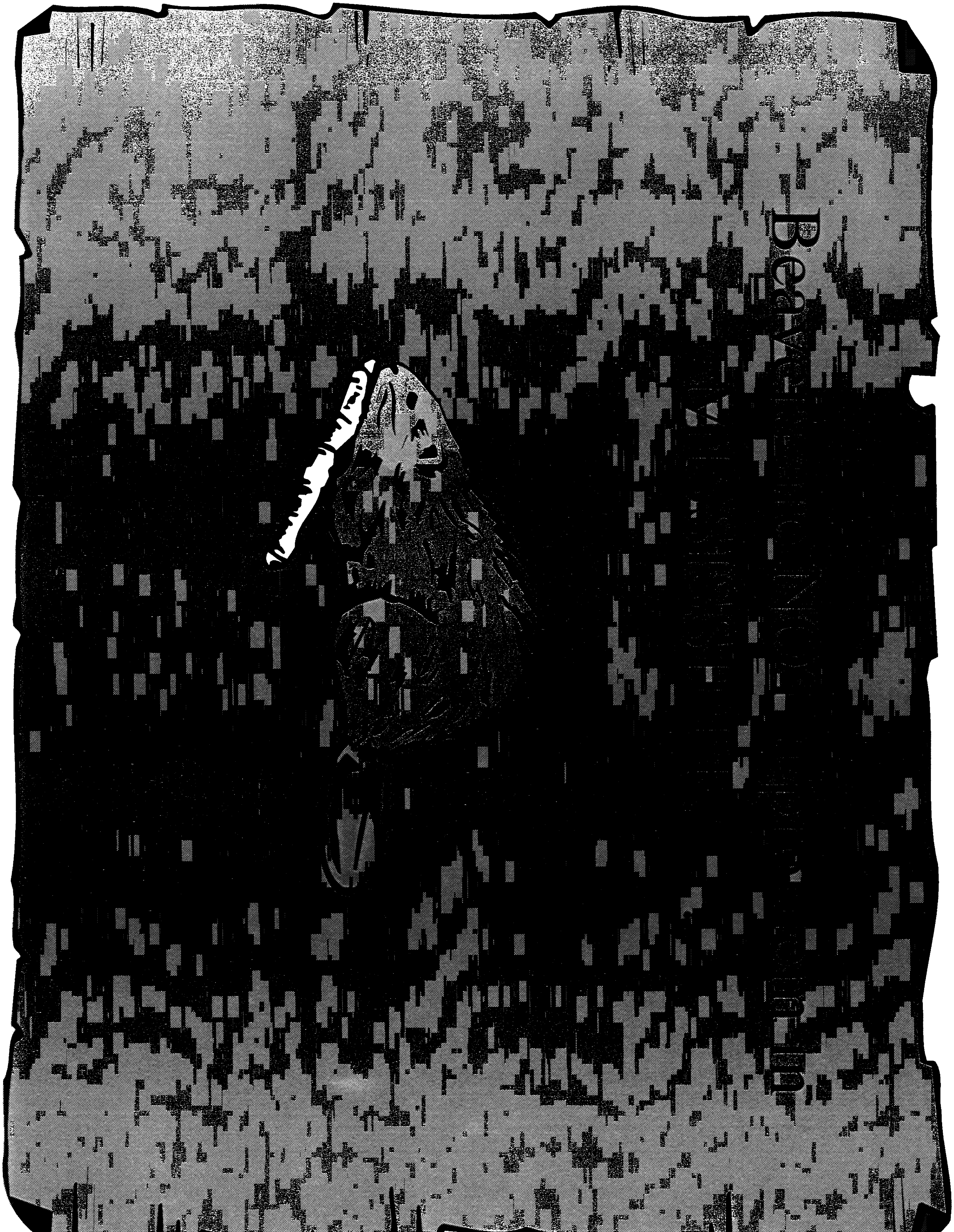
MISSISSIPPI EARTHEN DAMS AND THE BEAVER

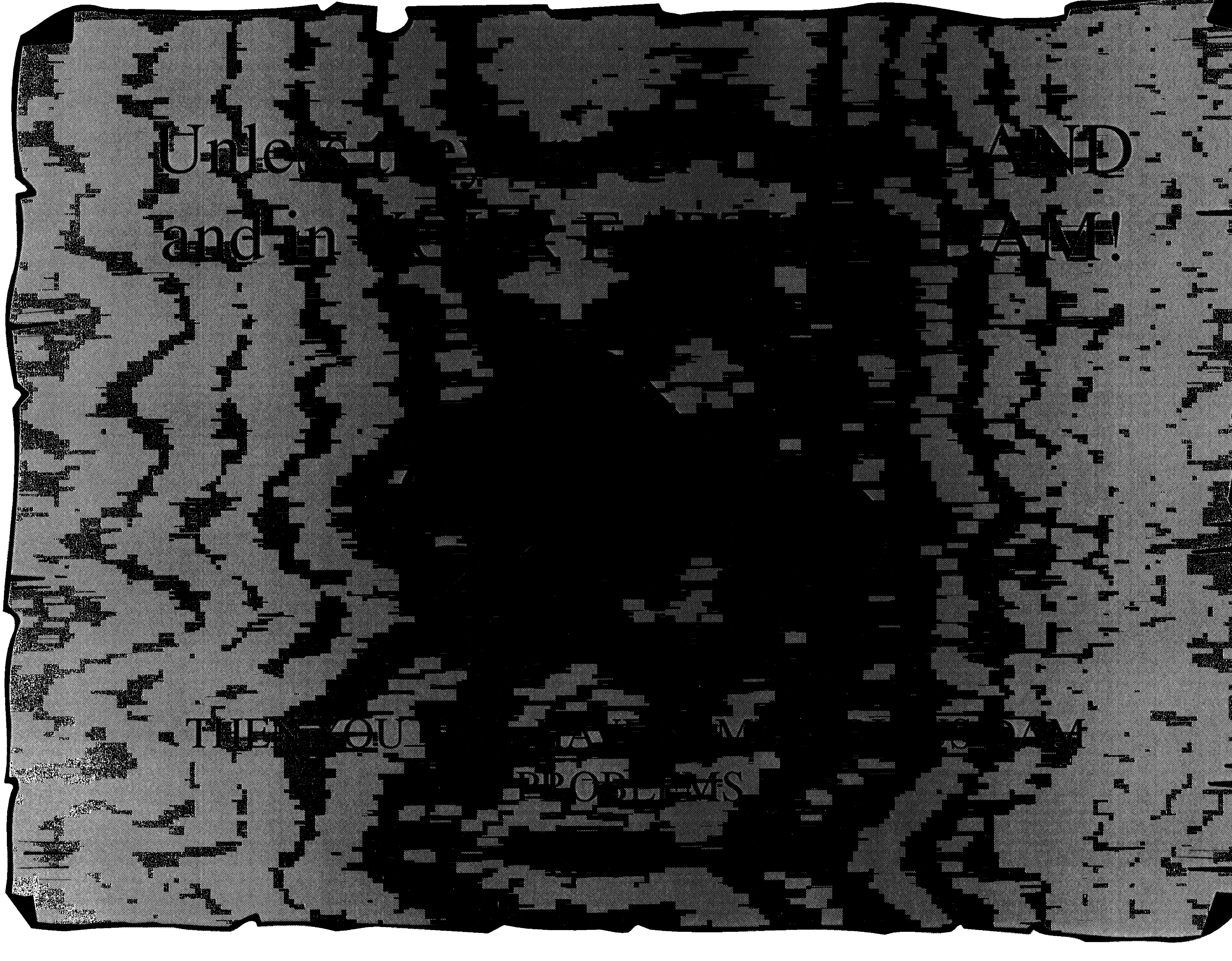
CHARLES E. CLEV[illegible], P.[illegible]

Chief of [illegible]

Office of [illegible] Resources

Mississippi [illegible] of Environmental Quality



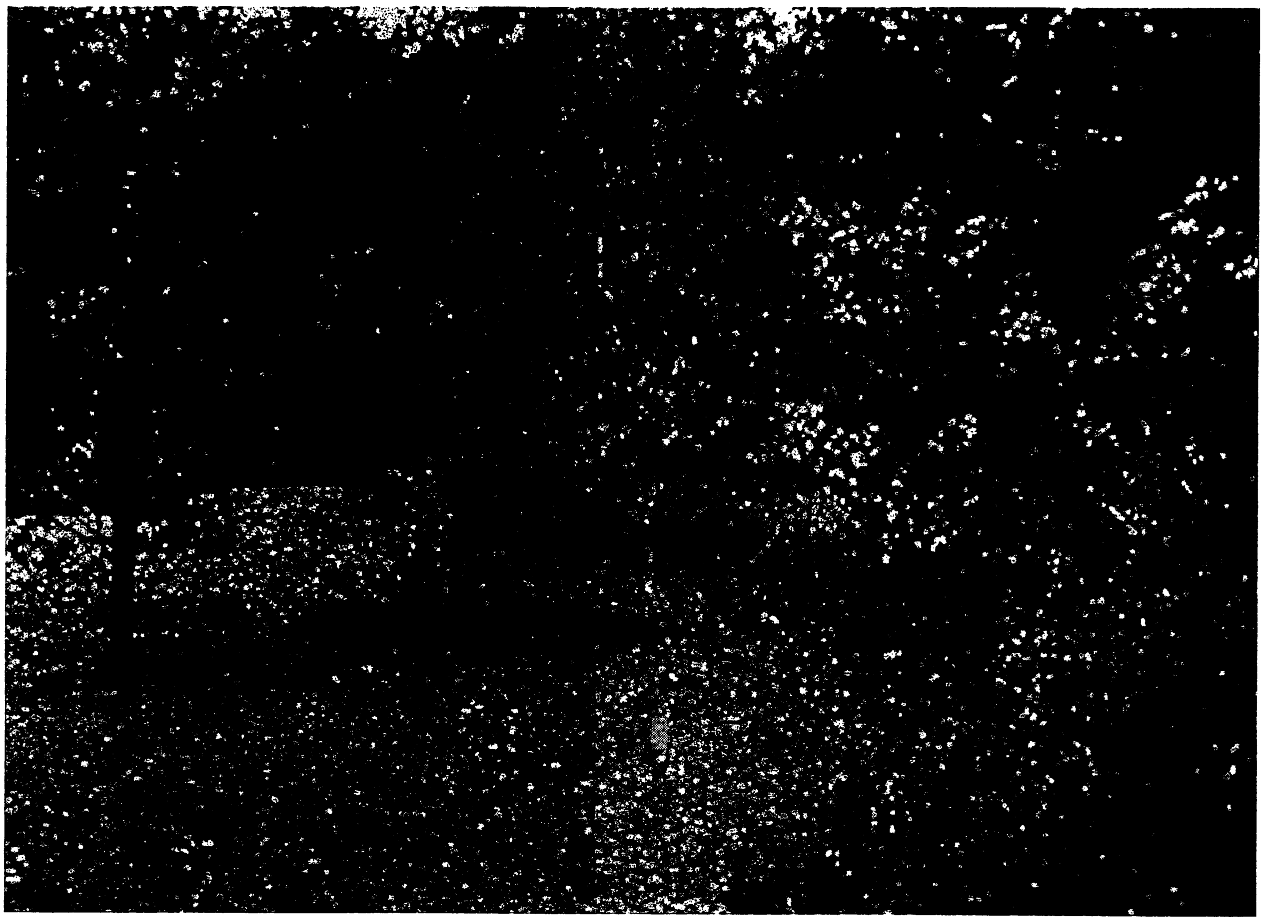

Unless AND
and in AM!
PROBLEMS

B E A V E R

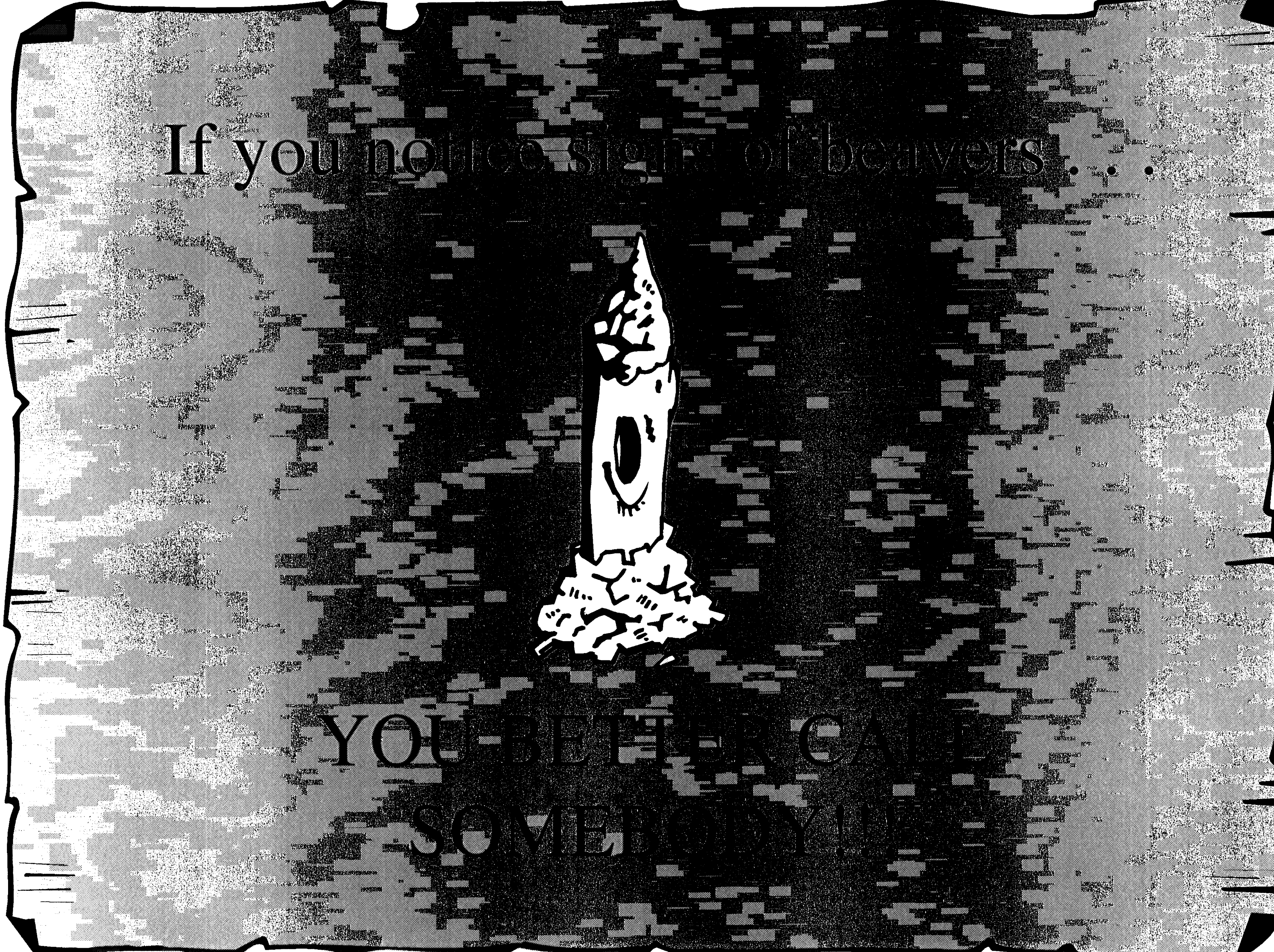
"Castor Canadensis" *

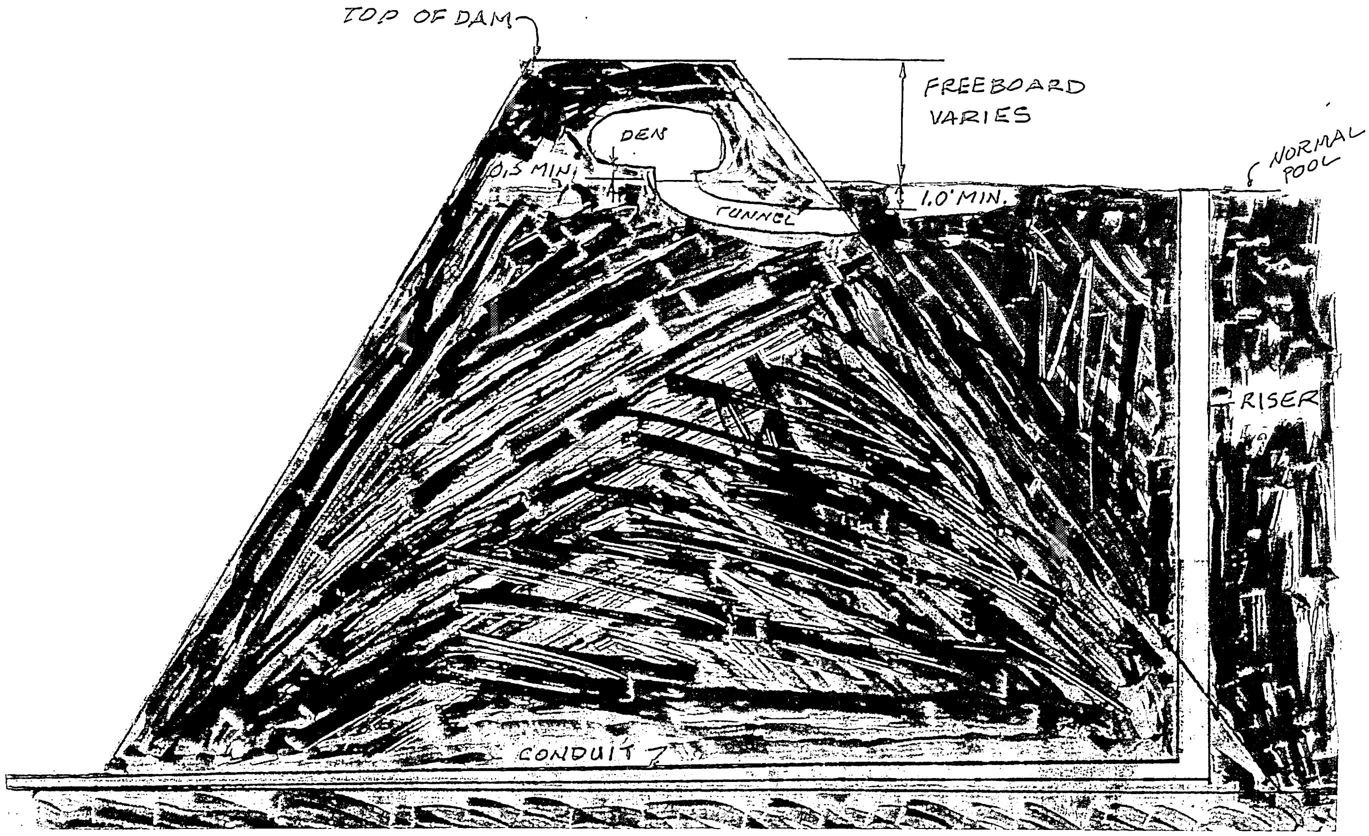
*Latin for "eater of saplings and digging tunnels into earthen dams."

A BEAVER'S ENVIRONMENT.

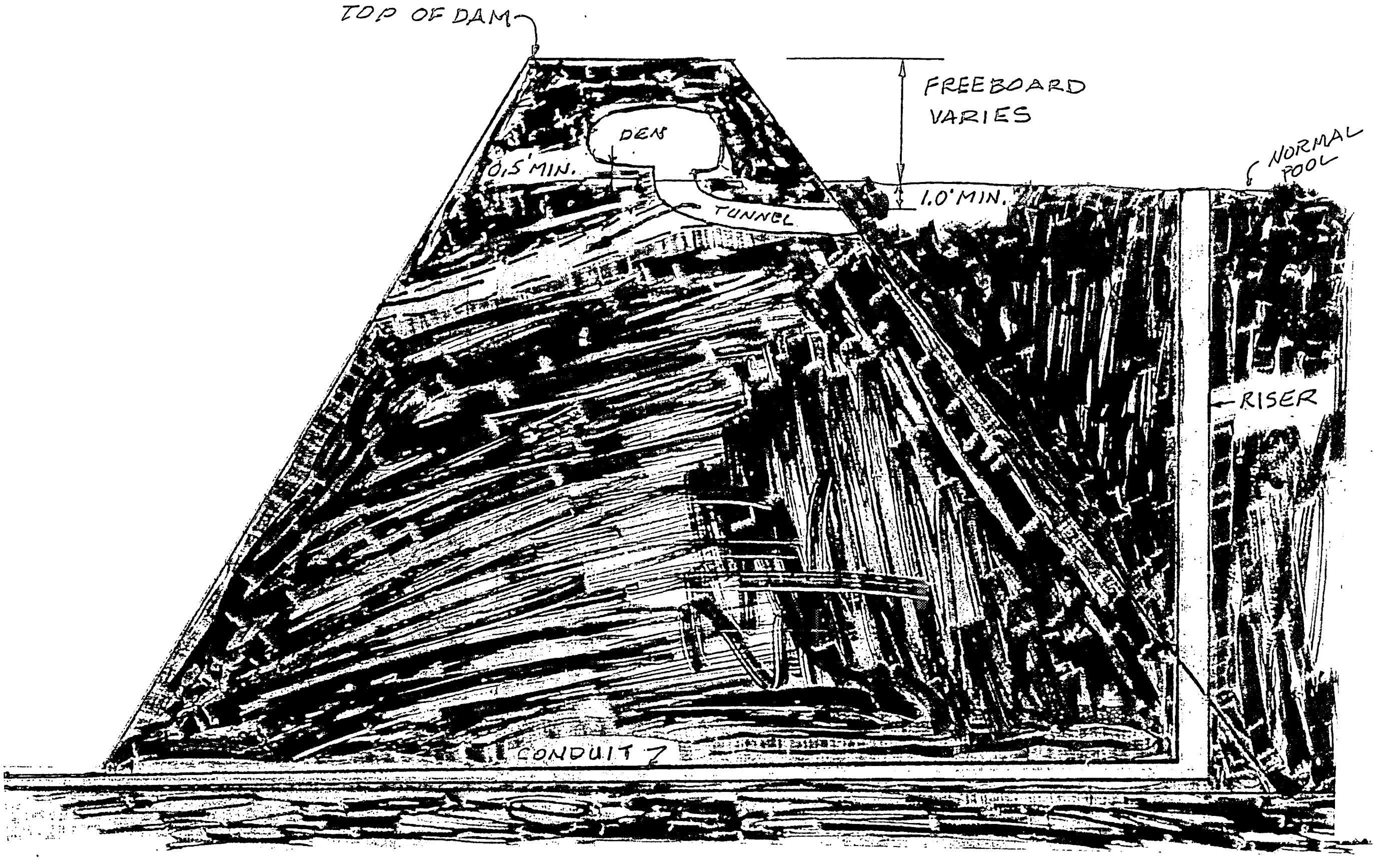


FLOODED TIMBER LAND RESULTING FROM BEAVER ACTIVITY.


If you notice signs of beavers . . .
YOU BETTER CALL SOMEBODY!!!

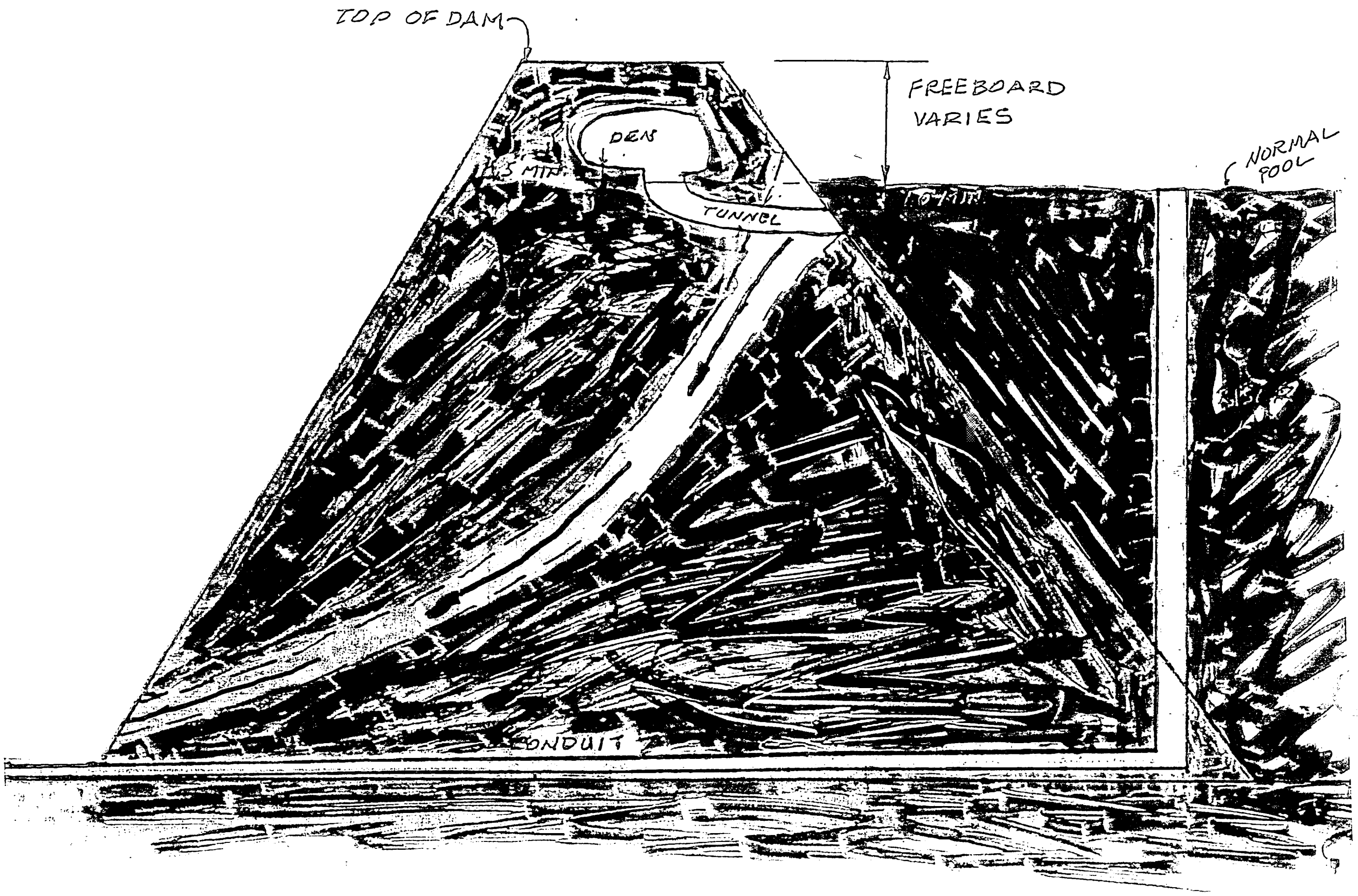


CROSS-SECTION OF DAM
SHOWING BEAVER DEN AND
TUNNEL

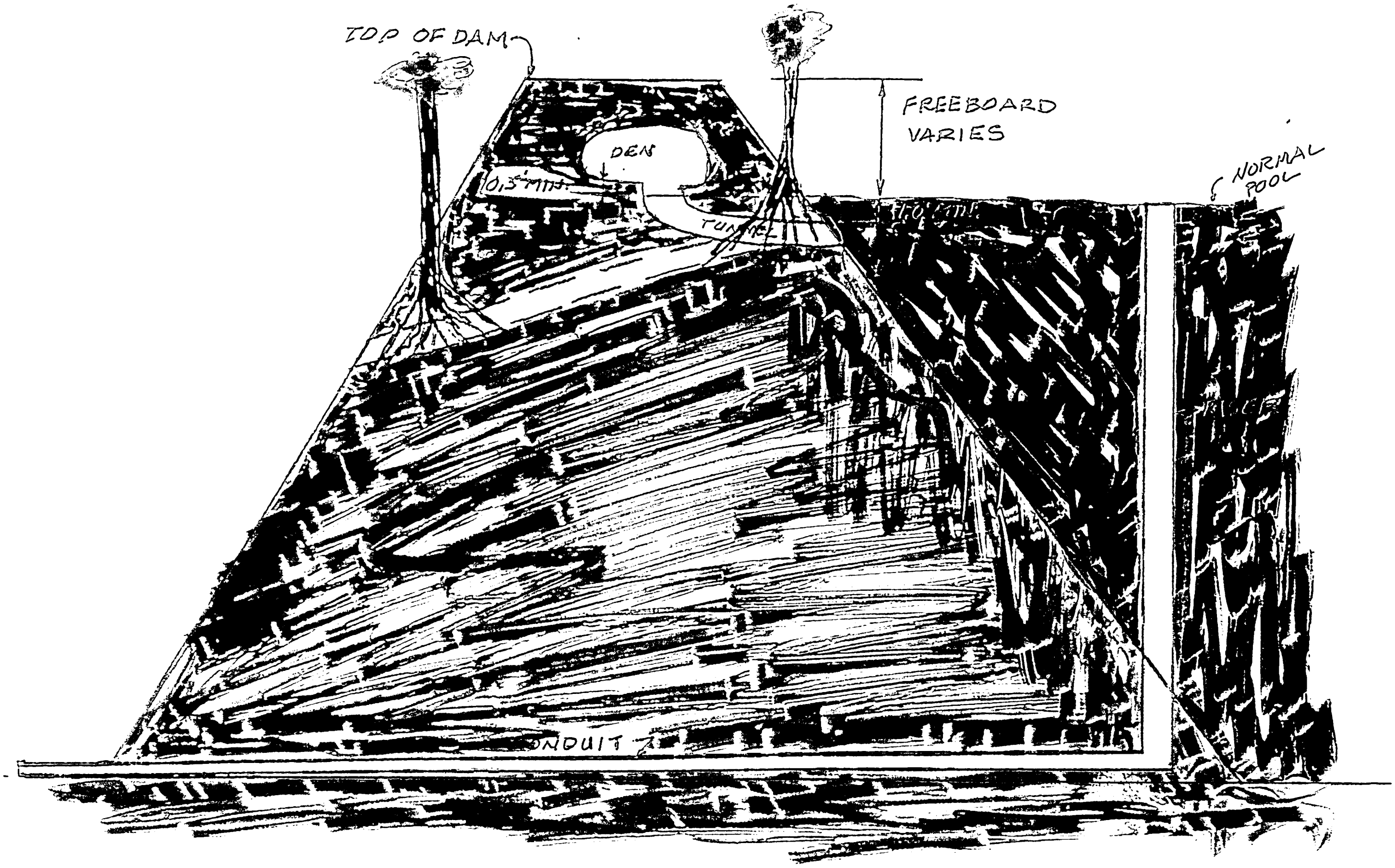


CROSS-SECTION OF DAM

PIPING FROM ERODED BEAVER TUNNEL

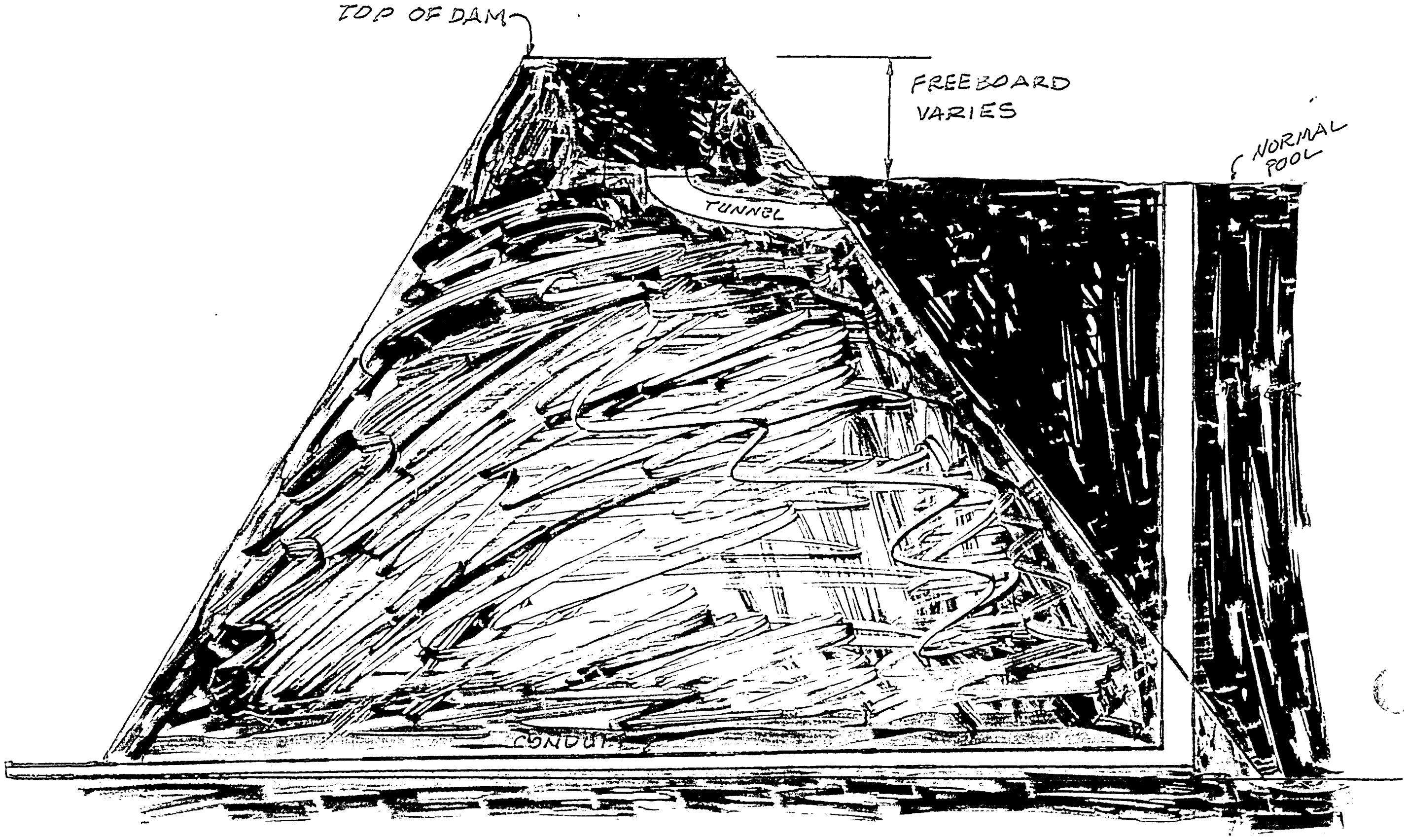


CROSS-SECTION OF DAM
PIPING FROM ERODED BEAVER TUNNEL

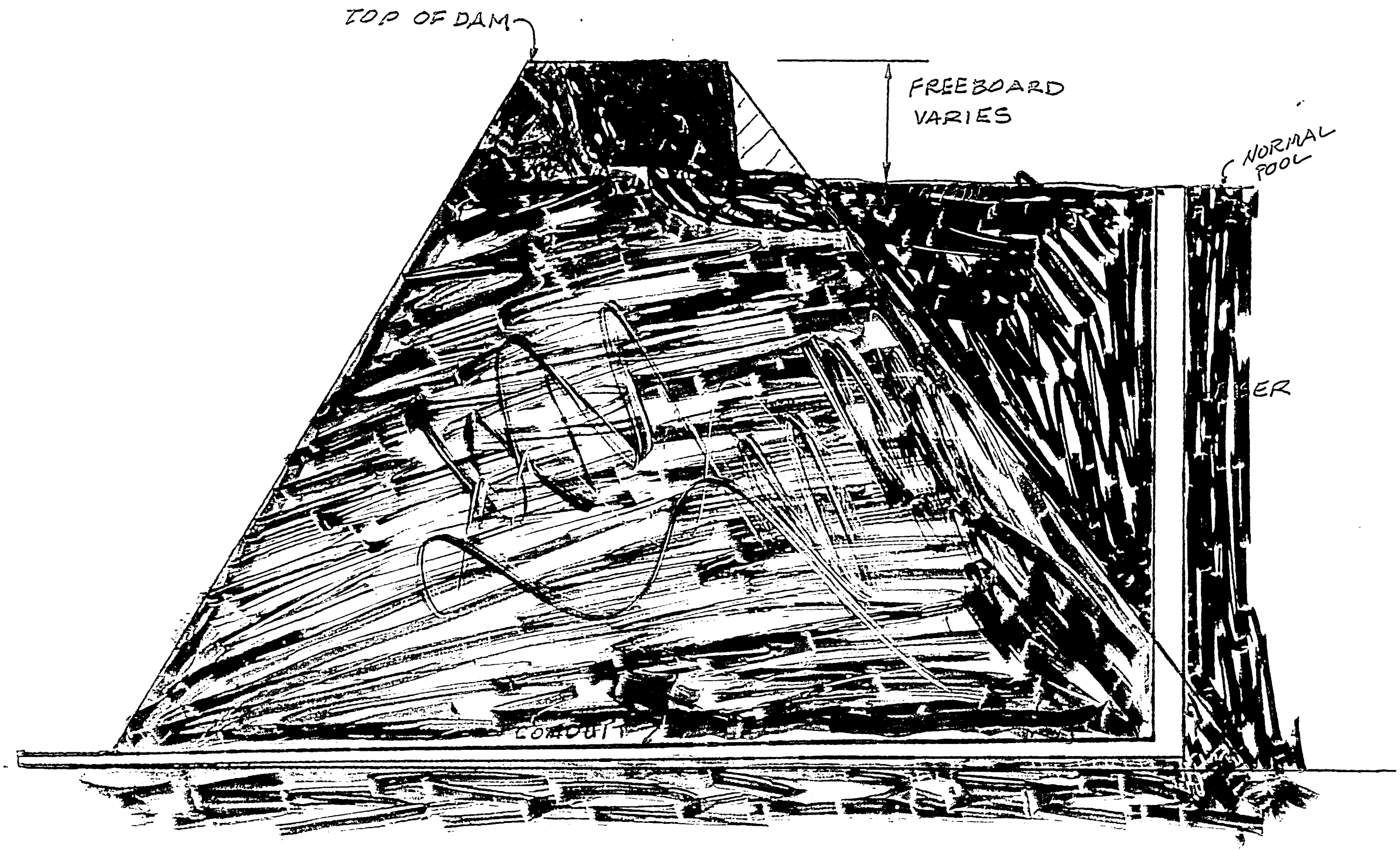


CROSS-SECTION OF DAM

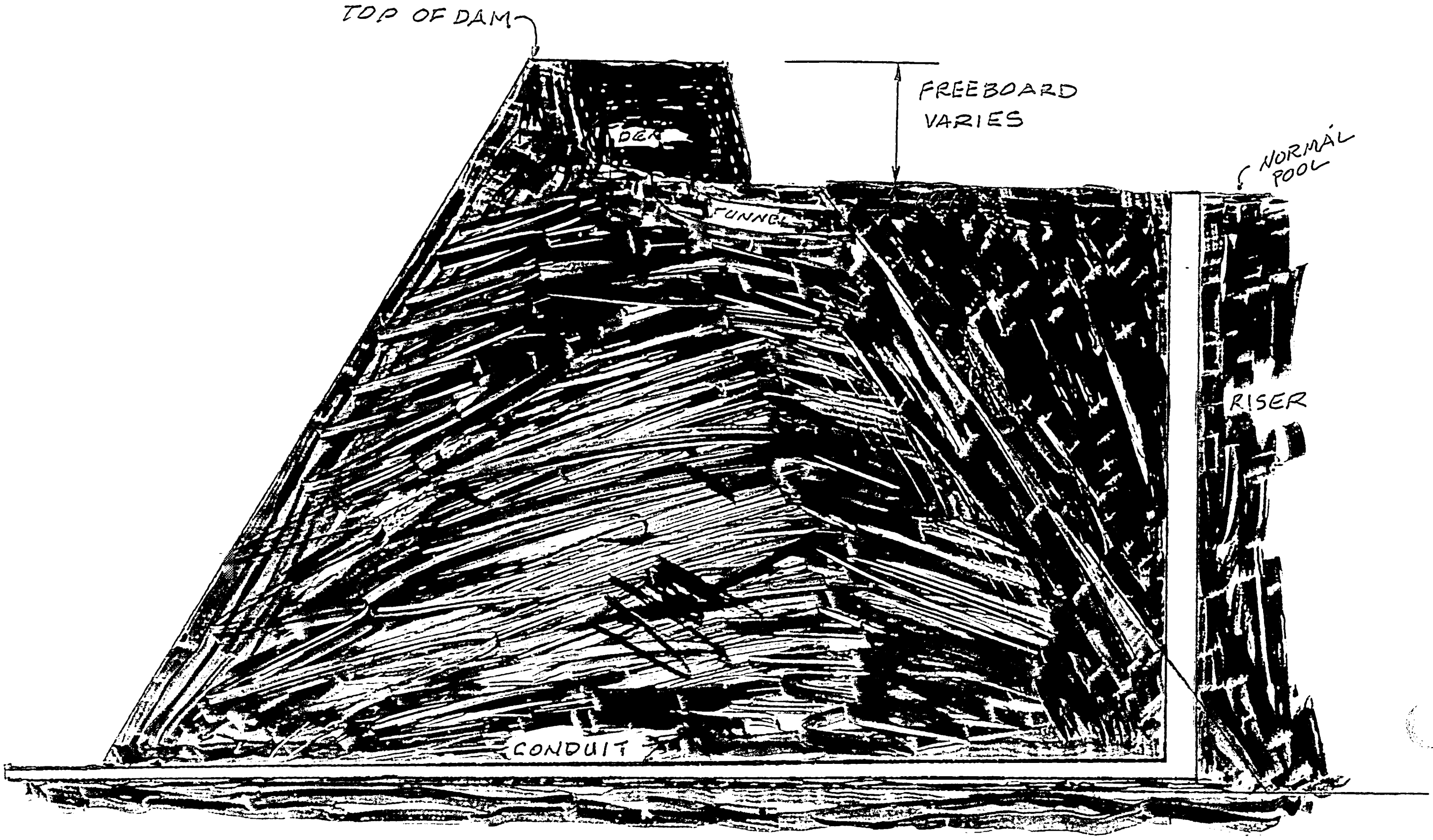
EROSION AROUND TREES AND BEAVER TUNNEL



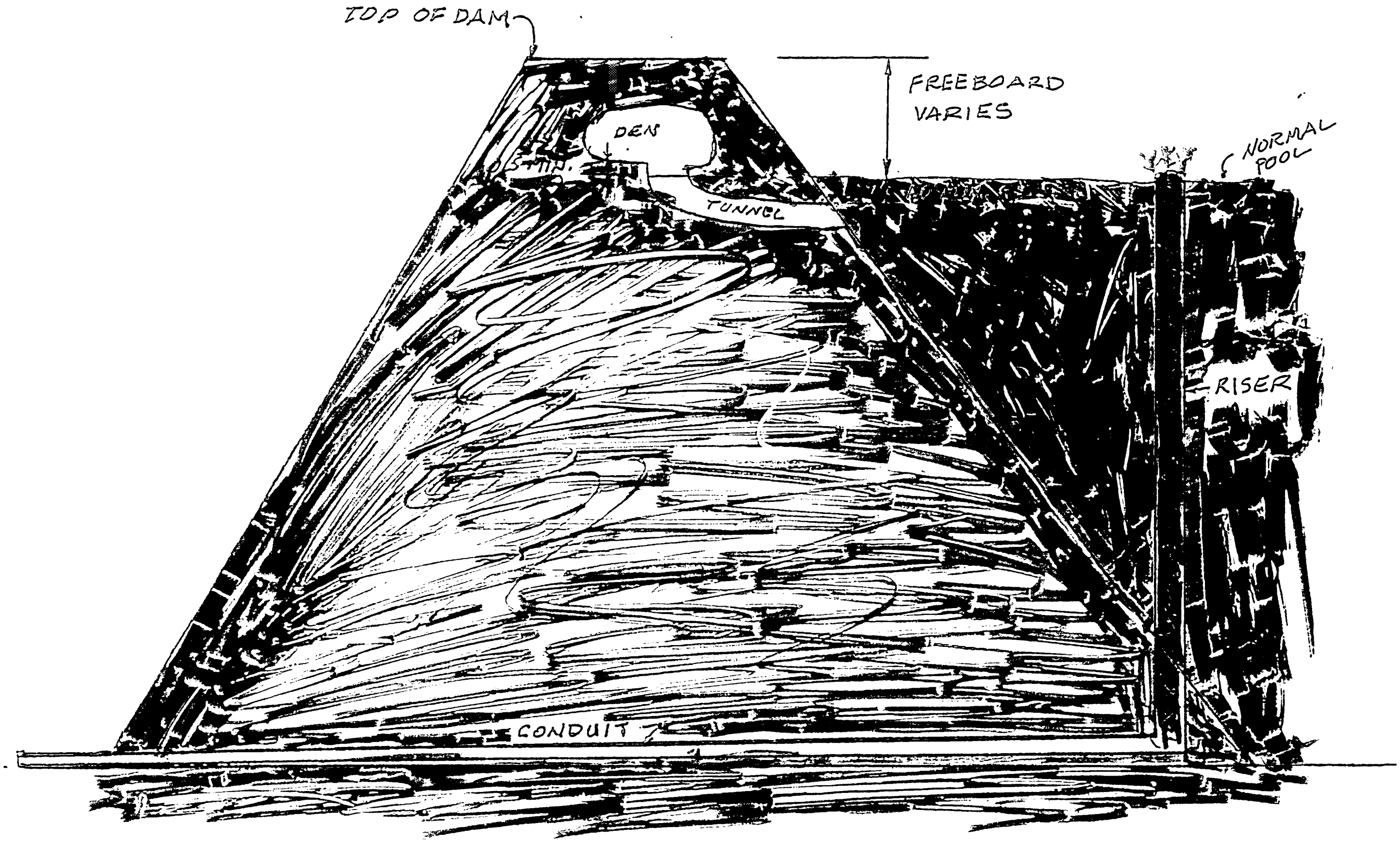
CROSS-SECTION OF DAM
COLLAPSED BEAVER DEN



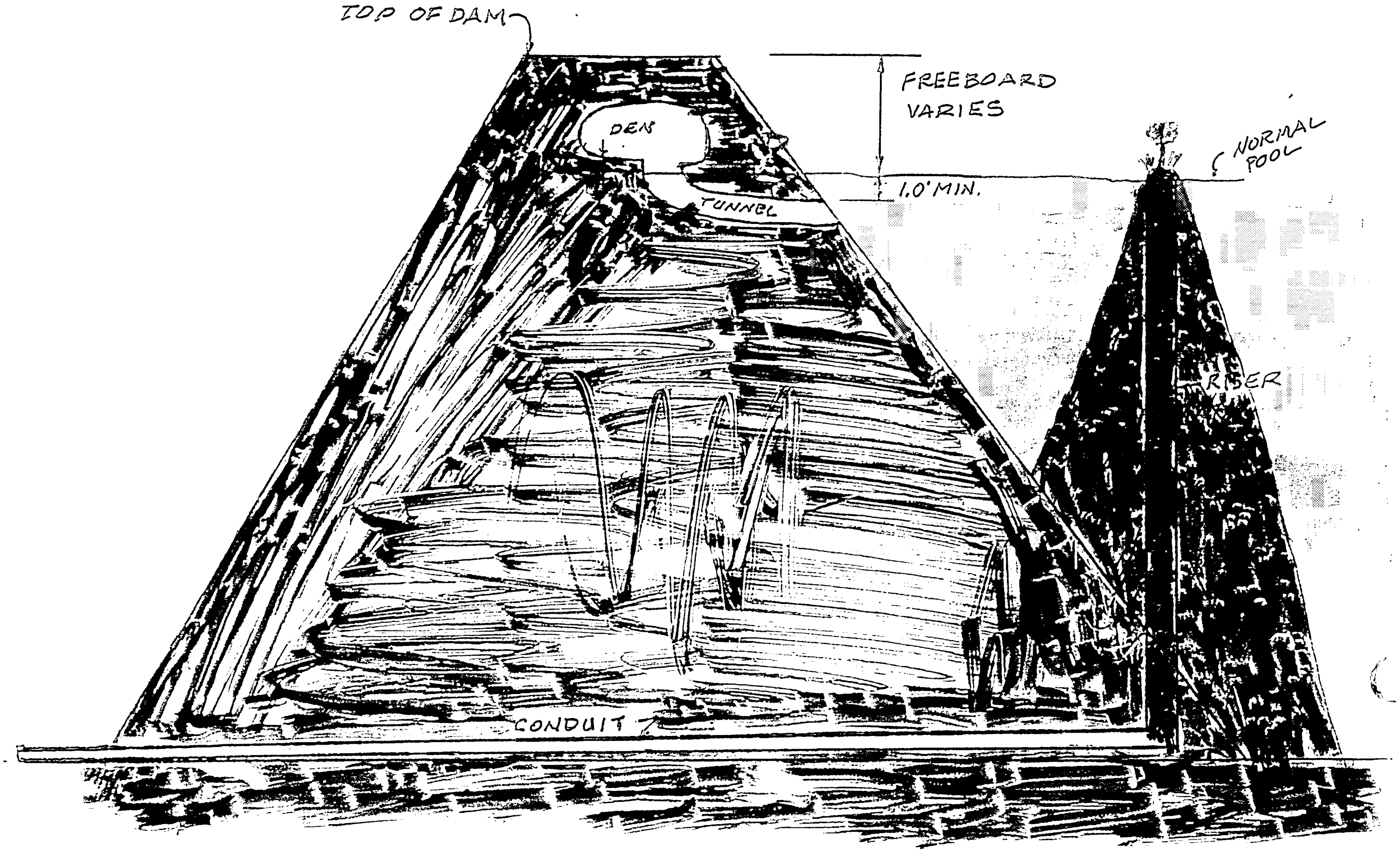
CROSS-SECTION OF DAM
EROSION OF DEN



CROSS-SECTION OF DAM
SHOWING ERODED BEAVER DEN



CROSS-SECTION OF DAM
BEAVER PLUGGED RISER



CROSS-SECTION OF DAM
BEAVER PLUGGED RISER

PIPING THROUGH DAM DUE TO ERODED BEAVER TUNNEL.

FOR SCALE, THAT IS A SIZE 10 BOOT.

ANOTHER VIEW OF ERODED BEAVER TUNNEL EXIT.

SAME SITE. A FEW FEET BACK.

VIEW IMMEDIATELY DOWNSTREAM OF ERODED BEAVER TUNNEL EXIT.

BEAVERS CANNOT STAND THE SOUND OF RUNNING WATER.

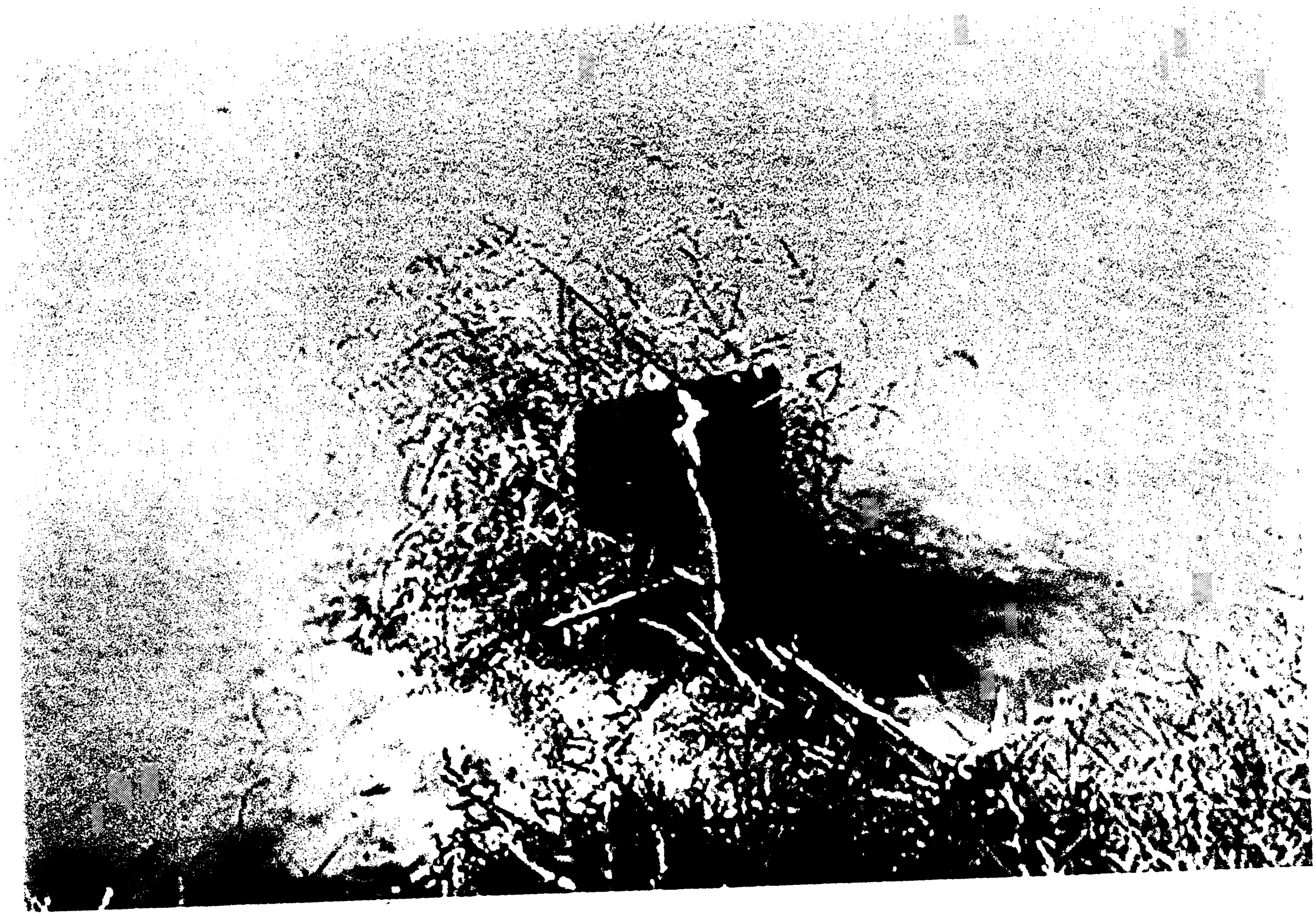
THEY WILL WORK AROUND THE CLOCK TO STOP IT.

THEY CAN BE VERY INGENIOUS IN THEIR EFFORTS TO STOP UP RISER PIPES.

THEY CAN ALSO STOP SMALL LEAKES IN DAMS.

THOSE DANG BEAVERS HAVE STOPPED UP THE RISER PIPE... AGAIN !!!

LOOKS LIKE A DAM GOOD JOB TO ME. THIS "BUSY BEAVER" IS DRAGGING HIS TAIL.

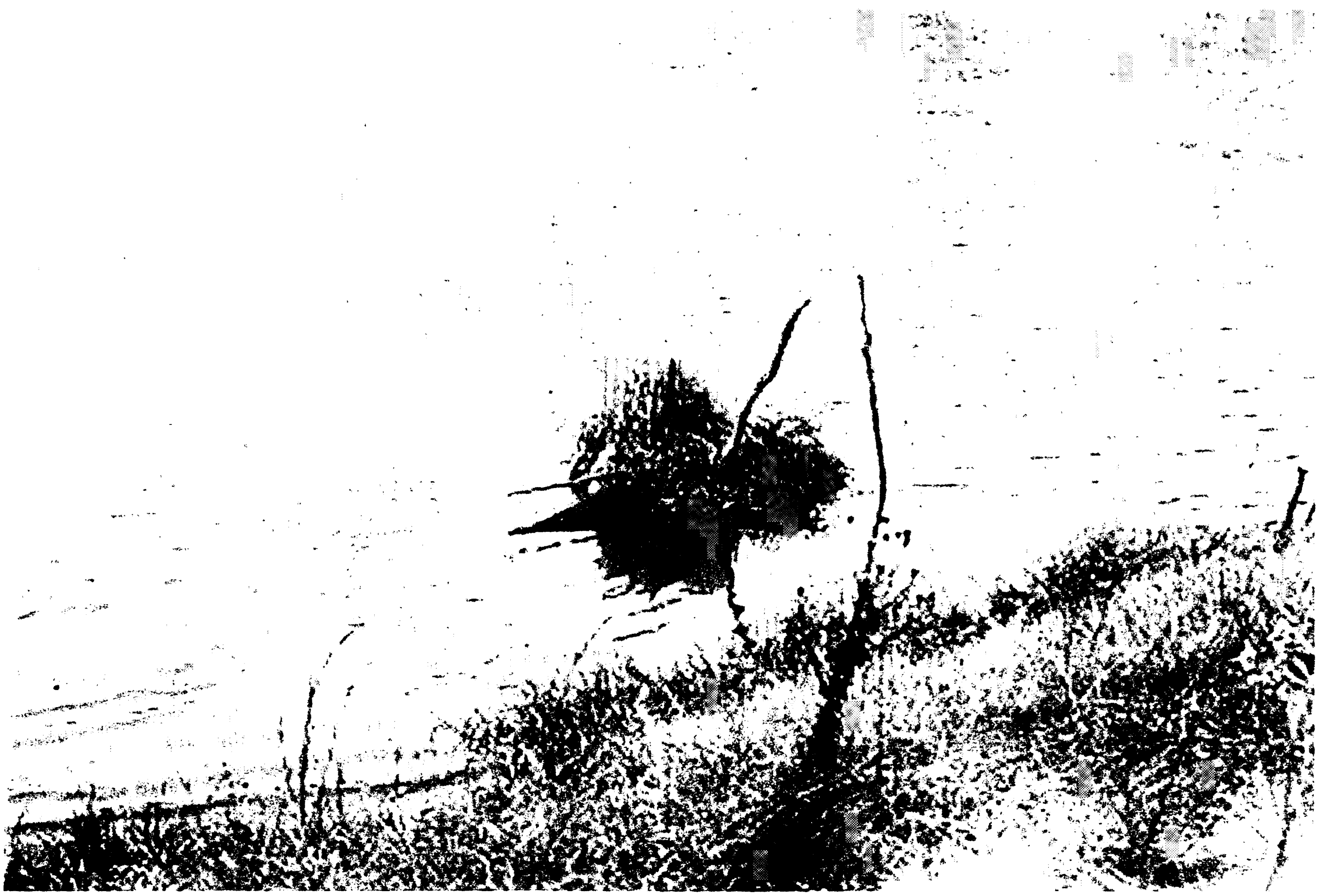


BEAVER PLUGGED RISER.

BEAVER PLUGGED RISER.

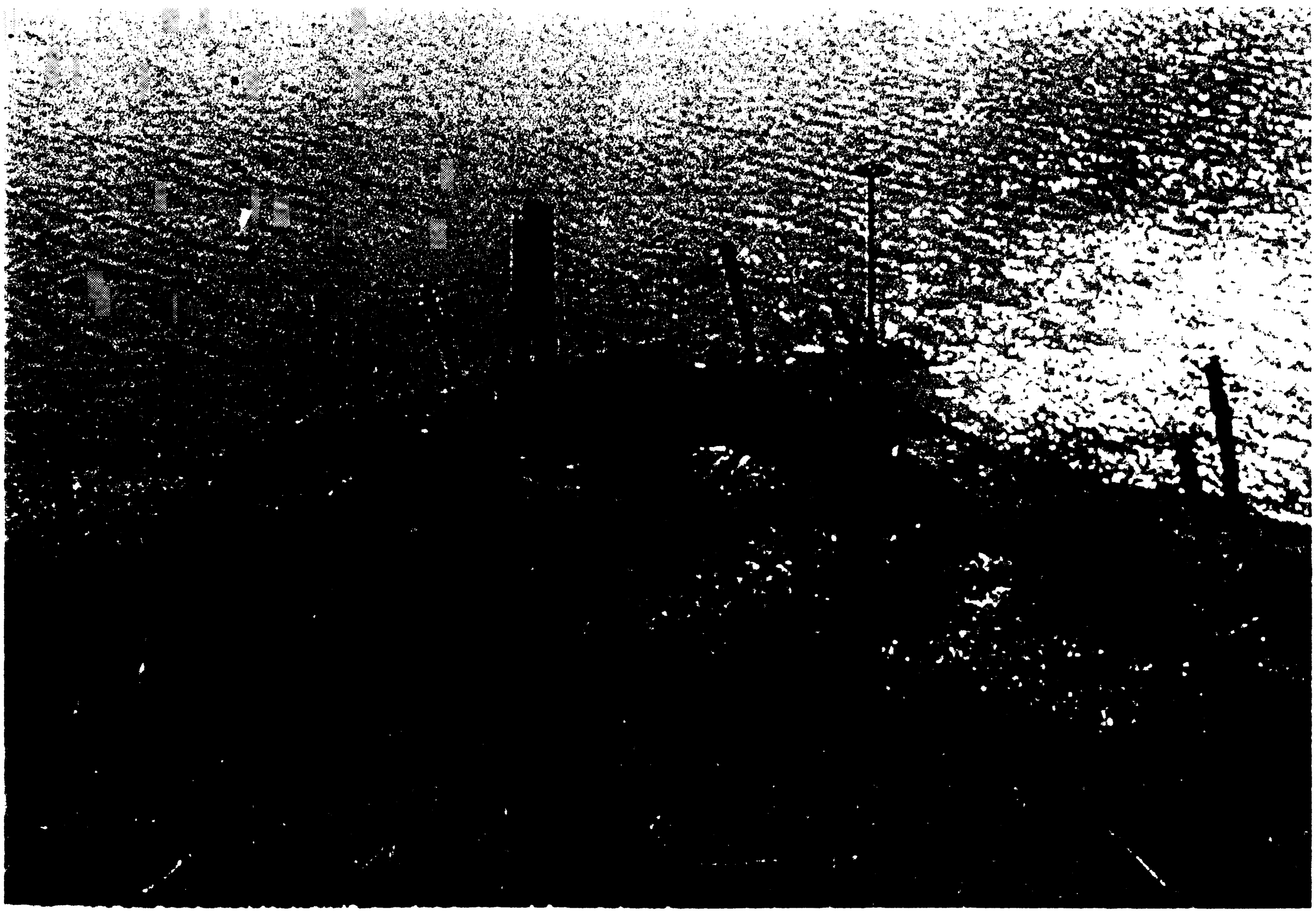
BEAVER PLUGGED RISER.

(Riser placed too near embankment.)



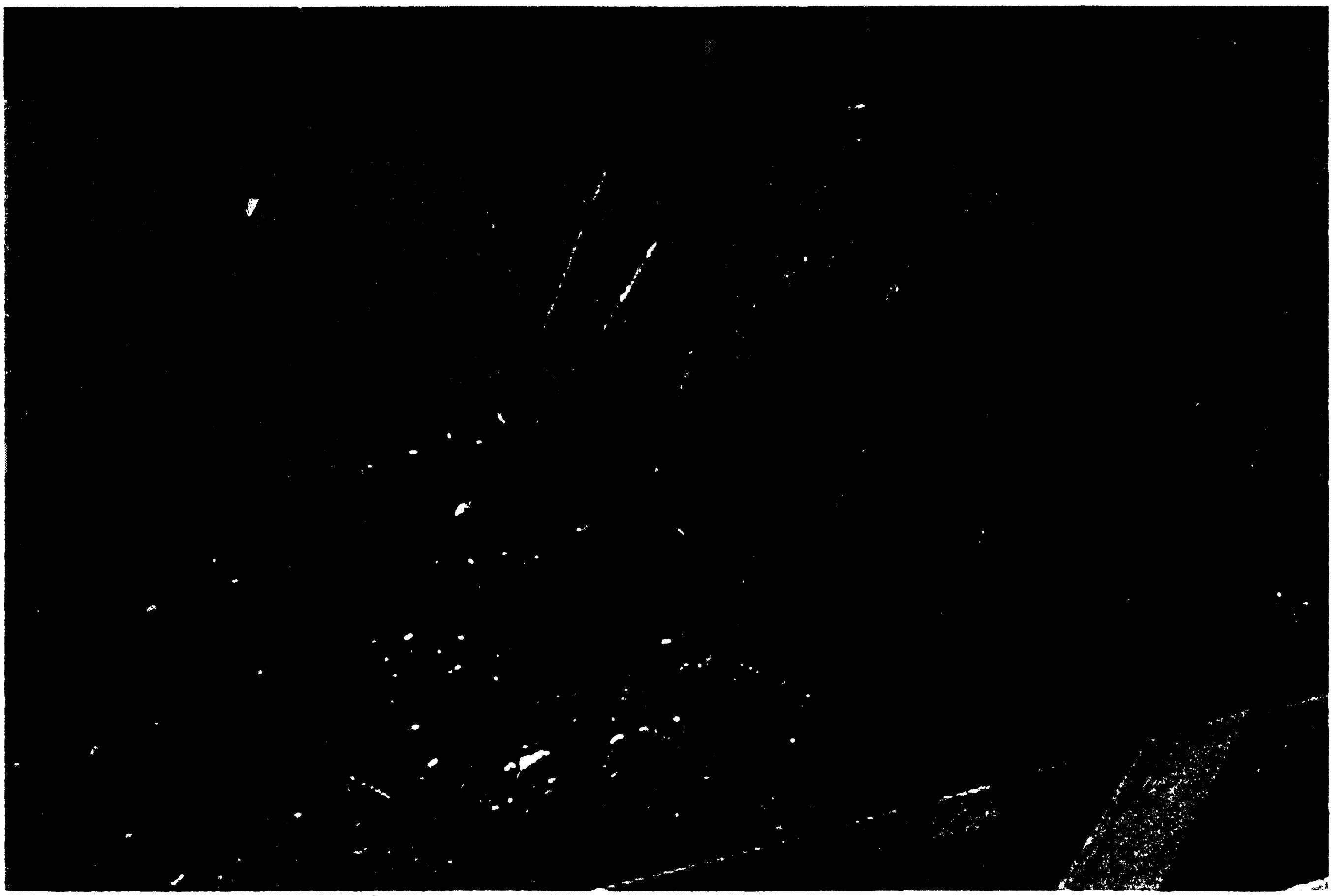
ANOTHER BEAVER PLUGGED RISER PLACED
TOO NEAR EMBANKMENT.

"I KNOW THERE IS SUPPOSED TO BE A RISER AROUND HERE SOMEWHERE!"



"AIN'T NO FENCE GOING TO STOP ME FROM PLUGGING UP
THIS RISER!"

A. Beaver



ANOTHER FENCED RISER PLUGGED BY BEAVER.

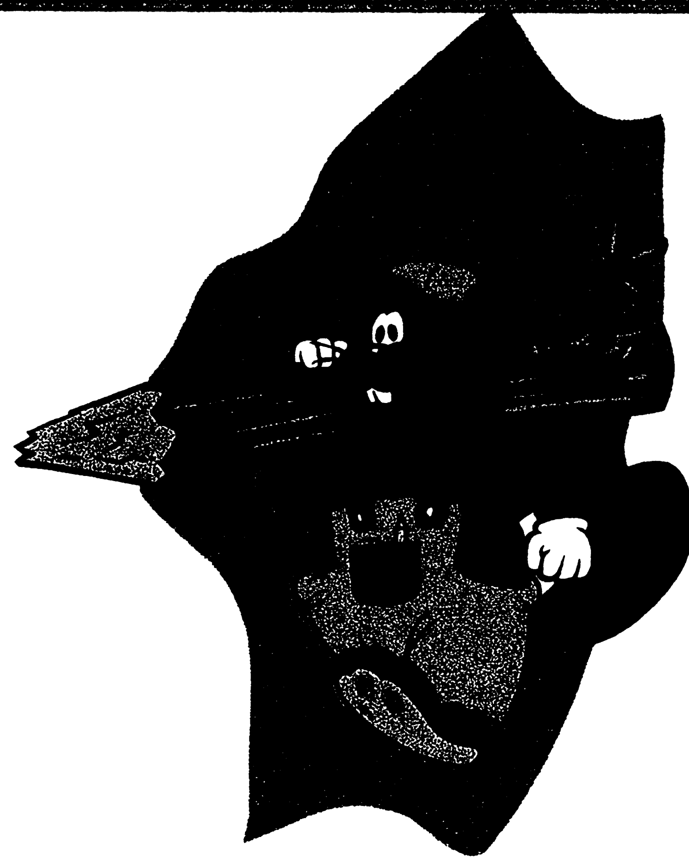
"I KNOW THERE IS A RISER HERE -- SOMEWHERE!"

ERODED EMERGENCY SPILLWAY

CAUSED BY BEAVER PLUGGED RISER.

SMALL DAM BREACHED DUE TO ERODED BEAVER ACTIVITY.

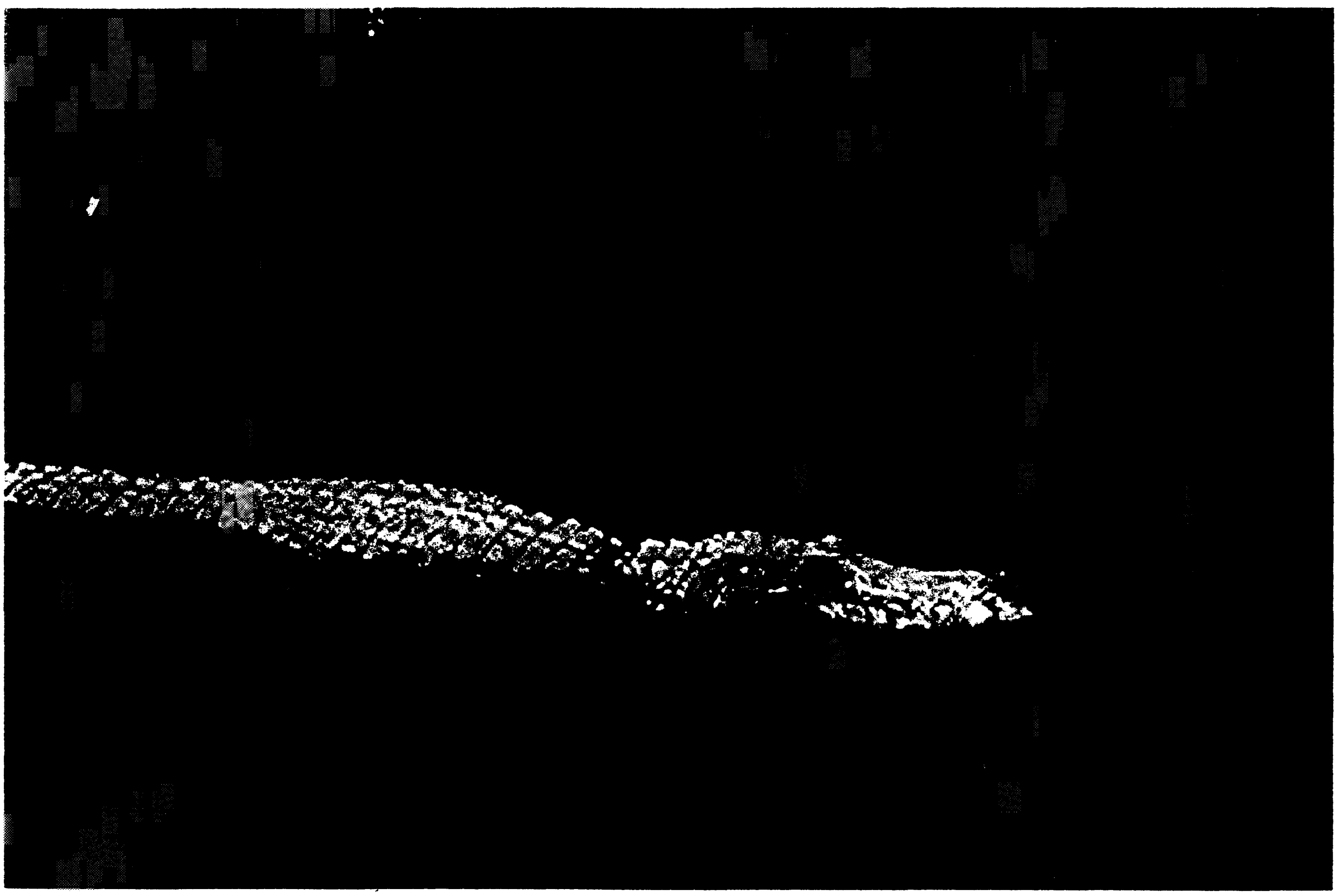
BEAVER DAM ACROSS EMERGENCY SPILLWAY.



MY JOB IS ONE DAM PROBLEM
AFTER ANOTHER.

TRAPPING IS BEST WAY TO GET RID
OF BEAVERS.
(CONIBEAR TRAPS BEST.)

THIS BEAVER SHOULD HAVE GONE SOMEWHERE ELSE
TO SET UP HOUSEKEEPING.



BEAVER CONTROL?

Can you say
"LIABLITY INSURANCE"

An Anniversary 50th Ohio Department of Natural Resources 1949-1999

Bob Taft • *Governor* Samuel W. Speck • *Director*

Division of Water James R. Morris • Chief

ANIMAL PENETRATIONS INTO EARTHEN EMBANKMENTS ASDSO KNOXVILLE WORKGROUP DECEMBER, 1999

Boris E. Slogar, P.E.
Repair Program Manager
Dam Safety Engineering Program

Case Study No. 1: Water's Edge Dam

Overview: Water's Edge Dam is located just north of Cincinnati in southern Ohio. It is a homogeneous earthen embankment 22.7 feet high, with a top of dam surface area and total storage volume of 19.3 acres and 90.8 acre-feet, respectively. The dam is considered a Class II dam in Ohio. This is a significant hazard classification where failure of the dam would cause structural damage and flooding to high value business property, but loss of human life is not envisioned.

Problem: During Thanksgiving of 1992, our office received a call from the Warren County Emergency Management Agency Director stating that the pool level in the dam was very high and a vortex had formed along the upstream slope. County officials were concerned with a possible dam failure. Engineers from our office responded and were on site in about two hours. The dam is located approximately 100 miles south of Columbus.

Engineers discovered that a vortex had formed where water was pouring into a burrow entrance on the upstream slope surface. The water followed the burrow horizontally through the dam and had collected in what looked to be a den just below the crest on the downstream slope. Water then flowed through another burrow and exited along the downstream toe area. It is believed that the turbulence in the den area caused a sinkhole to develop which had uncovered the den and burrows. Engineers filled the uncovered den with straw bales which slowed the flow and erosion. The lake level did eventually fall below the burrow entrance on the upstream slope and the dam did not fail.

Solution: The repair consisted of removing approximately half of the downstream cross section of the dam and rebuilding the embankment. A new spillway system was added which included an open-channel emergency spillway through the left abutment. A portion of the upstream slope was also removed and rebuilt. In essence, the majority of the embankment was rebuilt. To date, the "new" embankment is performing well.

Case Study No. 2: Pischieri Lake Dam

Overview: Pischieri Lake Dam is located south of Cleveland in the northeastern part of Ohio. The dam is a homogeneous earthfill embankment 36.7 feet high, with a top of dam surface area and total storage volume of 5.5 acres and 60 acre-feet, respectively. The dam was constructed in 1957 and was originally a low-hazard Class III dam. Following the events below, the dam was reclassified as a Class I high-hazard dam because failure of the dam will likely cause the loss of human life.

Problem: A routine safety inspection of the dam by engineers from our office revealed two significant issues. The first was the downstream hazard had changed as a subdivision consisting of single-family homes was constructed directly downstream of the dam. Second, our inspection revealed two holes, approximately twelve inches in diameter, along the downstream slope, about half way down the embankment. Water was flowing out of the holes at a trickle (less than one gallon per minute). The upstream slope was checked for a vortex or any sign of flow, but none were found initially. While moving debris and leaves around along the waterline at the upstream slope, a burrow was uncovered. Water poured into the burrow and out of the holes on the downstream slope rapidly at a rate estimated to be approximately 20 gallons-per-minute. The debris was moved back over the burrow and the flow slowed considerably.

Solution: Because of the concern for failure of the embankment and given the lack of a lakedrain device, the embankment was breached near the left abutment through a portion of the embankment which was four to five feet in height. The breach was excavated later that day and the lake level was lowered

approximately three feet. With the lake level below the burrow entrance, flow through the burrow was stopped.
A siphon lake drain was installed about three weeks later and the siphon was used to further lower the lake level another four feet. The section of embankment where the burrow was located was excavated and re-built. The owner is currently in the process of repairing the entire upstream slope which is riddled with collapsed burrows. The upstream face of the embankment will be covered with a clay liner and riprap stone is planned to be installed.

Case Study No. 3: Dam "X"

Overview: Dam "X" is located near the city of Cincinnati. Specific details about the dam are unavailable because the consultant which designed the repairs did not wish to release them. The dam was added to this report because of its unique repair design.

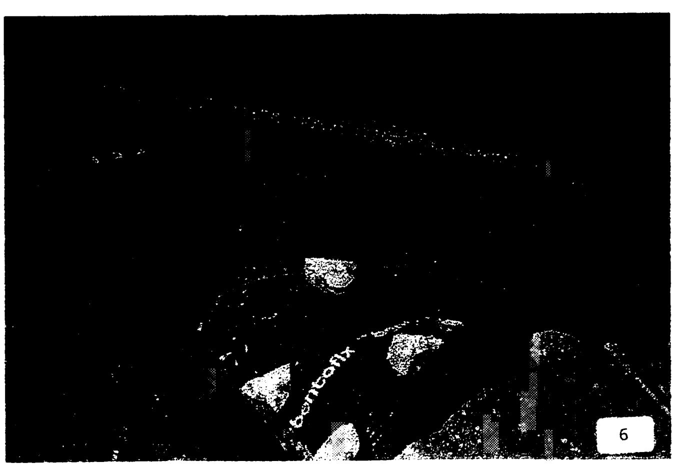
Problem: The embankment had a history of muskrat infestation during the past 10 years. The owner attempted to control the problem through the use of trapping which was somewhat effective. However, trapping served to control the muskrat population but did not eliminate them. When the lake level dropped two feet in the spring of 1999, the owner decided to take an engineering approach to solve the problem.

Solution: The repair design consisted of lowering the lake level, but not completely draining the lake in order to save the fish. The upstream slope was cleared and excavated forming a bench. A backhoe excavated a cutoff trench and the trench was filled with a mixture of clay and bentonite pellets. The upstream slope was then reconstructed. A small anchor trench was excavated into the slope to hold the bentonite liner in place. The liner was covered with clay soil and a wire mesh was placed on top along the length of the entire slope. Additional soil was placed and then seeded and mulched. To date, the repair is performing well.

ATTACHMENT "A"
PROJECT PHOTOS

Water's Edge Dam. A close-up view of the muskrat burrow and den which collapsed. This is on the downstream slope near the juncture with the crest.

Pischieri Lake Dam. The crest width has been considerably decreased because of collapsed muskrat burrows.



Dam "X". A view of the repairs along the upstream slope. The blue blanket is a bentonite liner which has been secured into the anchoring trench. Note also the wire mesh just beyond the concrete block which is used to discourage burrowing.

ATTACHMENT "B"
OHIO DAM SAFETY FACT SHEETS

- **Rodent Control**
- **Embankment Instabilities**
- **Trees and Brush**
- **Ground Cover**

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–27

Dam Safety: Rodent Control

Rodents such as the groundhog (woodchuck), muskrat, and beaver are attracted to dams and reservoirs, and can be quite dangerous to the structural integrity and proper performance of the embankment and spillway. Groundhog and muskrat burrows weaken the embankment and can serve as pathways for seepage. Beavers may plug the spillway and raise the pool level. Rodent control is essential in preserving a well-maintained dam.

Groundhog

The groundhog is the largest member of the squirrel family. Its coarse fur is a grizzled grayish brown with a reddish cast. Typical foods include grasses, clover, alfalfa, soybeans, peas, lettuce, and apples. Breeding takes place during early spring (beginning at the age of one year) with an average of four or five young per litter, one litter per year. The average life expectancy is two or three years with a maximum of six years.

Occupied groundhog burrows are easily recognized in the spring due to the groundhog's habit of keeping them "cleaned out." Fresh dirt is generally found at the mouth of active burrows. Half-round mounds, paths leading from the den to nearby fields, and clawed or girdled trees and shrubs also help identify inhabited burrows and dens.

When burrowing into an embankment, groundhogs stay above the phreatic surface (upper surface of seepage or saturation) to stay dry. The burrow is rarely a single tunnel. It is usually forked, with more than one entrance and with several side passages or rooms from 1 to 12 feet long.

Groundhog Control

Control methods should be implemented during early spring when active burrows are easy to find, young groundhogs have not scattered, and there is less likelihood of damage to other wildlife. In later summer, fall, and winter, game animals will scurry into groundhog burrows for brief protection and may even take up permanent abode during the period of groundhog hibernation.

Groundhogs can be controlled by using fumigants or by shooting. Fumigation is the most practical method of controlling groundhogs. Around buildings or other high fire hazard areas, shooting may be preferable. Groundhogs will be discouraged from inhabiting the embankment if the vegetal cover is kept mowed.

Gas cartridges may be purchased at garden supply and hardware stores. Information about the use and availability of gas cartridges may be obtained from county extension offices, or the U.S. Department of Agriculture at the following address:

The USDA
Animal and Plant Health Inspection Service
Wildlife Services
200 North High Street, Room 622
Columbus, Ohio 43215
(614) 469-5681

Muskrat

The muskrat is a stocky rodent with a broad head, short legs, small eyes, and rich dark brown fur. Muskrats are chiefly nocturnal. Their principal food includes stems, roots, bulbs, and foliage of aquatic plants. They also feed on snails, mussels, crustaceans, insects, and fish. Usually three to five litters, averaging six to eight young per litter, are produced each year. Adult muskrats average one foot in length and three pounds in weight. The life expectancy is less than two years, with a maximum of four years. Muskrats can be found wherever there are marshes, swamps, ponds, lakes and streams having calm or very slowly moving water with vegetation in the water and along the banks.

Muskrats make their homes by burrowing into the banks of lakes and streams or by building "houses" of bushes and other plants. Their burrows begin from 6 to 18 inches below the water surface and penetrate the embankment on an upward slant. At distances up to 15 feet from the entrance, a dry chamber is hollowed out above the water level. Once a muskrat den is occupied, a rise in the water level will cause the muskrat to dig farther and higher to excavate a new dry chamber. Damage (and the potential for problems) is compounded where groundhogs or other burrowing animals construct their dens in the embankment opposite muskrat dens.

Continued on back!

Muskrat Control

Barriers to prevent burrowing offer the most practical protection to earthen structures. A properly constructed riprap and filter layer will discourage burrowing. The filter and riprap should extend at least 3 feet below the water line. As the muskrat attempts to construct a burrow, the sand and gravel of the filter layer caves in and thus discourages den building. Heavy wire fencing laid flat against the slope and extending above and below the water line can also be effective. Eliminating or reducing aquatic vegetation along the shoreline will discourage muskrat habitation. Where muskrats have inhabited the area, trapping is usually the most practical method of removing them from a pond.

Eliminating a Burrow

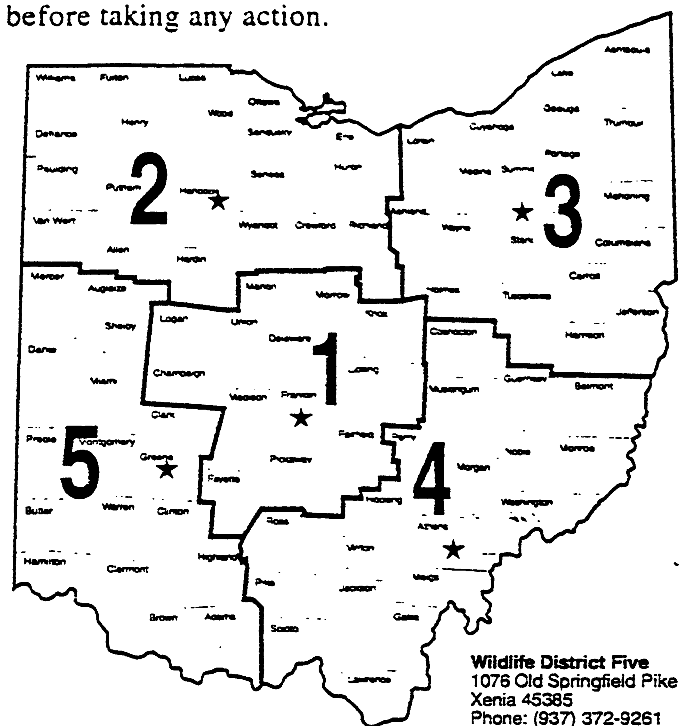
The recommended method of backfilling a burrow in an embankment is mud-packing. This simple, inexpensive method can be accomplished by placing one or two lengths of metal stove or vent pipe in a vertical position over the entrance of the den. Making sure that the pipe connection to the den does not leak, the mud-pack mixture is then poured into the pipe until the burrow and pipe are filled with the earth-water mixture. The pipe is removed and dry earth is tamped into the entrance. The mud-pack is made by adding water to a 90 percent earth and 10 percent cement mixture until a slurry or thin cement consistency is attained. All entrances should be plugged with well-compacted earth and vegetation re-established. Dens should be eliminated without delay because damage from just one hole can lead to failure of a dam or levee.

Beaver

Beaver will try to plug spillways with their cuttings. Routinely removing the cuttings is one way to alleviate the problem. Trapping beaver may be done by the owner during the appropriate season; however, the nearest ODNR, Division of Wildlife, District Office or state game protector should be contacted first.

Hunting and Trapping Regulations

Because hunting and trapping rules change from year to year, ODNR, Division of Wildlife authorities at one of the following offices should be consulted before taking any action.



Wildlife District One
1500 Dublin Road
Columbus 43215
Phone: (614) 644-3925
FAX (614) 644-3931

Wildlife District Two
952 Lima Avenue, Box A
Findlay 45840
Phone: (419) 424-5000
FAX (419) 422-4875

Wildlife District Three
912 Portage Lakes Drive
Akron 44319
Phone: (330) 644-2293
FAX (330) 644-8403

Wildlife District Four
360 E. State Street
Athens 45701
Phone: (740) 594-2211
FAX (740) 592-1626

Wildlife District Five
1076 Old Springfield Pike
Xenia 45385
Phone: (937) 372-9261
FAX (937) 376-3011

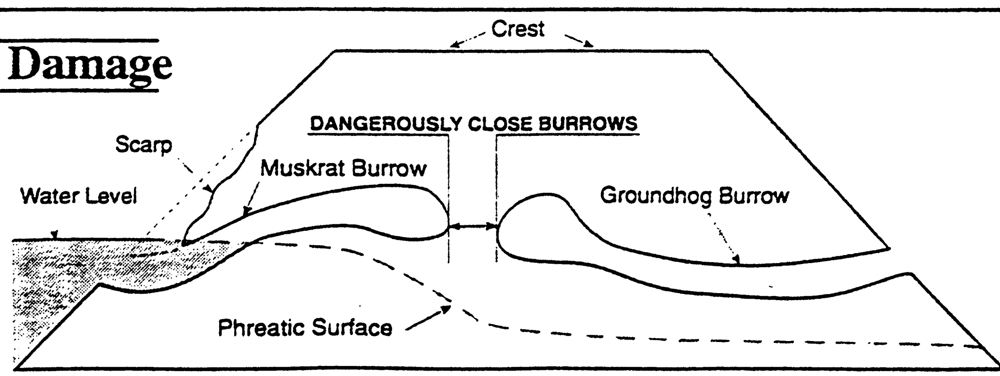
In Sandusky
305 East Shoreline Drive
Sandusky 44870
Phone: (419) 625-8062
FAX (419) 625-6272

In Fairport Harbor
Phone: (440) 352-6100
FAX (440) 350-0250

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
1939 Fountain Square, Building E-3
Columbus, Ohio 43224-1336
(614) 265-6731 (Voice) (614) 447-9503 (Fax)
http://www.dnr.state.oh.us/odnr/water/

Rodent Burrow Damage



OHIO Department of Natural Resources

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–53

Dam Safety: Embankment Instabilities

The dam embankment and any appurtenant dikes must safely contain the reservoir during normal and flood conditions. Cracks, slides, and depressions are signs of embankment instability and should indicate to the owner that maintenance or repair work may be required. When one of these conditions is detected, the owner must retain an experienced professional engineer to determine the cause of the instability. A rapidly changing condition or the sudden development of a large crack, slide, or depression indicates a very serious problem, and the Dam Safety Engineering Program should be contacted immediately. A professional engineer must investigate these types of embankment stability problems because a so-called "home remedy" may cause greater and more serious damage to the embankment and eventually result in unneeded expenditures for unsuccessful repairs.

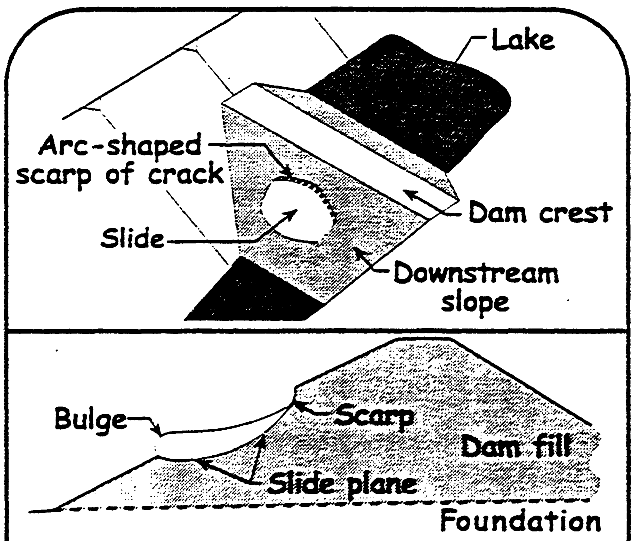
Cracks

Short, isolated cracks are commonly due to drying and shrinkage of the embankment surface and are not usually significant. They are usually less than 1 inch wide, propagate in various directions, and occur especially where the embankment lacks a healthy grass cover. Larger (wider than 1 inch), well-defined cracks may indicate a more serious problem. There are generally two types of these cracks: longitudinal and transverse. Longitudinal cracks extend parallel to the crest of the embankment and may indicate the early stages of a slide on either the upstream or downstream slope of the embankment. They can create problems by allowing runoff to enter the cracks and saturate the embankment which in turn can cause instability of the embankment. Transverse cracks extend perpendicular to the crest and can indicate differential settlement within the embankment. Such cracks provide avenues for seepage through the dam and could quickly lead to piping, a severe seepage problem that will likely cause the dam to fail.

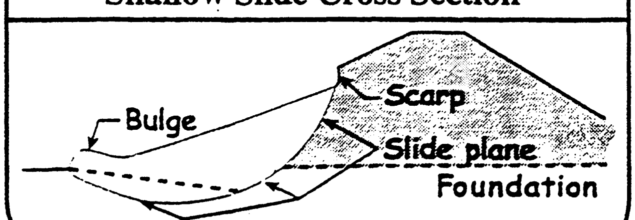
If the owner finds small cracks during inspection of the dam, he/she should document the observations, and seal the cracks to prevent runoff from saturating the embankment. The documentation should consist of detailed notes (including the location, length, approximate elevation, and crack width), photographs, sketches, and possibly monitoring stakes. The crack must then be monitored during future inspections. If the crack becomes longer or wider, a more serious problem such as a slide may be developing. Large cracks indicate serious stability problems. If one is detected, the owner should contact the Dam Safety Engineering Program and/or retain an engineer to investigate the crack and prepare plans and specifications for repairs. When muddy flow discharges from a crack, the dam may be close to failure. The emergency action plan should be initiated immediately and the Dam Safety Engineering Program contacted.

Slides

A slide in an embankment or in natural soil or rock is a mass movement of material. Some typical characteristics of a slide are an arc-shaped crack or scarp along the top and a bulge along the bottom of the slide (see drawing). Slides may develop because of poor soil com-



Shallow Slide Cross Section



Deep-seated Slide Cross Section

Continued on back!

paction, the gradient of the slope being too steep for the embankment material, seepage, sudden drawdown of the lake level, undercutting of the embankment toe, or saturation and weakening of the embankment or foundation.

Slides can be divided into two main groups: shallow and deep-seated. Shallow slides generally affect the top 2 to 3 feet of the embankment surface. Shallow slides are generally not threatening to the immediate safety of the dam and often result from wave erosion, collapsed rodent burrows, or saturated top soil. Deep-seated slides are serious, immediate threats to the safety of a dam. They can extend several feet below the surface of the embankment, even below the foundation. A massive slide can initiate the catastrophic failure of a dam. Deep-seated slides are the result of serious problems within the embankment.

Small slides can be repaired by removing the vegetation and any unsuitable fill from the area, compacting suitable fill and adding topsoil to make the embankment uniform, and establishing a healthy grass cover. If a shallow or deep-seated slide is discovered, the Dam Safety Engineering Program should be contacted and an engineer retained to investigate the slide. Plans and specifications may need to be prepared for its repair depending on the findings of the investigation.

Depressions

Depressions are sunken areas of the abutment, toe area, or embankment surface. They may be created during construction, or may be caused by decay of buried organic materials, thawing of frozen embankment material, internal erosion of the embankment, or settlement (consolidation) of the embankment or its foundation. To a certain degree, minor depressions are common and do not necessarily indicate a serious problem. (An embankment with several minor depressions may be described as hummocky.) However, larger depressions may indicate serious problems such as weak foundation materials, poor compaction of the embankment during construction, or internal erosion of the embankment fill.

Depressions can create low areas along the crest, cracks through the embankment, structural damage to spillways or other appurtenant structures, damage to internal drainage systems, or general instability of the embankment. They can also inhibit maintenance of the dam and make detection of stability or seepage problems difficult.

The owner should monitor depressions during the regular inspection of the dam. All observations should be documented with detailed notes, photographs, and sketches. Minor depressions can be repaired by removing the vegetation and any unsuitable fill from the area, adding fill and then topsoil to make the embankment uniform, and finally establishing a healthy grass cover. An engineer should be retained to investigate large depressions or settlement areas. Plans and specifications may need to be prepared for its repair depending on the findings of the investigation.

Importance of Inspection

Stability problems can threaten the safety of the dam and the safety of people and property downstream. Therefore, stability problems must be detected and repaired in a timely manner. The entire embankment should be routinely and closely inspected for cracks, slides, and depressions. To do this thoroughly, proper vegetation must be regularly maintained on the embankment. Improper or overgrown vegetation can inhibit visual inspection and maintenance of the dam. Accurate inspection records are also needed to detect stability problems. These records can help determine if a condition is new, slowly changing, or rapidly changing. A rapidly changing condition or the sudden development of a large crack, slide, or depression indicates a very serious problem, and the Dam Safety Engineering Program must be contacted immediately.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
1939 Fountain Square, Building E-3
Columbus, Ohio 43224-1336
(614) 265-6731 (Voice) (614) 447-9503 (Fax)
http://www.dnr.state.oh.us/odnr/water/

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–28

Dam Safety: Trees and Brush

The establishment and control of proper vegetation is an important part of dam maintenance. Properly main tained vegetation can help prevent erosion of embankment and earth channel surfaces, and aid in the control of groundhogs and muskrats. The uncontrolled growth of vegetation can damage embankments and concrete structures and make close inspection difficult.

Trees and Brush

Trees and brush should not be permitted on embankment surfaces or in vegetated earth spillways. Extensive root systems can provide seepage paths for water. Trees that blow down or fall over can leave large holes in the embankment surface that will weaken the embankment and can lead to increased erosion. Brush obscures the surface limiting visual inspection, provides a haven for burrowing animals, and retards growth of grass vegetation. Tree and brush growth adjacent to concrete walls and structures may eventually cause damage to the concrete and should be removed.

Stump Removal & Sprout Prevention

Stumps of cut trees should be removed so vegetation can be established and the surface mowed. Stumps can be removed either by pulling or with machines that grind them down. All woody material should be removed to about 6 inches below the ground surface. The cavity should be filled with well-compacted soil and grass vegetation established.

Stumps of trees in riprap cannot usually be pulled or ground down, but can be chemically treated so they will not continually form new sprouts. Certain herbicides are effective for this purpose and can even be used at water supply reservoirs if applied by licensed personnel. For product information and information on how to obtain a license, contact The Ohio Department of Agriculture at the following address:

The Ohio Department of Agriculture
Pesticide Regulation
8995 E. Main Street
Reynoldsburg, Ohio 43068
Telephone Number (614) 728-6987

These products should be painted, not sprayed, on the stumps. Other instructions found on the label should be strictly followed when handling and applying these materials. Only a few commercially available chemicals can be used along shorelines or near water.

Embankment Maintenance

Embankments, areas adjacent to spillway structures, vegetated channels, and other areas associated with a dam require continual maintenance of the vegetal cover. Grass mowing, brush cutting, and removal of woody vegetation (including trees) are necessary for the proper maintenance of a dam, dike, or levee. All embankment slopes and vegetated earth spillways should be mowed at least once a year. Aesthetics, unobstructed viewing during inspections, maintenance of a non-erodible surface, and discouragement of groundhog habitation are reasons for proper maintenance of the vegetal cover.

Methods used in the past for control of vegetation, but are now considered unacceptable, include chemical spraying, and burning. More acceptable methods include the use of weed whips or power brush-cutters and mowers. Chemical spraying to first kill small trees and brush is acceptable if precautions are taken to protect the local environment.

It is important to remember not to mow when the embankment is wet. It is also important to use proper equipment for the slope and type of vegetation to be cut. Also, always follow the manufacturer's recommended safe operation procedures.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
1939 Fountain Square, Building E-3
Columbus, Ohio 43224-1336
(614) 265-6731 (Voice) (614) 447-9503 (Fax)
http://www.dnr.state.oh.us/odnr/water/

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–54

Dam Safety: Ground Cover

The establishment and control of proper vegetation are an important part of dam maintenance. Properly maintained vegetation can help prevent erosion of embankment and earth channel surfaces, and aid in the control of groundhogs and muskrats. The uncontrolled growth of vegetation can damage embankments and concrete structures and make close inspection difficult.

Grass vegetation is an effective and inexpensive way to prevent erosion of embankment surfaces. If properly maintained, it also enhances the appearance of the dam and provides a surface that can be easily inspected. Roots and stems tend to trap fine sand and soil particles, forming an erosion-resistant layer once the plants are well established. Grass vegetation may not be effective in areas of concentrated runoff, such as at the contact of the embankment and abutments, or in areas subjected to wave action.

Common Problems

Bare Areas

Bare areas on an embankment are void of protective cover (e.g. grass, asphalt, riprap etc.). They are more susceptible to erosion which can lead to localized stability problems such as small slides and sloughs. Bare areas must be repaired by establishing a proper grass cover or by installing other protective cover. If using grass, the topsoil must be prepared with fertilizer and then scarified before sowing seed. Types of grass vegetation that have been used on dams in Ohio are bluegrass, fescue, ryegrass, alfalfa, clover, and redtop. One suggested seed mixture is 30% Kentucky Bluegrass, 60% Kentucky 31 Fescue, and 10% Perennial Ryegrass. Once the seed is sown, the area should be mulched and watered regularly.

Erosion

Embankment slopes are normally designed and constructed so that the surface drainage will be spread out in a thin layer as "sheet flow" over the grass cover. When the sod is in poor condition or flow is concentrated at one or more locations, the resulting erosion will leave rills and gullies in the embankment slope. The erosion will cause loss of material and make maintenance of the embankment difficult. Prompt repair of the erosion is required to prevent more serious damage to the embankment. If erosion gullies are extensive, a registered professional engineer may be required to design a more rigid repair such as riprap or concrete. Minor rills and gullies can be repaired by filling them with compacted cohesive material. Topsoil should be a minimum of 4 inches deep. The area should then be seeded and mulched. Not only should the eroded areas be repaired, but the cause of the erosion should be addressed to prevent a continued maintenance problem.

Footpaths

Paths from animal and pedestrian traffic are problems common to many embankments. If a path has become established, vegetation in this area will not provide adequate protection and a more durable cover will be required unless the traffic is eliminated. Gravel, asphalt and concrete have been used effectively to cover foot paths. Embedding railroad ties or other treated wood beams into an embankment slope to form steps is one of the most successful and inexpensive methods used to provide a protected pathway.

Vehicle Ruts

Vehicle ruts can also be a problem on the embankment. Vehicular traffic on the dam should be discouraged especially during wet conditions except when necessary. Water collected in ruts may cause localized saturation, thereby weakening the embankment. Vehicles can also severely damage the vegetation on embankments. Worn areas could lead to erosion and more serious problems. Ruts that develop in the crest should be repaired by grading to direct all surface drainage into the impoundment. Bare and eroded areas should be repaired using the methods mentioned in the above sections. Constructed barriers such as fences and gates are effective ways to limit access of vehicles.

Improper Vegetation

Crown vetch, a perennial plant with small pink flowers, has been used on some dams in Ohio but is not recommended (see Figure 1). It hides the embankment surface preventing early detection of cracks and erosion. It is not effective in preventing erosion.

Continued on back!

Figure 1: Crown Vetch
(Source: http://www.vg.com)

Vines and woody vegetation such as trees and brush also hide the embankment surface preventing early detection of cracks and erosion. Tall vegetation also provides a habitat for burrowing animals. All improper vegetation must be removed from the entire embankment surface. Any residual roots that are larger than 3 inches in diameter must be removed. All roots should be removed down to a depth of at least 6 inches and replaced with a compacted clay material; then 4 inches of topsoil should be placed on the disturbed areas of the slope. Finally, these areas must be seeded and mulched to establish a proper grass cover.

Maintenance

Embankments, areas adjacent to spillway structures, vegetated channels, and other areas associated with a dam require continual maintenance of the vegetal cover. Removal of improper vegetation is necessary for the proper maintenance of a dam, dike or levee. All embankment slopes and vegetated earth spillways should be mowed at least twice a year. Reasons for proper maintenance of the vegetal cover include unobstructed viewing during inspection, maintenance of a non-erodible surface, discouragement of burrowing animal habitation, and aesthetics.

Common methods for control of vegetation include the use of weed trimmers or power brush-cutters and mowers. Chemical spraying to kill small trees and brush is acceptable if precautions are taken to protect the local environment. Some chemical spraying may require proper training prior to application. Additional information can be found on the Trees and Brush Fact Sheet.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
1939 Fountain Square, Building E-3
Columbus, Ohio 43224-1336
(614) 265-6731 (Voice) (614) 447-9503 (Fax)
http://www.dnr.state.oh.us/odnr/water/

PLANTS AND ANIMAL PENETRATIONS OF EARTHFILLED DAMS WORKSHOP

University of Tennessee

November 30 – December 3, 1999

TITLE: Animal Borrows and Vegetation on USDA Forest Service Dams

Douglas E. McClelland, USDA Forest Service, P.O. Box 7669, Missoula, Montana, 59807
(406) 329-3351 FAX (406) 329-3198

ABSTRACT

Vegetation growing on and rodents borrowing in earth embankment dams are a risk to their stability because of the effects of root holes and rodent borrows on the flownet within the embankment which could lead to piping failure.

In the Northern Region of the USDA Forest Service (FS) there are approximately 125 earth embankment dams that meet the National Inventory of Dams (NID) criteria of 25 feet hydraulic height and 50 acre-ft of storage. Many of these dams have large trees growing on them, and many others have rodent borrows in them.

There are other aspects than stability which in the Northern Region of the FS impact earth embankment dams such as shrubs and grasses, and non-borrowing animals such as cattle, wildlife, and beavers.

The Northern Region of the FS has never had a dam fail due to vegetation or borrowing rodents effects. However, the risk is significant since, although the probability of the failure mode occurring is very small, the consequences of failure are very significant.

Forest Service Dam Program

There are 1750 dams which meet the National Inventory of Dams (NID) criteria of 25 feet hydraulic height and 50 acre-ft of storage. In addition, there are in excess of 1200 earth embankment dams in the Northern Region of the FS that do not meet the NID criteria for height and storage capacity. Most of these dams are in eastern Montana and western North Dakota, and are primarily stock water and wildlife dams. All 125 of the NID dams in the Northern Region of the FS are in Montana and western North Dakota.

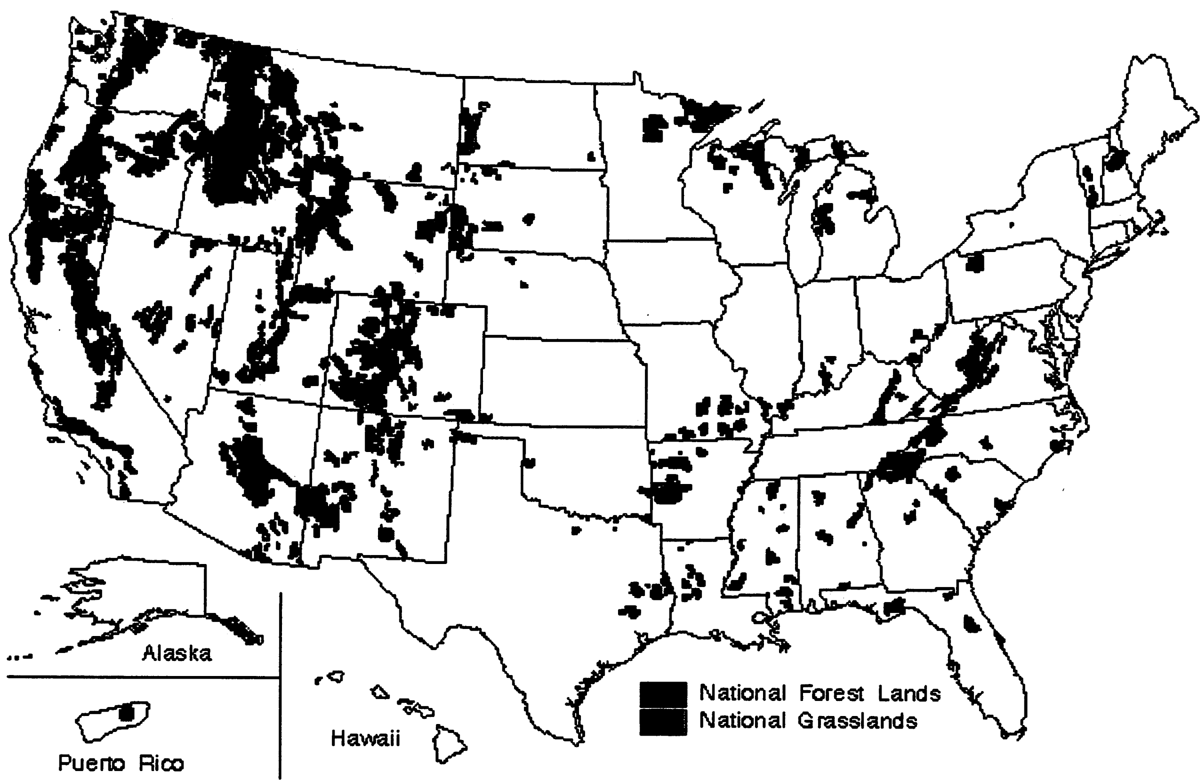
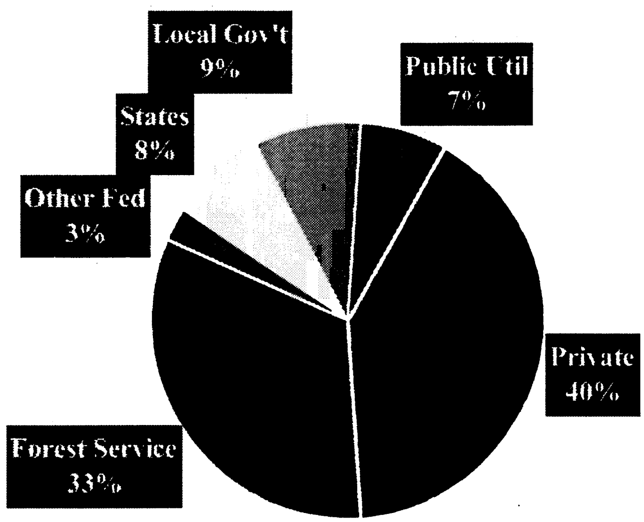


Figure 1 USDA Forest Service Lands

Figure 3 Dam Ownership



The Northern Region of the FS is relatively arid except for the mountains of northern Idaho and western Montana. Most dams were constructed for irrigation and mining. A majority of the dams on FS lands are non-FS owned, and are regulated through special use permits that contain stipulations on the maintenance and inspection of the dams. Maintenance and inspection is often difficult because of the remote location of the dams with some being in designated wilderness areas that in general precludes use of motorized equipment. Many of the FS owned dams were abandoned by the original owner and have a long history of neglect. The combination of increased maintenance needs, dam access restrictions, and the influx of people to western Montana raising the hazard classifications have made adequate dam maintenance difficult and marginally economic.

The dams in western Montana were constructed of primarily cohesionless soils, and, therefore, more prone to piping. Many of the older dams in the Northern Rockies were constructed with relatively coarse materials that were often confined with timber cribbing. Many are approaching 100 years in age with the timber cribbing deteriorating. Any fine grain soils were generally salvaged for a water seal on the upstream face of the dam. In general, there are fewer rodent borrows but often large trees on the embankments.

The dams in eastern Montana and western North Dakota have been constructed more recently, and are primarily for livestock and wildlife benefit. The soils are generally more cohesive with little riprap or coarse material available. The primary problems are rodent borrows, and wind, wave and cattle erosion.

Animal Borrows and Vegetation In Earth Dams

The general problem with vegetation and animal burrows in earth dams is that they can both seriously distort the seepage flownet, shorten seepage paths, increase the seepage pressure gradients which may ultimately increase the risk of piping failure. The risk depends on the root system characteristics of the vegetation. Vegetation may also obscure seepage problems on the downstream face of the dam.

There are three types of vegetation on earth dams which are trees, shrubs and grasses. There are negative and positive aspects of each type of vegetation which are discussed in the following paragraphs.

Trees

The primary benefit of trees is probably aesthetics although it could be argued that they do act as water pumps lowering or maintaining the phreatic surface, and that their roots may act as tensile reinforcement within the soil mass. However, both of these potential marginal benefits are only viable while the tree is alive, and they are both outweighed by the negative aspects that result when the tree dies. Some people within the Forest Service definitely have an attraction to trees and argue vociferously to not have them cut.

Photo 1 Beaverhead NF-May Lake Dam-Trees on Embankments

The obvious problem with dead trees is that the roots eventually rot leaving potential seepage paths through the dam. The seriousness of the relic root paths depends on their effect on the seepage flownet. If the roots do not penetrate to the depth of the phreatic surface, then they may not be a serious problem. Photos 1 through 4 show examples of large trees on FS dams.

Live trees also pose a potential hazard for an earth dam when they are uprooted by high winds which often occur in high mountain basins as well as the plains of Eastern Montana and North Dakota. The root wad holes can be large for some tree species. The impact of a large root wad hole can be much more devastating to the integrity of the dam than merely potential seepage paths left by dead roots.

The easiest method of preventing the impacts of trees is to cut them down while they are small. However, we have many dams with full-grown trees on them. We have essentially two options for dealing with full-grown trees which are to either water them and hope they don't die, or remove them by excavating their root system, and recompacting soil into the excavation.

Photo 2 Helena NF- Park Lake Dam-Large Trees on Embankment

Photo 3 Helena NF-Park Lake Dam-Large Trees on Embankment

Photo 4 Helena NF-Park Lake Dam-Large Trees on Embankment

If the aesthetic aspect is very important then trees could be allowed to grow to a small size before cutting them. Another possibility would be to allow sufficient cross-section in the dam so that the root wads for the permitted species would not impact the integrity of the dam.

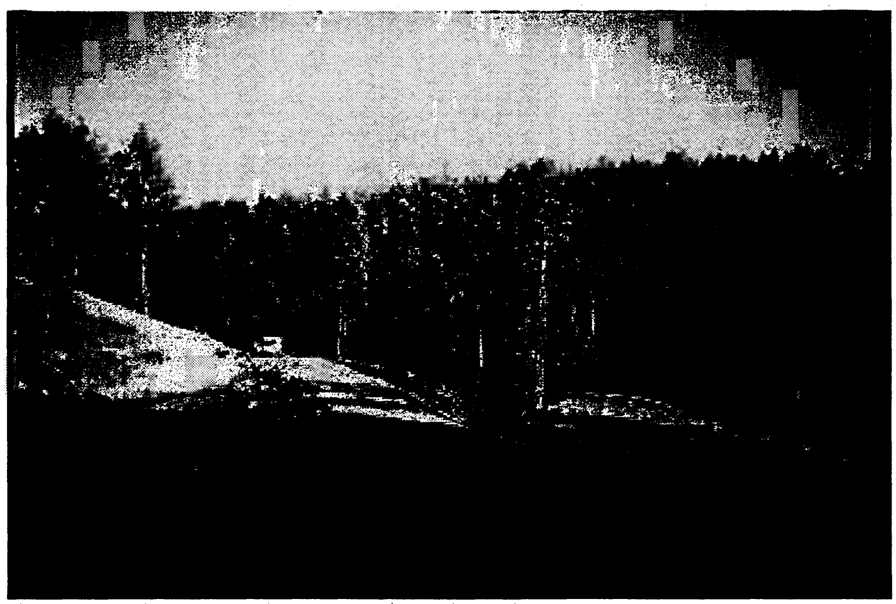


Photo 5 Custer NF-Yonkee Reservoir-Drowned Ponderosa Pines Below Dam

As shown in Photo 5 some species of trees cannot tolerate the elevated phreatic surface resulting from the dam.

An additional impact of trees on many Forest Service dams is their floating debris clogs the spillways, and abrades the upstream face of the dam as illustrated in Photo 6.

Photo 6 Beaverhead NF-Pear Lake Dam-Excess Tree Debris on Dam

Photo 7 Beaverhead NF-Sunrise Lake Dam-No Debris Problem

Often the trees surrounding the reservoir were not removed. They eventually die and drift to the dam where they must be removed. An operational log boom is necessary for dams with extensive available tree debris. In wilderness areas where motorized equipment is prohibited, removal of water logged tree debris is difficult. In addition, it is difficult to burn this debris. It is often burned on the face of the dam because space is severely limited in steep mountain basins. Burning on the dam face may degrade the riprap rock. Adequately clearing the trees to above the high water elevation prevents this problem.

Many of the older dams contain tree debris within the embankment, and the foundations were often not adequately stripped leaving a weak organic layer prone to seepage and settlement. The tree debris in Photo 8 was encountered during the emergency work on Tin Cup dam. The dam was constructed around 1900.

Photo 8 Bitterroot NF-Tin Cup Dam-Debris in Dam

Shrubs and Grasses

Shrubs and grasses can often satisfy the aesthetics requirement without their roots jeopardizing the dam. They also prevent wind and water erosion, inhibits colonization by noxious weeds, and may highlight seepage through the dam as demonstrated in Photos 9 through 11.

Photo 9 Deerlodge NF-Goldberg Reservoir
Vegetation change on downstream face near old slump

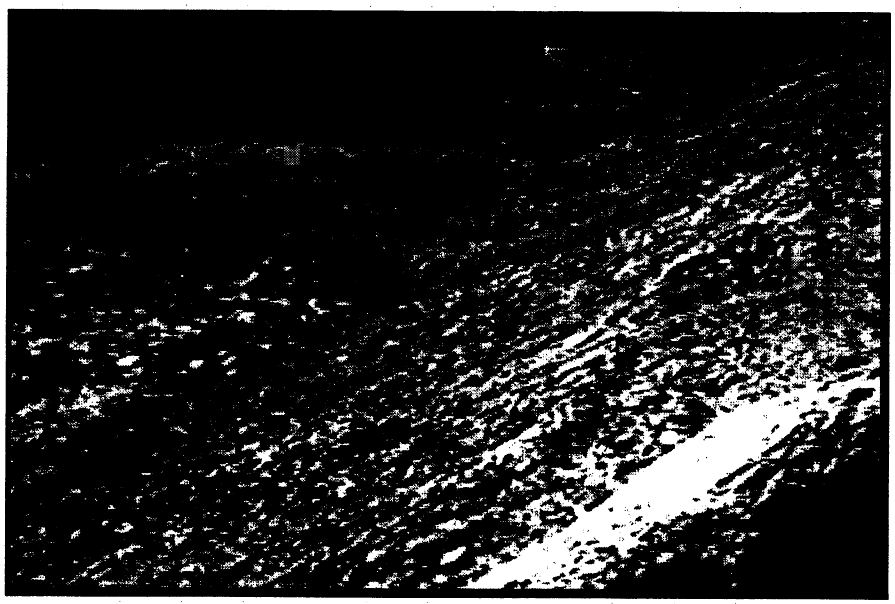


Photo 10 Beaverhead NF-Noble Lake Dam
Seepage at toe of dam but no vegetation on downstream face

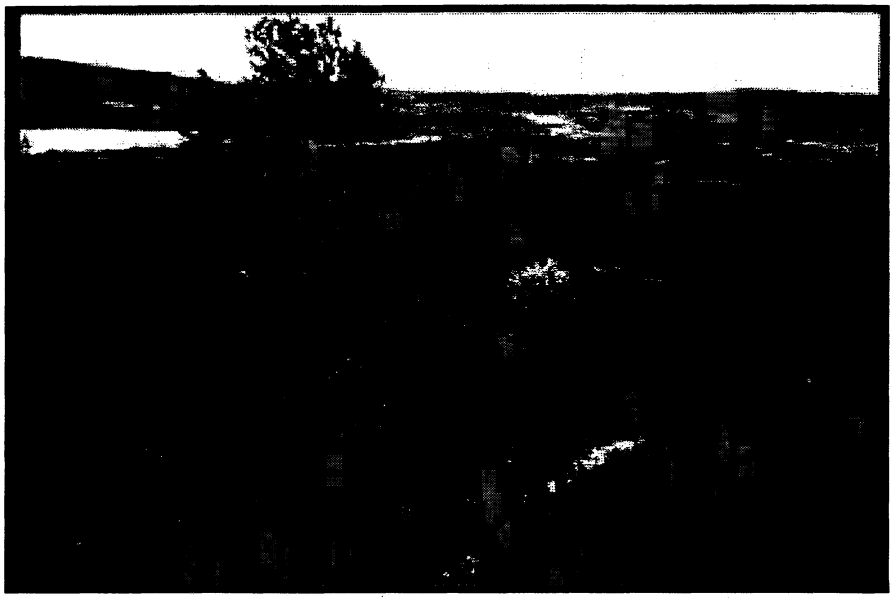


Photo 11 Montana State Prison Dam
Grass and brush on downstream face

The primary problem with shrubs and grasses are that they provide forage for rodents and cattle. The rodents burrow holes in the dam, and the cattle erode the dam embankment as shown in Photo 12.

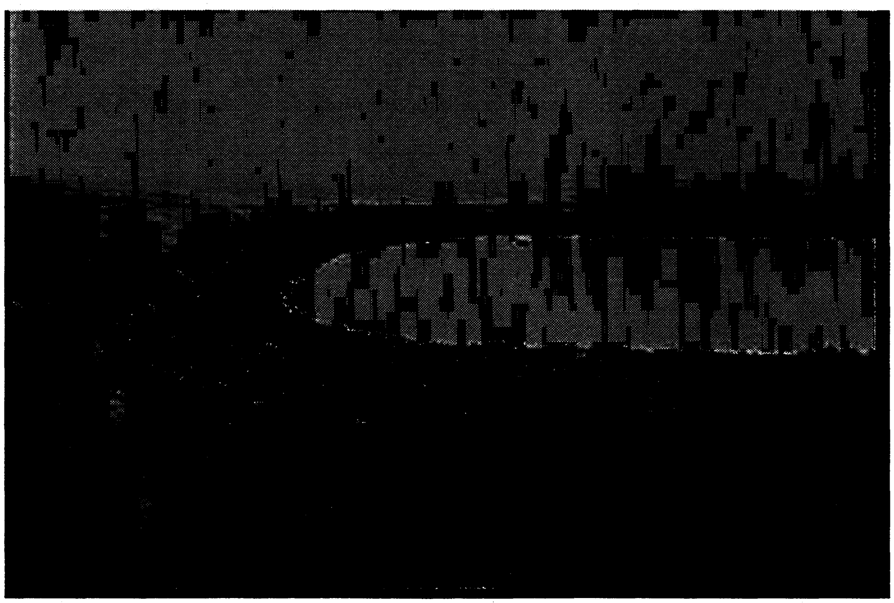


Photo 12 Dakota Prairies National Grasslands
Wind/Wave and Cattle Erosion

Rodent Impacts to Embankment Dams

The major rodent impact to earth dams are burrowing into the embankment and beavers obstructing flow through outlets and spillways. Photos 13 and 14 show evidence of beaver activity. The primary burrowing rodent in the Northern Region of the FS is the Columbian ground squirrel whose borrows are illustrated in photos 15 and 16. Prairie dogs have infested at least one dam in western North Dakota. Photos 17 through 19 show the prairie dogs infestation on the Bock Dam East in western North Dakota. Prior to construction of the dam it was observed that the prairie dogs, which had been living adjacent to the dam site, would probably immediately colonize the dam which they did. Badgers and coyotes enlarge the holes when they chase the burrowing rodents. The ground squirrels like to dig their holes slightly above the phreatic surface where the digging is easier. Below the phreatic surface they get wet and too far above it the ground is more difficult to dig.

Photo 13 Dakota Prairies National Grasslands-Beaver Trails on Dam

Photo 14 Deerlodge NF-Mud Lake Dam-Beaver Dam in Emergency Spillway

Photo 15 Deerlodge NF-Maney Lake Dam-Ground Squirrel Holes

Photo 16 Deerlodge NF-Maney Lake Dam-Ground Squirrel Hole

There are numerous methods for attempting to eradicate the rodents; however, I do not know of any instances where the Forest Service has attempted to do it.

Photo 19 Dakota Prairies NGL-Bock Dam East-Prairie Dog Holes

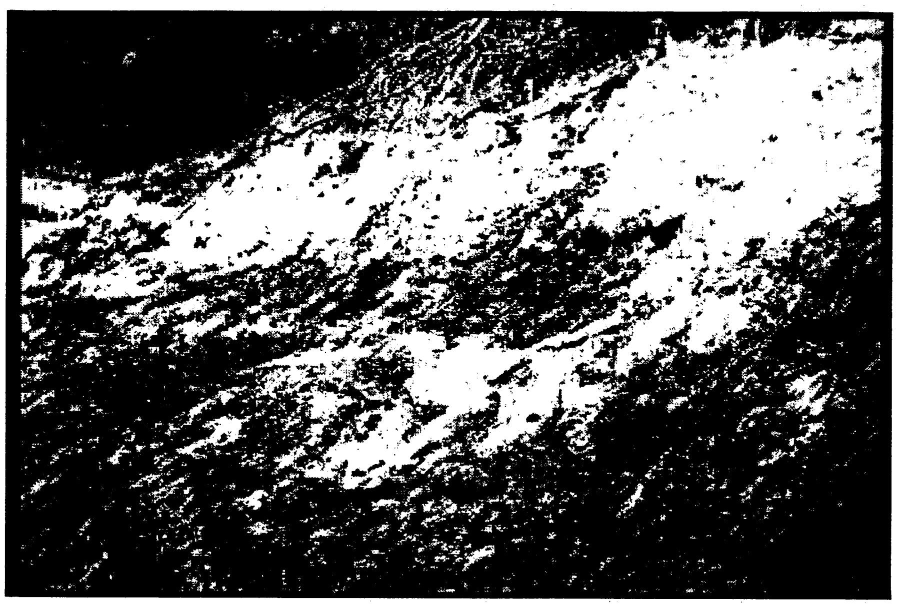


Photo 20 Helena NF-Park Lake Dam-Rodent Castings

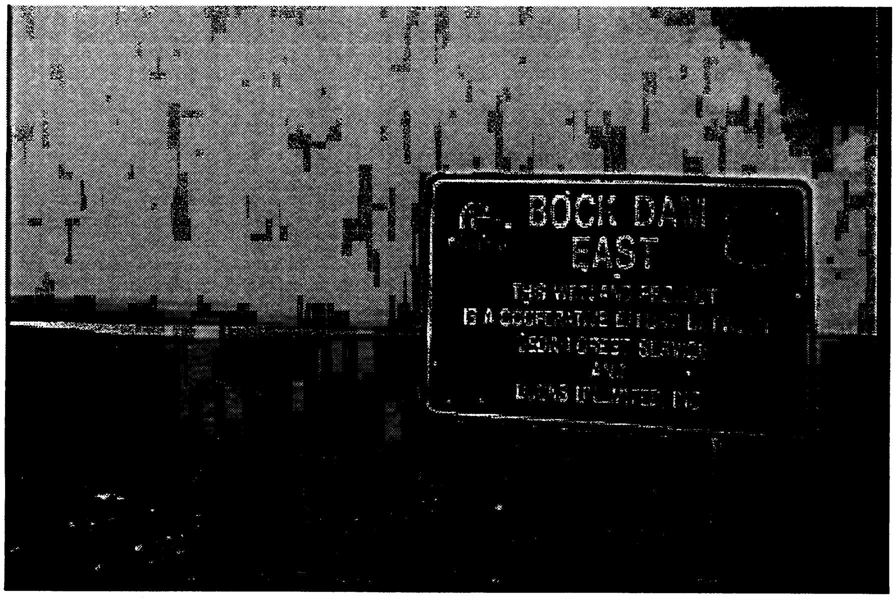


Photo 17 Dakota Prairies National Grasslands-Bock Dam East Prairie Dog Town

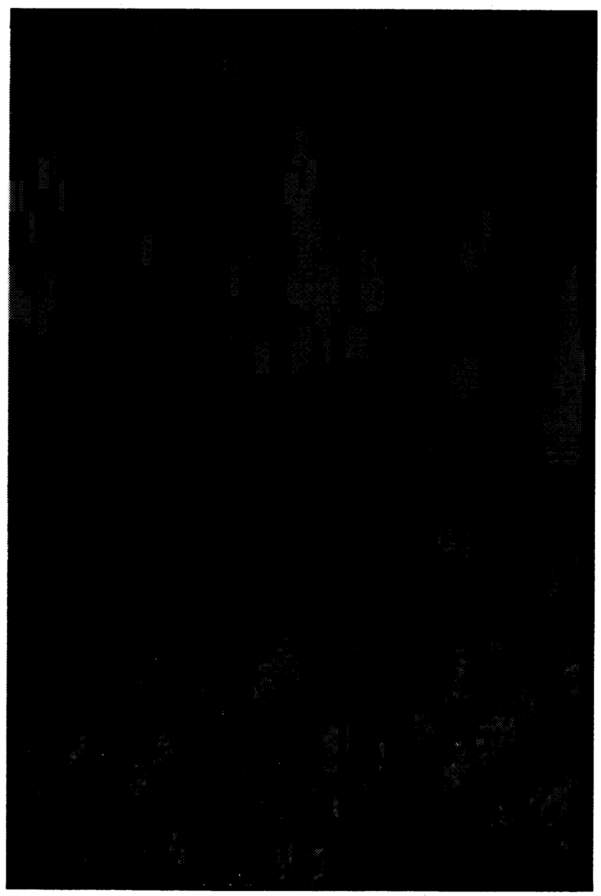


Photo 18 Dakota Prairies NGL-Bock Dam East-Prairie dog holes on downstream face

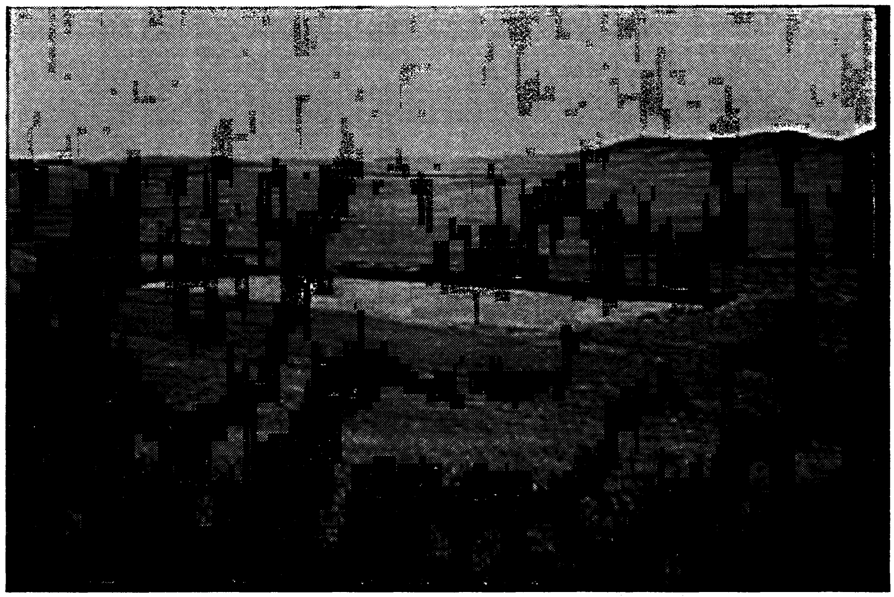


Photo 21 Dakota Prairies NGL Stock Water Dam
Few vegetation problems!

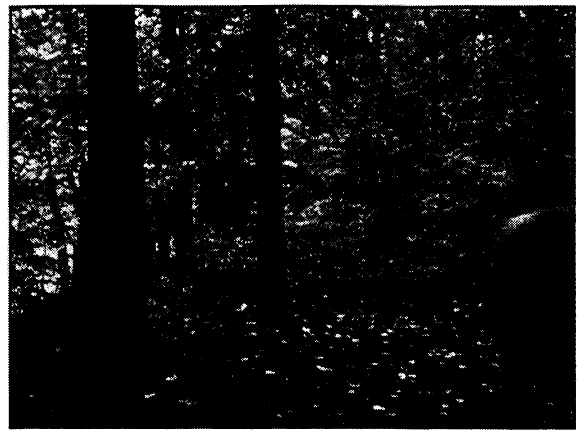
Conclusion

Although vegetation and animal burrows pose a definite risk to earth embankment dams, the author is not aware of any cases in the Forest Service where either vegetation or animal burrows have resulted in the failure of a dam. The primary impacts have been annual maintenance removing log debris accruing from the reservoir, removing spillway and outlet debris introduced by beavers, some vegetation removal, noting of rodent holes during dam inspections, and some concern about the large trees on some dams.

Plant and Animal Penetrations of Earthfill Dams Workshop

Tree Removal East
of
the Mississippi
by

Francis E. Fiegle II, P.E.
GA Safe Dams Program



Plant and Animal Penetrations of Earthfill Dams Workshop

23 State Representatives east of the Mississippi River were surveyed. 18 responded including Puerto Rico. Delaware, Alabama, and Rhode Island were not surveyed due to lack of a viable safe dams program.

Plant and Animal Penetrations of Earthfill Dams Workshop

12 states require removal of trees on regulated dams.

4 states recommend removal but lack statutory authority.

2 states do not require removal.

Plant and Animal Penetrations of Earthfill Dams Workshop

14 states do not change their policies towards tree removal based on hazard classification changes. 4 states do vary their approach towards tree removal based on hazard classification. Most states noted they spend the majority of their time on high and significant hazard dams.

Plant and Animal Penetrations of Earthfill Dams Workshop

12 states give specific guidance/directions to dam owners for tree removal. 6 states give no guidance.

Plant and Animal Penetrations of Earthfill Dams Workshop

2 states require owners to lower their lake level in conjunction with tree removal. 10 states sometimes require the lake level to be lowered on a case by case basis. 6 states do not require owners to lower the lake when removing trees. However, those states often recommend the lake level be lowered.

Plant and Animal Penetrations of Earthfill Dams Workshop

5 states require engineering supervision for tree removal. 13 states sometimes require engineering supervision for large tree removal or unique circumstances.

Plant and Animal Penetrations of Earthfill Dams Workshop

Acceptable methodology includes the following:

Cut trees, leave small stumps - 10 states

Cut trees, grub stumps - 14 states

Stump Grinding - 2 states

Blasting - 1 state

Other - 1 state

NOTE: A state may accept more than one methodology.

Plant and Animal Penetrations of Earthfill Dams Workshop

Additional modifications required with tree removal:

Backfill and compact stump holes with select materials - 9 states

Install internal drainage system - 5 states

Install internal drainage system based on site conditions - 6 states

5 states do not require anything.

Plant and Animal Penetrations of Earthfill Dams Workshop

16 states require the owner to keep trees and saplings off of their dam once it is upgraded. Two states do not.

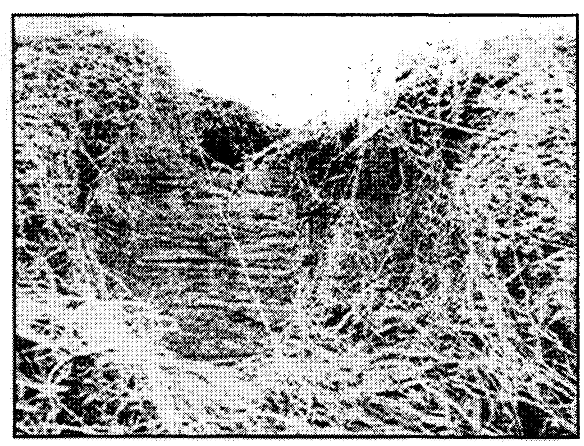
Plant and Animal Penetrations of Earthfill Dams Workshop

7 states allow ornamental plantings including trees on permitted dams. 11 states do not. 1 state tells owners to plant their trees in a pot if they want them on the dam.

Plant and Animal Penetrations of Earthfill Dams Workshop

Vegetation cover for burrowing animals.

Led to dam failure and nearly drowned a five year old girl.

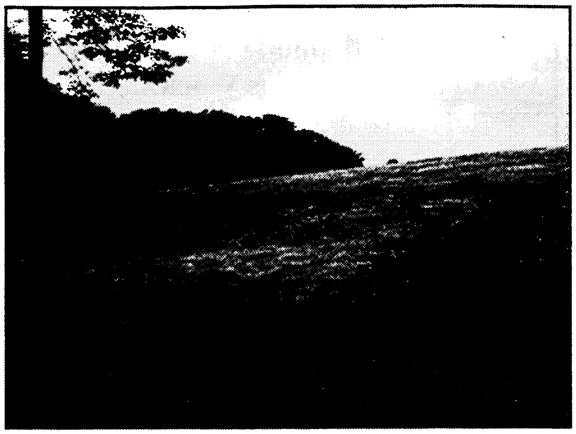


Plant and Animal Penetrations of Earthfill Dams Workshop

Tree Removal
by
Poisoning the Offenders

Plant and Animal Penetrations of Earthfill Dams Workshop

Clearing, Grubbing and Neglect

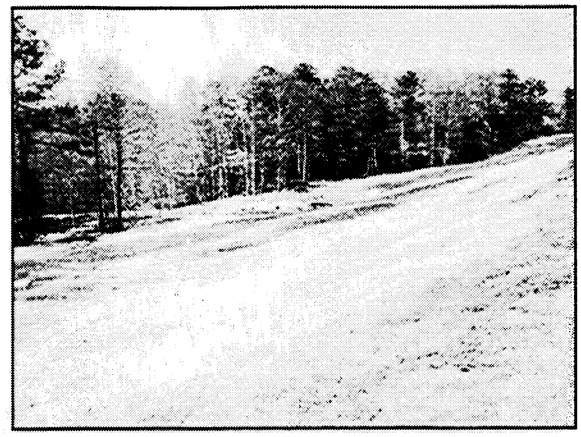


Plant and Animal Penetrations of Earthfill Dams Workshop

Ineffective toe drain installation

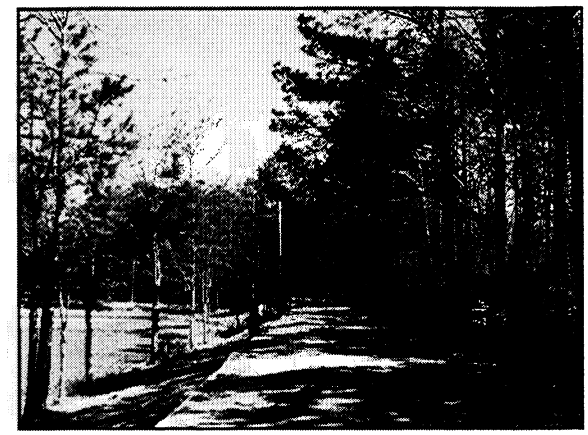
Plant and Animal Penetrations of Earthfill Dams Workshop

How to make a dam owner mad.



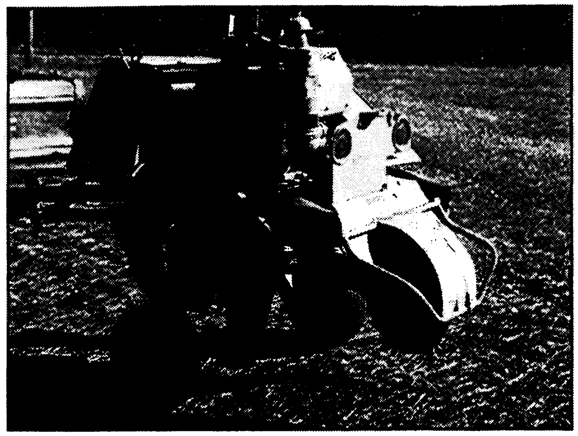
Plant and Animal Penetrations of Earthfill Dams Workshop

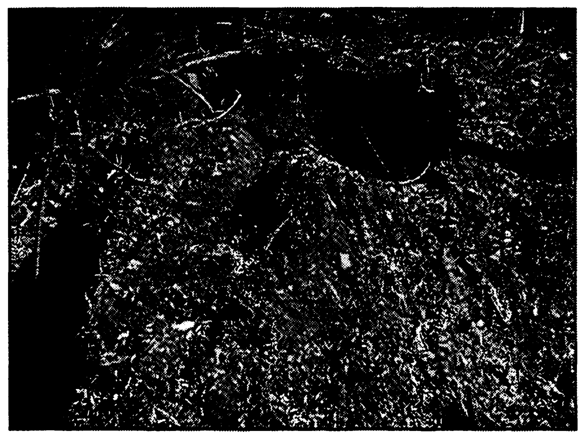
This shows that things do not change over time.



Plant and Animal Penetrations of Earthfill Dams Workshop

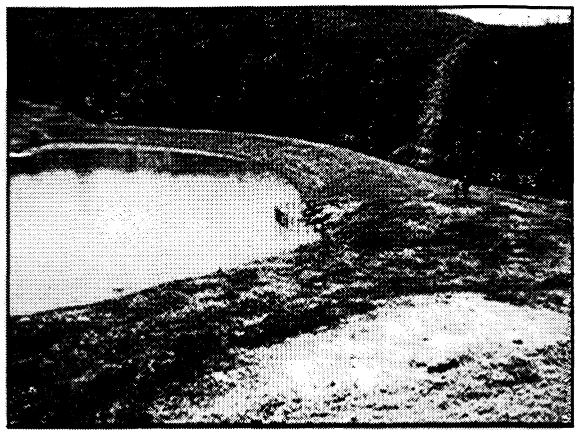
This would be really nice to show everyone. Why stump grinding may not be that great a methodology on dams.





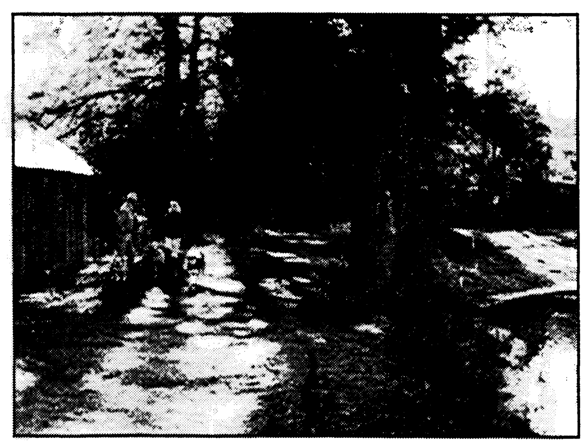
Plant and Animal Penetrations of Earthfill Dams Workshop

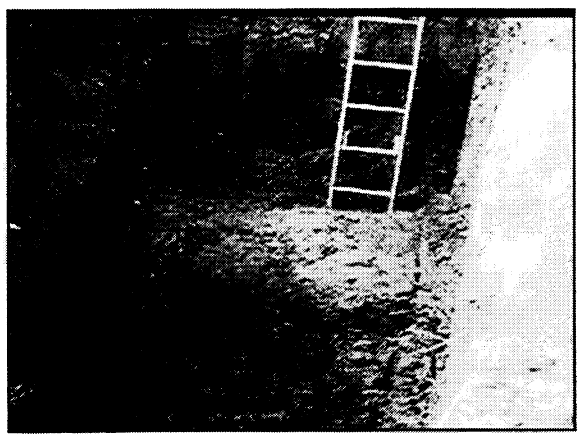
Georgia requires tree removal by the owner under the supervision of a registered engineer experienced with dams. Stumps over 6 inches have to be grubbed out. Practically all owners have to add internal drainage systems with flattening the downstream slope.

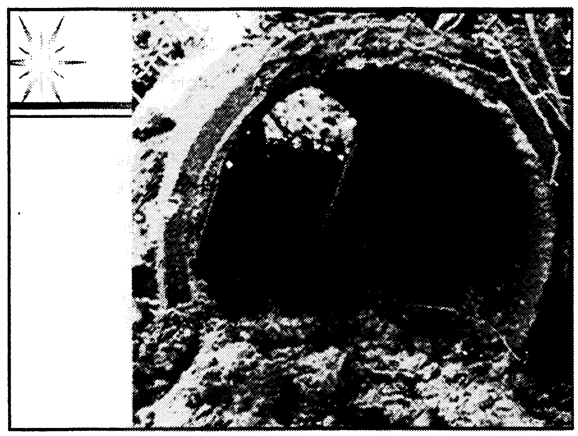


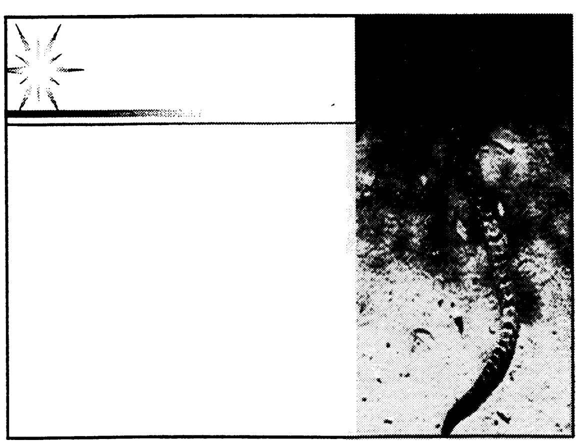
Plant and Animal Penetrations of Earthfill Dams Workshop

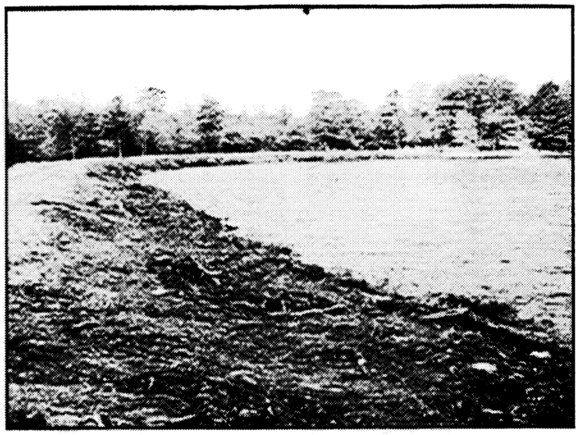
A well maintained dam is easier to inspect and maintenance costs are less over the years.

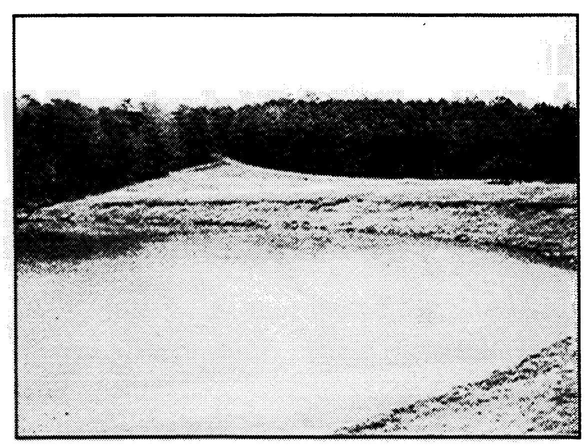












Bureau of Reclamation Guidelines for Removal of Trees and Other Vegetative Growth From Earth Dams, Dikes, and Conveyance Features

In the absence of a policy regarding vegetation removal for dams and other water resource structures, the guidelines for removal of trees and other vegetative growth from earth dams, dikes, and Conveyance Features were developed and published for use by water districts and Reclamation personnel responsible for operation and maintenance. The guidelines were initially issued in 1987 and were revised in 1989 to include environmental compliance criteria. The guidelines were subsequently published in Reclamation's quarterly Water Operation and Maintenance Bulletin, December 1989, to provide greater distribution to field personnel.

The primary reasons for establishing the guidelines were as follows:

1. To allow proper surveillance and inspection of the structures and adjacent areas for seepage, cracking, sinkholes, settlement, deflection, and other signs of distress.

2. To allow adequate access for normal and emergency operation and maintenance activities.

3. To prevent damage to the structures due to root growth, such as shortened seepage paths through embankments; voids in embankments from decayed roots or toppled trees; expansion of cracks or joints of concrete walls, canal lining, or pipes; and plugging of perforated or open-jointed drainage pipes.

4. To discourage animal/rodent activity (by eliminating their food source and habitat), thereby preventing voids within embankments and possible shortened seepage paths.

5. To allow adequate flow-carrying capability of water conveyance channels (e.g., spillway inlet and outlet channels; open canals, laterals, and drains).

Clearance zones (areas of control) should be maintained adjacent to the water storage or delivery structure to ensure there is no damage from deep-rooted vegetation to structural elements such as abutment or toe drains, observation wells or piezometers. Shallow-rooted vegetation should be encouraged in areas where erosion protection or slope stabilization is needed. Trees should be removed in their early stages of growth to be most cost effective. Mature trees could eventually provide habitat for endangered or protected species. Larger root masses associated with

For dams and dikes, a clearance zone of 25 feet beyond each contact between the embankment and the abutments (groins) and foundation (toe) should be established free of trees and other deep-rooted vegetation. Large tree growth or stumps from tree removal need to have the root systems grubbed out and the embankment replaced and compacted to prevent the development of piping action or erosion. Any sizable voids resulting from animal/rodent burrowing activity should be filled and compacted. Seeding may be needed for protection of surface erosion.

Large trees on adjacent abutments that could have the potential to damage structures would be evaluated for removal on a case-by-case basis. Factors such as right-of-way, original construction clearing limits, landscaping, and erosion susceptibility of the abutments would influence the necessity for removal.

Spillway inlet and outlet channels, outlet works discharge channels, and other open conveyances should be maintained free of growth that could significantly impede water flow or reduce design capacity. Concrete structures associated with such facilities should be maintained free of all trees and other growth that might be detrimental to the design functions of the structure, would restrict proper surveillance, or would prevent adequate access for operation and maintenance.

Buried pipe systems should be maintained with a clearance zone of 15 feet from each outside edge of the pipe to allow access to repair the pipe and prevent root encroachment.

PLANTS AND ANIMALS PENETRATIONS OF EARTHFILLED DAMS WORKSHOP

University of Tennessee

November 30-December 3, 1999

David Sisneros

Bureau of Reclamation

Abstract
Control Methods for Woody Vegetation

Deciduous saltcedar (genus *Tamarix*), a phreatophyte, was introduced as an ornamental into the United States from Eurasia during the late 18th century and has invaded a significant number of riparian habitats in the Western United States. Phreatophytes are defined as "plants that habitually grow where they can send their roots down to the water table, or the capillary fringe immediately overlying the water table, and are able to obtain a perennial and secure supply of water". While a number of species have been introduced, the saltcedar species which has invaded the Southwest is *Tamarix ramosissima*.

Saltcedar is a very hardy plant which is able to outcompete other plants, resulting in medium to dense monoculture stands. Once established, saltcedar is extremely difficult to control by chemical or mechanical methods. The plant is tolerant to saline soils, shallow aquifers, and poor water quality. It grows to heights of 10 to 12 feet under favorable conditions in one season and its root system can grow to depths of 25 feet or more. The plant exudes a salty secretion which, when accumulated on the soil, suppresses other seeds from germinating. The plant produces many blooms from early spring to late fall, and seeds which develop from mature plants are quite small (0.0001 gram) and numerous, ranging up to 500,000 from a single plant in one season. The seeds readily germinate in wet conditions. Seedlings will survive only where the soils are moist for several weeks in the summer period. Areas which have been flooded or are continuously moist along the edge of a reservoir or stream are likely to be invaded by tamarisk.

Saltcedar can cause flooding due to the partial barrier the stands form. This diverts water away from the normal waterway, resulting in inundation of other areas. Another major problem associated with saltcedar is the amount of water evapotranspired by the plant. Some authors indicate that water used by phreatophytes and hydrophytes probably represents the largest source of reclaimable water in the Western United States. An investigator in 1942 indicated that the average annual use of groundwater by saltcedar in the Pecos River Valley, New Mexico, was estimated, on the basis of plants grown in tanks, to be 5 0 acre-feet per acre. At two desert springs in California, after tamarisk was removed in 1968 via burning, mechanical removal, and herbicides, the waterflow was restored, resulting in a shallow pond spreading over an acre. The marsh vegetation and mesquite grove recovered rapidly.

Fish and Wildife refuge biologist at Bosque Del Apache in New Mexico indicate that the booming saltcedar population in the 10,000 acres of bottomland is surrounded by another 40,000 acres of refuge and is choking out the native tree species. Saltcedar sheds leaves, creating a thick duff which often catches fire, killing the cottonwoods. Saltcedar is actually very fire tolerant. As the brush grows dense areas of saltcedar can influence the numbers of wildlife species that originally populated the area. Officials at the refuge want to control saltcedar by replacing it with cottonwood and native black willow to restore natural bosque habitat.

Various EPA-registered herbicides have been or are currently being evaluated for their effectiveness on saltcedar by Federal and State agencies, local government, private organizations, universities, and conservancy districts. Some of these herbicides are specifically labeled for saltcedar or could be used for saltcedar control according to label requirements. In addition, other herbicides could potentially be used for saltcedar control, but will not be discussed because of leaching and degradation characteristics. Two main objectives of various agencies are removal of the nonnative tamarisk plant prior to the rehabilitation of lands back to native vegetation, and restoration of riparian areas.

The following methods used for controlling saltcedar in this presentation include : (1) aerial application by fixed-wing aircraft and helicopter, (2) cut-stump, (3) foliar application (high, moderate, and low volume) and potentially (4) biocontrol. Data from cost histories developed in 1994 indicate that treating large acreage of saltcedar by aerial application would be the most cost effective, especially by fixed-wing aircraft. Variables such as labor, specialized equipment, water tanks, and distance to application site will raise the cost of aerial application under contract for fixed-wing aircraft and helicopter. In addition, environmental issues which were not covered in this report could significantly raise the overall cost of these control methods. Generally, the larger the acreage to be sprayed the lower the per-acre cost.

In the fall of 1994, 2 years posttreatment, long-term efficacy was evident on the Pecos River Riparian Restoration project sites sprayed in 1992. During the fall of 1993 the Pecos River Riparian Restoration

Project made additional aerial applications using fixed-wing aircraft to further refine the lower limits of the tank mixtures of Arsenal + Rodeo (Roundup), which were used in 1992. These lower limits, if efficacious, could be more cost effective than prices quoted in this report.

The tank mixture of Arsenal and Rodeo (Roundup) acts on different plant systems and, therefore, together they inhibit the synthesis of six amino acids simultaneously. The tank mixture offers the best characteristics of each product when controlling saltcedar. The best benefit is that revegetation can take place more quickly because of the reduced application rate of Arsenal

Near Artesia, New Mexico at Spring Lakes aerial application using only Arsenal have been successful in controlling saltcedar. No long-term soil and water residue testing was done at the Spring Lakes site, which could have benefited this study and other future studies. Reinvasion may occur, especially if the area is not maintained. Observations made at Spring Lakes in April 29, 1993, indicate that vegetation (saltgrass, pepperweed) other than saltcedar is establishing at this site. The one aerial failure, made at the Bosque Del Apache Wildlife Refuge in New Mexico, was caused by a lack of long-term information on translocation properties of Arsenal Treated saltcedar were burned approximately one year following treatment resulting in resprouting. Sales specialists from American Cyanamid, indicate that treated saltcedar should not be disturbed for a period of 18 months to allow complete translocation of herbicide prior to being burned.

The cut-stump methods used by a number of agencies/groups in areas of critical habitat is very labor intensive and costly. This application of herbicide to the cut surface reduces any contamination to nontargeted plants, soil, and water, if done properly. One disadvantage is that saltcedar can have hundreds of stems arising from one root crown, and if an applicator does not treat all of these stems, there is the potential for that plant to reestablish. Periodic observations and follow-up treatment would be required for resprouts.

The cut-stump method is practical to use, especially in areas where topography is irregular and where there is limited vegetation, such as Death Valley National Monument, California, or Ash Springs, Nevada. This method would be practical to use along the banks of waterways because the spray is directed only on the cut stems if label procedures are followed carefully and pooling of sprays is avoided. This method is very advantageous to use, especially when saltcedar coverage is less than 50 percent. Cut stems are commonly left in the area to decay and provide wildlife habitat. In some cases, at a later date after stacking and drying, the cut material could be burned. Labor costs would increase significantly if biomass were stacked or transported from the area. The roots of cut stems will also tend to hold soil in place, thus preventing soil from washing away for a period of time.

Arsenal, Chopper, Garlon 3A, Garlon 4, and Pathfinder herbicides have been used most commonly for the cut-stump method with good to excellent results. Chopper and Pathfinder are available in ready-to-use formulations, and are economical and easy to use with conventional handheld squirt bottles, pump-up sprayers, or backpack sprayers.

Various foliar applications (high and moderate volume) by ground application equipment have resulted in good to excellent control. This method is particularly effective when resprouts 6 to 8 feet tall have formed following a fire. The reduced canopy allows an applicator with various types of equipment to move in and out of the treatment area and apply herbicides to foliage or to the basal part of resprouts. Labor costs for the burn/spray method involve preparation of the site prior to a fire, such as stacking of brush to ignite the fire, labor cost during the fire, and cost of herbicide spraying on resprouts. Total cost involving the burn/spray method could potentially be more than aerial cost, but less than foliar and cut-stump cost. Under some circumstances, large tracts of standing dead saltcedar could pose an unacceptably large fire risk. At a number of sites treated by foliar application, after 2 years posttreatment spraying, portions of larger dead saltcedar trees have fallen to the ground. Plans are to let this material decay and provide wildlife habitat.

Each of these control methods could be used in a management scheme in combination or singly if herbicide use was the only management option available.

ALTERNATIVES FOR REMOVING TREES FROM DAMS

Presented by B. Dan Marks, Ph.D.,P.E., S &ME, Inc.

One of the more important documents associated with state-of-practice issues associated with plant penetrations of earthfilled dams is a publication by the U. S. Department of Agriculture, Natural Resources Conservation Service (formerly the Soil Conservation Service). This publication is TECHNICAL NOTE Series No. 705; entitled "Operation and Maintenance Alternatives for Removing Trees from Dams" dated April 1, 1981. The South Technical Service Center of the Natural Resources Conservation Service, U. S. Department of Agriculture in Fort Worth, Texas, published this document.

The Steering Committee of the Workshop on Plant and Animal Penetrations of Earthfilled Dams felt strongly that this publication must be included in the Proceedings of the workshop. As such, the Chairman of the Steering Committee agreed to present and overview of the publication at the Workshop so that this document could be included in the Proceedings.

On behalf of the Steering Committee, the Chairman would like to acknowledge Mr. Danny McCook, Chief of the Geotechnical Laboratory of the U. S. Department of Agriculture, Natural Resources Conservation Service in Fort Worth, Texas for providing this document for presentation. The Chairman only hopes that he did a worthy job of presentation of this valuable publication.

One other document that was submitted by Mr. Danny McCook that was not presented at the Workshop is TECHNICAL NOTES ENGINEERING – OK-8 (Rev) entitled "Control of Trees and Brush on Dams", dated February 8, 1990. The Oklahoma State Office of the Natural Resources Conservation Service, U. S. Department of Agriculture in Stillwater, Oklahoma, published this document. This publication primarily addresses the use of herbicides for the control of tree growth and heavy underbrush on earthfilled dams. The harmful affects of plant penetrations of earthfilled dams are also addressed in this publication.

SOUTH
TECHNICAL
SERVICE
CENTER

TECHNICAL NOTE

Subject: **ENGINEERING**

Series No.: **705**

Reference: **Operations and Maintenance Alternatives for Removing Trees from Dams**

Date: **April 1, 1981**

4-36886 5-78
USDA—SCS—FORT WORTH TEXAS 1981

SOIL CONSERVATION SERVICE
U. S. DEPARTMENT OF AGRICULTURE

STSC TECHNICAL NOTE 705

Re: Operations and Maintenance Alternatives for Removing Trees From Dams

TABLE OF CONTENTS

I. General Operations and Maintenance Considerations

A. Purpose

The purpose of this technical note is to outline and discuss the alternatives for maintenance of dam embankments containing trees and heavy brush. This Technical Note contains general recommendations and provides guidance on evaluating the interrelationships between tree types, tree locations, soil types, and depth of normal pool. It is recognized that the responsible engineer may weigh additional factors in arriving at a final plan for tree removal or treatment. In some cases the final plan may require total removal of all tree roots.

The guidelines presented here assume that the dam in question has been properly designed and constructed prior to tree invasion. It is anticipated that this document will serve as a working tool and help promote consistency (1) when evaluating several damsites simultaneously, (2) when two or more individuals are involved in maintenance inspections and recommendations, and (3) over extended periods of time and changes in personnel.

B. Problem Discussion

SCS O&M Handbooks and project agreements have always required that dams and emergency spillways be kept free of trees and brush by regular mowing or treatment. It is also recognized that maintenance has not always been performed when needed. If yearly O&M inspections indicate the existence of trees and brush, our O&M recommendations require that trees and brush be removed from the dam embankments immediately.

1. Roots

a. Piping - Where trees have been allowed to grow to some size, cutting the trees may create a problem. The decay and deterioration of larger roots after the tree has been cut and killed can eventually result in open channels in the fill, creating possible seepage paths. This condition could be extremely serious in soils with a high potential for piping. The greatest concern usually involves trees on the downstream side of the earthfill dam where seepage exits occur.

b. Drain infiltration - Tree roots commonly plug drain lines used for subsurface land drainage, and they can and do plug drain outlets for dams.

2. Scour

   Scour damage can be induced by trees located in the exit of emergency spillways and on the slopes of dams. The scour damage occurs during overtopping of the dam or when the emergency spillway flows. The damage is caused by water turbulence around an obstruction to the flow. Trees providing obstructions along the top of the dam, on the downstream slopes or in the exit channel of the earth spillway can induce serious damage by progressive scour eorsion. This kind of failure has been observed and documented in numerous cases.

   During high water levels scour damages can occur on the upstream slope of the dam. The scour damage is caused when waves are wind driven up the slope and the sheet of water recedes at a faster rate causing scour below the tree obstruction.

3. Vegetation

   Trees reduce the available moisture in the soil due to interception and transpiration. They also reduce light available to desirable grass and legume cover and compete for space. It is clear that the establishment and maintenance of good grass and legume vegetative covers require the control of trees and other woody growth on dams.

C. Considerations for Tree Removal

1. The best alternative is to prevent the growth of trees by regular mowing of the dam. If a low maintenance cover is established, then cutting new trees every 2-3 years would be necessary.

2. Once trees have been allowed to establish, the recommendation is to remove them in all cases. Remaining stumps should be chemically treated to prevent sprouting.

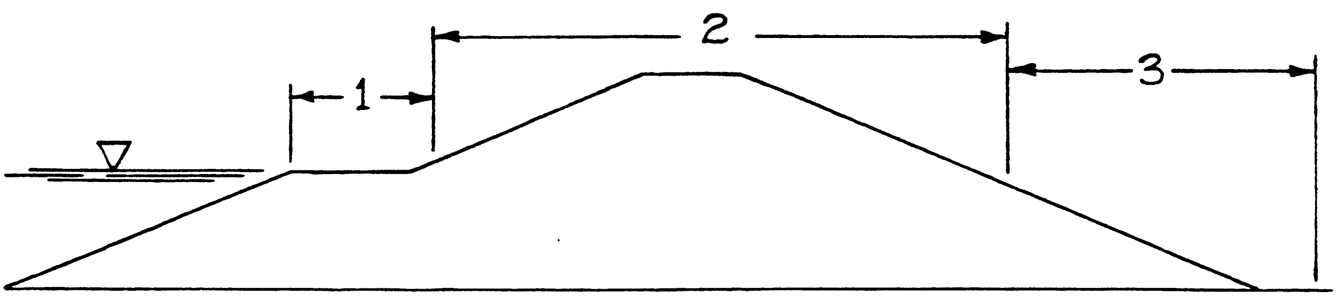
3. The removal of stumps and root mass will be required where the potential for problems from seepage, slope stability or drain clogging exists.

4. Where scouring potential exists from flowing water, the remaining stumps should be cut at least 6" below ground and filled over with compacted earth.

II. Factors Affecting Recommendations for Stump and Root Mass Removal

A. Tree Location Zones

These zones are general areas of an earthfill dam that can have significant differences with regard to alternatives for tree removal. Zone limits are variable with each individual structure. Recommendations in Table A are keyed to these zones.



1. Waterline - Potential problems include slope damage from tree blowdown, visual masking of the structure that may hinder clear observation of a potential problem, tree root interception of spillway conduits, treetop interference with hydraulic performance of principal spillways and wave action scour due to obstructions.

2. Frontslope, Crown and Backslope - Potential problems include seepage in root zone through the narrow top section at high water periods, damage from uprooting during blowdown, visual masking of covered areas, scour potential during overtopping due to obstructions, and seepage paths along roots that intercept the phreatic line from the backslope.

3. Toe of Dam - Potential problems include the development of a seepage path along roots that intercept drainage outlets or phreatic surfaces, root clogging of drainage systems, visual masking of the toe area where seepage is most likely, loss of the protective blanket if trees are uprooted by a storm event and scour from obstructions during overtopping. (This zone needs to extend at least 20 feet beyond the toe of slope.)

B. Types of Impoundments and Embankments

1. Impoundment

As the depth of permanently impounded water becomes a greater percent of dam height, the potential problems associated with existing trees may increase. This may require more careful and extensive removal and repair. Although this factor is not recognized in Table A, it must be a consideration in determining the extent of the problem and potential hazard in each case.

2. Embankment

The nature of the materials and their distribution in the embankment are the factors considered.

a. Dispersed clay shells or dispersed materials in dams with thin protective shell.

b. Embankment with chimney drain or pervious downstream shell.

c. Homogeneous or zoned embankment with outside shell soils of low PI, with moderate to high piping potential.

d. Homogeneous or zoned embankment with soils of moderate-high PI, low permeability, low piping potential.

C. Types, Sizes, and Distribution of Trees

1. Types of Trees (Root Systems)

A distinction is made between trees that have a deep taproot as opposed to the more common spreading root system. Special notes are used in the tables to address the root growth of water-loving trees such as willow.

a. Long taproot - Generally, pines and other coniferous trees.

b. Spreading root systems - Deciduous trees such as willows, cottonwood, sycamore, sweetgum, red maple, silver maple, water oak, willow oak, pin oak, Nuttall's oak, Southern red oak, elm, yellow poplar, hickory, etc.

2. Sizes of Trees

Eight inches diameter at breast height is used as the tree size where root system may start to be significant.

a. DBH $< 8"$ = Average diameter at breast height is less than 8".

b. DBH $\geq 8"$ = Average diameter at breast height is 8" or greater.

3. Distribution of Trees

Tree distribution will determine whether the root system can be considered isolated and independent or continuous and joined with other systems over a significant area.

a. Isolated or scattered trees = light cover. Light cover is defined as three trees per 400 square feet with a DBH $< 8"$ or two trees per 400 square feet with a DBH $\geq 8"$ or more.

b. Clumps or continuous tree growth = heavy cover. Heavy cover is defined as more than three trees per 400 square feet with a DBH $< 8"$ or more than two trees per 400 square feet with a DBH $\geq 8"$ or more.

III. Criteria and Recommendations for Stump and Root Mass Removal

A. Definition of Treatment Methods

Consideration of the factors previously listed was used to develop the appropriate treatment methods for stump and root mass removal on embankments. General recommendations are summarized in Table A.

Definitions of each of the treatment methods listed in this table is as follows:

1. Cut and Kill Stump

Trees should be cut approximately six inches below the ground surface to eliminate the hazard of any surface obstruction.

An approved silvicide should be applied to the stump surface, as recommended by the manufacturer, prior to backfilling and reseeding.

2. Cut and Grub Stumps and Root Mass to Specified Depth Uniformly

In the area specified, a uniform cut will be made with appropriate equipment. The underlying root mass that remains will be disturbed as little as possible by using sharp cutting tools. Exposed tap roots will be treated with an appropriate silvicide to prevent reemergence.

3. Cut and Grub Stumps and Root Mass to Depth and Diameter of Removal Dictated by Type and Size of Tree (See Tables)

   For taprooted trees, the removal of this mass should create a roughly parabolic shaped hole with a depth and diameter at the surface as specified in the tables. For spreading root trees, the depth of removal shown in the tables should be uniform over the diameter area specified in the tables.

4. Complete Removal of Stump and Root System

   It is anticipated that this treatment will be unusual and must be judged on an individual basis. Generally this would be an impractical solution and may, in some cases, be detrimental to the structure. Some of the complications are as follows: (1) area of disturbance, (2) depth and slopes of excavation, (3) procedures for effective backfilling of the excavation, (4) timing and duration of the removal operation.

5. Partial Removal of Stumps and Root Systems and the Addition of a Filter (See backfill method 3, page 6.)

   This treatment may be the most positive solution when there is concern for piping but treatment number 4 (complete removal) is not feasible.

B. Types of Backfill and Methods of Backfilling After Removal of Stumps and Root Mass

1. Selection of Soil Materials for Backfill

   The selection of soil for the backfilling of treated areas should be based primarily on the permeability characteristics of the backfill with respect to the surrounding embankment.

   Generally backfill materials in Zones 1 and 2 of the embankment should be of similar permeability to the adjacent embankment. In embankments of known dispersive clays care must be taken to find nondispersed clay borrow material or treat dispersed borrow material with hydrated lime.

   For backfill in Zones 3 and 4, if the materials in the embankment are permeable shell type materials, it is important that borrow material be at least as permeable and preferably more permeable than the adjacent fill material. At the same time, in critical locations, the borrow soils should satisfy filter design criteria to prevent any possible piping.

2. Method of Placement and Backfill

Where stump and root mass removal is to a uniform depth over an accessible area, backfill should be placed in lifts no thicker than 6" and compacted at about optimum moisture by at least two passes of the tracks of the earth moving equipment.

Where stump and root mass removal is in confined areas, backfill should be compacted with hand directed power tampers. Backfill should be placed at a minimum of 90 percent maximum dry density (ASTM D-698A) and approximately optimum moisture. Lift thickness should be 4-6".

3. Special Treatment

Where extensive root mass removal is necessary and seepage is either evident or probable, the use of a filter may be appropriate. Filter material gradations must be selected to prevent piping or movement of embankment materials but allow seepage and safe exit of water. The filter may be added in conjunction with partial removal of extensive root systems.

C. General Recommendations for Tree Removal

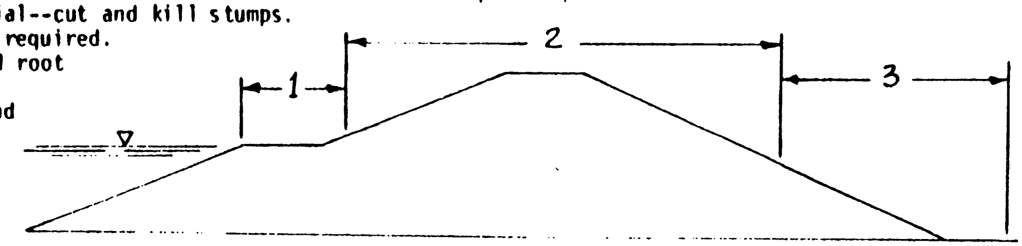
Table A on page 8 contains general recommendations for tree removal.

TABLE A

GENERAL RECOMMENDATIONS FOR TREE REMOVAL 1/

TREE LOCATION ZONE	TREE TYPE A (TAP ROOT)				TREE TYPE B (SPREADING ROOTS)			
	DBH < 8"		DBH ≥ 8"		DBH < 8"		DBH ≥ 8"	
	LIGHT COVER	HEAVY COVER	LIGHT COVER	HEAVY COVER	LIGHT COVER	HEAVY COVER	LIGHT COVER	HEAVY COVER
1 1/	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.	Cut and kill stumps.
2 4/	Cut and kill stumps. 2/	Cut and grub stumps and root mass to 18" depth uniformly.	Cut and grub stumps and root mass to 24" depth in 1/2 crown width diameter area.	Cut and grub stumps and root mass to 24" depth uniformly.	Cut and kill stumps 2/	Cut and grub stumps and root mass to 12" depth uniformly.	Cut and grub stumps and root mass to 18" depth in crown width diameter area.	Cut and grub stump and root mass to 18" depth uniformly.
3 7/	Cut and kill stumps.	Cut and grub stumps and root mass to 18" depth uniformly.	Cut and grub stumps and root mass to 24" depth in 1/2 crown width diameter area. 3/	Cut and grub stumps and root mass uniformly to 18" depth.	Cut and kill stumps. 5/	Cut and grub stumps and root mass to 12" depth uniformly. 5/	Cut and grub stumps and root mass to 18" depth in crown width diameter area. 3/ 5/	Cut and grub stumps and root mass uniformly to 12" depth. 6/

1/ Tree growth smaller than 2" DBH will be removed by spraying, injection or cutting and stump killing. Trees and shrubs planted for shoreline protection in Zone 1 shall be maintained at heights · 4 feet.
2/ In embankment type (a) dispersed soil--cut stumps 12 inches below surface and backfill with compacted soil.
3/ In embankment type (d) earthfill with low piping potential--cut and kill stumps.
4/ In riprapped or heavy rockfill sections grubbing is not required.
5/ For water-loving trees such as willows, remove stump and root mass in twice the crown width area.
6/ For water-loving trees such as willows, remove stumps and root mass to 18" depth uniformly.
7/ Individual large trees in this zone may need the special treatment as described in Section 3.



Plant and Animal Management Practices on Flood Control District of Maricopa County Dams

Tom Renckly and Gary Drake
Flood Control District of Maricopa County, Arizona

November 1999

Background

Since its inception in 1959, the Flood Control District of Maricopa County has participated as the local sponsor for 21 federally sponsored flood control dams. The USDA Natural Resources Conservation Service (NRCS- formerly SCS) was the federal sponsor for 16 of these structures. The U.S. Army Corps of Engineers (Corps) was the federal sponsor for 5 of these dams.

The Flood Control District of Maricopa County (District) currently owns, operates and maintains all of the 21 federally sponsored dams as well as one flood control dam designed and constructed by the District. Considerable District resources are utilized on an ongoing basis in the management and control of plant and animal penetrations on these dams.

Vegetation Management on District Dams

Vegetation Seeding for Erosion Control

All of the District's flood control dams are earthen dams. Erosion on these structures varies from minimal to severe. The primary purpose of the vegetation on the structures is to minimize erosion on the slopes of the embankment. The vegetation also serves as natural landscaping for the dams.

Seeding for the dams is conducted on an as needed basis. Typically the need for seeding arises when the amount of ground cover has been depleted to the point where an unacceptable level of erosion has occurred or appears imminent. This ground cover depletion is caused by various actions including: erosion repairs where the ground cover has been removed; off road vehicles driving on the slopes, fire, cattle, vandalism and natural causes. Desert vegetation tends to die off in 5-6 year cycles.

In 1990, the District began a re-vegetation program for the District's existing flood control dams. These early projects consisted of hand seeding the embankment slopes. This was followed up by shooting a 3-inch ground cover of straw over the seed and then coating the top of it with a S1 tackifier oil. This method proved to be very labor intensive and therefore expensive.

The process currently used for re-vegetation is much more streamlined than past methods and is cost effective. It involves 3 pieces of equipment (Dump Truck, Water Truck, and Hydromulch machine) and a 3-man crew. The seed, water, tackifier and a wood fiber or paper mulch are all mixed together in the Hydromulch machine. This mixture is then shot out onto the slopes. In areas of the slopes that are barren the mixture is applied directly to the structure. The seeds are encapsulated in the mulch and tackifier until enough moisture is present to begin the germination process. Typically it takes 2 to 3 years before signification re-vegetation results are achieved. The likely reasons re-vegetation takes so long is due to the low rainfall amount received in the desert environment and to the density of the compacted dam embankment.

Most erosion repairs are made with the use of a bulldozer, which eliminates all of the vegetation on the slope area being repaired. Initially it was believed that the dozer tracks would serve to trap some of the runoff water and thus give the seed mulch a better chance to germinate. Seeding was therefore applied over the tracks left by the dozer. However, experience has shown there is a better way.

The lesson learned involved a re-vegetation effort in which a dozer was sent in to track the upstream side of one of the structures, which had extensive rills down its face. The dozer tracked over everything, as there was little growth left. The slopes were re-seeded over the tracks left by the dozer. El Nino then brought a couple of good rains. New growth did occur, but not from the new seeding. Two years prior the same section of the dam had been repaired and re-seeded by the same method. The new vegetative growth was from the seed mixture from two years prior that was underneath the recent soil tracking. Based on this experience the District has changed it re-vegetation methods to apply mulch and seed just prior to the last tracking layer of the dozer.

The seed list is determined by laying out a test acre on the structure. A plant count is then taken of all the different species that are native to the structure and test acre. This count is converted by the seed supplier into ounces per pound of seed needed to germinate the desired amount of the species per acre. The amount of pure live seed applied for individual plant species also varies by availability from the local seed supplier. Table 1 lists a seed mix specified for Cassandro Wash Dam and is typical of specified hydroseed mixes. No deep-rooted species are allowed in the seed mix.

Where re-vegetation efforts have been successful, embankment erosion problems have been significantly reduced. The re-vegetation results in an additional benefit in the form of increased wildlife activity in the area including birds, rabbits and deer. Unfortunately rodent activity also tends to increase with the added vegetation.

Another form of erosion control that has been quite successful is the use of gravel or fractured rocks on the face of the slopes. This is applied on a 3-4 inch layer. The gravel layer has proven to reduce the embankment erosion effects caused by intense rainfall events typical in the Arizona desert. It also can act as a semi-percolating field and germinates any seeds below it. Desert plant seeds are extremely durable and can lay dormant for many years without germinating.

Table 1

SEED LIST
Cassandro Wash Dam

Common name	Scientific Name	Pounds of Pure Live Seed Per Acre
Purple three-awn	Aristida purpurea	4
Indian Wheat	Plantago insularis	3
Needle Grama	Bouteloua arstiodoides	1
Desert Marigold	Baileya multiradiata	1
Mexican Gold Poppy	Eschschotzia mexicana	1
Creosote	Larrea tridentata	8
Brittle Bush	Encelia farinosa	2.5
Bursage	Ambrosia deltoidea	2

** Note Apply 1500 pounds of wood fiber mulch in Hydro-seed mix, plus 150 - 200 pounds tackifier per acre.

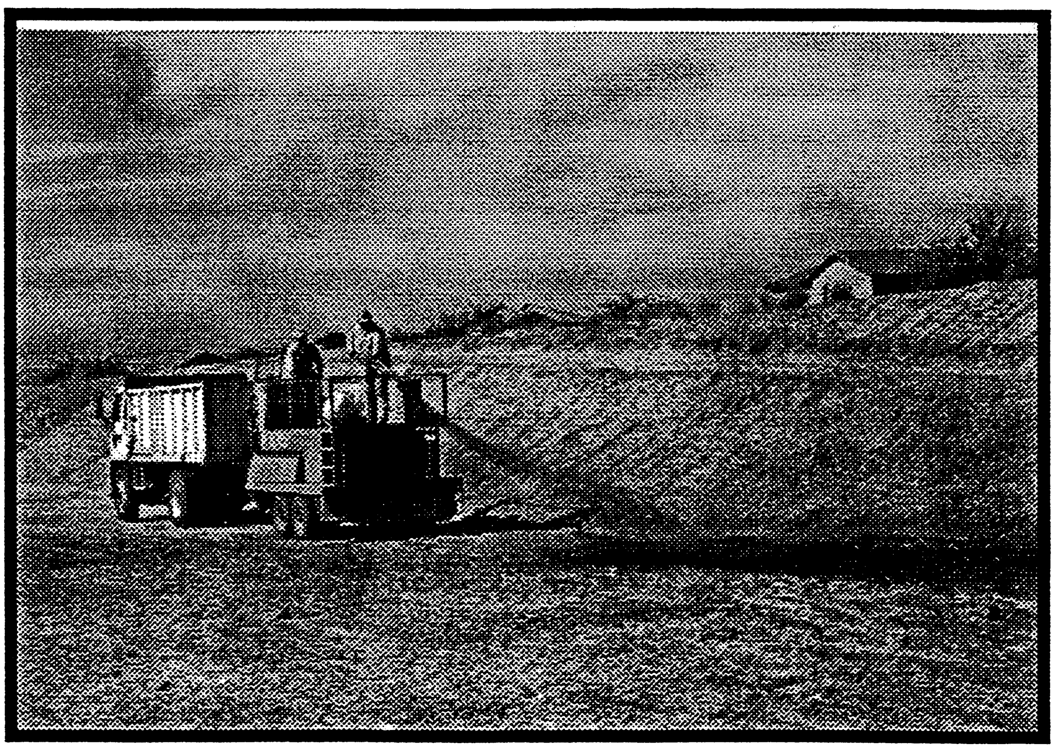


Photo 1 – Hydroseeding Operations on Floodway. This is the same equipment used for hydroseeding operations on the dams.

Vegetation Control
Dam Safety is the primary reason for controlling vegetation on the dams. Deep-rooted vegetation is not allowed on the dams and is removed when identified. In addition vegetative cover must be maintained such that potential dam safety deficiencies in the embankment can be readily observed during annual dam safety inspections and quarterly maintenance inspections. Past practices called for trimming of vegetation when it reached between 2 to 3 feet in height. Currently vegetation up to about 4 feet in height is allowed depending on overall vegetation density.

Unwanted vegetation is sprayed with herbicides on access roads on top of the structures and at the toes of the structures. Round-up Pro is used on all of the dams. For general spraying it is applied at a one and one half percent rate with the spray rigs calibrated to 100 gallons per acre. A spray schedule is set up for the various structures to coincide with the operational and dam inspections. An initial spray is done three months before the annual inspection with a follow up spray occurring two months before the inspections. The structures are usually sprayed for the first 18-24 inches up the slope from the toe. This is done for visibility.

Vegetation thinning is accomplished by either hand pruning and lopping or use of a boom-mower, which can extend its mowing arm a considerable distance and selectively cut down a bush.

Deep-rooted plant species are not allowed anywhere on the structures. Upstream and downstream access roads, in place at most structures, are utilized to create a buffer zone between these species and the toe of dams. The four main deep rooted plants that will propagate rapidly on the dams, if left alone for any length of time, are Desert Broom, Salt Cedar, Mesquite and Paloverde. All three species require considerable effort to control.

In cases where deep–rooted plants are two feet in height or less they are controlled with a 3-5% solution of Roundup Pro. If the plants are over two feet they are hand cut to ground level. The stumps are hand treated within the first five minutes by an almost straight mix of either Roundup Pro or Garlon 3A – Garlon 4; depending on the temperature conditions.

When treating Salt Cedar near waterways Rodeo is sprayed at a 3-5% solution with six ounces of Siltwet per acre added. This is sprayed on plants two feet in height and under. Plants over two feet are hand cut and stump treated with an almost straight solution of Rodeo within the first five minutes of the cut.

Photo 2 – Desert Broom – Deep Rooted Plant Not Allowed On The Dams

Control of Animals and Repair of Animal Holes on District Dams

Animal Control Measures at District Dams

There are three varieties of ground squirrel found at District dams. The Round-tailed Ground Squirrel (Spermophilus tereticaudus) accounts for approximately 95% of the rodent activity on the dams. Throughout Maricopa County the Rock Squirrel (Spermophilus variegatus) have been found to inhabit some of the structures which have a rip rap zone. To a much lesser degree, the Harris Antelope Squirrel (Ammosphermophilus harrisii) has been seen on structures in the northeastern part of Maricopa County.

The Round-tailed squirrels are prolific at most of the dam locations. They thrive in the creosote bush-saltbush desert environment where the dams are located. The species tends to be colonial in nature and they construct burrow systems that can extend a number of feet in length. Literature on the round-tailed squirrel (reference 1) indicates that its' burrows may be as deep as 3 feet, however inspections with hand probes at the dams indicates borrows are generally no more than 6 to 8 inches in depth. The shallow burrow depths are due likely to the density of the compacted embankment. The burrow systems have several burrow openings. Most often under bushes but with many also out in the open.

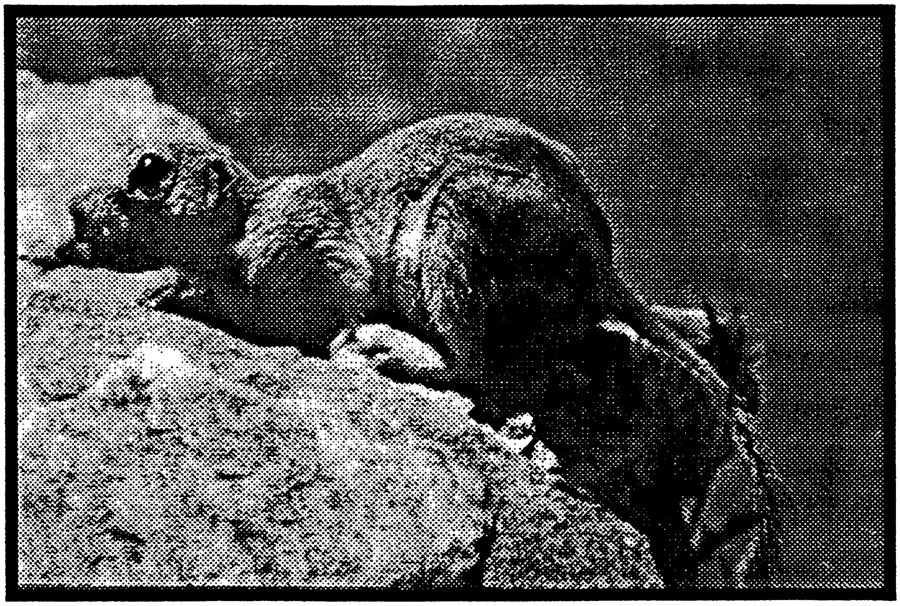


Photo 3 – Round-Tailed Rock Squirrel – Most Prevalent Rodent at District Dams

The Round-tailed ground squirrel is particularly difficult to control as they are active 9-10 months out of the year in Maricopa County. Their hibernation period appears to be from late October/early November through late December/early January.

It has been observed that when the ground squirrels have been eliminated from a structure that other desert dwellers take over some of their burrows. These can include snakes, lizards, kangaroo rats (Dipodomys Merriami), scorpions and beetles. Secondary larger holes have recently been found on several of the dams. These holes are suspected to be made by badgers and coyotes digging for prey.

Current rodent treatment practices involve the use of bait boxes and Ramik Brown Rodenticide (Diaphacinone). When significant ground squirrel activity is identified the bait boxes are placed in groups of 2-3 throughout the active area. They are staked down with 20-penny nails and then filled with Ramik Brown. Every 2-3 days the boxes are refilled until the bait is no longer being eaten. It usually takes two weeks to eradicate a colony. When this is done the boxes are removed to deter vandalism. The rodent treatment program coincides with the herbicide spray schedule for the structures. After eradication, a follow-up inspection is made three months later.

In 1995, the Flood Control District Ecology Department adopted procedures to help assure District rodent control practices do not impact the fragile desert ecosystem. Prior to 1995 it was a common practice to broadcast ZP Gopha Rid rodent bait (Zinc Phosphate) on the surfaces of the dams located in remote areas. Wilco Gopher Getter (Strychnine) was also used extensively, being placed in the openings of the ground squirrel open burrows. While these chemicals proved to be very effective for rodent control it was determined they could also harm the desert ecosystem by inadvertently killing non-target animals.

The rodent treatment procedures were reviewed and it was decided to use more environmentally safe products with bait traps. This was based on the following considerations:

1) Concern for all non-target desert animals that might eat the broadcasted ZP rodenticides.

2) Concerns of animals eating either the rodenticide placed in the opening of burrows or eating a rodent that dies in the open and thus poisoning the non-target animal.

3) Concerns of poisoning domestic animals due to the ever increasing urbanization in the vicinity of the dams.

After trying several products in the bait boxes, Ramik Brown was selected as the rodenticide to be used. The Ramik Brown was chosen because of its anticoagulant properties; the rodent feeds on it and eventually enough rodenticide accumulates in their system to cause a hemorrhage. If a ground squirrel dies in the open and is eaten by other predators it does not pass the poison on to the non-target animal.

Another change that has been implemented into the program has been the placement locations of the rodent bait boxes. Before the boxes were placed singularly at distances of 100-150 feet along the structures. Now they are placed in groups of two or three in active areas only and the spacing is dependent on the number of active holes present. Studies have shown that if you have one bait box and three active squirrels, one squirrel will be dominant and run off any other squirrels from the box.

Another change currently being implemented in the treatment program is the scheduled time from point of eradication to a follow-up inspection. The old schedule was six to nine months. At one structure it was recently observed that rodent colonies were re-established within 3 months after eradication. The new schedule will therefore require follow-up inspection of the structures every three months after eradication of rodents.

Animal Hole Repair Methods
The District is currently in the process of identifying the types of animal burrows experienced on the dams and is developing improved methods for repairing the holes.

There appears to be three types of animal burrows on the dams, shallow rodent burrows, deeper rodent borrows near the crest and holes made by larger animals digging for prey.

Repair methods will depend on the type of hole to be repaired and will likely range from minor repair efforts for small shallow burrows to specified embankment excavation and compacted backfill requirements for deeper and larger holes.

Regulatory Issues

The Arizona Department of Water Resources (ADWR) has jurisdictional authority over all of the District's 22 dams. ADWR's current practice is to perform annual dam safety inspections on all District dams. The District and ADWR now perform annual dam safety inspections jointly in a collaborative effort. The District has found this approach very useful in identifying and resolving issues pertaining to dam safety including the District's vegetation and animal management practices. This approach allows the owner's engineer and maintenance staff and the regulatory agency's engineer to focus site-specific attention on potential dam safety issues. In general site-specific vegetation management and rodent control issues are discussed on site and measures to be taken are agreed to, followed by appropriate documentation in inspection reports.

ADWR is currently in the process of drafting new dam safety regulations.
The draft rules identify ordinary repairs as "those activities which do not impair or adversely effect the safety of the dam" and as such do not require ADWR approval. The September 1999 draft rules list allowable ordinary repairs pertaining to vegetation maintenance and rodent control measures as follows:

"1. Removal of brush or tall weeds.
2. Cutting of trees and removal of slash from the embankment or spillway. Small stumps may be removed provided no excavation into the embankment occurs.
3. Rodent control or extermination by trapping or other methods. Minor rodent damage may be repaired provided it does not involve excavation into the embankment that exceeds 2 feet and replacement materials are compacted as they are placed."

The District is seeking a means by which ADWR's involvement and approval for the repair of rodent holes greater than 2 feet in depth can be achieved without need for a formal application to repair of the dam.

Flood Control District Structures Assessment Program

The District recently initiated a program called the Structures Assessment Program to assess and evaluate all 22 flood control dams and related features due to an ever increasing urbanized environment and to assure continued compliance with current standards and guidelines. The Structures Assessment Program is intended to address issues related to urbanization and dam safety as well as to enhance and improve the District's ongoing Dam Safety Program.

The Structures Assessment Program will be conducted in three phases. Phase I will primarily involve development of the program and policy foundation for the program, field examination of dams, and the development of planning level recommendations for future actions to be considered for each structure. Phase II will primarily involve detailed dam safety inspections and investigations of dams as identified by need and priority in Phase I. Phase III will primarily involve the implementation of identified dam safety modifications and projects designed to mitigate or eliminate issues related to impoundment areas, spillway discharges and urbanization. Phase I will evaluate all significant areas of the District's Dam Safety Program including current practices for plant and animal management. Recommendations for improvements to the program will be evaluated by the District and implemented as appropriate.

Investigations and Evaluations

Further investigation and evaluation on animal and vegetation issues at District Dams is needed. The following is a preliminary list of those needs:

- Field investigations to develop better a understanding of animal impacts on the dams
- Development of improved repair methods for animal holes based on varied impacts identified in the field
- Determination of allowable proximity of trees to upstream and downstream toes and abutments
- Evaluation of greater utilization of erosion control measures other than vegetation such as gravel surfacing as described above
- Evaluation of current methods to eliminate deep-rooted plants
- Evaluation of current vegetation and animal management practices with respect to potential for impact to threatened and endangered plant and animal species
- Site specific evaluation of flow capacity of emergency spillways with respect to existing vegetation in approach channels
- Evaluation of impacts of rodent activity and vegetation at transverse cracks. Transverse alignments of animal holes have been observed at several locations. Upon further inspection it was found the holes were on the alignments of transverse cracks. Roots of vegetation on dams has been observed in transverse cracks. Transverse cracks are prevalent on many the Flood Retarding Structures (SCS Dams). These dams have been modified with filter and drain systems to address transverse crack dam safety issues. Further investigation and analysis will be conducted to assure animal burrows and vegetation at transverse crack locations do not create a dam safety deficiency at the centerline filter or otherwise.

Conclusions

The Flood Control District of Maricopa County utilizes considerable resources in assuring its structures are well maintained and function as designed. Plant and animal management on the District dams is a significant part of that effort. The primary focus of these management activities is dam safety. As such conditions of the structures are monitored to assure potential problem areas are identified and addressed in a timely manner. Management practices for plants and animals are in practice a dynamic process in which procedures are revised to reflect lessons learned over years of operation and maintenance as well as to keep current with "state of the practice" dam safety methods and procedures.

References

1. "Mammals of Arizona 1981" , Donald F. Hoffmeister, University of Arizona and The Arizona Game and Fish Department

2. Internet Address: http://west.pima.edu/~bfiero/109ID/MAMMID.HTM

3. Internet Address: http://www.geobop.com/Mammals/1MFeatures/Places/NA2.htm

REMEDIAL REPAIR OF EARTHFILLED DAMS RELATED TO PLANT AND ANIMAL PENETRATIONS

PLANT AND ANIMAL PENETRATIONS OF EARTHFILLED DAMS WORKSHOP

University of Tennessee

Knoxville, Tennessee

November 30 - December 2, 1999

REMEDIAL REPAIR OF EARTHFILLED DAMS RELATED TO PLANT AND ANIMAL PENETRATIONS

PRESENTATION CONTENTS

CATAGORIES OF DAMS

POTENTIAL PROBLEMS

TREATMENTS FOR PLANTS

TREATMENTS FOR ANIMALS

CATAGORIES OF EARTHFILLED DAMS

- I. DOWNSTREAM SLOPE < 2:1(H:V)
- A. Cohesive Emb't/Cohesive Fdn
- B. Cohesive Emb't/Cohesionless Fdn
- C. Cohesionless Emb't/Cohesive Fdn
- D. Cohesionless /Cohesionless

CATAGORIES OF EARTHFILLED DAMS (CONT'D)

- II. DOWNSTREAM SLOPE>2:1(H:V)
- A. Cohesive Emb't/Cohesive Fdn
- B. Cohesive Emb't/Cohesionless Fdn
- C. Cohesionless Emb't/Cohesive Fdn
- D. Cohesioless/Cohesionless

POTENTIAL PROBLEMS

- **PLANT PENETRATIONS**
- **Animal Attraction**
- **Rootball Growth**
- **Root Penetration**
- **Blowdowns**
- **Disease/Death**

POTENTIAL PROBLEMS

- **ANIMAL PENETRATIONS**
- **Upstream Slope Collapses**
- **Accelerated Wave Erosion**
- **Crest Sinks and Dropouts**
- **Embankment Penetrations**
- **Accelerated Internal Erosion**

TREE REMOVAL CONSIDERATIONS

- RESERVOIR CONDITIONS
- SIZE AND TYPES OF TREES
- LOCATION OF TREES
- STEEPNESS OF SLOPES

TREE REMOVAL PROCEDURES

- RESERVOIR LEVEL
- ALWAYS LOWER RESERVOIR

- CUT SMALL TREES AT GROUND
- TREAT STUMP & MONITOR

- EXTRACT STUMP OF LARGE TREES
- REMOVE ROOTBALL & ROOTS

TREE REMOVAL PROCEDURES (CONT'D)

- UPSTREAM SLOPE
- REMOVE BY BENCHING
- CLEAN ROOTBALL AREA
- COMPACT BACKFILL SOIL
- INSTALL EROSION SYSTEM

- CREST OF DAM
- REMOVE BY PULLING , OR
- REMOVE BY UPROOTING
- COMPACT BACKFILL SOIL

TREE REMOVAL PROCEDURES
(CONT'D)

- STEEP DOWNSTREAM SLOPES
- CUT TREES ABOVE GROUND
- REMOVE STUMPS DURING
- SLOPE BENCHING
- REMOVE LARGE ROOTS
- COMPACT RE-SHAPED SLOPE

TREE REMOVAL PROCEDURES (CONT'D)

- MODERATE DOWNSTREAM EMBANKMENT SLOPES

- UPPER THIRD SLOPE HEIGHT
- REMOVE STUMP, ROOTBALL,
- CLEAN CAVITY, AND FILL
- CAVITY WITH COMPACTED
- SOIL BACKFILL

TREE REMOVAL PROCEDURES (CONT'D)

- MODERATE DOWNSTREAM EMBANKMENT SLOPES
- MID-THIRD HEIGHT OF SLOPE
- REMOVE STUMP/ROOTBALL,
- CLEAN CAVITY, & FILL
- CAVITY AS FOLLOWS:
- COMPACTED SOIL, <u>OR</u>
- FILTERED DRAIN SYSTEM

TREE REMOVAL PROCEDURES (CONT'D)

- MODERATE DOWNSTREAM EMBANKENT SLOPES
- LOWER THIRD SLOPE HEIGHT
- REMOVE STUMP/ROOTBALL,
- CLEAN CAVITY, FILL WITH
- COMPACTED GRANULAR
- SOIL(SAND), <u>OR</u> INSTALL
- FILTERED TOE DRAIN
- SYSTEM ALONG TOE OF THE
- EMBANKMENT

TREE REMOVAL PROCEDURES (CONT'D)

- BEYOND TOE OF DOWNSTREAM EMBANKMENT SLOPE

- REMOVE STUMP/ROOTBALL,
- CLEAN CAVITY, BACKFILL
- WITH GRANULAR SOIL(SAND),
- <u>OR</u> INSTALL WEIGHTED FILTER
- SYSTEM

ANIMAL DAMAGE REPAIR CONSIDERATIONS

- RESERVOIR CONDITIONS
- SIZE AND TYPE PENETRATION
- LOCATION OF PENETRATION
- STEEPNESS OF SLOPES

ANIMAL DAMAGE REPAIR PROCEDURES

- ALWAYS LOWER RESERVOIR

- EXCAVATE UPSTREAM DAMAGE BY BENCHING , BACKFILLING, AND INSTALLING PROTECTION SYSTEM

- EXCAVATE DOWNSTREAM DAMAGE, CLEAN CAVITY, AND BACKFILL WITH COMPACTED SOIL -- FILTERS TYPICALLY NOT NECESSARY UNLESS SEEPING OR LEAKING

REMEDIAL DAM REPAIR

CONCLUSIONS

- EVALUATE PLANT AND ANIMAL DAMAGE RELATIVE TO FOLLOWING:

- RESERVOIR LEVEL
- CATEGORY OF DAM
- SIZE & TYPE PENETRATION
- LOCATION OF PENETRATION
- STEEPNESS OF SLOPES

Biobarrier ®

A Long Term Root Control System
William M. Hawkins
BBA Nonwovens – Reemay, Inc.
December 1, 1999

Tree roots can cause major damage to desirable structures and features. They can be very powerful.

Tree and plant roots can survive in harmony with other structures without damage to either them or their surroundings for a long time with Biobarrier ® root control system. The system consists of small polyethylene nodules (hemispheres) molded on a geotextile fabric on 1.5 inch centers. It utilizes time release (technology) of an innocuous herbicide, trifluralin, which stops root tip cell division, i.e., root growth to prevent damage from root intrusion.

Unlike other root control products, the active ingredient in Biobarrier ® is non-systemic; the fabric is permeable to water, air and nutrients; very conformable; very low solubility in water; and lasts 15 to 150 years based on site conditions. It is very easy to install and requires no maintenance.

Biobarrier has been used by engineers, landscape architects, arborists, designers, developers, governmental agencies and homeowners for more than 10 years to protect streets, sidewalks, other pavements, drainage systems of all types, planter drains, retaining walls, foundations, underground utilities, septic systems, landfills, doors, levees and other structures from root intrusion.

Even though Biobarrier utilizes a herbicide, it presents very little hazard to its surroundings. The herbicide is trifluralin.

- Its acute oral toxicity is less than table salt – LD_{50} < 10,000 mg/kg. (US EPA Category IV)
- Its solubility in water is less than 0.3 ppm – so leaching into ground water is insignificant.
- It is non-systemic – so there is no other effect on the plant besides stopping root tip growth in the very focused zone of influence – about 2 inches from the time release device (nodule). There is no other effect on the plant, accumulative or otherwise.
- It biodegrades in the soil.
- And the US EPA does not require an applicators license to install Biobarrier

In many applications Biobarrier can serve the additional function of a drainage fabric since it is a standard geotextile which meets AASHTO (M-288 – Class 3) drainage specifications.

Developed by Battelle Institute for the DOE to prevent root damage to radio-active waste landfill covers for up to 150 years, the Biobarrier root control system should be very useful in protecting earth-filled dams from damage by root intrusion to their core and drain systems for a long time with no adverse effects.

(See paper by *Leon Zimmerman,* attached, for more detail. Also included is a case history and schematic of a dam.)

A New Herbicide Delivery System.

by Leon Zimmerman
Research Fellow
Reemay, Inc.
Old Hickory, TN USA

August 18,1993

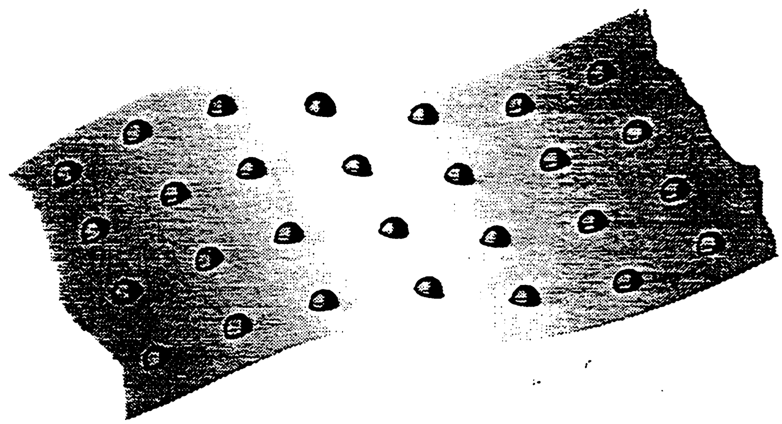


Figure 1.

Introduction

Conventional methods of herbicide application include spraying liquids, distributing granules and dusting. Most require repeated seasonal application and depend on the environment and the applicator to minimize detrimental effects to surrounding vegetation and personnel. Biobarrier®, introduced into the marketplace in1989, is a vegetation root control system (see figure 1). It is a unique 80 percent polymeric product enabling total placement control. Depending on use, it is effective for a minimum of 15 years with a maximum life approaching 100 years. Biobarrier® was originally designed to exclude roots long term from hazardous landfills. The current use categories for Biobarrier® include hardscape protection, subterranean structure root exclusion, root separation, aerial vegetation control and nursery applications.

Biobarrier® is a polypropylene spunbonded fabric with a pattern of permanently attached, herbicide impregnated polyethylene composite nodules. Each nodule serves as a protective reservoir and functions as a long term controlled release mechanism. Strategically positioned in soil, Biobarrier® creates a root inhibition zone of herbicide. Since it is a fabric, it can be contoured to protect virtually any shape structure from roots and, since the fabric is permeable, it does not alter the soil hydraulics. Based on this product, Reemay, Inc., the manufacturer, received an **INDEX '93 Award,** which is generally recognized as the highest accolade given for achievement in nonwovens. Biobarrier® was selected for this award based on the product's creativity and its unique solution to the problem of indiscriminate use of herbicides. In addition, Hazel O'Leary, United States Secretary of the Department of Energy (DOE), in a May 25, 1993 speech to the

National Press Club, cited Biobarrier® as a favored "government to industry technology transfer" example noting Biobarrier® as an environmentally correct product.

Biobarrier® is in use in all parts of the United States and is under test throughout the world. Ten United States universities plus three United States Forestry Service sites have been testing Biobarrier®, some for more than four years. Reemay, Inc. monitors these sites annually obtaining product and soil samples for laboratory analysis. Test sites also exist in France, Germany, Japan, Australia, Marshall Islands and United Arab Emirates. In addition, The Getty Conservation Institute is currently installing Biobarrier® in Tanzania, Africa to conserve the Laetoli foot prints (3.6 million year old hominid) .

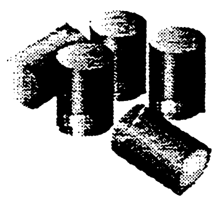


Figure 2.

Background

Early in the 1970s, the U.S. DOE recognized the need to prevent vegetation contamination of hazardous landfill overgrowth. Roots enter the waste and translocate active material into the plant aerial portion presenting the possibility of environmental dispersion. The Battelle Pacific Northwest Laboratory was commissioned to identify a means of preventing, for an extended time period, root penetration of the site seal cap. A preemergence herbicide, trifluralin, impregnated controlled release polymeric device was developed. Their 7 year landfill *in situ* test of hand-placed cylindrical mechanisms (see figure 2) indicated a near 100 year effective life [1]. Reemay, Inc. licensed this technology and developed a commercially viable process and product using its nonwoven fabric, Typar®, as the carrier.

Figure 3.

Mechanism

The nodules (polymeric devices) are a trifluralin impregnated polyethylene based composite. This material is injection molded through the Typar® polypropylene fabric (see figure 3) to assure maintenance of proper nodule spacing and permanent attachment. The nodules release herbicide vapor (1.03 x 10 $^{-4}$ mm

Hg at 25° C vapor pressure) at a controlled low rate established predominantly by nodule molecular structure, surface area and ambient temperature. The migrating vapors adsorb onto the surrounding soil, building a diminishing-with-distance herbicide concentration profile.

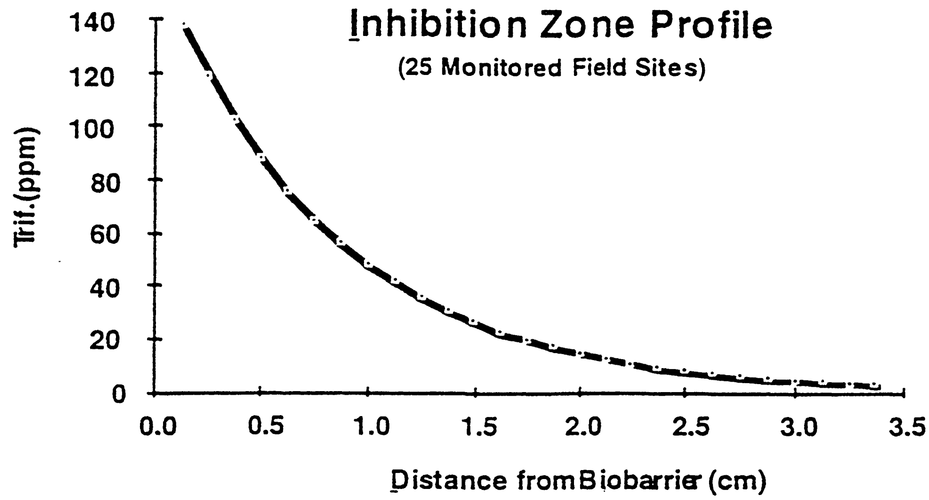


Figure 4.

With adjacent nodule support, a contiguous zone is established enveloping the barrier. As the exposed herbicide degrades, zone concentration is maintained by vapor emission from the nodules (see figure 4). A 10 ppm trifluralin concentration stops most specie root growth by preventing root tip cell division. This concentration typically occurs 0.75 inches (1.9 cm) from the barrier surface. Roots entering the zone swell and cease growing. Since trifluralin is not systemic, other roots in the system continue to develop normally but are diverted away from the zone.

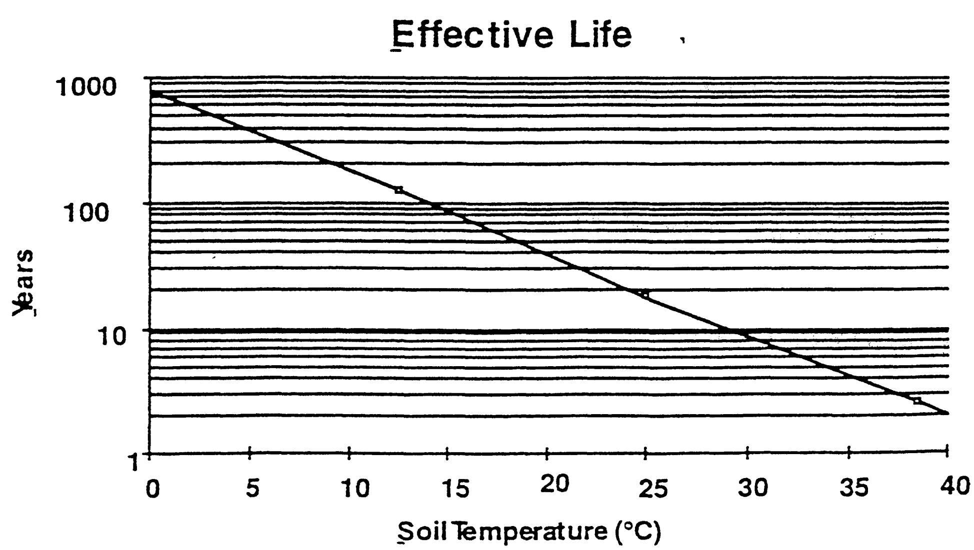


Figure 5.

Effective barrier life (see figure 5) is determined by the amount of trifluralin in the nodule and its release rate. With applications deep in the soil, in landfill caps for example, temperatures are relatively low and constant and projected effective life is estimated to be as long as100 years. With or in near soil-surface installations, typical of weed control applications, temperatures are elevated and cycle daily. As a result, projected effective life declines, but still exceeds the guaranteed minimum of 15 years.

Polyethylene and polypropylene in soil are stable and therefore ideal as a trifluralin protective reservoir. The trifluralin emitted from the nodule into the soil virtually degrades within one season into harmless derivatives (2). In most other ecosystems, trifluralin's half life is less than one week (3). It is not water soluble (0.3 ppm) and its toxicity rank is between salt and alcohol (4) (5).

Application Catagories

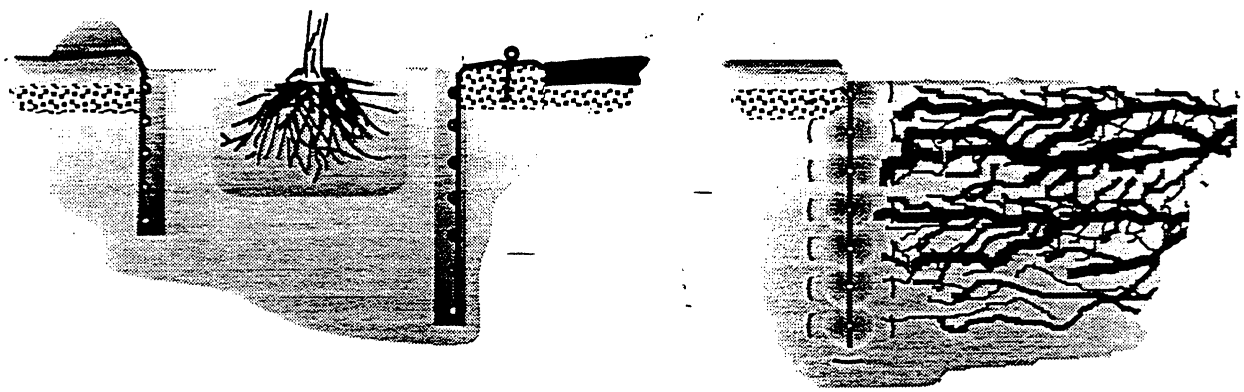


Figure 6.

Hardscapes are defined as structures located on the soil surface. Sidewalks, pathways, roads, curbs, tennis courts and swimming pools are examples.

Normally a vertical ditch, 2 inches (5.0 cm) or wider, is excavated adjacent to and on the root source side of the structure to be protected (see figure 6). The excavation depth must be greater than the width of the barrier. An easily removed plastic film flap is factory-attached along the length of the Biobarrier® top edge to assist in anchoring the product in the proper position, which is flush with the soil surface. With the Biobarrier® in place and after tamping the trench backfill, the flap is zipped off.

Although the fabric is herbicide coated and provides an instant inhibition wall on installation, up to a month is required to establish an inhibition zone of normal dimensions. Aggressive vegetation root species with trimmed roots adjacent or close to the barrier may require a one time trench wall herbicide treatment to accelerate establishing normal zone width.

The Biobarrier width recommended for a specific application depends on the environmental conditions, the plant species and the horizontal dimensions of the hardscape. Ninety percent of urban tree roots reside within ten inches (25.5 cm) of the soil surface [6]. However, plant roots are opportunistic. Even deep root plants species will migrate to the surface in search of survival nutrients. The most commonly used Biobarrier® is twelve inches (30.5 cm) wide. Wider product widths are available, 19.5, 38.0 and 58.5 inches (49.5, 96.5 and 148.5 cm) for extreme conditions or maximum assurance in coping with maverick roots. This application category is projected to exceed the guaranteed 15 years effective life.

Danny Hunt, assistant city engineer for the city of Bristol, VA, USA uses Biobarrier® to reduce sidewalk maintenance costs. "Once we explained to the neighborhood what we were trying to achieve - safer sidewalks and a more attractive neighborhood - we're had nothing but compliments." He added, "I'm very pleased!"

Ken DeYoung of the Carmichael Recreation and Park District in Carmichael, CA, USA had much the same experience. Tree roots were tearing up nine miles of sidewalk in seven parks. "Biobarrier® is relatively easy to install because it is flexible and we can custom contour it around our sprinkler systems. I'm really happy with it and planning to install more", said Ken.

John McNeal, landscape gardener at the Portland International Airport in Portland, OR, USA has to contend with 1,600 Poplar trees planted in a narrow median strip running the 1.5 mile length of Airport Way. John used Biobarrier® to successfully redirect roots away from his irrigation system. He has had no problems with the Poplar roots since Biobarrier's installation.

Cary Lewis, Grounds Care Supervisor at the Country Club of Orlando in Orlando, FL, USA was facing tree root competition in golf greens turf. He installed Biobarrier® the full length of the tees involved. It did the job. He is pleased and continues to use Biobarrier® in his renovation projects.

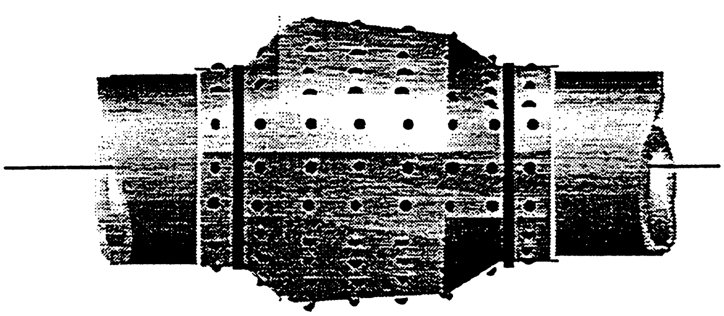


Figure 7.

Subterranean Structures can be protected from roots by covering or surrounding the structures with Biobarrier® fabric. Underground cables, clay pipes and joints (see figure 7), landfills, drains, building foundations, septic tanks and burial vaults are some examples.

Normally, this application category is installed several feet under the soil surface where temperatures are relatively low and constant. Under these conditions, effective life, based on long term installation sampling and laboratory tests, is predicted to approach one hundred years.

On new installations, when the soil is excavated for installation of the structure, Biobarrier® can be installed directly on or around the item to be protected. The herbicide zone surrounds the barrier providing a buffer zone for close proximity roots to grow in diameter without applying direct pressure to the structure. Additional buffer width can be created by applying the Biobarrier® over a cover coat of soil.

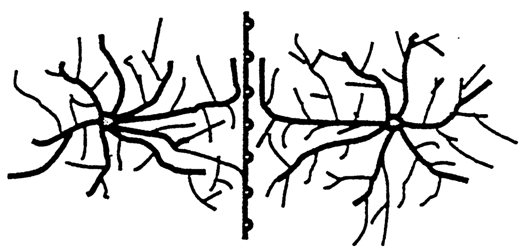


Figure 8.

Root Separation installations are used to prevent a plant from encroaching on other species. Golf course greens, flower beds and deseased roots are application examples. Golf green grasses often suffer due to nutrients being drained away by competing tree roots. Desirable bedded plants are crowded out of existence by a more root aggressive species. Diseases, transmitted via tree to tree root contact, spread rapidly through vast land areas. Biobarrier® installed as a root separator (see figure 8) is often the only effective control. Biobarrier® life in this application category is fifteen years or more.

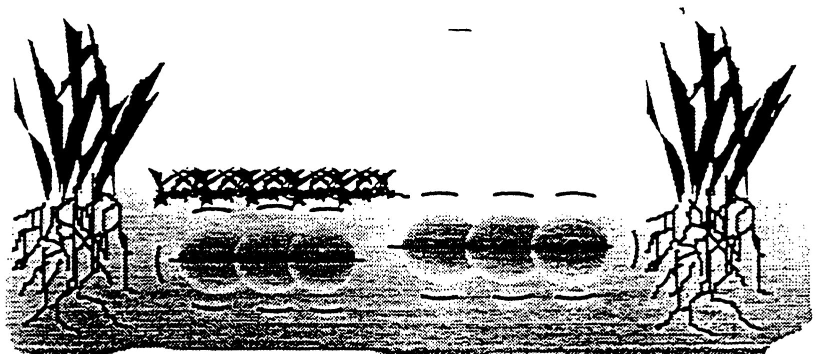


Figure 9.

Aerial Vegetation Control includes weed and selective plant control (see figure 9). Highway shoulders, utility substations, power transmission lanes and landscapes are application examples. Biobarrier® offers benefits in cost reduction, improved aesthetics and personnel safety. In this type application, installation is horizontal and close to grade level with a cover of soil, crushed stone, pavers, mulch or other appropriate material. Installation of Biobarrier® at a one to two inch (2.5 to 5.0 cm) depth essentially eliminates all vegetation directly above it because adequate material for the plant root system support is reduced to less than the minimum required to sustain vegetation. With a two to three inch (5.0 to 7.6 cm) cover thickness, most grasses struggle to survive but no deep root plants grow. A one foot (30.5 cm) cover will support some shallow-root tree species, but growth is limited. Effective life, based on field samples and laboratory data, is predicted to exceed the 15 year product guarantee.

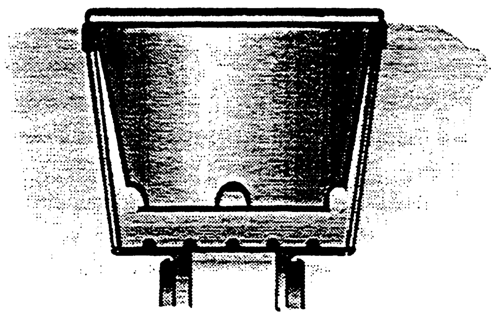


Figure 10.

Nursery applications involve most of the foregoing categories. Biobarrier® is used horizontally in nursery floors under planting tables to control surface vegetation. It is used to separate species and to protect hardscapes. A new application involves the pot-in-pot field planting technique (see figure 10). Biobarrier®, placed between the planter and socket pot, prevents roots from anchoring the planter pot. Therefore harvesting is easier and more cost effective. With specially designed planter pots, root circling is eliminated and a denser, finer root ball forms providing a heathier, more survival prone plant.

Summary

Biobarrier® is a new, unique product rapidly gaining market acceptance in a wide variety of applications. A world highly sensitive to chemicals welcomes the complete application control and the minimal herbicide quantities required for long term protection. There is no in-kind competition. Biobarrier allows water and gases to pass through yet blocks even the smallest roots. The inhibition zone stops most roots short of the barrier plane allowing root growth in diameter without structure damage. Biobarrier® use will proliferate as its merits become more widely recognized and as the demand for highly effective, environmentally responsible products continues to grow.

References

(1) Burton, F. G., Skiens, W. E., Cline, J. F., Cataldo, D. A. and Van Voris, P, 1986. A Controlled-Release Herbicide Device for Multiple-Year Control of Roots at Waste Burial Sites, Journal of Controlled Release, 3 Pg. 47 - 54, Elsevier Science Publishers B.V., Amsterdam

(2) Golab, T., Althaus, W. A., and Wooten, H. L., Jan. and Feb. 1979 Fate of [14C] Trifluralin in Soil, Agricultural and Food Chemistry, Vol 27, No. 1.

(3) The Agrochemicals Handbook, Second Edition, The Royal Society of Chemistry, Nottingham, NG7 2RD, England.

(4) Farm Chemicals Handbook, 1992 Trifluralin, Meister Publishing Company Willoughby, OH.

(5) Kamin, M. A., 1988. Toxicology, Lewis Publishing Inc. Pg. 46

(6) Watson, G.W., and Hennen, G. September/October 1989 , Journey to the Bottom of a Tree, American Forests

Additional Reading

- Zimmerman, L. H. 1989. Nonwovens World Buyer's Guide, MTS Publications, Kalamazoo MI, Pg. 153
- Kafkafi, Uzi, 1991. Plant Roots, The Hidden Half, Marcel Dekker, Inc.
- Glinski, Jan and Lipiec, Jerzy, 1990. Soil Physical Conditions and Plant Roots, CRC Press, Inc.
- Rice Jr., Robert P. 1992. Nursery and Landscape Weed Control Manual, Thomas Publications
- Gilman, Edward F., April 1988. Predicting Root Spread from Trunk Diameter and Branch Spread, Journal of Arboriculture, Vol. 14, No. 4

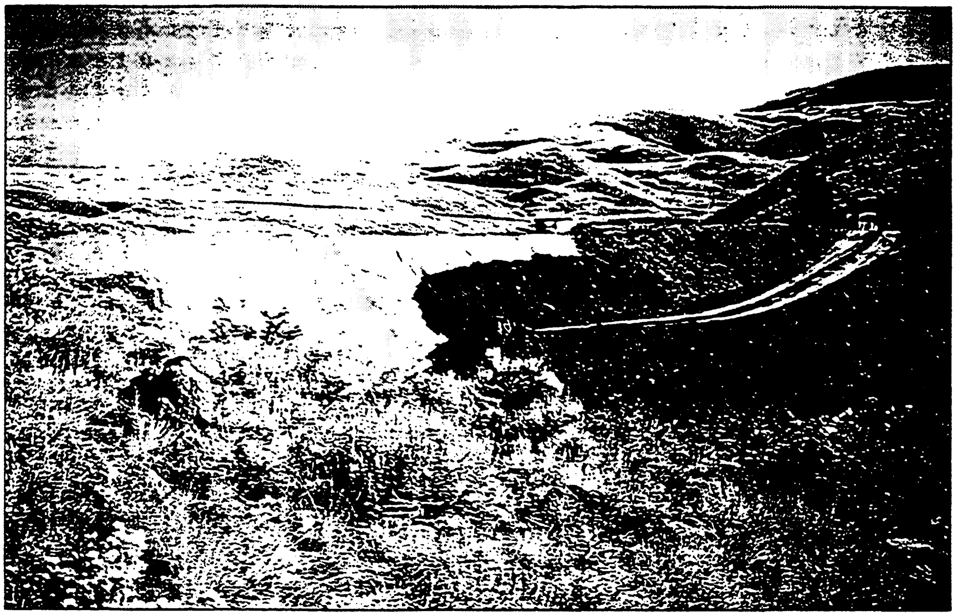
Biography

Prior to joining Reemay at its inception, Zim spent over 35 years in synthetic fiber industry research and development. He has spoken at industry conferences and has published several papers on nonwovens. Zim holds patents relating to rayon yarn, drainage systems and nonwovens including Biobarrier®. He is currently involved in Reemay's expansion activities.

by: Cindy Kershner

It's Only Natural

photo by Reemay Inc.



Installation of Biobarrier® on a ranch in Montanta. The dam had to look like a natural part of the scenery.

It took an unusual company, Inter-Fluve. Inc., using an innovative product called Biobarrier® to create one of the most unique earth dams in the country. At 25 feet high and 350 feet long, the dam and the five-acre reservoir it created appear to be a natural part of the landscape. That's just how it was planned.

The earth dam project came about when a client approached Inter-Fluve about creating a reservoir on his cattle ranch in Montana. It would be used primarily as a fish and wildlife habitat and secondarily to store irrigation water. The location was in a narrowended valley that had been the site of a reservoir in the early 1900s which had washed out in the 1930s. The area was poor in condition; it was essentially just a wet meadow. The biggest problem, however, came from the fact that the dam had to look like a natural part of the scenery; trees and shrubs planted on it would create the natural effect but their roots would pose a structural threat to the dam.

Inter-Fluve, the geological term meaning "land between two rivers," is a habitat enhancement company founded in 1983. The four principals and six associates have degrees in specialties such as geology, hydrology, ecology, geomorphology and fisheries biology. All these specialties are needed for the work Inter-Fluve does; improving and creating wildlife habitats, especially those around water.

The process for this particular project included building a conventional dam, then landscaping with 10,000 cubic yards of additional fill to create a natural-appearing hill complete with rock outcrops and other surface irregularities. All of the mechanics of the dam, such as pipe and gates, are beneath the fill and are accessed through a hidden trap door. The final step was planting native vegetation to make the dam look like a natural part of the scenery. All of this is fairly standard fare for Inter-Fluve.

> **Lovell says that if an area looks like Inter-Fluve has been working there after the project is finished, then they haven't succeeded.**

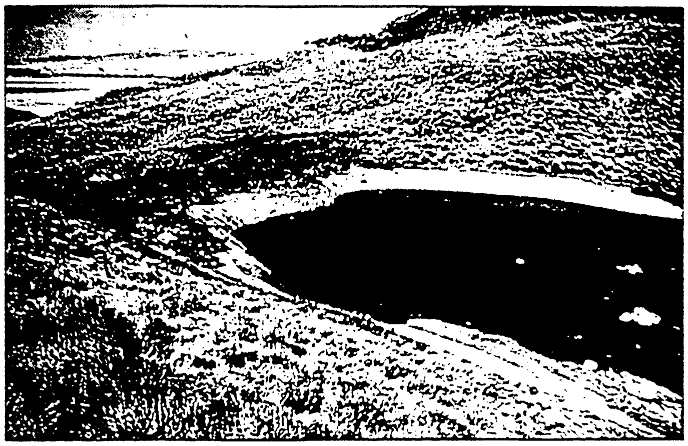
The possibility of roots penetrating the structural part of the dam was a situation t[h] had never been adequately solved bef[ore] and some of the native vegetation that would cover the dam - willows, sagebrush, and chokecherries - have deep penetrating roots. Project manager and Inter-Fluve associate Jim Lovell had limited choices for dealing with this challenge. One option was to devise a system of large concrete boxes as "planters" for the native species; however, this would limit how many and where they could be located. Another choice was to install a heavy layer of plastic between the dam workings and the fill; the difficulty here was that this would prevent gas and water exchange and could create problems with drainage.

Lovell had used geotextiles to stabilize the earth in other Inter-fluve projects, and he wondered if he could find a geotextile that would prevent root penetration. He found what he wanted in a new product called Biobarrier.

Manufactured by Reemay, Inc. in Old Hickory, Tennessee, Biobarrier was originally created in response to the U.S. Department of Energy's need for a product that could be used in the closure cap of haza[rd]ous waste sites to prevent root intrusion and any possible chance that hazardous waste could get into the food chain. Biobarrier manages roots through the slow, controlled release of Trifluralin, a herbicide that has been in use on food crops in the United States for 30 years. A pattern of 7/16-inch hemisphere nodules is through-injection molded to Reemay's four once per square yard spunbonded polypropylene Typar fabric on 1.5-inch centers. This creates a continuous zone of root control protection.

Trifluralin defuses from the protective nodules in vapor form, creating a root inhibition zone in the soil. Roots penetrate the zone until tips reach the herbicidal concentration that prevents that species' cell division. This is normally more than 3/8 inches from the fabric. Only the root tip cell's ability to divide is affected; neither the plant nor its roots is killed. Biobarrier simply diverts the roots and forces them to concentrate growth in branch roots away from the trifluralin zone. Because it is a geotextile, Biobarrier is permeable, does not disturb soil hydrology and is flexible enough to be contoured to various installation geometries.

Approximately 15,000 square feet—32 rolls measuring 58.5 inches by 100 feet—of Biobarrier were used. To improve the integrity of the barrier the rolls were hot-melt seamed. This was done on a level strip of access road rather than the steep banks of the dam, and to further simplify the operation, the portable generator and hot-melt machine were placed on the back of a pick-up truck. Seaming was accomplished by rolling out a starter roll, drawing a bead of hot-melt along its edge and pressing a second roll's edge into the still-hot glue. The size of the panels made through the hot melt seaming process was limited by the weight that the workers could easily handle. The largest panel was eight full-width rolls, approximately 3,900 square feet and 340 pounds.



Before Biobarrier® was installed.

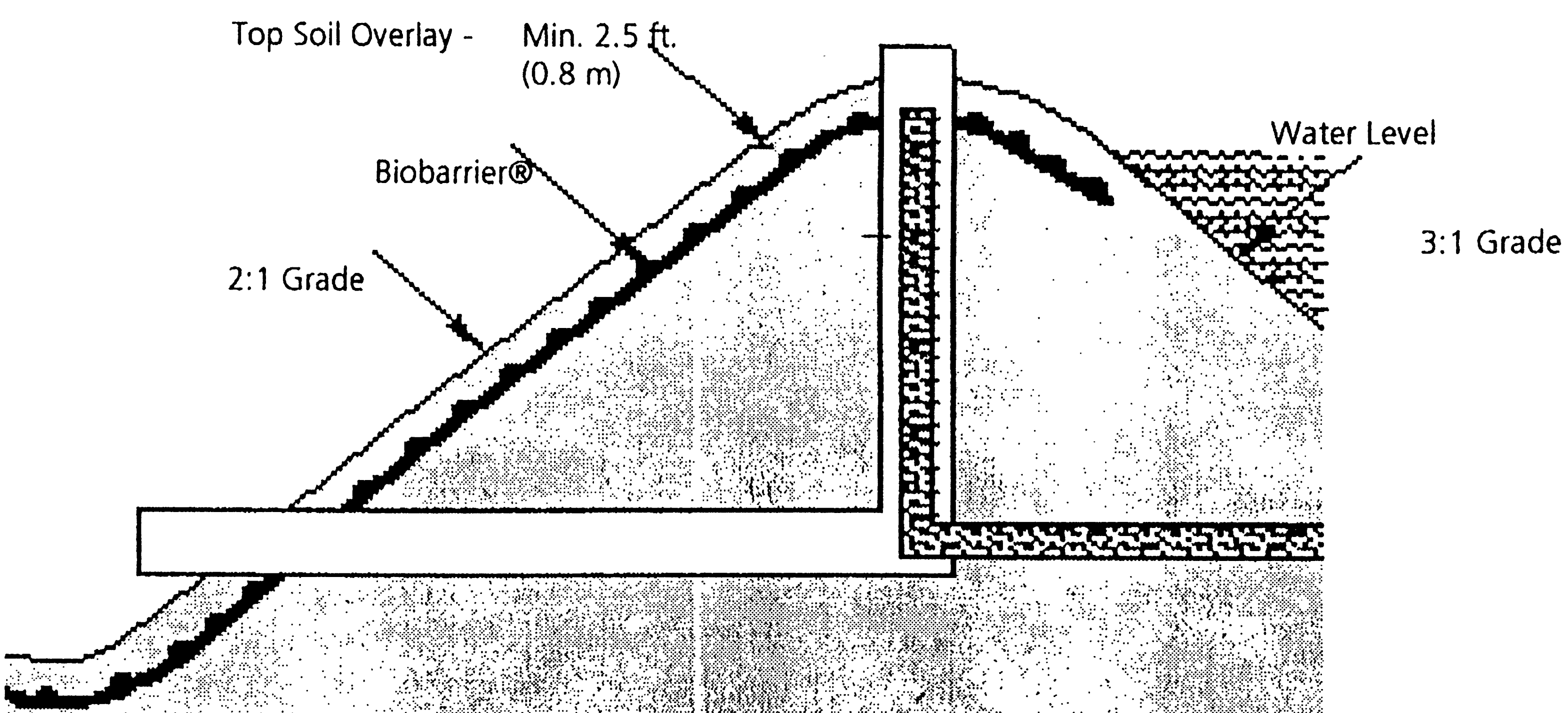
The panels were taken to the dam face, unfolded and slid into position, an operation that proved to be easier than anticipated. Once the Biobarrier was in place, dump trucks hauled and piled dirt near the edge of the dam; then a back hoe dumped and spread the dirt on the dam as far as it could, driving out onto the fresh fill and eventually progressing across the dam. A minimum of 2.5 feet was used at one end and a maximum of 15 feet was used at the other end to create the hill. The Biobarrier installation required four men approximately three days to complete.

Once the fill covered the Biobarrier, Inter-Fluve hydromulched with native species of grasses and wildflowers. They planted 1300 native trees and shrubs, some of which had been removed from areas that would be underwater once the dam went into operation. This was one of several instances where the company reused natural landscaping that would have otherwise been covered once the reservoir filled with water. Rocks taken from the area were placed on the dam, and sod taken from the meadow was used around the edges of the lake. Inter-Fluve also created extensive wetlands by excavating clay from shallow areas and replacing it with suitable topsoil material.

Next spring Inter-Fluve will plant the newly created wetland area with plants such as cattails, bullrushes and arrow arum. This will encourage waterfowl and other wildlife to use the area. Next summer the lake will be stocked with trout.

Lovell says that if an area looks like Inter-Fluve has been working there after the project is finished, then they haven't succeeded. With the assistance of Biobarrier, this earth dam will be covered with native plants and will look like a natural part of the scenery. L&W

Installation - Earth Dam



Section A - A

Biobarrier®

BBA Nonwovens/Reemay, Inc.

Table of Contents

Introduction

Biobarrier® is an award-winning, state-of-the-art technology using the finest materials. Designed as a long-term solution for vegetative root intrusion and possible structure damage, Biobarrier combines a proven geotextile fabric with the effective pre-emergence herbicide, trifluralin. Trifluralin, the active ingredient in Biobarrier, has been used extensively in commercial applications for more than 35 years and is widely recognized as a leading pre-emergence herbicide.

Utilizing a patented controlled-release process, Biobarrier delivers only the amount of trifluralin biologically necessary to inhibit root growth. Biobarrier's innovative technology ensures that precise amounts of herbicide will be dispersed at the correct location for an extended time. This provides a distinct advantage over repeated applications of herbicides required by conventional methods. **The U.S. EPA does not require a pesticide applicator license to install Biobarrier.**[1]

On the following pages, standard installation procedures for a variety of Biobarrier applications are summarized. While schematic drawings are supplied for more common applications, this manual does not include drawings for all applications.

Should you require additional drawings or instructions, please call (800) 284-2780 or (615) 847-7000 and ask for our technical department. We will be happy to assist you.

Biobarrier® is manufactured and marketed by:

BBA NONWOVENS

REEMAY, INC.

70 Old Hickory Boulevard.

Old Hickory, TN 37138-3651
(800) 284-2780
(615) 847-7000
FAX: (615) 847-7068
Email: beddins@reemay.com

[1] Check agency in your area for local regulations.

Mechanism

How Biobarrier® Works...

Biobarrier® consists of composite nodules injection-molded through Typar®*, a spunbonded polypropylene geotextile fabric. The through injection molding technique ensures permanent nodule attachment. Impregnated with trifluralin, the nodules function as a protective reservoir. The nodule composition is designed to slowly release trifluralin vapors which adsorb in the soil.

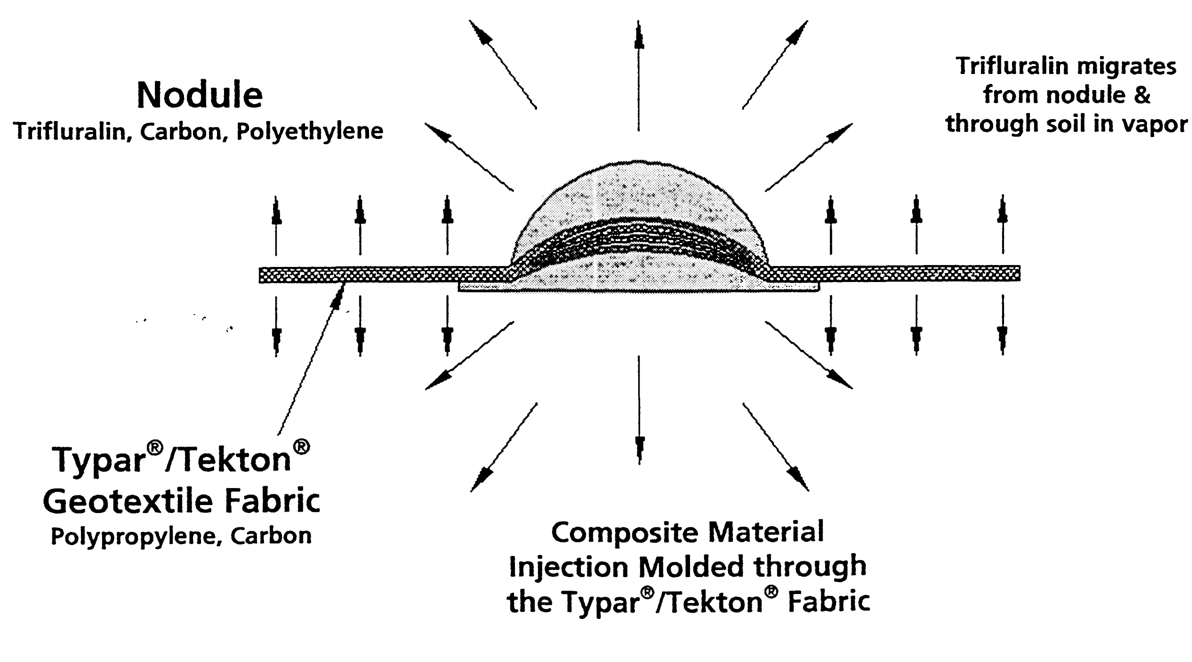
Outside the nodule, the trifluralin degrades but is continuously replaced by new material, building and maintaining a root inhibition zone. Accurate nodule spacing ensures the individual nodule zones overlap and reinforce each other. At equilibrium, the inhibition zone becomes contiguous, enveloping the Biobarrier fabric.

When roots enter the inhibition zone, root tip cells cannot divide, preventing growth in that direction. Trifluralin is not systemic; therefore, it is not taken into the plant. As a result, the root system is diverted away from the Biobarrier-protected structure without adversely affecting the desirable plants or trees. Root branches outside of the zone are not affected.

By utilizing a technology which combines a proven geotextile drainage fabric with an effective preemergence herbicide, Biobarrier II, marketed as a preemergence weed control fabric for landscaping, prevents grass and weed growth without affecting desirable plants. When covered with 2" (50 mm) of mulch , stone, or other medium, the trifluralin inhibition zone both above and below the plane of the fabric blocks grass and weeds from establishing a viable root system needed to support growth. Additional protection is provided by the 4 oz./sq. yd. (136 g/sq. m) geotextile fabric which blocks existing grass and weeds from coming up through the fabric. New plants or desirable existing plants which have roots below the 2" (50 mm) inhibition zone are not adversely affected.

*Tekton is the trademark used for polypropylene products outside of North, Central and South America, Israel and South Africa.

Nodule Cross-Section



Rev 07/26/99

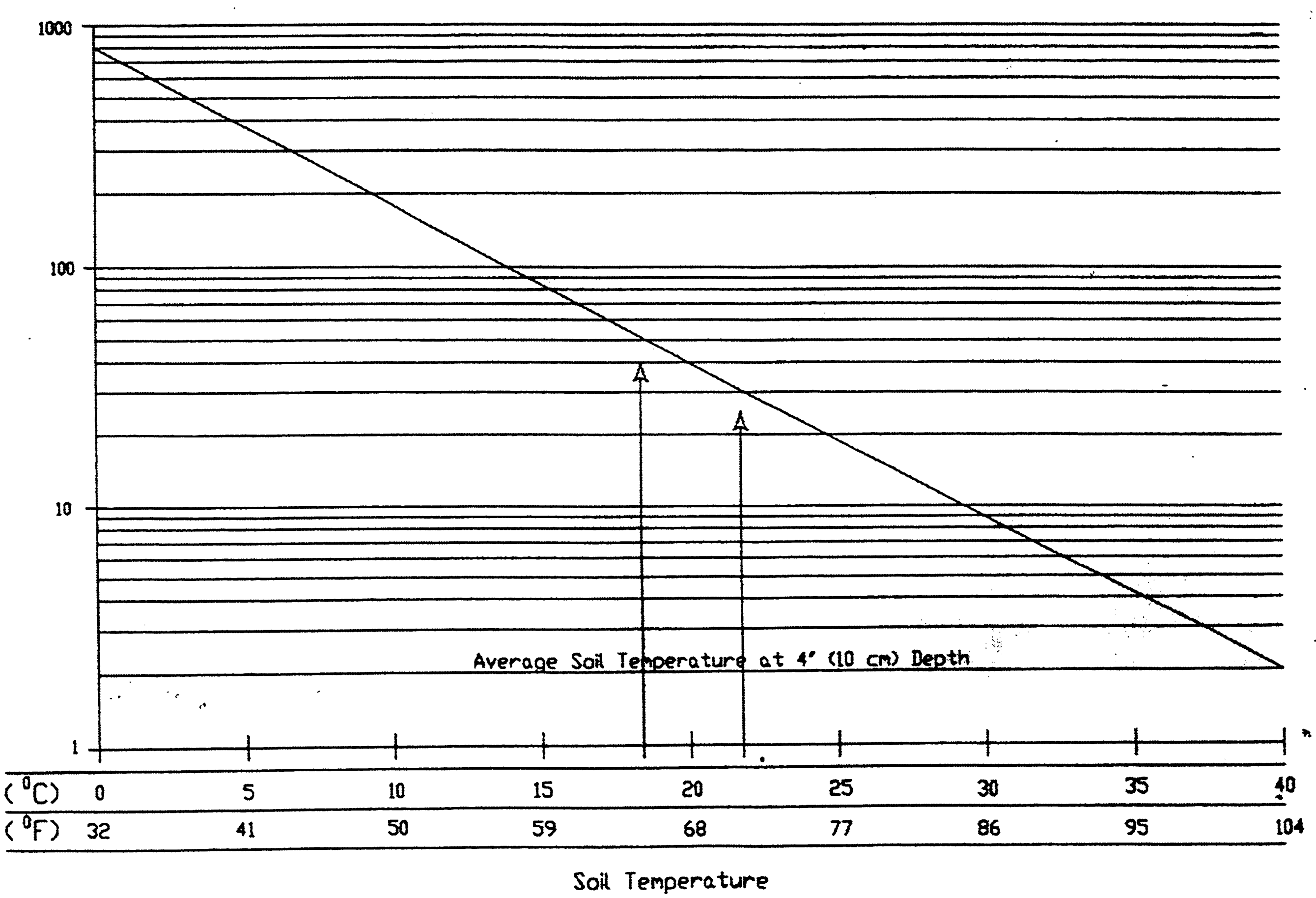
How Trifluralin Works...

The root inhibition zone is created and maintained by the trifluralin released from the nodules. Consequently, the highest trifluralin concentration in the soil is at the plane of the barrier, with concentration levels diminishing as distance from the barrier increases. The concentration level effective for all roots measured is less than 7.6 ppm. Plant species vary in resistance to trifluralin. This concentration level at zone equilibrium, based on field and laboratory measurements, occurs approximately 1" (25 mm) from the barrier. Some root branch elongation may occur after the root tip meets the effective concentration level, pushing the tip within the 1" (25 mm) zone.

With a water solubility of 0.3 ppm, trifluralin does not present a significant leaching problem. Additionally, trifluralin has a high soil adsorption and short half life.

With a U.S. EPA Class IV rating and an Oral LD50 of 10,000, technical grade trifluralin is considered practically non-toxic, ranking it between sugar (29,700) and salt (3,000). Since only a minute amount of trifluralin is emitted from the Biobarrier nodules at any point in time, the hazard is minimized. **The U.S. EPA does not require a pesticide applicator license to install Biobarrier.**[2]

Biobarrier Effective Life



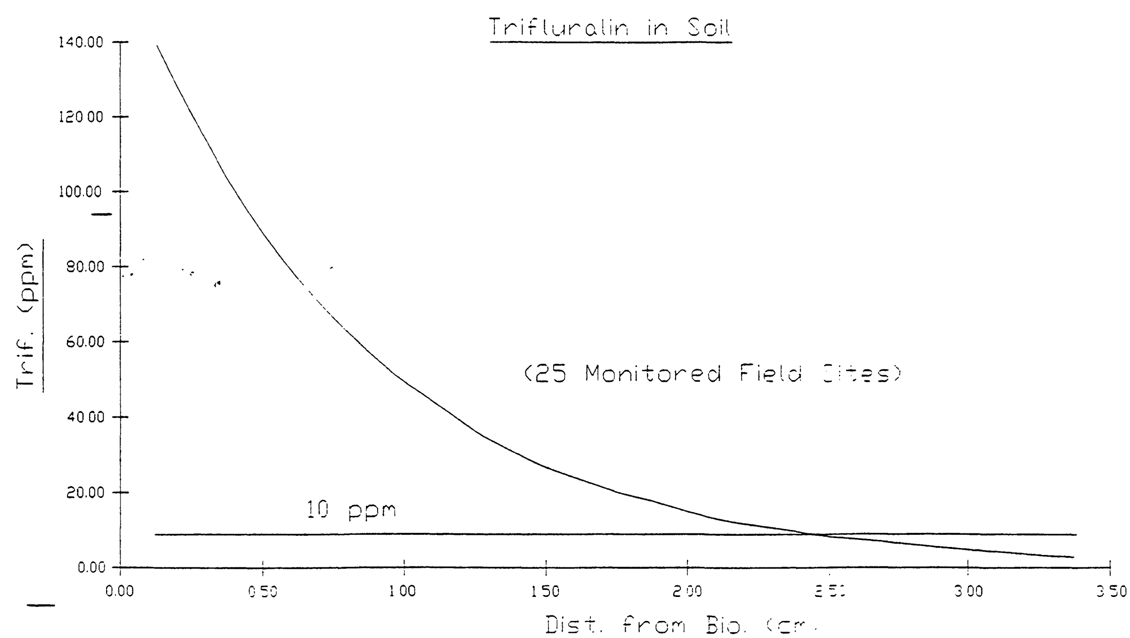
[2] Check agency in your area for local requirements.

Technical Data - Biobarrier®

The hemispherical shaped nodules on Biobarrier contain one active ingredient (trifluralin) and two inactive ingredients (polyethylene and carbon black). Biobarrier is engineered to release the trifluralin very slowly in vapor form and establish a narrow (see chart below) protective chemical zone in soil adjacent to the fabric. This unique delivery method, combined with the chemical characteristics of trifluralin detailed below, ensure that the chemical zone remains very near the fabric and does not present a significant leaching problem. Trifluralin has been used extensively in commercial applications for over 35 years and widely recognized as a leading preemergence herbicide. See EPA Toxicity Rating for trifluralin below. NOTE: The United States EPA does not require a pesticide applicator license to install Biobarrier®. Check agency in your area for local regulations.

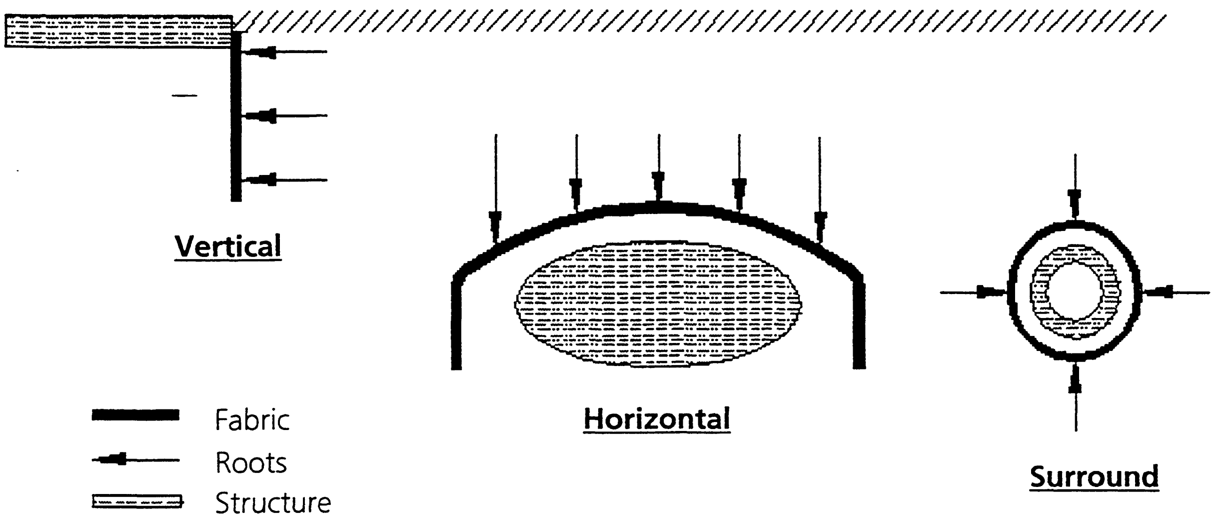
Environmental Fate of Trifluralin	
Solubility in Water	<0.3 ppm @ 25 c
Vapor Pressure (mm Hg @ 25 C)	1.0×10^{-4}
Degradation in Soil	1 to 6 Months
Half Life	
Air Photolysis	42 Minutes
Water Photolysis	9 Hours
Soil Photolysis (Dark)	41 Days
Soil Photolysis (Light)	66 Days

EPA Toxicity Ratings	
4 Classifications	*LD 50 (mg/kg)*
1. Extremely toxic	<50
2. Highly Toxic	50 to 500
3. Moderately Toxic	500 to 5,000
4. Practically Non-Toxic	5,000 to 15,000
Toxicity Examples	
1. Nicotine	32
2. Aspirin	1,000
3. Salt	3,000
4. Trifluralin	*10,000*
5. Alcohol	14,000
6. Sugar	29,700
	*Acute Oral (rats)



Application Categories

Biobarrier® is utilized in many ways to accomplish the common goal of preventing root intrusion and possible structural damage. The major application categories are: (1) Vertical, (2) Horizontal and (3) Surround, as illustrated below.



Vegetation roots are opportunistic, traveling long, erratic paths - when necessary - to survive. Lateral root growth, however, predominates. Under most conditions, 80% of the roots occupy the upper 18 inch (460mm) layer immediately below the grade level. Root system growth patterns are influenced by environmental and soil conditions. Typically, dry climate species' roots grow deeper. Densely packed soils, rock stratum, etc. sometimes produce the unexpected. The tree drip line is not a growth limitation.

Biobarrier is almost always used to exclude roots by diverting the growth path from protected areas. When used to confine root systems, care must be taken to provide sufficient soil volume within the confined area to support the mature species. Without sufficient soil volume, aerial growth will be stunted. In the worst case, the species will die from lack of nutrients, as with any method of reducing root growth. **Consult local arborist for site specific design**.

Root Control Applications

Purpose:

Biobarrier Root Control installations effectively divert lateral root growth. They are used to prevent hardscape damage by root encroachment and to separate root systems for nutrient allocation or to isolate diseased root systems.

In a vertical application, the top edge of the barrier is always positioned 1" (25 mm) below the soil surface. Selection of the barrier width is based primarily on the species involved, the lateral size of the hardscape, and the soil environment. Protection of subterranean structures usually involves overfills of 31 inches (800mm) or greater. This volume of soil permits normal vegetation growth, while excluding roots from structure encroachment. Most installations require no alteration for soil hydrology i.e. the drain layer in landfills or next to foundation or walls. If diversion of water flow is required, a geomembrane is used in conjunction with Biobarrier e.g. under landfill toe drains.

Typical Applications:

To Separate:

- Golf Course Greens
- Planting Beds
- Tree Farms

To Redirect Roots:

- Curbs, Sidewalks, Roads, Median Planters
- Bike/Golf Cart Paths, Golf Greens, Sand Traps, Fairways
- Tennis Courts, Swimming Pools
- Building Foundations, Drain Lines, Septic Fields
- Waste Landfill Caps and Drains, Utility Lines, Septic Fields, Burial Vaults, Earth Dams and Dikes

Note: In locations with a high water table, roots tend to resurface sooner. Biobarrier® may need to be installed deeper. Consult a local arborist for recommendation.

Vertical Installation Instructions

Contact your utility company prior to trenching if you suspect service lines are) present. Consult a professional arborist if extensive root trimming is involved. Wear impervious gloves and goggles when handling Biobarrier to avoid possible irritation from rubbing eyes and to avoid staining hands.

1. Cut a trench 2-4 inches (50-100mm) wide and at least 20 ft. (6100mm) long centered on the root source and adjacent to the structure using clean-cutting trench digging equipment (See FIGURE 1).

2. Install Biobarrier as quickly as possible (within 12 hrs.) after opening sealed wrap; high temperatures and direct sunlight reduce effective life. Place excess material in original wrap and seal with spare ties provided.

3. Roll out the Biobarrier and trim the length of the trench (See FIGURE 2).

4. Remove the paper backing from tape located on one edge of the II"x30' Installation strip (See FIGURE 3)

5. Place taped edge of strip between the first and second row of nodules starting at one end of the Biobarrier and press firmly to ensure good adhesion (See FIGURE 4).

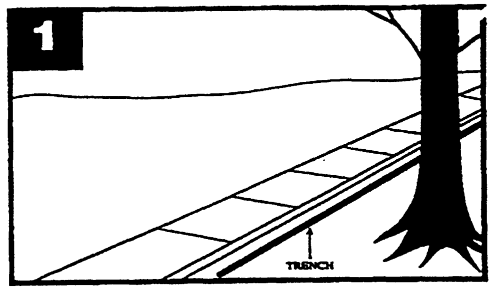
6. Place installation strips approximately 2.5 ft. (760mm) apart the entire length of Biobarrier.

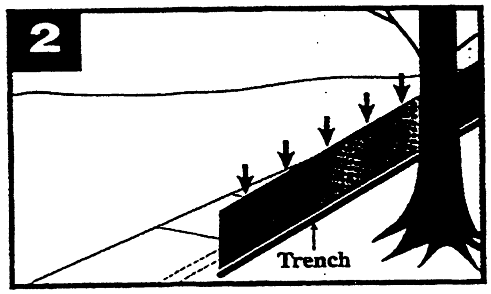
7. Use strips to lower Biobarrier into the trench and position the top edge of the fabric I inch (25mm) below the surface by folding the top edge of the strip over onto the flat soil or hardscape next to trench (See FIGURE 5).

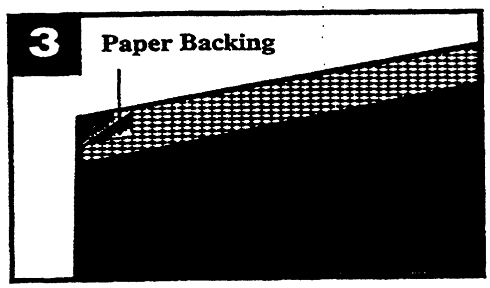
8. Anchor the Biobarrier by stapling the dark gray strips into the soil using staples provided, or by putting soil on top to hold in place; tamp backfill firmly and remove dark gray strips after job is complete.

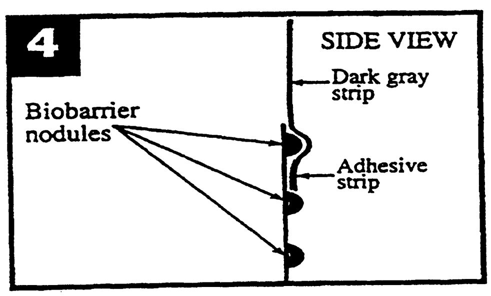
These guidelines treat a typical urban sidewalk application. Other installations such as property lines, building foundations, retaining walls, ornamental beds, septic systems and storm drains may require minor procedural adjustments.

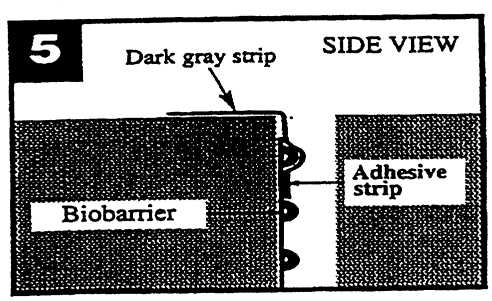
For technical assistance call toll-free: 1-800-284-2780.











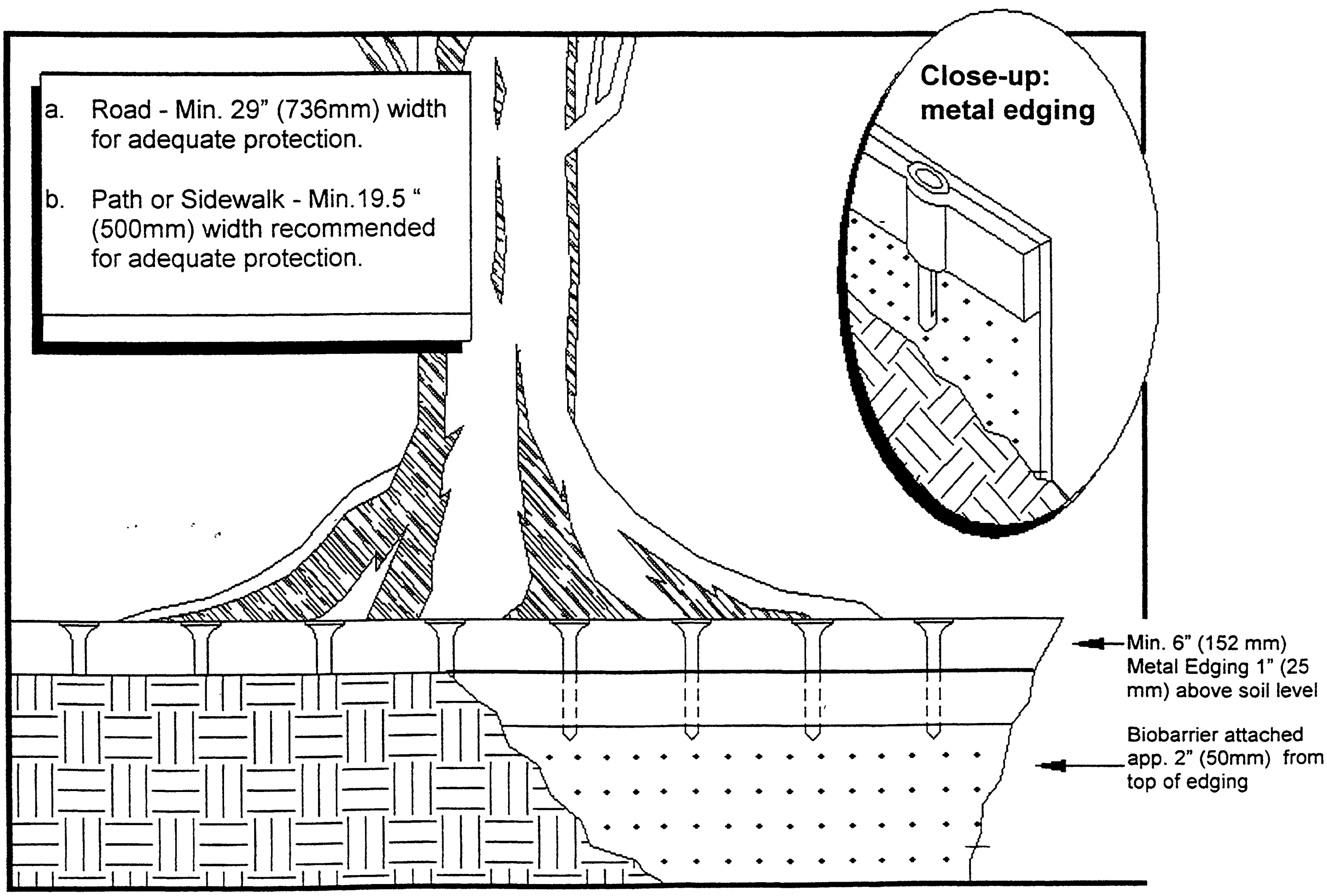
Special Installation Instructions for Unusual Conditions

When two or more of the following conditions exist, special precautions, detailed below, should be followed for maximum prevention of root overgrowth of fabric.

1. Base of potential problem tree is higher than protected hardscape
2. Soil is over 90% sand
3. Tree species is aggressive, top rooting variety such as maple, ficus, etc. Consult a local arborist for species questions or recommendations if necessary.
4. Tree is closer than eight feet (2400mm) from edge of protected hardscape.

Special Precautions (See Drawing Below)

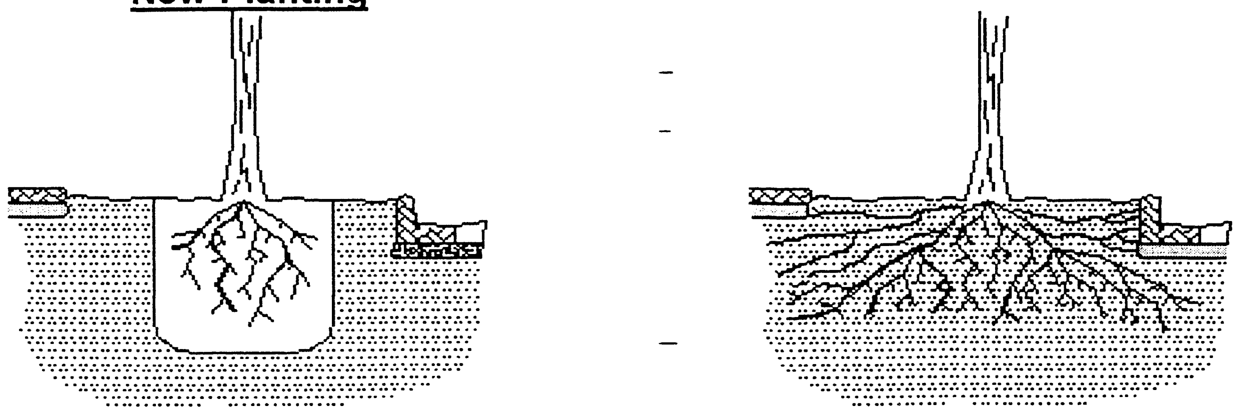
1. Wherever practical, build level of soil adjacent to protected hardscape to a level even with or above base of tree.
2. Attach Biobarrier approximately two inches (50 mm) from the top edge of commercially available metal edging using hot or cold adhesive. For hot application use general adhesives hot melt #64x884 or equivalent. For cold applications use Macco adhesives "Fix-n-Seal" high performance clear sealant F S- U S, Prod. No. 1450113 or equivalent.
3. Install metal edging adjacent to protected hardscape with Biobarrier attached. Leave metal edging approximately one inch above grade to prevent root overgrowth. Edging should extend a minimum of 10 feet (3000mm) in each direction from center of tree. Landscape timbers with Biobarrier attached to the bottom may be substituted for edging.

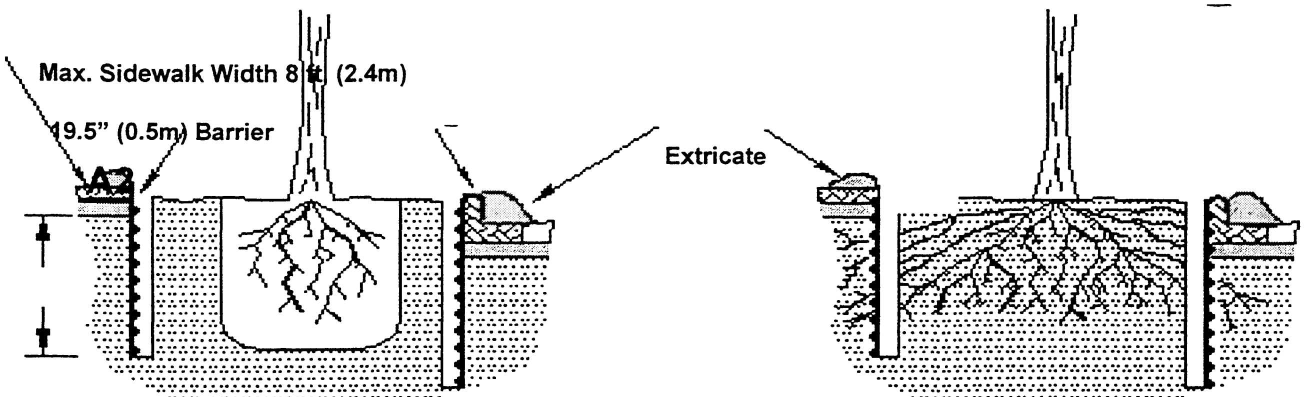


Rev. 08/06/99

Installations
Sidewalk & Curb

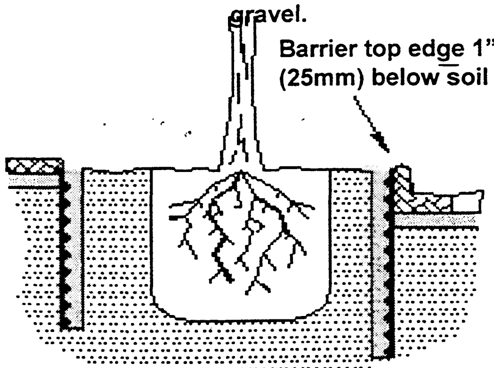
New Planting **Retrofit**

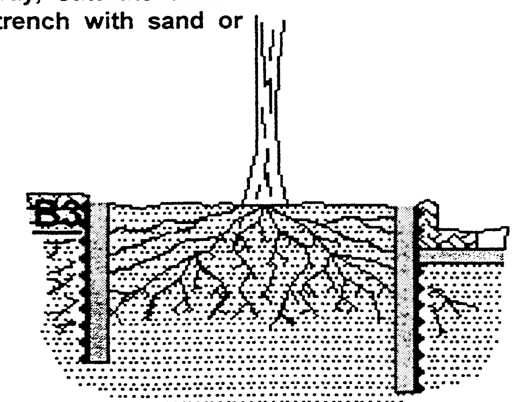




Preferred **Alternate**

For maximum protection in high organic soils (>10%), with aggressive root species (especially a retrofit installation) &/or in close proximity to olefin plastics, spray, saturate trench walls with liquid trifluralin. Mix or fill trench with sand or gravel.

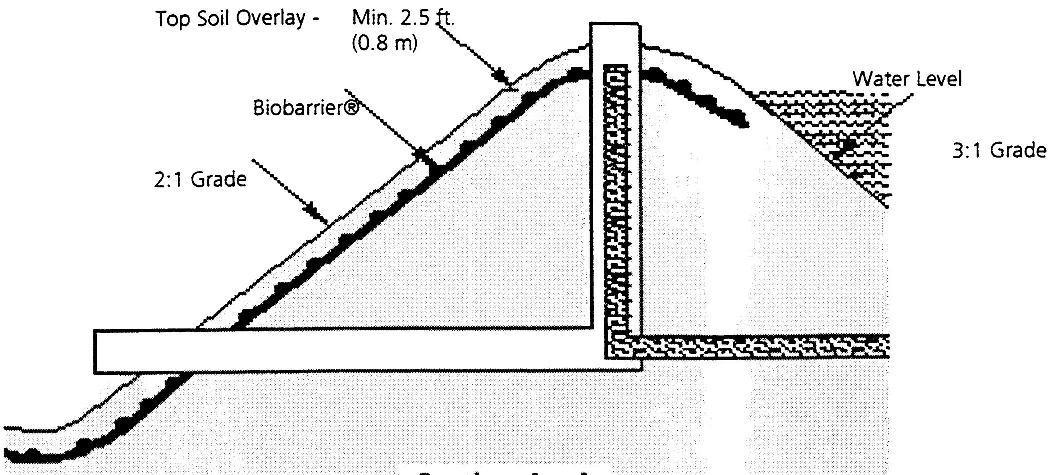




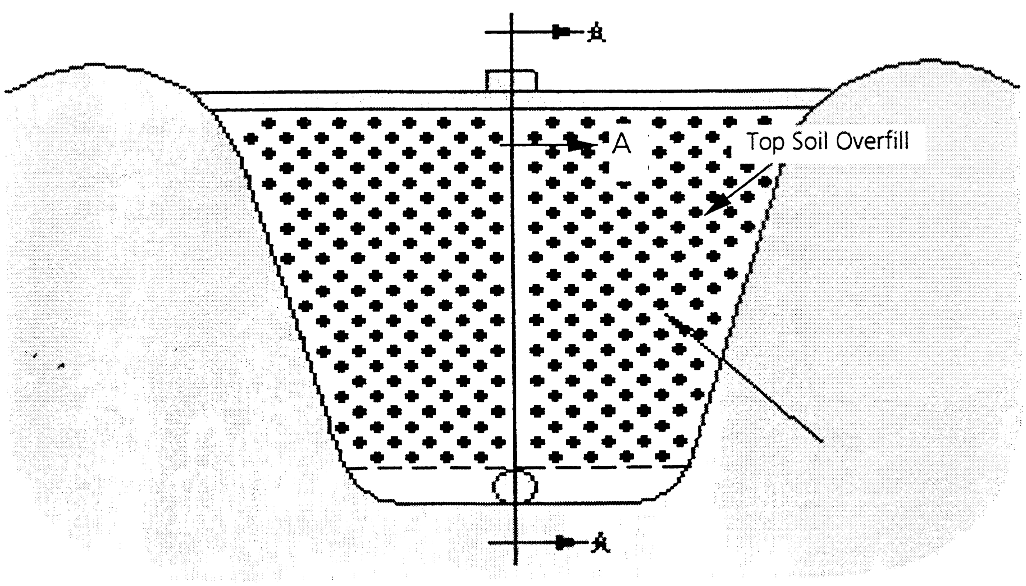
<u>Roots that have been severed should be removed or treated with a systemic herbicide, using caution not to come in contact with remainder of root on desired tree.</u>

Rev. 08/06/99

Installation - Earth Dam



Section A - A



30 x 100 ft. (9 x 46 meters)
Earth Dam

32 Strips of 58.5 inch (1.5 m) Biobarrier® with Continuous Hot Melt Seams

→ A

Surround Applications

Surround applications utilize an envelope of root control **Biobarrier**® to isolate root-sensitive objects from root systems. Therefore, they normally have a minimal effect on the soil volume available for root nutrients. Biobarrier provides the unique advantage of serving as a root barrier without affecting the soil hydrology.

Biobarrier's fabric construction offers easy contouring to fit any configuration. It can be readily cut with a knife or scissors. Because of its inhibition zone, root exclusion seams are obtained simply by overlapping or seaming. To resist the forces of soil shifting, seams can be permanently cemented using various adhesives (see seaming instructions).

Surround applications involve a wide variety of installation techniques. Sketches illustrating a few specific examples of how Biobarrier is applied are offered as guides. For your specific application, use our toll-free number (1-800-284-2780) or 615-847-7000. Our Technical Department will be glad to assist you.These guidelines treat a typical installation for subterranean structure protection. Actual installations must conform to local standards and codes and may require additional technical assistance to assure full Biobarrier benefits.

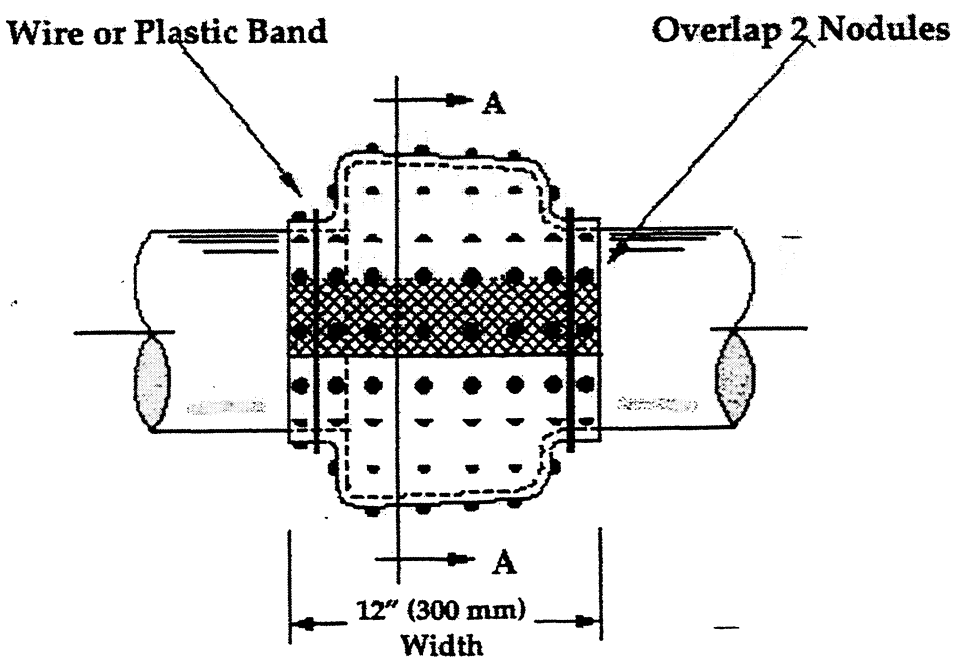
Typical Examples:

To Protect:

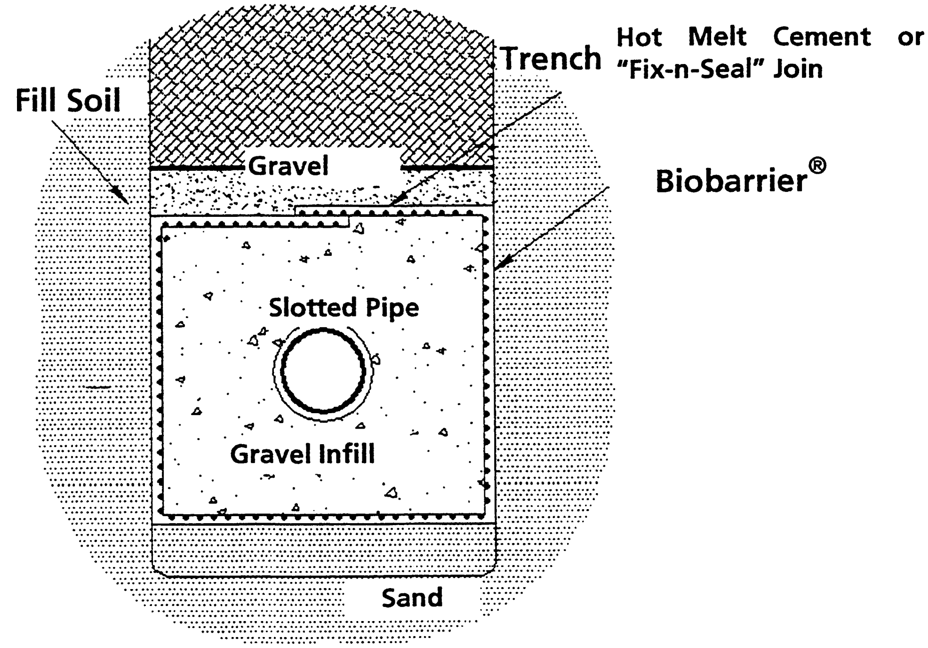
- Drain Lines, Septic Fields, Underground Pipes/Cables

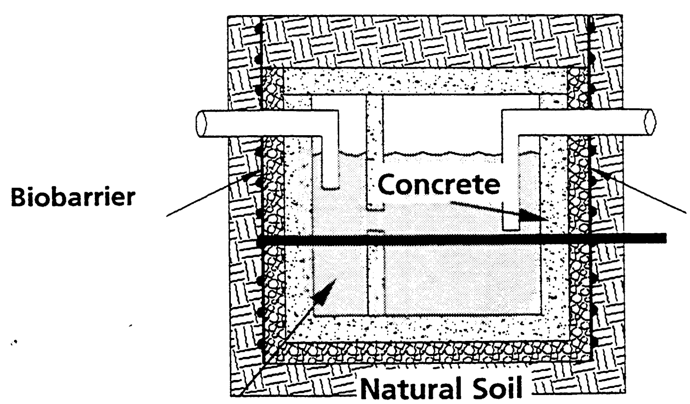
Surround Installations

(Pipe Joint Illustrated)



Drain Line/Septic Tank Installation





For maximum protection, place Biobarrier root control fabric in the ground as shown. Completely surround the tank and seam by placing the Biobarrier outside of the stone. The geotextile fabric also serves to maintain the separation between soil and stone. Cut-outs for inflow and outflow pipe penetrations should be snuggly attached around pipes. Wrap each inflow and outflow pipe junction with Biobarrier.

Combination Applications

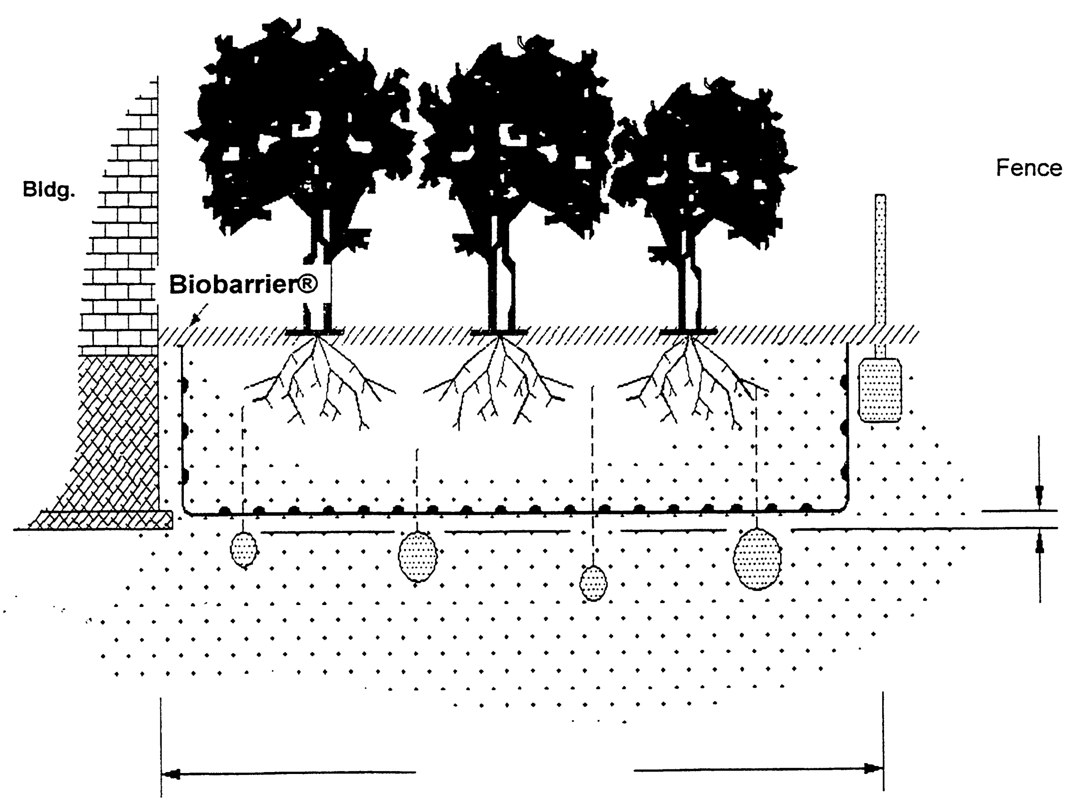
Combinations of these application categories are often used to meet multiple protection requirements. **Biobarrier**® readily lends itself to these more complex installations because of its flexibility, conformity and permeability characteristics; consequently, an effective, contiguous barrier of virtually any shape is possible.

To protect utility lines in a corridor, Biobarrier is positioned to confine the roots to the corridor, providing protection to the adjacent buildings and the roadway, as well as the four utility lines. This is accomplished without unduly restricting soil volume available for root system growth or altering soil hydrology.

Typical Examples:

Utility Lines, Corridors, etc.

Corridor Utility Line Illustrated



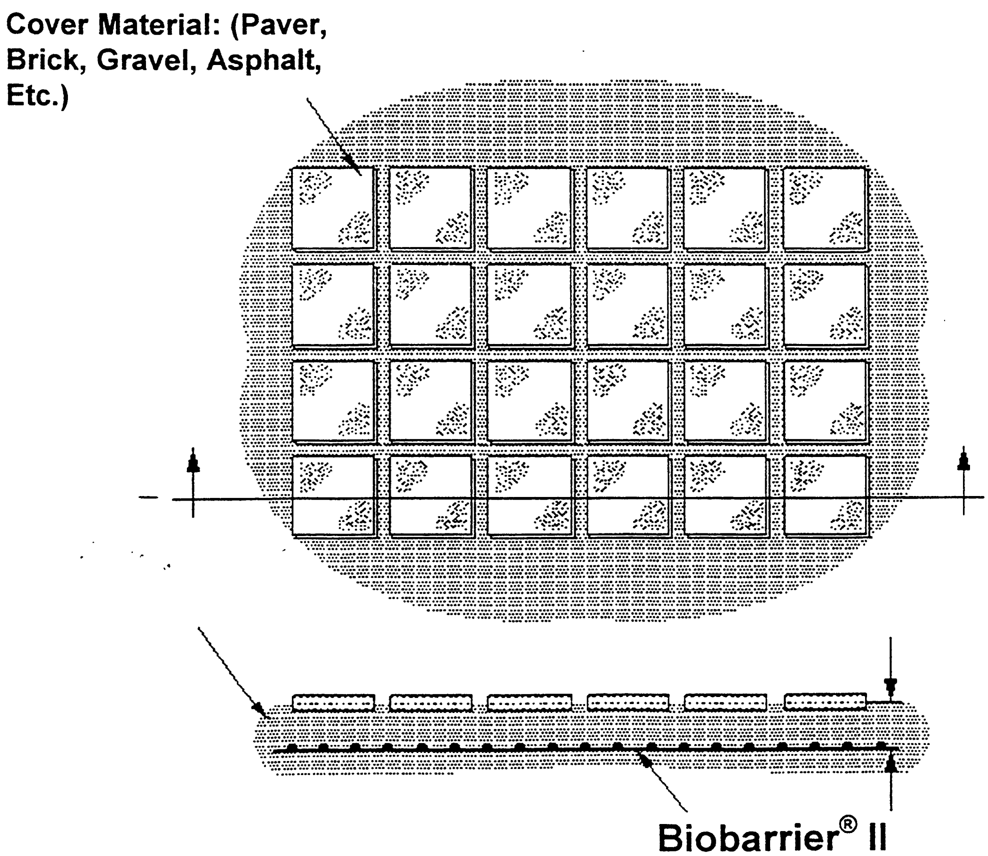
Weed Control Applications

Biobarrier® Pre-emergence Weed Control fabric is installed horizontally 2 inches (50 mm) beneath the surface for long-term weed control. Horizontal applications usually require flexible wide-width barriers capable of adjusting to soil shifts without damage. Biobarrier, utilizing a geotextile fabric, is designed for this purpose. Any required width can be obtained by overlapping the product or, preferably, hot-melt seaming.

When properly installed in weed control applications, Biobarrier limits soil available for weed roots to establish a viable root system. Trifluralin vapors migrate through the soil and into the cover material. Below a capped surface, the vapors are concentrated in cracks and crevices where unwanted vegetation would normally persist.

Typical Examples:

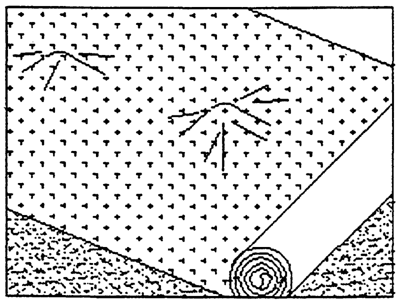
- Paver, Brick, Asphalt or Gravel Walkways, Planting Beds (Non-Food Ornamentals)
- Parking Lots, Playgrounds and Utility Substations



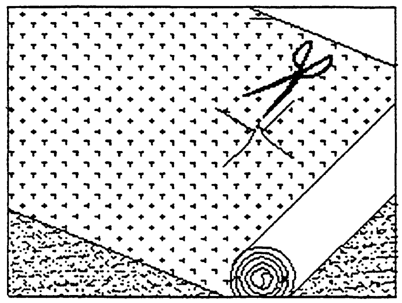
Biobarrier®II
Weed Control Installation

Installation Instructions:

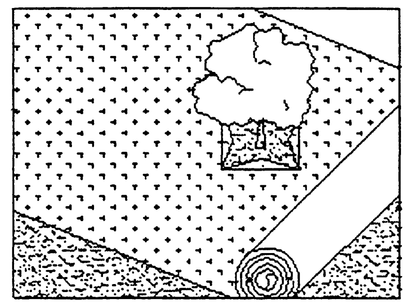
1. Remove unwanted vegetation (particularly green foliage) and materials that can puncture the fabric.
2. Wear gloves & eye protection (goggles); avoid contact with skin and clothing to prevent staining.
3. Open the sealed yellow barrier wrap and install Biobarrier as quickly as practical. High temperatures and direct sunlight can reduce effective life. Place unused material in the barrier wrap and seal with ties provided.
4. Position and cut the fabric allowing for existing or new plants. Add width, if required, and fix in place with stakes provided (see illustrations A through F):



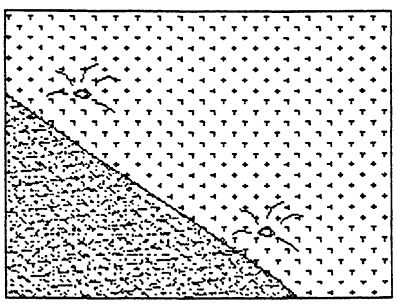
A. Simply roll fabric out gently over existing plants.



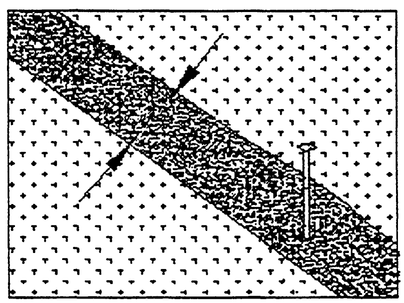
B. Cut "X" above each plant with household scissors or knife forming triangular flaps.



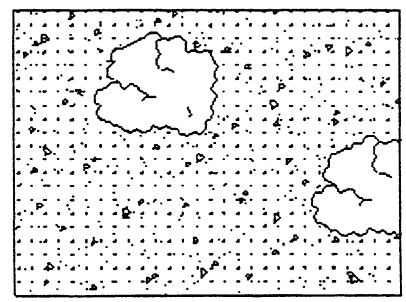
C. Fit fabric around each plant. Fold back flaps against each plant



D. Fix fabric edges in place, about every four feet (1.2 m) with stakes provided.



E. Add width if required by overlapping fabric three inches (75 mm) and staking in place.



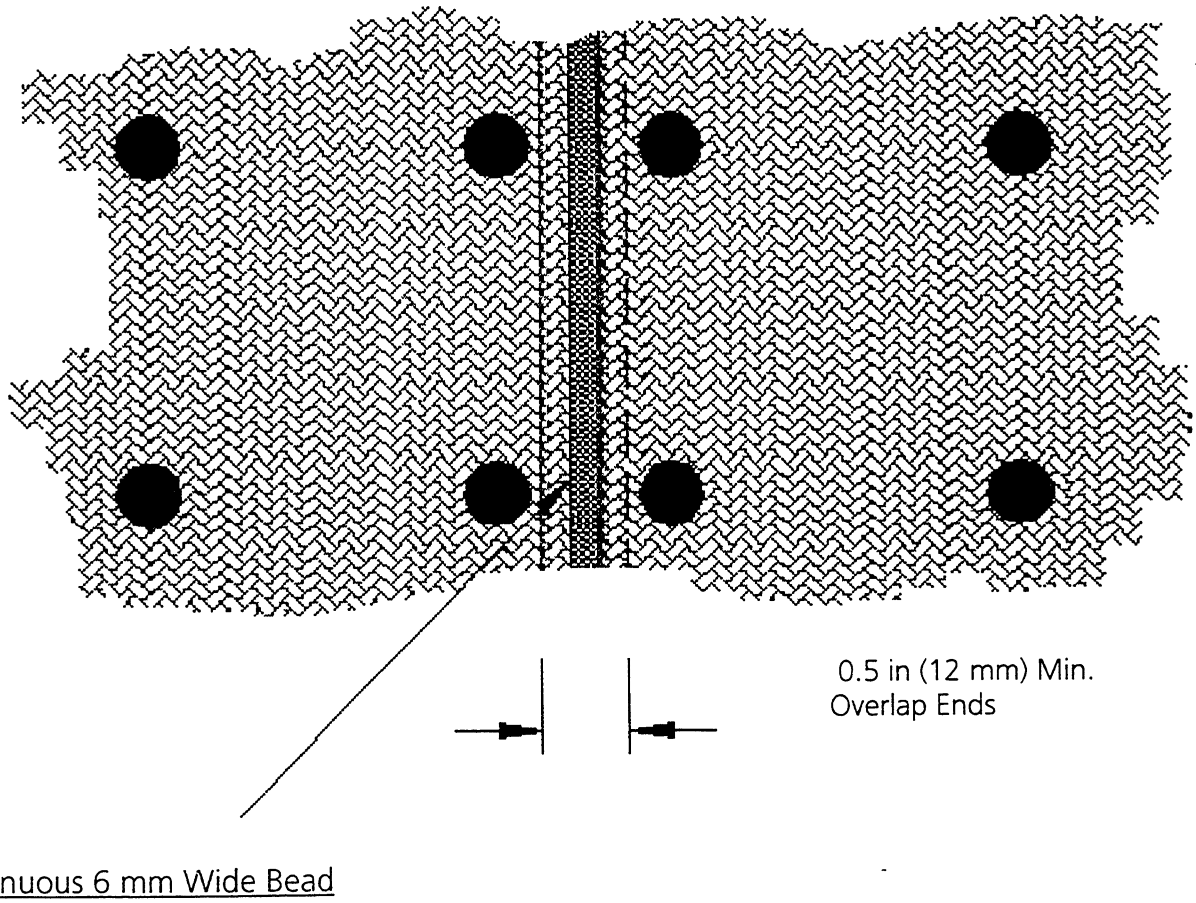
F. Cover fabric with 2 inches (50 mm) of material.

Ensure a two inch (50 mm) cover material depth is maintained.

These guidelines treat a typical installation for surface vegetation control. Minor procedural changes may be required depending on your specific application.

<u>For technical assistance, call our toll free number: 1-800-284-2780</u>

Biobarrier® Seaming Instructions



Hot Application
General Adhesive Co
Hot Melt #64 x 884
or equivalent

Cold Application
Macco Adhesives
"Fix-n-Seal"
High Performance Clear Sealant
FS-45, Product No. 1450113
or equivalent

Product Description

Biobarrier®Root Control

Biobarrier® is a long-term root control system which utilizes time release of a herbicide. When properly installed, it prevents damage to hardscape and other areas from root intrusion. Effective life of Biobarrier is more than 15 years with exact life depending on specific installation conditions.

		Typical
Active Chemical*:	Trifluralin (a,a,a-Trufluro 2,6 - dinitro - N,N, - Dipropyl - p - toluidine)	18.9%
Inert Ingredients:	100% Spunbonded Polypropylene, Polyethylene and Carbon	81.1%

Appearance: Gray (light) with Black Nodule
Specific Gravity: <1.00 **Odor:** No Appreciable

	English	Metric	Test Method*
Unit Wt. (Minimum Value)	12.0 oz/yd^2	410 g/m^2	ASTM D-5261
	Typical Values		
Trifluralin Characteristics	**English**	**Metric**	**Test Method***
Vapor Pressure (mm Hg @ 25 °C)	1x10^{-4}	1x10^{-4}	EPA CG 1600
Solubility in Water (ppm @ 25 ° C)	<0.3	<0.3	EPA CG 1500
	Minimum Values		
Fabric Properties	**English**	**Metric**	**Test Method***
Unit Weight	3.9 oz/yd^2	130 g/m^2	ASTM D-5261
Grab Tensile Strength	130 lbs.	575 N	ASTM D-4632
Elongation at Break	60%	60%	ASTM D-4632
Puncture Strength	40 lbs.	175 N	ASTM D-4833
Trap Tear	60 lbs.	265 N	ASTM D-4533
Permittivity	0.7 sec.	0.7 sec.	ASTM D-4491
AOS (Max. Value)	0.21 mm	0.21 mm	ASTM D-4751
Ultraviolet Stability	70% @ 500 hrs.	70% @ 500 hrs.	ASTM D-4355

*Test methods and revision dates available on request

***Biobarrier Width (in.)**

Intended Uses	19.5	29	39	58.5
Landscape Beds	*	*		
Sidewalks	*	*		
Driveways	*	*	*	
Curbs	*	*	*	
Walkways	*	*		
Parking Lots	*	*	*	
Tennis Courts	*	*	*	
Jogging/Bike Trails	*	*		
Drainage Pipes	*	*	*	*
Bldg. Foundations		*	*	*
Home Patios	*	*	*	
Greens	*	*	*	
Tees	*	*	*	
Fairways	*	*		
Cart Paths	*	*		
Bunkers/Traps	*	*		

Biobarrier Roll Sizes

Width In(cm)	Length ft(m)	Approx. Dia. in(cm)	Approx. Weight lb.(kg)	Approx. Area/Rl ft^2(m^2)
19.5(50)	20(6.1)	6(15)	6(2.7)	32.5(3.0)
19.5(50)	100(30.5)	11(28)	24(10.9)	162.4(15.1)
29(74)	20(6.1)	6(15)	8(4.8)	48(4.5)
29(74)	100(30.5)	11(28)	36(24.2)	242(22.4)
39(99)	20(6.1)	6(15)	10(5.5)	65(6.0)
39(99)	100(30.5)	11(28)	48(21.8)	325(30.2)
58.5(149)	20(6.1)	6(15)	16(7.3)	97.5(9.1)
58.5(149)	100(30.5)	11(28)	72(32.7)	487.5(45.3)

*This chart is a general guide only. Your specific applications may require slightly different sizes. As a general rule, the greater the fabric width, the greater the degree of protection against costly root damage. But, like any other barrier, the protection does not extend beyond the dimensions of the fabric. It is important to use adequate width to assure proper protection.

EPA Reg. #59823-1 EPA Est. 59823-TN-1

Specification-Root Control

1. SCOPE

1.1. This is a materials specification covering root control barrier in trenches, alongside hardscape structures such as sidewalks, curbing, pavements, concrete and building foundations to prevent structural damage due to root penetration. The product functions to provide both a physical and chemical barrier zone to restrict vegetative root encroachment.

1.2. This is a material purchasing specification and design review of its use is recommended.

2. REFERENCED DOCUMENTS

2.1. *ASTM Standards

D-5261	Test Method for Measuring Mass per Unit Area of Geotextiles
D-4632	Test Method for Grab Breaking Load and Elongation of Geotextiles
D-4833	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D-4533	Test Method for Trapezoid Tear Strength of Geotextiles
D-4491	Test Method for Water Permeability of Geotextiles by Permittivity
D-4751	Test Method for Determining the Apparent Opening Size of a Geotextile
D-4355	Test Method for Deterioration of Geotextiles from Exposure to Ultroviolet Light and Water (Xenon-Arc Type Apparatus)

2.2. *EPA Standards (Reference EPA Label)
Registration No. 59823-1 (Attached Exhibit B)

EPA	CG	1500	Water Solubility
EPA	CG	1600	Vapor Pressure

3. PHYSICAL AND CHEMICAL REQUIREMENTS

3.1. Fibers used in the manufacture of root control barrier substrate fabric shall consist of long chain synthetic polyolefins (at least 95% by weight) and a UV stabilizer. They shall be formed into a stable network such that the filaments or yarns retain their dimensional stability relative to each other.

3.2. Nodules consisting of trifluralin, carbon black, and polyethylene compounded in a patented method utilizing time-released characteristics are permanently attached to the substrate fabric on 1-1/2" centers by a through injection molding process.

3.3. All substrate property values, with the exception of apparent opening size (AOS), in these specifications represent minimum average roll values (MARV) in the weakest principal direction (i.e., average test results of any roll in a lot sampled for conformance or quality assurance testing shall meet or exceed the minimum values provided herein). Values for AOS represent maximum average roll values .

3.4. Property values for the trifluralin are average run values.

4. CERTIFICATION

4.1. The Manufacturer shall provide to the Engineer a certificate stating the name, product name, style number, chemical composition and other pertinent information to fully describe the product.

4.2. The Manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

4.3. The Manufacturer's certificate shall state that the root control product meets requirements of the specification as evaluated under the Manufacturer's quality control program. The certificate shall be attested to by a person having legal authority to bind the Manufacturer.

[1]Available from ASTM, 1916 Race Street, Philadelphia, PA 19103

Rev 07/26/99

4.4. Either mislabeling or misrepresentation of materials shall be reason to reject those products.

5. SAMPLING, TESTING, AND ACCEPTANCE

5.1. Root control substrate product shall be subject to sampling and testing to verify conformance with this specification. Acceptance shall be based on manufacturer's certifications.

5.2. Testing shall be performed in accordance with the methods referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method.

6. SHIPMENT AND STORAGE

6.1 Product labels shall clearly show the manufacturer or supplier name, style number, and roll number and shall include a compliance statement certifying that all ingredients and inspection standards for this product have been met.

6.2 Each root control product roll shall be wrapped with a protective EVOH bag and placed in a box that will protect the product from damage due to shipment, water, sunlight, contaminants and to prevent premature release of herbicide. The protective wrapping shall be maintained during periods of shipment and storage.

6.3 During storage, root control product shall be elevated off the ground and out of direct sunlight. It shall remain sealed in EVOH protective bag inside shipping box at a temperature of not more than 110°F.

7. PRODUCT DESCRIPTION

Overall Product Major Composition and Ingredients		**Typical**
Active Chemical*:	Trifluralin (a,a,a-Trufluro 2,6 - dinitro - N,N, - Dipropyl - p - toluidine)	18.9%
Inert Ingredients:	100% Spunbonded Polypropylene, Polyethylene and Carbon	81.1%

	Typical Values		
Trifluralin Characteristics	**English**	**Metric**	**Test Method***
Vapor pressure (mm Hg @ 25 ° C)	1x10-4	1x10-4	EPA CG 1600
Solubility in Water (ppm @ 25 ° C)	<0.3	<0.3	EPA CG 1500

	Minimum Values		
Fabric Properties	**English**	**Metric**	**Test Method***
Unit Weight	3.9 oz/yd^2	130 g/m^2	ASTM D-5261
Grab Tensile Strength	130 lbs.	575 N	ASTM D-4632
Elongation at Break	60%	60%	ASTM D-4632
Puncture Strength	40lbs.	175 N	ASTM D-4833
Trap Tear	60lbs.	265 N	ASTM D-4533
Permittivity	0.7 sec.	0.7 sec.	ASTM D-4491
AOS (Max Value)	0.21 mm	0.21 mm	ASTM D-4751
Ultraviolet Stability	70% @ 500 hrs	70% @ 500 hrs	ASTM D-4355

*Test methods or revision numbers available on request (18.9% Average trifluralin in total composite, Min. of 20% trifluralin in nodules)

Specification-Weed Control

1. SCOPE

1.1 This is a materials specification covering pre-emergence weed control fabrics for use under guardrails along highways, under fences, around posts and signs, and in any other areas where surface weeds must be controlled by use of mechanical means or spraying. The product functions to provide both a physical and chemical barrier zone to prevent vegetative root encroachment, minimizing surface vegetation.

1.2 This is a material purchasing specification and design review of its use is recommended.

REFERENCED DOCUMENTS

2.1 *ASTM Standards

D-5261	Test Method for Measuring Mass per Unit Area of Geotextiles
D-4632	Test Method for Grab Breaking Load and Elongation of Geotextiles
D-4833	Test Method for Index Puncture Resistance of Geotextiles, Geomembranes and Related Products
D-4533	Test Method for Trapezoid Tear Strength of Geotextiles
D-4491	Test Method for Water Permeability of Geotextiles by Permittivity
D-4751	Test Method for Determining the Apparent Opening Size of a Geotextile
D-4355	Test Method for Deterioration of Geotextiles from Exposure to Ultroviolet Light and Water (Xenon-Arc Type Apparatus)

2.2 *EPA Standards (Reference EPA Label)
Registration No. 59823-1

EPA	CG	1500	Water Solubility
EPA	CG	1600	Vapor Pressure

3. PHYSICAL AND CHEMICAL REQUIREMENTS

3.1 Fibers used in the manufacture of pre-emergence weed control substrate fabric shall consist of long chain synthetic polyolefins (at least 95% by weight) and a UV stabilizer. They shall be formed into a stable network such that the filaments or yarns retain their dimensional stability relative to each other.

3.2 Nodules consisting of trifluralin, carbon black, and polyethylene compounded in a patented method utilizing time-released characteristics are permanently attached to the substrate fabric on 1-1/2" centers by a through injection molding process.

3.3 All substrate property values, with the exception of apparent opening size (AOS), in these specifications represent minimum average roll values (MARV) in the weakest principal direction (i.e., average test results of any roll in a lot sampled for conformance or quality assurance testing shall meet or exceed the minimum values provided herein). Values for AOS represent maximum average roll values .

3.4 Property values for the trifluralin are average run values.

4. CERTIFICATION

4.1 The Manufacturer shall provide to the Engineer a certificate stating the name, product name, style number, chemical composition and other pertinent information to fully describe the product.

4.2 The Manufacturer is responsible for establishing and maintaining a quality control program to assure compliance with the requirements of the specification. Documentation describing the quality control program shall be made available upon request.

[1]Available from ASTM, 1916 Race Street, Philadelphia, PA 19103

4.3 The Manufacturer's certificate shall state that the preemergence weed control product meets requirements of the specification as evaluated under the Manufacturer's quality control program. The certificate shall be attested to by a person having legal authority to bind the Manufacturer.

4.4 Either mislabeling or misrepresentation of materials shall be reason to reject those products.

5. SAMPLING, TESTING, AND ACCEPTANCE

5.1 Preemergence weed control substrate product shall be subject to sampling and testing to verify conformance with this specification. Acceptance shall be based on manufacturer's certifications.

5.2 Testing shall be performed in accordance with the methods referenced in this specification for the indicated application. The number of specimens to test per sample is specified by each test method.

6. SHIPMENT AND STORAGE

6.1 Product labels shall clearly show the manufacturer or supplier name, style number, and roll number and shall include a compliance statement certifying that all ingredients and inspection standards for this product have been met.

6.2 Each preemergence weed control rproduct roll shall be wrapped with a protective EVOH bag and placed in a box that will protect the product from damage due to shipment, water, sunlight, contaminants and to prevent premature release of herbicide. The protective wrapping shall be maintained during periods of shipment and storage.

6.3 During storage, preemergence weed control product shall be elevated off the ground and out of direct sunlight. It shall remain sealed in EVOH protective bag inside shipping box at a temperature of not more than 110°F.

7. PRODUCT DESCRIPTION

Overall Product Major Composition and Ingredients		**Typical**
Active Chemical*:	Triflualin (a,a,a-Trufluro 2,6 - dinitro - N,N, - Dipropyl - p - toluidine)	18.9%
Inert Ingredients:	100% Spunbonded Polypropylene, Polyethylene and Carbon	81.1%

	Typical Values		
Trifluralin Characteristics	**English**	**Metric**	**Test Method***
Vapor pressure (mm Hg @ 25 ° C)	1x10-4	1x10-4	EPA CG 1600
Solubility in Water (ppm @ 25 ° C)	<0.3	<0.3	EPA CG 1500

	Minimum Values		
Fabric Properties	**English**	**Metric**	**Test Method***
Unit Weight	3.9 oz/yd^2	130 g/m^2	ASTM D-5261
Grab Tensile Strength	130 lbs.	575 N	ASTM D-4632
Elongation at Break	60%	60%	ASTM D-4632
Puncture Strength	40lbs.	175 N	ASTM D-4833
Trap Tear	60lbs.	265 N	ASTM D-4533
Permittivity	0.7 sec.	0.7 sec.	ASTM D-4491
AOS (Max Value)	0.21 mm	0.21 mm	ASTM D-4751
Ultraviolet Stability	70% @ 500 hrs	70% @ 500 hrs	ASTM D-4355

*Test methods or revision numbers available on request (18.9% Average trifluralin in total composite, Min. of 20% trifluralin in nodules)

Material Safety Data Sheet-Root Control

Identity: ***Biobarrier® Root Control System***

Manufacturer's Name:	Reemay, Inc.
Address:	70 Old Hickory Blvd. Old Hickory, TN 37138
Transportation Emergency Phone:	Infotrac 1-800-535-5053
Medical Emergency Phone:	1-800-535-5053
Product Information Phone:	1-800-321-6271
Date Prepared:	06/99
MSDS No.1180-6	

SECTION II
HAZARDOUS OR ACTIVE INGREDIENTS

Hazardous Components	OSHA PEL	ACGIH T LV	Other Limits Recommended	% (Optional)
Carbon Black (CAS No-. 133386-4)	3.5mg/m^3 8-hour TWA	3.5mg/m^3 8-hour TWA	None	Proprietary Information
Trifluralin (CAS No. 1582-09-8)	Not Established	Not Established	None	18.9

SECTION III
PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: Not Applicable
Specific Gravity (H_20=1): Less than 1
Vapor Pressure (mm Hg): 1×10^{-4}
Melting Point: Not determined
Vapor Density (AIR=1): Not applicable
Solubility in Water: Only slightly soluble at 0.3 PPM
Evaporation Rate (BUTYL ACETATE=1) Not applicable
Appearance and Odor: Gray or Black Fiber web material with black hemispherical nodules 1-1/2" apart. Aromatic odor.

SECTION IV
FIRE AND EXPLOSION HAZARD DATA

Flash Point (method used): Not applicable
Flammable Limits LEL: Not applicable UEL: Not applicable

NFPA Codes:			HMIS Codes:	
	Health	1	Health	1
	Flammability	0	Flammability	0
	Reactivity	0	Reactivity	0
	Other	0	Other	0

Extinguisher Media: Any Class A fire extinguishing media for ordinary combustibles.

MSDS 1180-6

Special Fire Fighting Precautions: Water spray should be used to cool material and extinguish fire. Dense smoke and toxic gases will be generated in a fire involving this material. Firefighters should use NIOSH/MSHA approved positive pressure self-contained breathing apparatus when any material is involved in a fire.

Unusual Fire and Explosion Hazards: None

SECTION V
REACTIVITY DATA

Stability: Stable:	Yes	Conditions to Avoid:	None Known
Incompatibility (materials to avoid):		None Known	
Hazardous Decomposition or By-Products:		None Known	
Hazardous Polymerization:	Will not occur	Conditions to Avoid:	None Known

SECTION VI
HEALTH HAZARD DATA

Routes of Entry: Inhalation: Yes Skin: No Ingestion: No

Health Hazards (acute and chronic): It is very unlikely a hazardous condition will exist or be created when working with this product. The ingredients are encapsulated in polypropylene and polyethylene, and unless the product construction is destroyed or severely altered, the ingredients will remain in the encapsulated state.

The regulated material in the product is Carbon Black (CAS No. 1333-86-4) that has an exposure limit of 3.5 mg/m^3 as an 8-hour Time Weighted Average. The product would have to be crushed and ground into a powder in order to free the carbon black before it would present a hazard.

Several studies have been conducted on Trifluralin, the active ingredient in this product. Four studies showed no carcinogenic effect. Two studies produced limited evidence of carcinogenic effect in animals, but these studies were found to be flawed; therefore, it is concluded Trifluralin is not carcinogenic.

Th. 1992 Registry of Toxic Effects of Chemical Substances (1992 RTECS) lists one study that reports Trifluralin as a reproductive toxin. Due to encapsulation in this product, any exposure to the ingredients is extremely unlikely.

Follow the handling and installation instructions on the package label when using this product.

Carcinogenicity: NTP: No IARC Monographs: No OSHA Regulated:No

Signs and Symptoms of Exposure: Inhalation of vapors may irritate eyes and nose. Avoid skin contact as it may cause skin irritation in certain individuals.

Medical Conditions Generally Aggravated by Exposure: None known.

Emergency and First Aid Procedures: If eyes are irritated, flush them with plenty of water. If on the skin, wash thoroughly with soap and water. If irritation or symptoms continue, get medical attention.

SECTION VII
PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be Taken in Case Material is Released or Spilled: No special precautions required.

Waste Disposal Method: Landfill in accordance with Federal, State or Local ordinances.

Precautions to be Taken in Handling and Storage: Avoid contact with skin and eyes. Avoid breathing smoke or vapors if the product is heated to decomposition. Keep material in original packaging until ready for use. Store in a dry place and do not expose to direct sunlight.

Other Precautions: None – Not regulated by OSHA or DOT.

SECTION VIII
CONTROL MEASURES

Respiratory Protection: Respiratory protection not generally required under normal use conditions. If concentrations do exceed the PEL, use NIOSH/MSHA approved respirators.

Ventilation: Local Exhaust: Not Required
Mechanical (General): Heating and cooling systems will normally provide adequate air movement.
Protective Gloves: Ordinary work gloves to prevent excessive skin contact is suggested.
Eye Protection: Yes, goggles
Other Protective Clothing or Equipment: Coveralls or long-sleeved shirt and gloves are recommended to avoid skin staining.
Work/Hygienic Practices: Wash thoroughly before eating, drinking, smoking or leaving the work place. Consult 29 CFR 1910.141, General Requirements for Sanitation.

This form may be used to comply with the OSHA Hazard Communication Standard 29 CFR 1910.1200.

Material Safety Data Sheet-Weed Control

Identity: ***Biobarrier® Preemergence Weed Control System***

Manufacturer's Name: Reemay, Inc.
Address: 70 Old Hickory Blvd.Old Hickory, TN 37138
Transportation Emergency Phone: Infotrac: 1-800-535-5053
Medical Emergency Phone: 1-800-535-5053
Product Information Phone: 1-800-321-6271
Date Prepared: 06/99
MSDS No.1185-3

SECTION II
HAZARDOUS OR ACTIVE INGREDIENTS

Hazardous Components	OSHA PEL	ACGIH T LV	Other Limits Recommended	% (Optional)
Carbon Black (CAS No-. 133386-4)	3.5mg/m^3 8-hour TWA	3.5mg/m^3 8-hour TWA	None	Proprietary Information
Trifluralin (CAS No. 1582-09-8)	Not Established	Not Established	None	18.9

SECTION III
PHYSICAL/CHEMICAL CHARACTERISTICS

Boiling Point: Not Applicable
Vapor Pressure (mm Hg): 1×10^{-4}
Vapor Density (AIR=1): Not applicable
Evaporation Rate (BUTYL ACETATE=1): Not applicable
Appearance and Odor: Gray or Black Fiber web material with black hemispherical nodules 1-1/2" apart. Aromatic odor.
Specific Gravity (H_2O=1): Less than 1
Melting Point: Not determined
Solubility in Water: Only slightly soluble at 0.3 PPM

SECTION IV
FIRE AND EXPLOSION HAZARD DATA

Flash Point (method used): Not applicable
Flammable Limits LEL: Not applicable UEL: Not applicable

NFPA Codes:		HMIS Codes:	
Health	1	Health	1
Flammability	0	Flammability	0
Reactivity	0	Reactivity	0
Other	0	Other	0

Extinguisher Media: Any Class A fire extinguishing media for ordinary combustibles.
Special Fire Fighting Precautions: Water spray should be used to cool material and extinguish fire. Dense smoke and toxic gases will be generated in a fire involving this material. Firefighters should use NIOSH/MSHA approved positive pressure self-contained breathing apparatus when any material is involved in a fire.
Unusual Fire and Explosion Hazards: None
MS 1185-3

SECTION V
REACTIVITY DATA

Stability: Stable: Yes — Conditions to Avoid: None Known
Incompatibility (materials to avoid): None Known
Hazardous Decomposition or By-Products: None Known
Hazardous Polymerization: Will not occur Conditions to Avoid: None Known

SECTION VI
HEALTH HAZARD DATA

Routes of Entry: Inhalation: Yes Skin: No Ingestion: No

Health Hazards (acute and chronic): It is very unlikely a hazardous condition will exist or be created when working with this product. The ingredients are encapsulated in polypropylene and polyethylene, and unless the product construction is destroyed or severely altered, the ingredients will remain in the encapsulated state.

The regulated material in the product is Carbon Black (CAS No. 1333-86-4) that has an exposure limit of 3.5 mg/m^3 as an 8-hour Time Weighted Average. The product would have to be crushed and ground into a powder in order to free the carbon black before it would present a hazard.

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Follow the handling and installation instructions on the package label when using this product.

Carcinogenicity: NTP: No IARC Monographs: No OSHA Regulated:No

Signs and Symptoms of Exposure: Inhalation of vapors may irritate eyes and nose. Avoid skin contact as it may cause skin irritation in certain individuals.

Medical Conditions Generally Aggravated by Exposure: None known.

Emergency and First Aid Procedures: If eyes are irritated, flush them with plenty of water. If on the skin, wash thoroughly with soap and water. If irritation or symptoms continue, get medical attention.

SECTION VII
PRECAUTIONS FOR SAFE HANDLING AND USE

Steps to be Taken in Case Material is Released or Spilled: No special precautions required.

Waste Disposal Method: Landfill in accordance with Federal, State or Local ordinances.

MSDS 1185-3

Precautions to be Taken in Handling and Storage: Avoid contact with skin and eyes. Avoid breathing smoke or vapors if the product is heated to decomposition. Keep material in original packaging until ready for use. Store in a dry place and do not expose to direct sunlight.

Other Precautions: None – Not regulated by OSHA or DOT.

SECTION VIII
CONTROL MEASURES

Respiratory Protection: Respiratory protection not generally required under normal use conditions. If concentrations do exceed the PEL, use NIOSH/MSHA approved respirators.

Ventilation: Local Exhaust: Not Required

Mechanical (General): Heating and cooling systems will normally provide adequate air movement.

Protective Gloves: Ordinary work gloves to prevent excessive skin contact is suggested.

Eye Protection: Yes, goggles

Other Protective Clothing or Equipment: Coveralls or long-sleeved shirt and gloves are recommended to avoid skin stating.

Work/Hygienic Practices: Wash thoroughly before eating, drinking, smoking or leaving the work place. Consult 29 CFR 1910.141, General Requirements for Sanitation.

This form may be used to comply with the OSHA Hazard Communication Standard 29 CFR 1910.1200.

MSDS 1185-3

Precautionary Statements
Hazards to Humans and
Domestic Animals

CAUTION

Causes eye irritation. Harmful if swallowed, inhaled, or absorbed through the skin. Do not get in eyes, on skin, or clothing. The active ingredient trifluralin may cause skin sensitization reactions in certain individuals.

Use eye protection and protective clothing such as coveralls, a long sleeve shirt, and impermeable gloves when handling this product. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash before reuse.

Environmental Hazards:

This pesticide is toxic to fish. Do not apply directly to water or to areas where surface water is present or to intertidal areas below the mean high water mark.

Physical Hazards:

Directions for Use:

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

STORAGE AND DISPOSAL

Storage: Store in original container only. Store in dry place out of direct sunlight.

Pesticide Disposal: Do not contaminate water, food, or feed by storage or disposal. Washes resulting from use of this product may be disposed of on site or at an approved waste disposal facility.

Container Disposal: Completely empty container. Then dispose of wrap and/or box in a sanitary landfill or by incineration, or, if allowed by State and Local authorities, by burning. If burned, stay out of smoke.

General Directions:
Biobarrier® is a multi-year root control system which is strategically positioned in the soil to protect structures from plant root encroachment (see applications). Biobarrier controls roots by establishling an in-soil barrier plane of trifluralin, which prevents root tip cell division. Roots are either stopped or redirected away from structures. Trifluralin is not systemic but can limit root mass. The multi-year feature of Biobarrier is provided by a time-release mechanism which continues to meter trifluralin into the soil as the exposed trifluralin biologically and chemically degrades. Structure protection is provided by placing the Biobarrier fabric between the root source and the structure. Since the fabric is flexible and permeable, installation may be custom contoured to obtain the most desirable root system redirection for the application and/or to accommodate obstacles.

Biobarrier®

Root Control System 1-4

Biobarrier lis a multi-year root control system consisting of time-release nodules impregnated with a herbicide. The nodules are attached permanently to a flexible and permeable geotextile fabric which can be contour applied to a wide variety of applications and which will inhibit plant weed encroachment in the applications set forth below.

Active Ingredient:

Trifluralin (α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine)	18.9%
Inert Ingredients:	81.1%
TOTAL	100.0%

KEEP OUT OF REACH OF CHILDREN

CAUTION

If in eyes:	Flush eyes with plenty of water. Call a physician.
If swallowed:	Call a physician or Poison Control Center. Drink one or two glasses of water and induce vomiting by touching back of throat with finger. Do not induce vomiting or give anything by mouth to an unconscious person.
f on skin:	Wash with plenty of soap and water. Get medical attention if irritation develops.
If Inhaled:	Remove individual to fresh air. If breathing difficulty occurs, get medical attention.

See Side Panel for Additional Precautionary Statements

Mfg. By:

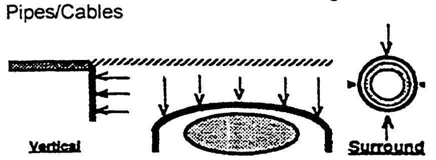
REEMAY

70 Old Hickory Blvd.
P.O. Box 511
Old Hickory, TN 37138
1-800-257-6687

EPA Registration No. 59823-1
Establishment No. 69823-TN-1

Biobarrier Applications*

Curbs	
Roads	Sidewalks
Septic Fields	Planting Beds
Swimming Pools	Tennis Courts
Bike/Golf Cart Paths	Building Foundations
Utility Substations	Hazardous Waste
Landfills	
Burial Vaults/Tombstones	Underground
Pipes/Cables	



*Non Food/Ornamentals

Applications Directions:

Biobarrier® is ready for in-soil installation as received. The fabric should be in soil as soon as practical after removal from the sealed shipping container minimizing exposure to direct sunlight and elevated temperatures. Prolonged exposure can reduce the effective life of the product. Store any unused portions of the product tightly resealed in the original container in a dry place.

Biobarrier can be installed in the soil vertically, horizontally, or as a surround. Vertical applications typically require standard ditch/trench digging equipment (follow all applicable codes when digging below surface). Vertical fabric position can be maintained by suspending it at the top with hangers. Horizontal applications may require seaming or hold down pegs. Surround applications may involve a variety of holding devices to assure fabric position. In all applications, nodules must be no further than 1-1/2. apart in order to assure a continuous weed control plane. Fabric should extend a minimum of 18" beyond structure area to be protected as roots can grow around edges of fabric. A minimum of 2" soil overlay should also be maintained for horizontal applications. For vertical applications, the top edge must be at least 1"below the soil surface.

Biobarrier used in retrofit applications, where roots are already present, requires roots be interrupted with a root pruner or equivalent device. Root control will not be effective if roots penetrate fabric at time of installation.

Disclaimer of Warranties

The Seller makes no warranties concerning this product or its use which extend beyond the standard specifications for the products. **The Seller makes no warranties of merchantability or fitness for a particular purpose, or any other express or implied warranty.**

Buyer assumes all risk and liability resulting from use of the products delivered hereunder, whether used singularly or in combination with other products. All statements concerning this product apply only when used as directed.

Limitation of Damages

No claim of any kind, whether as to products delivered or for nondelivery of products, and whether or not based on negligence, shall be greater in amount than the purchase price of the products in respect to which damages are claimed. No charge or expense incident to any claims will be allowed unless approved by an authorized representative of Seller. Products shall not be returned to seller without Seller's prior permission, and then only in a manner prescribed by Seller. **The remedy hereby provided shall be the exclusive and sole remedy of Buyer, and in no event shall either party be liable for special, indirect or consequential damages, whether or not caused by or resulting from the negligence of such party.**

Precautionary Statements
Hazards to Humans and Domestic Animals

CAUTION

Causes eye irritation. Harmful if swallowed, inhaled, or absorbed through the skin. Do not get in eyes, on skin, or clothing. The active ingredient trifluralin may cause skin sensitization reactions in certain individuals.

Use eye protection and protective clothing such as coveralls, a long sleeve shirt, and impermeable gloves when handling this product. Wash thoroughly with soap and water after handling. Remove contaminated clothing and wash before reuse.

Environmental Hazards:

This pesticide is toxic to fish. Do not apply directly to water or to areas where surface water is present or to intertidal areas below the mean high water mark.

Physical Hazards:

Do not store near heat or open flame.

Directions for Use:

It is a violation of Federal Law to use this product in a manner inconsistent with its labeling.

STORAGE AND DISPOSAL

Storage: Store in original container only. Store in dry place out of direct sunlight.

Pesticide Disposal: Do not contaminate water, food, or feed by storage or disposal. Washes resulting from use of this product may be disposed of on site or at an approved waste disposal facility.

Container Disposal: Completely empty container. Then dispose of wrap and/or box in a sanitary landfill or by incineration, or, if allowed by State and Local authorities, by burning. If burned, stay out of smoke.

General Directions:
Biobarrier®II is a multi-year preemergence weed control system which is strategically positioned in the soil to protect structures from plant root encroachment (see applications). Biobarrier II controls roots by established an in-soil barrier plane of trifluralin, which prevents root tip cell division. Roots are either stopped or redirected away from structures. Trifluralin is not systemic but can limit root mass. The multi-year feature of Biobarrier II is provided by a time-release mechanism which continues to meter trifluralin into the soil as the exposed trifluralin biologically and chemically degrades. Structure protection is provided by placing the Biobarrier II fabric between the root source and the structure. Since the fabric is flexible and permeable, installation may be custom contoured to obtain the most desirable root system redirection for the application and/or to accommodate obstacles

Biobarrier® II

PREEMERGENCE WEED CONTROL SYSTEM

Biobarrier II is a multi-year preemergence weed control system consisting of time-release nodules impregnated with a herbicide. The nodules are attached permanently to a flexible and permeable geotextile fabric which can be contour applied to a wide variety of applications and which will inhibit plant weed encroachment in the applications set forth below.

Active Ingredient:

Trifluralin (α,α,α-trifluoro-2,6-dinitro-N,N-dipropyl-p-toluidine)	18.9%
Inert Ingredients:	81.1%
TOTAL	100.0%

KEEP OUT OF REACH OF CHILDREN

CAUTION

If in eyes:	Flush eyes with plenty of water. Call a physician.
If swallowed:	Call a physician or Poison Control Center. Drink one or two glasses of water and induce vomiting by touching back of throat with finger. Do not induce vomiting or give anything by mouth to an unconscious person.
If on skin:	Wash with plenty of soap and water. Get medical attention if irritation develops.
If Inhaled:	Remove individual to fresh air. If breathing difficulty occurs, get medical attention.

See Side Panel for Additional Precautionary Statements

Mfg. By:

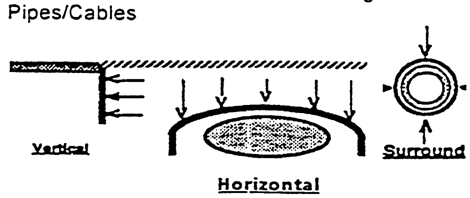
REEMAY

70 Old Hickory Blvd.
P.O. Box 511
Old Hickory, TN 37138
1-800-257-6687

EPA Registration No. 59823-3
Establishment No. 69823-TN-3

Biobarrier II Applications*

Curbs	
Roads	Sidewalks
Septic Fields	Planting Beds
Swimming Pools	Tennis Courts
Bike/Golf Cart Paths	Building Foundations
Utility Substations	Hazardous Waste
Landfills	
Burial Vaults/Tombstones	Underground
Pipes/Cables	



*Non Food/Ornamentals

Applications Directions:
Biobarrier®II is ready for in-soil installation as received. The fabric should be in soil as soon as practical after removal from the sealed shipping container minimizing exposure to direct sunlight and elevated temperatures. Prolonged exposure can reduce the effective life of the product. Store any unused portions of the product tightly resealed in the original container in a dry place.

Biobarrier II can be installed in the soil vertically, horizontally, or as a surround. Vertical applications typically require standard ditch/trench digging equipment (follow all applicable codes when digging below surface). Vertical fabric position can be maintained by suspending it at the top with hangers. Horizontal applications may require seaming or hold down pegs. Surround applications may involve a variety of holding devices to assure fabric position. In all applications, nodules must be no further than 1-1/2. Apart in order to assure a continuous weed control plane. Fabric should extend a minimum of 18" beyond structure area to be protected as roots can grow around edges of fabric. A minimum of 2" soil overlay should also be maintained for horizontal applications. For vertical applications, the top edge must be at least 1" below the soil surface.

Biobarrier II used in retrofit applications, where roots are already present, requires roots be interrupted with a root pruner or equivalent device. Root control will not be effective if roots penetrate fabric at time of installation.

Disclaimer of Warranties
The Seller makes no warranties concerning this product or its use which extend beyond the standard specifications for the products. **The Seller makes no warranties of merchantability or fitness for a particular purpose, or any other express or implied warranty.**

Buyer assumes all risk and liability resulting from use of the products delivered hereunder, whether used singularly or in combination with other products. All statements concerning this product apply only when used as directed.

Limitation of Damages
No claim of any kind, whether as to products delivered or for nondelivery of products, and whether or not based on negligence, shall be greater in amount than the purchase price of the products in respect to which damages are claimed. No charge or expense incident to any claims will be allowed unless approved by an authorized representative of Seller. Products shall not be returned to seller without Seller's prior permission, and then only in a manner prescribed by Seller. **The remedy hereby provided shall be the exclusive and sole remedy of Buyer, and in no event shall either party be liable for special, indirect or consequential damages, whether or not caused by or resulting from the negligence of such party.**

(PROPOSAL)

THE USE OF GROUND-PENETRATING RADAR, ELECTRICAL RESISTIVITY, AND STREAMING POTENTIAL TO ASSESS DAMAGE BY BURROWING ANIMALS TO THREE SELECTED PORTIONS OF EARTHEN LEVEES NEAR DAYTON, OHIO

Spring 1999 - Spring 2000
by

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Dayton, Ohio 45402

THE USE OF GROUND-PENETRATING RADAR, ELECTRICAL RESISTIVITY, AND STREAMING POTENTIAL TO ASSESS DAMAGE BY BURROWING ANIMALS TO THREE SELECTED PORTIONS OF EARTHEN LEVEES NEAR DAYTON, OHIO

Introduction and Statement of Problem

As part of the Miami Conservancy District's (MCD) flood control system, they own and maintain five earthen dams along major tributaries of the Great Miami River, within the greater Dayton area. In addition, the MCD owns approximately 55 miles of levee along the Great Miami River and these tributaries. Since these flood control structures were constructed in the aftermath of the Great Dayton Flood of 1913, no comparable flooding event has tested these structures to their limits. Routine inspections of the dams and levees are conducted by the MCD, and repairs are made as necessary. Very few technical studies have been conducted on the levees specifically, whereas the MCD possesses a greater wealth of information on the five dams. The Board of Consultants for the MCD presented a brief report, dated August 13, 1982, to the MCD Board of Directors, describing some technical investigations based on 15-20 auger samples collected from random locations along the entire extent of the MCD levee system. This report contains general information on the composition of the levees, along with measured permeability values for those particular sites sampled for the investigation. However, aside from this brief report, only limited technical information related to the levees' geologic properties exists for these levees.

Since the levees are an obvious integral part of the flood control system, the MCD is interested in quickly detecting any problems related to the internal structure and overall integrity of these levees. MCD field staff report they must routinely combat groundhog problems along these levees, as the animals like to burrow into and through the flood control structures. Understandably, this tunneling could severely compromise the overall integrity of the levees during a flood event. Concern exists over the potential for piping to occur in the burrows during a high water event. Water flowing into the holes may cause the material to wash out of the hole, and if the process is widespread enough throughout a section of levee, the levee may fail. Due to the lack of specific technical data, the extent of damage is not well known within the aging levee system. As a result, geophysical investigations will provide useful data to the MCD on the extent of damage to the levees selected for this study.

Groundhog behavior will comprise only a small portion of this study. This portion will include information on typical burrow design, seasonal behavior, and groundhog populations. However, the entire investigation will focus on the levee composition and internal properties, as well as the adverse affects due to burrowing.

Proposed Site Locations

Three sections of levee have been chosen for this research, as the time necessary to collect and process data does not allow for a larger number of study areas. Each of these three sections is suspected to have high internal damage, as reported by MCD field staff. After visiting each of the sites, they were included into the study, based on the varying concentrations of burrows and varying burrow designs at each site. In addition, the three sites all possess different dimensions and are located within different physiographic settings.

Sections of levee with extremely high concentrations of known burrows were not chosen as study sites, as it would prove difficult at the onset to determine if the readings reflected ambient conditions or if they were a result of the burrows. These three sites will hopefully show differences in the geologic properties, attributed to either ambient conditions or the burrows. If these investigations prove effective at the three test sites, only then would it prove worthwhile to investigate those levees within the flood control system with extremely high concentrations of known burrows.

The three sites chosen for this work, after consultation with MCD field staff, are as follows:

> **Stanley Avenue, downtown Dayton:** The section of levee to be tested is 120 feet long, and is located on the southern edge of the Mad River, adjacent to the City of Dayton, Ottawa Storage Yard.
>
> **Miami Shores / West Carrolton:** The stretch of levee, visible from I-75, is located along the old Montgomery County Miami Shores Well Field. The wells actually sit between the levee and the Great Miami River, where the actual stretch of levee sits approximately ¼ mile south of the MCD West Carrolton garage. There is a small private airport to the immediate west of the selected levee. The test site is also 120 feet long at this site. No burrows are visible on the backside of this section of levee, only on the river side.
>
> **Middletown:** The stretch of levee borders the southern edge of the Great Miami River and sits between the river and the businesses located on the northern edge of Carmody Street in the City of Middletown. The former city landfill sits farther to the east, along the southern side (property side) of the levee. This study section is 130 feet long, although this levee appears to have fewer holes than the first two. In addition, it is the steepest of the three sites and the highest of the three (above the floodplain).

In all three cases, typical riverside slopes for the levees range from 22-29°, whereas the height above the flood plain typically ranges from 20-30 feet. The Middletown section falls on the higher end of these ranges, with the Stanley Avenue section not as high and having a more gradual slope. Although only the Middletown site is close to a sample point for the 1982 MCD Board of Consultants Report, the materials encountered in this previous study indicate silty sands and sandy gravels, with permeability ranging from 10^{-4} to 10^{-6} cm/sec in order of magnitude (Cooke and others, Appendix p. 6). Preliminary digital photos of a few groundhog burrows were taken at each of these sites. On average, the entrance and exit holes are 1x1 ft. in size, but in many cases, slumping has already occurred around these holes. At this point, burrow length and extent inside the levee are uncertain, and it is also uncertain if storage chambers exist, how long the holes reach, and if they are interconnected. Based on site visits and information from the Ohio Department of Natural Resources' (ODNR) website, it is assumed that a single burrow can reach up to 40 feet long. In addition, the exit holes are usually located on the backside of the levee, at a point higher than the entrance point.

The three selected sections provide enough variance in burrow concentration, height of levee, and geographic location to account for differences in levee design across the entire flood control system. Naturally, these investigations will be a small representative of the entire levee system, and generalizations will be difficult to apply to the farthest reaches of the entire system. One of the underlying goals through this research is to find a reliable, quick, and cost-effective method for determining the extent of damage due to burrowing animals on earthen structures. If proven effective, the investigations could be easily carried out in additional portions of the levee system.

<u>Suitable Geophysical Methods</u>

In order to detect the groundhog holes (or the maze of holes), high-resolution data are needed for best results. The chosen methods must be able to detect small variations in the geologic media. Therefore, the equipment must be sensitive enough to detect these changes. High-resolution data simply refers to the fact that the data can indeed indicate these small changes within a small area. Through detecting these small changes, the goal is to pinpoint the location of the burrows and estimate structural integrity on a small scale within portions of the three selected levee sections. In essence, optimal results allow for more than simple generalizations about the entire study area, by enabling us to evaluate each portion within that selected area. Since few reliable reports on the composition of the levees are available, the material used to build the levee system may affect the method chosen for data collection. As stated above, the sensitivity of the equipment and the approximated extent of the holes will also affect which method produces the best results.

Electrical resistivity will be utilized to help determine the extent of groundhog burrows through the levees. All three sections chosen for this research will be evaluated using electrical resistivity, although this method (along with the others) only provides a snapshot for that particular location. Electrical resistivity measures the electrical potential differences between a certain number of electrodes placed in the ground. An electrical current is placed into the ground from the surface and based on subsurface conditions, the materials will act as conductors of electrical current or as resistors. Since electrical current will have difficulty passing through air (represented by the holes), the electrodes at the surface will record apparent resistivity values indicative of burrow locations—or areas of high resistance—at each test site. True resistivity values are not recorded, as the value calculated is an average over a certain volume within the subsurface. The current injected at the surface will pass through a set distance between each electrode and will pass through the sensitive electrodes, allowing the current loss to also be determined.

Initial field tests may indicate that exact holes are not distinguishable, but rather areas of "resistivity lows" or "resistivity highs" within each 120-130 ft section are easier to locate. Designation of either the exact holes or the areas of resistivity lows and highs will be at a small scale and at a relatively high resolution, enabling us to determine the location and extent of groundhog holes within that portion of the levee section. The spacing of the electrodes is based on the attempted depth of penetration, the height of the levee, the sensitivity of the meter, and any other factor that could affect resolution. Initial field tests will determine the appropriate design, although it can be assumed that a dipole-dipole array will be used in the actual resistivity survey. A simple diagram showing the dipole-dipole geometry, along with the geometries of other common arrays, is included at the end of this proposal. Basically, with the dipole-dipole survey, different electrode pairs are chosen automatically by the meter, allowing for apparent resistivity values to be calculated over different volumes, as each chosen pair will have an increased distance between electrodes. Since the Sting-Swift meter and 28 electrodes will be used, data collection will be quick and easy, as there is no need to change electrode spacing after each reading. The meter automatically chooses the electrodes and makes all necessary adjustments. Initial testing will be performed with 5 feet electrode spacing, as the closer spacing will allow for higher resolution at shallower depths (i.e. higher vertical resolution). Multiple parallel profiles will be recorded at each site, as it is important to ensure that the entire volume of the test location is sampled. The exact number of profiles will depend on the levee dimensions. Once the data are collected, they will be processed with special 2D software, producing a color-coded picture of the test sites, with the colors indicating the areas of resistivity lows and highs.

In addition to the standard resistivity survey, salt water will be pumped into the visible groundhog holes and allowed to saturate the holes. Before performing this work and all future work where pumping water into the burrows is necessary, all appropriate agencies will be contacted and any regulations concerning hibernating or non-hibernating groundhogs will be followed, as stated by these agencies. With this particular test, the resistivity profiles will be recorded at the exact same locations as before, with all of the exact same design specifics. Salt water will be pumped into the holes, as it is a high conductor of electrical current. As a result, instead of detecting areas of resistivity highs, denoted by the air-filled burrows, the salt water will hopefully provide a bridge for the electrical current to flow easily through the burrow, giving us an area of resistivity low. Water from a truck-mounted tank will be used for this portion of the study. The only limitation to the dipole-dipole survey with this equipment is that the resistivity values themselves will be inaccurate, as the meter and electrodes are programmed to assume a flat surface, not a sloping levee bank. However, the goal of this study is to detect changes in apparent resistivity values, not to determine what the apparent resistivity is at each site.

A method very similar to electrical resistivity is streaming potential. However, this method does not require the use of electrical current. Instead, as water is pumped into the holes from the truck-mounted tank, the flow of water generates electrical potential within the holes. At the surface, electrodes set up in arrays similar to resistivity arrays detect voltage differences in the ground. The design follows similar, if not identical, designs as in the electrical resistivity surveys. With this method, voltage differences are measured before, during, and after the water is pumped into the holes. As in the case with electrical resistivity, water will indeed be pumped into the holes. This method intends to measure changes in electrical potential due to the flowing water through the holes. As a result, the water will not be confined in the burrows; that is, the holes will not be plugged to contain the water. Water will be pumped into the highest burrow located within the survey section, and will flow with the assistance of a pump and gravity through the burrow. Through these processes, piping may occur, depending on the material within the levee. However, this action would indeed simulate the activity of river water, should there be a flood. If the water flows with t a high enough velocity, and if infiltration into the sides of the burrow is minimal, the water should flow out of a lower hole. Smoking the holes might provide a good preliminary qualitative method for determining the burrow network within the levee. Within the burrow itself, if lower sections exist where groundhogs may build their nests, the water should flow with enough force to flow through the entire hole. Infiltration is indeed a concern, but if there is a significant amount of silt or clay present—as assumed in the 1982 Board of Consultants Report—the water should still flow through the hole under a higher velocity. The amount of water obtained at the exit point is not crucial to electrical resistivity or streaming potential, so long as there is indeed water (or electrical current) flowing for the instruments to detect. The amount of water exiting the holes could nonetheless provide additional information on the permeability of the geologic media. In essence, the limitations involved with streaming potential are almost identical to electrical resistivity, although the amount of water flowing through the holes at the time of recording is more important. Streaming potential will initially be tested at one of the three sites, and if results are favorable, the method will be tested at the other two sites. Favorable results constitute having enough water flowing through the holes and meters sensitive enough to detect the generated potential. At this time, it is unsure what equipment will be used for this testing this method. The Sting-Swift is capable of conducting self-potential surveys, but resolution and meter sensitivity must be further examined.

Another method to be tested at all three sites will be ground-penetrating radar (GPR). This method measures changes in the dielectric constants (rate of absorption) of the earthen material, as it and air-filled cavities will exhibit different properties. Dielectric constants include the complex permittivity and the complex conductivity of the material (Reynolds 700). GPR works by sending a high-frequency wave through the subsurface, which reflects a signal back to an antenna waiting at the surface. An image of the subsurface appears based on these reflections, which are in turn based on the changes in the dielectric constants of the material. Waves encountering a void space reflect back and scatter differently than those encountering just the earthen material. However, this method typically produces accurate images close to the surface (approx. 20 feet or shallower), as the high-frequency waves are attenuated quickly with depth. As a result, it may not detect the deeper groundhog holes located closer to the base of the levee with the same resolution. In addition, if high clay contents are present in sections of the levee, the waves are more highly attenuated, as the clay absorbs them. If silty sands and gravels are determined to be the bulk of the composition, then the GPR may prove successful, depending on the amount of scatter from these larger particles. High water content also attenuates GPR waves, but in this case, groundwater will hopefully be at a minimum, only causing slight attenuation.

The GPR will be pulled at a certain velocity and at adjacent passes along the top and sides of the levee sections, in order to obtain a grid of data. The actual speed at which the GPR will be towed will be determined in field tests, as it depends on the roughness of the terrain, slopes of the levee, and general accessibility for the GPR equipment. A constant speed is desired, as data are collected at a certain time interval. If terrain does not enable a completely uniform rate of tow, these effects can be corrected during the data processing. The high-frequency waves generated by the GPR allow for good resolution at shallower depths. As a rule of thumb, the higher the frequency, the shorter the wavelength, where these conditions enable the detection of small features close to the surface. However, high-frequency waves are inherently attenuated faster than low-frequency waves. Long wavelengths may prove problematic as they could easily pass over the intended void (the burrow) without detecting it.

The signal is sent radiating outward in a conical shape through the subsurface under the GPR unit. Each of these signals has a uniform size, or rather, capture width. Each wavelength allows for a different range of view within the subsurface, although this range is determined both by the dimensions of the burrow, the depth to the burrow, and whether the burrows are at an angle or parallel to the levee crest. Data are recorded in small time intervals, where this "capture area" of the beam will most likely overlap with subsequent sections. The farthest reaches of the beam will decrease in reliability. Currently it is unclear as to what height above the burrow the GPR method will be effective. There are many factors to consider when designing the GPR survey, some of which include the following:

- the use of a monostatic (1 antenna) or a bistatic (2 antennas) receiver
- the sensitivity of the antenna(s)
- the position of the antenna(s) during data collection
- the affects on vertical and horizontal resolution by the depth and position of the burrow, the signal wavelength, the amount of attenuation, etc.
- whether the GPR unit should be towed along the levee sides at the given angles, or if it should be configured with a bistatic receiver to enable the unit to constantly remain on the crest of the levee
- the planned data processing steps (i.e. horizontal stacking, etc.)

These factors, plus many more, will be considered during the radar survey design. To describe all of these factors and the associated effects on the data is beyond the scope of this proposal, as only a general introduction to GPR is intended.

Added features within and around the levee may cause additional problems for the GPR. Bridges, chain-link fences, drainage pipes, metal survey flags, and power lines act as interference for the radar waves as they propagate through the material. In addition, they only add to the amount of data processing, where the effects of these objects must be removed. Since these objects exhibit drastically different dielectric constants, they may mask some of the data we are hoping to observe within the levees. However, any drainage pipes located near the levee base may indeed prove useful in the GPR survey, if other potential for interference is minimized. The drainage pipes may prove useful in obtaining travel times of the radar waves through the material. Since the depth to the pipe is known (MCD has records of their locations), and the frequency and wavelengths of the radar waves are known, the velocity of the waves can be determined. This information may also prove useful in obtaining more data regarding the physical parameters of the earthen material. Field tests will dictate the design of the radar survey.

Method of Repair

If all or any of these studies determines significant damage of the levees due to groundhog holes, quick-sealing grout can be used to plug the holes. The intent is to plug the entire hole, although if this does not happen due to the rate at which the grout hardens, it will be beneficial to at least plug both ends of the hole to prevent water from entering. Pumping water into the holes during the actual investigations will undoubtedly add to any piping that has previously occurred, but if detected, the holes can be adequately repaired. The grout will be pumped into the holes just as the water, and afterwards GPR and resistivity investigations will be conducted again to determine the amount of success, assuming it is possible to add more water to the holes. If additional grout is necessary, it can be pumped into the hole. There is some concern over whether the grout will cause structural problems for the levee, as the non-grouted material around it may weaken. In consulting with MCD engineers, the grout seems to pose little problem for the levee, especially if it infiltrates into the levee just as the water might during the resistivity and streaming potential methods. The compactness of the material and the geologic media should provide enough stability to the levee.

Depending on the network of holes, it may prove cost effective for the MCD to contract an outside company to grout the holes. Purchasing quick-sealing grout by the individual bag may become expensive, where better deals may be obtained by going through a contractor. These options will be discussed as the time approaches to grout the holes.

Resources and Estimated Costs

Associated costs for this study are not great. Most of the equipment can be obtained from the Departments of Geological Sciences and Physics at Wright State University, and some equipment may be currently located at the MCD. Ohio University possesses the Swift converter box and the 28 smart electrodes for the resistivity survey, where they allow Wright State to borrow the equipment free of charge. The MCD has offered a 325-gallon truck-mounted water tank, which can be driven to the levee crest.

Gas mileage and grout will prove the only substantial costs for this project. Wright State University vehicles will be used for the bulk of the work, although since all three sites are local, drive time is minimal. The Department of Geological Sciences operates a significant motor pool and grants graduate students use of these vehicles for research purposes. The grout costs will be affected by the MCD's decision to either contract the work, allow Wright State University to do the work, or to perform it in-house. MCD has agreed to cover gas mileage costs and grout costs.

Costs for this study could also depend on the amount of information the MCD wishes to obtain. Any information on the composition and physical properties of the levees would prove beneficial not only to this thesis, but also to any future work by the MCD. In order to determine these characteristics, core samples must be taken. The core samples would also assist in correlating the data obtained from this research and provide more evidence for conclusions made concerning the geologic media. For each site, one core sample should suffice due to the confined area of the levee sections, although two samples would prove even more effective for correlation, either horizontally or vertically. The Department of Geological Sciences owns and operates its own drill rig, capable of taking adequate samples at depths great enough to sample the entire levee height. If additional samples are desired to supplement the research and the 1982 Board of Consultants Report, an hourly rate will be charged for use of the rig as well as costs for additional samplers, which must be purchased prior to sampling.

If the MCD wishes to obtain professional, more-efficient core samples, it may wish to contract an outside drilling company. It may also wish to have a laboratory analyze the samples, as an outside organization will be able to measure many of the physical properties, such as bulk density, porosity, load capacity, etc. Wright State University is unable to perform these types of involved, time-consuming tests. Although these types of tests are quite expensive, the information obtained from them is highly beneficial. The only limitation—other than cost—to collecting core samples will be the accessibility of the levees by a drill rig. However, if the MCD truly wished to obtain

accurate core sample information to supplement their current records, modern drilling technology enables drill rigs to access less conventional places.
In addition to the work proposed for this thesis, an opportunity exists to test new resistivity equipment. Geometrics, designers of the OhmMapper, have developed this equipment as a means of gathering resistivity data at a rate twenty times faster than any conventional methods. The equipment simply consists of electrodes that are connected with dipole-dipole cables and are drug along the ground over an intended study area. Wright State University is not familiar with use of this equipment, so at the present time, not too much is know about its applicability to a project involving groundhog burrows in earthen levees. Resolution and depth of penetration, as related to the subsurface materials, are issues with this equipment. Geometrics has agreed to let Wright State University test the equipment, if scheduling and budget allows. Obviously Geometrics is interested in using their equipment for a new application, and it would give Wright State University some additional experience with new cutting-edge resistivity equipment.

Conclusions

This thesis will provide the MCD with valuable information on their levee system as well as help a graduate student fulfill requirements for a Master's Degree. This research tests three geophysical methods for determining the overall best-suited method for detecting the extent of damage due to groundhog holes in earthen levees. The results of the thesis could very well show that none of the aforementioned methods prove effective enough to determine the extent of internal structural damage to the earthen levees. Since this study is the first of its type at the Department of Geological Sciences, it is highly interesting to those involved—the results of which may lead to future research by the MCD or by other students.

It is recognized that this research provides only a snapshot of information for a highly localized area and cannot be used to make specific interpretations of other sections of the flood control system. In addition, it is recognized that these research methods may produce negative results. Negative results do not indicate inconclusive results, but perhaps these methods do not show the burrows and the extent of damage to the degree necessary for effective repair. Other methods do exist, which may be considered for future studies, although for the allotted time in this research, these methods would not prove time-efficient.

Works Cited

Burger, H. Robert, 1992. Exploration Geophysics of the Shallow Subsurface. Englewood Cliffs, NJ: Prentice Hall, 489 pp.

Cooke, J. Barry, C.J. Cortright, Ralph B. Peck, Abel Wolman, 1982. "Report to the Board of Directors, The Miami Conservancy District, by the Board of Consultants". 13 pp.

Reynolds, John M, 1998. An Introduction to Applied and Environmental Geophysics. New York: John Wiley & Sons, 796 pp.

Electrical Resistivity Survey Configurations
Geometry of current and potential electrode positions

(from Burger p. 289)

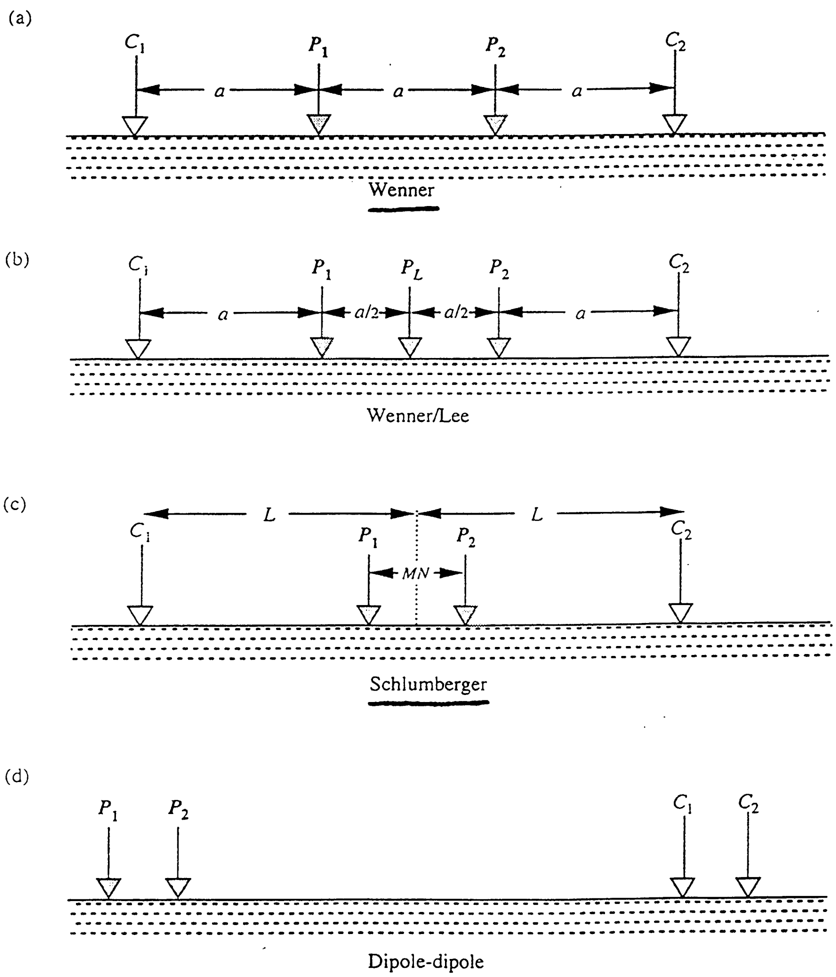


Figure 5-30 The most common electrode geometries used in resistivity surveying. (a) Wenner. (b) Wenner/Lee (Lee Partitioning). (c) Schlumberger. (d) Dipole-dipole.

C = current electrode
P = potential electrode

Dam Failure/Incident Case Study Database

Dr. Martin McCann, Director of the National Performance of Dams Program at Stanford University, compiled dam incident information related to animal and vegetation impacts on dams. The following is a summary of his presentation at the workshop.

Additionally, several state dam safety program representatives submitted case histories of dam incidents that were caused by anumals or vegetation problems on dams. These case histories can be found within the Workshop Proceedings contained in Tab 3.

ASDSO/FEMA Workshop on
Plant & Animal Penetrations of Earthfilled Dams

Plant & Animal Penetrations of Dams Incidents

Presented by
Martin W. McCann, Jr.
National Performance of Dams Program

University of Tennessee
Knoxville, TN

November 30, 1999

NPDP

Purpose

Provide a global perspective about plant and animal incidents at dams, in terms of their:

- Frequency
- Breadth
- Severity

NPDP

Topics

- Summary statistics
- Identify some of the impacts of plants and animals
- Look at some case histories to visual and appreciate the threat to dam safety

NPDP

Focus

- Frequency - How often do plant and animals impact the safety of a dam?
- Breadth - What is the range of problems do plants and animals cause?
- Severity - How serious is the impact of plants and animals?

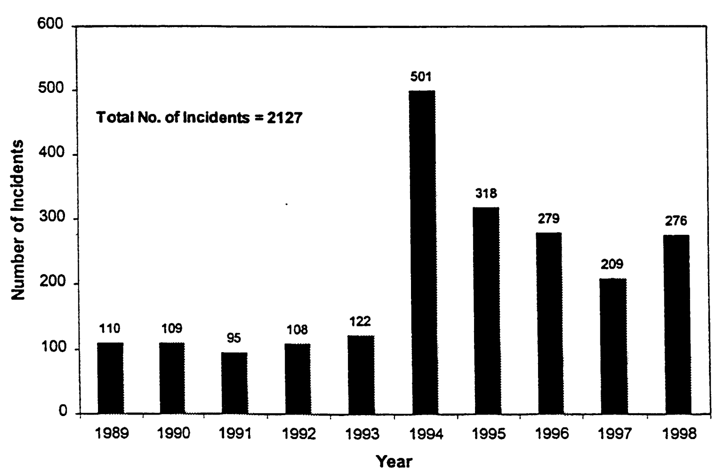
NPDP

NPDP Ten-Year Survey

- Period: 1989-1998
- Dams - 1623
- Dam Incidents - 2127
- Dam Failures - 488

NPDP

Yearly Incident Occurrence



NPDP

Incident Data Summary

Dam Failures: Total - 488
Biological Causes - 2

Dam Incidents (Non-Failures):
Total - 1322
Biological Causes - 51

NPDP

Broader Survey

- Looked for incidents involving plants & animals in the NPDP database
- Periodic Inspections/Non-inspections & Failed/Non-Failed Dams

NPDP

Summary

Category	Number Animals	Number Plants
Inspection (Non-Failure)	13	46
Non-Inspection (Non-Failure)	21	13
Dam Failures	7	6

NPDP

Breadth of Impact

- Plant and animal activity causes a range of problems at dams
- Interrelated - beavers find use for trees on dams
- Impacts:
  - geotechnical (i.e., foundation, seepage)
  - structural
  - hydraulic

NPDP

Sample Impact

- Geotechnical
  - Initiation of new seepage paths
  - Undermining outlet structure foundations
- Structural
  - Beaver activity can lead to increased loading on outlet structures (i.e., riser)
- Hydraulic
  - Plant growth/beaver activity clogging spillways/reducing outlet capacity
  - Beaver activity clogging inlets

NPDP

Severity

- Plant and animal activity can have a major impact on the integrity of a dam
  - Dam failure
  - Major O&M burden
- Two roles:
  - Initiator of an incident
  - Contributing factor to an incident initiated by other events

NPDP

Case Illustrations

NPDP

Hog Waste Lagoon Dike (NC)

Date: April 18-19, 1999
Dam Ht : 11 ft

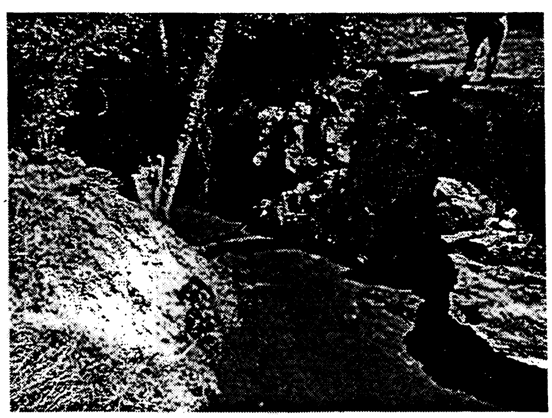
Summary: The dam failed releasing 1.5 million gallons of hog waste into a tributary of the Northeast Cape Fear River. Owners allege eco-terroism. The embankment is covered with trees and brush.

NPDP

View of the breach looking upstream

NPDP

View of the breach looking downstream



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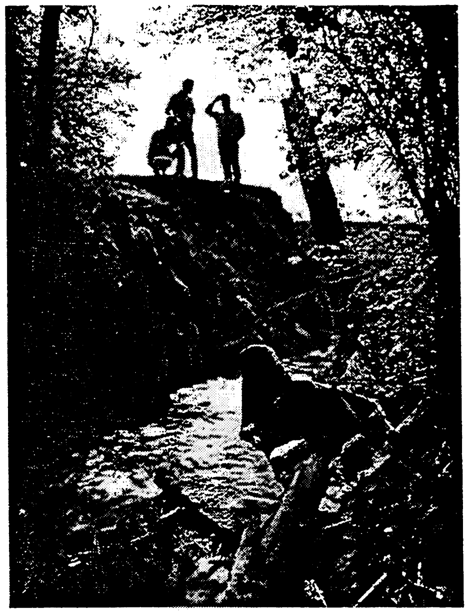


Another view of the breach looking upstream

NPDP

Oaklawn Pond Dam (TX)

Date: November 7, 1996
Dam Ht : 11 ft
Hazard: Significant

Summary: The dam was severely damaged when high winds uprooted 5 trees and a cluster of 5-6 trees on the embankment. The upheaving of the root mass, aggravated by beaver damage, left gaps in the crest and slopes of the dam. The effective width of the crest was reduced by half (from 14 to 7 feet).

NPDP

Hematite Dam (KY)

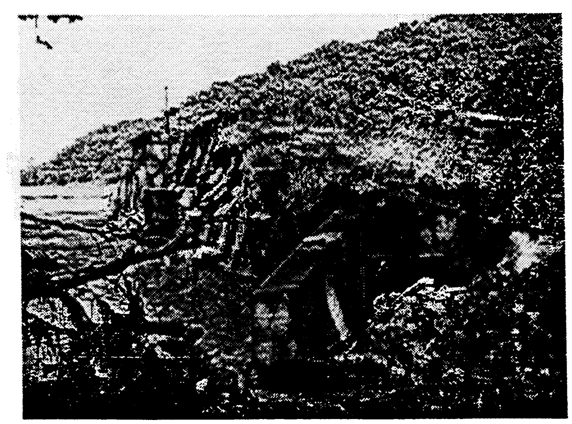
Date: June 11, 1998
Dam Ht : 13 ft
Hydraulic Head: 9 ft

Summary: The dam failed due to piping at or near the side of a sluiceway. Sinkholes indicate piping is active in the embankment. The breach exposed large tree roots (>6 inches in diameter). The investigation speculates that tree roots would have caused major problems in the future.

NPDP

View of the breach looking upstream

(Note the root system)



NPDP

View looking into the breach
(Note the root system).

NPDP

View of the breach looking downstream
(Note the root system).

NPDP

Persimon Creek Watershed - Site 50 (MS)

Date: June 11, 1998
Dam Ht : 23 ft

Summary: The dam failed due to erosion of an emergency earthen spillway. Beaver activity had clogged the primary spillway. Beavers had been an ongoing O&M problem. Sponsor "efforts were rather fruitless because of the particular riser features on this site which put the beaver at an advantage."

NPDP

Bibliography on the Effects of Woody Vegetation on Dams

Compiled by

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For

Association of State Dam Safety Officials (ASDSO)
Steering Committee on Plant and Animal Penetration of Earthen Dams

University of Tennessee
September 28, 1999

Table of Contents

Bibliography on the Effects of Woody Vegetation on Dams

Compiled by
University of Tennessee
September 28, 1999

I. General Physiology and Character of Woody Plants:

Bohm, W. (1979). "Methods of Studying Root Systems." Springer-Verlag, New York, NY.

Evans, James, (1999). E-mail correspondence on Friday, September 10, 1999 regarding Request for Information on Trees on Dams". Division of Dam Safety and Inspections, FERC.

Kozlowski, T.T. (1971). "Growth and Development of Trees." Academic Press, New York and London, pp. 196-202.

Kramer, P.J., Kozlowski, T.T. (1960). "Physiology of Trees." McGraw-Hill Book Company, New York, Toronto, London, pp. 2-4, 470, 471, 507, 508.

Kramer, P.J., Kozlowski, T.T. (1979). "Physiology of Woody Plants." Academic Press, New York, San Francisco, London, pp.43, 560.

O'Loughlin, C., Pearce, A., and Roy C. Sidle. (1985). "Hillslope Stability and Land Use." Water Resources Monograph Series, American Geophysical Union, Washington, D.C., pp.57-66.

Read, R., Sprackling, J.A. (1979). "Tree Root Systems in Eastern Nebraska." Conservation and Survey Division, The University of Nebraska-Lincoln, Nebraska Conservation Bulletin, No. 37, February 1979.

Sidle, R.C. (1991). "A Conceptual-Model of Changes in Root Cohesion in Response to Vegetation Management." J. Environmental Quality, American Society Agronomy, 20(1), pp.43-52.

University of Georgia, Extension Forest Resources (1999). World Wide Web Page. Internet address: http//:www.forestry.uga.edu.

University of Georgia, Extension Forest Resources (1999). World Wide Web Page. "Tree Root Growth Control Series: Tree Roots and Infrastructure Damage." Internet address: http//:www.forestry.uga.edu/abstracts/for98-009.html.

U.S. Department of Agriculture, Soil Conservation Service (1988). "Final Report on the Rooting Characteristics of Desert Broom, (Baccharis sarothroides)" Arizona.

U.S. Department of the Interior, Bureau of Reclamation (1998). "Root Characteristics of of Common Woody Vegetation in the Western United States." pp.53-54.

II. Documentation of Woody Plant-Caused Dam Safety, Operation, and Maintenance Problems and Damage:

ENR NEWS (1993). "Receding Flood Leaves Ugly Swath." The McGraw-Hill Construction Weekly, July 26, 1993.

Evans, James, (1999). E-mail correspondence on Friday, September 10, 1999 regarding Request for Information on Trees on Dams". Division of Dam Safety and Inspections, FERC.

Fisher, Leslie and Gordon Keller. (1993). "History and Repair of the Doyle Reservoir Dam." ASDSO Newsletter. Jan 1993. 8(1). pp. 20.

Gress, Kathryn (n.d.). "Dam Safety Controversy: Casper woman cuts down trees near dam site." Cow Country, Cheyenne, WY.

Gress, Kathryn (1990). "Rancher Threatens to Break Dams in Defiance of Dam Safety Act." The Wyoming Eagle, September 6, 1990, Cheyenne, WY.

Hinchey, Bruce Rep. (n.d.). "Even if Dam Broke, You Could Outwalk the Water." Commentary Article Response, Star-Tribune, Casper, WY.

Lazarus, Bill (1990). "State Engineer Pressures Tree Removal from SP Ranch Dam." Star-Tribune, August 31, 1990, Casper, WY.

McCook, Danny (1992). "Soil Conservation Service Experiences with Shallow Slope Failures on Highly Plastic Clay Embankments." ASDSO Southeastern Regional Conference, Atlanta, GA, April 1992.

McCrary, Ernest (1990). "Tree Roots Not Root of Dam Problem." Commentary Article Response, Star-Tribune, September 7, 1990, Casper, WY.

NPDP, Stanford University. (1999). "Dam Incidents Involving Tree/Brush Growth." Excel Spreadsheet Format.

Virginia Department of Game and Inland Fisheries. (1999). Letter from Kenneth E. Turner, Jr. (Capital Outlay Project Engineer) to Joseph Haugh of Soil and Water Conservation Division concerning an ASDSO request for tree and animal related dam experiences. Richmond, VA, June 21, 1999.

Yashkul, D.M. (1980). "Embankment Dams of Paz Cascade of Hydropower Stations and Some Conclusions from Their Operational Experience." J. Hydrotechnical Construction No. 11, pp.1140-1148.

Young, William. (n.d.). "Engineers' Bull Could Have Saved Thousands of Lives." Star-Tribune, Casper, WY

III. Case Histories Related to Tree-Caused Dam Failures or Safety-Related Incidents:

Corps of Engineers, Ohio River Division. (1979). "ORDED-G Memorandum for Record, Subject: Inspection of Dam, Anderson Township." 10/1/79.

Corps of Engineers, St. Paul District. (1999). World Wide Web Page. "Mississippi Headwaters Lakes Project - Cross Lake Recreation Area." Internet address: http//www.mvp.usace.army.mil/pp/headwaters/cross/cross.html.

Hammer, Greg. (1999). E-mail correspondence on Thursday, September 2, 1999 Regarding "Woody plants and earthen dams". State of Colorado.

Hammer, Greg. (1999). E-mail correspondence on Friday, September 10, 1999 regarding "Myron Isabel Dam Breach". State of Colorado.

McNeil, J.D. (1985). "Cultural Resources Survey of Item R-729-R Riverside Slide Repair, West Memphis, Crittenden County, Arkansas." Report No.: USAED/TN-199, Army Engineer District, Memphis, TN.

Samuelson, Warren D. (1990). "Bad Weather in 1989 Plagues Texas with Dam Failures." ASDSO Newsletter. Jan 1990, 6(1). pp. 3-4

Textor, G.N. (1992). "Dangerous Dam Turned into A Useful Asset." J. Public Works, PUWOAH, 123(7), pp.42-44.

Zampedro, Val. (1999). E-mail correspondence on Friday, August 20, 1999 regarding "Earthen dam failure due to vegetation". Department of Natural Resources. State of Ohio.

IV. Current and Past Federal, International, and Other Research Activities Involving Effects of Woody Plants on Dam Safety:

Barker, D.H. (1986). "Enhancement of Slope Stability by Vegetation." Ground Engineering, 19(3), pp. 11-13.

Basinger, Donald, Carl Montana, and Jonathan Phillippe. (1999). "Observations on the Wear and Tear of PL-566 Dams." Presented at ASDSO Annual Conference, 1999.

Beven, K., Germann, Peter (1982). "Macropores and Water Flow in Soils." Water Resources Research, 18(5), pp. 1311-1325.

Corps of Engineers: Repair, Evaluation, Maintenance, and Rehabilitation Research Program (1999). World Wide Web Page. "Issues Regarding Vegetation Management on Levee Embankments." Internet address: http://www.wes.army.mil/REMR/pdf/ei/m-1-4.pdf

Corps of Engineers: Repair, Evaluation, Maintenance, and Rehabilitation Research Program (1999). World Wide Web Page. "Vegetation and the Structural Integrity of Levees: Results of Field Investigations." Internet address: http://www.wes.army.mil/REMR/pdf/ei/m-1-3.pdf.

Darr, S., Klits, W. and Olkowski, W. (1984). "The Role of Vegetation in an Integrated Pest Management Approach to Levee Management." California Riparian Systems, University of California Press, Berkley, CA, pp. 551-557.

Evans, James, (1999). E-mail correspondence on Friday, September 10, 1999 regarding Request for Information on Trees on Dams". Division of Dam Safety and Inspections, FERC.

Haugh, J.S., Lin, S.S. (1994). "Maintenance Requirements: Vegetation Control on Embankment Dams." presentation to Seventh Annual Virginia Water Resources Conference, Richmond, Virginia, April 1994.

Huang, Y.H. (1986). "Unsteady State Phreatic Surface in Earth Dams." Journal of Geotechnical Engineering, ASCE, 112(3), pp.3353-353.

Moore, C. (1983). "Evaluation of Three Watering and Mulching Techniques on Transplanted Trees at Adobe Dam." Tempe Center for Environmental Studies, Arizona State University, Tempe, Arizona.

Nolan, Michael F. (1984). "Vegetation on US Army Corps of Engineers Project Levees in the Sacramento/San Joaquin Valley, California." California Riparian Systems, University of California Press, Berkeley, CA, pp. 538-547.

Shields, F.D., and Gray, D.H. (1992). “Effects of Woody Vegetation on Sandy Levee Integrity.” J. Water Resources Bulletin., WARBAQ, 28(5), pp.917-931.

Szczepank, S.G. (1987). "Trees and Tree Removal." presentation to Dam Safety Conference , Assoc. of State Dam Safety Officials, Columbus, OH, July 1987.

Tschantz, Bruce A. and Weaver, Jess D. (1988). "Tree Growth on Earthen Dams: A Survey of State Policy Practice." Report, Civil Engineering Department, The University of Tennessee, Knoxville, Tennessee, November 1988, p.36 + Appdcs. A, B.

Tschantz, Bruce A. (1989). “Tree Growth on Earthen Dams: A Survey of State Policy and Practice.” Presentation and Proceedings from 6th ASDSO Annual Conference, Oct. 1-5, 1989, Albuquerque, N. M., pp.446-452

West, Adam (1997). "Concrete Condition Evaluation and Repair Program for Carpenter Dam." Proceedings from Western Regional ASDSO Conference, Benham-Holway Power Group, Tulsa, OK.

V. Federal, State, International, and Other Organization Policies and Practices for Preventing and Solving Woody Plant Problems on Dams:

Arizona. (n.d.). "Arizona Dam Safety Guidebook." 1 page.

Arkansas. (n.d). "Dam Safety Manual." Subtitle VIII. Operation and Maintenance, 2 pages.

Beegles, Ken. (1999. E-mail correspondence on September 1, 1999 regarding "Woody plants and earthen dams". State of Colorado.

California Department of Water Resources, Division of Safety of Dams. (n.d.). "Vegetation Control on Embankment Dams." 1 page.

Curry, Hugh A., and Pfost, Donald L. (1996). "Maintaining Small Dams." Agricultural publication G1548.

Department of the Army. (1972). "Landscape Planting at Floodwalls, Levees and Embankment Dams." Engineer Manual No. 1110-2-301, Office of the Chief of Engineers, Washington, D.C.

Dewey, Steven A. (1992). "Vegetation Control on Dams: Selection and Use of Herbicides." presentation to Dam Safety Workshop, Utah, March 19, 1992.

Federal Emergency Management Agency (1987). "Dam Safety: An Owners Guidance Manual," p.64.

Federal Emergency Management Agency (1985). "Dam Safety Issues and Options: A Workbook for Owners of Small Dams in New England." February 6, 1985. pp. 6-8, 6-9.

Fondelier, Russ (1984). "Trees on Embankment Dams." ASDSO and Council of State Governments National Conference. *Dam Safety Issues of the 80's-Responsibilities, Liabilities, and Alternatives*. Denver, Colorado.

Fondelier, Russ (n.d.). "Trees on Embankment Dams – Abstract: Issues on Removing Trees." U. S. Corps of Engineers, Ohio River Division, Columbus, Ohio, 2 pp.

Gray, D.H., Leiser, A.T. (1982). "Biotechnical Slope Protection and Erosion Control." Van Nostrand Reinhold Company Inc., New York, Chapter 3.

Idaho Department of Water Resources. (1980). "Rules and Regulations on Safety of Dams. Boise, Idaho.

Idaho Department of Water Resources. (1980). "Rules and Regulations of Mine Tailings

Impoundment Structures." Boise, Idaho.

Illinois Department of Transportation. (1980). "Rules for Construction and Maintenance of Dams. Division of Water Resources. Springfield, Illinois.

Jansen, Robert B. (1980). "Dams and Public Safety." A Water Resources Technical Publication, U. S. Department of the Interior, Water and Power Resources Service (U.S.B.R.), United States Printing Office, Washington, D.C., pp.104, 282.

LeCount, P.L. (1983). "Tree & Brush Removal from Dam & Dike Embankments." Haley, & Aldrich, Inc., Technical Note, Pennsylvania.

Louisiana. (n.d.). "State Dam Safety Manual." Chapter 2, Technical Specifications, Clearing and Grubbing/Embankment and Backfill. 3 pages.

Maryland. (n.d.). "Maryland Dam Safety Manual." pp. 19-20.

Michigan Department of Environmental Quality, Land and Water Management Division (1999). World Wide Web Page. "Dam Safety: Trees and Brush." Internet address: http://www.deq.state.mi.us/lwm/water_mgmt/dams/treebrsh.html.

Missouri Department of Natural Resources, Division of Geology and Land survey, Dam and Reservoir Safety Program (1991). "Maintenance, Inspection, and Operation of Dams in Missouri." pp.29-32.

National Research Council, Committee on the Safety of Existing Dams. (1983). "Safety of Existing Dams: Evaluation and Improvement." National Academy Press, Washington, D.C., pp.249-251.

North Carolina Department of Environment and Natural Resources, Division of Land Resources, Land Quality Section, Dam Safety Program. (1999). "Trees in Dams." Policy memo. 2 pp.

New England. (1984). "Typical Periodic Maintenance Activites." Proceedings from New England Dam Safety Workshop, 2 pages.

New Jersey. (n.d.). "Dam Safety Manual" Part 2, 3 pages.

New Mexico. (1989). "Dam Owner's Guidance Manual." 2 pages.

Ohio Department of Natural Resources, Division of Water, 1999. World Wide Web Page. "Dam Safety: Trees and Brush." Internet address: http://www.dnr.state.oh.us/odnr/water/pubs/fs_div/fctsht28.html.

Ohio Department of Natural Resources (1983), Division of Water, Dam Inspection Section. "Operation and Maintenance and Inspection Manual." pp.15-18.

Ohio Department of Natural Resources, Division of Water, Engineering Group. "Division of Fact Sheet." Fact Sheet 94-28.

Pennsylvania Department of Environmental Protection, 1999. World Wide Web Page. "Vegetation/Erosion Control on Dams." Internet address: http://www.dep.state.pa.us/dep/deputate/watermgt/WE/FACTS/fs1909.htm.

Pennsylvania Department of Environmental Protection (n.d.), Bureau of Waterways Engineering, Harrisburg, "Vegetation/Erosion Control on Dams."2 pp.

Texas. (1990). "Guidelines for Operation & Maintenance of Dams in Texas." 1 p.

Texas Natural Resource Conservation Commission (1999). World Wide Web Page. Dam Safety Team, Internet address: http://www.tnrcc.state.tx.us/water/quantity/flood/guide.html, pp. 41, 45, 71, 72.

Townsend, John. (1999). E-mail correspondence on Thursday, September 9, 1999 regarding herbicides and chemicals used to prevent and eradicate woody plants on dams. Former Ecology Branch Manager at Maricopa County, Arizona Flood Control District.

Turnipseed, R.M. (1995). "Laws & Permitting Information Pertaining to Dams." Nevada Department of Conservation and Natural Resources, Division of Water Resources, 30 pp.

U.S. Corps of Engineers, Omaha District. (1980). "Policy Statement Regarding Tree Growth on Hydraulic Structures." Technical Note MROED-E, Omaha, Nebraska.

U.S. Department of Agriculture, Soil Conservation Service (1988). "Control of Trees and Brush on Dams." Technical Note Engineering-OK-8, Stillwater, Oklahoma.

U.S. Department of Agriculture, Soil Conservation Service, South Technical Service Center. (1981). "Operations and Maintenance Alternatives for Removing Trees from Dams." Technical Note 705, Ft. Worth, Texas.

U.S. Department of Interior, Bureau of Reclamation. (1987). "Criteria for the Removal of Trees and Other Vegetative Growth, and Rodent Burrows from Earth Dams, Dikes, and Conveyance Features." ASDSO Files.

U.S. Department of Interior, Bureau of Reclamation. (1986). "Guide for Preparation of Standing Operating Procedures for Dams and Reservoirs." Appendix H, pp. 125-126.

U.S. Department of Interior, Bureau of Reclamation. (1991). "Review of O&M Program, Field Examination Guidelines." Engineering Division, Facilities Engineering Branch, Denver, Colorado, Appendix B.

U.S. Department of Interior, Bureau of Reclamation. (1989). "Water Operation and Maintenance: Guidelines for Removal of Trees and Other Vegetative Growth from Earth Dams, Dikes, and Conveyance Features." Denver, Colorado.

Utah. (n.d.). "Dam Safety Manual." Vegetation Control Section, pp. 3-11, 22-24.

Virginia Department of Conversation and Recreation (n.d.). "Vegetation Control for Embankment Dams." Dam Safety Fact Sheet 3.

Yeomans, Ken. (1999). E-mail correspondence on August 30, 1999 regarding "Woody Plants on earthen dams". Australia.

VI. Documented Costs for Federal or State Programs Associated with and Engineering the Removal of Trees from Dams:

Hinchey, Bruce Rep. (n.d.). "Even if Dam Broke, You Could Outwalk the Water." Commentary Article Response, Star-Tribune, Casper, WY.

Virginia Department of Game and Inland Fisheries. (1999). Letter from Kenneth E. Turner, Jr. (Capital Outlay Project Engineer) to Joseph Haugh of Soil and Water Conservation Division concerning a request for tree and animal related dam experiences. Richmond, VA, June 21, 1999.

Appendix
Phase 1 of Non-Federal Dam Inspection Program Reports:

Berger Associates, Inc. (1980). "National Dam Safety Program. Lake Lattimore Dam (NDI-ID # PA-00406, DER-ID # 52-78) Delaware River Basin, Pike County, Pennsylvania. Phase I Inspection Report." Harrisburg, PA.

Berggreen, R.G., and Krazynski, L.M. (1980). " National Program for Inspection of Non-Federal Dams. Lower Valle Mines Dam (MO 30439), Mississippi-Kaskaskia-St. Louis Basin, Jefferson County, Missouri. Phase I Inspection Report." Woodward-Clyde Consultants, Chicago, IL.

Berggreen, R.G., and Krazynski, L.M. (1980). " National Program for Inspection of Non-Federal Dams. Hornsey Brothers (MO 30101), Mississippi-Kaskaskia-St. Louis Basin, Washington County, Missouri. Phase I Inspection Report." Woodward-Clyde Consultants, Chicago, IL.

Berggreen, R.G., and Perez, J.Y. (1981). " National Program for Inspection of Non-Federal Dams. Smitty's Catfish Pond Dam (MO 30613), Mississippi-Kaskaskia-St. Louis Basin, Madison County, Missouri. Phase I Inspection Report." Woodward-Clyde Consultants, Chicago, IL.

Berggreen, R.G., and Perez, J.Y. (1981). " National Program for Inspection of Non-Federal Dams. Slime Pond Dam (MO 306011), Mississippi-St. Francis Basin, Madison County, Missouri. Phase I Inspection Report." Woodward-Clyde Consultants, Chicago, IL.

Berggreen, R.G., and Krazynski, L.M. (1980). " National Program for Inspection of Non-Federal Dams. Potosi Lake Dam (MO 30477), Mississippi-Kaskaskia-St. Louis Basin, Washington County, Missouri. Phase I Inspection Report." Woodward-Clyde Consultants, Chicago, IL.

Berggreen, R.G., and Perez, J.Y. (1981). " National Program for Inspection of Non-Federal Dams. Newman Lake Dam (MO 30488), Mississippi-Kaskaskia-St. Louis Basin, Madison County, Missouri. Phase I Inspection Report." Woodward-Clyde Consultants, Chicago, IL.

Corps of Engineers, Waltham, MA. New England Division. (1979). "National Program for Inspection of Non-Federal Dams. Russell Pond Dam (MA 00392), Massachusetts Coastal Basin, Kingston, Massachusetts. Phase 1, Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1979). "National Program for Inspection of Non-Federal Dams. Tyler Tree Farm Dam (NH 00325), Connecticut River Basin, Monroe, New Hampshire. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Sugar Hill Dam (VT 00176), Richelieu River Basin, Town of Goshen, Addison County, Vermont. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Norumbega Reservoir Dam and Dikes, Norumbega Reservoir Dam and East Dike (MA 00782) Dike 2 and Dike 3 (MA 01208) Dike 4 (MA 01209), Massachusetts Coastal Area, Weston, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Manchester Pond Reservoir Dam (MA 00860) South Dike and East Dike (MA 01288, MA 01289), Providence River Basin, Attleboro, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Lee Pond Reservoir Dam (MA 00891) Massachusetts Coastal Basin, Uxbridge, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Linwood Pond Dam (MA 00896), Blackstone River Basin, Northbridge, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Noquochoke Lake at Route 6 Dam (ME 01085), Massachusetts Coastal Basin, Dartmouth & Westport, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Lowell Reservoir Dam (ME 01188), Merrimack River Basin, Lowell, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Putnamville Reservoir Dam and Dikes (MA 00745), East Dike (MA 01297), West Dike (MA 00744), Ipswich River Basin, Danvers, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Great Pond Upper Reservoir Dam (MA 00823), Weymouth River Basin, Braintree & Randolph, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Arlington Reservoir Dam (MA 00771), Massachusetts Coastal Basin, Arlington-Lexington, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Overlook Reservoir Dam and Dike; (MA 00876), (MA 01335), Merrimack River Basin, Finchburg, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Horsepond Dam (MA 00950), Connecticut River Basin, North Brookfield, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Brockton Reservoir Dam (ME 00786), Taunton River Basin, Avon, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Cambridge Reservoir Dam (MA 00750), Massachusetts Coastal Area, Waltham, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. West Parish Filter Number 3 Dam (MA 00610), Connecticut River Basin, Westfield, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Schencks Pond Dam (MA 00784), Massachusetts Coastal Area, Weston, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Whites Mill Pond Dam (MA 00630), Connecticut River Basin, Winchendon, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Crocker Pond Dam (MA 00638), Merrimack River Basin, Westminster, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Sugden Reservoir Dam (MA 00698), Connecticut River Basin, Spencer, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Upper Bemis Pond Dam (MA 00069), Lower Bemis Pond Dam (MA 00531), Connecticut River Basin, Chicopee, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Mill Pond Dam (MA 00027), Wareham River Basin, Wareham, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Northfield School Upper Reservoir Dam (ME 00051), Connecticut River Basin, Northfield, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Bearhole Reservoir Dam (MA 00073), Westfield River Basin, West Springfield, Massachusetts. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Scovill Reservoir Dam (CT 00431), Lower Connecticut River Basin, Haddam, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Upper Pond Dam (CT 00433), Lower Connecticut River Basin, Haddam, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Mashhpaug Pond Spillway (CT 00640), Dike (CT 01699), Dam (CT 01700), Quinebaug River Basin, Union, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Spring Lake Dam (CT 00261), Connecticut Coastal, Southington, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Glenville Pond Dam (CT 00334), Shetucket River Basin, Stafford, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Trading Cove Pond Dam (CT 00237), Lower Thames River Basin, Norwich, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Congdon Dam (CT 00234), Lower Thames River Basin, Montville, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Baldwins Pond Dam (CT 00133), Connecticut Coastal, Meriden, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Potash Pond Dam (CT 00193), Thames River Basin, Windham, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Crystal Lake Dam (CT 00138), Lower Connecticut River Basin, Middletown, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Prichards Pond Dam (CT 00033) Naugatuck River Basin, Waterbury, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Upper Lake Phipps Dam Number 1 (CT 00109), Dam Number 2 (CT 00110), Cove River Basin, West Haven, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1980). " National Program for Inspection of Non-Federal Dams. Winchester Lake Dam (CT 00105), Lower Housatonic River Basin, Winchester, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Pritchards Pond Dam (CT 00033), Naugatuck River Basin, Waterbury, Connecticut. Phase I Inspection Report."

Corps of Engineers, Waltham, MA. New England Division. (1981). " National Program for Inspection of Non-Federal Dams. Stillwater Reservoir Dam (RI 03101), Narragansett Bay Basin, Smithfield, Rhode Island. Phase I Inspection Report."

Guinan, W.A. (1980). "National Dam Safety Program. Shay Lake Dam (NJ 00266) Tributary to Flat Brook, Sussex County, New Jersey. Phase I Inspection Report." New Jersey Dept. of Environmental Protection, Trenton, NJ.

Healy, J.M. (1978). "National Dam Safety Program. Little Prarie Dam (MO 30090), Osage-Gasconade Basin, Phelps County, Missouri. Phase I Inspection Report." Anderson Engineering, Inc., Springfield, MO.

Appendix 1

Workshop Agenda

Tuesdav, November 30.1999

8:00am - 12:00 noon:

GENERAL SESSION
Welcome and Workshop Announcements
Susan Sorrell. ASDSO
Purpose and Objectives of the Workshop
Dr. B. Dan Marks, S & ME, Inc.
Overview of Plant Penetrations of Earthfilled Dams
Dr. Bruce Tschantz. University of Tennessee
Overview of Animal Damage to Earthillled Dams
David K. Woodward, NC State University
National Performance of Dams Program
Dr. Marty McCann, Stanford University
Plant and Animal Penetration Dam Incidents
Dr. Marty McCann, Stanford University

12:00 noon - 1:00 pm:

WORKSHOP LUNCHEON

1:00pm - 1:45 pm:

SESSION 11 - ANIMAL BEHAVIOR
Wildlife Damage to Earthen Dams. Dikes. Levees. and Related Structures
Dr. James E. Miller. USDA-CSREES National Program Leader Fish and Wildlife

1:45 pm - 2:30 pm

SESSION III - WILDLIFE DAMAGE
Wildlife Services Response to Animal Penetrations of Earthen Dams
Dr. Dale Nolte, USDAIAPHIS Research Wildlife Biologist

2:30pm - 3:15 pm

SESSION IV - PLANT PHYSIOLOGY
Tree Root Management: Physiology and Mechanics
Dr. Kim D. Coder, University of Georgia Professor of Forest Resources

3:15pm - 4:45 pm

SESSION V - FAILURE CASE STUDIES
Trees in Embankment Dams
Jim Leumas, P.E., State of North Carolina Dam Safety Engineer
Beaver Damage Related to Dam Problems
Charles Clevenger, P.E., P.L.S. Chief, Mississippi Dam Safety Division

6:00pm - 7:00 pm

WORKSHOP RECEPTION

UT Faculty Club

7:00pm - 9:00 pm

WORKSHOP BANQUET UT

Faculty Club

Wednesdav, December 1. 1999

8:15am - 12:00 noon

SESSION VI - MORE CASE HISTORIES

Dam Safety Versus Rodents: The California Experience

David R. Borger. P.E. California Division of Safety of Dams

Ohio Case Studies in Animal Penetrations

Boris E. Slogar, P.E, Program Manager Ohio Division of Water

Plant and Animal Damage of EarthiMed Dams

Doug McClelland, US Forest Service Forest Resources Biologist

Effects of Tree Removal on Earthfilled Dams

Ed Fiegle. P.E., State of Georgia Manager of Safe Dams Program

USBOR Practices of Tree Removal from Dams

Bill Bouley. P.E. US Bureau of Reclamation Technical Services Center Civil Engineer

12:00noon - 1:00 pm

WORKSHOP LUNCHEON

1:00pm - 2:00 pm

SESSION VII - PLANT AND ANIMAL CONTROL

Methods for Controlling Woody Vegetation

David Sisneros, US Bureau of Reclamation

2:00pm - 4:00 pm

SESSION VIII - REMEDIAL REPAIR ISSUES

Alternatives for Removing Trees from Dams USDA. NRCS Technical Notes Publications

Dr. B. Dan Marks, P. E., S & Ni E. Inc. Chief Geotechnical Consultant/Vice President

Plant and Animal Management Practices on Flood Control District Maricopa County Dams

Tom Renckly, P.E., and Gary Drake, P.E. Flood Control Projects Division Maricopa County, Arizona

Remedial Dam Repair of EarthfiUed Dams Related to Plant and Animal Penetrations
Dr. B. Dan Marks, P.E., S & ME, Inc. Chief Geotechnical Consultant &VicePresident

4:15pm - 5:00 pm
SESSION IX - NEW DAM DESIGN ISSUES
Vegetation Control Products and Procedures
William (Bill) Hawkins, Manager Biobarrier Root Control System Nashvdle, Tennessee

6:00pm - 7:00 pm
WORKSHOP RECEPTION
Hilton Hotel

Thursday, December 2, 1999

8:00am - 11:00 am
SESSION X - FACILITATED OPEN DISCUSSION
Research Needs Prioritization Session
David Harris, U.S. Bureau of Reclamation

11:00am - 11:30 am
SESSION XI - RESEARCH ACTIVITIES
Assessment of Burrowing Animal Damage Using Ground Penetrating Radar, Resistivity, and Streaming Potential Methods on Earthfdled Levee Systems
Matthew Barner, Wright State University Dayton, Ohio

CLOSURE OF WORKSHOP SESSIONS

1:30pm - 5:00 pm
WORKSHOP MANUAL WORK GROUP
Research Needs
Manual Outline & Contents
Manual Chapter Assignments
Publication Schedule & Timeline

Friday, December 3, 1999

9:00am - 2:00 pm
MANUAL WRITERS WORK SESSION
To Be Decided By Manual Writers

Appendix 2

List of Attendees

Mr. David R. Borger, Senior Engineer, DWR - Division of Safety of Dams, 7012 Kingsmill Way, CitrusHeights, CA, 95610, 916/323-5312, 916/324-0793, drborger@water.ca.gov

Mr. William L. Bouley, P.E., Civil Engineer, US Bureau of Reclamation, D-8470, PO Box 25007, Denver, CO, 80225-0007, 303/445/2754, 303/445-6381, wbouley@do.usbr.gov

Mr. Charles E. Clevenger, P.E., Chief, Dam Safety Division, Dept. of Environmental Quality, PO Box 10631, Jackson, MS, 39289-0631, 601/961-5204, 601/354-6938, charlie_clevenger@deq.state.ms.us

Mr. Francis E. Fiegle, II, Program Manager, GA Dept. of Natural Resources, Safe Dams Program, 4244 International Pkwy. Ste. 110, Atlanta, GA, 30354, 404/362-2678, 404/362-2591, ed_fiegle@mail.dnr.state.ga.us

Mr. James K. Leumas, P.E., State Dam Safety Engineer, DENR Land Quality Section, 1612 Mail Service Center, Raleigh, NC, 27699-1612, 919/733-4574, 919/733-2876, jim.leumas@ncmail.net

Dr. B. Dan Marks, Phd, P.E., Chief Geotechnical Consultant, S & ME Inc., 44 Buck Shoals Road G-9, Arden, NC, 28704, 828/687-9080, 828/687-8003, drdan@smeinc.com

Mr. Boris E. Slogar, P.E., Program Manager, OH Dept. of Natural Resources, Division of Water, 1939 Fountain Square, E-3, Columbus, OH, 43224, 614/265-6734, 614/447-9503, boris.slogar@dnr.state.oh.us

Dr. Bruce A. Tschantz, P.E., Professor of Civil Engineering, University of Tennessee, 63 Perkins Hall, Knoxville, TN, 37996, 423/974-7721, 423/974-2669, btschant@utk.edu

Mr. Doug McClelland, Geotech/Dams Engineer, US Forest Service, PO Box 7669, Missoula, MT, 59807 406/329-3351, 406/329-3198, dmcclell/rl@fs.fed.us

Mr. William M. Hawkins, Technical Consultant, Reemay, Inc., 70 Old Hickory Blvd, PO Box 511, Old Hickory, TN, 37138-3651, 615/847-7132, 615/847-7068, whawkins@reemay.com

Mr. Martin W. McCann, Jr., Director, National Performance of Dams Program, Dept. of Civil Engineering, Stanford University, Stanford, CA, 94305, 650/723-9323, 650/723-8398, mccann@ce.stanford.edu

Dr. David W Harris, Group Manager, US Bureau of Reclamation, PO Box 25007, D-8180, Denver, CO, 80225, 303/445-2375, dharris@do.usbr.gov

Mr. Tom Renckly, Project Manager, Flood Control Dist. of Maricopa County, 2801 West Durango, Phoenix, AZ, 85009-6399, 602/506-8610, 602/506-3890, trr@mail.maricopa.gov

Appendix 2

List of Attendees

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Appendix 3

Explanation of the MetaPlan Process

In the interest of collecting as many ideas as possible, but yet, preparing a workable list of possible topics, a special process was developed and used in the workshop. This process was a variation of the Strategic Planning Process known as MetaPlan developed by the IBM Corporation. The steps of this process are summarized below with accompanying outcome from the workshop.

Question to Resolve

The question developed for attendees to address:

What are needed developments to feel comfortable when dealing with woody vegetation and animals associated with dams?

The question is intended to be specific to the desired outcome, but somewhat vague so as to not influence input into predetermined categories.

Input from Attendees - The Brainstorming Phase

Input from attendees is collected on index cards, a few words per card. This is done by all participants simultaneously. The intent of this step is to collect as many ideas as possible from a fairly large group in a time efficient manner.

The cards are collected by a facilitator as completed, or at any time during the meeting. For this conference, Dr. David W. Harris from the U.S. Bureau of Reclamation Laboratories served as the facilitator. The cards are read one at a time and sorted into columns of similar topics at the front of the room, with everyone participating. A perfect distinction is not necessary at this phase.

Identifying the categories of research

With all cards sorted into columns, the test of distinction is to test if a headline can be established for each column. Some movement of initial cards may be necessary during this process. New cards may be added at any time as participants think of new ideas, want to clarify their idea, or find items that may belong in more than one category. The continued intention is to collect as much information as is possible in a time limit. A short description is sought for all items listed in any given column. This column then becomes a research area with possible individual tasks within the column.

Prioritizing the Categories

Individuals are next asked to define their own priority (Importance) for the categories using a multi-vote. In this case ten glued dots are provided to each participant. A participant may split their priorities within the following rules:

1. May use any or all of the dots distributed throughout the categories

2. As many as 3 dots may be used on any one category to represent increased importance of any particular category to the participant.

Appendix 3

Explanation of the MetaPlan Process

All votes are counted for each category. This voting creates a typical Pareto distribution of the categories. This typical distribution is shown below:

VOTES	A	B	C	D	E
	X				
	X	X			
	X	X	X		
	X	X	X		
	X	X	X		
	X	X	X	X	
	X	X	X	X	X

A is ________ B is ________
C is ________ D is ________
E is ________

Figure 1 - Pareto Distribution of Research Categories by Participant

In a Strategic Planning Context additional information can be useful. This is an estimate as to how difficult any particular category may be. Difficult may mean expensive, technically challenging, complex, or any context which the participant chooses for any given category. In this case each participant gives EACH category a score of 0 to 10, with 0 being easy and 10 being really hard. In this case participant scores are averaged.

This data provides a second dimension for plotting of the category data. This produces a decision quad of the data. The quad is formed by four quadrants in the data, each of which is given a descriptive name:

- *Quad : Easy and important : Low Hanging Fruit*
- *Hard and important: Strategic Items*
- *Easy but less important: Do later*
- *Hard and less important: Consider*

Sample decision quad

Importance	Low Hanging Fruit B	Strategic Items A
	Do later C,D	Consider E
	Difficulty	

Appendix 3

Explanation of the MetaPlan Process

Research and Development Issues

The full caucus of members was asked to work on the categories, to further develop the ideas to a level which could be understood and considered for funding by the ICODS Subcommittee on Research. Each attendee chose the category in which he or she was most interested to develop and submit research and development ideas. It was suggested that a format of the 6 Ws be used as a framework to the effort.

- *Who*
- *What*
- *Why*
- *Where*
- *When*
- *How*

Twelve research and development ideas were submitted. See Tab 3, Page 6 of this report.