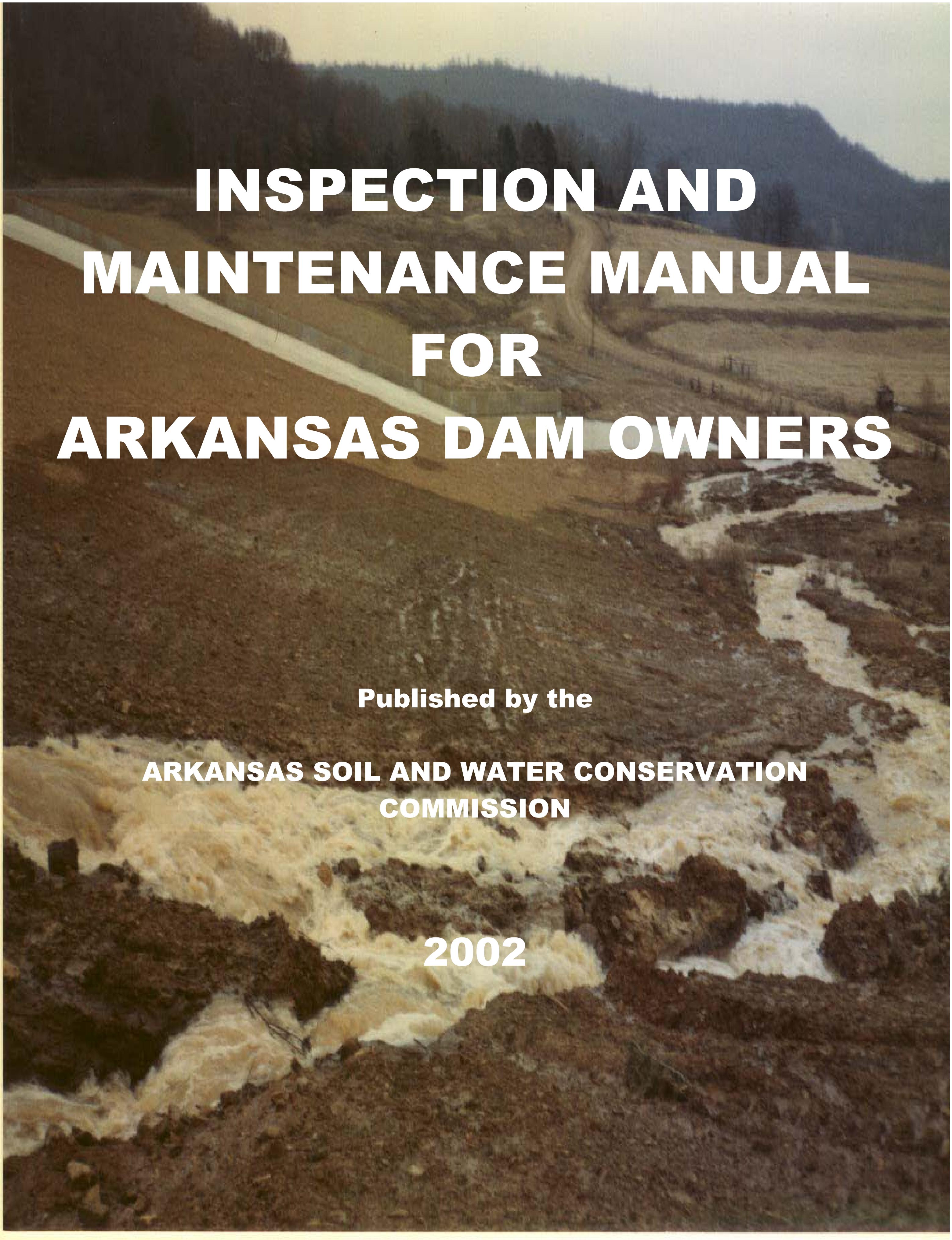

INSPECTION AND MAINTENANCE MANUAL FOR ARKANSAS DAM OWNERS

Published by the

ARKANSAS SOIL AND WATER CONSERVATION COMMISSION

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STATE OF ARKANSAS

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March 2002

TABLE OF CONTENTS

APPENDICES

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ACKNOWLEDGEMENTS

The subject of dam safety has attracted a great deal of attention in recent years, and in preparing this manual, information from a number of sources was used. The National Dam Safety Program, instituted in response to several major dam failures in the early 1970's, focused on the problem nationwide. Under this program the U.S. Army Corps of Engineers and the Arkansas Soil and Water Conservation Commission worked together to inspect many dams throughout the State. In recent years, the Federal Emergency Management Agency (FEMA) has taken the lead in providing assistance to states in promoting dam safety. The National Dam Safety Program Act of 1996 continues to reinforce the commitment by the Federal Government to dam safety.

The assistance and training provided by FEMA, the Association of State Dam Safety Officials (ASDSO) and other states is reflected extensively in this publication. Manuals and guidebooks published by these organizations were extremely helpful, especially the Training and Aids for Dam Safety (TADS) modules coordinated by the Bureau of Reclamation and Dam Safety: An Owner's Guidance Manual published by FEMA.

The cooperation of the owners of dams within the State is of course essential to the success of the State's dam safety effort. The agreeable and helpful response of most of the owners, both public and private, with which this agency has come in contact in the course of its dam safety activities, has been most gratifying. The ultimate purpose of such a program is the protection of the lives and property of citizens of the State, and the ready acceptance of this goal by the majority of the wide range of individuals and groups bearing the responsibility for the safety of dams is very much appreciated.

This publication was funded by a grant from the Federal Emergency Management Agency, National Dam Safety Program.

FOREWORD

This manual presents a basic discussion of how to evaluate the safety of a small earthen dam. Its intent is to inform the dam owner or operator of general aspects of inspections and preventive maintenance so that he should be able to recognize certain unsafe conditions that may be associated with such structures. Once unsafe conditions are recognized, professional services may be obtained to assess the problem and to take appropriate remedial action. The Arkansas Soil and Water Conservation Commission cannot provide consulting engineering services, but it does maintain a list of private firms that have performed this work in the State. This manual provides general guidance on some of the more common problems, but it is not intended to cover every type of condition, situation, or emergency that could possibly cause a dam to become unsafe or fail.

It should be noted that the condition of a dam depends on many internal and external conditions that may be constantly changing, thereby causing the overall health of the dam to evolve over time. It is incorrect and unwise to assume that the conditions of a dam at any given time will continue to represent its conditions at some time in the future. Only through continued care and evaluation can there be a reasonable chance that unsafe conditions will be detected.

The design of an earth dam is the task of an experienced professional engineer. Likewise the implementation of major remedial measures for a dam generally requires a consultant. The application of trial-and-error "home remedies" to dam problems is not recommended, and such an approach will, in the long run, likely prove to be far more costly than obtaining and acting on professional guidance. The text and illustrations of this manual are not intended to serve as a design guide either for the construction of new dams or for extensive remedial measures for existing dams. Rather they are intended to serve as a source of information which the owner can use in his regular maintenance and inspection activities and as a general guide as to when professional services are needed to insure the safety of a dam.

INTRODUCTION

This manual was written to assist you, the dam owner, in inspecting your dam and maintaining it in a safe and stable condition. The focus of any dam safety effort is, of course, safety: the protection of lives and property in the area downstream from the impoundment. Every owner should be aware of the potential hazard that his dam might pose to the downstream area and of the need to properly maintain the dam in such a way as to reduce this hazard as much as possible. The liability for damages resulting from a dam failure rests with the owner of the dam (Act 339 of 1983).

A good inspection and maintenance program is important. Your dam represents a considerable investment. Replacement costs would be high. Loss of the dam would probably mean the loss of a water source, recreational facility, flood protection, or other assets.

Dams are products of our technology and, like automobiles, provide us with many benefits. Like autos, however, they may not be thoroughly understood by persons who own them. Consequently, their maintenance is often neglected, and their potential for doing great harm and damage - and costing large amounts of money as a result - is often not appreciated until an accident occurs.

As in the case with buildings, highways, and other works that we construct, dams require an on-going maintenance program to insure their continued useful life. This fact has not always been fully appreciated. Often there is a tendency to neglect them once construction is completed.

There are many ways an earth dam can fail. These include, but are not limited to sliding, piping (internal erosion of soil particles from the embankment), overtopping during periods of high water, erosion, liquefaction of earth materials (which may occur when embankment material is poorly drained and loosely compacted), structural failures resulting from excessive seepage or other causes, and failures of the foundation upon which the structure rests. Problems associated with outlets and spillways can also be contributing factors.

Like most works of man, dams should not be considered to have an unlimited useful life. Ernest F. Wahlstrom, Professor of Geological Sciences at the University of Colorado, states in Dams, Dam Foundations, and Reservoir Sites: "The ultimate fate of all dams and reservoirs, unless they are carefully constructed and maintained, is deterioration and failure or filling by sedimentation. Every reservoir that impounds water behind a dam is a real or potential threat to those who live and work in flow channels below it and, in some locations where earthquake shocks, movements along bedrock faults beneath dams, or collapse of large volumes of earth materials into reservoirs are distinct possibilities, even the most skilled design and continued maintenance may not preclude failures that are disastrous to life and property." So, many events and circumstances can threaten the safety of a dam, including floods, landslides, earthquakes, and - less dramatically but just as surely - neglect and the deterioration which inevitably occurs through neglect.

CHAPTER 1: TYPES OF DAMS

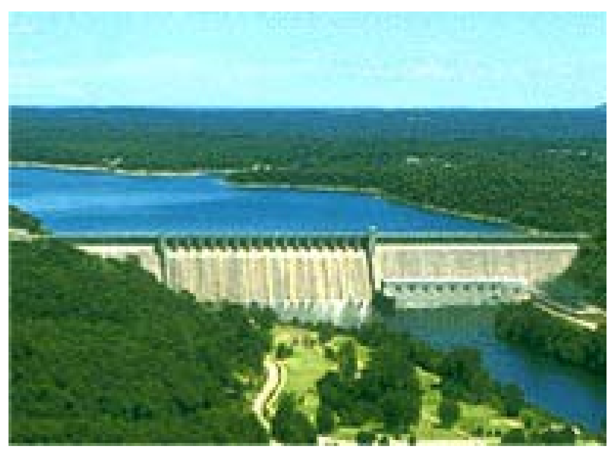
Before discussing some of the procedures for inspecting a dam, it is appropriate to make a few general comments about such structures. In simplestic terms, a dam is a barrier constructed across a watercourse for the purpose of storing water. Perhaps the most common type is the earthfill or earthen dam, and this manual deals with small dams of this mode of construction. There are also concrete dams (gravity, arch, multi-arch, and buttress types) and dams constructed of masonry, timber, rockfill, steel, and combinations of these materials (Figure 1.1).

FIGURE 1.1 Types of Dams

a. Rock-filled gravity dam

b. Concrete arch dam

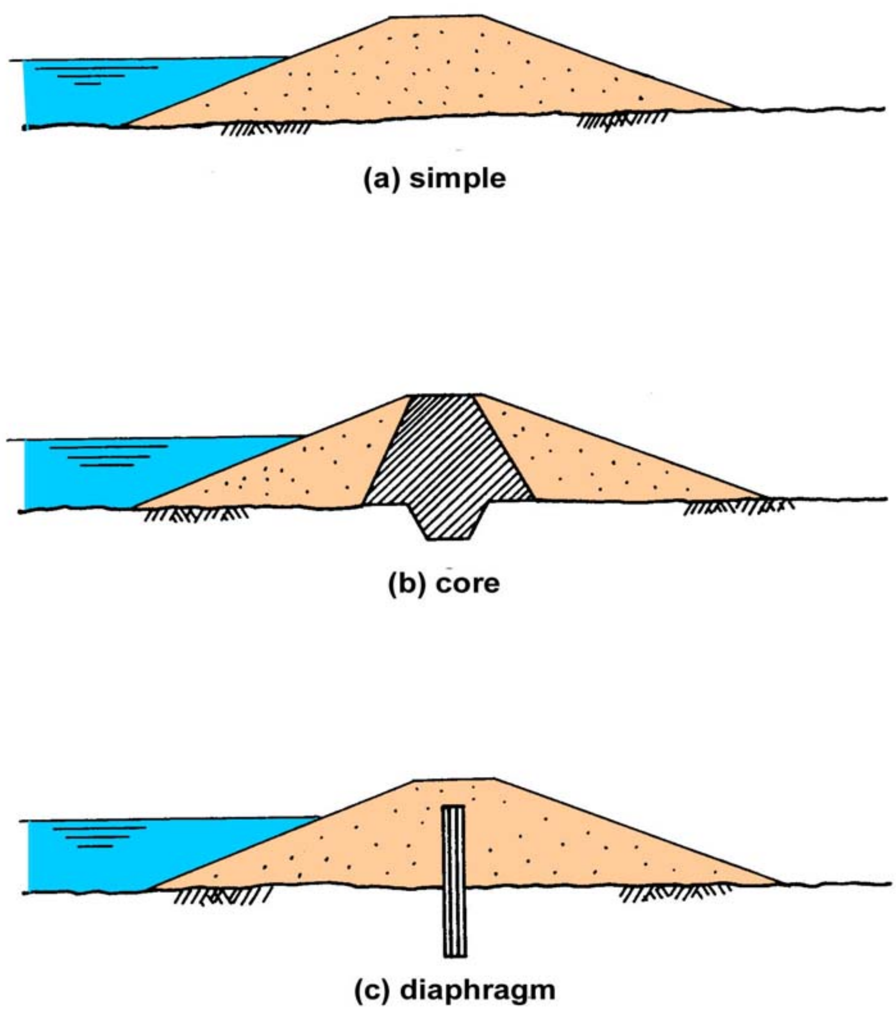
c. Small earthen dam



d. Concrete dam

Earth dams may be further classified as simple, core, and diaphragm (Figure 1.2). The simple embankment type consists of reasonably uniform material throughout, sometimes with a blanket of highly impervious material placed on its upstream face. This type of dam is also referred to as a homogeneous embankment dam. Core embankments employ a central zone or core of carefully chosen material, which is less pervious than the rest of the dam. Clay soils are often used for the core, as this type of material is particularly suitable. This dam is also referred to as a zoned embankment dam. Diaphragm type dams incorporate a relatively thin section of concrete, steel, or wood - sometimes referred to as a cut-off wall - in the central portion of the embankment, which forms a barrier to the flow of water percolating through the dam. Occasionally an earth dam is constructed with both a central core and a diaphragm.

FIGURE 1.2
TYPES OF EARTH DAMS



CHAPTER 2: A TYPICAL DAM AND ITS PRINCIPAL PARTS

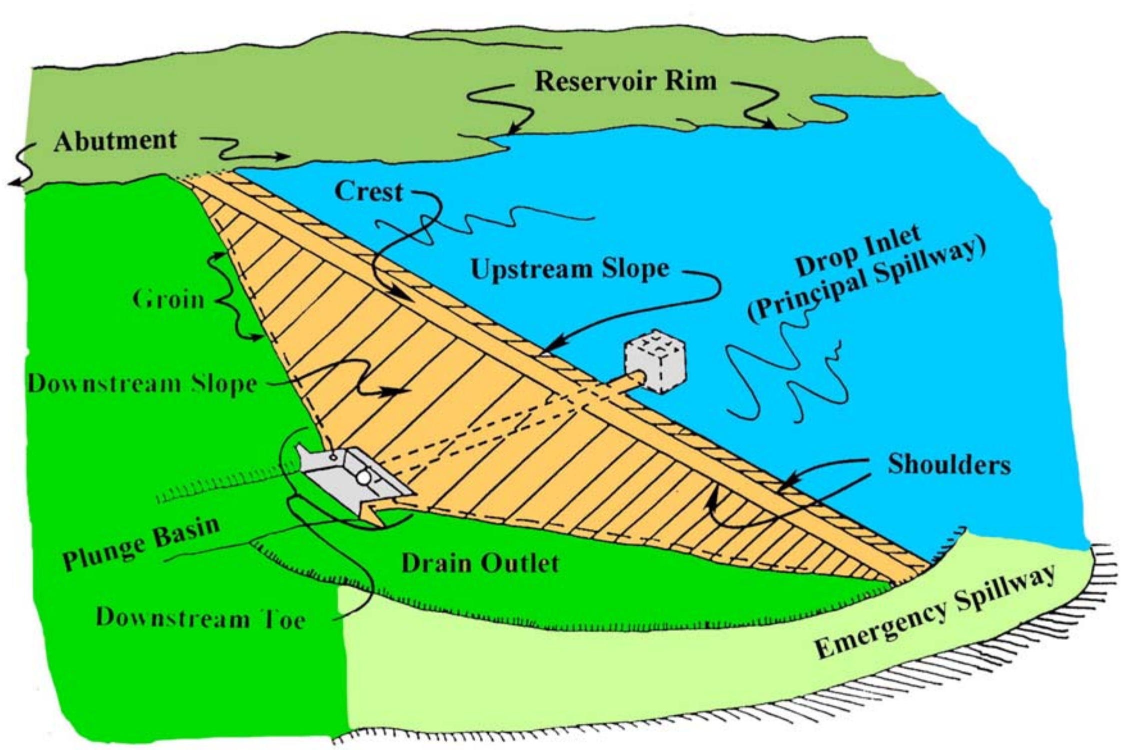
As stated earlier, a dam is essentially a barrier constructed across a watercourse for the purpose of storing water. There are certain features of such structures, such as the principal spillway, which perform vital functions and are common to practically all small earth dams.

DEFINITIONS

Figure 2.1 illustrates many of the principal parts of an earthfill dam. Understanding the purpose of these is essential to any evaluation of a dam's condition.

Abutment: The abutment is that part of the valley side against which the dam is constructed. The contact between the abutment and the embankment slope is called the slope-abutment-interface or **groin**. The abutments and groins are designated as left or right when facing downstream while standing on the crest of the dam.

FIGURE 2.1
PRIMARY COMPONENTS OF A DAM



Appurtenant structures: Appurtenant structures refer to ancillary features of a dam such as outlet works, spillways, powerhouse, tunnels, etc.

Core: The core is the central portion of a zoned earth dam, composed of impervious material.

Crest: The crest is the top surface of the dam. Often a roadway is established across the crest for traffic or to facilitate dam operation, inspection and maintenance. The shoulders are the upstream and downstream edges of the crest.

Cutoff trench: The cutoff trench is an excavation in the foundation of a dam for the purpose of construction of a vertical barrier (such as a core or diaphragm) to seepage.

Downstream Slope: The downstream slope is the inclined surface of the dam away from the reservoir. This slope also requires protection from erosive effects of rain. Grass is often used for erosion protection on the downstream slope.

Emergency Spillway: The emergency spillway is designed to safely pass the discharge of large storms or flood flows, thereby preventing the dam from being overtopped and possibly breached.

Foundation drains: Foundation drains are various types of systems employing pipe, gravel, etc., within an embankment which serve to collect seepage water and move it to a point where it can be safely discharged without deterioration of the dam.

Intake structure: The intake structure is the part of a drop inlet spillway through which water enters.

Outlet Works: The outlet works are structures (pipes or culverts) through which normal reservoir releases are made. Outlet works can also be used to drain the reservoir.

Principal Spillway: The principal spillway is the initial spillway to carry the storm or flood discharge. It may be either a drop inlet or an overflow structure. Usually, the principal spillway is designed to maintain the water in the reservoir at a constant level.

Reservoir: The reservoir is the body of water impounded by the dam.

Riprap: Riprap is a layer of stones, broken rock, or precast blocks placed in random fashion on the upstream slope of an embankment dam, on reservoir shores, or on the sides of channels to protect against wave erosion and ice action. Very large riprap is referred to as armoring.

Spillway: The spillway is a structure over or through which storm or flood flows are discharged from the reservoir. If the rate of flow is controlled by mechanical means, such as gates, the structure is considered a controlled spillway. Otherwise, the spillway is considered uncontrolled. See Emergency Spillway and Principal Spillway.

Stilling basin or plunge basin: The stilling basin or plunge basin is a basin or pool area at the toe of the dam into which the outlet works discharge. This area is designed to dissipate the energy of the flow so as to prevent downstream scour or erosion.

Toe: The toe (or downstream toe) is the junction of the downstream slope of the dam with the ground surface.

Toe Drain: The toe drain carries internal seepage water away from the dam. The toe drain is a collector pipe surrounded by a filter material and placed in the toe of the dam or laid in a trench beneath the toe. A toe drain collects seepage water from the embankment and foundation and carries it to an outfall pipe that discharges the seepage water into the spillway or outlet-works basins or otherwise safely away from the dam. The outfall is the discharge point from the toe drain. The outfall is a convenient point for measuring seepage quantities.

Trash rack: The trash rack is a screening device located at an intake structure to prevent the entry of debris.

Upstream Slope: The upstream slope is the inclined surface of the dam that is in contact with the reservoir. This slope must be protected from the erosion due to waves. Erosion protection may include grass, or the placement of riprap or some other durable material.

CHAPTER 3: IS YOUR DAM REALLY A HAZARD?

Every dam represents a potential hazard to the area downstream from it, simply because of the inherent amount of destructive energy that would be unleashed if the stored water behind it was suddenly released. Thus a dam is generally classified as to the degree of hazard it poses simply on the basis of its location, without regard to the type of structure or the physical condition. **High Hazard** dams are those whose location is such that in the event of a failure there would be probable loss of life and/or excessive damage. **Significant Hazard** dams are those where loss of life is unlikely and damage would be appreciable. For **Low Hazard** dams no loss of life is expected, and damage would be minimal. (See Figure 3.2)

FIGURE 3.1
House immediately below earthen dam

In view of the fact that a dam owner is legally liable for damages resulting from the failure of his dam, it is a good idea for every owner of a dam to pause and consider what lies below it. Several questions need to be asked.

What is the nature of the land use downstream: wooded or agricultural land, scattered homes, roads, villages, urban areas? How many structures are located within a half mile, a mile or several miles of the dam?

How are downstream structures located with regard to the watercourse or floodplain, with respect to both distances from the watercourse or river and elevation above it? Think about the first-floor elevation of the homes located downstream. Are they only a few feet above the level of the water surface, or are they on bluffs high above it and out of danger?

Is the valley below the dam characterized by steep hills forming a narrow gorge, or is there a broad floodplain? This is an important consideration, as it determines whether water released in a dam failure would soon spread out and lose its force or whether a destructive wall of water would travel a long distance downstream.

An awareness of the state of development of the downstream area should be a continuing concern, as conditions below a dam often change appreciably over the years. Thus a dam which posed little hazard when constructed may represent a formidable hazard later as the downstream area develops. When this is the case, it is imperative that an **emergency action plan** be prepared for the structure, with adequate provision for alerting those in the affected area in the event the dam's safety is threatened. The Arkansas Soil and Water Conservation Commission, in conjunction with the Arkansas Department of Emergency Management (ADEM), can provide guidance on the establishment of such plans. **See Chapter 6: Emergency Preparedness**.

The Dam Safety Program of the State of Arkansas defines dam safety hazards as follows:

FIGURE 3.2
HAZARD CLASSIFICATION FOR DAMS IN ARKANSAS

CATEGORY	LOSS OF HUMAN LIFE	ECONOMIC LOSS
HIGH	YES	Excessive (Extensive public, industrial, commercial, or agricultural development); over $500,000.
SIGNIFICANT	NO	Appreciable (Significant structures, industrial, or commercial development, or cropland); $100,000 to $500,000.
LOW	NO	Minimal (No significant structures; pastures, woodland, or largely undeveloped land); less than $100,000.

CHAPTER 4: LIABILITY AND RESPONSIBILITY OF DAM OWNERS

Dam ownership carries with it significant legal responsibilities. The dam owner should be aware of the potential liabilities and how to conscientiously deal with these liabilities.

This chapter will deal with general legal and insurance matters to help you minimize exposure to liability due to dam ownership or operation. You will become familiar with the responsibilities imposed by dam ownership. Since this guidebook is intended to provide general guidance to dam owners, it cannot answer specific legal issues. Dam owners and operators should obtain competent legal counsel when dealing with specific issues.

1. Potential Liability Problems for Dam Owners

A dam owner should first be familiar with the legal obligation to maintain a dam in a safe and reasonable condition. The general rule is that a dam owner is responsible for its safety. Liability can be imposed upon a dam owner if he or she fails to maintain, repair or operate the dam in a safe and proper manner. This liability can apply not only to the dam owner, but also to any company that possesses that dam, or any person who operates or maintains the dam. If an unsafe condition existed prior to ownership of the dam, the new dam owner could not be absolved of liability should the dam fail during his term of ownership. Thus, the owner must carefully inspect the structural integrity of any dam prior to purchase and then provide inspection, maintenance and repair thereafter.

Since the dam owner is responsible for dam safety, it is important to note what you must do to comply with that legal duty. The dam owner must do what is necessary to avoid injuring persons or property. This usually applies to circumstances and situations which can be anticipated. A dam owner would generally not be responsible for those circumstances that a reasonable person could not anticipate. One key action is almost universally recognized: In order to meet your responsibility to maintain your dam in a reasonable and safe condition, virtually every jurisdiction will require a dam owner to conduct regular inspections of the dam and maintain and/or repair deficient items. Regular inspections by qualified professionals are virtually mandated if a dam owner is to identify all problems and correct them.

2. Potential Personal Injury Liability

Dams and impoundments are popular places, even if located in remote areas. A dam may be visited by employees, contractors, invited visitors or trespassers. The presence of these persons is a potential liability to the dam owner. Liability or worker's compensation insurance should cover employees, contractors or invited guests. However, the trespasser presents a unique problem.

The majority of trespassers at a dam site are probably members of the public who wish to use the site for fishing, boating or swimming. While they may mean no harm, their unauthorized use of the site is a serious liability problem for the dam owner.

The dam owner is responsible for making and keeping his premises safe. The general rule is that the dam owner must avoid conduct or conditions which could injure any person, even one who trespasses. If the dam owner knows that an unsafe condition exists he is responsible to correct it and/or post warnings. Typical dangers at a dam site include fast moving water, open spillway (pipes) and thin ice. A particularly dangerous area is the spillway which not only has fast moving water but undertow at the spillway bottom.

Owners of dams are charged with greater responsibility when the trespassers are children. By reason of children's inability to understand the danger which a condition may pose, a dam owner is expected to protect children from the dangers of a dam site. In effect, this rule requires you to anticipate what parts of the facility would be particularly attractive to children. Since signs may not adequately warn children, security fencing is necessary. Dam sites located near state or county roads, campgrounds or picnic areas, or near populated areas will attract many more people. These popular dam sites require frequent visits by the dam owner to inspect and assure safety.

3. Potential Liability Due to Operation of the Dam

In addition to liability problems arising out of dam ownership, operation of the dam is also a significant legal issue. First and foremost is the simple right to operate. State law requires a permit to construct, repair and/or operate a dam. The Arkansas Soil and Water Conservation Commission should be consulted for particular matters regarding this issue. In addition, a dam on a navigable stream may involve federal government regulations, such as a Corps of Engineers permit, which may govern operation.

Beyond the basic permitting question, all dam owners must consider the effect of dam operation on the rights of other water users, whether they are upstream or downstream from the facility. For both upstream and downstream users, this responsibility includes a duty to avoid negligent flooding of their property.

A general rule in all states is that the dam owner must protect downstream landowners from additional flooding, if those downstream owners have come to rely on the existence and operation of the dam to reduce flooding. The extent of this duty will vary from state to state, so the dam owner is advised to consider dam operations in the light of the downstream landowners' expectations and dependency on the dam to prevent flooding.

In situations where there is no specific duty to protect downstream owners from flooding, the dam owner must still operate the dam conscientiously. As the dam owner, you must be in a position to clearly show that your dam did not increase flooding.

Upstream users may also have the right to be protected from damage caused by operation of the dam. Therefore, the dam owner is advised to assess the legal as well as the physical impact of any change in the level of the impoundment, including dam removal.

4. Environmental Concerns

While there are an infinite number of potential environmental issues, a few basic areas of concern should be addressed before a dam is purchased or its method of operation altered. Since this guidebook cannot address all environmental issues, you should seek professional evaluation of potential environmental problems. However, we can give you some general guidance.

Dams with gates for regulating the impoundment and downstream flow can cause water levels to fluctuate. These fluctuations can cause gain or loss of wetland habitat affecting fish spawning, waterfowl, and shorebird nesting. Fluctuations of water levels can also increase shore erosion, cause unsafe ice conditions and the like. At this time, virtually all states have laws concerning wetlands.

Variations in the impoundment and downstream elevations can also impact fish in the impoundment or the river. Evaluation of existing fisheries and the impact of changes will require consultation with the Arkansas Game and Fish Commission.

Within a dam impoundment, it is likely that sediments have accumulated over the years. Release of these sediments downstream by operation of the dam, changing the impoundment level, or removing the dam could result in significant damage and liability to the dam owner. In addition, release of sediments downstream could adversely impact plant and wildlife for significant time periods. It is also quite common that the sediments contain pollutants. Thus, the dam owner should carefully consider the possible impacts of dam operation and how it affects the environment.

5. A Final Word About Liability

The dam owner is liable. This section on liability is only a general introduction to the many issues regarding dam owner liability. The discussion is only intended to provide a basis for you to consider liability potentials and to encourage you, the dam owner, to seek competent legal counsel and/or technical experts to help resolve your problems. Where the ownership and operation of dams and impoundments are concerned, the old saying, "an ounce of prevention . . ." is appropriate. Following it will truly save you the "pound of cure."

6. Insurance

The purpose of this section is to provide dam owners with general information about dam insurance. The primary goal of dam insurance is to share the risk and protect the assets and financial well being of the dam owner. Insurance cannot make a dam safe, or make an inherently faulty construction or renovation project into a good one. Inadequate coverages or insufficient limits on those coverages, coupled with a major loss, can mean the financial ruin of a dam owner. In order to obtain insurance and get a reasonable rate, the dam owner will have to show that the dam meets all state standards with regard to design, construction and operation.

When insuring a dam, the owner should select and involve a competent insurance agent or broker as early as possible. Whenever a dam project requires new construction, reconstruction or renovation, any lender involved will be very interested in the adequacy of the dam owner's insurance program.

The primary job of the agent is to serve as a contact point between the client and the insurance companies, and to place the insurance coverage with appropriate companies. The agent, depending on his skill, dedication and relationship with insurance markets, can greatly affect both the premiums quoted by the companies and the availability of certain coverages. Although most types of insurance have standard contract forms, many of the details of the coverage are open to negotiation and can be tailored to meet the needs of the dam owner, except in those areas mandated by law. It is important to work with your agent to define conditions of the policy that are of real importance and those that need modification.

Although the size of an agency is not an indication of its quality or experience, large national firms will frequently have more extensive consulting services available. Also, dams are an unusual risk to most insurance companies and large agencies often have personnel who have worked with other dam owners and industries with dam experience.

Contact your insurance agency or state insurance commissioner to get a list of insurance agencies who may assist you with dam insurance.

There are various types of insurance the dam owner should consider, in consultation with his agent. These include the standard “All Risk” property damage policy with a flood coverage amendment, business interruption insurance, boiler machinery coverage, general liability, automobile liability, workers compensation, and umbrella liability policy coverage.

Because of the many types of insurance protection required and available, the development of an effective insurance program requires care and planning. If you involve a qualified insurance agent in the early planning and work diligently to define your insurance needs, then an effective and economic program can be developed.

CHAPTER 5: YOUR CONSULTANT'S ROLE IN DAM SAFETY

A dam is an active structure. In many ways, a dam is similar to a person's life. When it is constructed, it is essentially born, and as the years pass it begins to age. It is hoped that a sudden, unexpected "death" of the dam will not occur. Like a person, some ages are more susceptible to illness and death than others. Although the dam will continue to age, it can periodically be repaired and maintained to keep it "youthful." The only way that the aging process can be monitored and the condition of the dam evaluated is by the experienced, trained professional observing and testing the structure.

This chapter will provide some guidance for the dam owner regarding the role of a dam consultant in dam safety.

1. Why Do You Need A Consultant?

A dam is a special kind of structure which is simple in concept but has many complicated components. In the design and inspection of a dam, many engineering disciplines are needed to analyze, design, build, inspect and repair a dam. As an example, the following expertises are required when working with a dam:

— A **geotechnical engineer** is needed to analyze the foundation soil/rock conditions to determine how strong and how permeable (leaky) they are. He will also determine the best material to build the dam or to repair the dam, such as soil, concrete, rock, etc.

— A **hydrologist** studies the watershed (the region drained by a river), river flow characteristics, determines flood levels, and peak flow rates at the dam.

— A **hydraulic engineer** designs the spillway and outlet works. He would also be instrumental in designing hydroelectric facilities or irrigation facilities.

— **Mechanical and electrical engineers** may also be needed to design or maintain control mechanisms and dam operators.

— An often overlooked specialist is the **instrumentation specialist**. This technician is responsible for the installation of devices which monitor the condition of the dam and determine how the dam is performing.

CHAPTER 6: EMERGENCY PREPAREDNESS

1. Can an Emergency be Anticipated?

Dams should be designed with sufficient safety factors so as not to fail. However, conditions beyond the control of the dam owner and engineer can occur due to natural forces, mistakes in operation, negligence or vandalism. The purpose of this chapter is to identify typical dam failure scenarios. We will explain the effect of dam failures on upstream and downstream users and help the reader formulate an emergency action plan. The emergency action plan will include procedures for warning local units of governments. Local evacuation plans should be coordinated and developed with the local government agency.

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2. Types of Failures

In preparing emergency plans, two types of failures are usually considered. They are termed rainy day and sunny day failures. A **rainy day failure** could occur when heavy precipitation, in excess of that normally observed in the watershed above the dam, leads to a high runoff period. If the high water was to overtop the dam or add too much pressure, a rapid failure could result. The dam owner should be an astute weather watcher and be responsive to precipitation events.

A normal storm event could lead to overtopping the dam if the outlet works are plugged with debris, if the gates jammed or were broken, or if a power failure prevented operation of key mechanisms. All the items can be controlled by proper operation and maintenance of the dam.

Dams have also failed without any heavy precipitation. These failures are called **sunny day failures**. They are usually the result of neglected inspection programs and poor maintenance and operation of the dam. As an example, failure to consider embankment seepage could lead to piping (internal erosion). A sunny day failure could be caused by vandalism of the outlet works, such as damage to gate mechanisms, or if the outlet works are plugged with debris. Sunny day failures are more likely at unattended dams than frequently visited dams.

Both rainy and sunny day failures can occur at new dams. New dams are very susceptible during initial filling and for a few years after filling. In fact, many dams have failed during their first filling. **Emergency action plans are a good idea for all dams. Some states even require one prior to construction. In Arkansas, they are required for all high hazard dams.**

The downstream effect of a dam failure can be devastating. When a break in a dam (breach) develops, water discharge increases due to the uncontrolled release of water stored by the dam. Destruction of homes and property has been well publicized. The force of water through existing bridges and culverts and over roads can cause their collapse. It has been documented that the flood wave from a small dam can overtop roads and wash cars from the roadway. Overtopping of the roads also makes them impassable for emergency vehicles. Dam failures can kill people.

Damage to the environment and to upstream users from a dam failure can also be catastrophic. A breach in the dam and rapid loss of the impounded water can cause heavy silt loads to be passed downstream. These sediments, after a period of time, will settle out, clogging and covering the flooded land and streambed. Fish and wildlife habitat can also be damaged. Upstream slopes can fail and boaters could be washed downstream.

The ASWCC has prepared guidelines for the preparation of emergency action plans for dam owners. The following sections of this guidebook discuss, in general, the contents of an emergency action plan. Each should be modified for a specific dam site. Dam owners may need to retain an engineer to help prepare the emergency action plan.

3. Emergency Action Plans

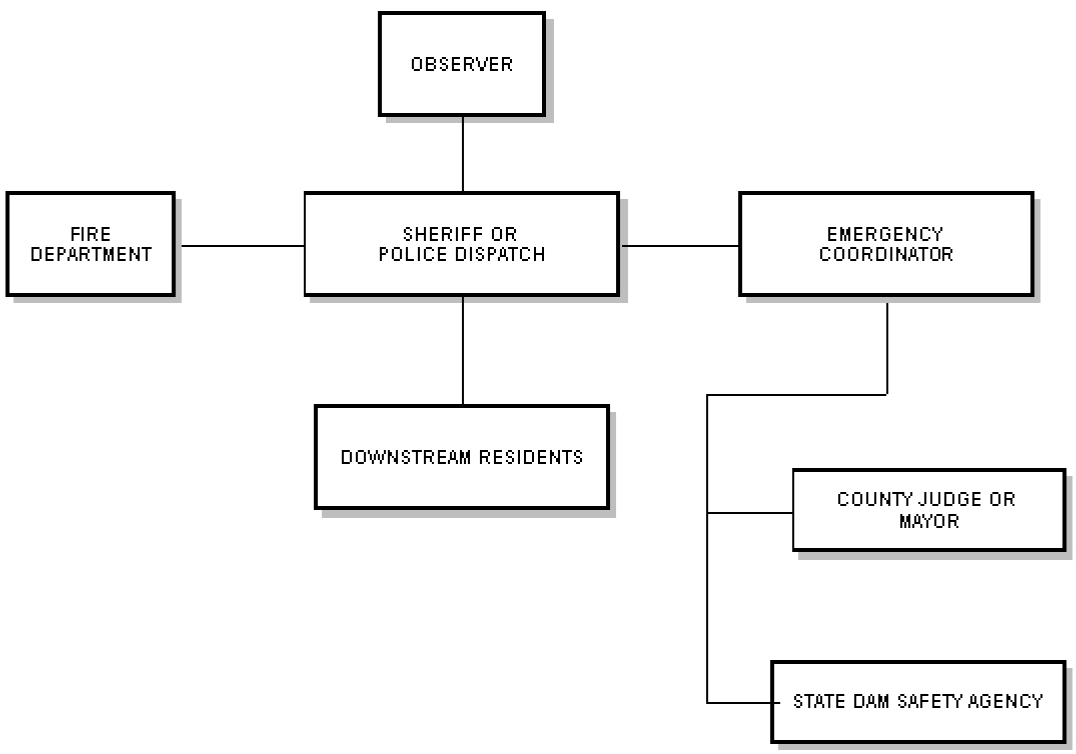
Emergency action plans for dam failures usually consist of three sections: preplanning, on-site assessment and initiating warning and evacuation plans. Each part of the plan calls for action by the dam owner.

Preplanning for an emergency may require detailed analysis by an engineer. The engineer will analyze and determine flooding that would happen after a dam failure. He or she will prepare flooding maps to be used for the evacuation portion of the emergency action plan. The analysis will also predict and map flood wave height and speed. All affected downstream landowners and buildings will be identified to develop a list of who to contact with flood warnings and evacuation notices.

It is also important to provide early warning of possible dam failure. This may include installation of sound alarms at unmanned dams. The consulting engineer or your state dam safety group can advise you as to whether or not alarms are needed.

During the time preceding a possible dam failure, the dam owner is responsible for implementation of the emergency action plan. Figure 6.1 is a simplified “flow chart” to help you make decisions and respond correctly to a failure of your dam. Two types of failures are normally considered, the instantaneous or rapidly developing failure (the failure will occur immediately), and the slowly developing failure.

FIGURE 6.1
SIMPLIFIED NOTIFICATION FLOWCHART



For a slowly developing failure, there may be time to take remedial or corrective actions to reduce the impact of the failure. For example, a controlled drawdown of the impoundment could be done. For the rapidly developing failure, immediate contact with local emergency authorities is essential.

The dam owner is responsible for providing early warning of the problems at the dam to the local emergency unit. The owner is responsible to convey the message; however, it is the ultimate responsibility of the local and state agencies to make the decision to initiate evacuation plans and re-entry plans.

It is a good idea to have a telephone list like that shown on Figure 6.2. Keep this list up to date and readily accessible. Many dam owners post it by their phones. In an emergency, it will save time searching for a number. Also, if you or your normal operator is absent, the substitute can rapidly respond to the emergency.

4. Summary

The development of an adequate emergency action plan requires coordination between the dam owner and the local and state agencies. It is important that each individual participating in the warning procedures and evacuation plan be provided with a copy of the plan. The plan should be updated annually and reviewed by all participants involved.

Developing and preparing an emergency action plan gives the dam owner the ability to make correct responses in times of emergency. As we have stated throughout this guidebook, you are responsible for the operation, maintenance and activities at your dam. This remains true - even in an emergency.

FIGURE 6.2
DAM OWNER/OPERATOR TELEPHONE LIST

(sample)

1. Local Police/Sheriff Department:: (   )____________________
2. State Police/Patrol: (   )________________________________
3. Dam Operator/Owner: (   )______________________________
4. Downstream Residence/Business:

Name	Telephone
____________________	( )____________________
____________________	( )____________________
____________________	( )____________________
____________________	( )____________________

1. Hospital/Ambulance: (   )______________________
2. State Dam Safety Agency: ________________________________
   Phone: (   )________________
3. Engineer: ____________________________
   Phone : (   )______________________
4. Others as needed.

Post this list in a prominent place at the dam and give a copy to all of your operators.

As can be seen, many specialists are needed to study a dam. It is uncommon that a dam owner has all of the technical skills needed to monitor the condition of the dam. Even if the dam owner did have such skills, it is unlikely that he could devote the time and effort necessary to do this work. Thus, the role of the consultant is critical in dam safety. Quite often, all of the needed technical expertise is not available in a single individual. Thus, owners often contract with consulting firms to provide dam services.

2. How Do You Hire A Consultant?

Experience has shown that it is most important to hire the expertise that you need rather than making the cost of the service the deciding factor. Owners often make the decision of which consultant to hire based solely on cost and end up getting only part of the service that they need. When hiring a consultant, certain steps will assure that the owner is getting what is really needed. First, the owner should pre-qualify consultants with regard to the background and experience of the company and the specific experience of the individuals who will do the work. This initial screening of possible consultants will be based on professional qualifications. In this way, the owner can be assured that he is getting the best quality of expertise. After the pre-qualification, the owner should try to define what work needs to be done. Some owners will select a consulting firm based on qualifications and then work with that consultant to develop the scope of work. If you would like to receive cost proposals from several consultants, you should define the scope of work; otherwise you could end up in a situation of having different prices for different scopes of work.

Finally, the dam owner must have confidence in his consultant. When your consultant gives you recommendations, they should be taken seriously.

Many consultants have a broad base of experience derived from the National Dam Safety Program, a federally funded program, as well as work with other federal and state agencies. You may be able to get a list of consultants who have dam experience from the Arkansas Soil and Water Conservation Commission (ASWCC).

3. What Can A Consultant Tell You About Your Dam?

The dam owner should know more about his dam than anyone else. This knowledge should include a history of the dam, such as when it was built, previous owners and what repairs have been done. If you don't have this information, it should be researched. Start by contacting the Arkansas Soil and Water Conservation Commission (ASWCC). A consultant could help with this, but this is something that a layman can do. If possible, secure design drawings and specifications of the original construction and any repairs. Photographs are also very useful to have. For a consultant to do his work, he'll need background information on the dam as described above. He will also need engineering drawings of the existing dam. The consultant can do these drawings as a part of his studies.

With this background information in hand, field measurements and office analysis can be done. Your consultant's report should advise you of the following items:

— The overall stability of the dam under normal and flood conditions.

— What repairs or maintenance needs to be done to the dam and appurtenant works. The consultant should identify the severity of any problems and in what order to do the repairs.

— Cost estimates for repair work.

— Adequacy of the spillway to pass the design flood.

— The dam owners preparation and procedures to deal with emergency conditions.

Hazardous conditions at the dam will be reported verbally to the dam owners. The ASWCC should also be advised of these conditions. A written report from your consultant is essential for every inspection.

Your consultant can also design the repairs or modifications to your dam. This is normally handled as a separate contract from the inspection.

4. Conclusion

If you realize that many of the items discussed in this guidebook are new and unfamiliar to you, you should contact a consultant or the Arkansas Soil and Water Conservation Commission (ASWCC). Professional consultants will be able to advise and guide you to a proper and safe evaluation of your dam.

CHAPTER 7: OVERVIEW OF INSPECTING YOUR DAM

The matter of inspecting your dam should be given the time and consideration it deserves in view of the impoundment's value to you and the possible consequences of its failure. Try to set aside enough time for the project to do a thorough job.

Before taking a close look at the dam itself, it would be a good idea to review all of the material (plans, specifications, construction history, records of operation, repairs, major floods, maintenance, etc.) that you may have or can locate. Once assembled, this material should be kept together in one place for future reference.

Sometimes a dam is so overgrown that it is difficult or impossible to evaluate. If this is the case, the underbrush should be cleared before doing anything else.

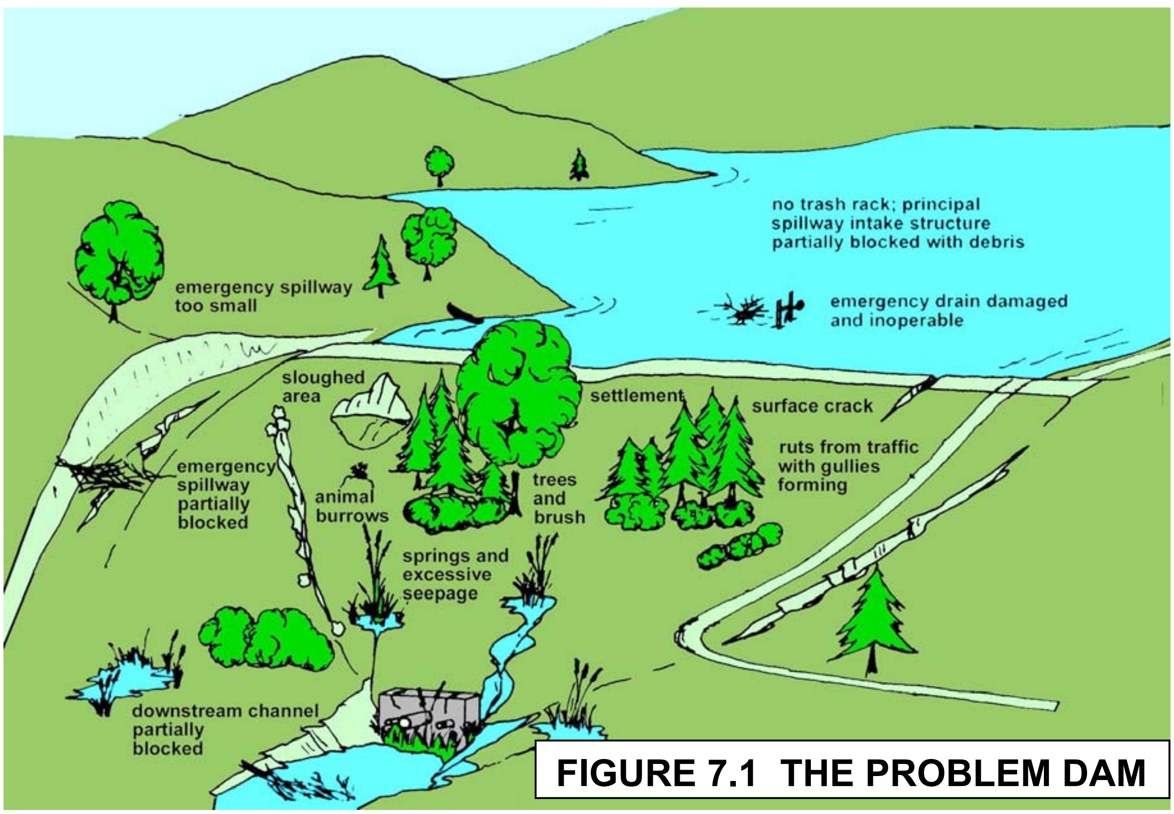


FIGURE 7.1 THE PROBLEM DAM

Some of the common problems associated with dams and the potential consequences of neglecting to maintain a dam are illustrated in the following figures.

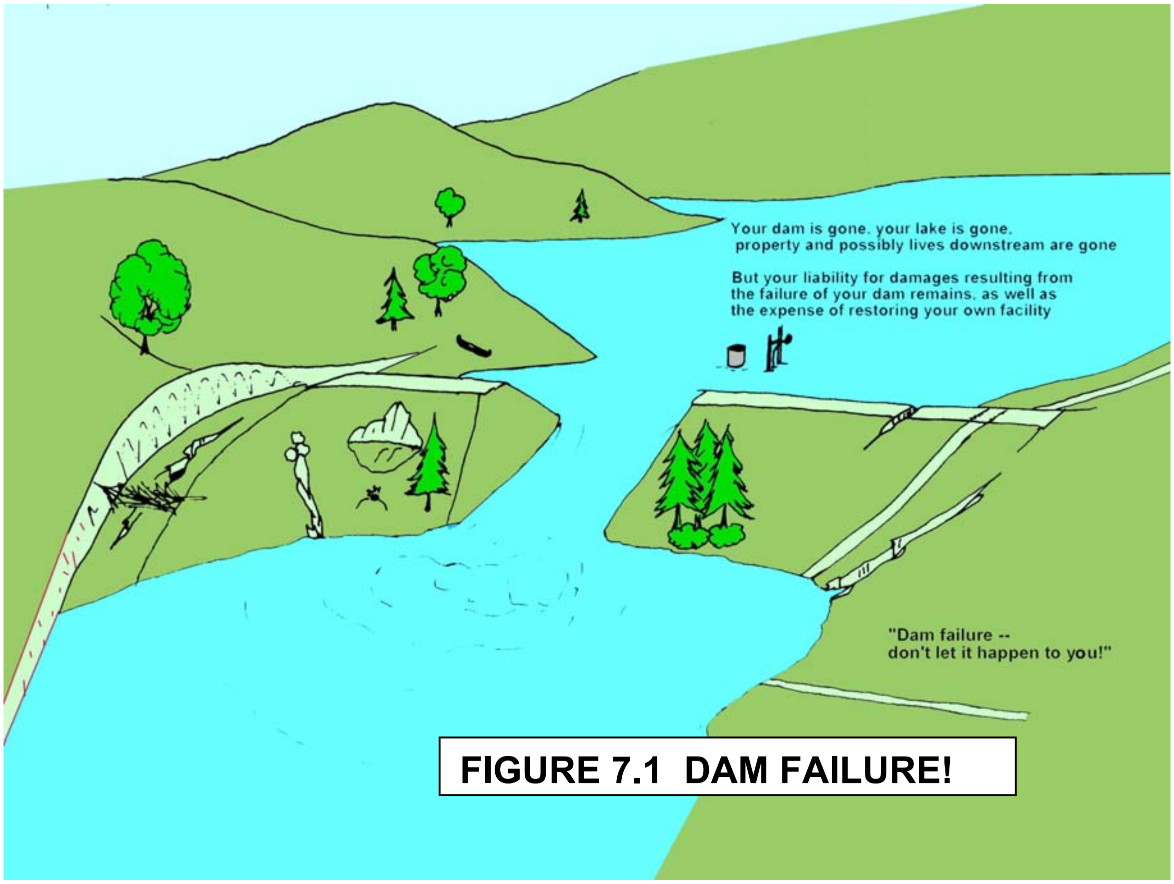


FIGURE 7.1 DAM FAILURE!

INSPECTING A DAM FOR DEFICIENCIES

The purpose of inspection is to identify existing or potential dam safety deficiencies. Once identified, remedial measures can be taken to bring the dam into compliance with acceptable safety standards.

Deficiencies are grouped by:

1. Dam Embankment
2. Spillway
3. Outlet Works
4. Foundation, Abutment and Reservoir Rim

Dam Embankment Deficiencies

Embankment dams are subject to several different types of deficiencies. These include:

- Seepage
- Cracking
- Instability
  - Slides
  - Bulging
- Depressions
  - Minor Depressions
  - Sinkholes
- Maintenance Concerns
  - Inadequate Slope Protection
  - Surface Runoff Erosion
  - Inappropriate Vegetative Growth
  - Debris
  - Animal Burrows

The following chapters discuss these deficiencies or problems in detail. Chapter 16 contains a summary checklist of inspection and maintenance tips.

CHAPTER 8: SEEPAGE

WHAT IS SEEPAGE?

All embankment dams pass water through the embankment materials. The passage of water through the embankment materials is called **seepage.**

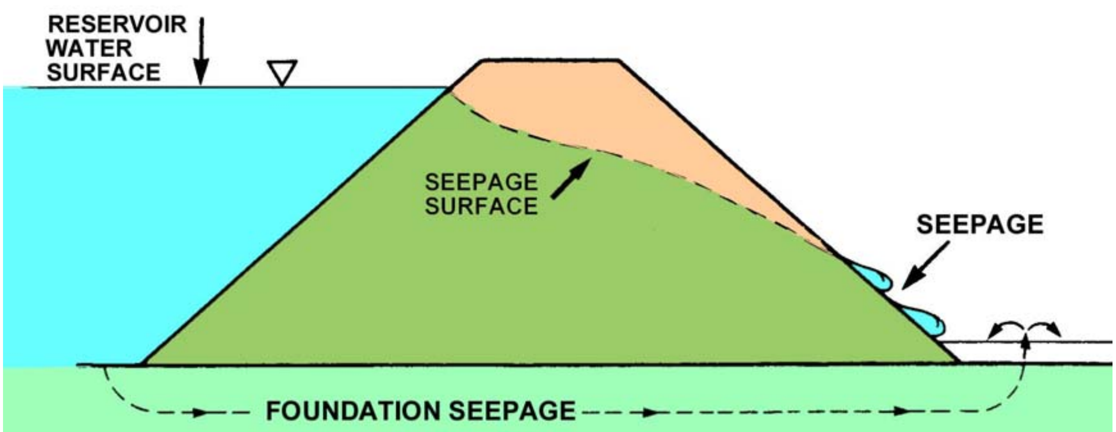
Seepage becomes a problem when embankment or foundation materials are moved by the water flow, or when excessive pressure builds up in the dam or its foundation. Problem seepage is often referred to as **uncontrolled seepage.** Figure 8.1 illustrates uncontrolled seepage through an embankment dam and its foundation.

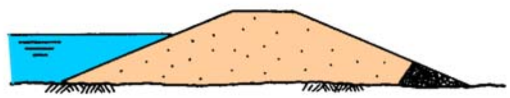
Seepage Control Through Internal Drains

Most modern embankment dams have internal drains to control seepage. Internal drains are designed to intercept seepage and to discharge it safely. Many different types of drains can be used to control seepage. Three common types of drains are the Toe Drain, the Horizontal Blanket Drain, and the Chimney Drain with Blanket. Figure 8.2 illustrates these common types of drains

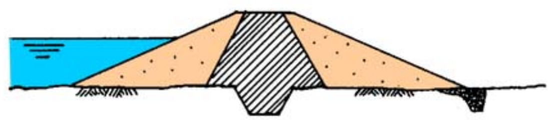
Dams without internal drains rely on material properties and the configuration of the materials to help control seepage. Dams without internal drains are more likely to have seepage problems.

FIGURE 8.1
UNCONTROLLED SEEPAGE THROUGH AN EMBANKMENT

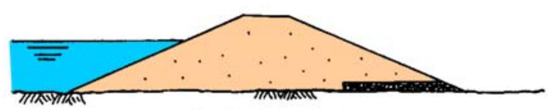




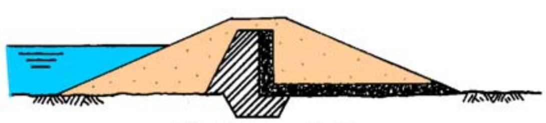
(a) toe drain



(b) toe drain,
clay core



(c) blanket drain



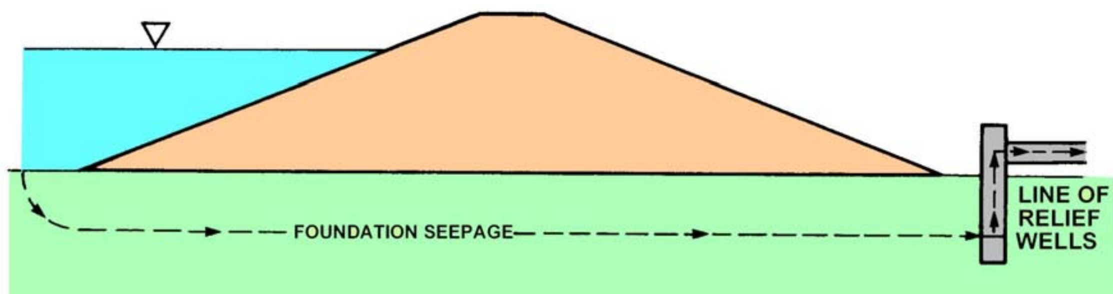
(d) chimney drain,
clay core

FIGURE 8.2
FOUNDATION DRAINS

SEEPAGE CONTROL THROUGH RELIEF WELLS

Relief wells may be installed in the downstream toe area to reduce potentially damaging uplift pressure from foundation seepage through pervious materials that were not cut off. Uplift pressure from excessive seepage can cause internal erosion of foundation material or embankment instability.

FIGURE 8.3
RELIEF WELLS



Also, relief wells may aid in controlling the direction and quantity of seepage under the dam. Relief wells may be used in conjunction with other seepage drains. Figure 8.3 shows a line of relief wells used to intercept and control foundation seepage in a safe manner.

If there are several wells, they will feed into one collection system, consisting of an open channel or a pipe system. The collection system is used to collect discharge from the relief wells and convey this water to a point downstream of the dam. Typically, this water is discharged back into the natural stream

Seepage Problems

Now let's look at some specific seepage problems. Uncontrolled seepage is a major cause of embankment dam failure. Seepage problems can be divided into the following two categories:

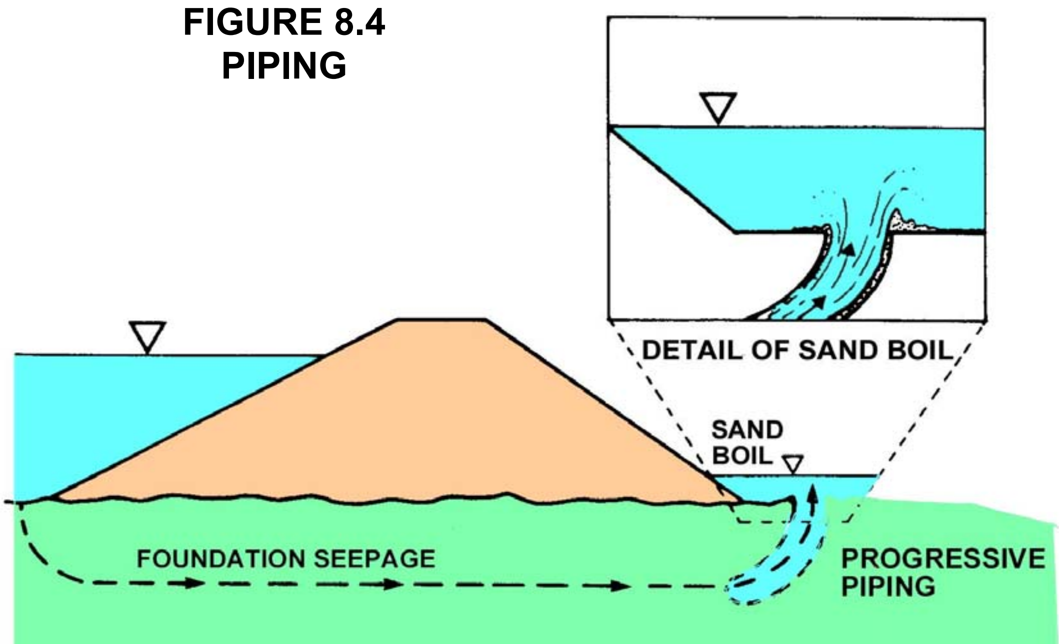
- Stability Problems
- Piping Problems

Seepage Problems: Stability

Seepage causes stability problems when high water pressure and saturation in the embankment and foundations cause the earth materials to lose strength. If uncontrolled seepage emerges on the lower downstream slope, as illustrated in Figure 8.1, very often the seepage will cause sloughing or massive slides.

Seepage Problems: Piping

FIGURE 8.4
PIPING



If seepage is concentrated through materials such as sands or cohesiveless silts, the force of the flowing water can start to remove material at the exit point, and cause progressive erosion known as piping. A common example of piping is shown in figure 8.4. In the illustration, the seepage is exiting near the downstream toe and has caused a sand boil.

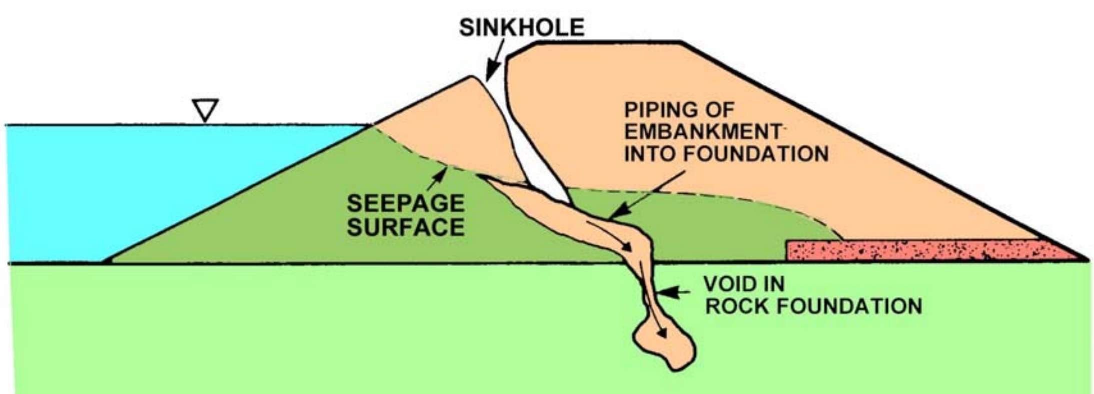
If you observe a sand boil, you should . . .

- ✓ Photograph and record the size of the deposition cone.
- ✓ Monitor the flow rate, if possible. The flow rate may be difficult to ascertain since sand boils are often under water.
- ✓ Make sure that all sand boils are evaluated by a qualified engineer so that appropriate remedial action can be taken.

Sometimes placing sandbags around the boil to increase the depth of water (head) over the boil will prevent continued growth of the boil.

Not all piping causes sand boils. Sand boils may not occur when concentrated seepage occurs through an embankment, along the groins, or in contact with concrete structures. In fact, severe piping problems can occur when seepage moves into voids in rock foundations. Figure 8.5 illustrates embankment piping into voids in a rock foundation.

FIGURE 8.5
EMBANKMENT PIPING INTO VOIDS IN ROCK FORMATIONS



The type of seepage illustrated above is difficult to detect since nothing is visible until the embankment starts to collapse, or until a vortex appears in the reservoir. A vortex is the rotational movement that will appear as the water rapidly enters the foundation. (See Figure 8.7b.) This same type of rotational movement can be seen when you pull the plug in a sink full of water. Piping may also exit through the downstream embankment as in Figure 8.7a.

Appearance of Seepage

Seepage varies in appearance. Seepage may appear as a wet area or as a flowing spring. (See Figures 8.6a and 8.6b.) Vegetation is another indication of seepage. Areas with a lot of water-loving vegetation, such as cattail, reeds and mosses, should be checked for seepage. Areas where the normal vegetation appears greener or more lush should be checked for seepage. These patches of rich vegetation are more obvious in arid environments.

FIGURE 8.6
EXAMPLES OF SEEPAGE

a. Seepage area on downstream embankment behind tree

b. Seepage at toe of dam

Areas Prone to Seepage

The contacts between the downstream slope and the abutments (or groins) are especially prone to seepage because the embankment fill near the abutments is often less dense than other parts of the embankment, and therefore less watertight. The embankment fill near the abutments is less dense because compaction is difficult along the embankment/abutment interface. Also, improperly sealed porous abutment rock can introduce abutment seepage into and along the embankment.

Difficulties with compaction also makes areas around conveyance structures like outlet works, spillway conduits, or penstocks more susceptible to uncontrolled seepage problems. Seepage exits from around conveyance structures is particularly alarming because it may also indicate that there is a crack or opening in the structure that is allowing reservoir water under pressure into the embankment. Rapid erosion and an eventual breach of the dam can result.

☞**INSPECTION TIP:**	Viewing the downstream slope from a distance is sometimes helpful in detecting subtle changes in vegetation. A distinct line of vegetation probably indicates the intersection of the seepage line with the slope.

Monitoring Seepage

If seepage is observed, then it should be monitored. To monitor seepage, you should record:

- The location and quantity or flow rate of all seepage at exit points.
- The occurrence of recent precipitation that may affect the appearance and quantity of seepage.
- The level of the reservoir at the time of observation.

> ☞**INSPECTION TIP**: Notes, sketches and photographs are useful in documenting and evaluating seepage problems.

The amount of seepage usually correlates with the level of the reservoir. Generally, as the level of the reservoir rises, the seepage flow rate increases.

> ☞**INSPECTION TIP**: Any changes in seepage flow rate which deviates from past seepage history are cause for concern.

In some cases, a dye test can be used to test whether or not the reservoir is the source of seepage.

FIGURE 8.7
EXAMPLE OF PIPING

a. Water flows through dam as a result of piping.

b. Note the eddy or whirlpool in the reservoir, indicating removal of water by piping

Toe Drains

Many toe drains have collector pipes that discharge embankment seepage and, in some cases, foundation seepage. Before conducting an inspection of an embankment dam that has toe drains, you should

- Review the site plan to determine the location of the toe drains and outfalls.

- Review previous data on both the reservoir level and flow rate from the drain(s).

Data on drain flow must be looked at in conjunction with reservoir-level data. Knowing how the reservoir level affects the drain flow can help you to determine if there is a problem. If you observe a drain flow that is atypical for the given reservoir level, more investigation may be warranted.

During the inspection, you should

- Locate each toe drain outfall.

- Measure the flow. A simple method of measuring the flow from a toe drain outfall is to catch the flow from the pipe in a container of known volume and to time how long it takes to fill the container. The flow rate is usually recorded in gallons per minute.

- Compare the amount of flow with the amount of flow you anticipated for the current reservoir level based on previous readings.

Blocked Drains

A drain that has no flow at all could simply mean that there is no seepage in the area of the dam serviced by the drain. However, an absence of flow could also indicate a problem.

If the drain ...

Has never functioned, it could mean that the drain was designed or installed incorrectly.

Flowed at one time but has now stopped flowing, it may have become plugged.

A plugged drain can be a serious problem because seepage may begin to exit downslope, or may contribute to internal pressure and instability. If possible, blocked drains should be cleaned so that the controlled release of seepage may be restored.

Decreasing amounts of flow from a drain for the same reservoir level may indicate that the drain is becoming blocked. Conversely, a sudden increase in drain flow may indicate that the core is becoming less watertight, possibly as the result of transverse cracking.

☞**INSPECTION TIP:**	Recording drain flow rates and reservoir levels will help you to assess a dam's seepage problems.

Relief Wells

Before conducting an inspection of an embankment dam that has relief wells, you should.

* Review the site plan to determine the location of the wells.

* Review previous data on both the reservoir level and well flow. Data on well flow must be looked at in conjunction with reservoir-level data. Knowing how the reservoir level affects the well flow can help you to determine if there is a problem. If you observe a well flow that is atypical for the given reservoir level, more investigation may be warranted.

During the inspection, you should.

* Locate each relief well.

* Visually check whether or not water flow is occurring.

    IF NO WATER IS FLOWING ... Determine if a flow should be present based on your assessment of the previous readings and the current reservoir level.

    IF WATER IS FLOWING ... Measure the rate of flow. The rate of flow can be measured either at the well or at the collector pipe discharge. You can use weirs, flumes, or a bucket and stopwatch to measure the flow rate.

* Compare the amount of well flow measured with the amount of flow you anticipated for the current reservoir level based on previous readings.

If the well flow is less than the amount you anticipated, the well screens or filters may have become clogged. If you suspect that the well is not functioning properly because it is clogged, cleaning should be recommended.

If the well flow is greater than the amount you anticipated, there may be excessive seepage. Make sure that you accurately record the flow amount and reservoir level. You should also note that there has been a change from the well-flow trends previously observed.

TURBIDITY

In addition to measuring the flow rate of seepage, you should evaluate the clarity of the seepage. Turbidity is cloudy seepage, which indicates that soil particles are suspended in the water. Turbidity means that the water passing through the embankment or foundation is carrying soil with it.

☞**INSPECTION TIP:**	Turbidity is cause for extreme concern. Each time seepage is measured, the clarity of the seepage should also be evaluated for change.

Checking Turbidity

A good way of detecting a change in turbidity is to collect a number of water samples as follows:

STEP	DESCRIPTION
1	Collect a sample of the water in a quart jar. Date the jar and note the level of clarity. Store the jar in a safe location.
2	Repeat step 1 each time seepage flow is measured until several samples have been collected.
3	Each time you collect a sample, shake up each jar and visually compare the new sample with the samples collected previously. Look for changes in the cloudiness of the samples. Also note the amount of sediment that accumulates in the bottom of the jars as suspended material settles out.

If seepage is clear, but you suspect that it contains dissolved material from the foundation (because, for instance, seepage has increased), it may be necessary to perform water quality testing.

☞**INSPECTION TIP:** As mentioned previously, the rate and turbidity of seepage flow should be recorded at each inspection. If seepage problems are suspected, then the frequency of inspections should be set by a qualified engineer**. If seepage problems do occur, further testing should be conducted by an engineer. Remember, uncontrolled seepage is a major cause of embankment dam failure.**

CHAPTER 9: CRACKING

WHAT IS CRACKING?

Another serious deficiency is cracking. Cracks are splits that appear in the crest or slopes of the dam. Cracking in an embankment dam falls into the following three major categories.

Desiccation Cracking
Transverse Cracking
Longitudinal Cracking

Each type of cracking is discussed below.

FIGURE 9.1
LONGITUDINAL CRACKING

DESICCATION CRACKING

Desiccation cracking is caused by the drying out and shrinking of certain types of embankment soils. Desiccation cracks usually develop in a random, honeycomb pattern. Typically, desiccation cracking occurs in the crest and the downstream slope.

The worst desiccation cracking develops when a combination of the following factors is present ...

- A hot, dry climate accompanied by long periods in which the reservoir remains empty.
- An embankment that is composed of highly plastic soil, such as clay.

Usually, desiccation cracking is not harmful unless it becomes severe. The major threat of severe desiccation cracking is that this type of cracking can contribute to the formation of gullies. Surface runoff erosion concentrating in the desiccation cracks or gullies can result in eventual damage to the dam.

Also, heavy rains can fill up these cracks and cause portions of the embankment to become unstable and to slip along crack surfaces where the water has lowered the strength of the embankment material. Deep cracks that extend through the core conceivably can cause a breach of the dam when the reservoir rises and the cracks fail to swell rapidly enough to reseal the area.

Desiccation Cracking: Inspection Actions

If you observe desiccation cracking, you should ...

- ✓ Probe the more severe cracks to determine their depth.
- ✓ Photograph and record the location, depth, length, and width of any severe cracks observed.
- ✓ Compare your measurements with past measurements to determine if the condition is worsening.

☞**INSPECTION TIP:**	If the depth of the cracking extends below the reservoir level or potential reservoir level, an experienced engineer should help identify appropriate remedial measures.

TRANSVERSE CRACKING

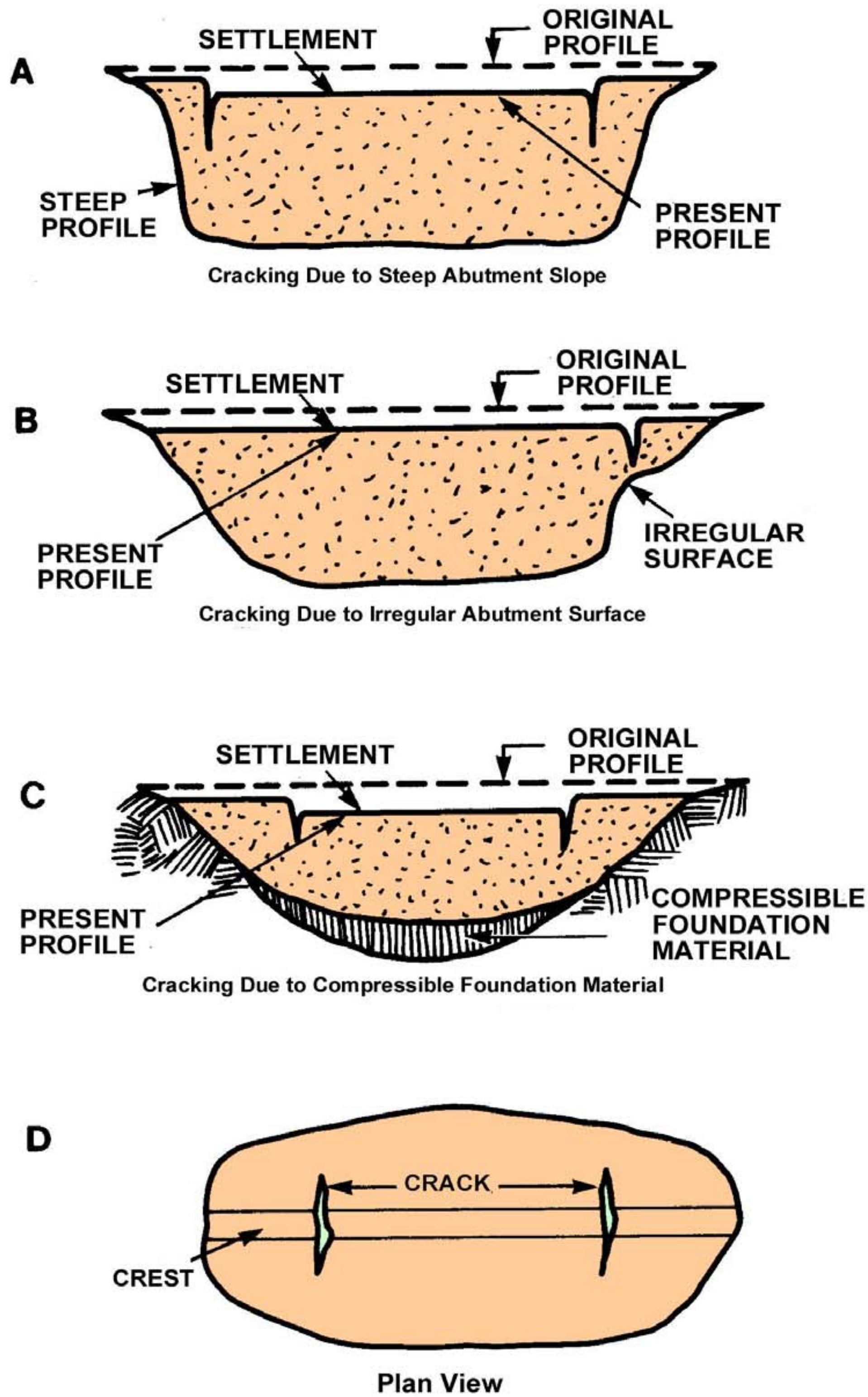
Transverse cracking appears in a direction roughly perpendicular to the length of the dam. If these cracks extend into the core below the reservoir level they are especially dangerous because they could create a path for concentrated seepage through the core. Transverse cracks usually appear on the dam crest, near abutments, and in U-shaped or trapezoidal-shaped valleys.

The presence of transverse cracking indicates differential settlement within the embankment or underlying foundation. This type of cracking frequently develops when compressible material overlies abutments consisting of steep or irregular rock. Areas of compressible material are in the foundation.

Figure 9.2, on page 9-4, shows how transverse cracks form in an embankment dam.

Transverse cracks may provide a path for seepage through the embankment. When the depth of the crack extends below the level of the reservoir, very rapid erosion of the dam may occur, eventually breaching the dam.

FIGURE 9.2
TRANSVERSE CRACKING



Transverse Cracking: Inspection Actions

If you observe transverse cracking you should ...

- ❑ Photograph and record the location, depth, length, width, and offset of each crack observed.
- ❑ Closely monitor the crack for changes.

☞**INSPECTION TIP:**	An experienced engineer should be consulted in order to determine the cause of the cracking.

LONGITUDINAL CRACKING

Longitudinal cracking occurs in a direction roughly parallel to the length of the dam. Longitudinal cracking is an indication of …

- √ Uneven settlement between adjacent embankment zones of differing compressibility.
- √ The beginning scarp of an unstable slope. In this case, the crack may appear arc-shaped.

Figure 93, page 9-5, illustrate longitudinal cracking.

Longitudinal cracks allow water to enter the embankment. When water enters the embankment the strength of the embankment material adjacent to the crack may be lowered. The lower strength of the embankment material can lead to or accelerate slope stability failure.

Longitudinal Cracking: Inspection Actions

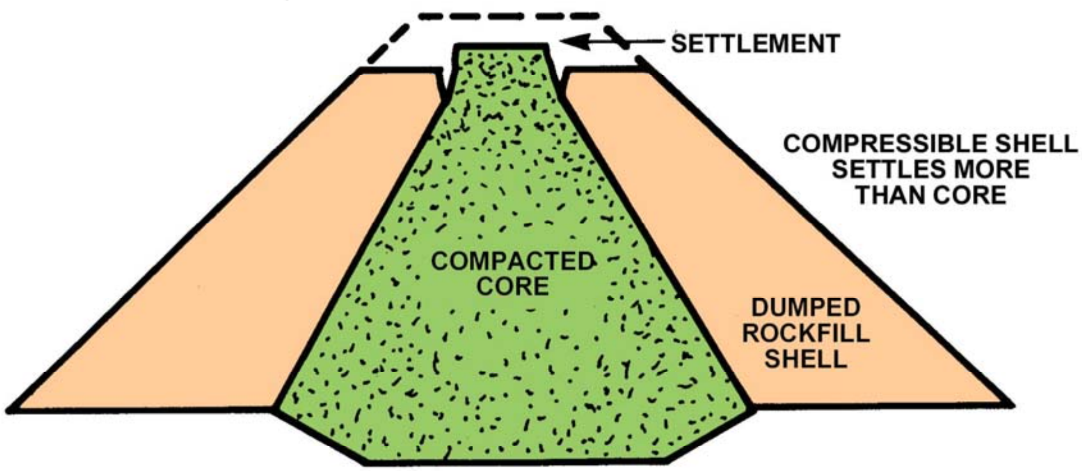
As with transverse cracking, if you observe longitudinal cracking you should * .

- ✓ Photograph and record the location, depth, length, width, and offset of each crack observed.
- ✓ Closely monitor the crack for changes.

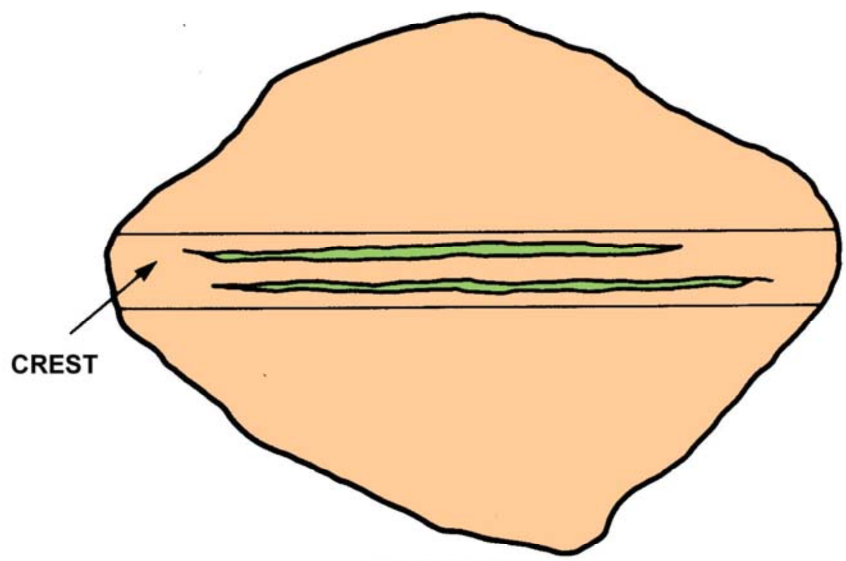
☞**INSPECTION TIP:**	An experienced engineer should be consulted in order to determine the cause of the cracking.

FIGURE 9.3
LONGITUDINAL CRACKING

HOW LONGITUDINAL CRACKS FORM



PLAN VIEW OF LONGITUDINAL CRACKING



PLAN VIEW Rotated 180 degrees

CHAPTER 10: INSTABILITY

WHAT IS INSTABILITY?

Instability of the embankment is very serious. The visual clues of instability may appear as ...

- Slides
- Bulging

SLIDES

Slide phenomena have various names including displacements, slumps, slips, and sloughs. Slides can be grouped into two major categories .

- Shallow Slides
- Deep-Seated Slides

Next you will learn more about each category of slides.

<u>Shallow Slides: Upstream Slope</u>

Shallow slides in the upstream slope are often the result of an overly steep slope aggravated by a rapid lowering of the reservoir. Shallow slides in the upstream slope pose no immediate threat to the integrity of the dam. However, shallow slides may lead to .

- The obstruction of water conveyance structure inlets.
- Larger, deep-seated slides.

<u>Shallow Slides: Downstream Slope</u>

Shallow slides in the downstream slope also indicate an overly steep slope (Figure 10.1 and 10.2). In addition, these slides may also indicate a loss of strength in the embankment material. A loss of strength in the embankment material can be the result of saturation of the slope from either seepage or surface runoff. Additional loads from snow banks or structures can aggravate the condition.

FIGURE 10.1
EXAMPLE OF SHALLOW SLIDE

Shallow slide or slump on downstream slope

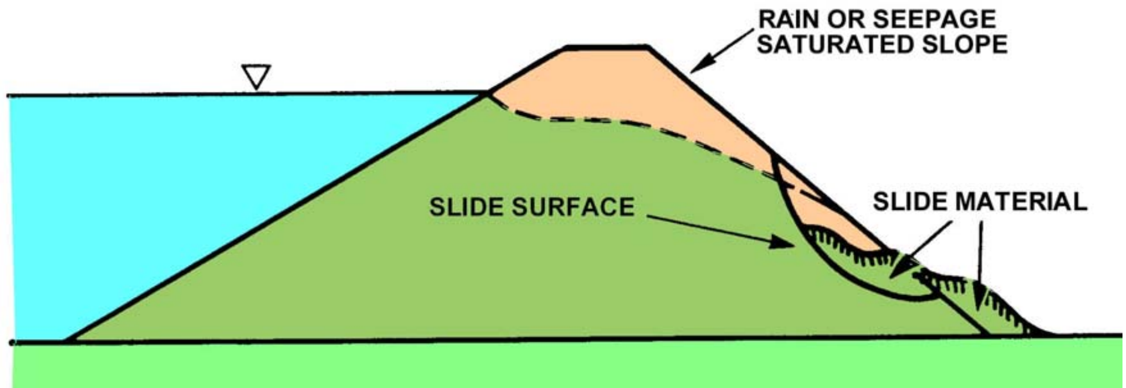
Shallow Slides: Inspection Actions

If you observe a shallow slide you should .

- ✓ Photograph and record the location of the slide.
- ✓ Measure and record the extent and displacement of the slide.
- ✓ Look for any surrounding cracks, especially uphill from the slide.
- ✓ Probe the entire area to determine the condition of the surface material.
- ✓ Make sure that there are no seepage areas near the slide.
- ✓ Monitor the area to determine if the condition is becoming worse.

☞**INSPECTION TIP:**	You should consult with an experienced engineer if you are unsure whether the slide presents a serious threat to the integrity of the dam.

FIGURE 10.2
SHALLOW SLIDE



Deep-Seated Slides

Deep-seated slides are serious threats to the safety of the dam. To recognize deep-seated slides look for .

- **Well-Defined Scarping**

  A scarp is a relatively flat area with a steep back slope.

- **Toe Bulge**

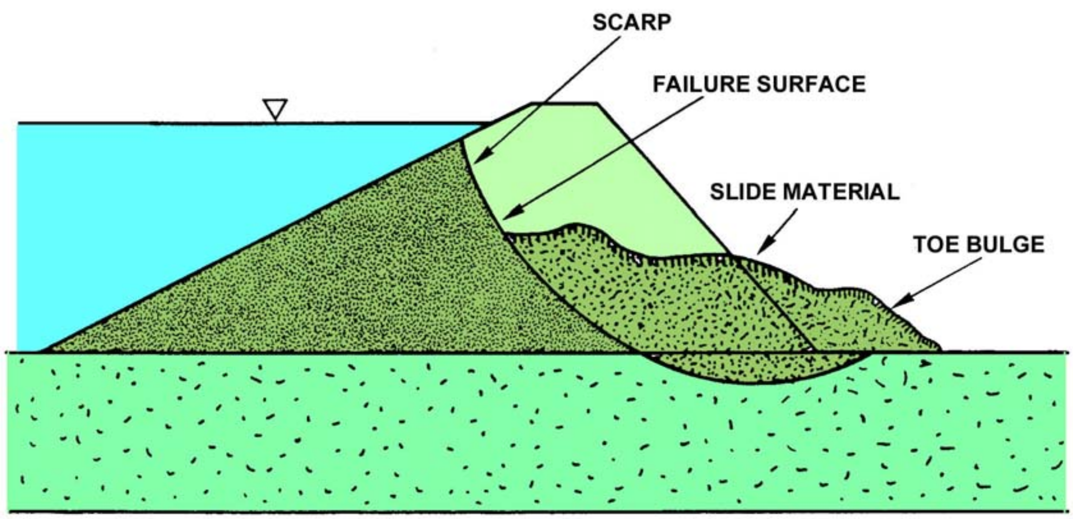
  A toe bulge is produced by the rotational or horizontal movement of embankment material. (Bulges are discussed in the next part of this section.)

- **Arc-Shaped Cracks**

  Arc-shaped cracks in the slope are indications that a slide is beginning. This type of crack may develop into a large scarp in the slope at the top of the slide.

Figure 10.3 presents a diagram of a deep-seated slide.

FIGURE 10.3
DEEP-SEATED SLIDE



Deep-Seated Slides: Inspection Actions

A deep-seated slide or scarping in either the upstream or downstream slope may be an indication of serious structural problems.

An experienced and qualified engineer should be consulted .

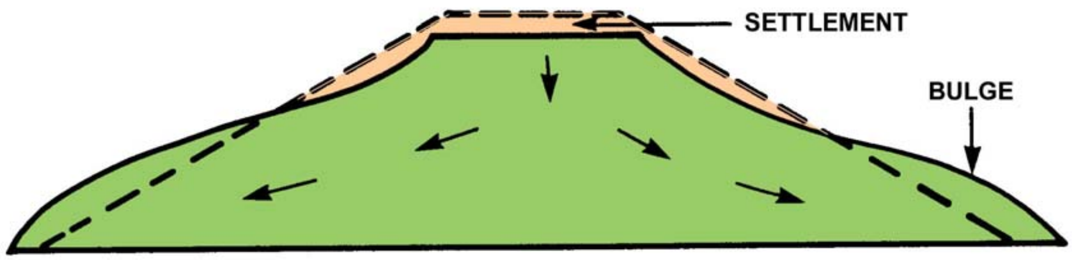
- To evaluate the cause of deep-seated slides.
- To prescribe remedial action.

☞**INSPECTION TIP:**	**IMMEDIATE ACTION IS NECESSARY!** In most instances, deep-seated slides will require the lowering or draining of the reservoir to prevent the possible breaching of the dam.

BULGING

Bulging is a phenomenon that usually is associated with the lateral spreading of the dam or with slides. Bulging as a result of lateral deformation is accompanied by settlement. The bulging is most evident at the toe of the dam. Figure I0.4 illustrates how bulges form due to lateral spreading of the dam. Figure 10.5 illustrates how bulges form in association with slides.

FIGURE 10.4
BULGE DUE TO LATERAL SPREADING



Bulging Due To Lateral Spreading: Inspection Actions

A toe bulge due to lateral spreading may mean that there has been some loss of freeboard. Freeboard is the distance between the maximum water elevation and the crest of the dam.

☞**INSPECTION TIP:**	If you suspect loss of freeboard, a survey of the crest should be performed. A survey will verify if there has been a loss of freeboard.

In addition to checking for freeboard loss ... .

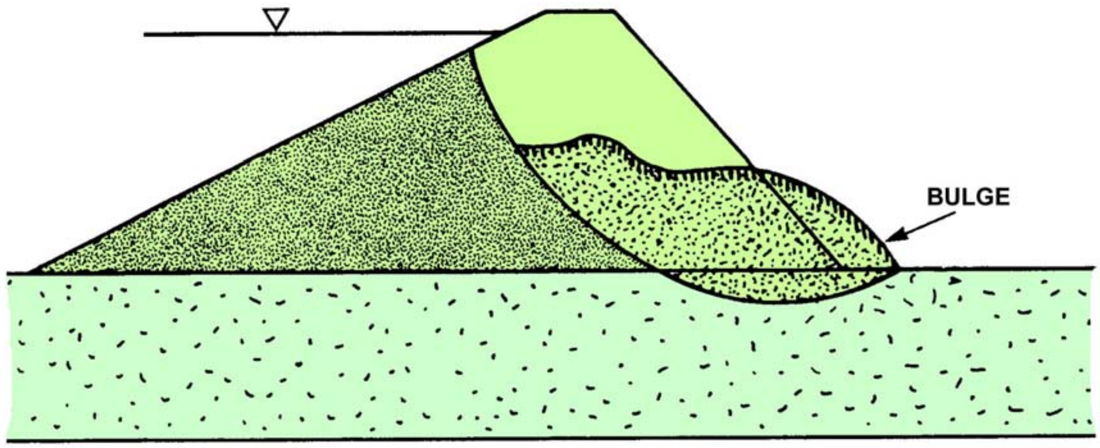
✓ Closely inspect the area above the bulge for cracking or scarps which indicate that a slide is the cause.

✓ Probe the bulge to determine if material is excessively moist or soft. Excessive moisture or softness also indicate that a slide is the cause.

Bulging Associated With Slides

Bulging associated with slides is a much more serious problem. The area above a bulge should be examined carefully in order to identify other indicators of instability such as cracks and scarps.

FIGURE 10.5
BULGE ASSOCIATED WITH DEEP-SEATED SLIDE



☞**INSPECTION TIP:**	If you observe bulging associated with cracks or scarps, contact an experienced and qualified engineer immediately. The engineer will determine the cause of the bulging and recommend a course of action.

The type of seepage illustrated above is difficult to detect since nothing is visible until the embankment starts to collapse, or until a vortex appears in the reservoir. A vortex is the rotational movement that will appear as the water rapidly enters the foundation. This same type of rotational movement can be seen when you pull the plug in a sink full of water.

CHAPTER 11: DEPRESSIONS

WHAT ARE DEPRESSIONS?

Depressions are caused by .

- Localized settlement in the embankment or foundation.
- Embankment spreading in the upstream and/or downstream direction. This type of spreading may result in a loss of freeboard and overtopping of the dam.
- Erosion. Wave action against the upstream slope that removes embankment fines or bedding from beneath riprap may form a depression as the riprap settles into the vacated space.

Some areas that appear to be depressions may be the result of improper final grading following construction.

Depressions can be minor or they can be very serious. Sinkholes are a serious type of depression. A good way of distinguishing between minor depressions and sinkholes is to look at their profiles.

Minor Depressions: Minor depressions have gently sloping, bowl-like sides.

Sinkholes: Sinkholes usually have steep, bucket-like sides, as in Figure 11.1.

Detecting Depressions

Depressions and other misalignment in the crest and embankment slopes often can be detected by sighting along fixed points. You should sight and take photographs along guardrails, parapet walls, or pavement striping. Some apparent misalignment may be due to irregular placement of the fixed points. For this reason, irregularities should be evaluated over time to verify suspected movement.

Sighting irregularities is facilitated by surveying permanent monuments across the crest to determine the exact location and the extent of misalignment. A record of survey measurements also can establish the rate at which movement is occurring.

Minor Depressions: Inspection Actions

Although minor depressions, in most cases, do not represent an immediate danger to the dam, they may be early indicators of more serious problems. If you observe a depression ...

- Photograph and record the location, size, and depth of the depression.
- Probe the floor of the depression to determine whether or not there is an underlying void. An underlying void is indicative of a sinkhole.
- Frequently observe the depression to ensure it has stopped developing.

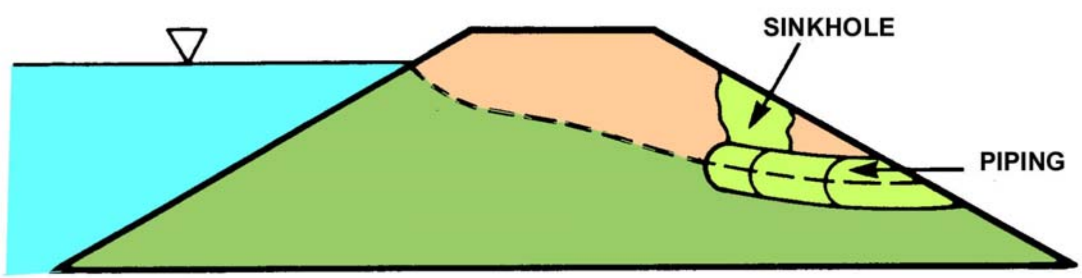
WHAT ARE SINKHOLES?

Sinkholes are a more serious type of depression. Sinkholes are formed when the removal of subsurface embankment or foundation material has caused overlying material to collapse into the resulting void. The decomposition of embedded wood or other vegetative matter also can cause sinkholes. In addition, animal burrows can contribute to the formation of sinkholes.

The presence of a sinkhole indicates that material is or has been transported out of the dam or foundation through the process of piping. (See the section on seepage for more information on piping.)

Figure 11.1 illustrates how a sinkhole is formed.

FIGURE 11.1
FORMATION OF A SINKHOLE



Sinkholes: Inspection Actions

If you observe a sinkhole ...

- ✓ Probe the sinkhole to determine if the void is larger than it appears.
- ✓ Photograph and record the location, size, and depth of the sinkhole.

☞**INSPECTION TIP:**	Sinkholes can be very serious. Request that an experienced and qualified engineer evaluate the situation immediately.

CHAPTER 12: MAINTENANCE CONCERNS

WHAT ARE MAINTENANCE CONCERNS?

Maintenance includes the routine measures taken to protect and maintain the dam.

Deficiencies associated with inadequate maintenance include .

- Inadequate Slope Protection
- Surface Runoff Erosion
- Inappropriate Vegetative Growth
- Debris
- Animal Burrows

In this section you will learn how to detect common maintenance concerns and what corrective actions should be taken.

INADEQUATE SLOPE PROTECTION

Slope protection is designed to prevent erosion of the embankment slopes. There are two primary types of slope protection used on embankment dams .

- Riprap
- Vegetative Cover (Grass)

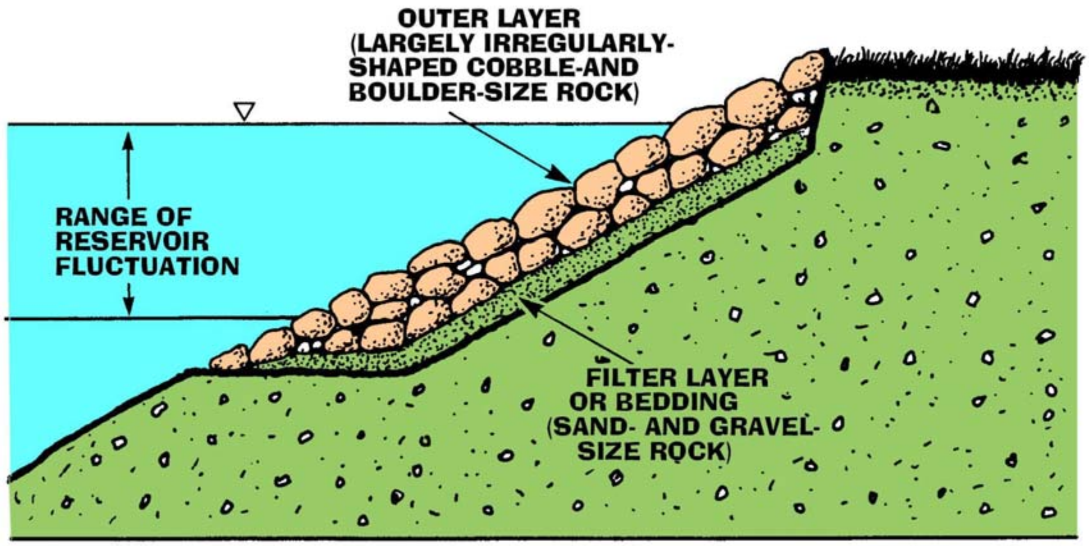
Soil cement, concrete, asphalt, and other types of slope protection also may be used. The type of slope protection selected depends upon economics and the prevailing conditions found at the site.

Before discussing inadequate slope protection, let's briefly review the different types of slope protection.

Riprap

Riprap is broken rock or boulders placed on the upstream slope and downstream outlet works of embankment dams. Riprap provides protection from erosion caused by wind or wave action, surface runoff erosion, and wind scour.

FIGURE 12.1
RIPRAP



Properly designed upstream riprap slope protection is made up of at least two layers of material ...

- **The Inner Layer(s):** The inner layer(s), called the filter layer or bedding, is sand and gravel-size rock. These smaller rocks prevent the underlying embankment from being washed out through the voids in the larger rocks found in the outer layer.

- **The Outer Layer:** The outer layer is cobble-size and boulder-size rock that is large enough not to be displaced by wave action. These larger rocks prevent erosion.

It is important to make sure that rocks of various sizes and shapes are used in the outer layer. Irregular sized and shaped rocks create an interlocking mass that prevents waves from passing between the larger rocks of the outer layer and removing the underlying material from the inner layer(s).

The slope upon which the riprap is placed must be flat enough to prevent riprap from dislodging and moving down the slope. Hand-placed riprap, while usually providing good protection, is a relatively thin blanket of protection. Thinly-layered riprap is susceptible to failure because the dislodging of one large rock may cause displacement of the surrounding rock due to a lack of adequate support. However, most modern riprap is dumped in place, resulting in a much thicker-layered blanket of protection. Figure 12.1 presents a diagram of riprap that is appropriately designed and placed on an upstream slope.

MAINTENANCE CONCERNS

Vegetative Cover

The outer portion of the embankment that consists of fine-grained soil must be protected from erosion. Failure to protect the slope could result in significant erosion. If significant erosion occurs there will be a need for considerable maintenance and repair, especially on the crest and the downstream slope. The planting of some type of vegetative cover (usually grass) on the slope can provide erosion protection. The root system of the vegetative cover holds the surface soil in place and protects the slopes from wind and surface runoff erosion.

In most geographic areas, a properly cultivated cover of grass provides satisfactory crest and downstream slope protection. Also, in many areas of the country, grass cover may provide adequate protection of the upstream slope. Using a grass cover to protect the upstream slope often is effective for small reservoirs and dams that have insignificant wave action.

It may be necessary to use other types of slope protection

- In arid climatic regions.
- In areas where surface runoff is excessive or concentrated, such as the groins.
- Where conditions combine to create severe wave action.

Soil Cement

A less commonly used type of slope protection is soil cement. Soil cement is a mixture of Portland cement and pulverized soil. This mixture is placed in horizontal layers directly over the embankment material of the upstream slope to prevent erosion. To be effective soil cement should be compacted uniformly and the layers should be well bonded to each other.

Wave Erosion And Slope Protection

The constant action of waves on the upstream slope may result in beaching, scarping, and degrading of the slope protection (Figures 12.2 and 12.3). Unless measures are taken to maintain adequate slope protection, wave action will begin to erode the embankment material. Let's look at the different effects of constant wave action on the upstream slope.

Beaching: Beaching is the removal, by wave action, of a portion of the upstream slope of the embankment. When beaching occurs, embankment material is deposited farther down the slope. In this extreme form of erosion, the slope protection (i.e., riprap or vegetative cover) and underlying material are removed. A relatively flat beach area with a steep back slope or scarp is formed.

Scarping: In the upstream slope, ice and wave action or local settlement due to removal of bedding material can cause soil and rock to erode and slide to the lower part of the slope. This type of erosion causes scarps to form which could lessen the width and height of the embankment, possibly leading to increased seepage, instability, or overtopping of the dam.

Degrading: Degradation of the slope protection may occur when the protective material cracks, becomes weathered, or breaks down. The degrading of the slope protection is accelerated by wave action. Even the best designed slope protection will experience some degradation over time. Degraded riprap, soil cement, or other slope protection should be monitored. If evidence shows that serious damage to the embankment is occurring, degraded slope protection must be repaired or replaced.

Inadequate Slope Protection: Inspection Actions

During the inspection, you should…

- ✓ Make sure that the slope protection is adequate enough to prevent erosion
- ✓ Look for beaching, scarping, and degrading of the slope protection

If inadequate slope protection is observed…

- ✓ Record your findings and photograph the area
- ✓ Determine the extent to which the embankment has been damaged (i.e., embankment material has been removed).
- ✓ Recommend that corrective action be taken to repair or to replace the inadequate slope protection

FIGURE 12.2
WAVE EROSION

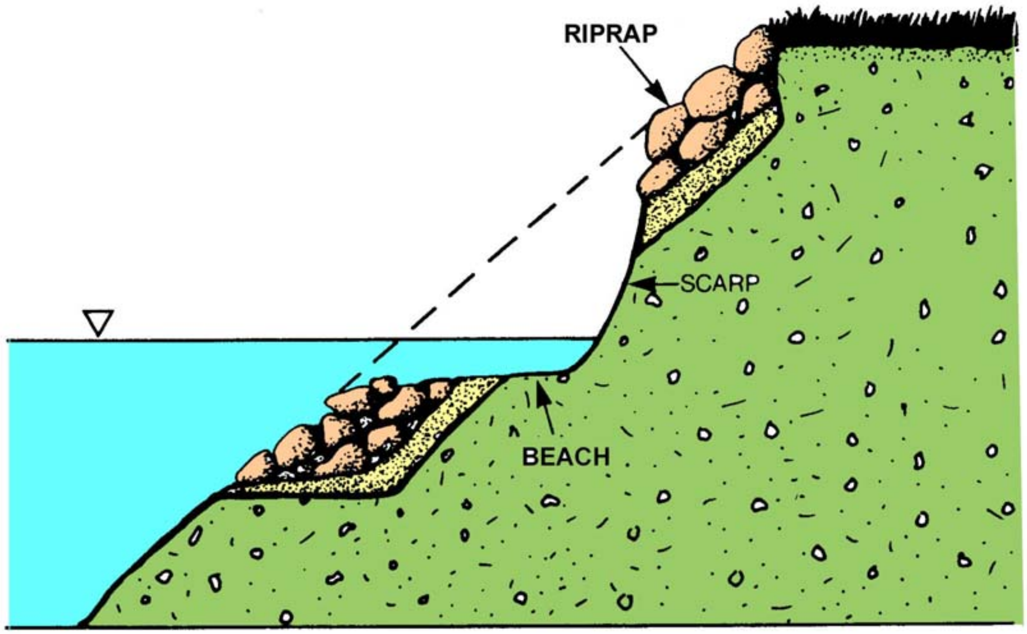
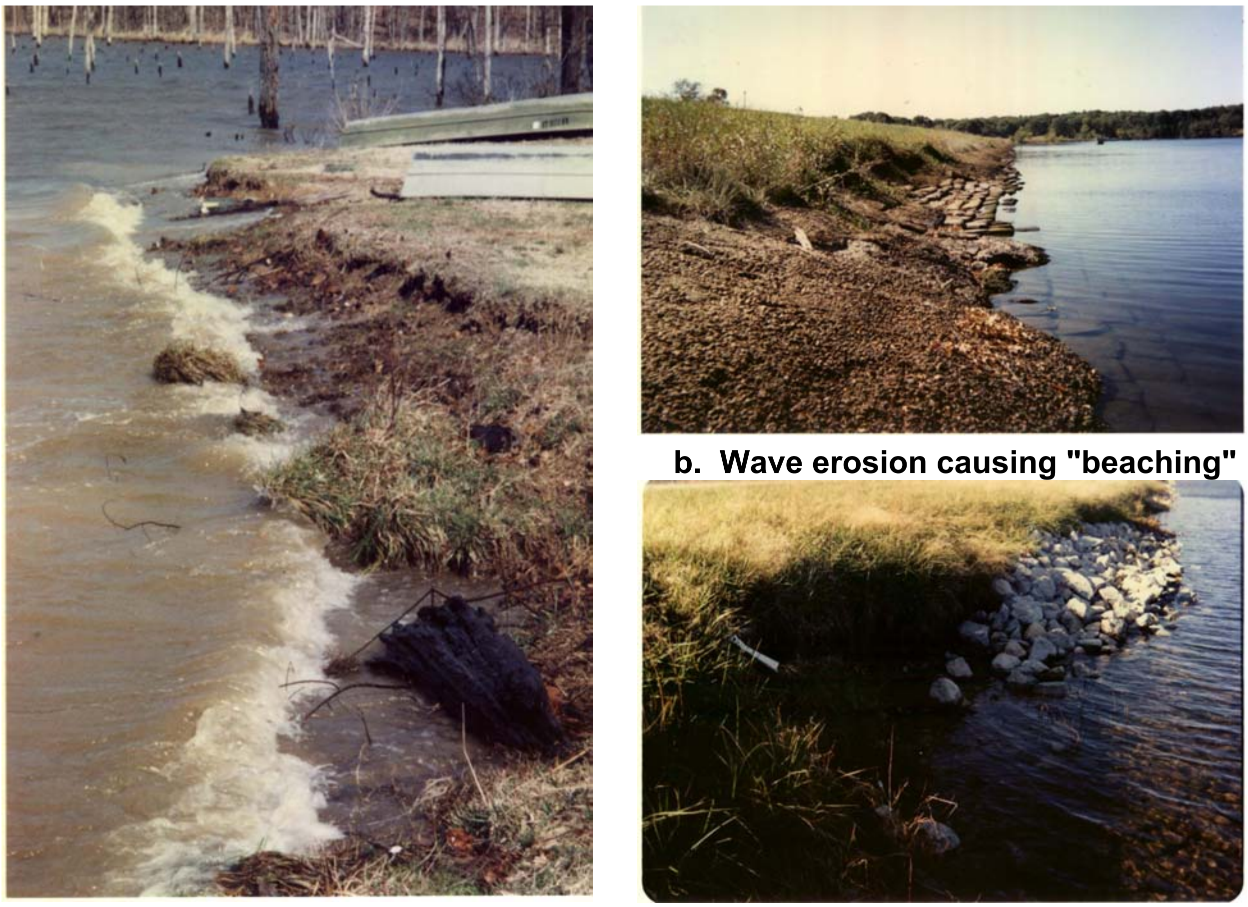


FIGURE 12.3
EXAMPLES OF WAVE EROSION



a. Wave erosion

b. Wave erosion causing "beaching"

c. Wave erosion with partial bank protection using riprap

SURFACE RUNOFF EROSION

Surface runoff erosion is one of the most common maintenance problems of embankment structures. If not corrected, surface runoff erosion can become a more serious problem (Figure 12.4).

Gullies

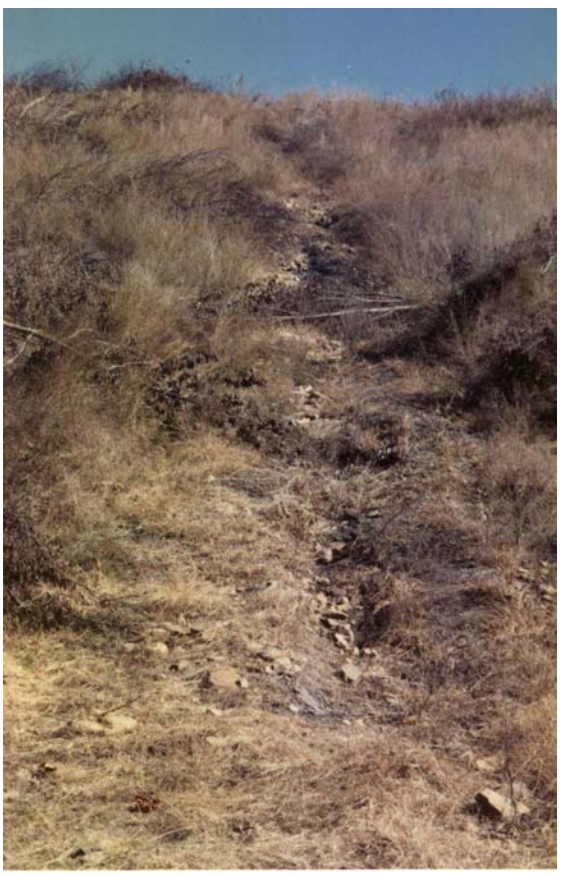
The worst damage from surface runoff is manifested by the development of deep erosion gullies on the slopes, both at the groins and in the central portion of the dam.

Gullies begin as narrow rill only a few inches wide. Severe gullies can ...

- Cause breaching of the crest.
- Shorten the seepage path through the dam, possibly leading to piping.

Gullies can develop from poor grading or sloping of the crest that leads to improper drainage, causing surface water to collect and to run off at the low points along the upstream and downstream shoulders. Gullies caused by this type of runoff eventually can reduce the cross-sectional area of the dam.

FIGURE 12.4
EXAMPLES OF SURFACE EROSION



a. Erosion on downstream slope

b. Erosion across downstream slope from right groin area

c. Erosion on downstream slope

Slope And Crest Protection

Bald areas, or areas where the protective cover is sparse, are more susceptible to surface runoff erosion problems.

On the upstream slope, erosion may undermine the riprap and cause it to settle. Settlement of the riprap may lead to the eventual degradation of the slope itself.

The crest also can experience weathering and erosion if it is not protected. Crest erosion protection may consist of a road surfacing such as gravel, asphalt, or concrete pavement. The type of crest protection used depends on the amount of traffic anticipated. If little or no traffic is expected on the crest, a grass cover should be adequate. Remember to check to see that the crest surfacing is providing adequate protection from erosion. Too much traffic on gravel- or grass-covered crests, especially during rainy periods, can lead to ruts in the crest surface. Ruts are undesirable because they will pond water, potentially causing stability problems. The crest should slope slightly toward the reservoir where runoff is less likely to cause erosion problems.

There are a number of special circumstances that can contribute to or initiate surface erosion of the crest and downstream slope. In some areas, livestock may establish trails on the embankment. Livestock traffic can damage the slope's vegetative cover. Recreational vehicles can cause ruts in the crest and can damage the slope protection. You need to be aware of any unique problems that may be common in a particular location or past problems that were noted on previous inspections. Make sure to look for these types of problems in your inspection.

Surface Runoff Erosion: Inspection Actions

During the inspection you should ...

- Make sure that the slope and crest protection is adequate to prevent erosion. Remember, areas where the surface protection is sparse are more susceptible to surface runoff problems.

- Look for rills, gullies, ruts, or other signs of surface runoff erosion. Make sure you check the low points along the upstream and downstream shoulders and groins since surface runoff can concentrate in these areas.

- Check for any unique problems, such as livestock or recreational vehicles, that may be contributing to erosion.

If surface runoff erosion is observed .

- Record your findings and photograph the area.

- Determine the extent or severity of the damage.

- Recommend that corrective action be taken to repair the areas damaged by surface runoff and that measures are taken to prevent more serious problems.

INAPPROPRIATE VEGETATIVE GROWTH

Inappropriate vegetative growth is another common maintenance problem. Inappropriate vegetative growth generally falls into two categories . .

- Excessive Vegetative Growth
- Deep-Rooted Vegetation

Excessive Vegetative Growth

Excessive vegetation is a problem wherever it occurs on an embankment dam (Figures 12.5a,b and c). Excessive vegetation can...

- Obscure large portions of the dam, preventing adequate visual inspection. Problems that threaten the integrity of the dam can develop and remain undetected if they are obscured by vegetation.

- Prevent access to the dam and surrounding areas. Limited access is an obvious problem both for inspection and maintenance, and especially during emergency situations, when access is crucial.

- Provide a habitat for rodents and burrowing animals. Burrowing animals can pose a threat to embankment dams by contributing to piping.

Also, there should be no vegetation in the riprap on the upstream slope. Vegetation in the riprap promotes displacement and degradation of the slope protection.

Vegetative growth should be controlled by periodic mowing or other acceptable means.

☞**INSPECTION TIP:**	To ensure that you will have the greatest visibility of the slopes and crest, schedule your inspection shortly after mowing has been completed.

FIGURE 12.5
EXCESSIVE VEGETATION ON DAMS

a. Excessive tree and brush growth on downstream slope

b. Excessive tree growth on upstream slope

c. Tree growth obscures entire embankment except for narrow trail

Deep-Rooted Vegetation

Although a healthy cover of grass is desirable as slope protection, the growth of deep-rooted vegetation, such as large shrubs and trees, is undesirable.

Large trees could be blown over and uprooted during a storm. The resulting large hole left by the root system could breach the dam or shorten the seepage path and initiate piping.

Root systems associated with deep-rooted vegetation develop and penetrate into the dam's cross section. When the vegetation dies, the decaying root system can provide paths for seepage and cause piping to occur.

Even healthy root systems of large vegetation can pose a threat by providing seepage paths. These seepage paths eventually can lead to internal erosion and threaten the integrity of the embankment.

☞**INSPECTION TIP:**	It is generally agreed that trees and shrubs more than 2 feet in height are undesirable growing on or adjacent to embankment dams. However, there is some debate in the engineering community over when and how to remove well-developed trees and root systems that are already in place in the dam. The location, size, type of tree, and prevailing policy will determine the course of action at a given site. See Appendix 3, Subtitle VIII, Sections 708.2, 708.3 and 708.4 for the Commission's policy on woody vegetation.

The best approach to trees in the crest, slopes, and adjacent to the dam is to cut them down <u>before</u> they reach significant size. If large trees have been cut down, but the root system not removed, carefully monitor the area around the remaining stumps for signs of seepage.

Inappropriate Vegetative Growth: Inspection Actions

During the inspection you should .

- ✓ Look for excessive and deep-rooted vegetation on all areas of the dam.
- ✓ Make sure that there is no vegetation growing in the riprap on the upstream slope.
- ✓ Check for signs of seepage around any remaining stumps or decaying root systems on the downstream slope or toe area.

If inappropriate vegetation is observed . .

- ✓ Photograph the area and record your findings.
- ✓ Note the size and extent of the inappropriate vegetation.
- ✓ Recommend that appropriate corrective action be taken to eliminate inappropriate vegetation and that measures be taken to prevent the future growth of undesirable vegetation.

DEBRIS

The collection of debris on and around the dam is not an immediate danger to the integrity of the dam. However, unattended debris can lead to serious problems. Listed below are common problems associated with debris.

- The buildup of brush and logs on the dam can obscure the upstream slope and can prevent adequate inspection.
- Debris can accelerate the process of degradation of the riprap or other slope protection by impact from wave action.
- Woody debris can become waterlogged and sink, possibly blocking an outlet-works inlet or spillway inlets. The blocking of these inlet structures can cause overtopping of the dam in the event of a flood.

Certain animals, such as beavers, can contribute to the accumulation of debris in and around the dam. As you will see in the next section, beavers are not the only animals to cause potential harm to an embankment dam.

Debris: Inspection Actions

If you see debris in and around the dam ...

- ✓ Photograph and record your observations.
- ✓ Recommend that appropriate corrective action be taken to remove the debris and that, if possible, measures are taken, such as the installation of a logboom, to prevent future accumulation.

ANIMAL BURROWS

Animal burrows can be dangerous to the structural integrity of the dam since they weaken the embankment and can create pathways for seepage (Figure 12.6). The following animals can cause destruction to embankment dams . .

- Groundhogs (Woodchucks)
- Muskrats
- Prairie Dogs
- Badgers
- Pocket Gophers
- Richardson Ground Squirrels

Burrowing animals make nests and passageways. These passageways may cause piping failures when they .

- Connect the reservoir to the downstream slope.

- Penetrate the dam's core.

FIGURE 12.6
ANIMAL BURROW

Shallow burrows or burrows that are confined to one side of the embankment may be less dangerous than these deep or connective passageways.

☞**INSPECTION TIP:**	If shallow burrows are so prevalent that they honeycomb an embankment, the integrity of the embankment is suspect. You should consult with an experienced and qualified engineer to determine how the deficiency might be corrected.

Burrowing Animals: Inspection Actions

If burrowing animals are evident ...

- ✓ Photograph the area and record your findings.
- ✓ Recommend that measures be taken before serious damage occurs to the dam. Eradication or removal is usually the recommended course of action.

CHAPTER 13: CONCRETE DAMS AND STRUCTURES

From a safety standpoint, the principal advantage of concrete dams over earth dams is their relative freedom from failure by erosion during overtopping as well as from embankment slides and piping failures.

Although concrete dams comprise a minority of all dams, they are commonly of greater height and storage capacity than earth structures. Thus, they often represent a potentially greater hazard to life and property. It is important that concrete dam owners be aware of the principal modes of failure of such dams and that they be able to discern between conditions which threaten the safety of the dam and those which merely indicate a need for maintenance.

Concrete dams fail for reasons that are significantly different from earth dams. These include:

- Structural cracks
- Foundation and weakness
- Deterioration due to aggregate reaction

Should any of these conditions be discovered during inspection, an owner should obtain engineering assistance immediately.

Structural cracks occur when portions of the dam are overstressed and are the result of inadequate design, poor construction or faulty materials. Structural cracks are often irregular, may run at an angle to the major axes of the dam and may exhibit abrupt changes in direction. These cracks can also have noticeable radial, transverse, or vertical displacement.

Concrete dams transfer a substantial load to the abutments and foundation. Although the concrete of a dam may endure, the natural abutments or foundation may crack, crumble, or move in a massive slide. If this occurs, support for the dam is lost, and it fails. Impending failure of the foundation or abutments may be difficult to detect because initial movements are often very small.

Severe deterioration can result from a chemical reaction between alkali present in cements and certain forms of silica present in some aggregates. This chemical reaction produces byproducts of silica gels which cause expansion and loss of strength within concrete. Alkali reaction is characterized by certain observable conditions such as cracking (usually a random pattern on a fairly large scale), and by excessive internal and overall expansion. Additional indications include the presence of a gelatinous exudation or whitish amorphous deposits on the surface, and a chalky appearance of freshly fractured concrete.

The alkali-aggregate reaction takes place in the presence of water. Surfaces exposed to the elements or dampened by seepage will deteriorate most rapidly. Once suspected, the condition can be confirmed by a series of tests performed on core samples drilled from a dam. Although the deterioration is gradual, alkali-aggregate reaction cannot be economically corrected by any means now known. Continued deterioration may require total replacement of a structure.

Inspection of a concrete dam is similar to that of an earth dam. However, the following additional items should be considered:

- Access and safety
- Monitoring
- Outlet system
- Cracks at construction and expansion joints
- Shrinkage cracks
- Deterioration due to spalling
- Minor leakage

Access and safety are important because the faces of concrete dams are often nearly vertical, and sites are commonly steep-walled rock canyons. Access to the downstream face, toe area, and abutments of such dams may be difficult and require special safety equipment such as safety ropes, or a boatswain's chair. Concrete dams pose a special problem for the dam owner because of the difficulty in gaining close access to the steep surfaces. Regular inspection with a pair of powerful binoculars can initially identify areas where change is occurring. When these changes are noted, a detailed close up inspection should be conducted. Close inspection of the upstream face may also require a boatswain's chair or a boat.

Monitoring helps detect structural problems in concrete dams such as cracks in the dam, abutments, or foundation. Cracks may develop slowly at first, making it difficult to determine if they are widening or otherwise changing over time. If a structural crack is discovered, it should be monitored for changes in width, length, and offset, and a monitoring network of instruments should be installed and read on a regular basis.

Outlet system deterioration is a problem for all dams but the frequency of such damage may be higher in concrete dams because of their greater average hydraulic pressure. Thus, outlet system inspection should be emphasized for large concrete dams.

Cracks at construction joints exist because concrete dams are built in segments, while expansion joints are built into dams to accommodate volumetric changes which occur in the structures after concrete placement. The latter are referred to as "designed" cracks (See Figure 13.1c). These joints are typically constructed so that no bond or reinforcing, except non-bonded waterstops and dowels, extend across the joints.

Shrinkage cracks often occur when, during original construction, irregularities or pockets in the abutment contact are filled with concrete and not allowed to fully cure prior to placement of adjacent portions of the dam. Subsequent shrinkage of the concrete may lead to irregular cracking at or near the abutment.

Shrinkage cracks are also caused by temperature variation. During winter months, the upper portion of a dam may become significantly colder than those portions which are in direct contact with reservoir water. This temperature differential can result in cracks which extend from the crest for some distance down each face of the dam. These cracks will probably occur at construction or expansion joints, if these are provided.

Shrinkage cracks can be a sign that certain portions of the dam are not carrying the design load. In such cases, the total compressive load must be carried by a smaller percentage of the structure. It may be necessary to restore load-carrying capability by grouting affected areas. This work requires the assistance of an engineer.

Spalling is the process by which concrete chips and breaks away as a result of freezing and thawing (Figure 13.1b). Almost every concrete dam in colder climates experiences continued minor deterioration due to spalling. Because it usually affects only the surface of a structure, it is not ordinarily considered dangerous. However, if allowed to continue, spalling can result in structural damage, particularly if a dam is of thin cross section. Also, repair is necessary when reinforcing steel becomes exposed. The method of repairing of spalled areas depends upon the depth of the deterioration. In severe situations, engineering assistance is required.

Minor leakage through concrete dams, although unsightly, is not usually dangerous, unless accompanied by structural cracking. The effect may be to promote deterioration due to freezing and thawing. However, increases in seepage could indicate that, through chemical action, materials are being leached from the dam and carried away by the flowing water. Dam owners should note that decreases in seepage could also occur as mineral deposits are formed in portions of the seepage channel. In either case, the condition is not inherently dangerous and detailed study is required before it can be determined if repair is necessary for other than cosmetic reasons.

The following are photographs of minor maintenance problems involving concrete dams, spillways and appurtenant structures.

FIGURE 13.1
EXAMPLES OF PROBLEMS WITH CONCRETE

a. Complete deterioration of portion of a concrete spillway

b. Spalling of concrete on dam

c. Crack needing application of sealant

CHAPTER 14: INLETS, OUTLETS AND DRAINS

A dam's inlet and outlet works, including internal drains, are essential to the operation of a dam. Items for inspection and special attention include:

- Reservoir pool level
- Lake drains and internal drains
- Corrosion
- Trash racks on pipe spillways
- Cavitation

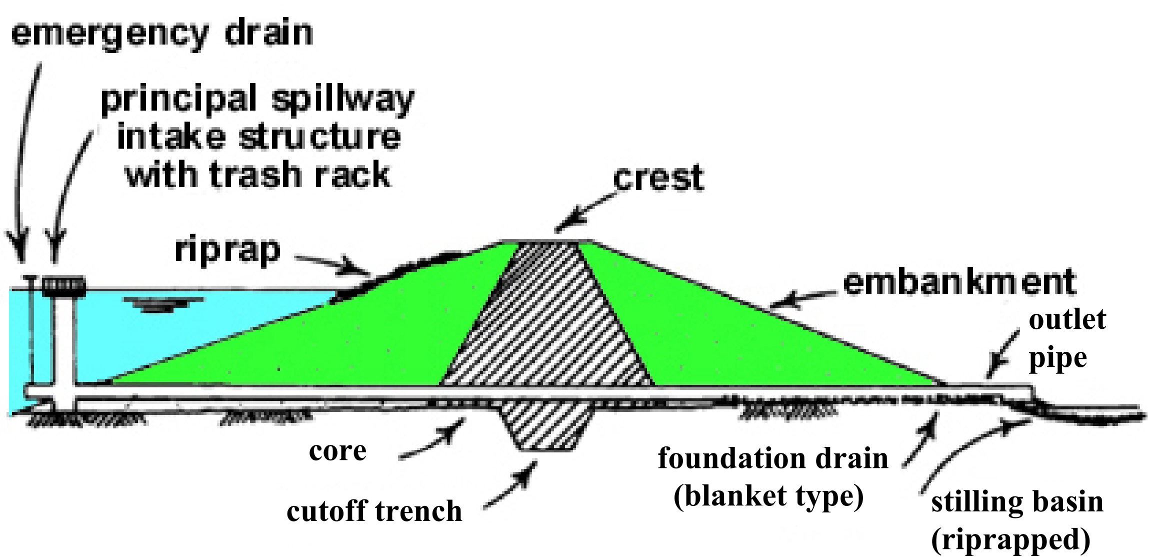


FIGURE 14.1
CROSS SECTION OF SMALL EARTHEN DAM

Reservoir pool levels - Reservoir pool levels are controlled by spillway gates, lake drain and release structures, or flashboards. Flashboards are sometimes used to permanently or temporarily raise the pool level of water supply reservoirs. Flashboards should not be installed or allowed unless there is sufficient freeboard remaining to safely accommodate a design flood. Pool level draw down should not exceed about 1 foot per week for slopes composed of clay or silt materials except in emergency situations. Very flat slopes or slopes with free-draining upstream soils can, however, withstand more rapid draw down rates. Conditions causing or requiring temporary or permanent adjustment of the pool level include:

- Development of a problem which requires that the pool be lowered. Drawdown is a temporary solution until the problem is solved.
- Release of water downstream to supplement stream flow during dry conditions.
- Fluctuations in the service area's demand for water.
- Repair of boat docks in the winter and growth of aquatic vegetation along the shoreline.
- Requirements for recreation, hydropower, or water fowl and fish management

Lake drains - A lake drain should always be operable so that the pool level can be drawn down in case of an emergency or for necessary repair. Lake drain valves or gates that have not been operated for a long time can present a special problem for owners. If the valve cannot be closed after it is opened, the impoundment could be completely drained. An uncontrolled and rapid drawdown could also cause more serious problems such as slides along the saturated upstream slope of the embankment or downstream flooding. Therefore, when a valve or gate is operated, it should be inspected and all appropriate parts lubricated and repaired. It is also prudent to advise downstream residents of large and/or prolonged discharges. To test a valve or gate without risking complete drainage, one must physically block the drain inlet upstream from the valve. Some drains have been designed with this capability and have dual valves or gates, or slots for stoplogs (sometimes called bulkheads) upstream from the valve. Otherwise, divers can be hired to inspect the drain inlet and may be able to construct a temporary block at the inlet.

Other problems may be encountered when operating a lake drain. Sediment can build up and block the drain inlet, or debris can enter the valve chamber, hindering its function. The likelihood of these problems is greatly decreased if the valve or gate is operated and maintained periodically.

Corrosion - Corrosion is a common problem of pipe spillways and other conduits made of metal. Exposure to moisture, acid conditions, or salt will accelerate corrosion. In particular, acid runoff from strip mine areas will cause rapid corrosion of steel pipes. In such areas, pipes made of non-corrosive materials such as concrete or plastic should be used. Metal pipes which have been coated to resist accelerated corrosion are also available. The coating can be of epoxy, aluminum, zinc (galvanization), asbestos or mortar. Coatings applied to pipes in service are generally not very effective because of the difficulty of establishing a bond. Similarly, bituminous coating cannot be expected to last more than one to two years on flowways. Of course, corrosion of metal parts of operating mechanisms can be effectively treated and prevented by keeping those parts greased and/or painted.

Corrosion can also be controlled or arrested by installing cathodic protection. A metallic anode made out of a material such as magnesium is buried in the soil and is connected to the metal pipe by wire. An electric potential is established which causes the magnesium to corrode and not the pipe.

FIGURE 14.2
OBSTRUCTION OF TRASH RACK

Trash on pipe spillways - Many dams have pipe and riser spillways (Figure 14.2). As with concrete spillways, pipe inlets that become plugged with debris or trash reduce spillway capacity. As a result, the potential for overtopping is greatly increased, particularly if there is only one outlet if a dam has an emergency spillway channel, a plugged principal spillway will cause more frequent and greater than normal flow in the emergency spillway. Because emergency spillways are generally designed for infrequent flows of short duration, serious damage may result. For these reasons trash collectors or racks should be installed at the inlets to pipe spillways and lake drains.

A well-designed trashrack will stop large debris that could plug a pipe but allow unrestricted passage of water and smaller debris. Some of the most effective racks have submerged openings which allow water to pass beneath the trash into the riser inlet as the pool level rises. Openings that are too small will stop small debris such as twigs and leaves, which in turn will cause a progression of larger items to build up, eventually completely blocking the inlet Trashrack openings should be at least 6 inches across regardless of the pipe size. The larger the principal spillway conduit, the larger the trashrack opening should be. The largest possible openings should be used, up to a maximum of about 2 feet.

A trashrack should be properly attached to the riser inlet and strong enough to withstand the forces of fast-flowing debris, heavy debris, and ice. If the riser is readily accessible, vandals may throw riprap stone into it. The size of the trashrack openings should not be decreased to prevent this. Instead rock that is larger than the trashrack openings or too large to handle should be used for riprap.

Maintenance should include periodic checking of the rack for rusted and broken sections and repair as needed. The trashrack should be checked frequently during and after storms to ensure that it is functioning properly and to remove accumulated debris.

Cavitation - When water flows through an outlet system and passes restrictions (e.g., valves), a pressure drop may occur. if localized water pressures drop below the vapor pressure of water, a partial vacuum is created and the water actually boils, causing shockwaves which can damage the outlet pipes and control valves. This process can be a serious problem for large dams where discharge velocities are high.

Testing the outlet system - All valves should be fully opened and closed at least once a year. This not only limits corrosion buildup on control stems and gate guides, but also provides an opportunity to check for smooth operation of the system. Jerky or erratic operation could signal problems, and indicate the need for more detailed inspection.

The full range of gate settings should be checked. The person performing the inspection should slowly open the valve, checking for noise and vibration - certain valve settings may result in greater turbulence. Listen for noise which sounds like gravel being rapidly transported through the system. This sound indicates that cavitation is occurring, and these gate settings should be avoided. The operation of all mechanical and electrical systems, backup electric motors, power generators, and power and lighting wiring associated with the outlet should also be checked.

Inspecting the outlet system - Accessible portions of the outlet, such as the outfall structure and control, can be easily and regularly inspected. However, severe problems are commonly associated with deterioration or failure of portions of the system which are either buried in the dam or normally under water.

Areas to be inspected include:

- Outlet pipes 30 inches or greater in diameter can be inspected internally, provided the system has an upstream valve allowing the pipe to be emptied. Tapping the conduit interior with a hammer can help locate voids behind the pipe. This type of inspection should be performed at least once a year.

FIGURE 14.4
PLUNGE BASIN SHOWING ERODED RIPRAP AND BANKS

- Small diameter outlet pipes can be inspected by remote TV camera if necessary. The camera is channeled through the conduit and transmits a picture back to an equipment truck. This type of inspection is expensive and usually requires the services of an engineer. However, if no other method of inspection is possible, inspection by TV is recommended at least once every five years.

- Outlet intake structures, wet wells, and outlet pipes with only downstream valves are the most difficult dam appurtenances to inspect because they are usually under water. These should be inspected whenever the reservoir is drawn down or at five year intervals, if a definite problem is suspected, or if the reservoir remains filled over extended periods, divers should be retained to perform an underwater inspection.

FIGURE 14.3
OBSTRUCTED OUTLET PIPE

a. Obstructed spillway outlet pipe

b. Spillway outlet pipe discharging into plunge basin

CHAPTER 15: EMERGENCY SPILLWAYS

This sections is concerned with the emergency or overflow spillway. Drop inlet spillways, which often serve as the principal spillway are included in Chapter 14. Figure 15.1 shows the position of a typical emergency spillway with outflow channel.

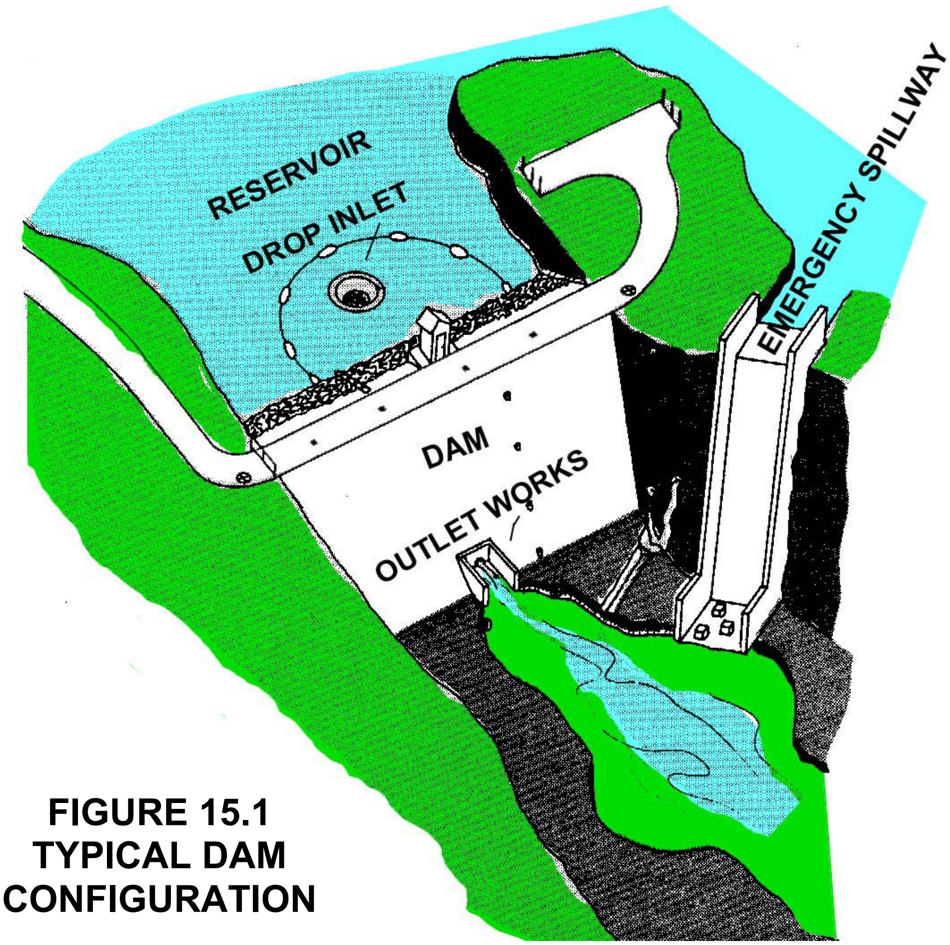


**FIGURE 15.1
TYPICAL DAM
CONFIGURATION**

The main function of a spillway is to provide a safe exit for excess water in a reservoir. If a spillway is of inadequate size, a dam could be overtopped and fail. Similarly, defects in a spillway can cause failure by rapid erosion. A spillway should always be kept free of obstructions, have the ability to resist erosion, and be protected from deterioration. Because dams represent a substantial investment and spillways make up a major part of dam costs, a conscientious annual maintenance program should be pursued not only to protect the public but also to minimize costs as well.

The primary problems encountered with spillways include:

• Inadequate capacity
• Obstructions
• Erosion
• Deterioration
• Cracks
• Undermining of spillway outlet

Inadequate capacity is determined by several factors, such as drainage area served, magnitude or intensity of storms in the watershed, storage capacity of the reservoir, and the speed with which rain water flows into and fills the reservoir. An inadequate spillway can cause the water in a reservoir to overtop the dam.

Obstructions of a spillway may result from excessive growth of grass and weeds, thick brush, trees, debris, or landslide deposits (Figure 15.2). An obstructed spillway can have a substantially reduced discharge capacity which can lead to overtopping of the dam. Grass is usually not considered an obstruction however; tall weeds, brush, and young trees should be periodically cleared from spillways. Similarly, any substantial amount of soil deposited in a spillway - whether from sloughing, landslide or sediment transport - should be immediately removed. Timely removal of large rocks is especially important, since they can obstruct flow and encourage erosion.

FIGURE 15.2
EXAMPLES OF DEBRIS BLOCKING SPILLWAY

Erosion of a spillway may occur during a large storm when large amounts of water flow for many hours (Figure 14.3). Severe damage of a spillway or complete washout can result if the spillway cannot resist erosion. If a spillway is excavated out of a rock formation or lined with concrete, erosion is usually not a problem. However, if a spillway is excavated in sandy soil, deteriorated granite, clay, or silt deposits, erosion protection is very important. Generally, resistance to erosion can be increased if a spillway channel has a mild slope, or if it is covered with a layer of grass or riprap with bedding material.

A spillway cannot be expected to perform properly if it has **deteriorated.** Examples include: collapse of side slopes, riprap, concrete lining, approach section, the chute channel, the stilling basin, the discharge channel, or protective grass cover. These problems can cause water to flow under and around the protective material and lead to severe erosion. Remedial action must be taken as soon as any sign of deterioration has been detected.

FIGURE 15.3
EROSION OF BEDROCK SPILLWAY

Drying **cracks** in an earth spillway channel are usually not regarded as a functional problem. However, missing rocks in a riprap lining can be considered a “crack” in the protective cover, and must be repaired at once. Cracks in concrete lining of a spillway are commonly encountered. These cracks may be caused by uneven foundation settlement, shrinkage, slab displacement, or excessive earth or water pressure. Large cracks will allow water to wash out fine material below or behind the concrete slab, causing erosion, more cracks, and even severe displacement of the slab. The slab may even be dislodged and washed away by the flow. A severely cracked concrete spillway should be examined by and repaired under the supervision of an engineer.

Undermining of a spillway causes erosion at a spillway outlet, whether it be a pipe or overflow spillway, is one of the most common spillway problems (Figure 15.4). Severe undermining of the outlet can displace sections of pipe, cause slides in the downstream embankment of the dam and eventually lead to complete failure. Water must be conveyed safely from the reservoir to a point downstream of the dam without endangering the spillway itself or the embankment Often the spillway outlet is adequately protected for normal flow conditions, but not for extreme flows. is easy to misestimate the energy and force of flowing water and the resistance of outlet material (earth, rock, concrete, etc). The required level of protection is difficult to establish by visual inspection but can usually be determined by hydraulic calculations performed by a professional engineer.

Structures that provide complete erosion control at a spillway outlet are usually expensive, but often necessary. Less expensive protection can also be effective, but require extensive periodic maintenance as areas of erosion and deterioration develop.

The following four factors, often interrelated, contribute to erosion at the spillway outlet:

1. Flows emerging from the outlet are above the stream channel. If outlet flows emerge at the correct elevation, tailwater in the stream channel can absorb a substantial amount of the high velocity flow and the hydraulic energy will be contained in the stilling basin.

2. Flows emerging from the spillway are generally free of sediment and thereby have substantial sediment-carrying capacity. In obtaining sediment, moving water will scour soil material from the channel and leave eroded areas. Such erosion is difficult to design for and requires protection of the outlet for a safe distance downstream from the dam.

3. Flows leaving the outlet at high velocity can create negative pressures that can cause material to be loosened and removed from the floor and walls of the outlet channel. This action is called “cavitation” when it occurs on concrete or metal surfaces. Venting can sometimes be used to relieve negative pressures.

4. Water leaking through pipe joints and/or flowing along a pipe from the reservoir may weaken the soil structure around the pipe. Inadequate compaction adjacent to such structures during construction can compound this problem.

FIGURE 15.4
UNDERMINING OF A CONCRETE SPILLWAY

Procedure for inspection - Spillway inspection is an important part of a dam safety program. The basic objective of spillway inspection is to detect any sign of obstruction, erosion, deterioration, misalignment, or cracking.

When inspecting an earthen spillway, it should be determined whether side slopes have sloughed, there is excessive vegetation in the channel; and signs of erosion and rodent activity. Use a probe to determine the hardness and moisture content of the soil, note the location of particularly wet or soft spots, and see if the stilling basin or drop structure is properly protected with rocks or rip-rap. Because some erosion is unavoidable during stilling, an owner should also determine whether such erosion might endanger the embankment itself. If the spillway is installed with a sill, the dam owner should also determine if there are any cracks or misalignment in the sill and check for erosion beneath or downstream of the sill.

Commonly encountered defects of concrete spillways and general inspection procedures for cracks, spalling, drains, joints, and misalignment are summarized in the following paragraphs.

Hairline cracks are usually harmless. Large cracks should be carefully inspected and their location, width, length, and orientation noted. Deterioration should be determined and exposure of reinforcing bars should be protected.

Spillway surfaces exposed to freeze-thaw cycles often suffer from surface spalling. Chemical action, contamination, and unsound aggregates can also cause spalling. If spalling is extensive, the areas should be sketched or photographed, showing the length, width, and depth. The problem should be examined closely to see if the remaining concrete has deteriorated or if reinforcing bars are exposed. The concrete should be tapped with a “bonker” or rock hammer to determine if voids exist below the surface. Shallow spalling should be examined from time to time to determine if it is becoming worse. Deep spalling should be repaired as soon as possible by an experienced contractor.

Walls of spillways are usually equipped with weep (or drain) holes. Occasionally spillway chute slabs are also equipped with weep holes. If all such holes are dry, the soil behind the wall or below the slab is probably dry. If some holes are draining while others are dry, the dry holes may be plugged by mud or mineral deposits. Plugged weep holes increase the chances for failure of retaining walls or chute slabs. The plugged holes should be probed to determine causes of blockage and soil or deposits cleaned out to restore drainage. If this work is not successful, rehabilitation should be performed as soon as possible under the supervision of a professional engineer.

Spillway retaining walls and chute slabs are normally constructed in sections. Between adjoining sections, gaps or joints must be tightly sealed with flexible materials such as tar, epoxies, or other chemical compounds. Sometimes rubber or plastic diaphragm materials or copper foil are used to obtain watertightness. During inspection, note the location, length, and depth of any missing sealant, and probe open gaps to determine if soil behind the wall or below the slab has been undermined.

Misalignment of spillway retaining walls or chute slabs may be caused by foundation settlement or earth or water pressure. The inspector should carefully look at the upstream or downstream end of a spillway near the wall to determine if it has been tipped inward or outward. Relative displacement or offset between neighboring sections can be readily identified at joints. The horizontal as well as vertical displacement should be measured. A fence on top of the retaining wall is usually erected in a straight line at the time of construction; thus any curve or distortion of the fence line may indicate wall deformation.

At the time of construction, the entire spillway chute should form a smooth surface. Thus, measurement of relative movement between neighboring chute slabs at joints will give a good indication of slab displacement. Misalignment or displacement of walls or, the slab is often accompanied by cracks. A clear description of crack patterns should be recorded or photos taken to help in understanding the nature of the displacement

CHAPTER 16: DAM INSPECTION AND MAINTENANCE CHECKLIST

THE EMBANKMENT

Key things to look for: Any evidence of movement, either within the dam itself, at its ends, or in the material on which it rests; and excessive surface erosion or other damage to the embankment, or excessive seepage. Is the dam overgrown with underbrush or trees?

SURFACE CRACKS

Yes No	Remarks	Maintenance Tips
❑ ❑ Are there any surface cracks?	May indicate movement within the dam.	Should be evaluated by a professional engineer.
❑ ❑ Is there any unusual movement or cracking at or beyond the toe?	Dam or its foundation may be unstable.	Should be evaluated by a professional engineer.

SURFACE EROSION

Yes No	Remarks	Maintenance Tips
❑ ❑ Is there erosion on upstream face from wave action or changes in pool level?	If severe or rapid, a serious problem.	If severe and progressive, protect upstream face with riprap or other form of wave protection.
❑ ❑ Is there erosion from runoff, either rills, gullies or bare areas?	Erosion of any sort is a problem, as it tends to worsen with time if not corrected.	Improve grass cover; reshape embankment to improve drainage pattern.
❑ ❑ Is there erosion from traffic (people, animals, vehicles)?	Any erosion is serious, as it will get worse with time if not corrected.	Try to keep all types of traffic to a reasonable level. Keep vehicles off dam. Stabilize crest roads to prevent rutting. Prohibit recreational vehicle traffic on slopes. Keep livestock off dam. Fill in existing ruts or eroded areas and reseed.

EMBANKMENT (continued)

ANIMAL BURROWS

Yes No	Remarks	Maintenance Tips
❑ ❑ Are there any animal burrows?	May provide passageways for water into or through the dam.	Fill burrows with earth or otherwise block entry. Try to keep woodchucks, muskrat and beaver away from the dam.

DEPRESSIONS

Yes No	Remarks	Maintenance Tips
❑ ❑ Are there depressed areas on the dam?	May have resulted from slope failures or settlement, or even piping.	If pronounced or progressive, must be evaluated by a professional engineer.

PIPING

Yes No	Remarks	Maintenance Tips
❑ ❑ Is there any evidence of piping? (This condition is evidenced by a muddy flow through the dam and/or the formation of soil deposits beyond the dam and depressions on its slopes.)	Piping is internal erosion within an embankment, or the progressive removal of soil particles adjacent to leaks through a soil mass.	Piping is always a serious condition, which can lead to failure of the dam. A piping condition must be evaluated by a professional engineer.
❑ ❑ Does the crest appear to have shifted or settled excessively? (Look for cracks in the em-bankment and associated structures. Compare alignment with plans if they are available.)	Crest movement may indicate a stability problem. However, some settlement of a new fill, such as an embankment dam, is normal.	Must be evaluated by a professional engineer.

EMBANKMENT (continued)

PIPING (continued)

Yes No	Remarks	Maintenance Tips
❑ ❑ If the upstream face is protected by riprap is it in good condition? (Riprap is a layer, facing, or protective mound of stone in random size pieces, randomly placed to prevent erosion, scour, or sloughing of an embankment or structure.)	Effectiveness is lessened if riprap has slipped out of place, has been undermined, or has become overgrown with brush.	Restore riprap as necessary; keep free of trees and bushes.
❑ ❑ If there is riprap in discharge channels or in the plunge pool downstream, is it in good condition?	Has riprap been displaced or overgrown?	Restore riprap as necessary; keep free of trees and bushes.
❑ ❑ If drainage channels at ends of embankment are protected with riprap, is it in good condition?	Drainage along abutments often causes gullying if there is no protection.	Riprap or other form of slope protection should be used as necessary.
❑ ❑ If there is riprap in miscellaneous areas (on downstream slope, on crest, etc.) is it in good repair?		Restore as necessary.

EMBANKMENT (continued)

ALIGNMENT

Yes No	Remarks	Maintenance Tips
❑ ❑ Does the crest appear to have shifted or settled excessively? (Look for cracks in the embankment and associated structures. Compare alignment with plans if they are available.)	Crest movement may indicate a stability problem. However, some settlement of a new fill, such as an embankment dam, is normal.	Should be evaluated by a professional engineer.

SEEPAGE

Yes No	Remarks	Maintenance Tips
❑ ❑ If there are any drains to collect and remove, seepage, are they operating properly?	Check plans for the presence of drains and search the dam to see if any others are present.	Keep drains clear of any blockages and assure proper operation.
❑ ❑ If there are foundation drain outlets, are they clear and flowing?	Foundation drains serve to collect seepage passing through the dam and conduct it away from the embankment.	Open outlets to such drains if they have become covered or clogged.
❑ ❑ Are there wet spots or areas on the downstream face, at the toe, or beyond the dam? (Such spots are often indicated by a change in color or type of vegetation, such as from grass to cattails.)	Some seepage is normal for an earth dam. Be concerned if it appears to be excessive (a lot of standing water; very soft and marshy areas; evidence of a seepage line high on the downstream face).	Observe seepage areas periodically to detect changes in the amount of moisture, new flows, or muddy flows. If the upper limit of seepage is fairly high on the downstream face, the dam may be unstable.

EMBANKMENT (continued)

SEEPAGE (continued)

❑ ❑ Are there seeps or springs with flowing water? Look closely for these at the ends of the dam, around any pipes passing through the embankment, on downstream face, at the toe of the dam and beyond, and at the base of trees on, near, or below the dam.	Flowing seeps or springs may indicate problems, and should be periodically monitored for changes in rate of flow or muddy flow. Creation of an impoundment often causes changes in the water table nearby.	Monitor seepage closely for any changes in amount, rate, extent, or clarity. Excessive or turbid seepage, or marked increases in rate of seepage, should be evaluated by a professional engineer.
❑ ❑ Is there swamp or marsh type vegetation on downstream face or beyond the dam (cattails, tall grass, etc.)?	Swamp type vegetation indicates the presence of seepage.	Cut frequently to make observation of the area easier. Such growth can hide problems.

VEGETATION

❑ ❑ Is the dam overgrown with trees and/or underbrush?	One of the most frequent problems, and highly undesirable. Roots may damage the embankment and allow water to pass into or through it. Trees may be uprooted in a storm and breach the dam.	Keep embankment faces free of trees and underbrush by periodic mowing. Remove existing trees and saplings, and establish and maintain a good grass cover on the dam.

EMBANKMENT (contined)

OVERTOPPING

❑ ❑ Has the dam ever been overtopped by water flowing over it?	Past overtopping may have resulted in erosion of the crest and downstream face of the dam. Overtopping indicates that the emergency spillway is probably too small.	Restore eroded areas or other damage done to the dam by overtopping. Consider enlarging the emergency spillway, lowering the normal pool level to allow more storage capacity during floods, or perhaps raising the height of the embankment to decrease the possibility of future overtopping. Consult a professional engineer.

MODIFICATIONS

❑ ❑ Has there been any modification of the embankment, such as raising the crest, changing the shape or size of the principal spillway or the emergency spillway, or changing the shape or size of the embankment?	Inappropriate or unsuitable modifications can drastically affect the safety of a dam, even one that may have originally been properly designed and constructed.	Dams that have been appreciably modified since construction should be evaluated for stability by a professional engineer.

THE PRINCIPAL SPILLWAY

Yes No	Remarks	Maintenance Tips
❑ ❑ Can water flow into the principal spillway without difficulty, as intended when constructed?	The riser, intake structure, or channel should be free of trash or other blockage.	Install a trash rack if one is not already in place. Periodically clear trash rack of any accumulated debris.
❑ ❑ Is outlet pipe or discharge channel clear and open to allow the free passage of the principal spillway discharge?	Flows passing through the spillway should not erode or otherwise damage the dam.	Keep outlet pipe, plunge basin, and all other outlet works clear and in good repair.
❑ ❑ Is the primary spillway structure in good condition (check concrete, wood, and metal portions for damage or deterioration)?	Such dam features as the principal spillway require continued maintenance like any other structure.	Repair and maintain as appropriate to insure the continued useful life of the dam.
❑ ❑ Does the lake have a drain that can be used to lower it in an emergency?	Lowering a lake may be necessary if the dam begins to develop problems.	Check plans or search dam for emergency drain system.
❑ ❑ If there is an emergency drain, is it known to be in working condition? **Danger**: If a drain has not been used for a long time, it may be possible to open it but not close it, thus draining the lake.	Drain valves and other mechanisms should receive sufficient maintenance to insure that they remain in working order.	Maintain system so that it can be used in an emergency. Normally, the pool behind an earth embankment dam should not be lowered at a rate of more than 1 inch per day.
❑❑ If there are other gates, valves, or operating equipment, are these in working condition?	Such devices are vital to the effective and safe operation of the dam.	Repair and restore if necessary, and maintain in an operable condition.

THE EMERGENCY SPILLWAY

Yes No	Remarks	Maintenance Tips
❑ ❑ Can water flow into the emergency spillway without difficulty, as intended when constructed?	To be effective, all portions of the spillway channel should be clear and unobstructed.	The approach channel should be kept free of trash, underbrush, or other blockage.
❑ ❑ Is the discharge channel clear and open to allow the free passage of the emergency spillway discharge?	Spillway flows must be effectively conducted away from the dam.	Clear as necessary.
❑ ❑ Is the emergency spillway constructed in such a way that its flows will not erode other portions of the dam?	A berm is often constructed to keep spillway flows from encroaching on the embankment.	Reshape dam if necessary to take care of this problem.
❑ ❑ Is the emergency spillway in good condition overall (check for erosion within the channel, adequacy of grass cover, etc.)?	Spillway erosion is a common problem.	Restore any erosion gullies or eroded areas. Provide channel protection (riprap, concrete, etc.) if necessary to eliminate recurring problems.

THE RESERVOIR AREA

Yes No	Remarks	Maintenance Tips
❑ ❑ Is serious wave erosion occurring along the shoreline?	Some minor erosion along a shoreline is to be expected.	Critical shoreline areas can be protected with vegetation or in some other manner.
❑ ❑ Is a lot of sediment entering the impoundment, or has this happened in the past?	This may occur as a result of construction or agricultural activity in the watershed.	Dredging may be required to restore the lake.

RESERVOIR AREA (continued)

❑ ❑ Does the nature of the land surrounding the lake or its use present any problems?	Intensive agricultural or development activities in the watershed may precipitate problems associated with surface runoff or other difficulties.	Problems of this nature are often complex and may be beyond the owner's direct control.
❑ ❑ Is there any evidence of landslides or instability on the slopes around the reservoir?	A large landslide into a lake can subject a dam to overtopping or other damage.	Suspected or evident problems of this type should be investigated by a professional engineer or engineering geologist.

DOWNSTREAM CHANNEL

Yes No	Remarks	Maintenance Tips
❑ ❑ Is the downstream channel free of obstructions, so that water in a flood will not back up against the toe of the dam?	The channel below a dam is often a neglected area.	Clear downstream channel if necessary.

WATERSHED AREA

Yes No	Remarks	Maintenance Tips
❑ ❑ Have there been any major modifications or significant changes in the watershed drainage area, such as new urban developments (shopping centers, housing projects), clear cutting of woodlands, or other basic changes in land use.	Intensive agricultural or development activities in the watershed may precipitate problems associated with greater surface runoff or other difficulties.	Problems of this nature are often complex and may be beyond the owner's direct control. Appeals to existing regulations dealing with erosion prevention, pollution control, etc. may be helpful.

THE DOWNSTREAM AREA

Yes No	Remarks	Maintenance Tips
❑ ❑ If the dam should fail, would loss of life or extensive property damage be likely?	Consider the number of occupied homes or businesses downstream, their distance from the dam, and their distance from and elevation above the streambed. Consider also potential losses in property and disruption of facilities, i.e., roads, railroads, or utilities.	Personally inspecting the area that would be affected will be useful in determining who needs to be alerted in an emergency. Topographic maps prepared by the U.S. Geological Survey are also useful for this purpose.
❑ ❑ Do you have on file the current telephone numbers of any persons living or working in areas downstream from the dam, as well as the telephone numbers of those responsible for facilities that would be affected, such as highways or public utilities.	Prior planning for an emergency is invaluable in terms of mitigating losses. When a dam failure is imminent, it is too late to begin wondering who is located downstream and how they can be reached.	Any list of phone numbers or other information to be used in an emergency should be checked for accuracy and updated periodically to insure that the information remains current.
❑ ❑ Do you have on file the current telephone numbers of local authorities who should be informed if the dam is endangered, such as the sheriff, county administrator, or emergency services coordinator?	In an emergency certain functions, such as compelling the evacuation of an area, can be performed only by those with the legal authority to do so.	The Arkansas Soil and Water Conservation Commission and the local Emergency Services Coordinator can offer guidance for preparing an emergency warning plan, if needed. Such a plan should be filed with local authorities.

CHAPTER 17: REPAIR, ALTERATION AND REMOVAL

An engineering inspection report, or even the owner's inspection, may identify the need for repair or modifications of the dam. Repair is performed to essentially restore a dam to its approved design condition. The dam owner will need to obtain engineering assistance to develop design plans and specifications for the repair, alteration or removal of the dam. The Arkansas Soil and Water Conservation Commission should be consulted. Such repairs or removal of the dam may require permits. Permit requirements are described in Appendix 3. Please read that appendix carefully. This chapter will identify some of the issues the dam owner must address.

I. Seek Help from Engineers and Contractors

If an engineering inspection reveals the need for repairs and/or further investigations, then an engineer should be retained to prepare plans and specifications and oversee the repair work. It is very important that the dam owner selects a qualified engineer in the area of dam design, construction, operation and inspection.

Just as important as selecting a qualified engineer, the owner must select a qualified contractor. The construction or repair work activity around a water retaining structure such as a dam requires specialized skills, knowledge and experience. It is important that the dam owner and/or engineer seek references from the contractor to pre-qualify them for the work. The competitive bidding process is not always the best procedure. Although it may appear to save the dam owner some cost, long-term effects from an improper repair job or cost overruns due to contractor inexperience can also occur.

II. Common Deficiencies and Remedies

Identifying dam deficiencies and remedies will probably require the assistance of an engineer who is able to assess the relative severity of a problem, which most laymen cannot do. Some maintenance items, if not promptly attended to, can deteriorate to the point where major repair is required.

Common items that could require repair include slumping and settlement, loss of riprap, seepage, piping, scour, embankment erosion, and severe concrete and metal deterioration.

A common hydraulic deficiency is an undersized spillway (that is, inadequate capacity), through which a major flood cannot be passed without overtopping the dam. This deficiency is serious and can be expensive to correct. The Arkansas Soil and Water Conservation Commission can help the owner provide a list of engineers qualified to preform hydraulic analyses.

III. Dam Removal

Dam removal or breaching so as not to damage downstream areas is the choice an owner must sometimes make after considering safety conditions and costs of repair and removal. It is recommended that an engineer be engaged not only to prepare plans and specifications, but also to supervise construction (actually "destruction") and removal phases. The engineer should provide documentation that all environmental protection measures are taken, and assure that upstream and downstream users are protected during removal of the dam.

Removal does not necessarily mean total removal of the earth embankment. Removal may simply involve taking away the stoplogs and lowering the impoundment. Arkansas Soil and Water Conservation Commission should be contacted to determine the extent of removal.

APPENDIX 1

DESCRIPTION OF DAM

DAMS DESCRIPTION
(SAMPLE)

It is a good idea to keep a record of a dam's history, and the following table may be used. Your record of inspections will serve to keep this history current. Also, it is desirable to record a few basic dimensions of the dam.

BASIC DIMENSIONS

Height (measured vertically from downstream toe to top of dam):___________

Elevation of top of dam:___________

Elevation of normal pool level:___________

Elevation of emergency spillway:___________

Width of crest of dam:___________

Distance across emergency spillway:____________

Upstream slope (for instance, 3 horizontal to 1 vertical, or 3:1): _____

Downstream slope: _____

DAM HISTORY

		Date
Designed by:	____________________________	_______
Constructed by:	____________________________	_______
Date of completion:	____________________________	_______
Has the dam ever failed, either partially or totally?	____________________________	_______
Has the dam ever been rebuilt or modified?	____________________________	_______
Has the dam been overtopped by flooding?	____________________________	_______
What is the maximum water level observed?	____________________________	_______
Other information relevant to dam's history:	____________________________	_______

APPENDIX 2

INSPECTION AND INCIDENT REPORT FORMS

NAME OF DAM: ____________ INSPECTION DATE: ____________

EMBANKMENT

1 of 2

AREA INSPECTED	ITEM NO.	CONDITION	OBSERVATIONS	CHECK ( ) ACTION NEEDED: MONITOR	INVESTI-GATE	REPAIR
CREST	1	SURFACE CRACKING				
	2	CAVE IN, ANIMAL BURROW				
	3	LOW AREA(S)				
	4	HORIZONTAL ALIGNMENT				
	5	RUTS AND/OR PUDDLES				
	6	VEGETATION CONDITION				
	7					
	8					
UPSTREAM SLOPE	9	SLIDE, SLOUGH, SCARP				
	10	SLOPE PROTECTION				
	11	SINKHOLE, ANIMAL BURROW				
	12	EMB.-ABUT. CONTACT				
	13	EROSION				
	14	VEGETATION CONDITION				
	15					
	16					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

NAME OF DAM: ____________ INSPECTION DATE: ____________

EMBANKMENT
2 of 2

AREA INSPECTED	ITEM. NO.	CONDITION	OBSERVATION	CHECK ( ) ACTION NEEDED: MONITOR	INVESTI-GATE	REPAIR
DOWNSTREAM SLOPE	17	WET AREA(S) (NO FLOW)				
	18	SEEPAGE				
	19	SLIDE, SLOUGH, SCARP				
	20	EMB.-ABUT. CONTACT				
	21	CAVE IN, ANIMAL BURROW				
	22	EROSION				
	23	UNUSUAL MOVEMENT				
	24	VEGETATION CONTROL				
	25					
	26					
INSTRUMENTATION	27	PIEZOMETERS/OBSERV. WELLS				
	28	STAFF GAUGE AND RECORDER				
	29	WEIRS				
	30	SURVEY MONUMENTS				
	31	DRAINS				
	32	FREQUENCY OF READINGS				
	33	LOCATION OF RECORDS				
	34					
	35					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

NAME OF DAM: ______________________ INSPECTION DATE: ____________

SPILLWAYS

1 of 1

AREA INSPECTED	ITEM NO.	CONDITION	OBSERVATIONS	CHECK ( ) ACTION NEEDED: MONITOR	INVESTI-GATE	REPAIR
ERODIBLE CHANNEL	51	SLIDE, SLOUGH, SCARP				
	52	EROSION				
	53	VEGETATION CONDITION				
	54	DEBRIS				
	55					
	56					
NON-ERODIBLE CHANNEL	57	SIDEWALLS				
	58	CHANNEL FLOOR				
	59	UNUSUAL MOVEMENT				
	60	APPROACH AREA				
	61	WEIR OR CONTROL				
	62	DISCHARGE AREA				
	63					
	64					
DROP INLET	65	INTAKE STRUCTURE				
	66	TRASHRACK				
	67	STILLING BASIN				
	68					
	69					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

NAME OF DAM: ____________________ INSPECTION DATE: ____________

OUTLET WORKS

1 of 1

AREA INSPECTED	ITEM NO.	CONDITION	OBSERVATIONS	CHECK ( ) ACTION NEEDED: MONITOR	INVESTI-GATE	REPAIR
OUTLET WORKS	70	INTAKE STRUCTURE				
	71	TRASHRACK				
	72	STILLING BASIN				
	73	PRIMARY CLOSURE				
	74	SECONDARY CLOSURE				
	75	CONTROL MECHANISM				
	76	OUTLET PIPE				
	77	OUTLET TOWER				
	78	EROSION ALONG DAM TOE				
	79	SEEPAGE				
	80	UNUSUAL MOVEMENT				
	81					
	82					
	83					

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

NAME OF DAM: ____________________ INSPECTION DATE: ____________

CONCRETE/MASONRY DAMS

AREA INSPECTED	ITEM NO.	CONDITION	OBSERVATIONS	CHECK ( ) ACTION NEEDED: MONITOR	INVESTI-GATE	REPAIR
UPSTREAM FACE	84	SURFACE CONDITIONS				
	85	CONDITION OF JOINTS				
	86	UNUSUAL MOVEMENT				
	87	ABUTMENT-DAM CONTACTS				
	88					
	89					
	90	SURFACE CONDITIONS				
DOWNSTREAM FACE	91	CONDITION OF JOINTS				
	92	UNUSUAL MOVEMENT				
	93	ABUTMENT-DAM CONTACTS				
	94	DRAINS				
	95	LEAKAGE				
	96					
	97					
CREST	98	SURFACE CONDITIONS				
	99	HORIZONTAL ALIGNMENT				
		VERTICAL ALIGNMENT				
		CONDITION OF JOINTS				
		UNUSUAL MOVEMENTS				

ADDITIONAL COMMENTS: REFER TO ITEM NO. IF APPLICABLE.

DAM INCIDENT REPORT FORM

DATE ______________________ TIME ______________________

NAME OF DAM ______________________

STREAM NAME ______________________

LOCATION ______________________

COUNTY ______________________

OBSERVER ______________________

OBSERVER TELEPHONE ______________________

NATURE OF PROBLEM ______________________

____

LOCATION OF PROBLEM AREA ______________________
(Looking Downstream)

____

EXTENT OF PROBLEM AREA ______________________

____

FLOW QUANTITY AND COLOR ______________________

____

WATER LEVEL IN RESERVOIR ______________________

WAS SITUATION WORSENING ______________________

EMERGENCY STATUS ______________________

CURRENT WEATHER CONDITIONS ______________________

____

ADDITIONAL COMMENTS: ______________________

____

____

____

____

____

____

____

____

____

APPENDIX 3

STATE DAM SAFETY
RULES AND REGULATIONS

TITLE VII

RULES GOVERNING DESIGN AND OPERATION OF DAMS
[As Restated October, 1993]

TABLE OF CONTENTS

TITLE VII

RULES GOVERNING
DESIGN AND OPERATON OF DAMS
[As Restated October, 1993]

SUBTITLE I. GENERAL PROVISIONS

Section 701.1. PURPOSE.

A. Provide for the comprehensive regulation and supervision of dams for the protection of the health, safety, welfare, and property of the citizens of Arkansas.

B. Assure proper planning, design, construction, maintenance, monitoring and supervision of dams, including such preventive measures as are necessary to provide an adequate margin of safety.

Section 701.2. AUTHORITY.

Rules governing design and operation of dams within the State of Arkansas are promulgated under authority of Subchapter 2 of Chapter 22 of title 15 of the Arkansas Code of 1987.

Section 701.3. SCOPE OF REGULATIONS.

All dams within the State of Arkansas, except those owned by the United State Government or those exempted by Section 701.4, must have a valid construction and operation permit issued under the provisions of this title.

Section 701.4. EXEMPTIONS.

Dams meeting either of the following criteria are not subject to rules contained in this title, unless Section 701.5 of this title is successfully invoked.

A. Dams with height less than 25 feet.

B. Dams with normal storage less than 50 acre-feet.

C. Dams with crest elevations below the ordinary high water mark of the stream at that location.

Section 701.5. PETITION BY AFFECTED PERSONS.

Persons who believe themselves or their property to be endangered by failure of a dam which is below the size requirements specified in Section 701.4 may file a petition requesting that the Commission require permitting and compliance with dam safety regulations for that dam.

A. Commission Investigation.Upon receipt of such petition, the Executive Director shall immediately begin an investigation of the petitioner's allegations.

B. Public Hearing.As a part of the Commission's investigation, a Public Hearing shall be held within the county in which the dam is located. Notice of the hearing shall be published in a manner consistent with Section 702.8.

C. Commission Order. Upon consideration of staff findings and testimony received, the Commission shall issue an order either approving or denying the petitioner's request.

Section 701.6. DUTIES, OBLIGATIONS, AND LIABILITIES OF DAM OWNERS.

Nothing in these rules shall be construed to relieve an owner or operator of a dam or reservoir of the legal duties, obligations, or liabilities incident to ownership or operation.

Section 701.7. NO LIABILITY BY COMMISSION, EMPLOYEES, OR AGENTS.

No action shall be brought against the State or the Commission or its employees or agents for the recovery of damages caused by the partial or total failure of any dam or reservoir or through the operation of any dam or reservoir upon the grounds that the aforementioned parties are liable by virtue of any of the following:

A. The approval of the dam or reservoir, or approval of flood-handling plans during construction;

B. The issuance or enforcement of orders relative to maintenance and operation of the dam or reservoir;

C. Inspection, control and regulation of the dam or reservoir;

D. Measures taken to protect against failure during an emergency.

Section 701.8. EXCEPTIONS.

The Commission may grant exceptions to requirements contained within this title. Any variance from these rules must be supported by written approval of the Commission's Executive Director setting forth the reason for its granting and the limits placed thereon.

SUBTITLE II. PERMITS FOR DAMS

Section 702.1. CONSTRUCTION PERMIT.

A permit issued by the Commission is required prior to construction of any dam not exempted under Sections 701.3 or 701.4 of this title.

Section 702.2. OPERATION PERMIT.

A. Before water is deliberately impounded by closing drain gates on a newly constructed dam, an operation permit must be issued by the Commission. An operation permit will be issued by the Chief Engineer upon completion of final inspection and receipt of the Certificate of Substantial Compliance by the owner's engineer. (See Section 706.6).

B. An operation permit is required for all existing dams not exempted under Sections 701.3 or 701.4 of this title.

Section 702.3. TRANSFER OF PERMIT.
Within six (6) months after change of ownership of a permitted dam, the new owner shall notify the Commission. The Commission shall issue a dam permit in the name of the new owner.

Section 702.4. WATER PLAN COMPLIANCE.
Filing of an application to permit a proposed dam also serves as filing for Water Plan Compliance Certification as described in Section 602.5 of the Commission's rules. The water plan compliance process may run concurrently with the dam permit review.

Section 702.5. APPLICATION.
Applicants for dam permits must provide all applicable information requested on the form supplied by the Commission.

Section 702.6. COMMISSION REVIEW.
Upon receipt of application for dam permit, the Commission staff will review data presented to determine compliance with State law, Commission rules, and accepted engineering practices. If necessary, the staff may request additional data to insure compliance.

Section 702.7. PUBLIC NOTICE.
Upon completion of Commission review, the Executive Director will cause a Public Notice to be published two times, one week apart. The Public Notice will be placed in a newspaper having general circulation in the county in which the dam is/will be located. Information in the public notice will include: the owner's name and address, the dam's location and pertinent physical data describing the dam. In addition, the Public Notice will request that questions, comments and objections to the dam's permitting and/or requests for public hearing be forwarded in writing to the Commission for action within twenty (20) days after the second publication.

Section 702.8. PUBLIC HEARING.
If requested, the Executive Director shall cause a Public Hearing to be conducted within the county in which the dam is/will be located. Said hearing will be for the purpose of describing the proposed actions and taking testimony regarding the public view of the proposal. The Executive Director shall cause publication of a public notice describing the time, place and purpose of the Public Hearing. Copies of the public notice shall be furnished to the owner(s), complainant(s) and adjacent landowners (if known). Publication shall be in a newspaper having general circulation in the county in which the dam is/will be located. Notice shall be published twice, one week apart.

Section 702.9. COMMISSION ACTION.

A. If no Public Hearing is requested as a result of the Public Notice, the Executive Director will either approve or deny the permit request.

B. If a Public Hearing is requested as a result of the Public Notice, the Executive Director will approve or deny the permit request based upon the evidence presented.

C. Prior to issuance of the permit, a Water Plan Compliance Certification must be obtained as prescribed in Title VI of the Commission's rules, if applicable.

SUBTITLE III. FEES

Section 703.1. ESTIMATED APPLICATION REVIEW FEES.
Any application for permitting a proposed dam after March 24, 1993, shall be accompanied by a check for one percent (1%) of the estimated construction cost of the dam or $100.00, whichever is greater, except that no application review fee shall exceed $1000.00.

Section 703.2. FINAL COST REPORT.
The owner shall provide to the Commission a report of actual construction costs within forty-five (45) days after completion of construction.

Section 703.3. FINAL APPLICATION REVIEW FEES.

A. If the estimated application review fee exceeds the fee based on actual construction cost, an amount equal to the difference will be refunded.

B. If the fee based on construction cost exceeds the estimated application review fee, an amount equal to the difference will be paid to the Commission.

Section 703.4. ANNUAL PERMIT FEE.
The annual permit fee shall be computed as specified in Ark. Code Ann. §15-22-219, as may be amended from time to time.

Excerpt from Ark. Code Ann. §15-22-219:

> *Any person obtaining a permit under the provisions of §15-22-210 shall, in consideration therefor, pay to the Commission a fee equal to twelve cents (12¢ per acre-foot of water which the dam involved is designed to impound, but not less than twenty-five dollars ($25.00), nor more than ten thousand dollars ($10,000.00). The permit shall provide that the same fee shall be paid by that person to the Commission each year thereafter during which the dam is*

maintained, on or before the anniversary date of the issuance of the permit.

The volume "the dam involved is designed to impound" is defined as the billing volume. (See Subtitle XII, GLOSSARY)

SUBTITLE IV. ENFORCEMENT

Section 704.1. NOTICE OF NON-EMERGENCY DEFICIENCY.
Upon discovery of a deficiency, which does not immediately threaten the dam's safety, the Chief Engineer will issue a letter specifying actions necessary to remedy the problem and requesting a schedule for implementing the required actions. Based on mutual agreement a consent order will be issued which will embody the agreed upon actions and timetable.

Section 704.2. PUBLIC HEARINGS.
In the event remedial measures for non-emergency deficiencies cannot be accomplished through the means of consent orders, the Executive Director shall cause a Public Hearing to be conducted to present the staff's proposed order and accept testimony. The hearing shall be conducted in the county in which the dam is located. Public notice of the hearing shall be provided in a manner consistent with Section 702.8 of this title.

Section 704.3. COMMISSION ORDERS.
After review of findings of the Public Hearing, the Commission may issue orders compelling specified actions.

Section 704.4. PENALTIES.
Non-compliance with commission rules or disregard of Commission orders may result in fines of up to $10,000. In general, penalties will be set by doubling the costs incurred by the Commission.

Section 704.5. EMERGENCY REMEDIAL ORDERS.
Upon discovery of a condition which renders a dam subject to rapid failure, the Executive Director may issue an Emergency Remedial Order describing actions which must be taken to protect life and property. Failure to comply with these orders may result in penalties under Section 704.4.

Section 704.6. APPEALS.
Actions by the Commission may be appealed as described in Subtitle V of Title I, *rules of Organization and General Operation of the Arkansas Soil and Water Conservation Commission.*

SUBTITLE V. DESIGN CRITERIA

Section 705.1. GENERAL STANDARDS. All dams must be designed in accordance with currently accepted engineering practices. Acceptable guidelines include those published and recommended by the U.S. Army Corps of Engineers; U.S. Department of Agriculture, Soil Conservation Service; U.S. Department of Interior, bureau of Reclamation; and Federal Energy Regulatory Commission.

Section 705.2. REGISTERED PROFESSIONAL ENGINEER. Preparation of all plans and specifications, and the construction, enlargement alteration, repair or removal of dams subject to Commission review shall be under the supervision of an engineer registered in this state.

Section 705.3. SIZE CLASSIFICATION CRITERIA. Size classification is based on the more stringent of two categories, either height of dam or maximum storage, and shall be in accordance with Table 1 of this section.

Table 1

SIZE CLASSIFICATION

SIZE	MAXIMUM STORAGE (ACRE-FEET)	HEIGHT (FEET)
Small	50 to 1000	25 to 40
Intermediate	• 1000 And < 50,000	•40 and < 100
Large	• 50,000	• 100

Section 705.4. HAZARD CLASSIFICATION CRITERIA. All dams will be classified or reclassified as required to assure appropriate safety considerations. Hazard classification shall be based on the more stringent of either potential loss of human life or economic loss in accordance with Table 2 of this section. If doubt exists concerning classification, the more hazardous category must be selected.

NOTE: The hazard classification does not indicate the physical condition of a dam.

Table 2

HAZARD CLASSIFICATION

CATEGORY	LOSS OF HUMAN LIFE	ECONOMIC LOSS
Low	No	Minimal (No significant structures; pastures, woodland, or largely undeveloped land); less than $100,000.
Significant	No	Appreciable (Significant structures, industrial, or commercial development, or cropland); $100,000 to $500,000.
High	Yes	Excessive (Extensive public, industrial, commercial, or agricultural development); over $500,000.

NOTE: Loss of human life is based upon presence of habitable structures.

<u>Section 705.5. SPILLWAY DESIGN FLOOD (SDF) FOR DAMS</u>. The size and hazard classifications are combined to determine the hydrologic criteria for dams.

A. The minimum acceptable spillway design floods (SDFs) for dams are shown in Table 3.

B. The minimum hydrologic criteria may be reduced if properly prepared dam breach analyses show that dam failure during the SDF would cause an increase in flood level of one foot or less at, and downstream of, the first habitable structure or financially significant development.

Table 3

SPILLWAY DESIGN FLOOD FOR DAMS

HAZARD CLASSIFICATION	SIZE	SPILLWAY DESIGN FLOOD
Low	Small	.25 PMF
	Intermediate	.25 to .50 PMF
	* Large	.50 to .75 PMF
Significant	Small	.25 to .50 PMF
	Intermediate	.50 to PMF
	Large	PMF
High	Small	.50 PMF to PMF
	Intermediate	PMF
	Large	PMF

NOTE: Where ranges are given in this table, the spillway design flood shall be determined by straight line interpolation, based upon the effective height of dam or maximum storage, whichever computed SDF is greater.

*SDF shall be extrapolated at the same rate of change as an intermediate size dam to a maximum of .75 PMF.

Section 705.6. DOWNSTREAM RELEASES.
Each dam constructed after the effective date of these regulations shall be equipped with a release port(s) designed to release a flow of water for instream and downstream riparian uses.

A. Minimum release quantities shall be sufficient to maintain existing instream and offstream uses and shall be defined after consideration of the best available low flow information.

B. Minimum release ports must be designed to operate without manual intervention.

Section 705.7. RESERVOIR DRAIN CONDUIT.
All proposed dams must include a permanent facility for draining the reservoir.

A. Such conduit shall have a minimum diameter of twelve (12) inches for watershed areas less than one square mile and eighteen (18) inches for watershed greater than one square mile. Such conduits must be capable of lowering the surface of the reservoir at a rate not less than two (2) inches per day (at normal pool) while inflow to the reservoir is twice the annual average daily flow.

B. Operating equipment for the drain facility must be accessible from above the maximum design water surface, unless inlet design is such that the conduit is flowing at capacity at a lower elevation.

Section 705.8. STRUCTURAL CRITERIA.
As a minimum, the design must address the following:

A. Slope stability under all probable loading conditions.
B. Stability against sliding and overturning.
C. Adequacy of foundation for imposed loads.
D. Adequacy of energy dissipating devices at discharge points.
E. Adequacy of channels and conduits for expected flows.
F. Protection of embankments and other earth slopes from erosion.
G. Stability against seismic forces for all “High or Significant Hazard” dams in Seismic Zones 2 and 3. (See Figure 1.)

SUBTITLE VI. CONSTRUCTION REQUIREMENTS

Section 706.1. PLANS AND SPECIFICATIONS.
Written approval of plans and specifications must be obtained from the Chief Engineer prior to start of construction.

Section 706.2. CONSTRUCTION INSPECTIONS.
An agent of the design registered professional engineer must be on site during construction to ensure that techniques and materials used comply with plans and specifications.

Section 706.3. CONSTRUCTION RECORDS.
The applicant (or applicant’s engineer) must retain construction records throughout the life of the dam. As a minimum, the records must include:

A. Daily log of construction activities.
B. Record of personnel and equipment on site.
C. Documentation of soil tests such as standard proctor, in-place density, and moisture.
D. Documentation of concrete cylinder tests.
E. Copies of all engineering change orders and field change notes.

Section 706.4. EROSION PROTECTION
During construction, adequate measures must be taken to prevent excessive erosion and off site sedimentation. Suitable

techniques include: temporary vegetation, mulching, staked straw bales, filter fences, and chemical stabilization. Other techniques may be sued is approved by the Chief Engineer.

Section 706.5. FINAL INSPECTION.
Upon substantial completion of construction, the owner must notify the Commission and schedule a final inspection of the work.

Section 706.6. ENGINEER'S CERTIFICATION.
Upon completion of construction, the project engineer shall file with the Commission a certificate of substantial compliance with approved plans and specifications.

Section 706.7. RECORD DRAWINGS.
Within sixty (60) days after completion of construction, the owner, or his engineer, shall submit to the Chief Engineer a complete set of record drawings of the project for filing as a permanent record with the Commission.

Section 706.8. PERMANENT REFERENCE MARKS.
Two or more permanent reference marks shall be established for future use near but not on the dam. Accurate longitude, latitude and elevation shall be shown on the record drawings. Elevations shall be referenced to the National Geodetic Vertical Datum of 1929.

SUBTITLE VII. EVALUATIONS OF EXISTING DAMS

Section 707.1. TYPES OF EVALUATIONS.

A. Spillway Design Flood. Existing dams will be evaluated periodically to determine if development of downstream areas warrants change in hazard classification and review of spillway design flood (SDF). Overtopping during the SDF may be allowed if properly prepared analyses demonstrate that: (1) overtopping will have a return interval greater than 25 years; and (2) the dam will withstand the projected overtopping without failure.

B. Structural. A complete evaluation of the structural integrity may include the following: geotechnical investigation, structural stability, seismic resistance, horizontal and vertical alignments, structural concrete reliability, erosion controls, inlet and outlet works, stilling basins, seepage, and others.

C. Operation and Maintenance. Evaluation of an existing structure shall include, but not be limited to: visual inspections and evaluations of potential problems such as leakage, seepage, cracks, slides, settlement, spillway blockages, conduit controls and other operational and maintenance deficiencies which could lead to failure of the dam. There may be sufficient evidence for a finding that an existing dam is inadequate.

Section 707.2. DEFICIENCIES.
Dams not meeting minimum acceptable standards (See Subtitle V and VIII) are deemed inadequate and therefore subject to necessary action under Subtitle IV.

Section 707.3. INTERIM ALTERNATIVES.
When the Commission considers the permanent upgrading or removal of an inadequate dam, the dam owner may request the Commission to consider interim alternatives including, but not limited to, temporary repairs, reservoir dewatering, insurance coverage, and downstream warning/evacuation plans. Consideration shall be given to the time required to overcome economic, physical and legal restraints to upgrading, the prospect of permanent repair, current use of the facility, degree of risk, and public welfare.

Section 707.4. VARIANCE.
Upon request by the owner of an existing dam which does not meet the minimum acceptable standards stated in Subtitles V and VIII of this title, the Chief engineer may authorize a variance from this criteria. The Chief Engineer’s decision shall consider: (a) consequences of dam failure, (b) the owner’s proposal for reduction of hazards, (c) barriers to upgrading of the structure, and (d) other pertinent factors.

SUBTITLE VIII. OPERATION AND MAINTENANCE

Section 708.1. COMPLIANCE WITH APPROVED DOCUMENTS.
Operation and maintenance must be performed in accord with documents filed by the owner or owner’s engineer in obtaining the dam permit.

Section 708.2. EROSION PROTECTION.
Maintenance of adequate means to protect embankments, abutments, crests, and earthen channels from erosion is required.

Section 708.3. WOODY VEGETATION PROHIBITED: EMBANKMENT DAMS.
Growth of woody vegetation is not permitted on the spillway, crest, upstream or downstream embankments, and within twenty (20) feet of the downstream toe or groin of the dam.

A. Remediation: Trees with roots likely to extend to the crest of the dam shall be removed. Trees whose roots are unlikely to extend to the crest may remain if erosion control vegetation can be maintained and inspections can be accomplished. Trees larger than six (6) inches in diameter which are to be removed from embankments, must be removed together with roots larger than two inches. The resulting voids shall be repaired with compacted soil similar to the remaining embankment material. Smaller trees and brush, and those not on embankments may be cut and/or treated with herbicide.

B. Time for compliance: New growth must be removed before it shades out desirable vegetation generally on a two-year cycle. Where extensive tree and brush growth were established prior to adoption of these rules, a compliance schedule of up to five years may be approved provided that: (a) No evidence of significant immediate hazard is detected; (b) The compliance schedule includes a reasonable estimate for costs, and a rational procedure for accumulating necessary funds; (c) Vegetation is not so dense that effective inspections are impossible; and (d) Appropriate annual efforts are scheduled. The long-term schedule may be cancelled if evidence of immediate hazards is discovered in subsequent inspections.

Section 708.4. WOODY VEGETATION PROHIBITED; CONCRETE OR MASONRY DAMS.

No grass, vines, brush, trees or other vegetation is permitted to grow in cracks or joint of concrete or masonry structures.

A. Remediation: Vegetation shall be removed by manual, mechanical or chemical means or a combination thereof. Open cracks or joints shall be repaired by approved means.

C. Time for compliance: In the absence of conditions indicating immediate hazards, a schedule resulting in complete compliance within six months may be approved.

Section 708.5. OPERATION OF GATES AND CONTROLS.

All gates, valves and controls, must be maintained in operational condition. Operation of each such item must be tested at least annually, and such tests must be documented in the owner's permanent records. However, tests may be waived by the Chief Engineer if the design of drainage facilities and/or their condition is such that reclosing the drain would be impossible until the reservoir was substantially emptied.

Section 708.6. REPAIRS AND MODIFICATIONS.

Written approval by the Chief Engineer is required before repairs or modifications to a dam or appurtenances may be undertaken. Plans and specifications prepared by a registered professional engineer may be required for major actions.

Section 708.7. RECORDS.

Documentation of all owner's inspections, and repairs or modifications to the dam or appurtenances must be retained by the owner.

SUBTITLE IX. INSPECTION

Section 709.1. OWNER INSPECTIONS.

At least once per year and after each major storm event, the owner (or owner's agent) of all permitted dams must perform a visual inspection of the dam. Results of such inspections must be summarized on forms supplied by the Commission and mailed to the Commission office within 10 days of inspection. Commission staff may provide training or assistance in performing or interpreting inspections. Any deterioration of the dam or appurtenances must be reported to the Commission, and remedial measures undertaken after approval by the Chief Engineer.

Section 709.2. COMMISSION INSPECTIONS.

Commission personnel will periodically perform inspections of each permitted dam. Commission inspections are of three types: Maintenance and Operation; Dam Safety Evaluation; and Emergency. The frequency of inspections and evaluations will vary according to the hazard rating, size and condition of the dam. Emergency inspections will be performed when conditions warrant.

Section 709.3. ACCESS.

The owner or owner's agent must provide Commission personnel access to the dam during reasonable working hours for Commission inspections. Access during emergency conditions must be available to Commission personnel.

Section 709.4. ASSISTANCE BY OWNER.

The owner or owner's agent may be requested to provide limited assistance to Commission personnel in performing inspections. Requested assistance may include:

A. Operating gates, valves, and other controls.
B. Cutting excessive vegetation in preparation for inspections.

SUBTITLE X. EMERGENCY ACTION PLANS

Section 710.1. EMERGENCY ACTION PLANS REQUIRED.

An emergency action plan (EAP) must be prepared by the owner for all permitted high hazard dams.

Section 710.2. APPROVAL OF EMERGENCY ACTION PLANS REQUIRED.

Written approval of the Chief Engineer must be obtained for all EAPs.

Section 710.3. CONTENTS OF EMERGENCY ACTION PLANS.

Site conditions will dictate exact contents of specific EAPs. Guidelines for preparation of EAPs are available from the Commission.

Section 710.4. ANNUAL EXERCISES AND DRILLS.

Implementation of EAPs must include at least one tabletop exercise per year and one test drill every three years. The Commission's Chief Engineer must be notified at least one week in advance of either procedure.

SUBTITLE XI. REMOVAL OF DAMS

Section 711.1. APPROVAL OF PLANS REQUIRED.
Prior to removal, a plan for removal and revegetation must be approved by the Chief Engineer.

Section 711.2. NOTICE TO DOWNSTREAM LANDOWNERS.
Downstream landowners must be notified of the proposed action if any measure of flood protection would be lost due to the removal of the dam.

Section 711.3. RIGHTS OF OTHER LANDOWNERS.
Downstream landowners and those adjacent to the reservoir have the right to notice of projected changes in streamflow patterns or reservoir levels, but do not have the right to continued benefits at the dam owner's expense, unless the dam owner is contractually bound to provide such benefits.

Section 711.4. PROCEDURE FOR BREACHING.
The procedure for breaching must adequately guard against downstream flooding, erosion, and sedimentation.

Section 711.5. RESTORATION OF ORIGINAL STREAM CHANNEL.
Dimensions of the final cut through the dam must be defined in the plan and must be of sufficient size to prevent impounding water when streamflow equals the 100-year flood.

Section 711.6. EROSION PROTECTION.
The plan must provide for establishment of vegetation or other erosion protection measures sufficient to guard against deposition of excessive sediment off site.

SUBTITLE XII. GLOSSARY

Unless clearly indicated by context, the following words and terms, when used in this title, shall have meanings as defined below:

A. Billing volume – Normal storage designed to contain sediment accumulation over the life of the dam.
B. Chief Engineer – The Deputy Director/Chief Engineer of the Arkansas Soil and Water Conservation Commission.
C. Commission – The Arkansas Soil and Water Conservation Commission.

D. Construction costs – Estimated or actual material and labor costs, including excavation, embankment placement, spillways, gates, valves, and conduits. Shall not include costs of: land, reservoir clearing, engineering, water treatment facilities, or other costs not directly related to construction of the dam.

E. Dam – Any barrier, including one for flood detention, designed to impound liquid volumes. This shall not include highway, railroad or other roadway embankments, including low water crossings that may temporarily detain floodwater, levees designed to prevent inundation by floodwater, or closed dikes to temporarily impound liquids in the event of emergencies and those barriers not exempt by Sections 701.3 or 701.4 of this title.

F. Effective crest of the dam – The elevation of the lowest pint on the crest of the dam excluding spillways.

G. Executive Director – The Executive Director of the Arkansas Soil and Water Conservation Commission.

H. Height of dam – The vertical distance from the effective crest of the dam to the lowest elevation on the downstream toe of the dam.

I. Maximum storage – The volume of the impoundment created by the dam at the effective crest of the dam.

J. Minimum release – Daily quantity of water which must be released to preserve downstream riparian rights, permitted non-riparian rights or to meet instream water needs including, but not limited to those of fish and wildlife.

K. Normal storage – The volume of the impoundment created by the dam at the lowest uncontrolled spillway crest.

L. PMF (probable maximum flood) – The maximum runoff condition resulting from the most severe combination of hydrologic and meteorologic conditions that are reasonably possible for a given watershed. The PMF is the maximum runoff computed from the spatial and temporal distribution of the PMP over the watershed.

M. PMP (probable maximum precipitation) – The greatest theoretical depth of precipitation (rainfall equivalent) for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year.

N. Spillway design flood (SDF) – The largest flood the spillway must pass without overtopping a dam.

APPENDIX 4

DAM PERMIT AND TRANSFER OF OWNERSHIP FORMS

ARKANSAS SOIL AND WATER CONSERVATION COMMISSION
APPLICATION FOR DAM PERMIT

☐ PROPOSED DAM
☐ EXISTING DAM DATE BUILT: ____________________

______________________________	______________________________
Owner Name	Alternative Contract
______________________________	______________________________
Address: Street	Address: Street
______________________________	______________________________
City, State, Zip	City , State, Zip
Home Phone: ( ) ______________	Home Phone: ( ) ______________
Office Phone: ( ) ______________	Office Phone: ( ) ______________

Name of Dam: ____

Name of Reservoir: ____

Location of Dam
(center of dam crest at center of stream)

______________________________	______________________________
County:	Latitude (D.M.S.):
______________________________	______________________________
¼, ¼, (Section, Township, Range):	Longitude (D.M.S.)

Name of U.S.G.S. Quadrangle Map: ____

The stream on which the dam is to be constructed: ______________________________

a tributary of ______________________ ,within the ____________________ river basin.

Reservoir Volume – Area – Elevation

	Volume (Ac-ft)	Area (Acres)	Elevation (feet)
Original Streambed at toe of dam……………………………………………………...			__________
Sediment Pool ………………………..…	__________	__________	__________
Normal Storage ………………………	__________	__________	__________
Emergency Spillway Crest …………..	__________	__________	__________
Maximum Design Storage …………...	__________	__________	__________
Effective Crest of Dam ………………	__________	__________	__________

Maximum Emergency Spillway Discharge: ____________________ (cfs)

Length of Dam: ______________ft. (Along centerline of crest, include spillways if integral to dam.)

Height of Dam: ______________ft. (Vertical distance from original streambed at toe of dam to lowest point on crest of dam excluding spillways.)

Structural Height of Dam: ______________ ft. (Vertical distance from lowest point of excavated foundation to lowest point on crest.)

Hydraulic Height: ______________ft. (Vertical distance from lowest point in original streambed at toe of dam to maximum design water level.)

Watershed Area: ______________square miles.

Indicate the major purpose(s), in approximate percentage(s), to be made of the storage volume:

(a) Municipal . . . . . . ________ %	(h) Hydroelectric . . . . ________ %
(b) Industrial . . . . . . ________ %	(i) Flood Control/Storm Water Mgmt ________ %
(c) Irrigation . . . . . . ________ %	(j) Navigation . . . . ________ %
(d) Aquaculture . . . . ________ %	(k) Fire Protection . . . . ________ %
(e) Recreation . . . . . ________ %	(l) Debris Control . . . . ________ %
(f) Livestock . . . . . . ________ %	(m) Tailings . . . . ________ %
(g) Fish & Wildlife. ________ %	(n) Other . . . . ________ %

Estimated amount of water to be withdrawn per year: ________________________(acre-feet).

Maximum withdrawl rate: ______________ (gpm).

Plans Developed by:

______________________________ Company Name	______________________________ Registered Professional Engineer ________ Reg. No.
______________________________ Address: (Street)	Office Phone: ( ) ______________________
	Home Phone: ( ) ______________________
______________________________ (City, State, Zip)	Telefax: ( ) ______________________

REQUIRED ENCLOSURES

1. Preliminary plans which have been prepared by a Registered Professional Engineer or and authorized agent of the United States Government. Plans must include U.S.G.S. Quadrangle or County Maps or drawings showing:

   A. Exact location of the structure
   B. Outline of impounded water
   C. Outline of watershed
   D. Access roads to all major facilities
   E. Property lines
   F. Utility lines
   G. Cross section of dam at deepest section
   H. Location, elevation, and size of spillways
   I. Elevation-volume relationship
   J. Elevation-discharge relationships

2. Description of watershed including land use, soil types, slopes, and ground cover.
3. Description of downstream area subject to damage in the event of a dam failure. Include:
   A. Name of nearest affected city/town downstream and distance from the dam along the stream.
   B. Number and types of buildings and their distance from the dam.
   C. If homes may be affected, number of persons involved.
   D. Description of roads or utilities affected.
   E. Distance from dam to downstream property line along the stream.
4. Describe arrangements for access to dam for inspection, during and after construction.
5. Proposed construction schedule.

The applicant certifies and/or agrees to the following:

All information presented in this application is correct and accurate.

The applicant agrees to comply with state law and commission regulations governing design, construction, operation and maintenance of dams. In addition, the applicant understands that failure to comply with applicable laws and regulations may result in cancellation of dam permit and assessment of fines not to exceed $10,000.

That prior to construction, the applicant will obtain all land rights or easements necessary for the construction and operation of the above described structure.

Construction shall not begin until final plans and specifications have been reviewed and approved by the Commission's Chief Engineer.

Construction and operation shall be in accordance with maps, plans, specifications filed and approved by the Commission.

Water shall not be deliberately impounded by closing of gates until issuance of an operation permit by the Commission's Chief Engineer.

Representatives of the Commission shall have the right, at any reasonable time, to enter upon the land where the dam is located to inspect the work of construction thereof or the operation and maintenance after construction.

An estimated review fee of one percent (1%) of the estimated cost of construction, (but not less than $100 nor more than $1,000) must accompany this application. (No review fee is required for existing dams);

The estimated cost of construction, excluding land, engineering, and legal fees is: $ ___________________

A check in the amount of $ _______________ and payable to the Arkansas Soil and Water Conservation Commission is enclosed;

Upon permit issuance, the applicant shall pay annually to the Commission a fee of twe1ve cents ($0.12) per acre-foot of water impounded at normal pool, excluding storage designated for sediment accumulation over the life of the project, but not less than twenty-five dollars ($25.00) nor more than ten thousand dollars ($10,000).

Nothing in the permit shall be construed to impose liability on the State, the Commission, or its agents or employees for partial or total failure of this dam and reservoir.

____________________________________ ____________________________________
Signature of Applicant/Agent Typed or printed name

State of ______________________, County of _________________________

Subscribed and sworn to before me this _________ day of_____________, 19____, at my office in

____________________________________ ____________________________________
Office Location Notary Public

My Commission expires:_____________________

ARKANSAS SOIL AND WATER CONSERVATION COMMISSION
101 EAST CAPITOL, SUITE 350
LITTLE ROCK, ARKANSAS 72201
(501) 682-1611

APPLICATION FOR TRANSFER OF DAM PERMIT NUMBER ______________

1. PERMIT IS PRESENTLY ISSUED TO:

   Name: ____
   Address: ____

2. PERMIT TO BE REISSUED TO:

   Name: _________________________________ SS# or Fed EI#______________
   Address: ______________________________ City: ______________________
   State: ____________ Zip: _____________ Phone: _____________________
   Alternative Contact Person & Phone Number: _____________________________
   ____

3. DAM NAME: ____

4. LOCATION OF STRUCTURE: ____¼, ____¼, SEC. ____,Twp. _____, Rge. _____
   County:_________________________. The stream on which the structure is constructed is __________________________, a tributary of _______________ __________________________, within the ______________________________ river basin.

5. Major uses to be made of reservoir water in approximate percentages:

(a) Municipal ______%	(f) Industrial ________ %	(k) Irrigation _________%
(b) Aquaculture _____%	(g) Livestock ________ %	(l) Domestic _________%
(c) Fish/Wildlife _____%	(h) Hydroelectric _______ %	(m) Flood Control _____ %
(d) Navigation ______%	(i) Fire Protection _____ %	(n) Debris Control _____%
(e) Tailings _________ %	(j) Other______________ %	

6. Estimate the amount of water to be withdrawn per year: _____________________ (acre-feet)

   Maximum withdrawal rate:_______________ (cfs)

(over)

7. The undersigned hereby certifies and/or agrees to the following:

That the undersigned either owns or has the right to occupy all lands necessary for the operation of the above described structure; and agrees to abide by the Rules Governing Design and Operation of Dams in Arkansas, and that failure to comply with these Rules may result in permit cancellation and fines of up to $10,000.00, per violation.

That no changes in design or operation of the dam or reservoir shall be made prior to having the proposed changes reviewed and approved by the Commission.

That within thirty (30) days after completion of any changes to the dam, the undersigned shall file with the Commission a statement certifying that the work has been performed in accordance with the plan approved by the Commission.

That any representative of the Commission shall have the right, at any reasonable time, to enter upon the land where the dam is built to inspect its operation and maintenance.

That upon permit issuance the undersigned shall pay annually to the Commission a fee of 12 cents per acre-foot of water impounded, at normal pool, but not less than $25.00, nor more than $10,000.00.

That the undersigned shall assume the legal duties, and liabilities incident to the ownership of said dam and reservoir.

That neither the State or its agents, nor the Commission or its employees, shall be held liable for partial or total failure of the dam.

________________________________	____________________________________
Applicant's Signature	Applicant's typed or printed name

Subscribed and sworn to before me this __________ day of _____________________ ,

_________ , at my office in____________________________, Arkansas.

My Commission Expires: ____________________

____

Notary Public

APPENDIX 5

SOURCES OF INFORMATION AND ASSISTANCE

SOURCES OF INFORMATION FOR DAM OWNERS

1. Arkansas Soil and Water Conservation Commission
   101 E. Capitol, Suite 350
   Little Rock, AR 72201
   (501) 682-3936

   The State agency responsible for dam safety.
   http://www.accessarkansas.org/aswcc

2. Natural Resources Conservation Service (NRCS)
   Room 3416, Federal Building
   Little Rock, AR 72201
   (501) 301-3100

   Each county is also served by a local Conservation District and NRCS office. The NRCS can provide techinical assistance regarding small earthen dams.
   http://www.ar.nrcs.usda.gov/

3. Arkansas Highway and Transportation Department
   P.O. Box 2261
   Little Rock, AR 72203
   or
   10324 Interstate 30
   Little Rock AR 72209
   (501) 569-2000

   There are also local highway department districts. The highway department has manuals which provide information on seeding embankments.
   http://www.ahtd.state.ar.us/

4. Arkansas Department of Emergency Management
   P.O. Box 758
   Conway, AR 72033
   (501) 730-9750

   There are 77 local emergency manangement offices, one for each county plus Little Rock and North Little Rock. Emergency managers can assist in developing and implementing emergency action plans.
   http://www.adem.state.ar.us/