

U.S. Fish & Wildlife Service Low Hazard Dams

S O P

**Standing
Operating
Procedures**



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SOP

STANDING OPERATING PROCEDURES

All USFWS Refuges

UNITED STATES DEPARTMENT OF THE INTERIOR
FISH & WILDLIFE SERVICE
All REGIONS



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Key references that were utilized in the preparation of this document include:

FEMA Publication – Technical Manual: Conduits through Embankment Dams

FEMA Publication - Technical Manual for Dam Owners – Impacts of Plants on Earthen Dams

FEMA Publication - Technical Manual for Dam Owners – Impacts of Animals on Earthen Dams

U.S. Army Corps of Engineers - Levee Owner's Manual for Non-Federal Flood Control Works

North Carolina Department of Environmental and Natural Resources - Dam Operation, Maintenance, and Inspection Manual

Texas Commission on Environmental Quality - Guidelines for Operation and Maintenance of Dams in Texas

U.S. Army Corps of Engineers - Susquehanna River Basin, Hornell, New York, Local Flood-Protection Project:

Operation and Maintenance Manual



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APPENDICES

- Appendix A: Glossary
- Appendix B: Dam Problems, Causes and Recommendations
- Appendix C: Operations Log and Inspection Checklist
- Appendix D: Instrument Monitoring Data Forms
- Appendix E: FEMA Technical Manual for Dam Owners - Impacts of Animals on Earthen Dams – SEE ASDSO OWNER WEBPAGE
- Appendix F: FWS Tree Removal Guidelines
FEMA Technical Manual for Dam Owners - Impacts of Plants on Earthen Dams – SEE ASDSO OWNER WEBPAGE
- Appendix G: Paper On Installing Temporary Siphon(s) to Drain Reservoir
- Appendix H: Fish & Wildlife Service –Definitions, Standards, and Guidelines
- Appendix I: Plans – FWS SITE SPECIFIC - NOT INCLUDED
- Appendix J: Manufacturer Manuals – FWS SITE SPECIFIC - NOT INCLUDED
- Appendix K: Hydrology & Hydraulics – FWS SITE SPECIFIC - NOT INCLUDED



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CHAPTER 1

BACKGROUND

1.1 Introduction

The purpose of this Standing Operating Procedures (SOP) is to furnish a comprehensive, single source document that provides accurate and current instructions, procedures and other information for the normal operation, maintenance, monitoring and inspection of U.S. Fish and Wildlife Service (FWS) low hazard inventory dams. This manual also includes guidance, information and procedures for addressing unusual events and emergency conditions that could be employed to prevent a dam failure or minimize the effects of a dam failure.

1.2 Typical Dam Features

A dam is an artificial barrier constructed on natural terrain in order to control, store, or divert water. Dams are classified according to their size, type of construction materials used, structure, function, and the consequences of their failure. For example, Hoover Dam is a large, high hazard, conventional concrete gravity dam constructed to provide hydropower. It is a high hazard structure because failure of the dam would likely cause loss of human life and significant property damage. Approximately 80-percent of the over 200 dams owned and maintained by the USFWS are small, low hazard, earth embankment dams constructed to create habitat for wildlife. They are low-hazard because their failure would cause little damage beyond the loss of the dam structure itself.

The most common dam types are earth embankment dams and concrete dams. Other dam types include timber crib, rock fill, masonry, inflatable rubber, and steel dams. Since most of the USFWS dams consist of small embankment dams with several concrete dams, only these types of dams are addressed herein. Figures 1-1 and 1-2 provide typical schematic illustrations for both embankment dams and concrete gravity dams, respectively.

The basic features common to most dams are illustrated in Figure 1-1, and include the dam structure, service or principal spillway(s), emergency spillway, and outlet works. A glossary of common terms used to describe dam features is provided in Appendix A. A brief discussion of basic dam features is provided below.

1.2.1 Embankment Dams

Most embankment dams have the general configuration shown in Figure 1-1. The upstream and downstream slopes of embankment dams are typically 2H:1V (horizontal to vertical) or flatter. Their capacity for water retention is due to the low permeability of the entire mass (in the case of a homogeneous embankment) or of a zone of low-permeability material (in the case of a zoned embankment dam).

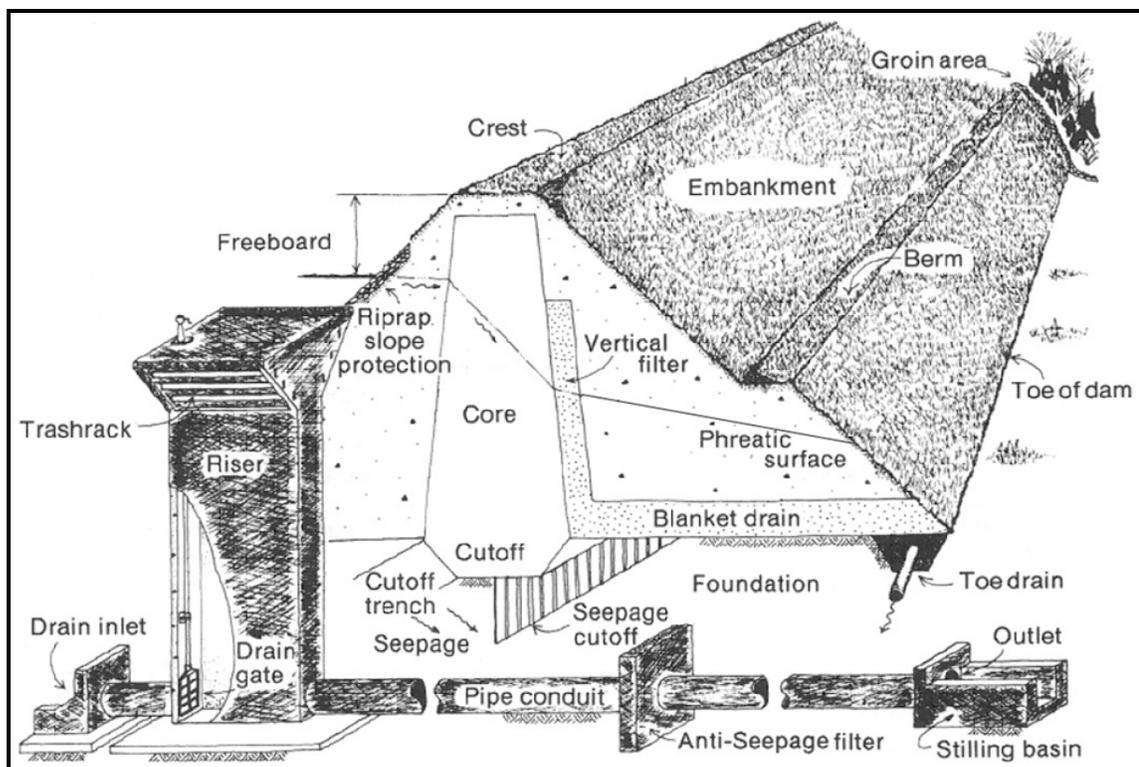


Figure 1-1: Typical Features of an Embankment Dam
(see glossary in Appendix A for term definitions)

Materials used to construct embankment dams include natural soil or rock obtained from borrow areas or nearby quarries. If the natural material has a high permeability, then a zone of very low permeability or impervious material is normally included in the dam to provide resistance to flow and dissipate the hydrostatic pressure caused by the reservoir over a short distance. Some embankment dams use a masonry or concrete corewall to create the impervious barrier within the embankment. The ability of an embankment dam to resist the hydrostatic pressure caused by reservoir water is primarily the result of the mass or weight of the structure and the internal strength of the soil materials.

Many small dams and older dams consist of a homogeneous earth embankment where the dam is constructed of similar material throughout. Modern embankment dams are normally constructed with a zoned embankment and are composed of zones of selected materials having different degrees of porosity, permeability and density. Most zoned embankments include a chimney drain and toe drain to collect and filter seepage through the embankment and increase the stability and long-term performance of the structure. The chimney and toe drain consist of coarse-grained material which has little resistance to the flow of water and is not prone to shrinking or cracking. Water entering the drains flows freely through the drain and exits safely beyond the dam without saturating the material in the downstream zone.

In general, embankment dams are designed to minimize seepage and the chance for water to exit on the downstream face.



1.2.2 Concrete Dams

Concrete is the most durable material for building dams and has very high resistance to erosion and seepage. Concrete dams are unique in that they directly transfer the pressures created by the stored water to the foundation and abutments. A concrete dam is therefore very dependent upon the ability of the foundation and abutments to hold the dam in place. Most concrete dams are constructed on bedrock foundations.

Concrete dams may be categorized into gravity, arch and buttress dams according to the designs used to resist the stresses from the reservoir water pressure. A concrete gravity dam (shown in Figure 1-2) is the most common and relies entirely on its mass or weight for stability. A buttress dam is a specific type of concrete dam in which the destabilizing forces are transmitted to the dam foundation through a series of vertical or sloping buttress walls. Concrete arch dams are thin concrete curved or arched sections that transmit the destabilizing forces laterally into the rock abutments. Buttress and arch dams usually require significantly less concrete to build than a gravity dam.

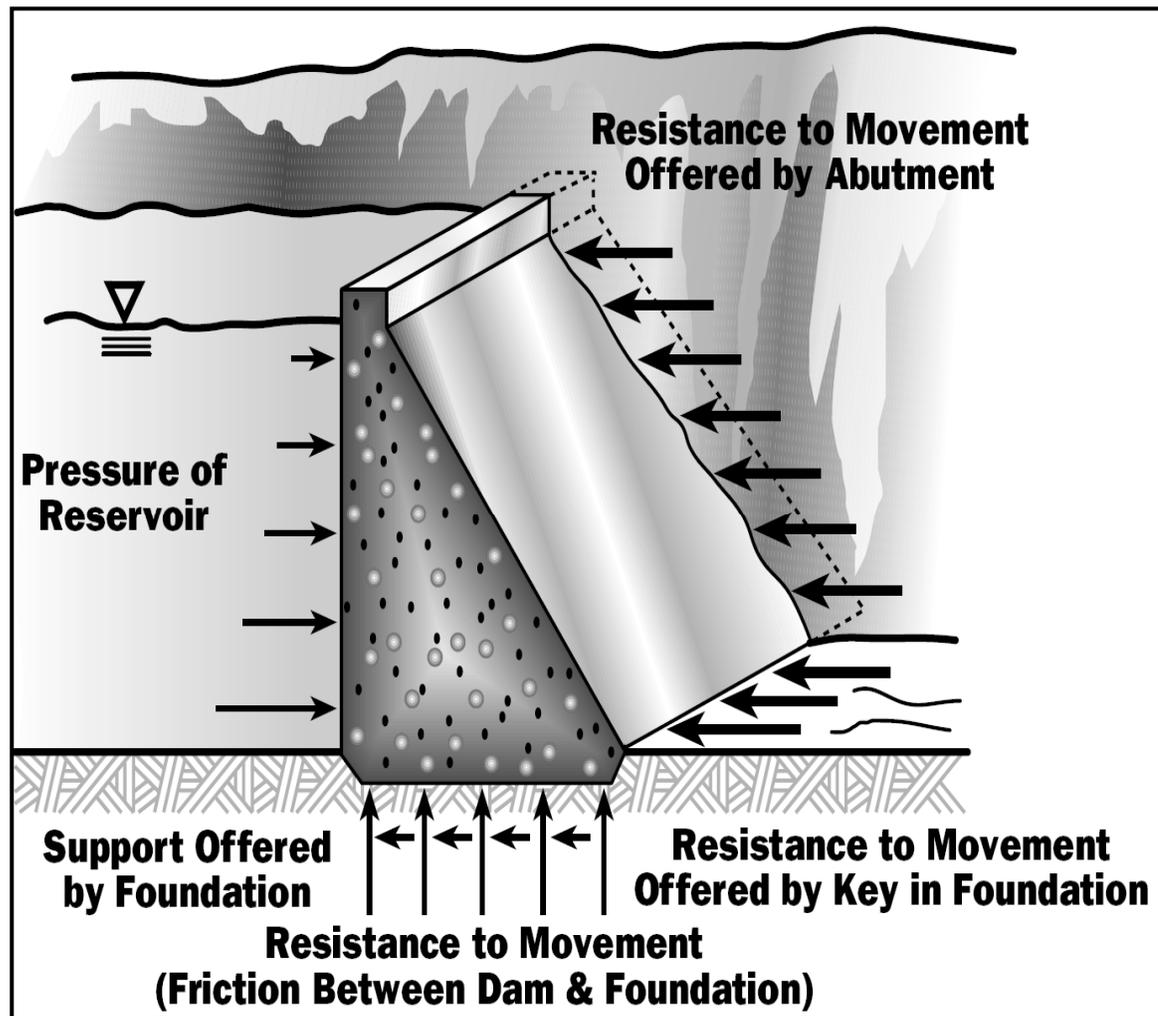


Figure 1-2: Typical Concrete Gravity Dam Section



1.2.3 Service Spillways

The service spillway, also referred to as the principal or primary spillway, is the main structure over or through which flow is discharged from the reservoir and is the means used to control the reservoir level. If the rate of flow is controlled by mechanical means such as gates or stoplogs, it is considered a controlled spillway. If the elevation of the spillway crest is fixed, it is considered an uncontrolled spillway. Since service spillways are the primary means of controlling reservoir flows, they are generally designed to a high standard of performance so that they perform satisfactorily under all flow conditions without damage.

Common types of service spillways on USFWS dams include stoplog-controlled concrete drop structures, concrete or corrugated metal riser structures, and concrete spillways controlled with tainter gates. Some dams use steel sheet pile instead of concrete to create the spillway structure. Many USFWS spillways are constructed using both steel sheet pile and reinforced concrete.

1.2.4 Emergency Spillways

Emergency spillways, also referred to as auxiliary or secondary spillways, are designed to operate only during exceptionally large floods and their purpose is to pass major flood flows around the structure and prevent dam overtopping. Because emergency spillways are intended for infrequent use, many are designed to allow some damage to occur during the passage of the design flood provided the safety of the embankment is not compromised.

Most emergency spillways consist of an open trapezoidal channel excavated through natural materials having an approach channel, a level crest or control section, and an outlet channel. They are normally covered with a layer of topsoil and vegetated with grasses adapted to the local environment.

Some emergency spillways are equipped with concrete control structures or are armored with articulating concrete blocks or other erosion resistant materials to prevent breaching or failure of the spillway where a grass cover cannot provide reliable erosion protection.

1.2.5 Low-Level Outlets

Low-level outlets provide a means for lowering or draining the reservoir and normally consist of a conduit through the embankment equipped with one or more valves. The low-level outlet must be able to evacuate the major portion of the reservoir storage volume by gravity flow. Low-level outlets are sometimes incorporated as a feature within a concrete spillway structure such as a stoplog bay extending to the bottom of the structure or a gated opening at the base of the structure. In some cases, at low hazard dams where the reservoir is very small, low-level outlets are omitted and the reservoir is lowered or drained using portable pumps or by installing a temporary siphon. Current USFWS policy requires all inventory dams to have a low-level outlet unless a waiver is obtained.



1.3 Roles, Responsibilities, and Authority

1.3.1 General

The USFWS has a well-established Dam Safety Program that includes considerable resources that are available to the Refuges. Within this program, specific roles, responsibilities and authority have been established. The roles, responsibilities and authority of key individuals within the USFWS as they pertain to the normal operation, maintenance, monitoring and inspection of USFWS low hazard inventory dams are described in this section.

1.3.2 Refuge Manager

The Refuge Manager is responsible for the safety of the dam, routine operation and maintenance, station inspections, and implementing the SOP.

1.3.3 Regional Dam Safety Officer (RDSO)

The Regional Dam Safety Officer (RDSO) of the FWS is responsible for the following:

- Providing technical, operational, and maintenance guidance to the Refuge Manager.
- Receiving and interpreting observations and instrumentation data from the dam.
- Providing technical and decision-making support to the Refuge Manager during an unusual or emergency event.
- Revising, publishing, and distributing the SOP.
- Conducting the SOP Annual Reviews.

1.3.4 Regional Director

The Regional Director is responsible for the safety and operation of all facilities in his/her Region.

1.3.5 Service Dam Safety Officer, Division of Engineering, Dam Safety Branch (SDSO)

The Service Dam Safety Officer (SDSO) for the Division of Engineering, Dam Safety Branch, of the FWS is responsible for:

- Formulating and recommending plans, technical guidelines and standards, and procedures necessary for the effective implementation of the FWS Dam Safety Program.
- Providing technical, operation, and maintenance guidance to the RDSO and Refuge Manager.
- Providing technical and decision-making support to the RDSO and Refuge Manager during an unusual or emergency event.

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- Managing the Safety Evaluation of Existing Dams (SEED) program for all FWS dams, which includes performing periodic SEED inspections of each dam.
- Implementing project planning, engineering design, and construction management for dam safety rehabilitation at high and significant hazard dams.



CHAPTER 2

INSPECTIONS AND MONITORING

2.1 Types of Inspections

An effective inspection program is essential to identification of problems for safe maintenance of a dam. The program should involve three types of inspections:

1. Periodic technical inspections or SEED inspections.
2. Periodic maintenance inspections referred to as Station Inspections.
3. Informal observations by project personnel as they operate the dam.

Periodic technical SEED inspections involve specialists familiar with the design and construction of dams and include assessments of structural safety. For low hazard dams, SEED inspections are performed once every six years. These inspections are normally performed by engineering consultants with special expertise in dam engineering that have been engaged by the SDSO. All other inspections including periodic maintenance inspections (Station Inspections) and informal observations are performed by Refuge/Hatchery Personnel.

2.2 Inspections by Refuge Personnel

2.2.1 Frequency of Inspections

Station Inspections are performed more frequently than technical inspections in order to detect, at an early stage, any detrimental developments in the dam, and involve assessing the operational capability as well as structural condition of the dam. Informal observations are made by project personnel (operators, maintenance staff, security staff and others) as they operate or patrol the dam. This type of inspection should be an ongoing activity performed in the course of normal refuge duties.

A Station Inspection should be performed at a minimum monthly as indicated in the Operations Schedule (Table 4-1). Other scheduled activities should be combined with the Station Inspection if practical. All inspections should be organized and systematic, and all Station Inspection information should be recorded on an Operations Log Form (Form 1a) located in Appendix C. The Informal Inspection Checklist (Form 1b) located in Appendix C should also be completed during the inspection. In addition to the inspection schedule presented in the Operations Schedule, a Station Inspection is recommended for the following special conditions:

1. Prior to a major storm or heavy snowmelt: check spillway, outlet channel, and riprap.
2. During or after a severe storm: check spillway, outlet channels, and riprap.
3. Severe windstorm: check riprap performance during a storm and after it as subsided.



4. Earthquake: make complete inspection right after the event and weekly inspections for the next six weeks to detect any delayed effects (i.e. cracking, seepage, slumps, excessive settlement, etc.).

2.2.2 Conditions to Look For

Table 2-1 includes descriptions of new and existing conditions to look for during a Station Inspection, and what information to record. Additional information on potential dam problems, causes and recommendations is presented in Appendix B. At a minimum, for each Station Inspection, the following are required:

1. Record the weather, reservoir water surface elevation, sluice gate positions, tainter gate openings, number of stoplogs in place in the Service Spillway and other structures, and attendance.
2. If the dam has instrumentation, monitor all appropriate instruments [reference the Operation Schedule (Table 4-1)]. Record this data on the back of the Operations Log.
3. Perform any scheduled maintenance.
4. Perform any maintenance observed to be needed based on previous dam visits, if practical, at the time of this inspection.
5. Perform any required maintenance observed during the current Station Inspection, if practical, at the time of this inspection.
6. Walk the entire length of the dam and inspect the following dam features looking for the conditions listed in Table 2-1.
 - Upstream slope
 - Crest
 - Downstream slope
 - Downstream toe
 - Service spillway structure(s)
 - Emergency spillway structure
 - Downstream service and emergency spillway channels
 - Low-level outlet
 - Downstream outlet works channel
 - Abutment contacts
 - Reservoir area
7. Perform a visual inspection of the following structural features as appropriate for each dam for signs of changing conditions:
 - Check for debris in inlet structure and outlet conduit
 - Check condition of concrete structure, note any deterioration
 - Check condition of gates and operating mechanisms
 - Check condition of fencing
 - Check signs that warn public of hazards and restrictions

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- Check condition of stoplogs, bulkheads, chain hoist, and lifting frame for signs of corrosion or disrepair
- Note areas to be painted; schedule painting for next monthly inspection
- Record results of the inspection in the Operations Log



Table 2-1
Station Inspection Checklist (See Also Information in Appendix B)

CONDITIONS TO LOOK FOR:	WHAT TO RECORD IF FOUND:
	For all the conditions: <ul style="list-style-type: none"> ▪ location limits (width, length, depth) ▪ new or existing
Seepage <ul style="list-style-type: none"> ▪ Flowing water ▪ Lush vegetation ▪ Wet areas 	<ul style="list-style-type: none"> ▪ size limits (width, length) ▪ clear or cloudy ▪ flow rate ▪ station, offset and elevation
Erosion <ul style="list-style-type: none"> ▪ Gullies ▪ Scarps ▪ Riprap displacement 	<ul style="list-style-type: none"> ▪ limits (width, length, depth) ▪ station, offset and elevation
Embankment Movement <ul style="list-style-type: none"> ▪ Cracks ▪ Settlement ▪ Bulges ▪ Slides ▪ Misalignment of downstream toe or crest edge 	<ul style="list-style-type: none"> ▪ limits (width, length, depth, height) ▪ station, offset and elevation
Structure Movement <ul style="list-style-type: none"> ▪ Spillway walls ▪ Spillway control structure ▪ Outlet works 	<ul style="list-style-type: none"> ▪ limits (width, length, displacement) ▪ station, offset and elevation
Operational Components <ul style="list-style-type: none"> ▪ Damage ▪ Deterioration ▪ Malfunction 	<ul style="list-style-type: none"> ▪ description ▪ location
Excessive vegetation	<ul style="list-style-type: none"> ▪ limits (width, length) ▪ station, offset and elevation
Animal burrows	<ul style="list-style-type: none"> ▪ limits (diameter, depth) ▪ station, offset and elevation
Damaged Concrete <ul style="list-style-type: none"> ▪ Cracks and Spalling ▪ Erosion ▪ Deterioration 	<ul style="list-style-type: none"> ▪ limits (width, length, depth) ▪ station, offset and elevation
Damaged Gates (sluice and tainter)	<ul style="list-style-type: none"> ▪ description ▪ location
Public Safety <ul style="list-style-type: none"> ▪ Warning and Restriction Signage ▪ Traffic Control Devices 	<ul style="list-style-type: none"> ▪ description ▪ location
Debris Buildup	<ul style="list-style-type: none"> ▪ location and limits
Damaged Stoplogs	

Caution: Do not attempt to cross the Emergency Spillway, either by foot or by vehicle, when water is flowing through the Emergency Spillway.

**Immediately inform the Refuge Manager if during the inspection:**

1. A new condition is found (reference Table 2-1);
2. An existing condition has worsened; or
3. An instrument reading was abnormal.

The Refuge Manager should determine if emergency actions are warranted and contact the RDSO for assistance. If emergency actions are not warranted, the Refuge Manager should consult with the RDSO and address the condition.

2.2.3 Recommended Inspection Equipment

The inspectors should use the appropriate equipment to perform the inspection. Suggested equipment for performing Station Inspections includes:

- **Notebook and pencil** – should be available so that observations can be written down at the time they are made, reducing mistakes and avoiding the need to return to the site to refresh the inspector’s memory.
- **Inspection checklist** – serves as a reminder of all important conditions to be examined.
- **Digital camera** – can be used to photograph field conditions. Photographs taken from the same vantage points as previous photographs can also be valuable in comparing past and present conditions.
- **Pocket tape** – allows for accurate measurements so that meaningful comparisons can be made of movements.
- **Flashlight** – may be needed to inspect the interior of an outlet in a small dam.
- **Tapping device** – is used to determine the condition of support material behind concrete or asphalt faced dams by firmly tapping the surface of the facing material. Concrete fully supported by fill material produces a “click” or “bink” sound, while facing material over a void or hole produces a “clonk” or “bonk” sound. The device can be made from a 1-inch hardwood dowel with a metal tip firmly fixed to the tapping end or a length of reinforcing steel.
- **Binoculars** – useful for inspecting limited-access areas, especially on concrete dams.
- **Volume container and timer** – used to make accurate measurements of the rate of leakage. Various container sizes may be required, depending on the flow rates.
- **Stakes and flagging tape** – used to mark areas requiring future attention and to stake the limits of existing conditions, such as wet areas, for future comparison.
- **Hand-held GPS receiver** (for very long dams) – used to collect positional data on locations of interest.
- **Watertight boots** – recommended for inspecting areas of the site where water is standing.



2.2.4 Dam Inspection Guidelines

The upstream slope of the dam requires careful inspection since the slope protection and water stored can hide problems. Whenever the reservoir is emptied, the slope should be thoroughly inspected for settlement areas, rodent activity, sinkholes, or slides. The reservoir basin (bottom of the reservoir) should be inspected at this time for sinkholes or settlement.

As the inspector(s) criss-crosses the upstream slope during an inspection, he/she should look carefully for these items:

1. Cracks
2. Slides
3. Whirlpools
4. Missing slope protection

The first three conditions may indicate serious problems within the embankment.

Looking for and spotting cracks is difficult. The slope must be traversed in such a manner that the inspector is likely to walk over the cracks. Cracks may be only a fraction of an inch wide but 2 or 3 feet deep. Usually a depth of 3 feet shows that the crack is not a harmless drying type of crack. A 20-foot long line of recently dislodged riprap along the upstream slope could indicate a crack underneath the riprap. Cracks indicate possible foundation movement, embankment failure, or a surface slide.

Slides are almost as difficult to spot as cracks. Their appearance is subtle, since there may be only minor settlement or bulging out from the normal slope. It is possible that when the dam was constructed, it may not have been uniformly graded by the bulldozer or grade operator. A good familiarity with how the slope looked at the end of construction helps identify new slides. The lack of protection against wave action on the upstream slope can lead to erosion, and the decrease of the embankment width and/or freeboard.

When walking on riprap, caution should be used to avoid losing one's footing. Often the water-line alignment will indicate a change in the uniformity of the slope. The inspector should stand at one end of the dam and sight along the water line. Also, if a crack is seen, the crest and downstream slope in that area should be carefully inspected to note any other changes in that area on the embankment that could be associated with the upstream crack.

Frequent inspection of outlet conduits is necessary to ensure the conduits are functioning properly. Conduits which are 24 inches or more in diameter can be entered and visually inspected. Conduits having a diameter less than 24 inches can be inspected by remote controlled equipment such as a video camera mounted on a mobile vehicle. The conduits should be inspected for improper alignment (sagging), elongation and displacement at



joints, cracks, leaks, surface wear, loss of protective coatings, corrosion, and blockage.

Problems with conduits occur most often at joints and special attention should be given to them during inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause leakage of water into the embankment during pressure flow. The outlet should be checked for signs of water seepage along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

2.3 SEED Inspections

SEED inspections are the responsibility of the FWS Division of Engineering, Dam Safety Branch. SEED inspections for low hazard dams shall be performed every 6 years. The Refuge will be notified prior to the SEED inspection and given a checklist of activities to be completed before the inspection team arrives. Checklist activities might include mowing the grass, if needed, and preparing for stoplog operation or gate operation. At the start of the inspection, the inspectors will meet with the Refuge Manager and discuss the planned inspections and activities for the day. After this meeting, at least one Refuge staff member involved with the dam operations should accompany the inspector(s) to the dam. The inspector(s) and Refuge staff member should discuss the dam operations and maintenance since the last inspection, and any problems or concerns that may have occurred. The inspector will ask the Refuge staff member to perform certain routine dam operations, including operating the stoplog equipment and reading the water level in a piezometer, if applicable. The inspector also will review the SOP.

2.4 Correcting Observed Deficiencies

Appendix B provides information on some of the more common problems that may occur, the possible consequences of each of the problems, and the recommended action. Any significant modifications or corrective actions to the dam should be coordinated with the SDSO.

2.5 Record Keeping

Proper documentation of the dam's current condition and past performance is necessary to assess the adequacy of operation, maintenance, surveillance, and proposed corrective actions. A complete record or history of the investigation, design, construction, operation, maintenance, surveillance, periodic inspections, modifications, repair and remedial work should be established and maintained so that relevant data relating to the dam is preserved and readily available for reference. This documentation should commence with the initial site investigation for the dam and continue through the life of the structure. Records should be well organized, complete, and accurate, enabling easy understanding and evaluation of the recorded information.

Routine operation and maintenance should be fully documented, including the routine activities and systematic inspection processes, and complete information on project maintenance, rehabilitation and improvements. In addition to records of the actual operations, the operating record should include data relating to reservoir levels, inflow and outflow, drainage system



discharge and structural behavior. If there are maintenance problems that require continuing remedial work, a thorough record of the work should be maintained, and a final report made after complete remedy of the problem.

One copy of all documents concerning the project should be assembled in a single project file. The file should be kept up to date and should be maintained as a permanent archival reference. A second file of the materials should always be easily accessible to responsible personnel for reference in future reviews and inspections, and in dealing with problems, repairs, etc. Both files should be continuously updated with records on problems, repairs, operation, instrumentation, and inspection for the life of the project. Information such as foundation reports and as-built drawings and maps should be permanently retained at the project and also at the office of the SDSO.

The inspector should fill out a dated Operations Log Form (see Appendix C, Form 1a), which should be filed along with any photographs taken (which should also be dated). In addition to inspection observations, monitoring measurements and weather conditions (especially recent rains, extended dry spells and snow cover) should also be systematically included in the inspection record. A sketch of the dam with problem areas noted is helpful.

Immediately following an inspection, observations should be compared with previous records to see if there are any trends that may indicate developing problems. If a questionable change or trend is noted, and failure is imminent, the owner should consult a professional engineer experienced in dam safety. Reacting quickly to questionable conditions will ensure the safety and long life of a dam and possibly prevent costly repairs.

Inspection details should be recorded on an Operations Log (See Appendix C, Form 1a) on the date they occur. The following are examples of Operations Log entries:

Operations:

- Removed two 6-inch stoplogs from service spillway
- Added all stoplogs to diversion structure intake
- Measured the water level in the piezometers
- Performed dam visit or station inspection
- A SEED inspection was performed

Maintenance:

- Mowed grass on the downstream slope
- Removed vegetation other than grass from the spillway channel
- Repaired erosion on the upstream slope. Repair area was between Station 8+90 and 9+00, from the crest to the toe of the embankment



Observations:

- Observed thick vegetation growth (tall weeds) from the downstream toe to 50 feet downstream of the downstream toe between dam Stations 6+00 and 6+20
- Observed two animal burrows on the downstream slope at Station 7+30 and 7+60. Both burrows were approximately 4 inches in diameter and 1 foot deep
- Had difficulty in opening piezometer B-101; lock has become rusty
- RDSO performed a site visit and noted that brush and small trees should be removed from the dam toe to 50 feet downstream of the dam toe between Stations 6+00 and 7+20.

Completed Operations Log forms should be inserted into Appendix C after every visit to the dam. The working copies of the Instrument Monitoring Data Forms (See Appendix D, Forms 2a – 2e) should be stored in Appendix D. Transmit a copy of the Operations Log and the Instrument Monitoring Data Forms to the RDSO as indicated in the Operations Schedule (Table 2-1). At the end of each year, the completed Appendix C and Appendix D should be removed from the SOP and sent to the SDSO to be permanently filed with all other dam documentation. A copy of the preceding year's Operations Log and Instrument Monitoring Data Forms should always be kept at the Refuge headquarters for reference.



CHAPTER 3

INSTRUMENTATION AND MONITORING

3.1 General

Various devices exist which can be used to monitor the performance and any physical changes occurring within the dam over time. These devices provide a quantitative measure of the changes. When used in combination with visual inspections, a more complete assessment of the condition of a dam may be made. The following devices are the most common monitoring devices found:

1. **Reservoir Staff Gage:** A graduated marker mounted on a structure within the reservoir or on a pole that is used to measure the water level in the reservoir.
2. **Survey Monuments or Measurement Points.** A set of defined points (to be surveyed during the dam's life) from which the displacements that the dam undergoes may be measured.
3. **Piezometers.** Used to measure the height of the water surface or hydrostatic pressure in the embankment.
4. **Weirs and Seepage Outfalls.** Measures the quantity of leakage occurring through the embankment and/or foundation.

Instrumentation and proper monitoring and evaluation are extremely valuable in determining the performance of a dam. Specific information that instrumentation can provide includes:

- Warning of a problem (i.e., settlement, movement, seepage, instability)
- Definition and analysis of a problem, such as locating areas of concern
- Proof that behavior is as expected
- Evaluating remedial actions.

3.2 Instructions for Monitoring

The instruments, as applicable to the particular dam, should be read periodically as indicated in the Operations Schedule (Table 4-1). Most low hazard dams do not have any instrumentation beyond the reservoir staff gage and outfall drains.

Instrumentation is used to supplement visual inspections in evaluating the performance and safety of dams. Careful examination of instrumentation data on a continuing basis may reveal a possible critical condition. Conversely, instrumentation may be a means of assuring that an observed condition is not serious and does not require immediate remedial measures.



Instruments should be examined periodically for proper functioning. The adequacy of the installed instrumentation should be assessed from time to time by specialists to determine if it is sufficient to help evaluate the performance of the dam. When required, additional instrumentation should be installed to confirm suspicious trends or to explore an indicated potential adverse trend.

The instrument readings should be recorded on the Operations Log sheets at the dam, and then transferred to the Instrument Monitoring Forms. The data now transferred to the Instrument Monitoring Forms should be converted to the specified values using the conversion procedure noted at the bottom of each Instrument Monitoring Form.

A master copy of each Instrument Monitoring Form is included in Appendix D. The forms include:

- Form 2a: Reservoir Staff Gage Monitoring Data
- Form 2b: Piezometer Monitoring Data
- Form 2c: Drain Outfall Monitoring Data
- Form 2d: Survey Point Monitoring Data
- Form 2e: Weir Rating Table

Instrumentation data should be collected by personnel trained specifically for the purpose, including training to recognize and immediately report to those responsible for inspections any anomalies in the readings or measurements. Performance observation data should be properly tabulated for record purposes.

It is essential that instrumentation data be processed, reviewed and assessed in a timely manner by specialists familiar with the design, construction and operation of the project. Design information should be referred to in the evaluation of possible adverse trends. The performance observation data should be periodically analyzed to determine whether project structures are reacting as assumed in the design, and to detect behavior conditions that may indicate the need for corrective action.

All instrumentation observation data and evaluations thereof should be properly tabulated and documented for record purposes. Maintenance of instrumentation systems requires that details of the installation be available for clear understanding of its functioning. A complete history of past repairs, testing, readings, and analyses should be available as pertinent reference data in the evaluation of current instrumentation data.

3.3 Reservoir Water Staff Gage

3.3.1 Reading Procedure

Reservoir water surface elevations should be read to the nearest tenth of a foot, and be recorded in the Operations Log and on Form 2a. When reading the reservoir water



surface on the staff gage is difficult due to windy conditions, the average water surface elevation observed over several minutes should be recorded as the reservoir elevation. A note should be recorded in the comment section that the weather conditions were windy at the time of the instrument reading.

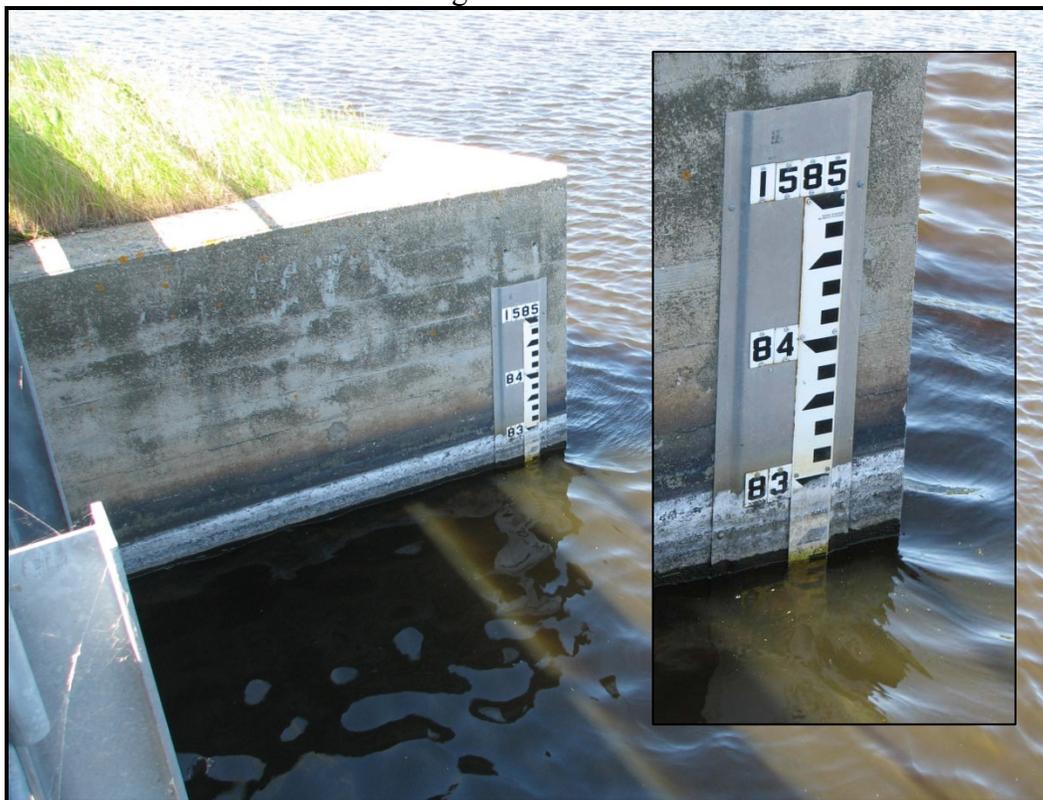


Figure 3-1: Reservoir Staff Gage

3.3.2 Normal Readings

Reservoir water surface elevations within 1 foot of the normal pool elevation are generally considered to be normal, although flood watch procedures should be initiated when the reservoir is spilling over the Emergency Spillway crest.

3.3.3 Abnormal Readings

When the reservoir water surface elevation is spilling through the emergency spillway, flood operations are in effect. Follow the instructions in Section 4.3.2, Flood Operations.

3.4 Piezometers

3.4.1 Reading Procedure

The following procedure is recommended for reading the water level in a piezometer:

1. Use the piezometer data sheet (Form 2b) to record the piezometer monitoring data.
2. Prior to reading the piezometers, record the reservoir water surface elevation by



- reading the staff gage. Record the reservoir water surface elevation on the piezometer data sheet.
3. Unlock and remove the steel cap from the casing and the plastic cap from the riser pipe. It is recommended that the plastic cap be placed in a clothing pocket to avoid losing the cap in the thick grass around the piezometer casing.
 4. Lower the probe end of the water level indicator down the riser pipe until the indicator alert (beeper) sounds. Raise and lower the probe until the exact point of contact is determined.
 5. Read the water depth from the top of the PVC pipe to the water surface. Read the depth in feet from the 1-foot marks on the probe cable; use a hand-held tape measure to determine the depth reading to the nearest 0.1 foot.
 6. Record the depth reading on the back of the Operations Log and transfer to the piezometer data sheet (Form 2b).
 7. Replace the cap on the riser pipe. Replace and lock the cap on the casing.
 8. Repeat steps 3 through 7 for each piezometer.

3.4.2 Data Reduction

Water level elevations are calculated by subtracting the measured depth to the water surface from the elevation of the top of the PVC pipe. Record the water level elevation in the appropriate locations of Form 2b.

3.4.3 Normal Readings

Water levels in the piezometers are expected to fluctuate with the reservoir water levels. At low reservoir levels, the water levels in the piezometers should be relatively low; and at high reservoir levels, the water levels in the piezometers are expected to be higher. However, the amount of fluctuation cannot be estimated. Readings may generally be considered normal if the above trends are observed. It is important to gather piezometer data according to the recommended schedule, and to transmit the data in a timely fashion for evaluation by experienced personnel. There are many possible abnormalities that may appear normal to a person inexperienced in dam behavior.

3.4.4 Abnormal Readings

Examples of readings that would be considered abnormal are given below. This is not a comprehensive list of potentially abnormal readings, and therefore all monitoring information should be evaluated by qualified personnel as soon as possible after being obtained, in order to identify other potential abnormal observations.

1. A drop in the water level in a piezometer when the reservoir rises. Conversely, a rise in the water level in a piezometer when the reservoir is maintained at uniform level or drops. This may indicate a change in the seepage regime in the embankment or foundation, or problems with the piezometer.



2. Significant changes (1-foot or more) in the piezometer water levels under relatively constant reservoir water levels.

Contact the RDSO immediately if an abnormal reading has been obtained.

3.5 Outfall Drains

3.5.1 Reading Procedure

For outfall drains equipped with weirs, the amount of seepage discharging from the underdrain system is calculated by measuring the depth of flow using the staff gage mounted upstream of a V-notch weir. Measure the depth to the nearest hundredth of a foot and record the data in the Operations Log. Transfer the data to the Drain Outfall Monitoring Data form and convert to the appropriate gallons per minute (gpm) value.

For drain outfalls not equipped with a flow measuring device, the amount of seepage discharging from the underdrain system can be calculated by placing a 5-gallon bucket or other type of container of known volume under the outfall and measuring the time it takes to fill the container. Record the data in the Operations Log. Transfer the data to the Drain Outfall Monitoring Data form (Form 2c) and convert to the appropriate gallons per minute (gpm) value. An example of a flow measurement calculation is presented below.

A 5 gallon bucket filled in 45 seconds

$$\frac{5 \text{ gallons}}{45 \text{ seconds}} \times \frac{60 \text{ seconds}}{1 \text{ minute}} = 2 \text{ gallons per minute (gpm)}$$

If the drain outfall is not easily accessible, the measuring container can often be lowered under the drain outfall using a rope. See Figure 3.2 for examples of typical flow measurements techniques.

3.5.2 Normal Readings

The drain discharge rates are expected to fluctuate with reservoir water levels. As the reservoir water level increases, the drain discharge rates should also increase. Likewise, drain discharge rates should decrease as the reservoir water level decreases. Drain discharge rates are considered normal as long as this trend is observed and the discharge water is clear.

3.5.3 Abnormal Readings

Drain discharge rates are considered abnormal if one or more of the following observations are made:

1. Discharge water is cloudy, muddy, or contains sand particles.
2. A drop in the discharge rates when the reservoir water level increases, or a rise in the drain discharge rates when the reservoir water level decreases.



3. A change of 25-percent or more, from one reading to the next, under near-constant reservoir water level.

Immediately inform the Refuge Manager of an abnormal reading.



Figure 3-2: Typical Flow Measurement Techniques at Drain Outfalls



3.6 Embankment Measurement Points

3.6.1 Reading Procedure

The SDSO will obtain a licensed surveyor to measure offset and elevations of the embankment measurement points and northing, easting, and elevation of the horizontal and vertical control points to the nearest 0.01-foot. The reservoir water surface elevation should be recorded. The surveyor will tabulate the results and draft a letter summarizing the survey. This letter, along with the tabulated data and a copy of the field notes, will be submitted to the SDSO.

The SDSO will review the survey. Upon approval, the data should be transferred to the appropriate Instrument Monitoring Data Form (Forms 2a and 2d). Determine if the readings are normal or abnormal.

3.6.2 Normal and Abnormal Readings

Excessive changes in offset, northing, easting, or elevation are not expected. Any change in offset, northing, easting, or elevation in excess of 0.1-foot shall be considered an abnormal reading.

The SDSO should immediately contact the RDSO and Refuge Manager and discuss what should be done about an abnormal reading.



CHAPTER 4

OPERATIONS

4.1 General Operations

4.1.1 Schedule

Table 4-1 provides a schedule of operations.

4.1.2 Dam Visits

A dam visit should be performed as indicated in the Operations Schedule (Table 4-1). Combine other operation activities with the dam visit if practical. All dam visit information should be recorded on an Operations Log form. At a minimum, for each dam visit, the following are required:

- Record the weather, reservoir water surface elevation, number of stoplogs, and attendance.
- Drive (if applicable) or walk the dam crest from the right abutment to the left and back, scanning the entire dam for any change in condition or any of the conditions listed in Table 2-1, Station Inspection Checklist.

4.2 Instructions for Operational Components

4.2.1 General

Not all FWS low hazard dams have identical features. The instructions for operational components provided herein have been generalized to address common features at these dams and may include components that do not exist at some dams. Follow the instructions for those components that apply.

4.2.2 Stoplogs

Addition of stoplogs shall be started in sufficient time to permit completion before flood waters reach the top of the structure sill. The stoplogs will be inspected frequently during flood periods to ascertain that no undue leakage is occurring and that drains provided to care for ordinary leakage are functioning properly. In preparation for closing stoplog structures, all recesses should be thoroughly cleaned of sand, silt, and other materials. After the stoplogs have been placed with the neoprene seal on the downstream side, wedges should be driven tight to prevent floating. Leakage through the stoplogs can be prevented or largely overcome by applying caulking material or by tacking a tarpaulin or roofing paper over the upstream slope after the logs have been placed.

Additional stoplogs should not be added to raise the lake level above the established normal pool level or cause frequent flow in the emergency spillway. Check with the



RDSO regarding the normal operating pool level.

**Table 4-1
Operations Schedule**

		Weekly	Monthly	Quarterly	Semi-Annually	Annually	Every 3 Years	Every 6 years	Occasional Occurrence	Responsible Entity				
										Refuge Manager	RDSO	SDSO		
STANDING OPERATION														
Operations	Dam Visit		✓								E ⁽²⁾			
	Transmit Log & Forms					✓								
	Flood Operations								✓		E	E		
Instrumentation	Reservoir Staff Gage		✓								E,A			
	Piezometers		✓								E,B			
	Drain Outfalls		✓								E,C			
	Survey Points								✓			E,D		
Inspection	Station Inspection		✓								E			
	SEED Inspection ⁽³⁾							✓			E			
	Diversion Structure	Per RDSO										E		
Maintenance	Mow Grass				✓ ⁽¹⁾						E			
	Maintain Stoplogs & Hoist	Per Manufacturer's Recommendation										E		
	Maintain Gates & Operators	Per Manufacturer's Recommendation										E		
	Control Vegetation				✓ ⁽¹⁾						E			
	General Maintenance				✓						E			
Unusual or Emergency Event	Emergency Action								✓		E			

Shading indicates responsible entity.

(1) At least twice during growing seasons.

(2) Letters indicate forms used for respective activity:

A Form 2a

D Form 2d

B Form 2b

E Form 1a - Operations Log

C Form 2c

(3) Alternate Formal SEED Inspection and Intermediate SEED Inspection every 6 years.



An adequate supply of required items mentioned above should be kept on hand at all times. As soon as the water level reaches the closure structure, an inspector should be assigned to make frequent checks on the amount of leakage. Necessary measures to control excessive leakage should be taken whenever it is found. Seepage should be conveyed into storm inlets, or other means of runoff provided. After the water has receded, but only after official forecast information relative to the continued recession of the water surface has been obtained from the National Weather Service, or at time of routine removal after each spring flood season, all materials used in the closure should be carefully removed, cleaned, and replaced in storage. Any damaged materials should be replaced immediately for future use.

4.2.3 Normal Operation of Outlet Works and Sluice Gates

The following procedures should be used when outlet releases are made through an outlet works sluice gate:

1. Verify that the upstream is free of debris.
2. Verify that the downstream discharge channel is free of debris.
3. Open the outlet works sluice gate to the appropriate level for the desired release rate.
4. After the desired release has been made, return the outlet works sluice gate to the fully closed position.

Use caution not to exceed the safe channel capacity or cause downstream flooding through intentional reservoir releases.

4.2.4 Tainter Gate(s)

The tainter gate(s) will be operated as needed to manage reservoir operations. The following procedures should be used when outlet releases are made through a tainter gate:

1. Refer to the manufacturer's product information before operating the tainter gates.
2. When operated, the tainter gate(s) should be lifted through both up and down cycling to verify function. A tainter gate should not be fully open because this would result in excessive downstream flow discharges. Distribute the discharge flow equally among the gates that are to be opened.
3. Use caution not to exceed the safe channel capacity or cause downstream flooding through intentional reservoir releases.

Use caution not to exceed the safe channel capacity or cause downstream flooding through intentional reservoir releases.

4.2.5 Debris Removal

For better hydraulic performance and to minimize damage to the structure, it is important to remove floating logs and debris from the reservoir on an annual basis, or more often if conditions warrant.



4.3 Reservoir Operations

4.3.1 Release Rates and Drawdown

Pool level drawdown should generally not exceed 1-foot per week for slopes composed of clay or silt materials except in an emergency situation. If the drawdown rate exceeds 1-foot per week, contact the RDSO. Very flat slopes or slopes with free-draining upstream soils can, however, withstand more rapid drawdown rates. Conditions causing or requiring temporary or permanent adjustment of the pool level include:

- A problem that requires lowering of the pool. 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.
- Requirements for recreation, hydropower, or waterfowl and fish management.

During emergencies, care should be taken to lower the reservoir at such a rate so as to prevent possible flooding downstream and to reduce the risk of an upstream slope failure from rapid drawdown.

4.3.2 Flood Operations

When the reservoir water surface elevation is above flood elevation, visits to the dam should be made at least twice daily, or more often if conditions warrant. Observe and record the reservoir water surface elevation and any changes in the condition of the dam and appurtenances since the last visit. At a minimum, a flood visit should include inspecting the full length of the upstream slope, crest, downstream toe, and downstream slope. Also, check the reservoir area, abutments, and downstream channel for signs of changing conditions. If culverts are obstructed and can be cleared safely, remove the obstructions.

4.3.3 Flood Forecasting

The Refuge Manager or RDSO may choose to have the reservoir level lowered below the maximum normal pool as a preparation to a severe weather forecast.

Use caution not to exceed the safe channel capacity or cause downstream flooding through intentional reservoir releases.



CHAPTER 5

MAINTENANCE

5.1 General

A good maintenance program will protect a dam against deterioration and prolong its life. A poorly maintained dam will deteriorate, and may fail. Nearly all the components of a dam and the materials used for its construction are susceptible to damaging deterioration if not properly maintained. Lack of proper maintenance can lead to deterioration, can make inspection difficult, may cause critical components such as flood gates to be inoperable when needed, and may ultimately cause the dam to fail. The cost of a good maintenance program is small compared to the cost of major repairs.

Routine maintenance must be performed on the dam and its appurtenant structures. Any unusual conditions noted when performing maintenance, which may adversely affect the safety of the dam, should be immediately reported to the Refuge Manager.

The regular schedules for maintenance are given in the Operations Schedule (Table 4-1). Recommendations for correcting common dam deficiencies are also provided in Appendix B.

5.2 Operational Components

5.2.1 Stoplogs

There is no regularly scheduled maintenance for stoplogs. Replace a stoplog if it becomes excessively deteriorated. When not in use, store the stoplogs on a flat, hard surface, elevated with blocks. Maintain the hoisting equipment in accordance with the hoist manufacturer's recommendations.

5.2.2 Sluice Gate(s)

To assure good operation and maintenance of sluice gates, all gates should be exercised and inspected for the condition of all gate components as part of the normal dam and reservoir Operations Schedule (Table 4-1). The recommended procedure to ensure the smooth operation of outlet gates is to operate all gates through their full range at least once a year and preferably more often. Some manufacturers recommend operating gates as often as four times a year. Because operating gates under full reservoir pressure can result in large outlet discharges, schedule gate testing during periods of low storage, if possible, or else operate them during periods of low stream flow. If large releases are expected, only have the outlets tested after coordinating releases with the local floodplain administrator and other dam owners located downstream and after notifying downstream residents and water users.

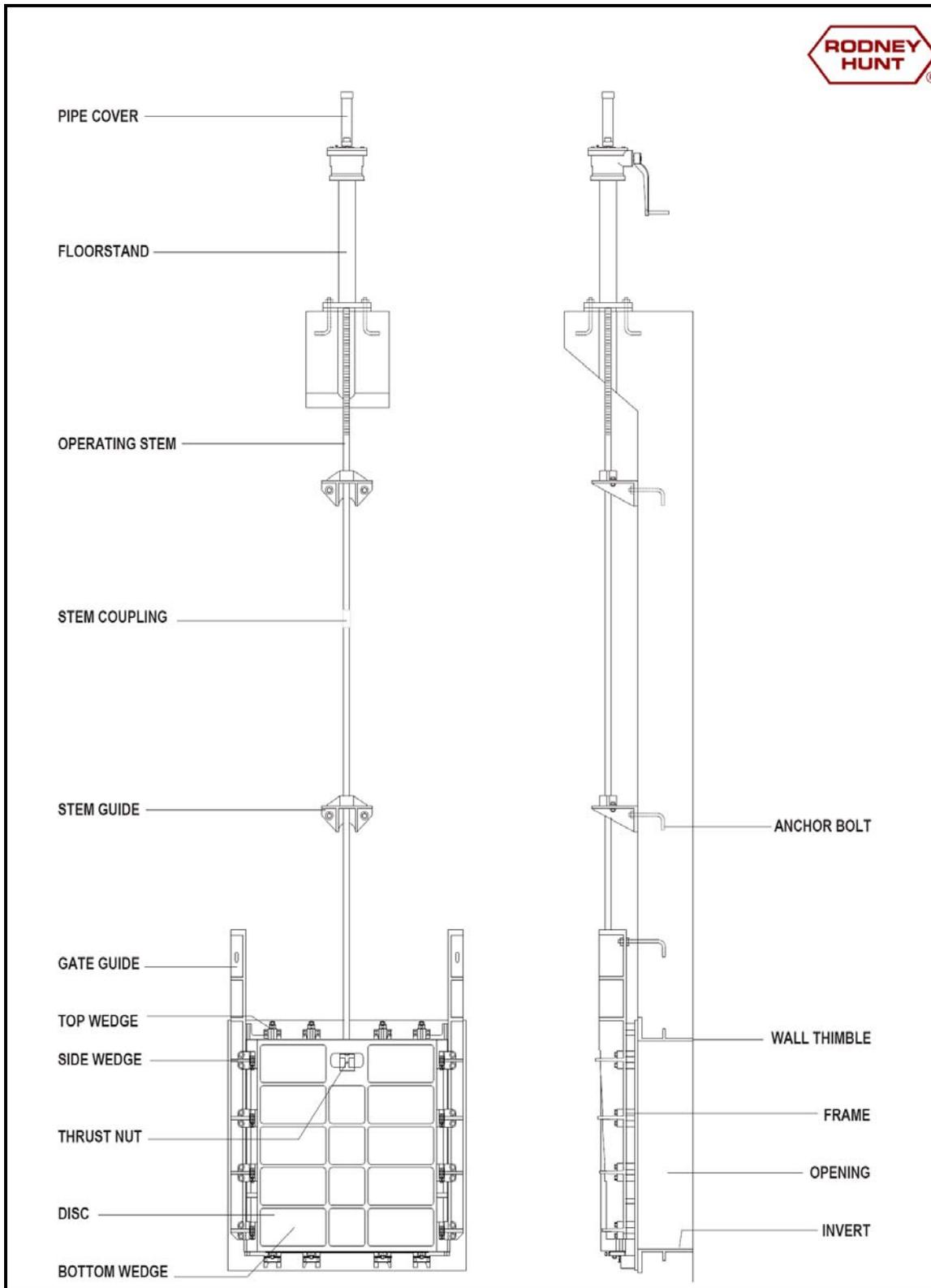


Figure 5-1: Typical Sluice Gate Configuration
 (Source: Rodney Hunt Gates and Valves)



Operation of the gates minimizes the buildup of rust in the operating mechanism and therefore the likelihood of its seizure. During this procedure:

- Check the mechanical parts of the hoisting mechanism—including drive gears, bearings, and wear plates—for adverse or excessive wear.
- Check all bolts, including anchor bolts, for tightness.
- Replace worn and corroded parts.
- Make mechanical and alignment adjustments as necessary.

The way the gate actually operates should also be noted. Rough, noisy, or erratic movement could be the first signs of a developing problem. The causes of operational problems should be investigated and corrected as soon as possible.

Excessive force should be neither needed nor applied to either raise or lower a gate. Most hoisting mechanisms are designed to operate satisfactorily with a maximum force of 40 pounds on the operating handle or wheel. If excessive force seems necessary, something may be binding the mechanical system. Excessive force may result in increased binding of the gate or damage to the outlet works. If there does seem to be undue resistance, the gate should be worked up and down repeatedly in short strokes until the binding ceases or the cause of the problem should be investigated.

If a gate does not properly seal when closed, debris may be lodged under or around the gate leaf or frame. Raise the gate at least two to three inches to flush the debris; then attempt to reclose the gate. This procedure should be repeated until proper sealing is achieved. However, if this problem or any other problem persists, consult a manufacturer's representative or engineer experienced in gate design and operation. **CAUTION:** If, at any time, the sluice gates will not close, open or otherwise malfunction, stop operating the gate and determine the cause of the malfunction. Contact the RDSO before resuming gate operation. Do not try to force a malfunctioning gate to open or close; this may damage the gate and/or the lifting mechanism.

An outlet gate's operating mechanism should always be well-lubricated in accordance with the manufacturer's specifications. Proper lubrication will not only reduce wear in the mechanism, but also protect it against adverse weather. Gates with oil-filled stems (i.e., stems encased in a larger surrounding pipe) should be checked semiannually to assure the proper oil level is maintained. If such mechanisms are neglected, water could enter the encasement pipe through the lower oil seal and could cause failure of the upper or lower seals, which in turn could lead to the corrosion of both the gate stem and the interior of the encasement pipe.

The metal used in gate seats is usually brass, stainless steel, bronze, or other rust resistant alloys. Older or smaller gates may not be fitted with seats, making them susceptible to rusting at the contact surfaces between the gate leaf and gate frame. Operation of gates should prevent excessive rust buildup or seizure.



Any operational adjustments or repair of damaged components should be performed immediately. All mechanical parts of the sluice gates should be periodically lubricated in accordance with the manufacturer's instructions. All gates should be repainted periodically.

The following procedure should be used when exercising the sluice gate:

1. Check operator, stem guide and gate attaching bolts for proper tightness.
2. Apply tension to stem and check stem guides for proper alignment. Visually confirm that the clearance between the operating stem and all stem guides is uniform.
3. Check gate guide groove and clean any foreign matter. Also remove foreign matter from top of disc, especially between the disc and frame.
4. Remove locking plates for sluice gates and open the gates according to the following procedures.
5. Verify that the downstream discharge channel is clear of debris.
6. Barely open (crack) the sluice gate, then close the gate.
7. Open the sluice gate 5-percent, then close.
8. Open the sluice gate 10-percent, then close.
9. Observe whether there is still water discharge through the pipes when the gates are closed completely. Record the observations.
10. Fully open the sluice gate.
11. Return the sluice gate to the fully closed position, or to the opening required to provide required releases.

All exercising activities and results should be recorded on the Operations Log.

Many outlet gates are equipped with wedges that hold the gate leaf tightly against the gate frame as the gate is closed, thus ensuring a tight seal. Through years of use, gate seats may become worn, causing the gate to leak increasingly. If an installation has a wedge system, the leakage may be substantially reduced or eliminated by readjusting the wedges.

Because adjustment of these gates is complicated, inexperienced personnel can cause extensive damage to one. Improper adjustment could cause premature seating of the gate, possible scoring of the seats, binding, vibration, leakage, uneven closing, or damage to wedges or gate guides. Thus, only experienced personnel should perform adjustments; consult a gate supplier or manufacturer to obtain names of persons experienced in such work.



Figure 5-2: Examples of Typical Outlet Works Gate and Valve Operation and Maintenance Problems



5.2.3 Tainter Gate(s)

Tainter gates should be exercised semi-annually as part of the normal dam and reservoir Operations Schedule (Table 4-1). When operated, the tainter gate should be lifted through both up and down cycling to verify function. A tainter gate cannot be fully opened because this would result in excessive downstream flow discharges. In order to minimize potential for flooding downstream, do not open any individual tainter gate more than 12 inches. Distribute the discharge flow equally among the gates that are to be opened. At no time should adjacent gates be opened in excess of 1-foot of each other.

Occasionally, manufacturers will recommend the tainter gate trunnion and hoist bearings be lubricated to prevent dirt and moisture buildup. In those cases where lubrication is recommended, lubricate these features as recommended by the manufacturer.

Some tainter gate trunnion and hoist bearings are maintenance-free and should NOT be lubricated for two reasons: (1) the bearing life expectancy exceeds the project design life because the bearings are rated for loads 7 to 8 times the actual loads in this application, and (2) lubricants that are not pure lithium-based will cause the plastic in the bearing materials to dissolve. Do not lubricate tainter gate trunnion and hoist bearings unless it is recommended by the manufacturer.

5.3 Instrumentation

5.3.1 Reservoir Staff Gage

If the reservoir staff gage is not firmly fixed, tighten the bolts or use other methods to firmly fix the gage. If necessary, remove and reinstall the gage making sure that the correct elevation is maintained. If the reservoir staff gage becomes damaged, so as not to be accurate or readable, it should be replaced.

5.3.2 Piezometers

Sediment sometimes builds up within the PVC pipe of a piezometer. This can cause inaccurate readings. To remove the sediment, gently agitate the sediment with a pipe or wire that is longer than the piezometer is deep. Be careful not to damage the piezometer screen or loosen the joints of the piezometer pipe. Then bail the water and sediment with an appropriately sized well bailer. A bailer is a cylindrical tube fitted with a valve at the bottom which is used to remove fluid from a well. Fill the piezometer with water and repeat until the bailed water is relatively clear, or the pipe can be lowered to the bottom of the piezometer without “feeling” sediment. Figure 5-3 illustrates a bailer.

Steel casings should be painted or otherwise protected against corrosion. Each piezometer casing should be numbered according to the appropriate numbering for the installation. The number should be written or stenciled with oil-based paint on the top of the casing cap and pipe. Re-paint any number if it becomes illegible. The casing cap should be kept locked to prevent vandals from dropping rocks or other objects into the casings or riser pipes. Caps for the riser pipes should be replaced if lost or stolen. The riser pipes should be repaired if damaged.



Figure 5-3: Photo of Piezometer Bailers

5.3.3 Weirs at Drain Outfalls

Keep the surfaces of the weir plate clean and the edge of the V-notch true. Replace the weir plate if stolen or damaged.

5.3.4 Survey Monuments

The brass cap survey monuments should be protected from damage, not covered or moved. If they become damaged or stolen they should be replaced with the assistance of the RDSO. A licensed surveyor should assist in the replacement of the survey monuments. Figure 5-4 depicts a typical survey monument.



Figure 5-4: Typical USFWS Survey Monument



5.4 General Maintenance Items

5.4.1 Concrete

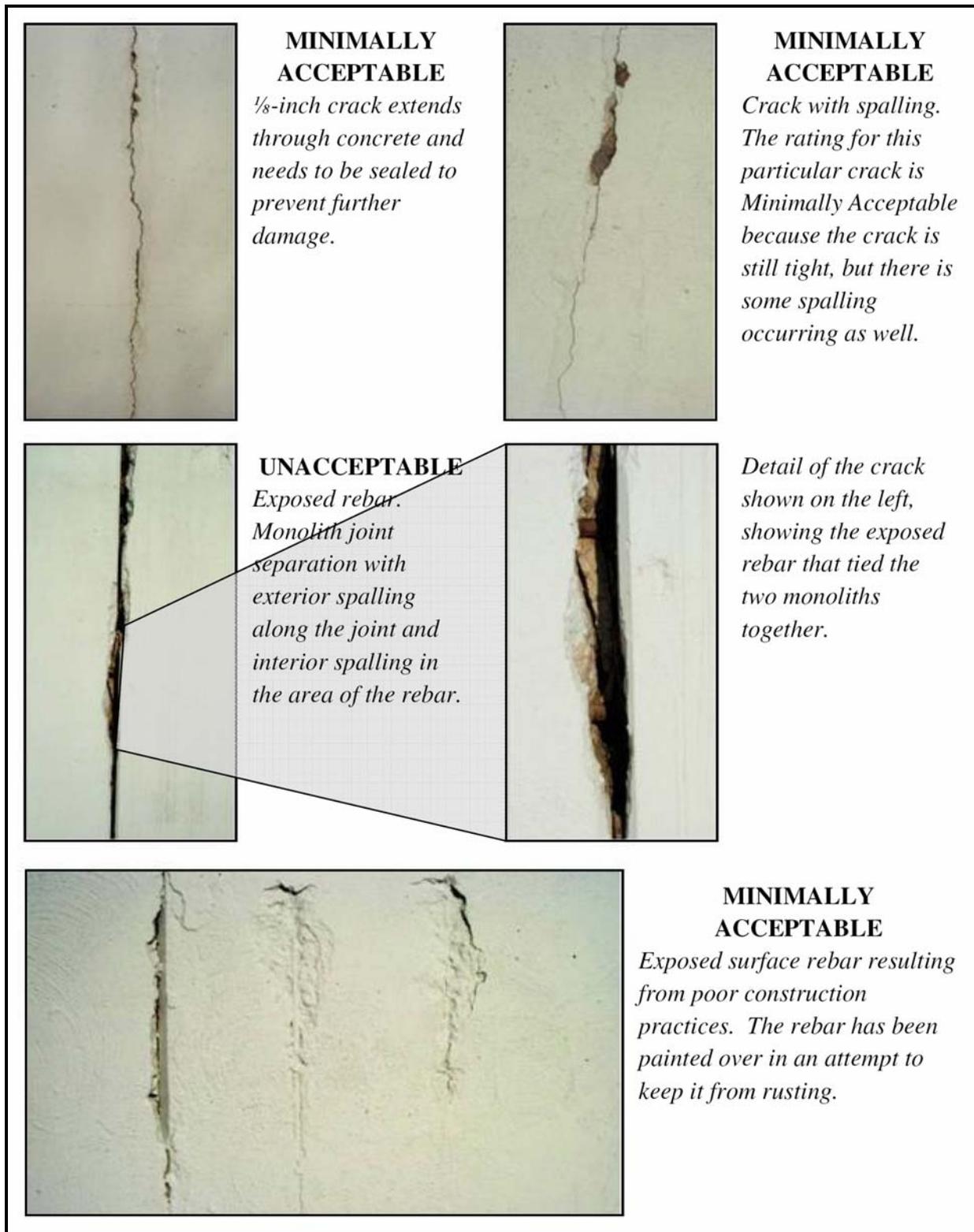
Repair of deteriorated concrete should be discussed with the RDSO. The RDSO will make all concrete repair decisions. Any vegetation observed growing from cracks in the concrete should be removed.

Over time, concrete surfaces will weather, leaving the concrete rough to the touch, or will hold moisture on the surface. When this occurs consider applying a protective coating to the concrete to help prevent moisture from entering the structure. By applying a protective coating to the concrete surface and sealing the cracks the chances of freeze / thaw damage will be greatly reduced, increasing the life expectancy of the structure. Prior to the application of a concrete sealer, the structure should be cleaned, existing cracks should be sealed with a flexible sealant, and any spalling repaired. Any sealer chosen for the concrete floodwall should be a water or solvent-based acrylic protective coating, which may be either clear or colored, and may be textured.

Periodic maintenance should be performed on all concrete surfaces to repair deteriorated areas. Repair deteriorated concrete as soon as possible when noted; it is most easily repaired in its early stages. Deterioration can accelerate and, if left unattended, can result in serious problems. Consult an experienced engineer to determine both the extent of deterioration and the proper method of repair. Seal joints and cracks in concrete structures to avoid damage beneath the concrete.

More serious damage such as spalling should be repaired as soon as it is identified, especially if steel reinforcing has been exposed. All surfaces to be patched need to be structurally sound, clean, and free of loose debris, oils, vegetation, paints, sealants, and other contaminants. Remove all deteriorated concrete to a minimum of ¼-inch in depth. Cut edges should be square with the concrete surfaces, and not feathered. Surfaces should be sufficiently rough to ensure a good bond. Any existing reinforcing bars should be thoroughly cleaned. If required, existing concrete should be removed to fully expose the reinforcing bar. Sandblasting may be required to clean them thoroughly. All surfaces should be fully saturated and freestanding excess water should be removed before applying the repair material.

Visible cracking, scaling, or spalling are signs of concrete movement and stresses within the concrete. Cracks in concrete walls that aren't repaired are subject to freeze/thaw damage, which widens the gap and leads to additional spalling of the concrete. When examining any concrete structures, spalling, scaling, or cracking should be very minimal. Figure 5-5 shows various degrees of cracking and spalling.



MINIMALLY ACCEPTABLE

1/8-inch crack extends through concrete and needs to be sealed to prevent further damage.

MINIMALLY ACCEPTABLE

Crack with spalling. The rating for this particular crack is Minimally Acceptable because the crack is still tight, but there is some spalling occurring as well.

UNACCEPTABLE

Exposed rebar. Monolith joint separation with exterior spalling along the joint and interior spalling in the area of the rebar.

Detail of the crack shown on the left, showing the exposed rebar that tied the two monoliths together.

MINIMALLY ACCEPTABLE

Exposed surface rebar resulting from poor construction practices. The rebar has been painted over in an attempt to keep it from rusting.

Figure 5-5: Examples of Concrete Cracking and Spalling



5.4.2 Metal

There may be two or more types of metal components. Galvanized and painted are common metal treatments. Galvanized metal components are galvanized to protect against corrosion. However, if corrosion does form, it should be completely removed with an appropriate method, and the area re-coated with a galvanizing touch-up product.

Any corrosion that forms on painted metal components should be completely removed with an appropriate method, and the area re-coated with paint.

When areas are repainted, ensure that paint does not get on gate seats, wedges, or stems (where they pass through the stem guides), or on other friction surfaces where paint could cause binding. Use heavy grease on surfaces where binding can occur. Because rust is especially damaging to contact surfaces, remove existing rust before the periodic application of grease.

5.4.3 Conduits

Effective repair of a conduit defect such as a crack, open joint or corrosion is difficult, and should not be attempted without approval from the RDSO and SDSO. Careful planning and proper professional supervision is required. The following are guidelines to repairing conduits:

1. When using joint filler, the material used should be impervious to water, and should be flexible throughout the range of expected air and water temperatures.
2. When repairs to the internal surfaces of the conduit are being made, the surface should be made as smooth as possible so that high-velocity flow will not damage the repair material.
3. Hairline cracks in concrete are not generally considered a dangerous problem, and repair is not needed unless leakage or signs of leakage are visible or the crack has a surface width of 0.01-inch or more and extends for a length of 12 inches or more.

Corrosion is a common problem of pipe spillways and other conduits made of metal. Exposure to moisture, acid conditions, or salt will accelerate the corrosion process. In these areas, pipe made of non-corrosive materials such as reinforced concrete or plastic should be used. **Corrugated galvanized steel pipes should not be used to replace existing conduits or for new conduits in FWS dams.**

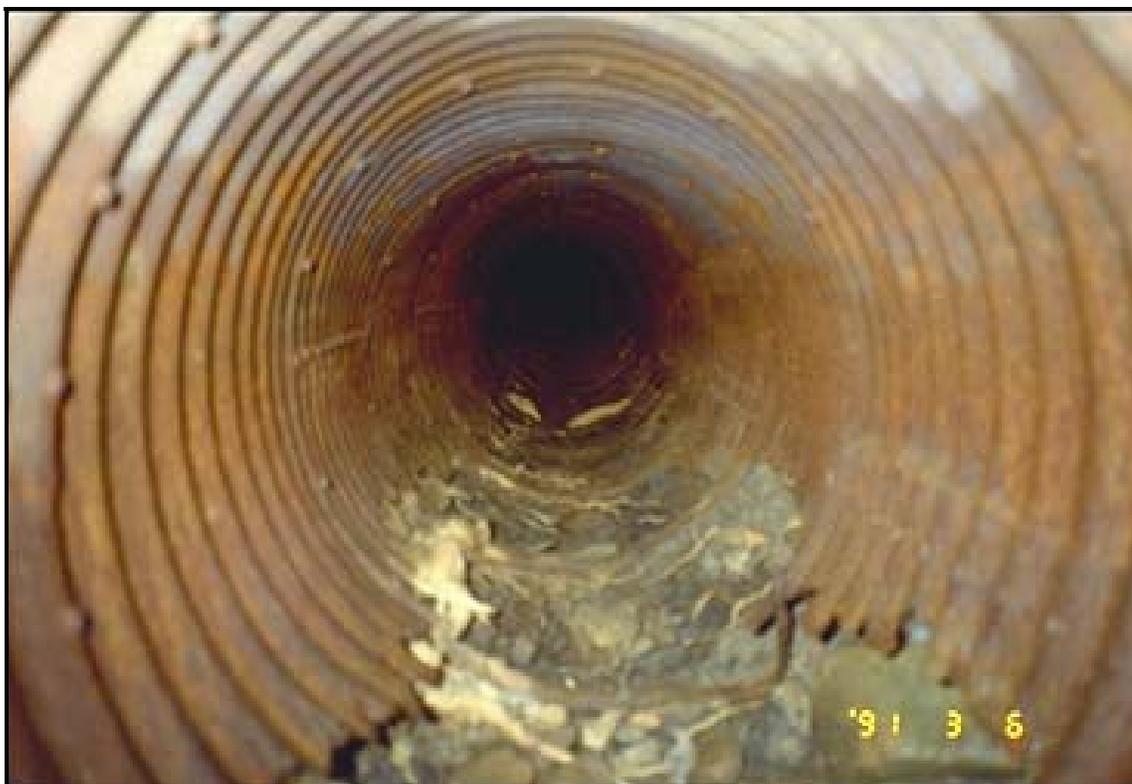


Figure 5-6: Photo of Inside of Corrugated Metal Pipe Showing Corrosion and Deterioration

Metal pipes are available which have been coated to resist accelerated corrosion. Coatings can be of epoxy, aluminum, zinc (galvanized), or bituminous asphalt. Coatings applied to pipes in service are generally not very effective because of the difficulty in establishing a bond.

Corrosion can also be controlled or arrested by installing cathodic protection. A metallic anode such as magnesium is buried in the soil and is connected to the metal pipe by wire. Natural voltage flows from the magnesium (anode) to the pipe (cathode) and will cause the magnesium to corrode and not the pipe.

Erosion at the conduit outlet is a common problem. Severe undermining of the outlet can displace sections of pipe and cause slides in the downstream slope of the dam as erosion continues, and eventually lead to complete failure of a dam.

Eroded and undermined areas at spillway outlets can sometimes be repaired by filling these areas with large stone or riprap. Slush grouting riprap can be used to provide additional erosion protection. In many cases, professional help should be sought for complete redesign and construction of the conduit outlet.

Figures 5-7 and 5-8 show various defects of concrete and metal conduits.



Concrete conduit with severely leaking joints



Concrete conduit with separated joints

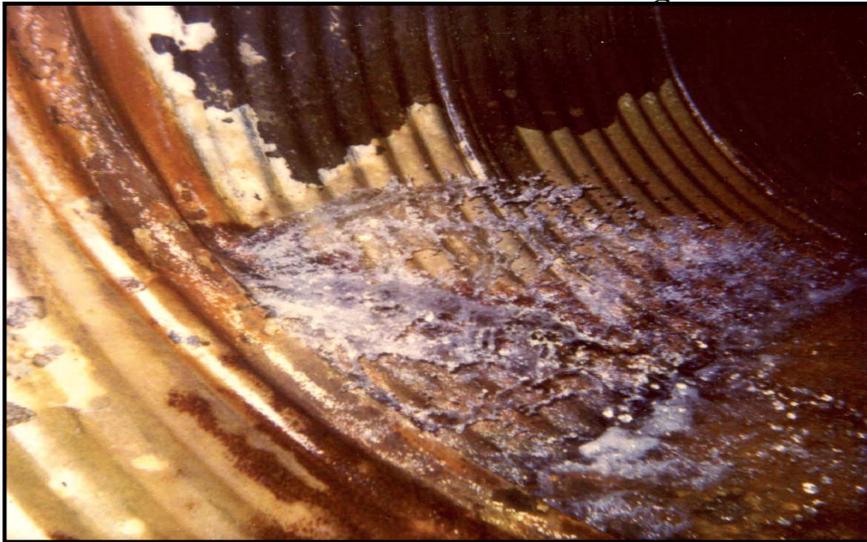


Concrete conduit with crack along top of pipe



Concrete conduit filled with sediment

Figure 5-7: Examples of Concrete Conduit Defects



Metal conduit corroded with severely leaking joints



Metal conduit with seepage along exterior



Deformed corrugated metal conduit



Deformed and broken corrugated metal conduit

Figure 5-8: Examples of Metal Conduit Defects



5.4.4 Trash Racks

A well-designed trash rack will stop large debris that could plug the outlet pipe but allow unrestricted passage of water and smaller debris. Trash racks usually become plugged because the openings are too small, or the head loss at the rack causes material and sediment to settle and accumulate. Small openings will stop small debris such as pine needles, twigs, and leaves, which in turn cause a progression of larger items to build up, eventually completely blocking the inlet. Trashracks should be routinely inspected and accumulated debris removed.

Maintenance should include periodically checking the rack for rusted and broken sections, and repairing as needed. The trashrack should be checked frequently during and after storm events, to ensure it is functioning properly, and to remove accumulated debris.

5.4.5 Embankment Earthwork

The surfaces of an earthen dam may deteriorate for several reasons. Wave action may cut into the upstream slope, vehicles may cause ruts in the crest or slopes, or runoff waters may leave erosion gullies on the downstream slope. Other problems, such as shrinkage cracks or rodent damage, may also occur. Damage of this nature must be repaired continually. The maintenance procedures described below are effective in repairing minor earthwork problems. Conditions such as embankment slides, structural cracking, and sinkholes threaten the immediate safety of a dam and require immediate repair under the direction of a professional engineer and should not be performed without approval of the RDSO and SDSO.

The material selected for repairing embankments depends upon the purpose of the earthwork. Generally, earth should be free from vegetation, organic materials, trash, and large rocks. Most of the earth should be fine-grained soils or earth clods that easily break down when worked with compaction equipment. The intent is to use a material which, when compacted, forms a firm, solid mass, free from excessive voids.

If flow-resistant portions of an embankment are being repaired, materials that are high in clay or silt content should be used. If the area is to be free draining or highly permeable (riprap bedding, etc.), the material should have a higher percentage of sand and gravel. It is usually satisfactory to replace or repair damaged areas with soils similar to those originally in place.

An important soil property affecting compaction is moisture content. Soils that are too dry or too wet do not compact well. One may roughly test repair material by squeezing it into a tight ball. If the sample maintains its shape without cracking and falling apart (which means it is too dry), and without depositing excess water onto the hand (which means it is too wet), the moisture content is probably near the proper level.

Before placement of earth, prepare the repair area by removing all inappropriate material. Clear vegetation such as brush, roots, and tree stumps, along with any large rocks or trash removed. Also, unsuitable earth, such as organic or loose soils, should be removed, so



that the work surface consists of exposed, firm, clean embankment material. Following cleanup, shape and dress the affected area so that the new fill can be compacted and will properly tie into the existing fill. Trim slopes and roughen surfaces by scarifying or plowing to improve the bond between the new and existing fill and to provide a good base to compact against. Grade the slopes in a direction such that the soil ridges are parallel to the length of the dam—this will help to minimize or reduce rill erosion. Roughening in the wrong direction will likely increase rill erosion.

Place soils in loose layers up to 8 inches thick and compacted manually or mechanically to form a dense mass free from large rock or organic material. Maintain soil moisture in the proper range. The fill should be watered and mixed to the proper wetness or scarified and allowed to dry if too wet.

During backfilling, take care that the fill does not become too wet from rainstorm runoff. Direct runoff away from the work area and overflow repair areas so that the fill maintains a crown that will shed water.

Occasionally minor cracks will form in an earthen dam because of surface drying. These are called *desiccation* (drying) cracks and should not be confused with *structural* or *settlement* cracks. Drying cracks are usually parallel to the main axis of the dam, typically near the upstream or downstream shoulders of the crest. These cracks often run intermittently along the length of the dam and may be up to four feet deep.

As a precaution, initially monitor suspected desiccation cracks with the same care used for other types of cracks. The problem area should be marked with survey stakes, and monitoring pins should be installed on either side of the crack to allow recording of any changes in width or vertical offset. Once you are satisfied that observed cracking is the result of shrinkage or drying, you may stop monitoring.



Figure 5-9: Photos Showing Cracks in an Embankment Dam

These cracks should close as climatic or soil moisture conditions change. If they do not, it may be necessary to backfill the cracks to prevent entry of surface moisture, which could result in saturation of the dam. The cracks may be simply filled with earth that is tamped in place with hand or tools. It is also recommended that the crest of a dam be graded to direct runoff waters away from areas damaged by drying cracks.

Repair ruts or settlement on any of the roads. In the event of any repairs, a description of the earthwork, estimated labor and cost, and sketches should be provided to the RDSO to assess the required work.

5.4.6 Animal Damage and Control

Burrowing animals are naturally attracted to the habitats created by dams and reservoirs and can endanger the structural integrity and proper performance of embankments and spillways. The burrows and tunnels of these animals generally weaken earthen embankments and serve as pathways for seepage from the reservoir.

Beavers usually construct their tunnels and dens in the banks surrounding the reservoir or in the dam. The main entrance to a beaver's den is generally 4–10 feet below the normal water level of the reservoir. The tunnel systems become very extensive as the colony grows, and embankment material located above these systems will eventually settle or collapse. Tunnels occasionally extend through a dam where pools of water are allowed to collect along its toe, and provide pathways for water to pass through the embankment.



Common signs of the presence of beaver include gnawed or cut vegetation around the waterline; burrows or sunken or collapsed areas in the crest or slopes of the embankment; and obstructions across spillways and inlets that produce unusual changes in the water level of the reservoir.

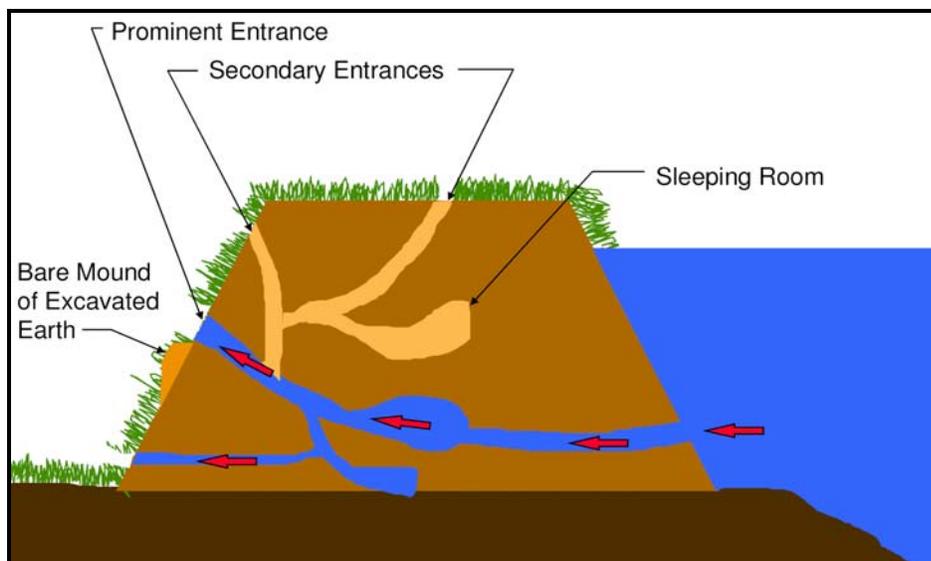


Figure 5-10: Schematic of Animal Burrows In Embankment Illustrating Potential for Developing a Piping Failure

Barriers such as properly constructed riprap and filter layers offer the most practical protection from these animals. When an animal tries to construct a burrow, the sand and gravel of a filter layer will cave in and discourage den building. Filter layers and riprap should extend at least three feet below the waterline. Heavy wire fencing laid flat against a slope and extending above and below the waterline can also be effective. Eliminating or reducing aquatic vegetation along a shoreline will also discourage habitation.

Methods of repairing rodent damage depend upon the nature of the damage but, in any case, extermination of the rodent population, if possible, is the most effective method. If the damage consists mostly of shallow holes scattered across an embankment, repair may be necessary to maintain the appearance of the dam, to keep runoff waters from infiltrating the dam, or to discourage rodents from subsequently returning to the embankment. In these cases, tamping of earth into the rodent hole should be sufficient repair. Soil should be placed as deeply as possible and compacted with a pole or shovel handle.

Large burrows on an embankment should be filled by mud packing. This simple, inexpensive method involves placing one or two lengths of metal stove or vent pipe vertically over the entrance of the den with a tight seal between the pipe and den. A mud-pack mixture is then poured into the pipe until the burrow and pipe are filled with the earth-water mixture. The pipe is removed and more dry earth is tamped into the den.



The mud-pack mixture is made by adding water to a mixture of 90 percent earth and 10 percent cement until a slurry of thin cement is obtained. Plug all entrances with well-compacted earth and reestablish vegetation. Eliminate dens promptly—one burrow can lead to failure of a dam.

Different repair measures are necessary if a dam has been damaged by extensive small rodent tunneling or by beaver, nutria, or muskrat activity. In these cases, it may be necessary to excavate the damaged area down to competent soil and repair. Small rodent activity can be discouraged by flattening the embankment slopes. Embankment with slopes flatter than 7H:1V make tunneling difficult as the tunnels collapse easily from the relatively shallow canopy of overhead earth material.

Occasionally, rodents will dig passages all the way through the embankment that could result in leakage of reservoir water, piping, and ultimate failure. In those cases, do not plug the downstream end of the tunnel since that will add to the saturation of the dam. Tunnels of rodents or ground squirrels will normally be above the phreatic surface with primary entrance on the downstream side of the dam, while those of beaver, nutria, and muskrat normally exist below or at the water surface with entrance on the upstream slope. If a rodent hole extends through the dam, first locate its upstream end. Excavate the area around the entrance and then backfill it with impervious material, plugging the passage entrance so that reservoir water is prevented from saturating the dam's interior. This should be considered a temporary repair. Excavation and backfilling of the entire tunnel or filling of the tunnel with cement grout are possible long-term solutions, but pressure cement grouting is an expensive and sometimes dangerous procedure. Pressure exerted during grouting can cause further damage to the embankment via hydraulic fracturing (an opening of cracks by high-pressure grouting). Thus, grouting should be performed only under the direction of an engineer.

Any animal burrows observed on the dam embankment should be repaired. The burrow should first be assessed to eliminate the possibility of any seepage or piping through or near the burrow. If any seepage or piping is observed, immediately inform the Refuge Manager. The burrow locations should be recorded and the hole should be completely backfilled and compacted. If digging into the slope more than three feet is required to locate the limits of the burrow, inform the RDSO before proceeding.

Included in Appendix E is a comprehensive manual that provides additional information on impacts of animals on earthen dams. This technical manual was prepared specifically for dam owners and discusses 23 wildlife species with regard to their habitat, behavior, threat to dams, and management options. The manual also provides state-of-practice guidance for repair and preventative design associated with nuisance intrusion.

5.4.7 Traffic Damage

Vehicles driving across an embankment dam can create ruts in the crest if it is not surfaced with roadway material. The ruts can then collect water and cause saturation and softening of the dam. Other ruts may be formed by vehicles driving up and down a dam



face; these can collect runoff and cause severe erosion. Vehicles, except for maintenance, should be banned from dam slopes and kept out by fences or barricades. Repair any ruts as soon as possible using the methods outlined in Section 5.4.5. Maintenance vehicles should only travel on the soil and grass portions of the dam when the surface is dry unless necessitated by an emergency.

Any traffic damage that occurs should be handled by Refuge law enforcement authorities. Damage should be assessed and responsibility for repair should be determined. Repair of the damage should be performed by the Refuge.

5.4.8 Riprap

An erosion problem called *benching* can develop on the upstream slope of a dam. Waves caused by high winds can erode the exposed face of an embankment by repeatedly striking the surface just above the pool elevation, rushing up the slope, then tumbling back into the pool. This action erodes material from the face of the embankment and displaces it down the slope, creating a “bench.” Erosion of unprotected soil can be rapid and, during a severe storm, could erode the dam. Figure 5-11 illustrates wave erosion.



Figure 5-11: Example of Wave Erosion and Beaching

The upstream face of a dam is commonly protected against wave erosion and resultant benching by armoring with a layer of riprap on bedding material. Materials such as bituminous or concrete facing, bricks, or concrete blocks have also been used to armor upstream slopes. Protective benches can also be built into the upstream slope of small dams by placing a berm (8–10 feet wide) along the upstream face a short distance below the normal pool level, supplying a surface on which wave energy can dissipate.



Figure 5-12: Riprap Erosion Protection on Upstream Embankment Slope

Benching can occur in existing riprap if the embankment surface is not properly protected by a filter. Water running down the slope under the riprap can erode the embankment. Sections of riprap that have slumped downward are often signs of this kind of benching. Similarly, concrete facing used to protect slopes may fail because waves wash soil from beneath the slabs through joints and cracks. Detection is difficult because the voids are hidden, and failure may be sudden and extensive. Effective slope protection must prevent soil from being removed from the embankment.

When erosion occurs and benching develops on the upstream slope of a dam, repairs should be made as soon as possible. Lower the pool level and prepare the surface of the dam for repair. Have a small berm built across the face of the dam at the base of the new layer of protection to help hold the layer in place. The size of the berm needed depends on the thickness of the protective layer.

A riprap layer should extend a minimum of 3 ft below the lowest expected normal pool level. Otherwise, wave action during periods of low reservoir level will undermine and destroy the protection. If rock riprap is used, it should consist of a heterogeneous mixture of irregular shaped stone placed over gravel bedding. The biggest rock must be large and heavy enough to break up the energy of the maximum expected waves and hold smaller stones in place. (An engineer may have to be consulted to determine the proper size.) The smaller rocks help to fill the spaces between the larger pieces and to form a stable mass. The gravel bedding material prevents soil particles on the embankment surface from being washed out through the spaces between the rocks in the riprap. If the bedding material itself can be washed out through the voids in the riprap, graded layers of bedding



material may be required with the lower layer finer than the top layer.

Riprap should be monitored for deterioration from weathering. Freezing and thawing, wetting and drying, abrasive wave action and other natural processes can break down the riprap material. Maintain a uniform riprap surface. Reposition any riprap that becomes displaced. Replace any riprap that becomes deteriorated or is missing. Remove any vegetation in riprap areas.

5.4.9 Vegetation Control

Keep the entire dam clear of unwanted vegetation such as brush and trees. Growth of brush and trees on an embankment will cause several problems:

- It will obscure the surface of an embankment and prevent a thorough inspection of the dam.
- Large trees can be uprooted by high wind or erosion and leave large holes that can lead to breaching of the dam.
- Some root systems can decay and rot, creating passageways for water, causing erosion or piping of embankment material.
- Growing root systems can lift concrete slabs or structures.
- Trees, brush, and weeds can prevent the growth of desirable grasses.
- Rodent habitats can develop as brush hides the burrows and provides protection.

When brush is cut down, it should be removed to permit a clear view of the embankment. Following removal of large brush or trees, also remove their leftover root systems, if possible, and properly fill and compact the resulting holes. In cases where they cannot be removed, treat root systems with herbicide (properly selected and applied) to retard further growth.

If properly maintained, grass is not only an effective means of controlling erosion, it also enhances the appearance of a dam and provides a surface that can be easily inspected. Grass roots and stems tend to trap fine sand and soil particles, forming an erosion-resistant layer once the plants are well established. Grass is least effective in areas of concentrated runoff or in areas subjected to wave action.

Periodic mowing is essential to maintaining a good ground cover. Mow the grass areas regularly in order to control weeds, remove excessive vegetation, and to prevent the growth of brush, saplings, woody vegetation, or tall brush on:

- upstream slope,
- downstream slope,
- spillway(s),
- diversion structure(s),
- 20 feet from the downstream toe of the dam.



According to the FWS Tree Removal Guidelines, trees growing on the upstream slope that are less than 2 inches in diameter should be cut and treated. Trees growing on the downstream slope that are greater than 2 inches should be removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are less than 6 inches in diameter should be cut and removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are greater than 6 inches in diameter should be removed. A schematic of the FWS Tree Removal Guidelines is included in Appendix F.

Figures 5-13 and 5-14 illustrate unacceptable and acceptable vegetation control on a dam, respectively.



Most of downstream slope is mowed but trees and tall grass remain on slope and at toe of slope.



Downstream slope with trees growing on slopes and waist-high grass making visual inspection nearly impossible



Upstream slope is mowed, but trees and tall grass growing along toe of slope above normal pool reservoir.



Upstream slope with waist-high grass making visual inspection nearly impossible.



Mature trees growing on slopes and knee-high grass, making visual inspection difficult.



Missing vegetation on slope.

Figure 5-13: Examples of Unacceptable Control of Vegetation



Figure 5-14: Examples of Acceptable Control of Vegetation



Long grasses (greater than 12 inches in length) can make a visual inspection nearly impossible and can hide serious concerns such as rodent activity, embankment slides, and cracking; all of which can lead to the failure of the dam. For these reasons, the grass should be mowed to a minimum height of 3 inches. The last mowing of the season should be accomplished under conditions that will allow the grass to grow approximately 8 to 10 inches by the winter season. It's important to ensure that the entire dam has been mowed, including zones extending 20 feet beyond the toe of the embankment, which should be free of all woody growth and should be clear of other obstructions so that a truck could drive beside the dam if need be.

If the dam is mowed at regular intervals, the growth of saplings, trees, and brush will not become a problem. However, if the dam is not mowed regularly, the resulting growth will make it difficult to properly maintain and inspect the project.

Remove all of the roots when removing vegetation. The holes remaining should be backfilled and compacted. Remove any vegetation growing from riprap areas. All trees and brush must be cleared and disposed of away from the dam. The disposal of material on the upstream side of the dam or areas where flood waters can carry the material downstream is prohibited. In riprap protected areas, ditches, or in other areas of the project where power mowing is impractical, the unwanted vegetation should be controlled with an approved herbicide spray or should be cut by hand. According to the FWS Tree Removal Guidelines (See Appendix F), any trees growing on the upstream slope that are less than 2 inches in diameter should be cut and treated. Trees growing on the downstream slope that are greater than 2 inches should be removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are less than 6 inches in diameter should be cut and removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are greater than 6 inches in diameter should be removed. The voids from tree or vegetation removal shall be filled with impervious material, and the fill material firmly compacted and reseeded.

Included in Appendix F is a comprehensive manual that provides additional information on impacts of plants on earthen dams. This technical manual was prepared specifically for dam owners and discusses problems associated with tree and woody vegetation growth impacts on earthen dams, discusses current damage control policies, and provides state-of-practice guidance for remediation designs. Rationale and state-of-practice techniques and procedures for management of desirable and undesirable vegetation on earthen dams is also provided.

5.4.10 Erosion

Erosion is one of the most common maintenance problems at embankment structures. Periodic and timely maintenance is essential to prevent continuous deterioration and possible failure.

Sturdy sod, free from weeds and brush, is an effective means of preventing erosion. Embankment slopes are normally designed and constructed so that surface drainage will



be spread out in thin layers (sheet flow) on the grassy cover. When embankment sod is in poor condition or flows are concentrated at any location, the resulting erosion will leave rills and gullies in the embankment slope. Look for such areas and be aware of the problems that may develop. Eroded areas must be promptly repaired to prevent more serious damage to the embankment. Rills and gullies should be filled with suitable soil (the upper four inches should be topsoil, if possible), compacted, and then seeded. The local Natural Resources Conservation Service office can help select the types of grass to use for protecting dam surfaces. Erosion in large gullies can be slowed by stacking bales of hay or straw across the gully until permanent repairs can be made.



Figure 5-15: Sparse Vegetation and Erosion of Downstream Embankment Slope

Not only should eroded areas be repaired, but the cause of the erosion should be found to prevent a continuing maintenance problem. Erosion might be caused or aggravated by improper drainage, settlement, pedestrian traffic, animal burrows, or other factors. The cause of the erosion will have a direct bearing on the type of repair needed.

Paths due to pedestrian, livestock, or vehicular traffic (two- and four-wheeled) are a problem on many embankments. If a path has become established, vegetation will not provide adequate protection and more durable cover will be required unless traffic is eliminated. Small stones, asphalt, or concrete may be used effectively to cover footpaths. All vehicular traffic, except for maintenance, should be prohibited from the dam.

Erosion is also common at the point where an embankment and the concrete walls of a spillway or other structure meet. Poor compaction adjacent to such a wall during



construction and subsequent settlement can result in an area along the wall that is lower than the grade of the embankment. Runoff, therefore, often concentrates along these structures, resulting in erosion. People also frequently walk along these walls, wearing down the vegetative cover. Possible solutions include regarding the area so that it slopes away from the wall, adding more resistant surface protection, or constructing wooden steps.

Adequate protection against erosion is also needed along the contact between the downstream face of an embankment and the abutments. Runoff from rainfall can concentrate in gutters constructed in these areas and can reach erosive velocities because of relatively steep slopes. Berms on the downstream face that collect surface water and empty into these gutters add to the runoff volume. Sod surfaced gutters may not adequately prevent erosion in these areas. Paved concrete gutters may not be desirable because they do not slow the water and can be undermined by erosion. Also, small animals often construct burrows underneath these gutters, adding to the erosion potential.

A well-graded mixture of rocks up to 9–12 inches in diameter (or larger), placed on a layer of gravel (which serves as a filter), generally is the best protection for these gutters on small dams. Riprap covered with a thin concrete slurry has also been successful in preventing erosion on larger dams, and should be used if large stone is not available.

As with erosion around spillways, erosion adjacent to gutters results from improper construction or a poor design in which the finished gutter is too high with respect to adjacent ground—preventing much of the runoff from entering the gutter. Instead, the flow concentrates along the side of the gutter, eroding and potentially undermining it.

Care should be taken when replacing failed gutters or designing new gutters to assure that:

- The channel has adequate capacity.
- Adequate erosion protection and a satisfactory filter have been provided.
- Surface runoff can easily enter the gutter.
- The outlet is adequately protected from erosion.

A serious erosion problem, which can develop on the upstream slope, is “beaching.” Waves caused by winds or high-speed powerboats can erode the exposed face of the embankment. Waves repeatedly strike the surface just above the pool elevation, rush up the slope, then tumble downward into the pool. This action erodes material from the face of the embankment and displaces it farther down the slope, creating a “beach.” Erosion of unprotected soil can be rapid, and during a severe storm could lead to complete failure of a dam.



The upstream face of a dam is commonly protected against wave erosion and resultant beaching by placement of a layer of rock riprap over a layer of gravel bedding material. This provides an armored surface on which the wave energy can dissipate.

Beaching can also occur in existing riprap if a filter does not properly protect the embankment surface. Water running down the slope under the riprap can erode the embankment. Sections of riprap slumped downward are often signs of beaching. Concrete facing used to protect slopes often fails because the wave action washes soil particles from beneath the slabs through joints and cracks. Detection, in this case, is difficult because the voids are hidden and failure may be sudden and extensive. Effective slope protection must prevent soil particles from being removed from the embankment.

When erosion occurs and beaching develops on the upstream slope of a dam, repairs should be made as soon as possible. The pool level should be lowered and the surface of the dam prepared for replacing the slope protection. A small berm or "bench" should be made across the face of the dam to help hold the protective layer in place. The bench should be placed at the base of the new layer of protection. Depth of the bench will depend on the thickness of the protective layer.

The layer should extend a minimum of 3 feet below the lowest anticipated pool level. Otherwise, wave action during periods when the reservoir level is drawn down can undermine and destroy the protective layer. Figure 5-16 illustrates the proper configuration to minimize or eliminate beaching.

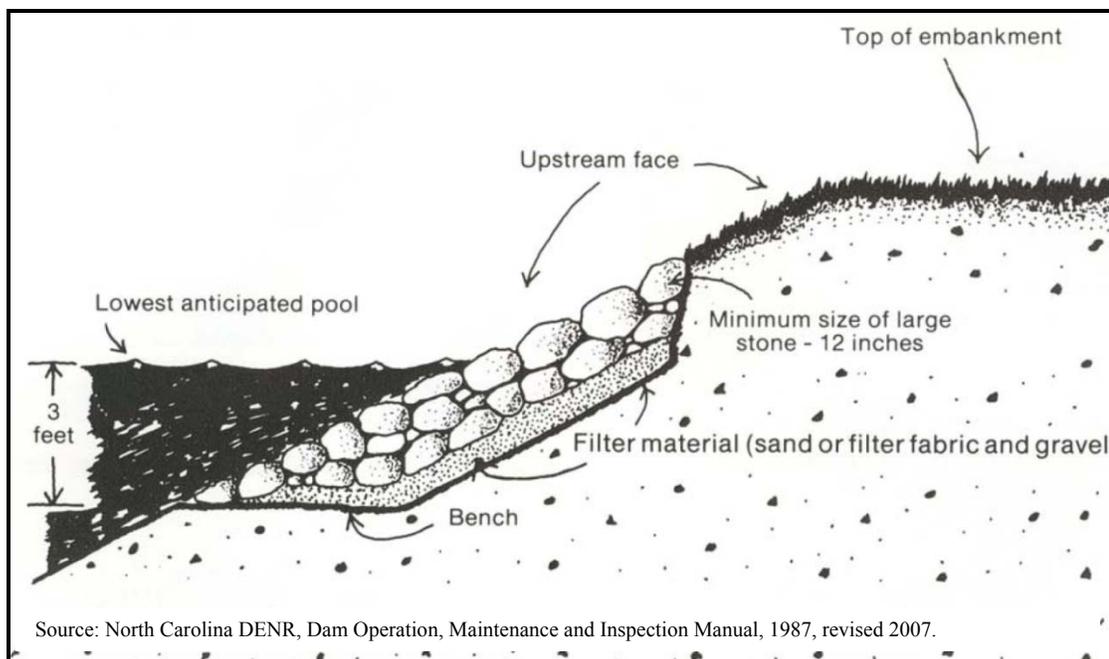


Figure 5-16: Typical Beaching Protection Detail for the Upstream Slope of an Embankment Dam



If rock riprap is used, it should consist of a heterogeneous mixture of irregular shapes placed over a sand or geotextile and gravel filter. The maximum rock size and weight must be large enough to break up the energy of the maximum anticipated wave action and hold the smaller stones in place. Generally, the largest stones should be at least 12 inches in diameter. The smaller rocks help to fill the spaces between the larger pieces, forming a resistant mass. The gravel bedding prevents soil particles on the embankment surface from being washed out through the spaces (or voids) between the riprap.

5.4.11 Reservoir Sedimentation

Erosion and sedimentation are natural processes in which soil particles are detached from the earth by rain drops or flowing water and carried away by streamflow. The velocity of the flowing stream carries the sediment load. When streams enter reservoirs, their velocities suddenly drop and the sediment load is deposited on the bottom of the reservoir. Typically, about 90-percent of the sediment load carried by incoming streams is deposited in the reservoir.

Sedimentation rates vary widely and depend on many factors of the watershed areas. Among these are soil type, land cover, land slope, land use, stream slope, size of watershed, total annual precipitation, number and intensity of severe storm events, material in the streambed, and volume of the reservoir with respect to size of the drainage area. Sediment deposits first become apparent when deltas build up at the mouths of streams entering the reservoir. Aquatic vegetation, such as cattails and lily pads, soon develops in the shallow water over these deltas. As sediment deposition continues, the delta will rise above the normal water surface. The best way to avoid sediment problems is to reduce erosion and disturbances in the watershed area.

5.4.12 Mechanical

Mechanical equipment includes spillway gates, sluice gates or valves, stoplogs, sump pumps, flashboards, relief wells, emergency power sources, siphons and other equipment associated with spillways, drain structures, and water supply structures. Mechanical and associated electrical equipment should be checked for proper lubrication, smooth operation, vibration, unusual noises, and overheating.

Many dams have structures above and below ground that require some type of access. Water supply outlet works, reservoir drains, gate spillways, drop box spillways, and toe drain manhole interceptors are typical structures that will require bridges, ladders, or walkways. Care should be taken to properly design, install, and maintain these means of access for the safety of persons using them. State and local safety codes should be followed. Requirements for walkways may include toe plates and handrails. Fixed ladders should have proper rung spacing and safety climbing devices, if necessary. Access ladders, walkways, and handrails should be examined for deteriorated or broken parts or other unsafe conditions.

Gate stems and couplings should be examined for corrosion, broken or worn parts, and damage to protective coatings. Fluidways, leaves, metal seats, guides, and gate and valve



seals should be examined for damage due to cavitation, wear, misalignment, corrosion, and leakage. Sump pumps should be examined and operated to verify reliability and satisfactory performance. Air vents for pipes, gates and valves should be checked to confirm that they are open and protected. Wire rope or chain connections at gates should be examined for proper lubrication and worn or broken parts. Rubber or neoprene gate seals should be examined for deterioration, cracking, wear, and leakage. Hydraulic hoists and controls should be checked for oil leaks and wear. Hoist piston and indicator stems should be examined for contamination and for rough areas that could damage packings.

For satisfactory operation, a gate stem must be maintained in proper alignment with the gate and hoisting mechanism. Proper alignment and support are supplied by stem guides in sufficient number and properly spaced along the stem. Stem guides are brackets or bearings through which a stem passes. They prevent lateral movement of the stem and bending or buckling when a stem is subjected to compression as a gate is closing.

The alignment of a stem should be checked during routine inspections by sighting along the length of the stem, or more accurately by dropping a plumb line from a point near the top of the stem to the other end. The stem should be checked in both an upstream–downstream direction as well as in a lateral direction to ensure straightness. While checking alignment, all gate stem guide anchors and adjusting bolts should be checked for tightness. A loose guide provides no support to the stem and could cause it to buckle at that point.

If, during normal inspection, the stem appears out of alignment, the cause should be remedied. Completely lower the gate and take all tension or compression off the stem. Loosen any misaligned stem guides and make them move freely. Then operate the hoisting mechanism so as to put tension on the stem, thereby straightening it, but do not open the gate. Then align and fasten the affected guides so that the stem passes exactly through their centers.

5.4.13 Electrical

Electricity is typically used at a dam for lighting and to operate outlet gates, spillway gates, recording equipment, and other miscellaneous equipment.

It is important that an electrical system be well maintained, including a thorough check of fuses and a test of the system to ensure that all parts are properly functioning. The system should be free from moisture and dirt, and wiring should be checked for corrosion and mineral deposits. Carry out any necessary repairs as soon as possible, and keep records of the work. Maintain generators used for auxiliary emergency power; change the oil, check the batteries and antifreeze, and make sure fuel is readily available.

The adequacy and reliability of the power supply should also be checked during operation of the equipment. Auxiliary power sources and remote control systems should be tested for adequate and reliable operation. All equipment should be examined for damaged, deteriorated, corroded, loose, worn, or broken parts.



There is no regularly scheduled maintenance for the electrical components at the dam. Electrical repairs should be performed by a certified electrician.

5.4.14 Access Roads

The safe operation of a dam depends on reliable and safe means of access. Usually this involves maintaining a road to the dam. The road should be of all-weather construction, suitable for the passage of automobiles and any required equipment for servicing the dam. Cut-and-fill slopes, both uphill and downhill from the road, should be stable under all conditions. The road surface should be located above the projected high-water elevations of any adjacent streams and the reservoir pool, so access can be maintained at times of flooding.

5.4.15 Vandalism

Vandalism is a common problem faced by dam owners. Particularly susceptible to damage are the vegetated surfaces of the embankment, mechanical equipment and riprap. Theft of manhole covers, gratings, aluminum stoplogs and other removable metal items is a growing problem. Precautions should be taken to limit access to the dam by unauthorized persons and vehicles.

Dirt bikes (motorcycles) and four-wheel drive vehicles can severely damage the vegetation on embankments. Worn areas could lead to erosion and more serious problems. Constructed barriers such as fences, gates, and cables strung between poles are effective ways to limit access of these vehicles. Boulders or a highway metal guardrail constructed immediately adjacent to the toe of the downstream slope is an excellent means for keeping vehicles off embankments. However, these features may interfere with the operation of mowing equipment.

Mechanical equipment and its associated control mechanisms should be protected. Buildings housing mechanical equipment should be sturdy, have protected windows, have heavy-duty doors, and should be secured with deadbolt locks or padlocks. Detachable controls such as handles and wheels should be removed when not in use and stored inside. Other controls should be secured with locks and heavy chains, where possible.

Rock used as riprap around dams is often thrown into the reservoir, spillways, stilling basins, pipe spillway risers, and elsewhere. Riprap is often displaced by fishermen to form benches. The best way to prevent this abuse is to use rock too large and heavy to move easily or to slush grout the riprap. Otherwise, the rock must be constantly replenished and other damages repaired.

Owners should be aware of their responsibility for public safety, including the safety of people not authorized to use the facility. "No Trespassing" signs should be posted and fences and warning signs should be erected around dangerous areas.



CHAPTER 6

EMERGENCY ACTIONS TO PREVENT A DAM FAILURE OR MINIMIZE EFFECTS OF FAILURE

6.1 Common Causes of Dam Incidents and Failures

Understanding the risks and reasons for dam incidents including failure is a first step in any effort to improve dam safety, prevent a dam failure, or minimize the effects of failure. Dam failures are usually the result of poor design, improper construction, improper operation, inadequate maintenance, deterioration from aging, or a combination of these factors. The fundamental causes of dam incidents and their relative percentage of occurrence is summarized in Table 6-1.

Table 6-1
Causes of Dam Incidents

<u>Cause</u>	<u>Percentage</u>
Earthquake Instability	1
Faulty Construction	2
Gate Failure	2
Sliding	10
Embankment Deformation	11
Spillway Erosion	14
Overtopping	25
Seepage/Piping	35

Natural hazards such as floods, earthquakes, and landslides are important contributors to dam incidents. The most important natural hazards threatening dams are floods. Human behavior is another element of dam failure risk; simple mistakes, operational mismanagement, negligence, unnecessary oversights, or destructive intent can interact with other hazards to compound the possibility of failure.

Flood fighting is an art, and can be extremely difficult to execute. There is no absolute method that one can apply to guarantee success. However, failure to react in a timely manner and apply proven flood fighting techniques greatly increases the risk of failure. Although each flood is unique, there are many common elements from one flood to the next, and plans and preparations will improve your response time and success.

The action to be taken upon the discovery of a potentially unsafe condition will depend on the nature of the problem and the time estimated to be available for remedial or mitigation measures. As time permits, one or more of the following actions will be required:



1. **Notification of RDSO and SDSO.** This is essential, if time permits, since development of failure could vary in some or may respects from previous forecasts or assumptions, and advice may be needed.
2. **Initiation of Remedial Action.** It is recommended that at least one technically qualified individual, previously trained in problem detection, evaluation, and remedial action, be at the project or on call at all times. Depending on the nature and seriousness of the problem and the time available, emergency actions can be initiated.

6.2 Identifying and Understanding Emergency Conditions

Refuge personnel should be knowledgeable of the potential problems which can lead to dam failure. In an emergency situation, various individuals may be involved in the decision-making process. If a problem is noted early, the RDSO and SDSO can be contacted to recommend and help implement corrective measures. If there is any question as to the seriousness of an observation, the RDSO should be contacted. Acting promptly may avoid a possible dam failure.

Since only superficial inspections of a dam can usually be made, it is important that Refuge personnel be aware of the prominent types of failures and their revealing signs. The manner in which a dam fails and the particular causes of failure are usually varied, multiple, complex, and interrelated. However, failure modes may be divided into three general categories.

6.2.1 Embankment Overtopping

Overtopping failures result from the erosive action of water overtopping the embankment. Erosion is due to the uncontrolled flow of water over, around and adjacent to the dam. Earth embankments are generally not designed to be overtopped and therefore are particularly susceptible to erosion. Once erosion has begun during overtopping, it is almost impossible to stop. A well vegetated earth embankment may withstand limited overtopping if its top is level and water flows over the top and down the face as an evenly distributed sheet without becoming concentrated.



Figure 6-1: Dam Overtopping During a Flood



6.2.2 Structural Failure

Structural failures can occur in either the embankment or the appurtenances such as spillways or low-level outlets. Structural failure of a spillway, reservoir drain or other appurtenance may lead to failure of the embankment. Cracking, settlement, instability and slides are the most common signs of structural failure of embankments. Large cracks in either an appurtenance or the embankment, major settlement, or sliding require emergency measures to ensure safety, especially if these problems occur suddenly.



Figure 6-2: Structural Failure of a Concrete Spillway from Uncontrolled Seepage and Uplift Pressures Developing Under the Structure

6.2.3 Uncontrolled Seepage and Piping

All earth dams have seepage resulting from water percolating slowly through the dam and its foundation. Seepage must, however, be controlled in both velocity and quantity. If uncontrolled, it can progressively erode soil from the embankment or its foundation, resulting in potential rapid failure of the dam. Erosion of the soil begins at the downstream side of the embankment, either in the dam proper or the foundation, progressively works toward the reservoir, and eventually develops a “pipe” or direct conduit to the reservoir. This phenomenon is known as “piping”. Piping action can be recognized by an increased seepage flow rate, the discharge of muddy or discolored water, sinkholes at or near the embankment, and a whirlpool in the reservoir. Once a whirlpool (eddy) is observed on the reservoir surface, complete failure of the dam will probably follow. As with overtopping, fully developed piping is difficult to control and will likely cause failure if not arrested.

Seepage can cause slope failure by creating high pressures in the soil pores or by saturating the slope. When soil saturation occurs, the slope loses stability and cannot support its own weight. A slope which becomes saturated and develops slides may be showing signs of excess seepage pressure. Slope failures have occurred during prolonged periods of high water or heavy rainfall, and can lead to serious problems. The pressure of seepage within an embankment is difficult to determine without proper instrumentation.



Figure 6-3: Photo of a Small Whirlpool and Sinkhole on Upstream Slope Below Reservoir Level

The classic signs of slope stability problems are listed below, and you should watch for these signs during routine inspections:

1. Wide deep cracks that parallel the dam crest. These cracks may also extend down the slope.
2. Vertical movement of the material along the crack. Remember that this movement may be very obvious or very subtle if the stability problem is just starting to develop.
3. If the slope has slumped or is starting to slump, examine the area along the toe of the embankment. In many cases there will be a noticeable bulge in the slope.

Deep seated sliding often requires the removal and replacement of that section of the dam, and the stabilization of the area with a soil or rock berm. If you identify signs of a developing slope stability problem, it is very important that you contact the RDSO immediately.



Figure 6-4: Photos Showing Examples of Downstream Slope Instability and slides on Embankment Dams



Underseepage can produce three distinctly different effects on a dam, depending upon the condition of flow under the dam.

6.2.3.1 Piping Flow

Erosion can occur underground if there are cavities, cracks in rock, or other openings large enough so that soil particles can be washed into them and transported away by seeping water. When this type of underground erosion progresses and creates an open path for flow, it is called “piping.” In extreme conditions of excessive underseepage, the movement of seepage water erodes the foundation materials, and a clearly defined pipe or tube develops within the embankment dam. Unless corrective actions are taken, water continues to erode and enlarge this pipe, so that a cavern develops within the dam, and dam material collapses to fill in the void. In an advanced state, piping under the dam can be identified by a slumping of the dam crown, and the dam can quickly fail if it’s overtopped through this low spot. To prevent this condition from developing, any boils found to be transporting soil material need to be treated as early as possible.

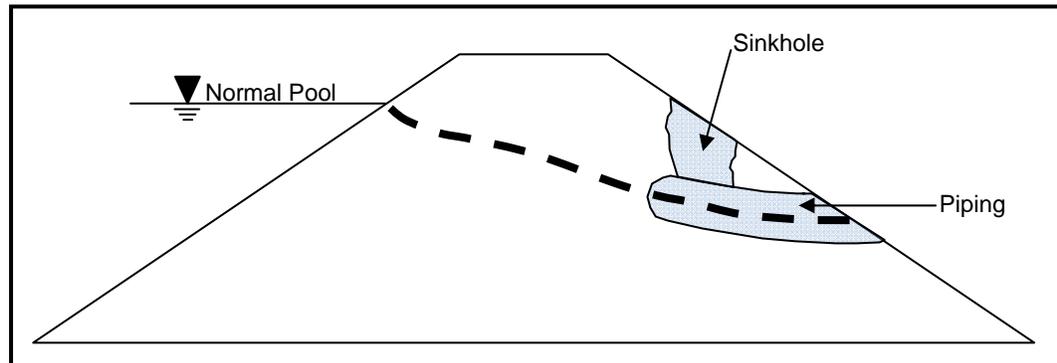


Figure 6-5: Depiction of Piping In An Embankment

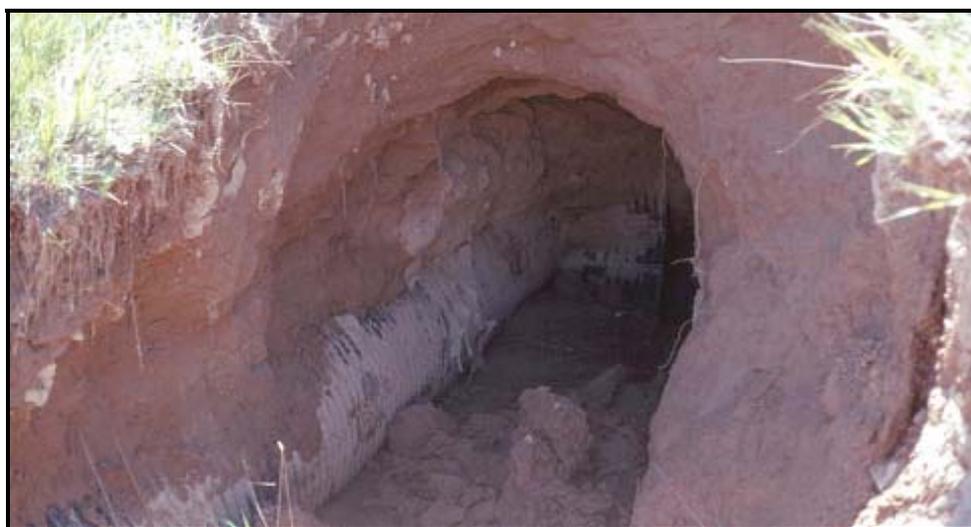


Figure 6-6: Photo Showing Example of a Piping Failure Along an Outlet Conduit



Figure 6-7: Photo Showing Example of Piping Failure Along an Outlet Conduit

6.2.3.2 *Non-Piping Flow*

In this case, seepage water flows under the dam without following a well-defined path, and results in one or more boils outcropping at or near the downstream toe. The flow from these boils tends to undercut and ravel the downstream toe, resulting in sloughing of the downstream slope. Sloughing is the movement of small amounts of soils from the embankment slopes. Sloughing may also occur if the dam embankment becomes saturated as a result of prolonged high reservoir stages (see Figure 6-4).

6.2.3.3 *Saturating Flow*

In this case, numerous small boils, many of which are scarcely noticeable, outcrop at or near the downstream toe. While no boil may appear dangerous in itself, a group of boils may cause significant damage. The flowing water may erode away supporting material and/or keep the area saturated and cause flotation ("quickness") of the soil, reducing the shearing strength of the material at the toe (where maximum shearing stress occurs) which could lead to slope failure. In a slope failure condition, a substantial section of the dam embankment breaks away along a clearly defined crack and slides away from the dam. The displacement of the soil will result in a reduction in the cross sectional area of the dam and poses a major threat to the integrity of the structure.



Figure 6-8: Examples of Uncontrolled Seepage on Downstream Slopes of Embankment Dams



The three types of failure previously described are often interrelated in a complex manner. For example, uncontrolled seepage may weaken the soil and lead to a structural failure. A structural failure may shorten the seepage path and lead to a piping failure. Surface erosion may result in structural failure.

Most embankment failures from piping occur along outlet conduits where compaction of the fill material is difficult.

6.3 Resources and Procedures for Making Temporary Emergency Measures

6.3.1 Responding to an Emergency Situation

After making appropriate notifications to the RDSO of the changing dam conditions, the Refuge Manager should initiate efforts to prevent or delay failure of the dam. Any repair work to prevent the dam from failure should be undertaken only if working conditions are safe. Because of the likely limitation on time, it is important to identify available resources quickly. Any emergency repair will require equipment, materials, labor and expertise. If feasible, materials such as clay fill, sand, gravel, stone, riprap, sandbags, cement, plastic sheeting, geotextile, etc. and equipment for handling these materials should be kept at the site. If this is not possible, then prior identification and arrangements of locally available off-site materials and equipment should be made along with a current list of local contractors and other sources of labor and equipment.

When reporting a dam incident to the RDSO, remember that when locating problem areas, all directions, e.g., “left of,” or “right from,” are taken while facing downstream. Items that should be reported include:

1. Name of the dam and its locations.
2. Nature of the problem (e.g., excessive leakage, cracks, sand boils, slides, wet spots, etc.).
3. Location of problem area in terms of embankment height, (e.g., about 1/3 up from the toe) and location along the dam’s crest (e.g., 100 feet to the right of the outlet or abutment) and whether on the upstream slope, crest, or downstream slope.
4. Extent of the problem area. This can be satisfactorily established by pacing.
5. Estimated quantity of unusual flows as well as whether the water is clear, cloudy, or muddy.
6. Water level in the reservoir below the dam’s crest or below the spillway, or the staff gage reading.
7. Is water level in reservoir rising or falling?
8. Name and how to contact person making report.
9. Did the situation appear to be worsening while being observed for this report?



10. Does the problem appear to be a containable problem at this time or is it an emergency situation?
11. What are current weather conditions at the site?
12. Digital photos showing the condition are helpful.
13. Anything else that seems important.

Temporary repair of appurtenant structures will depend on the nature of the problem. Permanent repairs must be made in accordance with plans developed by a professional engineer with experience in dam design.

The following descriptions of possible actions to take to avoid failure are offered. Caution must be exercised by those working around the dam during the implementation of any of these emergency measures.

6.3.2 Lowering the Reservoir

One of the first considerations in an emergency situation is to lower the reservoir in order to stop or reduce seepage and its effects, or prevent overtopping of the dam. Lowering the reservoir reduces the hydraulic head producing the seepage and will have an immediate impact on serious seepage problems. For this reason, outlet works and other control structures should always operate properly. Current practice is to consider the need for emergency drawdown in sizing the capacity of outlet work facilities. For existing dams, the drawdown capability and downstream consequences of large releases should be considered.

If the reservoir cannot be lowered fast enough through outlet works or other control structures, a “controlled” breach of an earth dam can be accomplished to speed the process. The controlled breach should be a location that would produce the least damage downstream from the released reservoir water. It is important to remember that a controlled breach is a dangerous operation that can quickly become out of control.

When deciding whether to quickly lower the reservoir, consider these factors:

1. The effects on the purpose(s) of the reservoir/dam
2. The potential for instability of the upstream slope of the existing embankment from rapid drawdown, and
3. The potential damage downstream because of higher-than-normal discharges.

These factors may be secondary, however, when a dam failure is imminent.

In some cases, if the reservoir is small and the dam is not equipped with a low-level outlet or the low-level outlet is inoperable, pumps or siphons can be used to lower the reservoir. A technical paper prepared by the Pennsylvania Department of Environmental Protection, Division of Dam Safety that provides detailed information on how to



construct a temporary siphon to drain or lower a small reservoir is presented in Appendix G.

6.3.3 Whirlpools in the Reservoir

A whirlpool in the reservoir is a serious condition because it is caused by flow through a channel in or under the dam that can enlarge until the dam is breached. The reservoir should be lowered as rapidly as possible. Attempts can be made to plug the entrance of the whirlpool with riprap, sandbags, plastic sheeting or other available coarse fill materials. If the plug attempt decreases the flow, add progressively smaller material such as gravel, sand, etc. If the whirlpool is due to an animal burrow, it may be possible to plug the burrow by placing a mixture of soil and straw or dry hay into the water at the burrow entrance. Efforts should be made to locate the exit point downstream and attempt to construct a ring dike or filter berm to retard the removal of material (see Section 6.3.4 – Active Boils).



Figure 6-9: Photo of a Whirlpool on the Upstream Slope of an Embankment Dam

6.3.4 Active Boils

A boil is an artesian condition usually near the toe of the dam or in the exit channel. An active boil is a boil that is actively upwelling sandy or muddy water. Sandboils usually occur within 10 to 300 feet from the downstream toe of the dam and, in some instances,



have occurred up to 1,000 feet away. Boils often will have an obvious exit, such as a rodent hole, but the hole may be very small. When material is carried upward through a boil, it is deposited in a circular pattern around the exit location, and is comparable to an ant hill or volcano. Alternately, sandboils may exit into standing water. In this case, they may be difficult to identify, especially if the hole is small and the water cloudy from siltation. If you see any movement in what appears to be standing water on the landward side of the structure, this may be the exit point for a sandboil. Carefully approach the site, disturbing the water as little as possible, and let the water settle in order to look for the exit point. All boils should be conspicuously marked with flagging and named so that they can be easily located and observed for changes in their condition.



Figure 6-10: Sandboil at the Toe of an Embankment Dam

Water that flows from a boil can transport material from the dam and may lead to a piping condition and failure of the dam. A boil that discharges clear water with a constant discharge may not be an immediate threat to the safety of the dam. Continuous observation of the boil is recommended until it is determined that the condition is stable and safe. If the flow from the boil is increasing and is muddy or is transporting sand, corrective action should be taken immediately.

If it is determined that the boil is a threat to the safety of the dam, the first step is to begin lowering the reservoir. Effective corrective actions can include either sandbagging the



area around the boil to create an enclosure and backpressure over the boil, or constructing a filtered drainage berm over the boil.

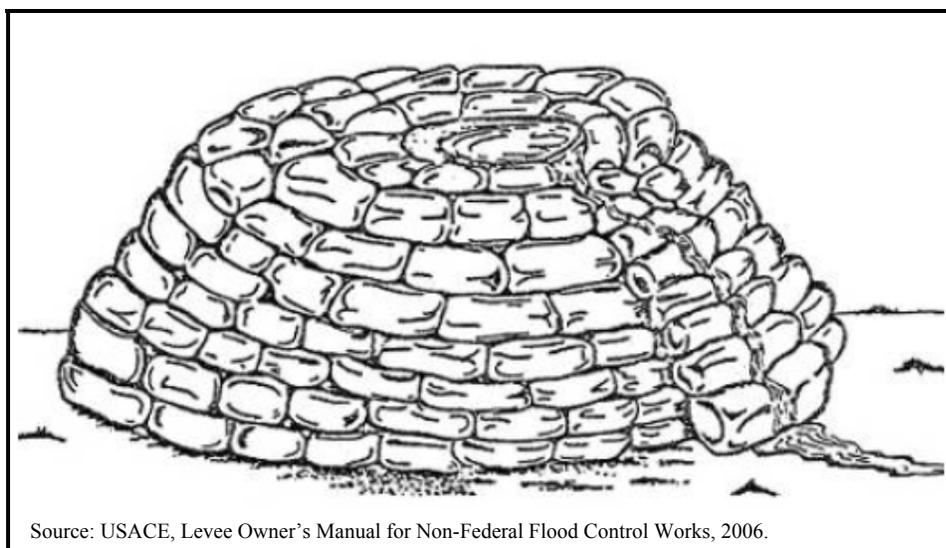


Figure 6-11: Filtered Drainage Berm at Toe of an Embankment Dam

If a ring dike is constructed around the boil, it should not be built too high or it can develop new boils outside of the affected area. The primary objective is to prevent the loss of embankment material with the seepage. The purpose of the ring is to raise a head of water over the boil to counterbalance the upward pressure of the seepage flow. The height of the water column is adjusted so that the water exiting the boil runs clear and no longer removes soil from the dam foundation. It is important that the flow of water is not stopped completely, as this may cause additional boils to break out nearby. Treated areas should be kept under constant surveillance until the water recedes. Sandbag rings are the most common method of constructing ring dikes, however concrete well rings, short pieces of large diameter pipe, earth berms, sheet piling, etc., can also be used. A sandbag ring levee around a boil is illustrated in Figures 6-12 and 6-13.



Figure 6-12: Sandbag Ring Levee Around a Boil at the Downstream Toe of an Embankment Dam



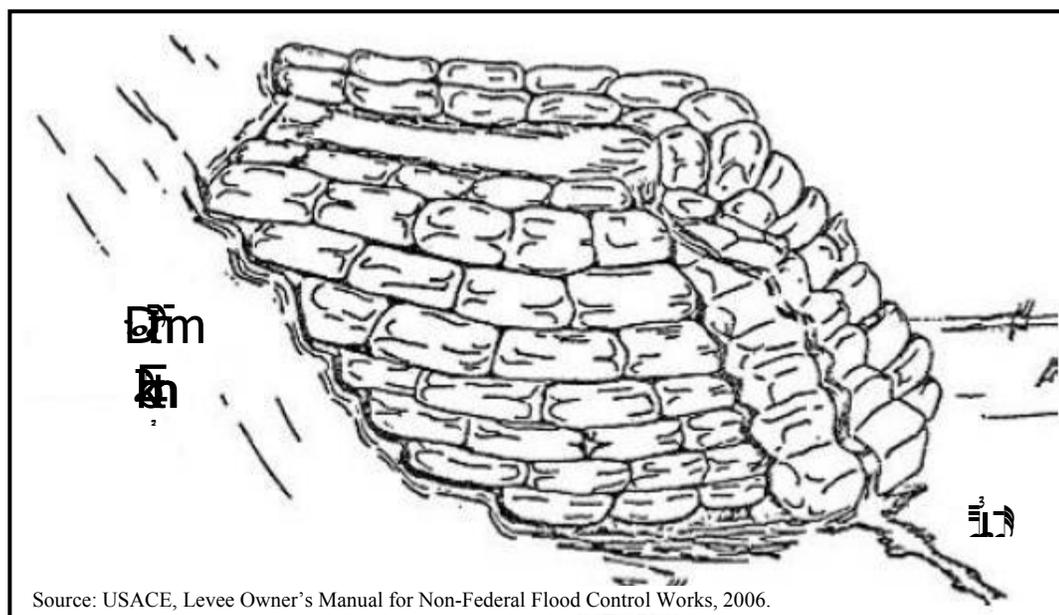
Source: USACE, Levee Owner's Manual for Non-Federal Flood Control Works, 2006.

Figure 6-13: Sketch of a Typical Ring Levee with Spillway

The diameter and height of the ring will depend on the actual conditions at each sandboil. The base width should be at least $1\frac{1}{2}$ times the contemplated height, and the inner ring of sandbags should begin between one and three feet from the outer edge of the sandboil. "Weak" or "quick" ground near a boil should be included within the sack ring to prevent these areas from developing into new boils when the active boil is treated. Where several sandboils develop in a localized area, a ring dam of sandbags should be constructed around the entire area. The ring should ideally be of sufficient diameter to permit sacking operations to keep ahead of the flow of water. When a sandboil is located near the dam



toe, the sandbag ring may be tied into the downstream slope of the dam, as shown in Figure 6-14.



Source: USACE, Levee Owner's Manual for Non-Federal Flood Control Works, 2006.

Figure 6-14: Sketch of Ring Levee Tied to the Downstream Slope of the Dam

The base or foundation for the sandbag ring should be cleared of debris and scarified to provide a reasonably watertight bond between the ground surface and the sandbags. The ring should be constructed with sacks filled approximately two-thirds ($\frac{2}{3}$) full of sand, and tamped firmly into place. Do not tie the ends of the sacks. When adding subsequent layers, the joints should be staggered for stability and water tightness. The untied ends of sandbags should be laid towards the inside of the ring and folded under.

A spillway or exit channel should be constructed on the top of the sack ring so that the level of the water in the ring dam can be adjusted, and the overflow water can be carried a safe distance from the boil, away from the direction of the dam. Because the height of the water is the critical factor in adjusting the rate of flow through the boil, the spillway will require constant monitoring and adjustment once the sandbag ring dam is filled with water. This spillway is normally constructed of sandbags, but alternately, a V-shaped drain can be constructed of two boards (See Figure 6-15); or PVC pipe, plastic sheeting, or other materials may be helpful in building the spillway.



Figure 6-15: Photo of Sandbag Levee with V-notch Weir Outlet to Monitor Changes in Seepage

An alternate method of ringing sandboils is by use of corrugated sheet-steel piling, as shown in Figure 6-16. The area is cleared of debris, and the piling is driven about 1½ feet into the ground around the boil. This method accomplishes the same task faster than sandbagging, but is limited in use by the availability of material, equipment, and the location and foundation condition of boils. Expedient methods can be improvised in other ways, to include using sections of corrugated metal piping. Special care must be taken with the design of these structures to make sure there is a reliable means for adjusting the water level, so the water column doesn't completely stop the flow of water through the boil.

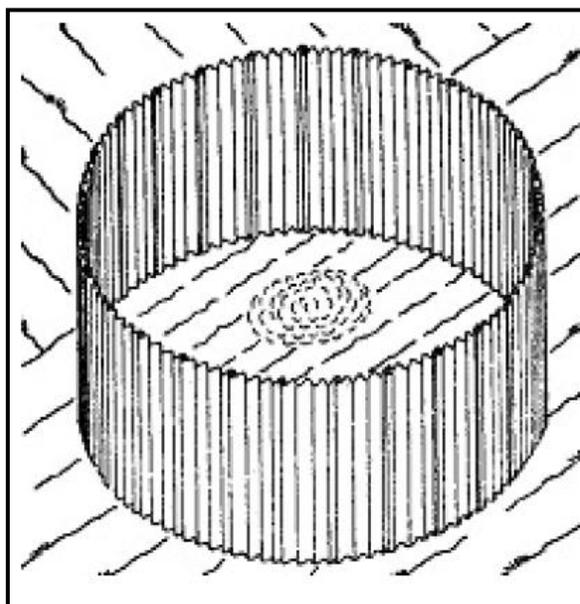


Figure 6-16: Illustration of a Ring of Corrugated Sheet Steel Piling to Encircle a Boil

Alternately, it may sometimes be possible to locate the inlet side of a boil under the water on the upstream slope of the dam. A swirl may be observed in the water at this point, or the location of the entry point may have been identified after a previous high water event.



If the opening is located, it may be possible to block the seepage flow at its entry point, since blocking the entry point may take much less time than constructing a sandbag ring dam. If the entry point is blocked, both the blockage and the location of boil need to be closely monitored for any changes (see Section 6.3.3 - Whirlpools in the Reservoir).

A geotextile covered by coarse aggregate may also be used as a filter to prevent the loss of material. If relief wells or standpipe piezometers are nearby, they can be pumped to reduce uplift pressure.

6.3.5 Sinkholes

If sinkholes are observed on the embankment or downstream from the dam with no indication of seepage flow, the area should be closely monitored until detailed investigation and analyses can be performed and the cause is determined.

If the sinkholes exhibit seepage flow, or increase in size or number, consider filling the holes with graded material similar to the treatment recommended in Section 6.3.3 - Whirlpools in the Reservoir. The reservoir should be lowered if the condition worsens. Sinkholes that appear in the reservoir floor or rim upstream of the dam represent seepage entrance locations. Unless the reservoir is drawn down periodically, these may not be detected. They should be filled with an impervious material to seal the entry, and the area carefully monitored thereafter. Investigation and analysis should be undertaken to determine the need for a more permanent solution.



Figure 6-17: Sinkhole in Upstream Slope of a Dam at Waterline (left); Temporary Repaired Sinkhole w/Gravel, Geotextile and Sandbags (right)

6.3.6 Embankment Deformation

An embankment slope failure or slides may be caused by seepage pressures, a saturated slope, a slope which is too steep, or an unusual loading condition such as a flood or earthquake. Earthquakes can cause structural damage to the embankment or appurtenances, which might lead to liquefaction of the soils and significant slumping or deformation of the embankment. If a large slide in the upstream or downstream slope has



occurred which significantly lowers the dam crest and threatens to release impounded water, the reservoir should be lowered or drained and sandbags or other methods approved by the RDSO used to temporarily raise the dam crest to prevent overtopping.



Figure 6-18: Example of a Deformed Embankment Caused by an Earthquake

6.3.7 Piping and Other Uncontrolled Embankment Seepage

Failures from piping in the foundation and from the embankment to the foundation are mostly from backward erosion, or backward erosion following blowout or heave. It should not necessarily be expected that seepage increases as the erosion is gradually working back from the downstream exit point. However, when the erosion has progressed to within a short distance of the reservoir/foundation interface, it can break through very rapidly.

Approximately two-thirds of failures from piping occur on the first filling or in the first five years of operation. In the vast majority of the remaining one third of piping failure cases, the reservoir was at or near historic high level when progression of the erosion from piping occurred. This is an important factor in dam safety management as it shows that more aggressive surveillance and monitoring should be carried out on embankment dams during flood events.

The success of intervention measures are dependent on the detailed circumstances for a dam. Factors which will influence this include the rate of progression of internal erosion,



the mechanism of piping involved, the zoning of the dam, the size of the reservoir and whether the reservoir can be drawn down rapidly, and the resources available to carry out intervention measures.

If a piping or uncontrolled embankment seep is identified early, successful intervention can be accomplished by lowering the reservoir. If lowering the reservoir cannot be accomplished quickly, additional intervention can include constructing a filtered drainage berm over the seepage area provided it is accessible and working conditions are safe. A filtered drainage berm is constructed by placing a layer of filter material over the seepage exit and overlaying that with pervious drainage material. A geotextile can be substituted as the filter material. These emergency measures to temporarily control piping are depicted in Figure 6-19. An example of a filter diaphragm at the downstream end of an outlet conduit constructed using commonly available quarry and concrete plant aggregate materials is illustrated in Figure 6-20.

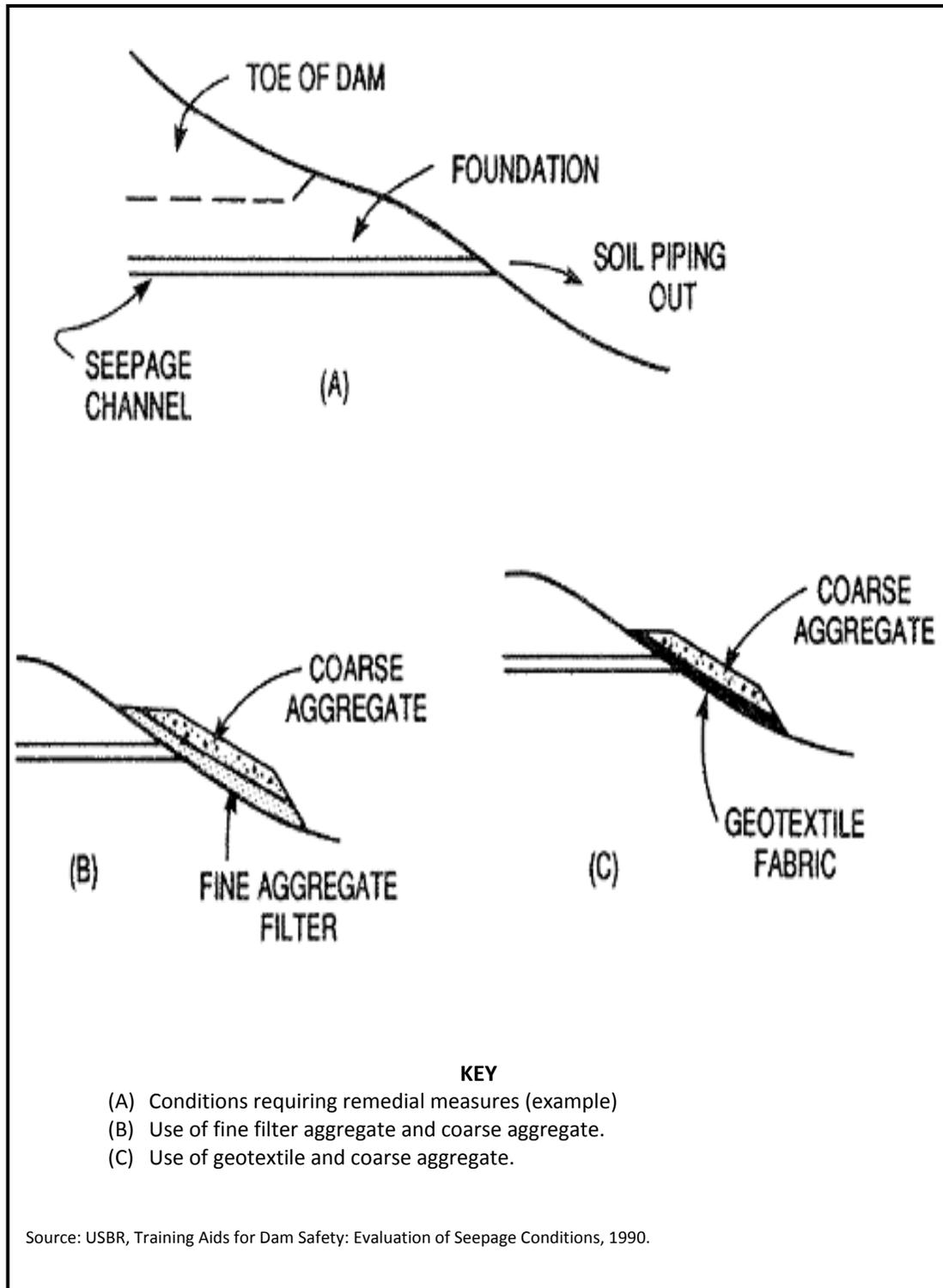


Figure 6-19: Emergency Filter Installation to Temporarily Control Piping on the Downstream Slope of an Embankment Dam



6.3.8 Erosion from Wave Action

During high water, continuing wave action against the upstream slope of a dam can erode wide terraces along the length of the dam if it is unprotected. This causes scour or beaching along the upstream slope of the dam and reduces the cross sectional area, which can potentially lead to a failure. This type of damage does not typically occur during short storms, especially if the slope has good sod cover or is armored with riprap. However, during prolonged periods of high water, especially during windy or icy conditions, the damage can develop rapidly if the upstream slope is unprotected.

Effective protection from wave erosion can be provided by dumping riprap over the affected area(s). If riprap is not readily available, experience has shown that a combination of polyethylene sheeting and sandbags can be an expedient, effective, and economical method of temporarily combating slope attack in a flood situation. Other materials such as snow fence, cotton, or burlap have successfully been used in place of the polyethylene sheeting. Polyethylene sheeting and sandbags can be used in a variety of combinations, and time becomes the factor that may determine which combination to use. Ideally, polyethylene sheeting and sandbag protection should be placed in the dry. However, many cases of unexpected slope attack will occur during high water, and a method for placement in the wet is described below. See Figures 6-21 and 6-22 for recommended methods of laying polyethylene sheeting and sandbags. Figure 6-23 shows a minimal configuration for emergency use. Since each situation is unique (available personnel, materials, etc.), specific details of placement and materials handling will not be covered, though some guidelines are provided below.

6.3.8.1 *Placement of Polyethylene Sheeting in the Dry*

Anchoring the polyethylene sheeting along the upstream toe is important for a successful job. It may be done in three different ways:

1. After completion of the dam, a trench excavated along the toe, polyethylene sheeting placed in the trench, and the trench backfilled;
2. Polyethylene sheeting placed flat-out away from the toe, and earth pushed over the flap;
3. Polyethylene sheeting placed flat-out from the toe and one or more rows of sandbags placed over the flap.

The polyethylene sheeting should then be unrolled up the slope and over the top enough to allow for anchoring with sandbags. Polyethylene sheeting should be placed from downstream to upstream along the slopes and overlapped at least two feet. The polyethylene sheeting is now ready for the "hold-down" sandbags.

It is mandatory that polyethylene sheeting placed on dam slopes be held down along the slopes as well. An effective method of anchoring polyethylene sheeting is a grid system of sandbags, unless extremely high velocities, heavy debris or a large amount of ice is anticipated. Then, a solid blanket of bags over the



polyethylene sheeting should be used. A grid system can be constructed faster and requires fewer bags and much less labor than a total covering. Various grid systems include vertical rows of lapped bags, two-by-four lumber held down by attached bags, and rows of bags held by a continuous rope tied to each bag. Polyethylene sheeting has been held down by a system using two bags tied with rope and the rope saddled over the dam crown with a bag on each slope.

6.3.8.2 Placement of Polyethylene Sheeting in the Wet

In many situations during high water, polyethylene sheeting and sandbags placed in the wet must provide the emergency protection. Wet placement may also be required to replace or maintain damaged polyethylene sheeting or polyethylene sheeting displaced by current action. Figure 6-22 shows a typical section of dam covered in the wet. Sandbag anchors are formed at the bottom edge and ends of the polyethylene sheeting by bunching the polyethylene sheeting around a fistful of sand or rock, and tying the sandbags to this fist-sized ball. Counterweights consisting of two or more sandbags connected by a length of ¼-inch rope are used to hold the center portion of the polyethylene sheeting down. The number of counterweights will depend on the uniformity of the dam slope and current velocity. Placement of the polyethylene sheeting consists of first casting out the polyethylene sheeting with the bottom weights and then adding counterweights to slowly sink the polyethylene sheeting into place. The polyethylene sheeting, in most cases, will continue to move down slope until the bottom edge reaches the toe of the slope. Sufficient counterweights should be added to insure that no air voids exist between the polyethylene sheeting and the dam face and to keep the polyethylene sheeting from flapping or being carried away in the current. For this reason, it is important to have enough counterweights prepared prior to the placement of the sheet.

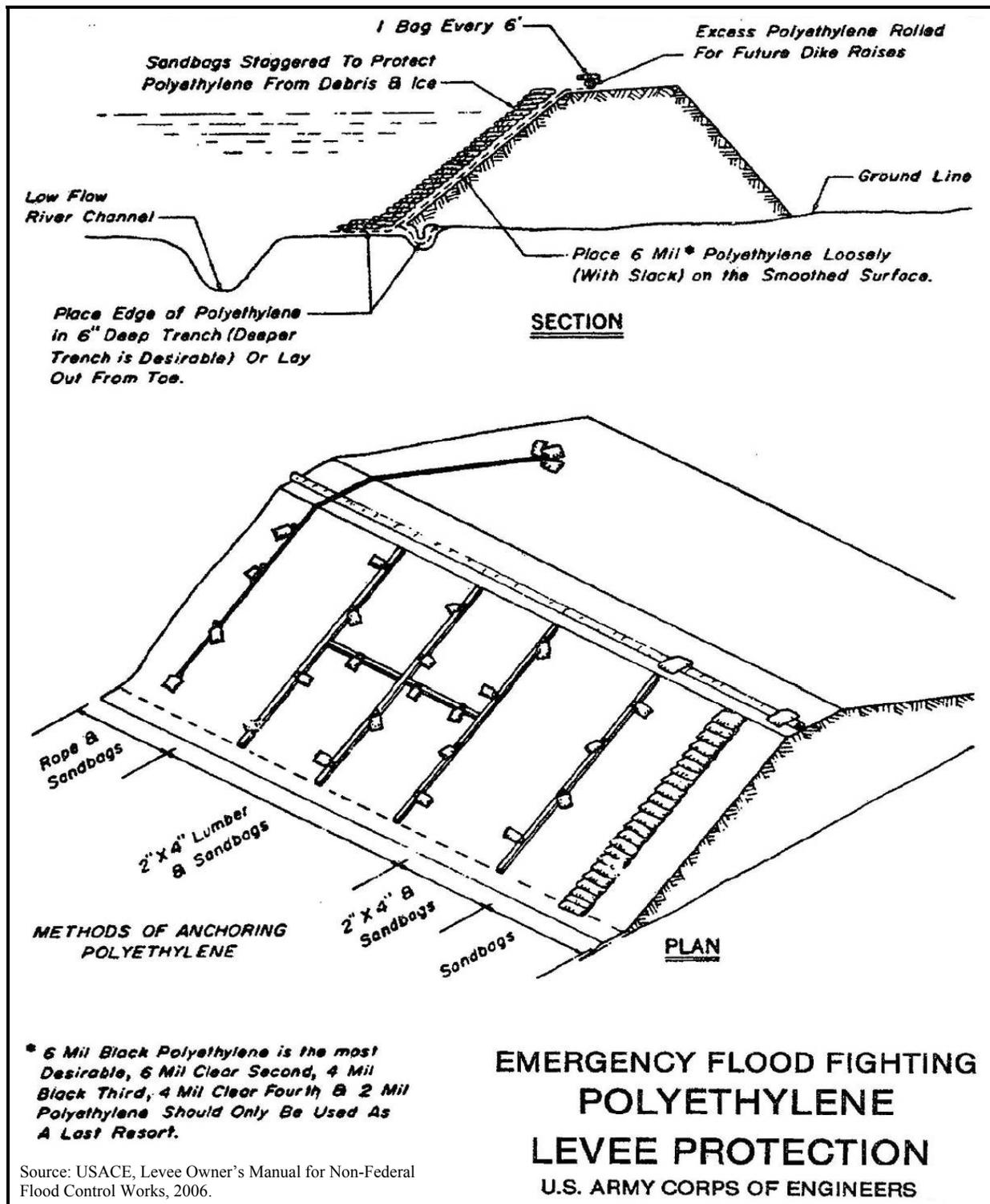
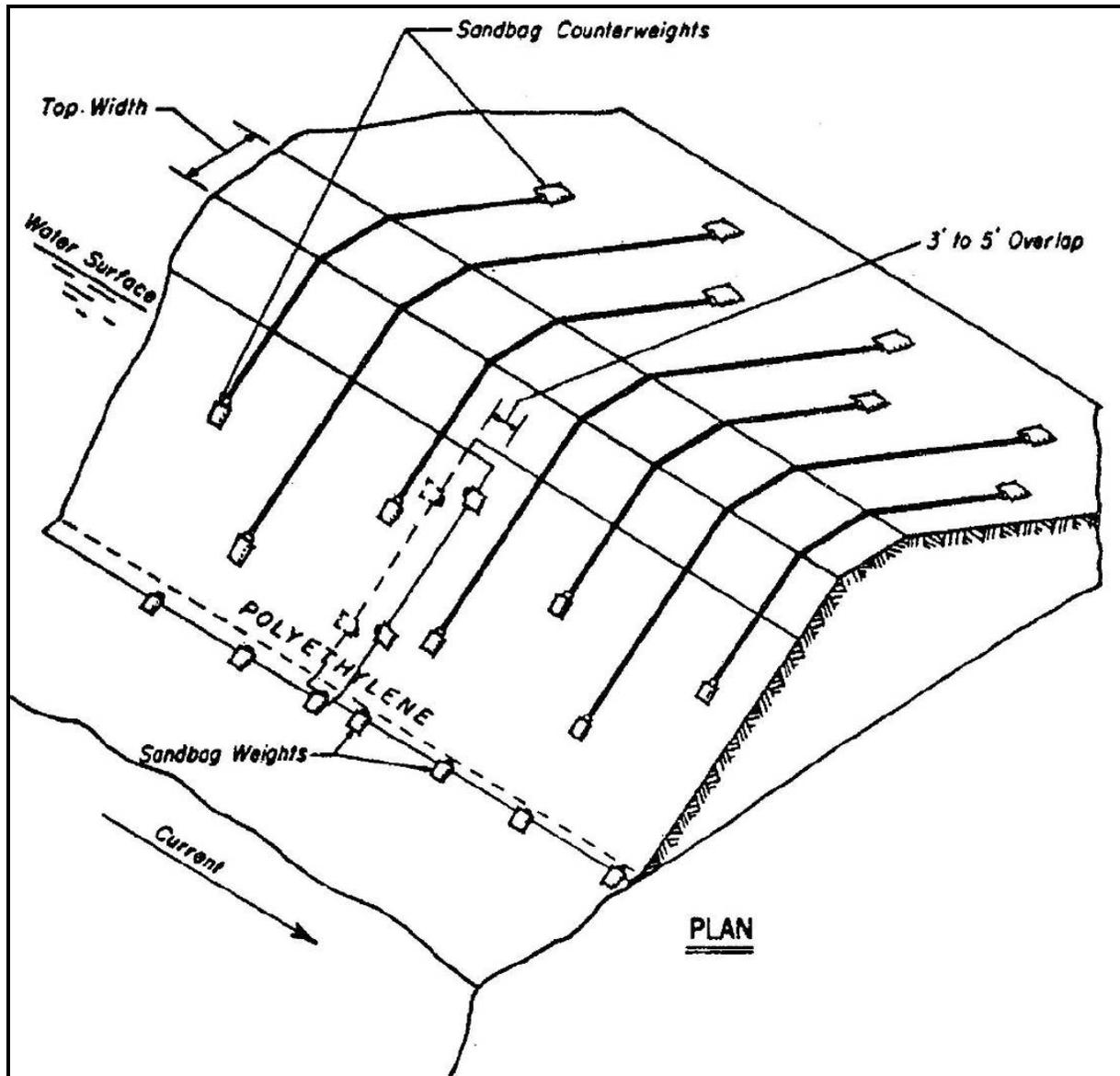


Figure 6-21: Placement of Polyethylene Slope Protection for Wave Erosion Protection In The Dry



**EMERGENCY FLOOD FIGHTING
PLACEMENT OF
POLYETHYLENE
SHEETING IN THE WET
U.S. ARMY CORPS OF ENGINEERS**

Source: USACE, Levee Owner's Manual for Non-Federal Flood Control Works, 2006.

Figure 6-22: Placement of Polyethylene Sheeting For Wave Erosion Protection In The Wet

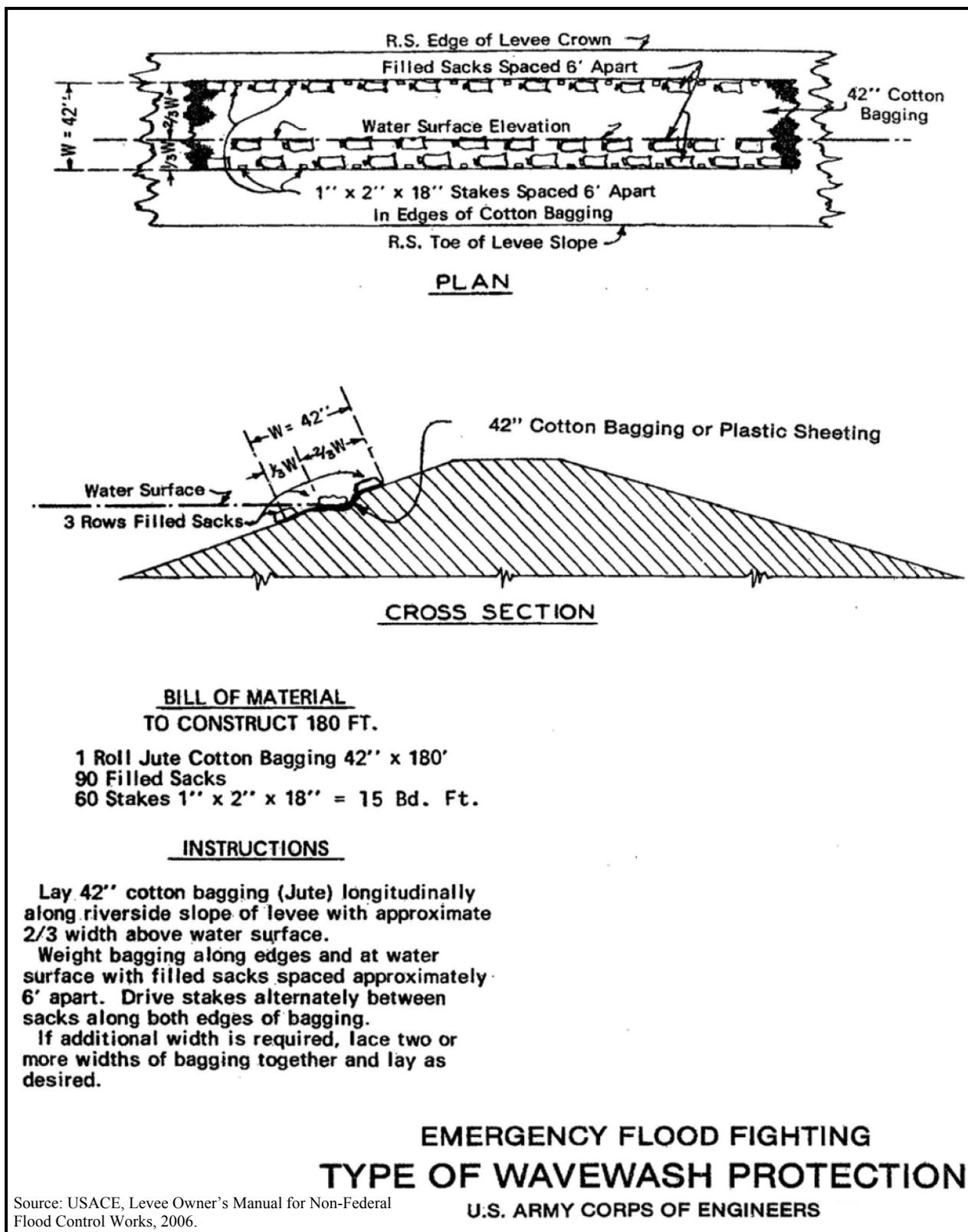


Figure 6-23: Minimal Configuration of Polyethylene Sheeting Used for Wave Erosion Protection



6.3.8.3 *Embankment Overtopping*

If overtopping appears imminent, the following actions should be considered:

1. Verify that the spillway(s) are not obstructed with debris and are functioning as efficiently as possible. Debris removal may be difficult due to pressure from the high velocity flow and should be accomplished by using long poles or hooks on ropes. Personnel should not be allowed close to spillway inlets.
2. Open low-level outlets or other facilities to lower the pool level. Using pumps and/or siphons may also be helpful on small reservoirs.
3. Dig a bypass channel around the dam through an abutment. The location for this channel should be chosen with extreme caution so that the embankment will not be affected by rapid erosion of the channel. This action should not be undertaken without approval from the RDSO and supervision by an experienced professional engineer.
4. Consider raising the embankment or filling in low areas along the dam crest using sandbags or other available means. Great care should be taken when attempting to temporarily raise the top of an embankment to prevent overtopping during a severe storm as the flood inflow may continue to increase and result in the overtopping of the raised dam. If the temporarily raised dam fails, the flow could concentrate at the failure point and prematurely erode the embankment and release an even greater volume and depth of water than would have otherwise occurred. Ideally, the crest of the dam should be completely level so that there is a shallow uniform flow over the embankment rather than concentrated flows.



Figure 6-24: Debris Accumulation at Service Spillway Structure Can Obstruct Flow and Lead to Embankment Overtopping



6.4 Emergency Supplies and Resources

Refuge personnel can manage emergency situations more safely and effectively by stockpiling materials and equipment for emergency use and identifying locally available equipment labor and materials. The specific requirement for supplies varies depending on the size and type of dam.

A list of common equipment used to respond to dam emergencies includes:

- Dump truck
- Backhoe
- Front end loader
- Bulldozer
- Shovels
- Buckets
- Sand bag filling machine

A list of common materials used to respond to dam emergencies includes:

- Sand
- Gravel
- Clay borrow
- Geotextile
- Sandbags (*See Chapter 6.3.4 for details on sandbagging operations*)
- Plastic sheeting – *6 mil polyethylene sheeting is the minimum thickness recommended for flood fighting applications*
- Geotextile
- Riprap/rock fill
- Cement
- Caulk
- Tarpaulin/roofing paper (*if stoplogs are part of the facility*)
- Portable generators and lighting
- Communication system – *two-way radios are preferable because they are extremely reliable for short distances and have the capability to broadcast to several people at once*



Local resources that are often available and could be called upon to provide material, equipment and labor include:

- Ready-mix concrete suppliers
- Equipment rental services (pumps, heavy equipment, sandbag supplies, etc.)
If pumps are needed during a flood, you should contact your state, because the local Corps district office may have pumps available, but your state may need to coordinate and prioritize these requests before passing them to the Corps.
- Underwater diving contractors
- Quarries
- Heavy Construction Contractors
- Sources of borrow materials – *Sources of borrow material should be located prior to a flood event. Several borrow areas should be identified in advance, because wet or sloppy weather could unexpectedly limit access to some sites. Carefully consider the access points to your levee when you choose the sites for the borrow material.*

Refuges should make an inventory of both in-house resources and local resources, including contact information so that this information is readily available during an emergency.



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APPENDIX A

GLOSSARY

Abutment. The undisturbed natural material of the valley side against which the dam is constructed. The left and right abutments are defined as being on the right and left side of an observer looking downstream.

Acre-Foot. A term used in measuring the volume of water that would cover one acre to a depth of one foot. It is equal to 43,560 cubic feet.

Air-Vent Pipe. A pipe designed to provide air to the outlet conduit to reduce turbulence during release of water. Extra air is usually necessary downstream on constrictions.

Appurtenant Structure. A structure necessary for the operation of a dam such as outlets, trashracks, valves, spillways, power plants, tunnels, etc.

Arch Dam. A concrete or masonry dam that is curved so as to transmit the major part of the water pressure to the abutments.

Auxiliary Spillway. *See Spillway*

Base Width (*Base Thickness*). The maximum width or thickness of a dam measured horizontally between upstream and downstream faces and normal (perpendicular) to the axis of the dam but excluding projections for outlets, etc.

Berm. A horizontal step or bench in the sloping profile of an embankment dam.

Breach. An eroded opening through a dam that drains the reservoir. A controlled breach is a constructed opening. An uncontrolled breach is an unintentional opening that allows uncontrolled discharge from the reservoir.

Butress Dam. A dam consisting of a watertight upstream face supported at intervals on the downstream side by a series of buttresses.

Channel. A general term for any natural or artificial watercourse.

Cofferdam. A temporary structure enclosing all or part of a construction area so that construction can proceed in a dry area. A *diversion cofferdam* diverts a river into a pipe, channel, or tunnel.

Conduit. A closed channel to convey water through, around, or under a dam.



Construction Joint. The interface between two successive placings or pours of concrete where a bond, not permanent separation, is intended.

Core Wall. A wall built of impervious material, usually concrete or asphaltic concrete, in the body of an embankment dam to prevent leakage.

Crest of Dam. Top of dam.

Crest Length. The length of the top of a dam, including the length of the spillway, powerhouse, navigation lock, fish pass, etc., where these structures form part of the length of the dam. If detached from a dam, these structures should not be included.

Cross-section. A sectional view of a dam formed by passing a plane through the dam perpendicular to the axis.

Culvert. A closed channel to convey water.

Cutoff Wall. A wall of impervious material (e.g., concrete, asphaltic concrete, steel-sheet piling) built into the foundation to reduce seepage under the dam

Dam. A barrier constructed across a watercourse for the purpose of impounding or diverting water.

- a. Embankment Dam. Any dam constructed of excavated natural materials or of industrial waste materials.
- b. Concrete Dam. Any dam constructed of conventional concrete, roller compacted concrete, or cyclopean concrete.

Dam Failure. The uncontrolled release of reservoir contents.

Design Flood. See *Spillway Design Flood*.

Diversion Channel, Canal, or Tunnel. A waterway used to divert water from its natural course. These terms are generally applied to temporary structures such as those designed to bypass water around a dam site during construction. “Channel” is normally used instead of “canal” when the waterway is short. Occasionally these terms are applied to permanent structures.

Drain, toe. A system of pipe and/or pervious material along the downstream toe of a dam used to collect seepage from the foundation and embankment and convey it to a free outlet.

Drainage Area. The area that drains to a particular point on a river or stream.

Drawdown. The difference between a water level and a lower water level in a reservoir within a particular time. Used as a verb, it is the lowering of the water surface due to release of water from the reservoir.



EAP Operations. All actions taken by the U.S. Fish & Wildlife Service and other involved agencies to address an unusual or emergency event.

Earthen Dam or Earthfill Dam. See *Dam, Embankment*.

Earthquake. A sudden motion or trembling in the earth caused by the abrupt release of accumulated stress along a fault.

Emergency Action Plan (EAP). A comprehensive, single-source document providing accurate and current instructions intended to help dam owners/operators save lives, minimize property damage, and minimize environmental impacts caused by large releases from a dam, dam failure, or other events that present hazardous conditions.

Emergency Event. An event which takes place or a condition which develops that is of a serious nature that may endanger the dam, or endanger persons or property, and demands immediate attention.

Emergency Spillway. See *Spillway*.

Face. The external surface of a structure, e.g., the surface of a wall of a dam.

Filter (filter zone). A band of granular material graded (either naturally or by selection) so as to allow seepage through or within the layers while preventing the migration of material from adjacent zones.

Flashboards. A length of timber, concrete, or steel placed on the crest of a spillway to raise the retention water level but that may be quickly removed in the event of a flood, either by a tripping device or by deliberately designed failure of the flashboard or its supports.

Flood. A temporary rise in water levels resulting in inundation of areas not normally covered by water. May be expressed in terms of probability of exceedance per year such as one percent chance flood or expressed as a fraction of the probable maximum flood of other reference flood. Some related terms are:

- a. Flood, Inflow Design (IDF). That flood used in the design of a safe dam and its appurtenant works particularly for sizing the spillway and outlet works, and for determining maximum temporary storage and height of dam requirements.
- b. Flood, Probable Maximum (PMF). The largest flood reasonably expected at a point on a stream because of a probable maximum storm and favorable runoff conditions.

Floodplain. An area adjoining a body of water or natural stream that has been, or may be, covered by flood water.



Flood Routing. The determination of the attenuating effect of storage on a flood passing through a valley, channel, or reservoir.

Foundation of Dam. The natural material on which the dam structure is placed.

Freeboard. Vertical distance between a stated water level and the top of dam.

Gallery. A passageway within the body of a dam or abutment.

Gate. A device in which a leaf or member is moved across the waterway from an external position to control or stop the flow.

- a. Bulkhead Gate. A gate used either for temporary closure of a channel or conduit to empty it for inspection or maintenance or for closure against flowing water when the head difference is small, e.g., for diversion tunnel closure.
- b. Crest Gate (Spillway Gate). A gate on the crest of a spillway to control overflow or reservoir water level.
- c. Emergency Gate. A standby or reserve gate used only when the normal means of water control is not available.
- d. Flap Gate. A gate hinged along one edge, usually either the top or bottom edge.
- e. Flood Gate. A gate to control flood release from a reservoir
- f. Outlet Gate. A gate controlling the flow of water through a reservoir outlet.
- g. Radial Gate (Tainter Gate). A gate with a curved upstream plate and radial arms hinged to piers or other supporting structures.
- h. Regulating Gate (Regulating Valve). A gate or valve that operates under full pressure and flow to throttle and vary the rate of discharge.
- i. Slide Gate (Sluice Gate). A gate that can be opened or closed by sliding in supporting guides.

Gravity Dam. A dam constructed of concrete, masonry, or both that relies on its weight for stability.

Height, Hydraulic. The vertical difference between the maximum flood control pool (no surcharge) and the lowest point along the downstream toe.

Height, Structural. The vertical difference between the top of the dam and the lowest point of contact with the foundation.

Hydrograph, Breach or Dam Failure. A flood hydrograph resulting from a dam breach.

Hydrograph, Flood. A graphical representation of the flood discharge with respect to time for a particular point on a stream or river.



Hydrograph, Unit. A hydrograph with a volume of one inch of runoff resulting from a storm of a specified duration and areal distribution. Hydrographs from other storms of the same duration and distribution are assumed to have the same time base but with ordinates of flow in proportion to the runoff volumes.

Incident Command System (ICS). A management system designed to control personnel, equipment, supplies, and communications at the scene of an unusual or emergency event. An Incident Command System is typically deployed at the beginning of an event until the management of the on-scene operations are no longer needed. The structure of the Incident Command System can be expanded or contracted depending on the changing needs of the event. The Incident Command System allows agencies of all kinds to effectively communicate using common terminology.

Incident Commander. The Incident Commander is the highest ranking official available at the scene of an unusual or emergency event. All FWS personnel involved in the operating procedures of the dam or emergency operations should be trained in the fundamentals of ICS.

Inclinometer. An instrument, usually consisting of a metal or plastic tube inserted in a drill hole and a sensitized monitor either lowered into the tube or fixed within it. The monitor measures at different points the tube's inclination to the vertical. By integration, the lateral position at different levels of the tube may be found relative to a point, usually the top or bottom of the tube, assumed to be fixed. The system may be used to measure settlement.

Instrumentation. An arrangement of devices installed into or near dams (i.e., piezometer, inclinometer, strain gage, survey points, etc.) that provide measurements that can be used to evaluate performance parameters of a structure.

Intake. Any structure in a reservoir, dam or river for the purpose of directing water into a conduit, tunnel, canal or pipeline.

Inundation Map. A map delineating the area that would be submerged by a particular flood event.

Leakage. Uncontrolled loss of water by flow through a hole or crack.

Length of Dam. The length along the top of the dam between contact abutments. This also includes the spillway, power plants, navigation lock, fish pass, etc., where these form part of the length of the dam. If detached from the dam, these structures should not be included.

Masonry Dam. A dam constructed mainly of stone, brick, or concrete blocks that may or may not be joined with mortar. A dam having only a masonry facing should not be referred to as masonry dam.

Outlet. An opening through which water can be discharged.



Parapet Wall. A wall built along the top of a dam (upstream or downstream edge) used for safety of vehicles and pedestrians, to prevent overtopping caused by wave runup, or ornamentation.

Peak Flow. The maximum instantaneous discharge that occurs during a flood. It coincides with the peak of a flood hydrograph.

Pervious Zone. A part of the cross-section of an embankment dam comprising material of high permeability.

Phreatic Surface. The free surface of water seeping at atmospheric pressure through soil or rock.

Piezometer. An instrument for measuring pore water pressure within soil, rock, or concrete.

Piping. The progressive development of internal erosion by seepage appearing downstream as a hole or seam discharging water containing soil particles.

Probability. The likelihood of an event occurring within a given period of time.

Probable Maximum Precipitation (PMP). Theoretically, the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location.

Public Information Officer (PIO). A Refuge staff member designated by the Refuge Manager. During EAP operations, the PIO will be the contact person at the Refuge for the media, and will keep the media informed of the EAP operations.

Relief Wells. A line of vertical wells or boreholes to facilitate drainage of the foundation and abutments and to reduce water pressure.

Reservoir. A body of water impounded by a dam and in which water can be stored.

Reservoir Surface Area. The area covered by a reservoir when filled to a specified level.

Riprap. A layer of stone, precast blocks, bags of cement or other suitable material, generally placed on the upstream slopes of an embankment or along a watercourse as protection against wave action, erosion, or scour. It consists of pieces of relatively large size as distinguished from a gravel blanket.

Seepage. Flow or movement of water through a dam, its foundation, or its abutments.

Slope. Inclination from the horizontal, measured as the ratio of horizontal units to corresponding vertical units.

Slope Protection. The protection of a slope against wave action or erosion.



Spillway. A structure over or through which flow is discharged from a reservoir. If the rate of flow is controlled by mechanical means such as gates, it is considered a controlled spillway. If the elevation of the spillway crest is the only control, it is considered an uncontrolled spillway.

- a. Auxiliary Spillway (Emergency Spillway). A secondary spillway designed to operate only during exceptionally large floods.
- b. Fuse-Plug Spillway. An auxiliary or emergency spillway comprising a low embankment or natural saddle designed to be overtopped and eroded away during a very rare and exceptionally large flood.
- c. Primary Spillway (Principal Spillway). The principal or first-used spillway during flood flows.

Spillway Channel. An open channel or closed conduit conveying water from the spillway inlet downstream.

Spillway Crest. The lowest level at which water can flow over or through the spillway.

Spillway, Chute. An inclined channel, usually separate from the dam, to convey reservoir overflow into the natural channel below the dam or into an adjacent natural drainage channel.

Standing Operating Procedures (SOP). A comprehensive, single-source document providing accurate and current instructions for normal operation, maintenance, monitoring, and inspection of a dam and appurtenant features.

Stilling Basin. A basin constructed to dissipate the energy of fast-flowing water, e.g., from a spillway or bottom outlet, and to protect the riverbed from erosion.

Stoplogs. Timbers or steel beams placed on top of each other with their ends held in guides on each side of a channel or conduit so as to provide a cheaper or more easily handled means of temporary closure than a bulkhead gate.

Storage. The retention of water or delay of runoff either by planned operation, as in a reservoir, or by temporary filling of overflow areas, as in the progression of a flood wave through a natural stream channel. Definitions of specific types of storage in reservoirs are:

- a. Dead Storage. The reservoir volume between the invert of the lowest intake and the reservoir bottom.
- b. Active Storage. The reservoir volume between the normal reservoir water surface elevation and the invert of the lowest intake.
- c. Flood Storage. The reservoir volume between the crest of the dam and the normal reservoir water surface elevation.



Toe of Dam. The junction of the downstream face of a dam with the ground surface, referred to as the *downstream toe*. For an embankment dam the junction of upstream face with ground surface is called the *upstream toe*.

Top of Dam. The elevation of the uppermost surface of a dam, usually a road or walkway, excluding any parapet wall, railings, etc.

Trashrack. A screen located at an intake to prevent the ingress of debris.

Unusual Event. An event which takes place, or a condition which develops, that is not normally encountered in the routine operation of the dam and reservoir, or necessitates a variation from the operating procedures.

Uplift. The upward pressure in the pores of a material (interstitial pressure) or on the base of a structure.

Valve. A device fitted to a pipeline or orifice in which the closure member is either rotated or moved transversely or longitudinally in the waterway so as to control or stop the flow.



APPENDIX B

DAM PROBLEMS, CAUSES AND RECOMMENDATIONS

Modified from "Texas Commission on Environmental Quality; Guidelines for Operation and Maintenance of Dams in Texas"

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Inspection Guidelines – Upstream Slope

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Sinkhole</p>	<p>Piping or internal erosion of embankment materials or foundation causes a sinkhole. The cave-in of an eroded cavern can result in a sinkhole. A small hole in the wall of an outlet pipe can develop into a sinkhole. Dirty water at the exit indicates erosion of the dam. Piping can empty a reservoir through a small hole in the wall or can lead to failure of a dam as soil pipes erode through the foundation or a pervious part of the dam. Dispersive soils are particularly susceptible to sinkholes.</p>	<p>Inspect other parts of the dam for seepage or more sinkholes. Check seepage and leakage outflows for dirty water. A qualified engineer should inspect the conditions, identify the exact cause of sinkholes, and recommend further actions. Depending on the location in the embankment, the reservoir may need to be drawn down.</p> <p>RDSO NOTIFICATION REQUIRED</p>
<p>Large Cracks</p>	<p>A portion of the embankment has moved because of loss of strength, or the foundation may have moved, causing embankment movement. Indicates onset of massive slide or settlement caused by foundation failure.</p>	<p>Depending on embankment involved, draw reservoir level down. A qualified engineer should inspect the condition and recommend further actions.</p> <p>RDSO NOTIFICATION REQUIRED</p>
<p>Slide, Slump, or Slip</p>	<p>Earth or rocks move down the slope along a slippage surface because of too steep slope, or the foundation moves. Also, look for slide movements in reservoir basin. A series of slides can lead to obstruction of the inlet or failure of the dam.</p>	<p>Evaluate extent of the slide. Monitor slide. Draw the reservoir level down if safety of dam is threatened. A qualified engineer should inspect the conditions and recommend further actions.</p> <p>RDSO NOTIFICATION REQUIRED</p>



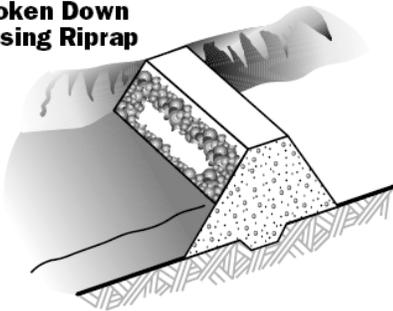
Problem	Probable Cause and Possible Consequences	Recommended Actions
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Scarps, Benches Oversteep Areas

Wave action, local settlement, or ice action cause soil and rock to erode and slide to the lower part of the slope, forming a bench. Erosion lessens the width and possible height of the embankment and could lead to seepage or overtopping of the dam.

Determine exact cause of scarps. Do necessary earthwork, restore embankment to original slope, and supply adequate protection (bedding and riprap).

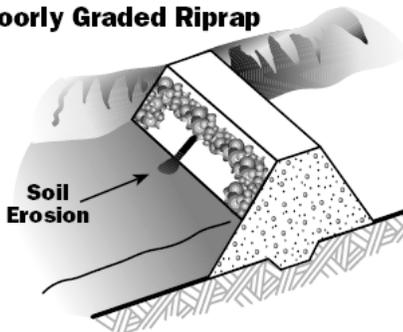
Broken Down Missing Riprap



Poor-quality riprap has deteriorated. Wave action or ice action has displaced riprap. Round and similar-sized rocks have rolled downhill. Wave action against these unprotected areas decreases embankment width.

Reestablish normal slope. Place bedding and competent riprap.

Erosion Behind Poorly Graded Riprap



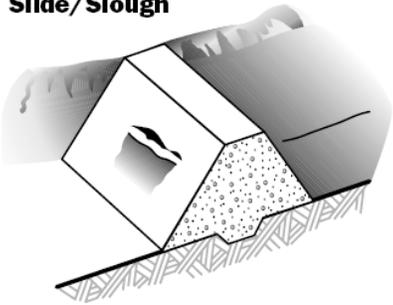
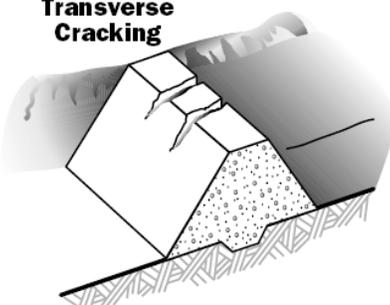
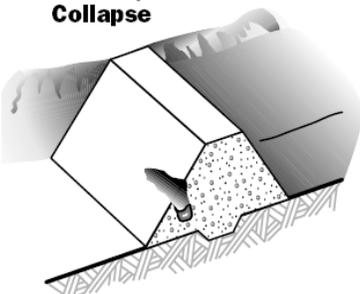
Similar-sized rocks allow waves to pass between them and erode small gravel particles and soil. Soil is eroded away from behind the riprap. This allows riprap to settle, offering less protection and decreased embankment width.

Reestablish effective slope protection. Place bedding material.

RDSO NOTIFICATION REQUIRED for design – for graduation and size for rock for bedding and riprap. A qualified engineer should inspect the conditions and recommend further actions.



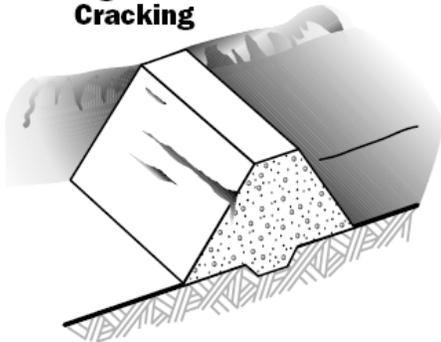
Inspection Guidelines – Downstream Slope

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Slide/Slough</p> 	<p>Lack loss of strength of embankment material. Loss of strength can be attributed to infiltration of water into the embankment or loss of support by the foundation. Massive slide cuts through crest or upstream slope reducing freeboard and cross-section. Structural collapse or overtopping can result</p>	<ol style="list-style-type: none"> 1. Measure extent and displacement of slide. If continued movement is seen, begin lowering water level until movement stops. 2. Have a qualified engineer inspect the condition and recommend further action. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Transverse Cracking</p> 	<ol style="list-style-type: none"> 1. Uneven movement between adjacent segments of the embankment. 2. Deformation caused by structural stressor instability. <p>1. Can provide a path for seepage through the embankment cross-section.</p> <ol style="list-style-type: none"> 2. Provides local area of low strength within embankment. Future structural movement, deformation or failure could begin. 3.. Provides entrance point for surface runoff to enter embankment 	<ol style="list-style-type: none"> 1. Inspect crack and carefully record crack location, length, depth, width and other pertinent physical features. Stake out limits of cracking. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and correct condition. 2. Excavate slope along crack to a point below the bottom of the crack. Then, backfill excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface runoff. This should be supervised by engineer. Continue to monitor crest routinely for evidence of future cracking. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Cave In/ Collapse</p> 	<ol style="list-style-type: none"> 1. Lack of adequate compaction. 2. Rodent hole below. 3. Piping through embankment or foundation. 4. Presence of dispersive soils. <p>Indicates possible washout of embankment.</p>	<ol style="list-style-type: none"> 1. Inspect for and immediately repair rodent holes. Control rodents to prevent future damage. 2. Have a qualified engineer inspect the condition and recommend further action. <p>RDSO NOTIFICATION REQUIRED</p>



Problem	Probable Cause and Possible Consequences	Recommended Actions
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Longitudinal Cracking

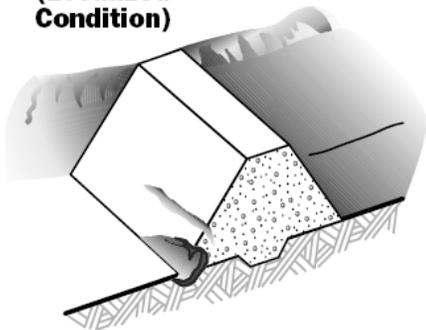


1. Drying and shrinkage of surface material.
 2. Downstream movement or settlement of embankment.
1. Can be an early warning of a potential slide.
 2. Shrinkage cracks allow water to enter the embankment and freezing will further crack the embankment.
 3. Settlement or slide, showing loss of strength in embankment that can lead to failure.

1. If cracks are from drying, dress area with well-compacted material to keep surface water out and natural moisture in.
2. If cracks are extensive, a qualified engineer should inspect the condition and recommend further actions.

RDSO NOTIFICATION REQUIRED

Slump (Localized Condition)

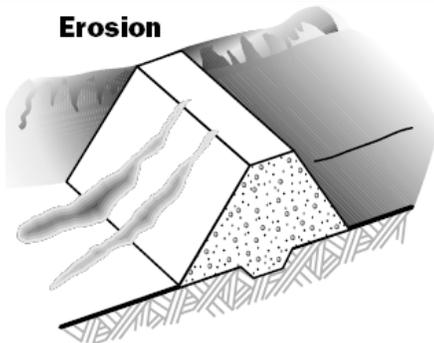


Preceded by erosion undercutting a portion of the slope. Can also be found on steep slopes. Can expose impervious zone to erosion and lead to additional slumps.

1. Inspect area for seepage.
2. Monitor for progressive failure.
3. Have a qualified engineer inspect the condition and recommend further action.

RDSO NOTIFICATION REQUIRED

Erosion



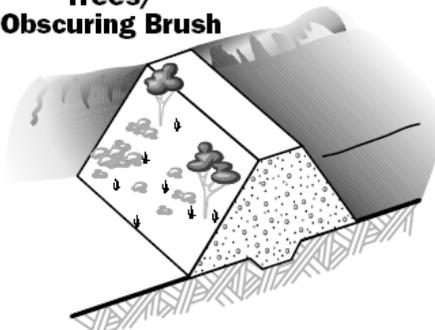
Water from intense rainstorms or snowmelt carries surface material down the slope, resulting in continuous troughs. Can be hazardous if allowed to continue. Erosion can lead to eventual deterioration of the downstream slope and failure of the structure.

1. The preferred method to protect eroded areas is rock or riprap.
2. Reestablishing protective grasses can be adequate if the problem is detected early.



Problem	Probable Cause and Possible Consequences	Recommended Actions
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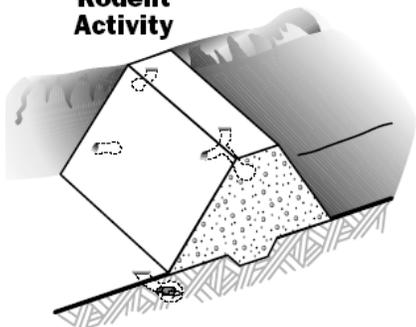
**Trees/
Obscuring Brush**



Natural vegetation in area. Large tree roots can create seepage paths. Large trees can blow over during storms and damage dam or cause breach. Bushes can obscure visual inspection and harbor rodents.

1. According to the FWS Tree Removal Guidelines (See Appendix F), any trees growing on the upstream slope that are less than 2 inches in diameter should be cut and treated. Trees growing on the downstream slope that are greater than 2 inches should be removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are less than 6 inches in diameter should be cut and removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are greater than 6 inches in diameter should be removed.
2. Control vegetation on the embankment that obscures visual inspection.

**Rodent
Activity**

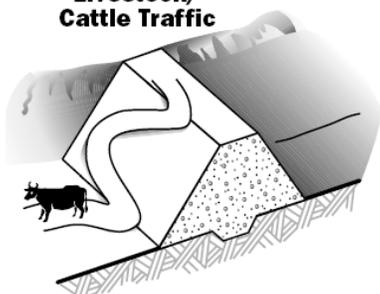


Overabundance of rodents. Animal burrowing creates holes, tunnels, and caverns. Certain habitats, such as cattail-filled areas and trees close to the reservoir encourage these animals.

Can reduce length of seepage path and lead to piping failure. If tunnel runs through most of the dam, it can lead to collapse.

1. Control rodents to prevent more damage.
2. Backfill existing rodent holes.
3. Remove rodents. Determine exact location and extent of tunneling. Remove habitat and repair damages.

**Livestock/
Cattle Traffic**



Excessive travel by livestock especially harmful to slope when wet.

Creates areas bare of erosion protection and causes erosion channels. Allows water to stand. Area susceptible to drying cracks.

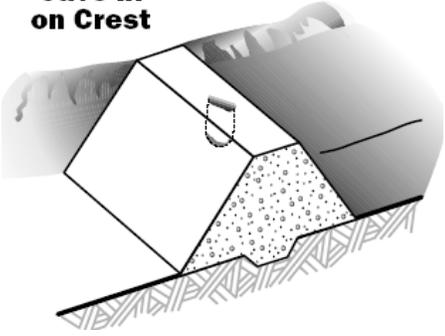
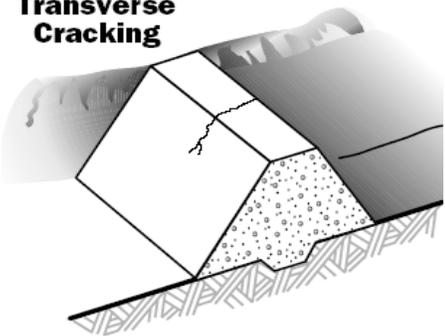
1. Fence livestock outside embankment area.
2. Repair erosion protection, i.e. riprap, grass.



Inspection Guidelines – Crest

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Longitudinal Crack</p>	<ol style="list-style-type: none"> 1. Uneven settlement between adjacent sections or zones within the embankment. 2. Foundation failure causing loss of support to embankment. 3. Initial stages of embankment slide. <ol style="list-style-type: none"> 1. Creates local area of low strength within an embankment. Could be the point of initiation of future structural movement, deformation or failure. 2. Provides entrance point for surface runoff into embankment, allowing saturation of adjacent embankment area and possible lubrication which could lead to localized failure. 	<ol style="list-style-type: none"> 1. Inspect crack and carefully record location, length, depth, width, alignment, and other pertinent physical features. Immediately stake out limits of cracking. Monitor frequently. 2. Engineer should determine cause of cracking and supervise steps necessary to reduce danger to dam and correct condition. 3. Effectively seal the cracks at the crest surface to prevent infiltration by surface water. 4. Continue to routinely monitor crest for evidence of further cracking. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Vertical Displacement</p>	<ol style="list-style-type: none"> 1. Vertical movement between adjacent sections of the embankment. 2. Structural deformation or failure caused by structure stress or instability, or by failure of the foundation. <ol style="list-style-type: none"> 1. Creates local area of low strength within embankment which could cause future movement. 2. Leads to structural instability or failure. 3. Creates entrance point for surface water that could further lubricate failure plane. 4. Reduces available embankment cross-section. 	<ol style="list-style-type: none"> 1. Carefully inspect displacement and record its location, vertical and horizontal displacement, length and other physical features. Immediately stake out limits of cracking. 2. Engineer should determine cause of displacement and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate area to the bottom of the displacement. Backfill excavation using competent material and correct construction techniques, under supervision of engineer. 4. Continue to monitor areas routinely for evidence of cracking or movement. <p>RDSO NOTIFICATION REQUIRED</p>

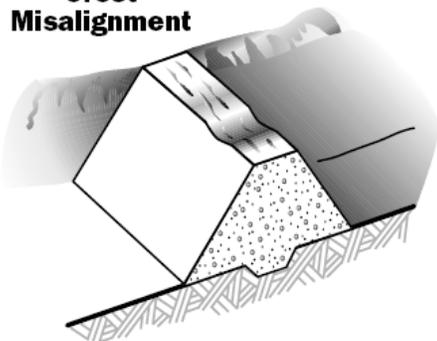


Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Cave-In on Crest</p> 	<ol style="list-style-type: none"> 1. Rodent activity. 2. Hole in outlet conduit is causing erosion of embankment material. 3. Internal erosion or piping of embankment material by seepage. 4. Breakdown of dispersive clays within embankment by seepage waters. <ol style="list-style-type: none"> 1. Void within dam could cause localized caving, sloughing, instability or reduced embankment cross-section. 2. Entrance point for surface water. 	<ol style="list-style-type: none"> 1. Carefully inspect and record location and physical characteristics (depth, width, length) of cave-in. 2. Engineer should determine cause of cave-in and supervise all steps necessary to reduce threat to dam and correct condition. 3. Excavate cave-in, slope sides of excavation and backfill hole with competent material using proper construction techniques. This should be supervised by engineer. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Transverse Cracking</p> 	<ol style="list-style-type: none"> 1. Uneven movement between adjacent segments of the embankment. 2. Deformation caused by structural stressor instability. <ol style="list-style-type: none"> 1. Can provide a path for seepage through the embankment cross-section. 2. Provides local area of low strength within embankment. Future structural movement, deformation or failure could begin. 3. Provides entrance point for surface runoff to enter embankment. 	<ol style="list-style-type: none"> 1. Inspect crack and carefully record crack location, length, depth, width and other pertinent physical features. Stake out limits of cracking. 2. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate crest along crack to a point below the bottom of the crack. Then backfilling excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface runoff. This should be supervised by engineer. 4. Continue to monitor crest routinely for evidence of future cracking. <p>RDSO NOTIFICATION REQUIRED</p>



Problem	Probable Cause and Possible Consequences	Recommended Actions
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Crest Misalignment

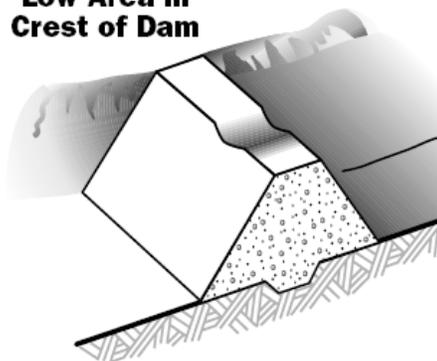


1. Movement between adjacent parts of the structure.
 2. Uneven deflection of dam under loading by reservoir.
 3. Structural deformation or failure near area of misalignment.
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1. Area of misalignment is usually accompanied by low area in crest which reduces freeboard.
 2. Can produce local areas of low embankment strength which may lead to failure.

1. Establish monuments across crest to determine exact amount, location, and extent of misalignment.
2. Engineer should determine cause of misalignment and supervise all steps necessary to reduce threat to dam and correct condition.
3. Following remedial action, monitor crest monuments according to a schedule to detect any movement.

RDSO NOTIFICATION REQUIRED

Low Area in Crest of Dam

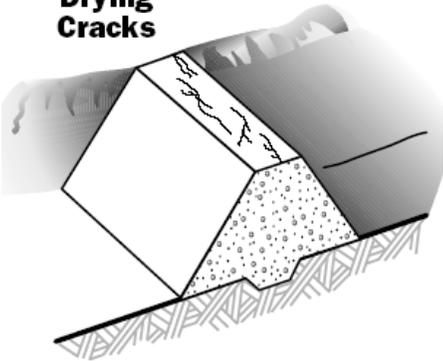
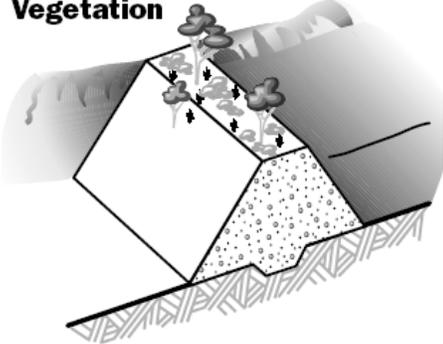


1. Excessive settlement in the embankment or foundation directly beneath the low area in the crest.
2. Internal erosion of embankment material.
3. Foundation spreading to upstream and/or downstream direction.
4. Prolonged wind erosion of crest area.
5. Improper final grading following construction. Reduces freeboard available to pass flood flows safely through spillway.

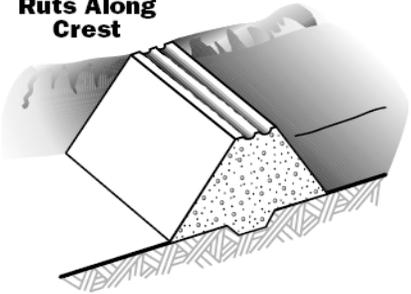
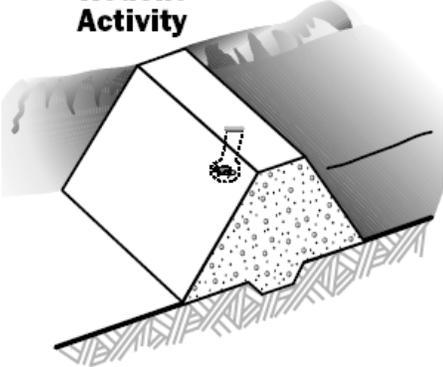
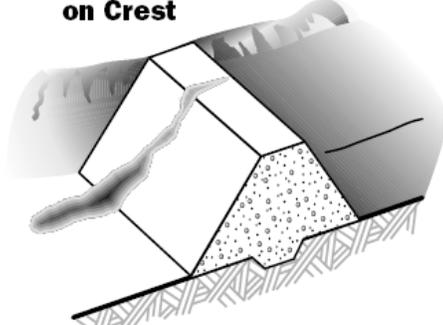
1. Establish monuments along length of crest to determine exact amount, location, and extent of settlement in crest.
2. Engineer should determine cause of low area and supervise all steps necessary to reduce possible threat to the dam and correct condition.
3. Reestablish uniform crest elevation over crest length by filling in low area using proper construction techniques. This should be supervised by engineer.
4. Reestablish monuments across crest of dam and routinely monitor monuments to detect any settlement.

RDSO NOTIFICATION REQUIRED

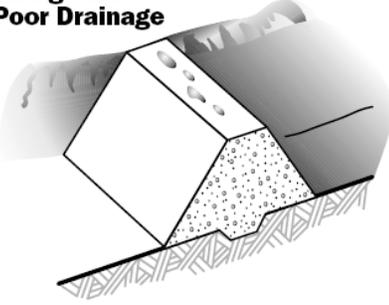


Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Drying Cracks</p> 	<p>Material on the crest of dam expands and contracts with alternate wetting and drying of weather cycles. Drying cracks are usually short, shallow, narrow, and numerous. Point of entry for surface runoff and surface moisture, causing saturation of adjacent embankment areas. This saturation, and later drying of the dam, could cause further cracking.</p>	<ol style="list-style-type: none"> 1. Seal surface cracks with a tight, impervious material. 2. Routinely grade crest to proper drainage and fill cracks. 3. Cover crest with non-plastic material (not clay) to prevent large variations in moisture content.
<p>Obscuring Vegetation</p> 	<p>Neglect of dam and lack of proper maintenance procedures.</p> <ol style="list-style-type: none"> 1. Obscures large parts of the dam, preventing adequate, accurate visual inspection of all parts of the dam. Problems which threaten the integrity of the dam can develop and remain undetected until they progress to a point that threatens the dam's safety. 2. Associated root systems develop and penetrate into the dam's cross section. When the vegetation dies, the decaying root systems can provide paths for seepage. This reduces the effective seepage path through the embankment and could lead to possible piping situations. 3. Prevents easy access to all parts of the dam for operation, maintenance and inspection. 4. Provides habitat for rodents. 5. Large trees can blow over during storms, resulting in damage and possible breach of the dam. 	<ol style="list-style-type: none"> 1. According to the FWS Tree Removal Guidelines (See Appendix F), any trees growing on the upstream slope that are less than 2 inches in diameter should be cut and treated. Trees growing on the downstream slope that are greater than 2 inches should be removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are less than 6 inches in diameter should be cut and removed. Trees growing on the crest, downstream slope and 20 feet beyond the toe of the dam that are greater than 6 inches in diameter should be removed. Grass should be encouraged on all segments of the dam to prevent erosion by surface runoff. The void which results from removing the root system should be backfilled with well-competent, well-compacted material. 2. Future undesirable growth should be removed by cutting or spraying, as part of an annual maintenance program. 3. All cutting or debris resulting from the vegetative removal should be immediately taken from the dam and properly disposed of outside



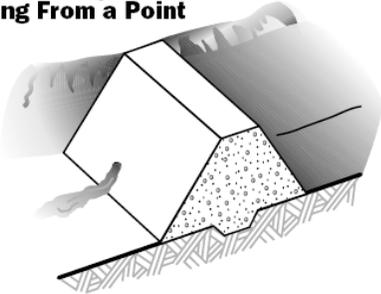
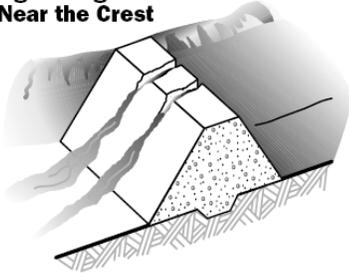
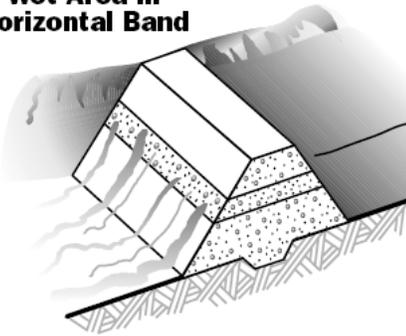
Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Ruts Along Crest</p> 	<ol style="list-style-type: none"> 1. Inhibits easy access to all parts of crest. 2. Allows continued development of rutting. 3. Allows standing water to collect and saturate crest of dam. 4. Operating and maintenance vehicles can get stuck. 	<p>the reservoir basin. An engineer should be involved if the tree removal process poses a threat to the dam.</p> <ol style="list-style-type: none"> 1 Drain standing water from ruts. 2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope. 3. Provide gravel or road base material to accommodate traffic. 4. Periodically maintain and regrade to prevent ruts reforming.
<p>Rodent Activity</p> 	<p>Burrowing animals.</p> <ol style="list-style-type: none"> 1. Entrance point for surface runoff to enter dam. Could saturate adjacent portions of the dam. 2. Especially dangerous if hole penetrates dam below phreatic line. During periods of high storage, seepage path through the dam would be greatly reduced and a piping situation could develop. Tunnels can lead to collapse of crest and possible failure. 	<ol style="list-style-type: none"> 1. Completely backfill the hole with competent well-compacted material. 2. Initiate a rodent control program to reduce the burrowing animal population and to prevent future damage to the dam.
<p>Gully on Crest</p> 	<ol style="list-style-type: none"> 1. Poor grading and improper drainage of crest. Improper drainage causes surface runoff to collect and drain off crest at low point in upstream or downstream shoulder. 2. Inadequate spillway capacity which has caused dam to overtop. <ol style="list-style-type: none"> 1. Can reduce available freeboard. 2. Reduces cross-sectional area of dam. 3. Inhibits access to all parts of the crest and dam. 4. Can result in a hazardous condition if due to overtopping. Heavy vehicle traffic without 	<ol style="list-style-type: none"> 1. Restore freeboard to dam by adding fill material to low area, using proper construction techniques. 2. Regrading crest to provide proper drainage of surface runoff. 3. If gully was caused by overtopping, create adequate spillway that meets current design standards. This should be done by engineer. 4. Reestablish protective cover.



Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Puddling on Crest— Poor Drainage</p> 	<p>adequate or proper maintenance or proper crest surfacing</p> <ol style="list-style-type: none"> 1. Poor grading and improper drainage of crest. 2. Localized consolidation or settlement on crest allows puddles to develop. <ol style="list-style-type: none"> 1. Causes localized saturation of the crest. 2. Inhibits access to all parts of the dam and crest. 3. Becomes progressively worse if not corrected. 	<ol style="list-style-type: none"> 1. Drain standing water from puddles. 2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope. 3. Provide gravel or road base material to accommodate traffic. 4. Periodically maintain and regrade to prevent low areas reforming.



Inspection Guidelines – Embankment Seepage Areas

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Excessive Quantity and/or Muddy Water Exiting From a Point</p> 	<ol style="list-style-type: none"> 1. Water has created an open pathway, channel or pipe through the dam. The water is eroding and carrying embankment material. 2. Large amounts of water have accumulated in the downstream slope. Water and embankment materials are exiting at one point. Surface agitation may be causing the muddy water. 3. Rodents, frost action or poor construction have allowed water to create an open pathway or pipe through the embankment. 	<ol style="list-style-type: none"> 1. Begin measuring outflow quantity and establishing whether water is getting muddier, staying the same or clearing up. 2. If quantity of flow is increasing, water level in reservoir should be lowered until flow stabilizes or stops. 3. Search for opening on upstream side and plug if possible. 4. A qualified engineer should inspect the condition and recommend further actions to be taken. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Stream of Water Exiting Through Cracks Near the Crest</p> 	<ol style="list-style-type: none"> 1. Continued flows can saturate parts of the embankment and lead to slides in the area. 2. Continued flows can further erode embankment materials and lead to failure of the dam. 	<ol style="list-style-type: none"> 1. Severe drying has caused shrinkage of embankment material. 2. Settlement in the embankment or foundation is causing the transverse cracks. Flow through the crack can cause failure of the dam. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Wet Area in Horizontal Band</p> 	<p>Frost layer or layer of sandy material in original construction.</p> <ol style="list-style-type: none"> 1. Wetting of areas below the area of excessive seepage can lead to localized instability of the embankment, resulting in slides. 2. Excessive flows can lead to accelerated erosion of embankment materials and failure of the dam. 	<ol style="list-style-type: none"> 1. Plug upstream side of crack to stop flow. 2. Lower water level in the reservoir should be lowered until below level of cracks. 3. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p> <ol style="list-style-type: none"> 1. Determine as closely as possible the flow being produced. 2. If flow increases, reservoir level should be reduced until flow stabilizes or stops. 3. Stake out the exact area involved. 4. Using hand tools, try to identify the material allowing the flow. 5. A qualified engineer should inspect the condition and recommend

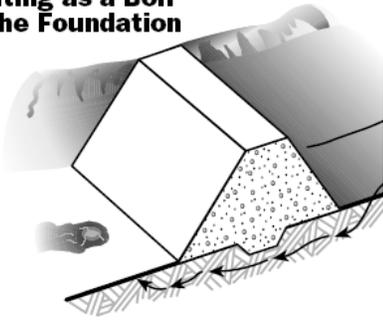
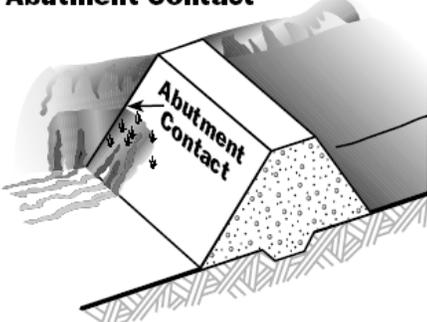
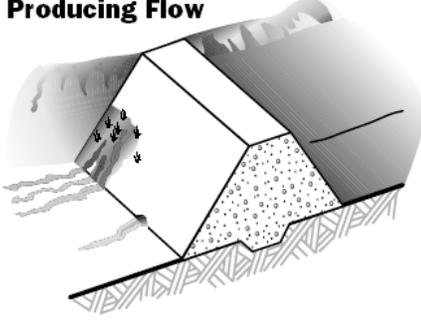


Problem	Probable Cause and Possible Consequences	Recommended Actions
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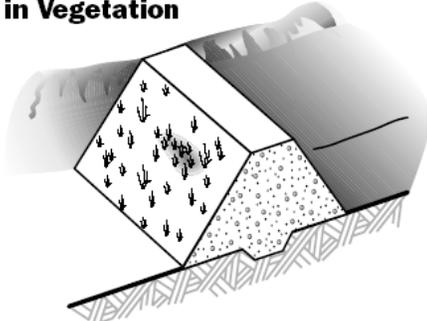
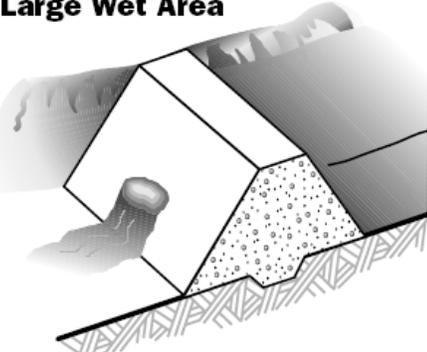
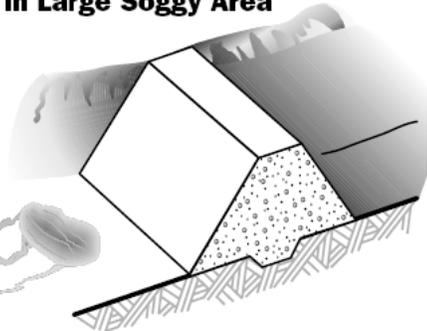
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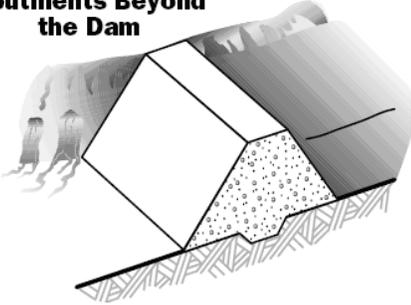


Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Seepage Water Exiting as a Boil in the Foundation</p> 	<p>Some part of the foundation material is supplying a flow path. This could be caused by a sand or gravel layer in the foundation. Increased flows can lead to erosion of the foundation and failure of the dam. See Figures 6-9 thru 6-13 for examples.</p>	<ol style="list-style-type: none"> 1. Examine the boil for transportation of foundation materials. 2. If soil particles are moving downstream, sandbags or earth should be used to create a dike around the boil. The pressures created by the water level with the dike may control flow velocities and temporarily prevent further erosion. 3. If erosion is becoming greater, the reservoir level should be lowered. 4. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Seepage Exiting at Abutment Contact</p> 	<ol style="list-style-type: none"> 1. Water flowing through pathways in the abutment. 2. Water flowing through the embankment. Can lead to erosion of embankment materials and failure of the dam. 	<ol style="list-style-type: none"> 1. Study leakage area to determine quantity of flow and extent of saturation. 2. Inspect daily for developing slides. 3. Water level in reservoir may need to be lowered to assure the safety of the embankment. 4. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Large Area Wet or Producing Flow</p> 	<p>A seepage path has developed through the abutment or embankment materials and failure of the dam can occur.</p> <ol style="list-style-type: none"> 1. Increased flows could lead to erosion of embankment material and failure of the dam. 2. Saturation of the embankment can lead to local slides which could cause failure of the dam. 	<ol style="list-style-type: none"> 1. Stake out the saturated area and monitor for growth or shrinking. 2. Measure any outflows as accurately as possible. 3. Reservoir level may need to be lowered if saturated areas grow at a fixed storage level or if flow increases. 4. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>



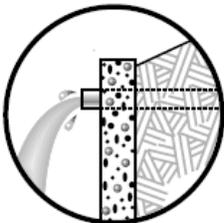
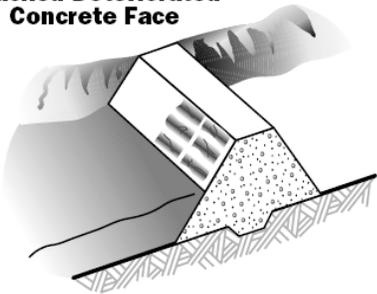
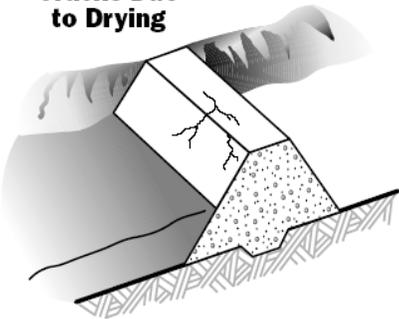
Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Marked Change in Vegetation</p> 	<ol style="list-style-type: none"> 1. Embankment materials are supplying flow paths. 2. Natural seeding by wind. 3. Change in seed type during early post-construction seeding. Can show a saturated area. 	<ol style="list-style-type: none"> 1. Use probe and shovel to establish if the materials in this area are wetter than surrounding areas. 2. If area shows wetness, when surrounding areas are dry or drier, a qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Bulge in Large Wet Area</p> 	<p>Downstream embankment materials have begun to move. Failure of the embankment resulting from massive sliding can follow these early movements.</p>	<ol style="list-style-type: none"> 1. Compare embankment cross-section to the end of construction condition to see if observed condition may reflect end of construction. 2. Stake out affected area and accurately measure outflow. 3. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Trampoline Effect in Large Soggy Area</p> 	<p>Water moving rapidly through the embankment or foundation is being controlled or contained by a well-established turf root system. Condition shows excessive seepage in the area. If control layer of turf is destroyed, rapid erosion of foundation materials could result in failure of the dam.</p>	<ol style="list-style-type: none"> 1. Carefully inspect the area for outflow quantity and any transported material. 2. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>



Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Leakage From Abutments Beyond the Dam</p> 	<p>Water moving through cracks and fissures in the abutment materials. Can lead to rapid erosion of abutment and evacuation of the reservoir. Can lead to massive slides near or downstream from the dam.</p>	<ol style="list-style-type: none"> 1. Carefully inspect the area to determine quantity of flow and amount of transported material. 2. A qualified engineer or geologist should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>

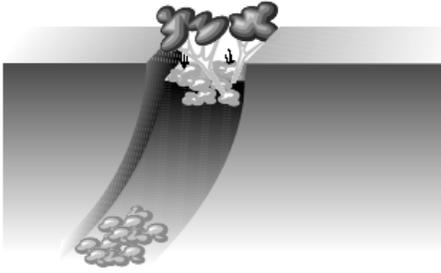
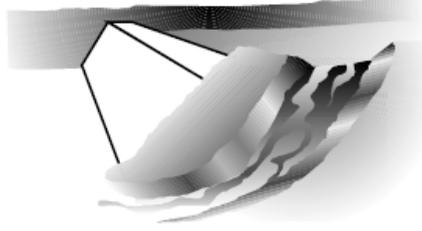
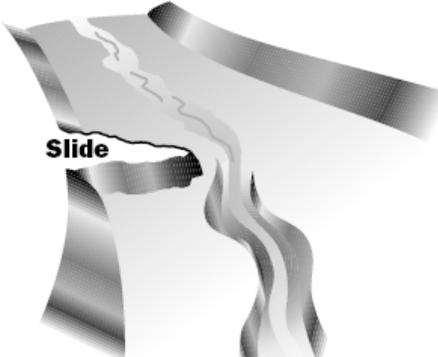


Inspection Guidelines – Concrete Upstream Slope

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Large Increase in Flow or Sediment in Drain Outfall</p> 	<p>Shortened seepage path or increased storage levels.</p> <ol style="list-style-type: none"> Higher velocity flows can cause erosion of drain, then embankment materials. Can lead to piping failure. 	<ol style="list-style-type: none"> Accurately measure outflow quantity and determine amount of increase over previous flow. Collect jar samples to compare turbidity. If either quantity or turbidity has increased by 25%, a qualified engineer should evaluate the condition and recommend further actions. <p style="text-align: center;">RDSO NOTIFICATION REQUIRED</p>
<p>Cracked Deteriorated Concrete Face</p> 	<p>Concrete deteriorated from weathering. Joint filler deteriorated or displaced. Soil is eroded behind the face and caverns can be formed. Unsupported sections of concrete crack. Ice action may displace concrete.</p>	<ol style="list-style-type: none"> Determine cause. Either patch with grout or contact engineer for permanent repair method. If damage is extensive, a qualified engineer should inspect the condition and recommend further actions. <p style="text-align: center;">RDSO NOTIFICATION REQUIRED</p>
<p>Cracks Due to Drying</p> 	<p>Soil loses its moisture and shrinks, causing cracks. <i>Note:</i> Usually limited to crest and downstream slope. Heavy rains can fill cracks and cause small parts of embankment to move along internal slip surface.</p>	<ol style="list-style-type: none"> Monitor cracks for increases in width, depth, or length. A qualified engineer should inspect condition and recommend further actions. <p style="text-align: center;">RDSO NOTIFICATION REQUIRED</p>



Inspection Guidelines – Spillways

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Excessive Vegetation or Debris in Channel</p> 	<p>Accumulation of slide materials, dead trees, excessive vegetative growth, etc., in spillway channel.</p> <p>Reduced discharge capacity; overflow of spillway, overtopping of dam. Prolonged overtopping can cause failure of the dam.</p>	<p>Clean out debris periodically; control vegetative growth in spillway channel. Install log boom in front of spillway entrance to intercept debris.</p>
<p>Erosion Channels</p> 	<p>Surface runoff from intense rainstorms or flow from spillway carries surface material down the slope, resulting in continuous troughs. Livestock traffic creates gullies where flow concentrates varies.</p> <p>Unabated erosion can lead to slides, slumps or slips which can result in reduced spillway capacity. Inadequate spillway capacity can lead to embankment overtopping and result in dam failure.</p>	<p>Photograph condition. Repair damaged areas by replacing eroded material with compacted fill. Protect areas against future erosion by installing suitable rock riprap. Re-vegetate area if appropriate. Bring condition to the attention of the engineer during next inspection.</p>
<p>Excessive Erosion in Earth-Slide Causes Concentrated Flows</p> 	<p>Discharge velocity too high; bottom and slope material loose or deteriorated; channel and bank slopes too steep; bare soil unprotected; poor construction protective surface failed.</p> <p>Disturbed flow pattern; loss of material, increased sediment load downstream, collapse of banks; failure of spillway; can lead to rapid evacuation of the reservoir through the severely eroded spillway.</p>	<p>Minimize flow velocity by proper design. Use sound material. Keep channel and bank slopes mild. Encourage growth of grass on soil surface. Construct smooth and well-compacted surfaces. Protect surface with riprap, asphalt or concrete. Repair eroded portion using sound construction practices.</p>



Problem	Probable Cause and Possible Consequences	Recommended Actions
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End of Spillway Chute Undercut

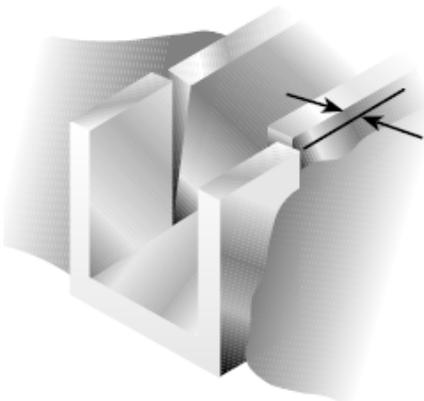


Poor configuration of stilling basin area. Highly erodible materials. Absence of cut-off wall at end of chute.

Structural damage to spillway structure; collapse of slab and wall lead to costly repair.

Dewater affected area; clean out eroded area and properly backfill. Improve stream channel below chute; provide properly sized riprap in stilling basin area. Install cutoff wall.

Wall Displacement



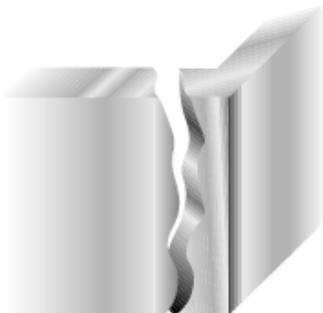
Poor workmanship; uneven settlement of foundation; excessive earth and water pressure; insufficient steel bar reinforcement of concrete.

Minor displacement will create eddies and turbulence in the flow, causing erosion of the soil behind the wall. Major displacement will cause severe cracks and eventual failure of the structure. See Figure 5-5 for examples.

Reconstruction should be done according to sound engineering practices. Foundation should be carefully prepared. Adequate weep holes should be installed to relieve water pressure behind wall. Use enough reinforcement in the concrete. Anchor walls to prevent further displacement. Install struts between spillway walls. Clean out and back flush drains to assure proper operations. Consult an engineer before actions are taken.

RDSO NOTIFICATION REQUIRED

Large Cracks



Construction defect; local concentrate distress; local material deterioration; foundation failure, excessive backfill pressure. Disturbance in flow patterns; erosion of foundation and backfill; eventual collapse of structure. See Figure 5-5 for examples.

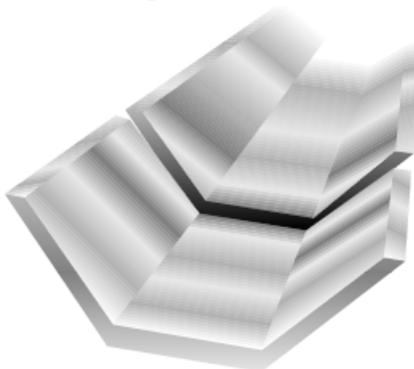
Large cracks without large displacement should be repaired by patching.

Surrounding areas should be cleaned or cut out before patching material is applied. Installation of weep holes or other actions may be needed.



Problem	Probable Cause and Possible Consequences	Recommended Actions
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Open or Displaced Joints



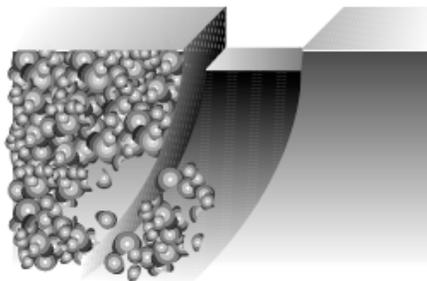
Excessive and uneven settlement of foundation; sliding of concrete slab; construction joint too wide and left unsealed. Sealant deteriorated and washed away.

Erosion of foundation material may weaken support and cause further cracks; pressure induced by water flowing over displaced joints may wash away wall or slab, or cause extensive undermining.

Construction joint should be no wider than 1/2". All joints should be sealed with asphalt or other flexible materials. Water stops should be used where feasible. Clean the joint, replace eroded materials, and seal the joint. Foundations should be properly drained and prepared. Underside of chute slabs should have ribs of enough depth to prevent sliding. Avoid steep chute slope.

RDSO NOTIFICATION REQUIRED

Breakdown and Loss of Riprap



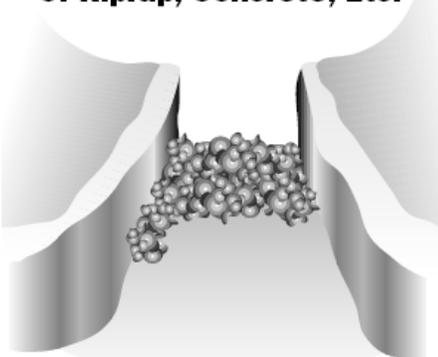
Slope too steep; material poorly graded; failure of subgrade; flow velocity too high; improper placement of material; bedding material or foundation washed away.

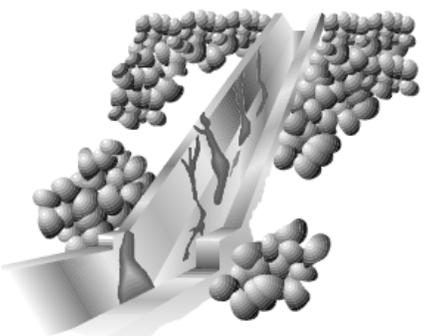
Erosion of channel bottom and banks; failure of spillway.

Design a stable slope for channel bottom and banks. Riprap material should be well-graded (the material should contain small, medium and large particles). Subgrade should be properly prepared before placement of riprap. Install filter fabric if necessary. Control flow velocity in the spillway by proper design. Riprap should be placed according to specification.

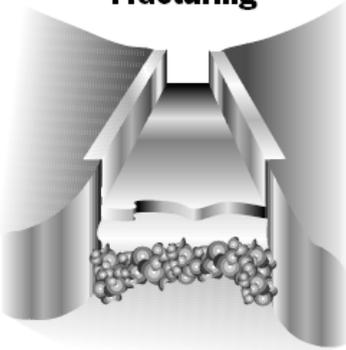
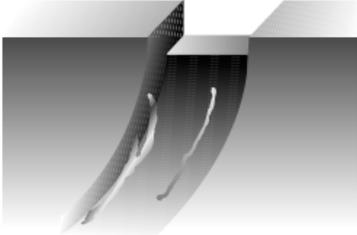
RDSO NOTIFICATION REQUIRED



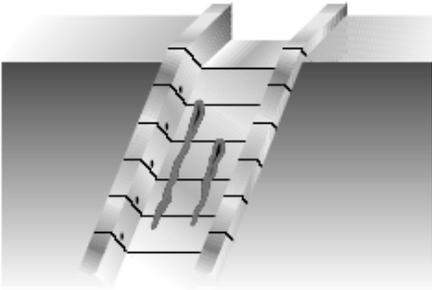
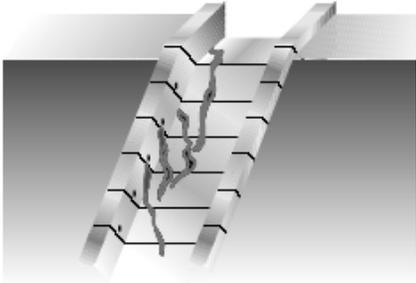
Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Material Deterioration—Spalling and Disintegration of Riprap, Concrete, Etc.</p> 	<p>Use of unsound or defective materials; structures subject to freeze-thaw cycles; improper maintenance practices; harmful chemicals. Structure life will be shortened; premature failure.</p>	<p>Avoid using shale or sandstone for riprap. Add air-entraining agent when mixing concrete. Use only clean, good quality aggregates in the concrete. Steel bars should have at least 1" of concrete cover. Concrete should be kept damp and protected from freezing during curing.</p>

<p>Poor Surface Drainage</p> 	<p>No weep holes; no drainage facility; plugged drains.</p> <p>Wet foundation has lower supporting capacity; uplift pressure resulting from seepage water may damage spillway chute; accumulation of water may also increase total pressure on spillway walls and cause damage.</p>	<p>Install weep holes on spillway walls. Inner end of hole should be surrounded and packed with graded filtering material. Install drain system under spillway near downstream end. Clean out existing weep holes. Back flush and rehabilitate drain system under the supervision of an engineer.</p> <p>RDSO NOTIFICATION REQUIRED</p>
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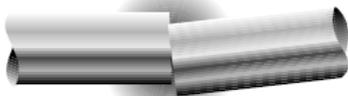
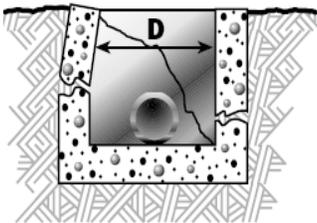
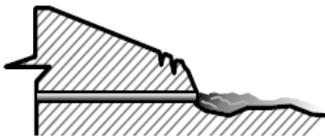
Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Concrete Erosion, Abrasion, and Fracturing</p> 	<p>Flow velocity too high (usually occurs at lower end of chute in high dams); rolling of gravel and rocks down the chutes; cavity behind or below concrete slab.</p> <p>Pockmarks and spalling of concrete surface may progressively worsen; small hole may cause undermining of foundation, leading to failure of structure.</p>	<p>Remove rocks and gravels from spillway chute before flood season. Raise water level in stilling basin. Use good quality concrete. Assure concrete surface is smooth.</p> <p>RDSO NOTIFICATION REQUIRED</p>
<p>Leakage in or Around Spillway</p> 	<ol style="list-style-type: none"> Cracks and joints in geologic formation at spillway are permitting seepage. Gravel or sand layers at spillway are permitting seepage. <ol style="list-style-type: none"> Could lead to excessive loss of stored water. Could lead to a progressive failure if velocities are high enough to cause erosion of natural materials. 	<ol style="list-style-type: none"> Examine exit area to see if type of material can explain leakage. Measure flow quantity and check for erosion of natural materials. If flow rate or amount of eroded materials increases rapidly, reservoir level should be lowered until flow stabilizes or stops. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>



Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Too Much Leakage From Spillway Under Drains</p> 	<p>Drain or cutoff may have failed.</p> <ol style="list-style-type: none"> 1. Excessive flows under the spillway could lead to erosion of foundation material and collapse of parts of the spillway. 2. Uncontrolled flows could lead to loss of stored water. 	<ol style="list-style-type: none"> 1. Examine exit area to see if type of material can explain leakage. 2. Measure flow and check for erosion of natural materials. 3. If flow rate or amount of eroded materials increases rapidly, reservoir level should be lowered until flow stabilizes or stops. 4. A qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>
<p>Seepage From a Construction Joint or Crack in Concrete Structure</p> 	<p>Water is collecting behind structure because of insufficient drainage or clogged weep holes.</p> <ol style="list-style-type: none"> 1. Can cause walls to tip in and over. Flows through concrete can lead to rapid deterioration from weathering. 2. If spillway is located within embankment, rapid erosion can lead to failure of the dam. 	<ol style="list-style-type: none"> 1. Check area behind wall for puddling of surface water. 2. Check and clean as needed; drain outfalls, flush lines and weep holes. 3. If condition persists, a qualified engineer should inspect the condition and recommend further actions. <p>RDSO NOTIFICATION REQUIRED</p>



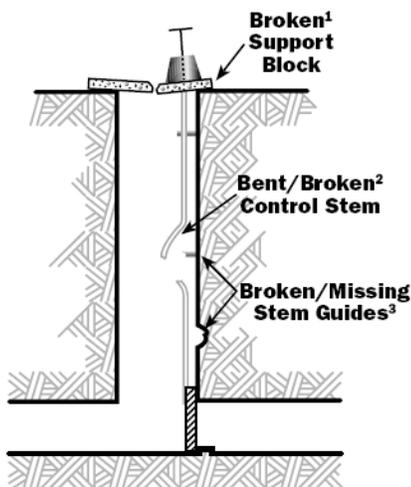
Inspection Guidelines – Inlets, Outlets, and Drains

Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Outlet Pipe Damage Crack</p> 	<p>Settlement; impact. Excessive seepage, possible internal erosion.</p>	<p>Check for evidence of water either entering or exiting pipe at crack, hole, etc. RDSO NOTIFICATION REQUIRED</p>
<p>Outlet Pipe Damage Hole</p> 	<p>Rust (steel pipe); erosion (concrete pipe); cavitation.</p>	<p>Tap pipe in vicinity of damaged area, listening for hollow sound which indicates a void has formed along the outside of the conduit. RDSO NOTIFICATION REQUIRED</p>
<p>Outlet Pipe Damage Joint Offset</p> 	<p>Settlement or poor construction practice. Provides passageway for water or exit or enter pipe, resulting in erosion of internal materials of the dam.</p>	<p>If a progressive failure is suspected, request engineering advice. RDSO NOTIFICATION REQUIRED</p>
<p>Failure of Concrete Outfall Structure</p> 	<p>Excessive side pressures on non reinforced concrete structure. Poor concrete quality. Loss of outfall structure exposes embankment to erosion by outlet releases.</p>	<ol style="list-style-type: none"> 1. Check for progressive failure by monitoring typical dimension, such as “D” shown in figure. 2. Repair by patching cracks and supplying drainage around concrete structure. Outfall structure may need total replacement.
<p>Outlet Releases Eroding Toe of Dam</p> 	<p>Outlet pipe too short. Lack of energy-dissipating pool or structure at downstream end of conduit. Erosion of toe over steepens downstream slope, causing progressive sloughing.</p>	<ol style="list-style-type: none"> 1. Extend pipe beyond toe (use pipe of same size and material, and form watertight connection to existing conduit). 2. Protect embankment with riprap over suitable bedding.



Problem	Probable Cause and Possible Consequences	Recommended Actions
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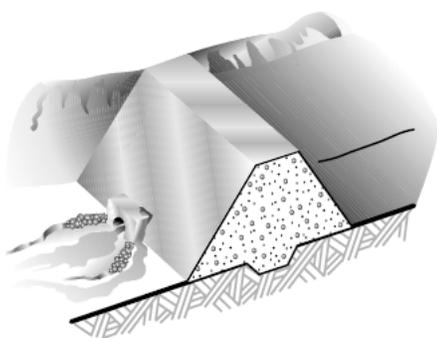
Control Works



- 1. BROKEN SUPPORT BLOCK** Concrete deterioration. Excessive force exerted on control stem by trying to open gate when it was jammed. Causes control support block to tile; control stem may bind. Control head works may settle. Gate may not open all the way. Support block may fail completely, leaving outlet inoperable.
- 2. BENT/BROKEN CONTROL STEM** Rust. Excess force used to open or close gate. Inadequate or broken stem guides. Outlet is inoperable.
- 3. BROKEN/MISSING STEM GUIDES** Rust. Inadequate lubrication. Excess force used to open or close gate when jammed. Loss of support for control stem. Stem may buckle and break under normal use (as in this example).

Any of these conditions can mean the control is either inoperable or, at best, partly operable. Use of the system should be minimized or discontinued. If the outlet system has a second control valve, consider using it to regulate releases until repairs can be made. Engineering help is recommended.

Seepage Water Exiting From a Point Adjacent to the Outlet



1. A break in the outlet pipe.
 2. A path for flow has developed along the outside of the outlet pipe.
- Continued flows can lead to erosion of the embankment materials and failure of the dam.

1. Thoroughly investigate the area by probing and/or shoveling to try to determine cause.
2. Determine if leakage water is carrying soil particles.
3. Determine quantity of flow.
4. If flow increases or is carrying embankment materials, reservoir level should be lowered until leakage stops.
5. A qualified engineer should inspect the condition and recommend further actions.
6. Investigate if there are any signs of settlement or sinkholes on the embankment along the alignment of the spillway pipe.

RDSO NOTIFICATION REQUIRED



Problem	Probable Cause and Possible Consequences	Recommended Actions
<p>Valve Leakage Debris Stuck Under Gate</p> 	<p>Trashrack missing or damaged. Gate will not close. Gate or stem may be damaged in effort to close gate.</p>	<p>Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trashrack.</p>
<p>Valve Leakage Cracked Gate Leaf</p> 	<p>Ice action, rust, affect vibration, or stress resulting from forcing gate closed when it is jammed. Gate-leaf main fail completely, evacuating reservoir.</p>	<p>Use valve only in fully open or closed position. Minimize use of valve until leaf can be repaired or replaced.</p>
<p>Valve Leakage Damage Gate Seat or Guides</p> 	<p>Rust, erosion, cavitation, vibration or wear. Leakage and loss of support for gate leaf. Gate may bind in guides and become inoperable.</p>	<p>Minimize use of valve until guides or seats can be repaired. If cavitation is the cause, check to see if air vent pipe exists, and is unobstructed.</p>



APPENDIX C

OPERATIONS LOG & INSPECTION CHECKLIST

INFORMAL INSPECTION CHECKLIST FOR DAMS

DAM NAME: _____

DATE INSPECTED: _____

STATION: _____

WEATHER/TEMP.: _____

HAZARD CLASSIFICATION: _____

POOL ELEVATION: _____

TAILWATER ELEVATION: _____

INSPECTED BY: _____

DIRECTIONS: MARK CONDITIONS FOUND BY CHECKING BOXES AND BOLDING/UNDERLINING WORDS THAT APPLY. GIVE LOCATION AND EXTENT IN COMMENTS. REFERENCE APPLICABLE PHOTO NUMBERS IN PHOTOS.

UPSTREAM SLOPE

PROBLEMS NOTED: (1) None (2) Excessive vegetation (3) Animal burrows (4) Wave erosion; with scarps
 (5) Appears too steep (6) Depressions or bulges (7) Sinkholes (8) Cracks; with displacement (9) Slides
 (10) Concrete facing: holes; cracks; displacement; undermined (11) Slope protection: missing; sparse; displaced;
 weathered (12) Other

COMMENTS:

CREST

PROBLEMS NOTED: (1) None (2) Excessive vegetation (3) Animal burrows (4) Erosion (5) Sinkholes
 (6) Cracks; with displacement (7) Ruts or puddles (8) Inadequate surface drainage (9) Not wide enough
 (10) Misalignment (11) Low areas (12) Other

COMMENTS:

DOWNSTREAM SLOPE

PROBLEMS NOTED: (1) None (2) Excessive vegetation (3) Animal burrows (4) Erosion or gullies (5) Appears
 too steep (6) Depressions or bulges (7) Sinkholes (8) Cracks; with displacement (9) Slides (10) Slope
 protection: missing; sparse; displaced; weathered (11) Soft areas (12) Livestock damage (13) Other

COMMENTS:

SEEPAGE

PROBLEMS NOTED: (1) None (2) Flow adjacent to outlet (3) Saturated embankment areas (4) Seepage area at
 toe (5) Seepage exists at point source (6) Seepage exists on embankment (7) Seepage increased/muddy
 (8) Other

DRAIN OUTFALLS SEEN? yes no (9) Flow increased/muddy (10) Drain dry/obstructed (11) Pipe deteriorated
 (12) Animal guard (13) Other

COMMENTS:

SERVICE SPILLWAY

PROBLEMS NOTED: (1) None (2) No service spillway (3) Appears to be structurally inadequate (4) Appears too small (5) Inadequate freeboard (6) Erosion; with backcutting (7) Flow obstructed (8) Concrete/masonry deteriorated/undermined (9) Cracks; with displacement (10) Restricted by vegetation (11) Other

COMMENTS:

EMERGENCY SPILLWAY

PROBLEMS NOTED: (1) None (2) No emergency spillway (3) Appears to be structurally inadequate (4) Appears too small (5) Inadequate freeboard (6) Erosion; with backcutting (7) Flow obstructed (8) Concrete/masonry deteriorated/undermined (9) Cracks; with displacement (10) Restricted by vegetation (11) Other

COMMENTS:

OUTLET WORKS

PROBLEMS NOTED: (1) None (2) No outlet works (3) Upstream or downstream structure deteriorated (4) Outlet not operated during inspection (5) Outlet inoperable (6) Poor operating access (7) Restricted by vegetation (8) Other

INTERIOR INSPECTED? yes no (8) Conduit deteriorated or collapsed (9) Joints displaced (10) Valve leakage (11) Other

COMMENTS:

MONITORING

EXISTING INSTRUMENTATION FOUND: (1) None (2) Gage rod (3) Seepage weirs/flumes (4) Piezometers (5) Survey monuments (6) Other

MONITORING OF INSTRUMENTATION? yes no

COMMENTS:



APPENDIX D

INSTRUMENT MONITORING DATA FORMS

PIEZOMETER MONITORING DATA

Date _____
 Reservoir Water Surface Elevation _____
 Read by _____
 Checked by _____

Piezometer No.	Station	Top of PVC Pipe Elev.	Depth to Water (feet)	Water Elevation (feet)	Depth to Water (feet)	Water Elevation (feet)	Depth to Water (feet)	Water Elevation (feet)

Date _____
 Reservoir Water Surface Elevation _____
 Read by _____
 Checked by _____

Piezometer No.	Station	Top of PVC Pipe Elev.	Depth to Water (feet)	Water Elevation (feet)	Depth to Water (feet)	Water Elevation (feet)	Depth to Water (feet)	Water Elevation (feet)
B-301	21+00	929.15						
B-302	21+00	923.52						
B-303	18+10	929.03						
B-304	18+10	921.95						
B-305	13+60	929.43						
B-306	13+60	921.74						

Water Elev.	=	Top of PVC Elev.	-	Depth to Water
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DRAIN OUTFALL MONITORING DATA

Date _____
Reservoir Elevation _____
Read by _____
Checked by _____

Location	Depth of Flow Over Weir (ft)	Discharge (gpm)	Depth of Flow Over Weir (ft)	Discharge (gpm)	Depth of Flow Over Weir (ft)	Discharge (gpm)

Date _____
Reservoir Elevation _____
Read by _____
Checked by _____

Location	Depth of Flow Over Weir (ft)	Discharge (gpm)	Depth of Flow Over Weir (ft)	Discharge (gpm)	Depth of Flow Over Weir (ft)	Discharge (gpm)

Date _____
Reservoir Elevation _____
Read by _____
Checked by _____

Location	Depth of Flow Over Weir (ft)	Discharge (gpm)	Depth of Flow Over Weir (ft)	Discharge (gpm)	Depth of Flow Over Weir (ft)	Discharge (gpm)

Notes

Use the following equation to compute flow in gallons per minute (gpm): $Q = 461.558 (H)^{5/2}$
 Where H = height (in feet, measured to nearest hundredth) of water flowing over the weir.

SURVEY POINT MONITORING DATA

Date: _____

Reservoir

Elevation: _____ feet

Surveyor: _____

EMBANKMENT MOVEMENT MONUMENTS											
Survey Data	Original	Current									
Northing											
Easting											
Elevation											

STRUCTURE SURVEY CONTROL POINTS									
Survey Data	Original	Current	Original	Current	Original	Current	Original	Current	
Northing									
Easting									
Elevation									

Notes:

All points will be surveyed by a licensed surveyor to measure northings, eastings, and elevations to the nearest 0.01 foot.



APPENDIX E

FEMA TECHNICAL MANUAL FOR DAM OWNERS – IMPACTS OF ANIMALS ON EARTHEN DAMS

NOT INCLUDED



APPENDIX F

FWS TREE REMOVAL GUIDELINES

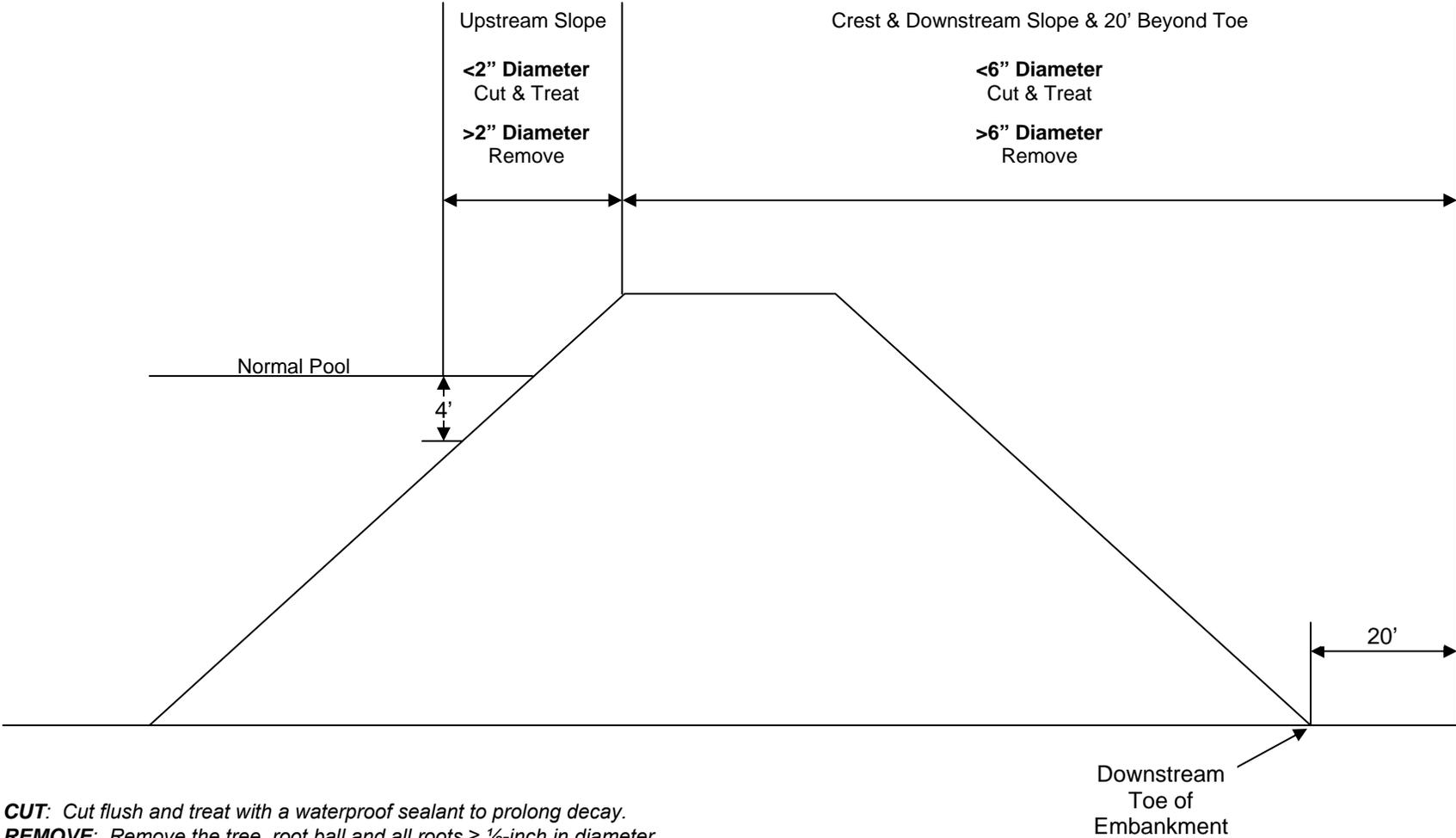
SEE BELOW

FEMA TECHNICAL MANUAL FOR DAM OWNERS – IMPACTS OF PLANTS ON EARTHEN DAMS

NOT INCLUDED



Fish and Wildlife Service Tree Removal Guidelines



CUT: Cut flush and treat with a waterproof sealant to prolong decay.
REMOVE: Remove the tree, root ball and all roots \geq 1/2-inch in diameter



APPENDIX G

PAPER ON INSTALLING TEMPORARY SIPHON(S) TO DRAIN RESERVOIR

**NO DRAIN TO PULL? WELL THAT SUCKS!
PENNSYLVANIA'S EMERGENCY RESPONSE TEAMS MAY BE ABLE TO
HELP!**

*Richard A. Reisinger, E.I.T.
PA Dept. of Environmental Protection
Division of Dam Safety*

Introduction

In past practices, construction of smaller dams, whether farm ponds, historic ice ponds, or strictly aesthetic amenities constructed prior to the mid 1970s, rarely incorporated a low level or drawdown conduit. Additionally, aging facilities with a drawdown system may have operability issues stemming from rusted or stuck gates, broken controls, or deteriorated conduits. Therefore, if a dam emergency were to occur at one of these facilities, lowering of the impoundment level to aid in preserving the structure and averting a potential disaster could be very involved and costly.

Noting the lack of a drawdown conduit as a significant concern, the PADEP Division of Dam Safety began taking steps to secure compact mobile siphoning setups in 2002. These setups are comprised of 6-inch diameter schedule 40 pvc pipe, assorted fittings and connectors, a gasoline-powered trash-pump, and hand tools. All of these supplies are stored within an enclosed cargo trailer, which can be easily connected to a truck and moved to the site of an emergency.

Siphon Theory

A siphon, despite its apparent complicated theory, is a simple yet powerful tool proven very useful for moving fluids over small elevation gradients. Siphons are commonly used to move water, gasoline, oil, and liquid metals. Siphons range in size and variability from small compact systems such as the common toilet bowl to large-scale water supply systems and

emergency spillways for dams. However, in all applications the workings of the siphon are the same.

The crest height at which a siphon will successfully operate (point B in Figure 1) is limited by the effective atmospheric pressure and the fluid density of the reservoir. Theoretically, for water at standard atmospheric pressure in a vacuum, the maximum crest or “lift” height obtained is about 33 feet. A reservoir filled with mercury would limit this crest height to about 30 inches. However, in “real world” applications water typically begins to vaporize at lift heights approaching 20 feet, and for every 1,000 feet in elevation above sea level, the reduction in atmospheric pressure results in a decrease to the lift height of about 1 foot. This combined with the fact that a perfect vacuum cannot be obtained in field applications and minor air leaks will undoubtedly exist, the typical lift height is usually limited to about 15 feet.

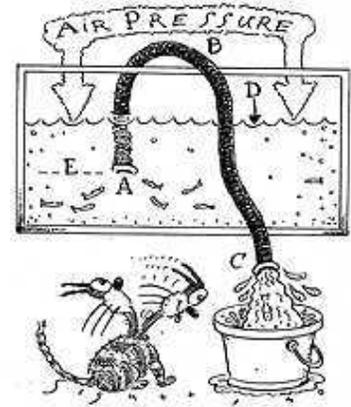


Figure 1

Siphon Equipment

In 2002, the Division of Dam Safety began investigating the use of temporary siphon setups to be implemented in certain situations to aid in averting dam emergencies. Then, beginning in 2003, a decision was made to purchase equipment for two mobile siphon units, with three more completed in 2005, and an expected addition of two more this year. Each trailer is supplied with enough material to construct up to 250-linear feet of 6-inch siphon. Currently, four of these trailers are distributed across the State to Regional Office Emergency Response Teams, with one being maintained by Dam Safety staff in Harrisburg.

The following is a list of equipment and supplies:

- 6-foot by 12-foot cargo utility trailer
- 3.5 horsepower 2-inch diameter gasoline powered trash pump



- 6-inch diameter Schedule 40 pvc pipe (cut to 10-foot lengths)
- rubber Fernco[®] fittings for 6-inch diameter pipe
- assorted 6-inch diameter fittings and elbows
- battery powered cordless tool kit (drill, saw, etc.)
- assorted hand tools (pipe wrench, hammer, pliers, etc.)
- pad locks for trailers
- pvc cleaner and glue
- gas can and oil for trash pump
- personal protective equipment (gloves, goggles, etc.)
- reinforcing bars / steel stakes for anchoring siphon
- vehicle to pull trailer and associated hitching equipment



The Commonwealth was able to purchase this equipment at a cost of roughly \$6,500 per trailer (not including the tow vehicle). Monies for these purchases were used from Federal Dam Safety Grants and the State's Dam Safety and Encroachments Fund.

Initial Preparations

In order to maximize the efficiency of setup, a great deal of initial prep work can be performed prior to placing the siphon supplies into operation. Since pvc glue takes time to dry, the use of glue should be minimized on site. Additionally, these supplies are intended to be re-



usable, so coupling and gluing together long straight sections of pipe will result in wasted materials when the pipe is disassembled and needs to be cut. When using pvc glue on elbows, caps, or tees, a small straight



section of pipe should be incorporated into each end to allow for the use of rubber Fernco[®] fittings for quick field connections. Also, self-tapping screws can be placed through the coupler or elbow and into the pipe to aid in preventing the pipe from torquing and breaking the glue bond. Air leaks can be prevented by placing pvc glue over the screw head. It is also

advantageous to prepare a few “over the crest” sections with fill tees and a valve or cleanout plug.

Initial preparations should not stop with the pvc siphon pipe itself. If the trash pump is brand new, it may take some time to get it operational and running smoothly, and the cordless tool kit batteries will need charged. Having these items prepared prior to arriving at the site can save valuable time during an emergency situation.

Site Considerations

These small mobile siphon systems are limited in operation and may not be the appropriate means for obtaining the desired objective. Before heading to a dam site with the intent to install these siphons, a brief review of the site characteristics should be conducted to answer the following five questions:

What Is the Intended Final Result of the Dam and Purpose of the Siphon?

Answering this question will provide justification for using a siphon as an emergency operation. The key to determining if a dam emergency exists is whether the dam in question poses a downstream safety hazard. If a hazard exists, siphons can be used to accomplish two main goals during an emergency. Depending on the intended final result of the dam, lowering the pool level and performing an emergency repair to damaged or inoperable structures, or lowering the pool level to perform an emergency breach of the dam’s embankment, are the two main options. The setup location of the siphons, amount of siphons, and coordination of other activities should be considered. If the intent is to repair the dam, then the proper materials and equipment must be present to perform the repair. If the impoundment is to be drained and the dam breached, then the setup location of the siphons should be evaluated to prevent problems during the breach.

What is the Estimated Drainage Area to the Dam?

The use of 6-inch diameter siphons on a dam with a contributory drainage area exceeding a couple square miles will not be very useful for draining or lowering the pool level. However, if the intent of these siphons is to relieve or reduce spillway flows through a

damaged area, then siphons may be considered on large drainage areas. Considering the size of the watershed will aid in prescribing the number of siphons needed for the intended result. The Commonwealth has found that these siphons are most useful for watersheds under one square mile during normal flow conditions.

What is the Height of the Dam?

The height of the dam plays a major part in determining whether siphons are a feasible method to avert a potential emergency. Constructing three siphons on a 50-foot high dam will require more materials than constructing five siphons on a 20-foot high dam. Additional materials may need to be located and sent to the site. Since the weight of the water within a long run of siphon pipe on a slope can break the fittings, the downstream leg of the siphon should be anchored to the face of the dam for a run exceeding 25-feet. Placement of a siphon on a very steep slope will require more anchoring.

Where is the Normal Pool Level Relative to the Top of Dam?

It is clear from the siphon theory presented earlier, the maximum lift height is usually limited to between 15 and 20 feet. Therefore, if the normal pool level is set 10-feet below the top of dam elevation, a siphon setup over the dam crest would be limited to lowering the pool up to 10 feet. However, in some situations the crest of the siphon could be placed closer to the pool level by setting the siphon through the spillway section, which will increase its draw depth.

Can the Utility Trailer and Equipment Gain Reasonable Access to the Dam?

If a pickup truck and utility trailer cannot get close to the dam, preferably on the dam, then the time it will take to setup and render a siphon operable may not be sufficient, and another means of handling this emergency should be considered.

Siphon Setup

Once it is determined that a siphon will be useful for a particular situation, then begins the daunting task of getting the equipment to the dam site and setting up the siphon. The 6-inch diameter pvc pipe was mainly selected for ease of quick construction without the need for

large lifting equipment. Ten-foot sections of 6-inch pvc pipe are about the maximum size that one person can safely handle. A well-trained two-man crew can assemble, prime, and have an operational siphon on a 20-foot high dam in about one hour or less.

The siphon(s) should be located where the minimum “lift” height from the pool level exists, while taking into account where the best location of the discharge end should be. The outlet should be placed preferably within a downstream spillway channel, plunge pool, or other protected area to prevent scour and erosion. If possible, the outlet end of the siphon should be submerged to prevent air from being introduced into the siphon. When this cannot be accomplished, placing a 90-degree elbow on the discharge end pointed straight up will aid in keeping air from entering the siphon. Additionally, an elbow is recommended on the upstream (intake) end of the siphon, which also should be turned up within the reservoir to reduce the potential for sucking in mud, small gravel, and other reservoir bottom debris.

The straight 10-foot long sections of pipe should be connected using the rubber Fernco[®] fittings. These fittings contain metal tightening bands on each end and are connected by turning the adjusting screw clockwise. The battery-powered drill, with the appropriate attachment, can be used to tighten these bands. The interior surface of the Fernco[®] fitting and the exterior surface of the pvc pipe must be clean and free of debris. Any type of dirt can cause a bad seal and reduce the effectiveness of the siphon. The pipe can be adjusted within the Fernco[®] fittings to make a tight straight connection or allow a small amount of movement resulting in an adjustable elbow connection. The tight straight connection is accomplished by butting the two ends of the pipe against each other within the fitting and tightening the metal bands. This action provides a minimal amount of open space between the two sections of pipe, which ultimately locks the pipes together. If open space is left within the center of the fitting, the two sections of pipe can move until they butt against each other. This adjustable elbow connection can be very useful for uneven terrain or small alignment changes.

The section used across the crest should incorporate a means of “priming” the siphon. There are two main methods that have proven useful to prime an emergency siphon. The least complicated method is to use a trash pump to fill the downstream leg of the siphon with water. In order to do this, a threaded plug must be placed on the discharge end, and a tee

section containing a threaded plug must be placed within the crest section of the siphon. In place of threaded plugs shut off valves could be used; however these can be costly items to purchase. The second method replaces the trash pump with a vacuum pump. The vacuum pump is connected to the siphon at the crest section. As a vacuum is induced inside the siphon, water is pulled from the reservoir up the upstream leg of the siphon, and ultimately fills the downstream leg as the air is removed. Once the entire siphon is filled with water, a valve is closed at the vacuum pump connection and the discharge end of the siphon is opened. Using this method requires electricity to operate the vacuum pump, and therefore a generator should be included with the setup. Since this entire operation will take place around or in water, extreme caution should be taken when using electricity. In addition to the generator, an intermediate collection container must be placed between the vacuum pump and the siphon to prevent water from entering the electric vacuum pump.



Using a Vacuum Pump



Using a Trash Pump

As can be seen in the above photos, the use of the vacuum pump is more complicated and requires a great deal of small diameter pipe connections, fittings, and increased setup time.

Case Studies

The Department has used the siphon trailers and supplies on a few occasions since their implementation. Valuable knowledge was gained and “hands-on” training experience has proven very useful in the operation, setup, and tear down of these systems. Other than one training exercise, every dam where these emergency siphons have been implemented was breached and stabilized.

Betsy Lake Dam

The Betsy Lake Dam, owned and operated by the Pymatuning Village Club Allotments (PVCA), was constructed during the 1960s without obtaining a permit from the Department. The dam is an 18-foot high earthen embankment, approximately 460-feet long, located on a 0.6 square mile drainage area in North Shenango Township, Crawford County. This dam did not contain a low level drawdown, and a corrugated steel riser pipe served as the primary spillway. The Division of Dam Safety was unaware of this dam until the fall of 2004 when a site inspection and jurisdictional determination was conducted. This dam was found to be jurisdictional and subsequently classified as hazard potential category 1 or “High” hazard.

On December 27, 2004, the Department’s Northwest Regional Office (NWRO) was contacted by a resident of the PVCA regarding concerns about the dam’s primary outlet pipe. This call prompted a regional engineer to perform an inspection the following day. This inspection revealed a failure of the outlet pipe between the downstream toe of the dam and a roadway crossing further downstream along the toe, resulting in a large erosion hole. At that time, it appeared as though the PVCA was in the process of removing the roadway culvert and replacing a portion of the outlet conduit. During this process, serious problems with the outlet conduit became apparent. Also, the PVCA had excavated into the toe of the dam to expose the deteriorated spillway conduit and connect a new pipe section. All of this work had been performed without approval from the Division of Dam Safety, or direction of a professional engineer. The Regional Office staff contacted the Division of Dam Safety. Dam Safety advised Regional staff to direct the PVCA to complete the intended repairs immediately, backfill the area, and begin draining the lake. The Department sent a letter on January 10,

2005 to the PVCA requesting the lake be drained and maintained in a drained condition until appropriate plans were developed and approved for the rehabilitation of the dam.

NWRO staff conducted a follow-up site inspection early on January 11, 2005, noting the previous erosion hole had doubled in size, further causing concern for the dam's embankment. NWRO staff notified Dam Safety and the Department's Northwest Emergency Response Program Manager (NWERPM). The NWERPM, Crawford County Emergency Management Coordinator, two members of the North Shenango Fire Department, and representatives from the PVCA conducted an additional site inspection later the same day. The NWERPM conducted a downstream assessment of structures and determined the only immediate threat was to anyone using the downstream roadway should the dam fail.

At this time, only two siphon trailer setups existed within the Commonwealth, one located with the Southwest Region, and one within the Southcentral Region. The NWERPM contacted the Southwest Regional Emergency Response office and requested the use of their supplies. On January 12, 2005, two 6-inch diameter siphons were set up and rendered operational. These siphons were primed using a vacuum pump. At this time, the dam remains breached awaiting a decision from the PVCA to reconstruct the structure. The following photos are from the Betsy Lake Incident.



Temporary Repair Attempt



Downstream Face During Setup

Looking Upstream



Looking Into Lake



Priming Siphon



3 Siphons Running



Hole Within Riser



Breach Section



Cummingswood Dam

The Cummingswood Dam, owned and operated by Mr. Charles Vorum, was constructed prior to 1979 without obtaining a permit from the Department. The dam is a 10-foot high earthen embankment, approximately 300-feet long, located on a 0.23 square mile drainage area in Mount Pleasant Township, Westmoreland County. This dam did not contain a low level drawdown, and the primary spillway was an earthen overflow channel. The Division of Dam Safety was unaware of this dam until the summer of 1998 when a site inspection noted a severe lack of maintenance, moderate seepage along the downstream toe, and two depressions on the crest. A downstream hazard potential review found a downstream roadway could be impacted by a small amount of water if the dam were to fail, and therefore, this dam was classified as a hazard potential category 2, “non-high” hazard structure.

From 1998 until 2003, the Division of Dam Safety made several requests to the owner for the development of a schedule to conduct repairs and remove excessive vegetation. Additionally, the spillway capacity was evaluated following a June 2003 inspection. This analysis found that the dam’s spillway was only capable of passing the 5-year storm event instead of the minimum 100-year event specified by State Regulations. Given the owner’s disregard for the Division’s continued requests, the Department issued an Order to drain the impoundment on October 10, 2003. The Order detailed the process for draining and repairing or breaching the dam.

The owner’s receipt of the Order prompted him to call and practically thank the Department for requiring the impoundment to be drained. He wanted to breach the dam anyway, but was concerned about repercussions from local residents and municipal leaders. Since the owner agreed to work with the Department, a decision was made to relax the directed timeframes allowing Mr. Vorum the ability to search for an engineer to develop the plans for draining and breaching the dam. Mr. Vorum’s search continued until late winter 2003 when he advised Division staff the estimated costs to develop the required plans were outrageous. With Mr. Vorum’s inability to fund an expensive project, the Department agreed to develop the breach plans and assist in draining the lake. While the use of the siphons at this dam may not be considered a true emergency, failure of this dam would have caused private property damage and an adverse effect upon the environment.

Two 6-inch diameter siphons were installed by Department staff on April 8, 2004. These siphons operated perfectly for the first day or so, but then began to randomly stop working. It quickly became apparent that local residents were upset with the removal of this lake, and were opening the fill caps to stop the siphons. The Department provided Mr. Vorum with Notices he could post on site to aid in alleviating the vandalism. The following photographs are from the Cummingswood Lake siphon and breach project.

Looking Across Crest



Downstream Area



Seepage/Piping



Primary Spillway



Preparing Fill Section



Connecting Straight Sections



Downstream Face



Impoundment During Drawdown



Breach in Progress



Completed Breach



Summary

While the use of siphons is limited to specific site constraints, the Department has found these mobile systems very useful in averting potential dam failures. Most of the materials used in constructing these siphons can be easily broken down and reused, providing for an initial upfront investment with minor maintenance and restocking costs. Also, depending on the statutes or regulations of the dam safety agency, these costs along with the cost of manpower, travel, and subsistence could legally be recovered from the dam owner.

In addition to regulating agencies using this equipment, a local municipality, fire department, or individual dam owner could keep or have quick access to siphoning equipment of this nature. In recent scenarios, the Department has used this equipment to construct a few siphons while training the owner or contractor in the proper construction technique. Then the dam owner can purchase additional siphon equipment to construct more siphons in order to accomplish the impoundment drawdown. Training the owner or operator in the set up and maintenance of the siphons alleviates the regulating agency's personnel from remaining onsite allowing them to return to normal operations or assist at other facilities during a widespread emergency.

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APPENDIX H

FISH & WILDLIFE SERVICE – DEFINITIONS, STANDARDS AND GUIDELINES

**FISH AND WILDLIFE SERVICE
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2.1 What is the purpose of this chapter? This chapter provides definitions for terms used in this Part and describes standards and requirements of the Dam Safety Program.

2.2 What are definitions for the terms used in this Part?

A. Dam. An artificial barrier, including appurtenant works, constructed for the purpose of storage, control, or diversion of water.

B. Dam Height. The vertical distance between the lowest point on the dam crest and the lowest point in the original streambed.

C. Hydraulic Height. The vertical distance between the maximum design water level and the lowest point in the original streambed.

D. Structural Height. The vertical distance between the maximum design water level and the lowest point of the excavated foundation.

E. Maximum Water Storage Elevation. The elevation commensurate with the maximum impounding capacity of the dam, including temporary storage of flood water.

F. Maximum Design Water Level. The elevation commensurate with the maximum water surface elevation as a result of safely passing the Inflow Design Flood (IDF).

G. Hazard Classification. Hazard Classification is a rating based on the potential loss of life or property damage downstream of a dam caused by failure or misoperation. Hazard Classification is not determined by the existing condition of a dam and its appurtenant structures or the anticipated performance or operation of a dam.

H. Inventory Dam. A dam is included in the Service Inventory of Dams and the National Inventory of Dams if it meets any of the following three criteria. (For example, if a dam is 6.5 feet high and impounds 51 acre-feet of water, it is considered to be an inventory dam.)

(1) It exceeds 25 feet in height from the natural bed of the stream (or a watercourse) measured at the downstream toe of the dam, or if it is not across a stream channel or watercourse, measured from the lowest elevation of the outside limit of the dam, to the maximum water storage elevation, **and** has a storage capacity at maximum water storage elevation in excess of 15 acre-feet.

(2) It exceeds an impounding capacity at maximum water storage elevation of 50 acre-feet **and** a height, measured

as in (1) above, of at least 6 feet.

(3) It has a high or significant hazard classification regardless of height or storage capacity.

I. Noninventory Dam. Noninventory dams are defined as follows:

(1) A low hazard dam that does not satisfy the criteria as set forth in the Inventory Dams (paragraph 2.2H).

(2) An interior dike or cross dike located within an impoundment or levee.

2.3 What are the standards and requirements of the Dam Safety Program?

A. Hazard Classification. The purpose of determining the hazard classification for a dam is to identify minimum requirements for security, investigation, design, and construction.

(1) A Regional Dam Safety Officer (RDSO) or a member of the Service's Dam Safety inspection team provides a preliminary hazard classification recommendation.

(2) The Division of Engineering (DEN) will perform a hazard classification analysis, when appropriate, in accordance with the latest version of Downstream Hazard Classification Guidelines, Department of the Interior, the Bureau of Reclamation (BOR), Assistant Commissioner Engineering and Research (ACER) Technical Memorandum (TM)#11.

(3) A hazard classification panel, as defined in this Part, assigns a formal hazard classification to all Service dams. The hazard classification panel will utilize the preliminary hazard classification recommendation, the hazard classification analysis, and other data to determine the hazard classification for a dam.

(a) The panel consists of a Service Dam Safety Officer (SDSO) designee(s), the appropriate RDSO and another RDSO mutually agreeable to the SDSO and the appropriate RDSO. The panel provides a written determination to the SDSO. A majority vote of the panel is required to classify new dams, and a unanimous vote of the panel is required to change the hazard classification of existing dams.

(b) The hazard classification panel determines the formal classification of a dam in accordance with the latest version of Downstream Hazard Classification Guidelines, Department of the Interior, the Bureau of Reclamation (BOR)..

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(4) The RDSO reviews the hazard classification of noninventory dams at least every 5 years.

(5) The RDSO and the SDSO have the authority to request the reclassification of a dam.

B. Size Classification. An RDSO or a member of the Service's Dam Safety inspection team determines the size classification of a dam. The structural height or the water storage capacity at maximum water storage elevation, whichever yields the larger size classification, is used to determine the size of a dam. For example, if a dam is 35 feet high (small size) and impounds 2,000 acre-feet of water (intermediate size), the dam would be classified as intermediate size. Size classification categories are as follows.

(1) Small dams are structures that are less than 40 feet high or that impound less than 1,000 acre-feet of water.

(2) Intermediate dams are structures that are 40 to 100 feet high or that impound 1,000 to 50,000 acre-feet of water.

(3) Large dams are structures that are more than 100 feet high or that impound more than 50,000 acre-feet of water.

C. New Dams.

(1) All plans, designs, drawings, and construction specifications for Service dams will be reviewed and approved as follows:

(a) The RDSO will perform the review and approval for noninventory dams.

(b) The RDSO and the SDSO will perform the review and approval for all low hazard, inventory dams.

(c) The SDSO will perform the review and approval for high and significant hazard dams. The SDSO will also attain an independent review by an outside organization such as the BOR, the Corps of Engineers or an independent consultant.

(2) Project Planning, Design, and Construction.

(a) The RDSO is responsible for the project planning, design, and construction of all low hazard, inventory, dams.

(b) The SDSO is responsible for the project planning, design, and construction of high and significant hazard dams.

(3) The RDSO classifies all new dams as either inventory or noninventory dams based on the vital statistics of the dam. The RDSO will forward this determination, along with the vital statistics of the dam, to the Chief, DEN.

D. Acquired Dams. A Formal Safety Evaluation of Existing Dams (SEED) inspection and report will be prepared for all dams acquired on "new" lands before the property where the dam is located is acquired.

(1) The SEED Inspection should be performed as a supplement to the Engineering Assessment (341 FW 2). The SEED Inspection should describe the condition of the dam and the cost of the work required to bring the dam up to Service safety standards.

(2) SEED II studies will be performed on all newly acquired dams. The SEED II study is a detailed assessment of the design and condition of the dam and will normally include hydrologic and hydraulic, structural, and geotechnical analyses (stability, seepage, liquefaction, etc).

(3) The acquisition contract or legally enforceable instrument should include the cost associated with work required to bring the dam up to Service safety standards. Land acquisition budget requests should include the costs for SEED Inspections and SEED II studies (341 FW 3).

E. Rehabilitation of Inventory Dams.

(1) Project planning, design and construction, review of project plans, engineering designs, and construction specifications for major rehabilitation, modification, or emergency repair of inventory dams will follow the procedures established for new dams (paragraph 2.3C). Major rehabilitation or modification may include such work items as raising a dam crest, enlarging or replacing spillways and outlets, constructing auxiliary or emergency spillways, and any alteration of the dam from its original design. Major rehabilitation, modification, or emergency repair does not include annual operation and maintenance work such as repairs to gates, repair of erosion on embankments, simple concrete repair, etc.

(2) Review of project plans, engineering designs, and construction specifications for a low hazard inventory dam will follow individual Regional policy.

F. The SEED Inspection Program. The purpose of the SEED Program is to ensure protection of life and property and to assure the integrity of Service inventory dams and appurtenant structures. These inspections are required by Federal Regulation. Periodic inspections disclose conditions that might disrupt operation or threaten dam safety. Deficiencies noted, as a result of inspections will be corrected. Priorities for correction will be assigned in accordance with the relative level of failure potential and

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downstream consequences. It may be necessary to determine the adequacy of structures and facilities to continue serving the purposes for which they were constructed, and to identify the extent of deterioration as a basis for planning maintenance, repair, rehabilitation, or intentional breaching.

(1) The SEED Inspector will immediately report all dangerous or unusual conditions to the Project Leader and the RDSO. The RDSO will immediately report them to the Regional Director or designee, in accordance with the Emergency Action Plan (EAPs), as appropriate. In addition, the RDSO must immediately contact the Regional Safety Manager if an inspection indicates imminent danger, or threat of serious injury or significant property damage.

(2) Periodic inspections for inventory dams include three types of inspections.

(a) Informal inspections consist of visual examinations carried out during day-to-day operations. They provide frequent surveillance of the general appearance and functioning of the dam and its appurtenances to identify, at the earliest possible time, any readily observable changes. These inspections are performed in accordance with the Standing Operating Procedures (SOPs) for high and significant hazard dams.

(b) Formal inspections are made for the purpose of providing an assessment of the safety and integrity of a dam in all aspects. Formal inspections are comprehensive searches for evidence of deterioration of materials, developing weaknesses, and unsafe hydraulic or structural conditions. These inspections consist of field examinations, video recording of all physical features, examination of any adjacent endangering conditions, and review and evaluation of all performance data recorded, including instrumentation and spillway discharge measurements. Formal inspections also include the use of advanced methods and current design criteria and practices where appropriate to evaluate the performance of the dam and a comparison of the long-term examination record with current conditions. Formal inspections also include an overall condition rating and recommendations to maintain or improve the integrity of the dam.

(c) Special inspections are made following (or during, if possible) unusual floods, significant earthquakes, mishaps, or the appearance of unexpected dam performance. These inspections are made to determine the extent of any damage and the need for emergency repair or other action.

(3) Frequency of inspections for Service inventory dams.

(a) Informal inspections are performed routinely during day-to-day operations. These inspections are ongoing and need not be scheduled or as documented in the SOPs.

(b) Frequency for formal inspections is determined by the hazard classification of the dam.

(i) High and significant hazard dams have a formal inspection every 2.5 years.

(ii) Low hazard dams have a formal inspection every 5 years.

(c) Frequency of special inspections depends upon the occurrence of an unusual event (e.g., seepage through the dam has become turbid). Consequently, it is not possible or necessary to establish cyclical evaluation frequencies for special inspections. However, those responsible for the dam must be alert to identify situations or occurrences that may require reevaluation.

(4) Inspector qualifications.

(a) Inspectors for informal inspections are project leaders, dam operators, and other individuals who are in the vicinity of the dam in the course of their regular activities, or as prescribed by the RDSO. These individuals should have a basic knowledge of dams so they may recognize unusual conditions, abrupt changes from previous conditions, and obvious new defects such as seepage, cracks, and displacements.

(b) The DEN, or DEN consultants, performs formal inspections of high and significant hazard dams. Registered Professional Engineers or Registered Geologists trained in the safety inspection of dams will compose the inspection team.

(c) The DEN, or DEN consultants, perform formal inspections of low hazard dams. Dam safety professionals will perform the inspections under the direct supervision of a Registered Professional Engineer trained in the safety inspection of dams.

(5) Inspection reports.

(a) Informal inspection reports may be written or oral. They follow a checklist format and contain enough information to allow a determination to be made regarding whether or not further action is necessary.

(b) Formal inspection reports are written reports prepared in a format consistent with established Service guidelines.

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G. Standing Operating Procedures. The SDSO will prepare SOPs for all high and significant hazard dams. The SOPs are prepared in accordance with Service guidelines.

(1) The RDSO will annually review and update, as appropriate, the SOPs for each high hazard and significant hazard dam within the Region in accordance with procedures outlined in the SOPs.

(2) The SDSO is responsible for updating SOPs associated with major repair or rehabilitation to high and significant hazard dams.

H. Emergency Action Plans (EAPs). The SDSO will prepare EAPs for all high and significant hazard dams. The EAPs are prepared in accordance with Service guidelines (095 FW 9).

(1) The RDSO will perform an EAP annual review for each high and significant hazard dam within the Region in accordance with procedures outlined in the EAPs. The RDSO is responsible for annual testing, verification and certification of EAPs by November 1st of each year. The RDSO is responsible for submitting a verification statement, in accordance with the SOPs, along with any revisions to the EAPs, to the SDSO, annually, on or before November 30th.

(2) The SDSO is responsible for performing EAP periodic tests every 5 years in accordance with procedures in the EAPs.

(3) The SDSO is responsible for updating EAPs associated with major repair or rehabilitation to high and significant hazard dams.

I. Coordination with State Dam Safety Programs. The Service consults fully with any State, in which it owns, operates, or proposes to construct a dam on the design and safety of that dam. State officials are invited to participate in all safety inspections of Service dams.

J. Inspection of Private Dams. Non Federal dams located on Service property are inspected in accordance with State regulations. Service inspection teams do not inspect private dams, but a listing of those dams is maintained by the Chief, DEN. If difficulties or unusual circumstances are encountered, the SDSO should be contacted for advice and guidance.

K. Requirements for Federal Aid Dams. Federal funds are used to supplement approved State dam safety projects on a cost-sharing basis through the Federal Aid Program. The Service will review and approve Federal Aid Dams in accordance with procedures established for new dams (361 FW 2.3C). States are to provide a written certification, signed by a Registered Professional

Engineer, certifying that proposed projects involving the construction, enlargement, or rehabilitation of any dam (including appurtenant works) that satisfies the criteria for the Service's inventory as defined in (361 FW 2.1) meet Federal requirements. These requirements do not apply to any dam that does not satisfy the criteria for the Service's inventory. A Registered Professional Engineer must certify each of the following:

(1) That the hazard and size classification of the dam are correct and that its present condition and deficiencies have been accurately identified;

(2) That the proposed project has been designed to meet Federal standards for dam design, construction, and rehabilitation including, but not limited to, the Federal Guidelines for Dam Safety (June 25, 1979), Recommended Guidelines for Dam Safety--Inspection of Dams (Corps of Engineers, 1974), and any other technical requirements identified in the Federal Aid project agreement documents; and

(3) That the technical review of the project design and specifications by the State has been completed by a Registered Professional Engineer qualified in the design and construction of dams.

L. Privately Funded Dams. The review and approval of privately-funded dams on Service property will be in accordance with the procedures established for new dams (paragraph 2.3C).

2.4 What are the technical standards for the Dam Safety Program? The planning, design, construction, and rehabilitation of all inventory dams will follow the technical standards documented in this Part. All other technical standards not specifically included in this section are in accordance with standards set forth in (361 FW 1).

A. Inflow Design Flood. The Inflow Design Flood represents the largest flood hydrograph a dam is capable of safely passing through a combination of spillway and outlet works capacity and attendant surcharge storage.

(1) Existing inventory dams constructed prior to January 1, 2002, should be evaluated according to information found in Exhibit 1 for determining the Inflow Design Flood.

(2) New inventory dams constructed, or which have had major reconstruction on or after January 1, 2002, should be evaluated according to information found in Exhibit 2 for determining the Inflow Design Flood.

(3) The Chief, DEN and the SDSO must approve a waiver from the Inflow Design Flood requirements shown in Exhibits 1 and 2 for high and significant hazard dams. The SDSO and the RDSO must approve a waiver from the Inflow Design Flood requirements shown in Exhibits 1 and

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2 for a low hazard, inventory dams. Inflow Design Floods other than those in Exhibits 1 and 2 will be approved only after performing an incremental damage assessment or risk-based analysis to determine if tradeoffs and other factors are relevant.

(a) Detailed studies and mapping must clearly demonstrate that consequences of dam failure at flood flows larger than the selected Inflow Design Flood causes no incremental increase in projected loss of life and no significant incremental increase in property damage. Federal Emergency Management Agency 97, Federal Guidelines for Selecting and Accommodating Inflow Design Floods for Dams, or a more conservative approach, will be followed. Analysis will include existing structures and inhabitants and projected inhabitants and structures in the next 50 (minimum) years. The incremental increase in property damage versus a flood frequency event will be clearly identified in a management decision chart and understood by decision making officials.

(b) The annual probability of loss of life and failure of the structure and corresponding probabilities over a projected 50-year period should be clearly demonstrated. The average annual loss of life probability will be less than 1 in 1000. The annual failure probability of the structure will be less than 1 in 10,000.

(c) The RDSO or the SDSO will provide the proposed Inflow Design Flood using an Incremental Damage Assessment or Risk-based Analysis to the respective state dam safety office for review and discussion.

(d) Under no circumstance will an Inflow Design Flood less than the 100-year flood frequency event be approved for high or significant hazard dams.

B. Freeboard Requirements. Freeboard requirements are as set forth in ACER TM No. 2, "Freeboard Criteria and Guidelines for Computing Freeboard Allowances for Storage Dams."

C. Low-Level Outlets. All inventory dams must have a low-level outlet. The low-level outlet must be able to evacuate the major portion of the reservoir storage volume by gravity flow. The RDSO and the SDSO must justify and approve a waiver to this requirement. However, criteria for reservoir draining should recognize site-specific conditions, economic aspects, and project needs to provide an acceptable balance between costs and rates of draining and filling. Draining times established for a dam reflect downstream channel capacity, level of risk to the dam, and hazard potential to the downstream areas. A low-level outlet works, in conjunction with other release facilities, should be located and sized to draw down the reservoir in accordance with Criteria and Guidelines for

Evacuating Storage Reservoirs and Sizing Low-level Outlet Works, ACER TM No. 3, the Department of the Interior, BOR 1990 or the latest revision. As a minimum for small low-hazard inventory dams, the low-level outlet works, in conjunction with other release facilities, should be located and sized to draw down the reservoir within 1 to 4 months to the lower of the following levels:

- (1) The reservoir level commensurate with a storage capacity that is 10 percent of that at the normal reservoir level, or;
- (2) The reservoir level with less than 50 percent of the hydraulic height.

2.5 How is funding for safety of dam modifications requested? Funds for maintenance, repair and rehabilitations to existing dams to correct identified deficiencies are requested as follows:

A. The Project Leaders and Regional Maintenance Management System (MMS) Coordinators should request Resource Management funds for routine maintenance, operations and monitoring, minor repairs of all high, significant and low hazard dams through the MMS.

B. The Project Leaders and Regional MMS Coordinators should request Resource Management funding for Priority 1 and Priority 2 recommendations identified during SEED inspections, with the exception of major repair or rehabilitation recommendations, the year they are identified, through the MMS.

C. The Project Leader, in consultation with the RDSO and the Regional Engineer, should request Resource Management or Construction funding for planning, design, and construction of major rehabilitation or modification to a low hazard dam and/or appurtenances. Funding should be requested through the MMS or the Construction Five-Year Plan.

D. The SDSO, through the Chief, DEN, should request funding for major repair or rehabilitation to high and a significant hazard dams and/or appurtenances through the Construction Five-Year Plan.



APPENDIX I

PLANS

NOT INCLUDED



APPENDIX J

MANUFACTURERS MANUALS

NOT INCLUDED



APPENDIX K

HYDROLOGY & HYDRAULICS

NOT INCLUDED