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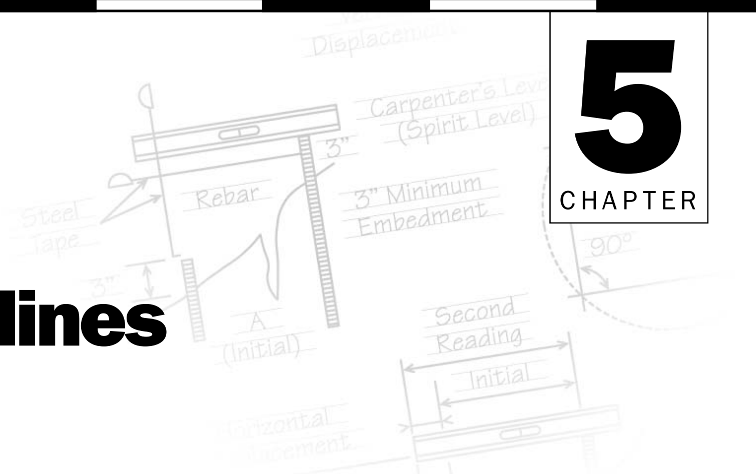
CHAPTER

Chapter 5: Inspection Guidelines



5.0 Introduction

An effective inspection program is essential for identifying problems and providing safe maintenance of a dam. An inspection program should involve three types of inspections: (1) periodic technical inspections; (2) periodic maintenance inspections; and (3) informal observations by project personnel as they operate the dam. Technical inspections must be performed by specialists familiar with the design and construction of dams and should include assessments of structure safety. Maintenance inspections are performed more frequently than technical inspections in order to detect, at an early stage, any developments that may be detrimental to the dam. They involve assessing operational capability as well as structural stability. The third type of inspection is actually a continuing effort by the dam owner's on-site project personnel (dam tenders, powerhouse operators, maintenance workers) performed in the course of their normal duties. The continued effectiveness of these inspections requires education of new personnel.

Regular visual inspections are among the most economical means you, the owner, can use to ensure the safety and long life of a dam and its immediate environment. Visual inspection is a straightforward procedure that can be used by any properly trained person to make a reasonably accurate assessment of a dam's condition. The inspection involves careful examination of the surface and all parts of the structure, including its adjacent environment. The equipment required is not expensive, and the inspection usually can be completed in less than one day.

A dam owner, by applying the maximum prudent effort, can identify any changes in previously noted conditions that may indicate a safety problem. Quick corrective action to conditions requiring attention will promote the safety and extend the useful life of the dam while possibly preventing costly future repairs.

5.1 Organizing for Inspection

All inspections should be organized and systematic, and inspectors should use equipment appropriate for the task, record observations accurately, and survey the structure and site comprehensively. It is essential that documentation be developed and maintained in order to ensure adequate follow-up and repair. Chapter 9 further discusses what form this documentation should take.

Equipment useful for inspections is listed in Table 5.1.

Recording Inspection Observations. An accurate and detailed description of conditions during each inspection will enable meaningful comparison of conditions observed at different times. The inspector should record all measurements and observed details required for an accurate picture of a dam's current condition and possible problems. Using the forms discussed in Chapter 9 and given in the appendixes will help record the details. This information has three elements:

(1) *Location*—Accurately describe the location of any questionable area or condition so that it can be evaluated for changes over time or reexamined by experts. Photographs can help. Record the location along the dam, as well as above the toe or below the crest. Similarly, document the location of problems in the outlet or spillway.

(2) *Extent or area*—The length, width, and depth or height of any suspected problem area should be determined.

(3) *Descriptive detail*—Give a brief yet detailed description of any anomalous condition. Some items to include:

- quantity of drain outflows
- quantity of seepage from point and area sources
- color or quantity of sediment in water
- depth of deterioration in concrete
- length, displacement, and depth of cracks
- extent of moist, wet, or saturated areas
- adequacy of protective cover
- adequacy of surface drainage
- steepness or configuration of slopes
- apparent deterioration rate
- changes in conditions

Coverage. An inspection is conducted by walking along and over a dam as many times as is required to observe the entire

Table 5.1
Inspection Equipment and Its Use

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.

Tape recorder—can be effective in making a record of field observations.

Digital camera—can be used to photograph field conditions. Photographs taken from the same vantage points can also be valuable in comparing past and present conditions. Photographs can also be e-mailed to consultants or the Texas Dam Safety Program when necessary.

Hand level—may be needed to accurately locate areas of interest and to determine embankment heights and slope.

Probe—used to gather information on conditions below the surface, such as the depth and softness of a saturated area.

Hard hat—should be used when inspecting large outlets or working in construction areas.

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.

Shovel—useful in clearing drain outfalls, removing debris, and locating monitoring points.

Rock hammer—can be used to check questionable-looking riprap or concrete for soundness. Care must be taken not to break through thin spots or cause unnecessary damage.

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 it can be 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 cracks and wet areas, for future comparison.

GPS receiver—used to collect positional data on locations of interest.

Slope tool—used to measure degree of slope from horizontal.

Watertight boots—recommended for inspecting areas of the site where water is standing.

Snake leggings or chaps—recommended for situations where heavy brush or snakes may be encountered.

Bug repellent—recommended during warm weather. Insects that bite can reduce the efficiency and effectiveness of the inspector.

First-aid kit—particularly recommended for inspections in areas where poisonous snakes might be present.

structure. From any given location, a person can usually gain a detailed view for 10 to 30 feet in each direction, depending upon the smoothness of the surface or the type of material (grass, concrete, riprap, brush) on the surface. On the downstream slope, a zigzag inspection path will ensure that any cracking is detected.

Sequence. Here is sequence of inspection that ensures systematic coverage of an entire site:

- upstream slope
- crest
- downstream slope
- seepage areas
- inlet
- outlet
- spillway

Following a consistent sequence lessens the chance of an important condition being overlooked. Reporting inspection results in the same sequence is recommended to ensure consistent records. Inspection forms are included in Appendix A. The forms should be supplemented with additional details specific to a given dam.

Record keeping. The inspector should fill out a dated report for each inspection, 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 not imminent, you, 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 or expensive litigation.

Crucial inspection times. There are at least five special times when an inspection is recommended regardless of the regular schedule:

(1) Prior to a predicted major rainstorm or heavy snow melt: check spillway, outlet channel, and riprap.

(2) During or after a severe rainstorm: check spillway, outlet channel, and riprap.

(3) During or after a severe windstorm: check riprap performance during the storm (if possible) and again after the storm has subsided.

(4) Following an earthquake in the area: make a complete inspection immediately after the event and weekly inspections for the next several months to detect any delayed effects.

(5) During and immediately after the first reservoir filling: schedule a regular program of frequent complete inspections during the period a reservoir is first being filled to ensure that design and site conditions are as predicted. In most states, including Texas, an inspection and filling schedule are prescribed by the design engineer and approved by the state engineer.

5.2 Embankment Dams and Structures

Embankment dams constitute the majority of structures in place in the U.S. The major features include:

- upstream slope
- downstream slope
- crest
- seepage areas

A spillway is also a necessary feature (Section 5.4). Many of the principles and guidelines presented in that section are also applicable to concrete structures.

5.2.1 Upstream Slope

Typically, major problems encountered on an upstream slope are:

- cracks
- slides
- cave-ins or sinkholes
- severe erosion

The first three conditions may indicate serious problems within the embankment. Severe erosion obviously can weaken the structure. An upstream slope should receive a close inspection because riprap, vegetative cover, and high water levels can hide problems. (When walking on riprap, take caution to avoid personal injury.) When a reservoir is emptied, the exposed slope should be thoroughly inspected for settlement areas, rodent (beaver) activity, sinkholes, or slides. Also, the reservoir basin (bottom of the reservoir) should be inspected for cave-ins or sinkholes.

Again, most importantly, a crisscross path should be used when inspecting the slope so that cracks and slides can be easily identified. In many instances, sighting along the waterline alignment will indicate a change in the uniformity of the slope; an inspector should stand at one end of the dam and sight along the waterline, checking for straightness and uniformity. If a crack is seen, the crest and downstream slope in its immediate area should be carefully inspected.

Cracks indicate possible foundation movement, embankment failure, or a surface slide. Locating them can be difficult. Cracks less than an inch in width can still be several feet deep. Cracks more than one foot deep usually are not produced by drying and usually are cause for concern. A line of recently dislodged riprap on an upstream slope could indicate a crack below the riprap.

Slides can be almost as difficult to detect as cracks. When a dam is constructed, the slopes may not be uniformly graded. Familiarity with the slope configuration at the end of construction can help identify subsequent slope movements. Moreover, the appearance of slides may be subtle; for example, they may produce only about two feet of settlement or bulging in a distance of 100 feet or more, yet that would still be a significant amount of settlement. Dated photographs are particularly helpful in detecting such changes.

Sinkholes or cave-ins result from internal erosion of the dam—a very serious condition for earthen embankments. The internal erosion, or piping, may be reflected by turbid seepage water on exit. Surface soil may be eroded by wave action, rain runoff, and animal burrowing. Such erosion, if allowed to continue, can lessen the thickness of the embankment and weaken the structure.

Animal burrows on the upstream slope can also indicate a serious problem on smaller dams. Beavers, nutria, and other burrowing animals can create pathways for seepage. See Chapter 7.

To ensure adequate inspection and prevent potential seepage paths, keep the upstream slope free from obscuring weeds, brush, or trees.

Figures 5.1 show potential problems with the upstream slope, causes, possible consequences, and recommended actions.

5.2.2 Downstream Slope

A downstream slope should be inspected carefully because it is the area where evidence of developing problems appears most frequently. To ensure adequate inspection, keep this area free from obscuring weeds, brush, or trees.

When cracks, slides or seepage are noted in the downstream slope, notify the designated dam-safety authorities immediately.

On the downstream slope, some of the more threatening conditions that could be identified are:

- cracks
- slides
- seepage

Cracks can indicate settlement, drying and shrinkage, or the development of a slide. Whatever the cause, cracks should be monitored and changes in length and width noted. Drying cracks may appear and disappear seasonally and normally will not show vertical displacement as will settlement cracks or slide cracks.

Slides require immediate detailed evaluation. Early warning signs include a bulge in the embankment near the toe of a dam or vertical displacement in the upper portion of an embankment.

Seepage is discussed separately below (Section 5.2.4).

If a downstream slope is covered with heavy brush or vegetation, a more concentrated search must be made and may require cleaning off the vegetation.

In addition, the downstream slope should be inspected for animal burrows and excessive vegetative cover and for erosion, especially at the contacts with the abutments,.

Figures 5.2 show potential problems with the downstream slope, causes, possible consequences, and recommended action.

5.2.3 Crest

A dam's crest usually provides the primary access for inspection and maintenance. Because surface water will pond on a crest unless that surface is well maintained, this part of a dam usually requires periodic regrading. However, problems found on the crest should not be simply graded over or covered up. When a questionable condition is found, the Texas Dam Safety Program should be notified immediately.

On the crest, some of the more threatening conditions that may be identified are:

- longitudinal cracking
- transverse cracking
- misalignment
- sinkholes

Longitudinal cracking can indicate localized instability, differential settlement, movement between adjacent sections of the embankment, or any combination of the three. Longitudinal cracking is typically characterized by a single crack or a close, parallel system of cracks along the crest, more or less parallel to the axis of the dam. These cracks, which are usually continuous over their length and usually greater than one foot deep, can be differentiated from drying cracks, which are usually intermittent, erratic in pattern, shallow, very narrow, and numerous.

Longitudinal cracking may precede vertical displacement as a dam attempts to adjust to a position of greater stability. Frequently, longitudinal cracking occurs at the edge of the crest with either slope. Vertical displacements on the crest are usually accompanied by displacements on the upstream or downstream face of a dam.

Transverse cracking can indicate differential settlement or movement between adjacent segments of a dam. Transverse cracking usually manifests as a single crack or a close, parallel system of cracks that extend across the crest more or less perpendicular to the length of the dam. This type of cracking is usually greater than one foot in depth. If this condition is seen or suspected, notify the Texas Dam Safety Program office immediately.

Transverse cracking poses a definite threat to the safety and integrity of a dam. If a crack should progress to a point below the reservoir water-surface elevation, seepage could progress along the crack and through the embankment, causing severe erosion and—if not corrected—leading to failure of the dam.

Misalignment can indicate relative movement between adjacent portions of a dam—generally perpendicular to its axis. Excessive settlement of dam material, the foundation, or both can also cause misalignment. Most problems are usually detectable during close inspection. Misalignment may, however, only be detectable by viewing a dam from either abutment. If on close inspection the crest appears to be straight for the length of the structure, alignment can be further checked by standing away from the dam on either abutment and sighting along the upstream and downstream edges of the crest. On curved dams, alignment can be checked by standing at either end of a short segment of the dam and sighting along the crest's upstream and downstream edges, noting any curvature or misalignment in that section. Leaning utility poles or poles used for highway barriers also can indicate movement.

Sinkholes can indicate internal collapse, piping, or the presence of animal dens. The formation or progression of a sinkhole is dangerous because it poses a threat to inspectors or vehicles traversing the crest. A sinkhole collapse can also lead to a flow path through a dam, which can create an uncontrolled breach.

In addition, the crest should be inspected for animal burrows, low areas, vegetative cover, erosion, slope of the crest, narrowing of the crest, and traffic ruts.

Figures 5.3 show potential problems with the crest, causes, possible consequences, and recommended action.

5.2.4 Seepage Areas

As discussed previously, although all dams have some seepage, seepage in any area on or near a dam can be dangerous, and all seepage should be treated as a potential problem. Wet areas downstream from dams are not usually natural springs, but seepage areas. Seepage must be controlled in both velocity and quantity. High-velocity flows through a dam can cause progressive erosion and, ultimately, failure. Saturated areas of an embankment or abutment can move in massive slides and thus also lead to failure.

Seepage can emerge anywhere on the downstream face of a dam, beyond the toe, or on the downstream abutments at elevations below normal reservoir levels. A potentially dangerous condition exists when seepage appears on the downstream face above the toe of a dam. If seepage is found on the top half of the downstream slope, the Texas Dam Safety Program should be notified immediately. Seepage on the downstream slope can cause a slide or failure of the dam by internal erosion (piping). Evidence of seepage may vary from a soft, wet area to a flowing spring and may appear initially as only an area where vegetation is lush and dark green in color. Cattails, reeds, mosses, and other marsh vegetation often become established in seepage areas. Downstream abutment areas should always be inspected closely for signs of seepage, as should the area of contact between an embankment and a conduit spillway, drain, or other appurtenant structures and outlets. Slides in the embankment or an abutment may be the result of seepage causing soil saturation and high pore pressures.

Since seepage can be present but not readily visible, an intensive search should be made of all downstream areas where seepage water might emerge. Even in short grass cover, seepage may not be visible and must be walked on to be found. Ideally, an inspection for seepage should be made when a reservoir is full.

Figures 5.4 show potential problems with seepage, causes, possible consequences, and recommended action.

5.3 Concrete Dams and Structures

From a safety standpoint, the principal advantage of concrete over earthen dams is their relative freedom from failure by erosion during overtopping as well as from embankment slides and piping failures. Although concrete dams comprise a minority of all dams, they are commonly of greater height and storage capacity than earthen structures. Thus, they often represent a potentially greater hazard to life and property. It is important that concrete-dam owners be aware of the principal modes of failure of such dams and that they be able to discern between conditions which threaten the safety of the dam and those that merely indicate a need for maintenance.

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

- structural cracks
- foundation and abutment weakness
- deterioration due to alkali-aggregate reaction

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

Structural cracks occur when portions of the dam are overstressed; they result from inadequate design, poor construction, foundation settlement, or faulty materials. Structural cracks are often irregular, may run at an angle to the major axes of the dam and may exhibit abrupt changes in direction. These cracks can also be noticeably displaced, radially, transversely, or vertically.

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

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

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

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

- access and safety
- monitoring
- outlet system
- cracks at construction and expansion joints
- shrinkage cracks
- deterioration due to spalling
- minor leakage

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

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

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

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

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

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

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

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

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

Figures 5.4 show potential problems with concrete dams and structures, causes, possible consequences, and recommended action.

5.4 Spillways

As detailed in Chapter 2, the main function of a spillway is a safe exit for excess water in a reservoir. If a spillway is too small, a dam could be overtopped and fail. Similarly, defects in a spillway can cause failure by rapid erosion. A spillway should always be kept free of obstructions, have the ability to resist erosion, and be protected from deterioration. Because dams represent a substantial investment and spillways make up a major part of dam costs, a conscientious annual maintenance program should be pursued not only to protect the public but also to minimize costs as well.

The primary problems encountered with spillways include:

- inadequate capacity
- obstructions
- erosion
- deterioration
- cracks
- open joints
- undermining of the spillway outlet
- deterioration of spillway gates

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

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

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

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

Drying cracks in an earthen spillway channel are usually not regarded as a functional problem. However, missing rocks in a riprap lining can be considered a crack in the protective cover, and must be repaired at once.

Cracks in concrete lining of a spillway are commonly encountered. These cracks may be caused by uneven foundation settlement, shrinkage, slab displacement, or excessive earth or water pressure. Large cracks will allow water to wash out fine material below or behind the concrete slab, causing erosion, more cracks, and even severe displacement of the slab. The slab may even be dislodged and washed away by the flow. A severely cracked concrete spillway should be examined by and repaired under the supervision of an engineer.

Open or displaced joints can occur from excessive and uneven settlement of the foundation or the sliding of a concrete slab. In some cases, a construction joint is too wide or has been left unsealed. Sealants deteriorate and wash away. Water can flow through the joints, undermining the slabs, which in turn could result in collapse of the spillway slabs. Pressures resulting from water flowing over the open slabs could also result in lifting and displacement of slabs. Joints need to be sealed and kept sealed.

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

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

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

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

1. Flows emerging from the outlet are above the stream channel. If outlet flows emerge at the correct elevation, tailwater in the stream channel can absorb a substantial amount of the high velocity. The flow and the hydraulic energy will be contained in the stilling basin.
2. Flows emerging from the spillway are generally free of sediment and therefore have substantial sediment-carrying capacity. In taking on sediment, moving water will scour soil material from the channel and leave eroded areas. Such erosion is difficult to design for and requires protection of the outlet for a safe distance downstream from the dam.
3. Flows leaving the outlet at high velocity can create negative pressures that can cause material to come loose and separate from the floor and walls of the outlet channel. This process is called *cavitation* when it occurs on concrete or metal surfaces. Venting can sometimes be used to relieve negative pressures.
4. Water leaking through pipe joints or flowing along a pipe from the reservoir may weaken the soil structure around the pipe. Inadequate compaction adjacent to such structures during construction can compound this problem.

Deterioration of gates in spillways can result in an inability of the gates to function during storm events. Causes of structural deterioration include, but are not limited to:

1. *Corrosion* can seriously weaken a structure or impair its operation. The effect of corrosion on the strength, stability, and serviceability of gates must be evaluated. A loss of cross-section in a member causes a reduction in strength and stiffness that leads to increased stress levels and deformation without any change in the imposed loading. Flexure, shear, and buckling strength may be affected. A buildup of corrosion products can be damaging at connection details. For example, corrosion buildup in a tainter gate trunnion can lead to extremely high hoist loads. Localized pitting corrosion can form notches that may serve as fracture initiation sites, which could significantly reduce the member's fatigue life.
2. ***Fracture*** usually initiates at a discontinuity that serves as a local stress raiser. Structural connections that are welded, bolted, or riveted are sources of discontinuities and stress concentrations.
3. *Fatigue* is the process of cumulative damage caused by repeated cyclic loading. Fatigue damage generally occurs at stress-concentrated regions where the localized stress exceeds the yield stress of the material. Fatigue is particularly a concern with spillway gates with vibration problems.
4. *Operation and maintenance.* Proper operation and maintenance of spillway gates are necessary to prevent structural deterioration. The following items are possible causes of structural deterioration.
   a. Weld repairs are often sources of future cracking or fracture problems, particularly if the existing steel had poor weldability.
   b. If moving connections are not lubricated properly, the bushings will wear and result in misalignment of the gate, resulting in wear of other parts and unforeseen loads.
   c. Malfunctioning limit switches could result in detrimental loads and wear.
   d. A coating system or cathodic protection that is not maintained can result in detrimental corrosion of metal components.
5. *Unforeseen loading.* Accidental overload or dynamic loading of a gate can result in deformed members or fracture. When structural members become deformed or buckled, they may have significantly reduced strength or otherwise impair the performance of the gate. Dynamic loading may be caused by hydraulic flow at the seals. Other unusual loadings may occur from malfunctioning limit switches or debris trapped at interfaces between moving parts. Unusual loads may also develop on gates supported by walls that are settling or moving. These unusual loads can cause overstressing and lead to deterioration.

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

An inspection of an earth spillway should determine whether side slopes have sloughed and whether there is excessive vegetation in the channel, and should look for signs of erosion and rodent activity. The inspector should also use a probe to determine the hardness and moisture content of the soil, note the location of particularly wet or soft spots, and see if the stilling basin or drop structure is properly protected with rocks or riprap. Because some erosion is unavoidable during spilling, an owner should also determine whether such erosion might endanger the embankment itself. If the spillway is installed with a sill or wall, a dam owner should also determine if there are any cracks or misalignment in the sill or wall and check for erosion beneath of the sill or wall or downstream from it.

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

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

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

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

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

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

The following areas should be inspected on all gates in spillways:

- main framing members and lifting and support assemblies
- locations susceptible to fracture or weld-related cracking
- corrosion-susceptible areas—normal waterline, abrasion areas, crevices, areas where water could stand
- lifting connections and chains or cables
- trunnions
- intersecting welds
- previous cracks repaired by welding
- locations of previous repairs or where damage has been reported
- seal plates

Figures 5.6 show potential problems with spillways, causes, possible consequences, and recommended action.

5.5 Inlets, Outlets, and Drains

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

- reservoir pool levels
- lake drains and internal drains
- Corrosion
- trashracks on pipe spillways
- cavitation

The topics discussed above for spillways also are relevant.

Reservoir pool levels are controlled by spillway gates, lake drain-and-release structures, or flashboards. Flashboards, sometimes used to permanently or temporarily raise the pool level of water supply reservoirs, should not be installed or allowed unless there is sufficient freeboard remaining to safely accommodate a design flood. Pool-level drawdown should not exceed about 1 foot per week for slopes composed of clay or silt materials except in an emergency. 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.
- Repair of boat docks in the winter and growth of aquatic vegetation along the shoreline.
- Requirements for recreation, hydropower, or waterfowl and fish management.

Lake drains—A lake drain should always be operable so that the pool level can be drawn down in case of an emergency or for necessary repair. Lake-drain valves or gates that have not been operated for a long time can present a special problem for owners. If the valve cannot be closed after it is opened, the impoundment could be completely drained. An uncontrolled and rapid drawdown could also cause more serious problems such as slides along the saturated upstream slope of the embankment or downstream flooding. Therefore, when a valve or gate is operated, it should be inspected and all appropriate parts lubricated and repaired. It is also prudent to advise downstream residents of large or prolonged discharges.

Testing a valve or gate without risking complete drainage entails physically blocking the drain inlet upstream from the valve. Some drains have been designed with this capability and have dual valves or gates, or slots for stoplogs (sometimes called *bulkheads*) upstream from the valve. Otherwise, divers can be hired to inspect the drain inlet and may be able to construct a temporary block at the inlet. Since that could be dangerous, safety precautions are needed.

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

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

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

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

A well-designed trashrack will stop large debris that could plug a pipe but allow unrestricted passage of water and smaller debris. Some of the most effective racks have submerged openings which allow water to pass beneath the trash into the riser inlet as the pool level rises. Openings that are too small will stop small debris such as twigs and leaves, which in turn will cause a progression of larger items to build up, eventually completely blocking the inlet. Trashrack openings should be at least 6 inches across, regardless of the pipe size. The larger the principal spillway conduit, the larger the trashrack opening should be. The largest possible openings should be used, up to a maximum of about 2 feet. A trashrack should be properly attached to the riser inlet and strong enough to withstand the forces of fast-flowing debris, heavy debris, and ice. If the riser is readily accessible, vandals may throw riprap stone into it. The size of the trashrack openings should not be decreased to prevent this. Instead rock that is larger than the trashrack openings or too large to handle should be used for riprap.

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

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

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

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

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

- Outlet pipes 30 inches or greater in diameter can be inspected internally, provided the system has an upstream valve allowing the pipe to be emptied. Tapping the conduit interior with a hammer can help locate voids behind the pipe. This type of inspection should be performed at least once a year.
- Small-diameter outlet pipes can be inspected by remote TV camera if necessary. The camera is channeled through the conduit and transmits a picture back to an equipment truck. This type of inspection is expensive and usually requires the services of an engineer. However, if no other method of inspection is possible, inspection by TV is recommended at least once every five years.
- Outlet intake structures, wet wells, and outlet pipes with only downstream valves are the most difficult dam appurtenances to inspect because they are usually under water. These should

be inspected whenever the reservoir is drawn down or at five-year intervals. If a definite problem is suspected, or if the reservoir remains full over extended periods, divers should be hired to perform an underwater inspection.

Figures 5.7 show potential problems with inlets, outlets, and drains, causes, possible consequences, and recommended action.

5.6 General Areas

Other areas requiring inspection include:

- mechanical and electrical systems
- the reservoir surface and shoreline
- the upstream watershed
- downstream floodplains

Mechanical equipment includes spillway gates, sluice gates or valves for lake drains or water supply pipes, stoplogs, sump pumps, flashboards, relief wells, emergency power sources, siphons, and other devices. All mechanical and associated electrical equipment should be operated at least once a year and preferably more often. The test should cover the full operating range of the equipment under actual operating conditions. Each operating device should be permanently marked for easy identification, and all operating equipment should be kept accessible. All controls should be checked for proper security to prevent vandalism or malicious intent, and finally, all operating instructions should be checked for clarity and maintained in a secure, but readily accessible, location.

The reservoir surface and shoreline should be inspected to identify possible problems away from the actual structure. Whirlpools can indicate submerged outlets. Large landslides into the reservoir could cause waves to overtop the dam.

Floods arise from the upstream watershed. Therefore, characteristics of the watershed, such as impervious areas (e.g., parking lots), relate directly to the magnitude of a flood. Urban development in a watershed can increase the size of flood peaks and the volume of runoff, making a previously acceptable spillway inadequate. Awareness of upstream development and other factors that might influence reservoir inflows is important in order to determine the necessity for any modifications to the dam or spillways.

Development in downstream floodplains is also very important to the dam owner as the extent of development and flood preparedness relates directly to loss of life and damages should the dam fail. Downstream development may raise the hazard rating of the dam; therefore, it should be accounted for during annual assessments.

(Chapter figures on following pages.)

Figure 5.1
Inspection Guidelines - Upstream Slope

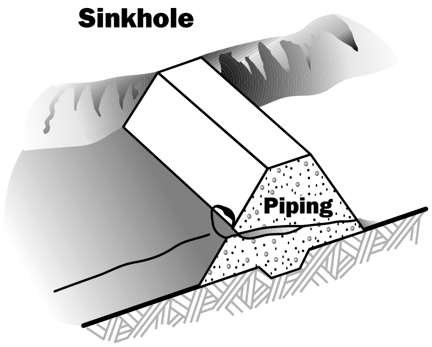


Figure 5.1a

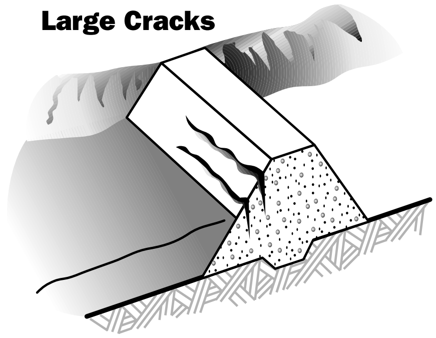


Figure 5.1b

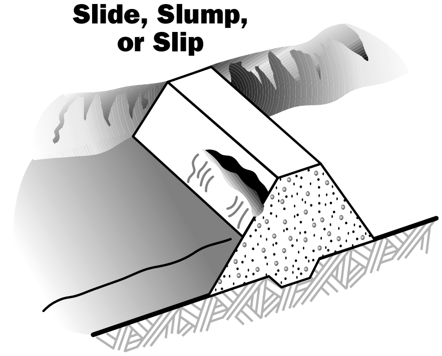


Figure 5.1c

Problem	Probable Cause and Possible Consequences	Recommended Actions
Sinkhole *(Figure 5.1a)*	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.	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. ENGINEER REQUIRED
Large Cracks *(Figure 5.1b)*	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.	Depending on embankment involved, draw reservoir level down. A qualified engineer should inspect the condition and recommend further actions. ENGINEER REQUIRED
Slide, Slump, or Slip *(Figure 5.1c)*	Earth or rocks move down the slope along a slippage surface because of too steep a 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.	Evaluate extent of the slide. Monitor slide. (See Chapter 6.) Draw the reservoir level down if safety of dam is threatened. A qualified engineer should inspect the conditions and recommend further actions. ENGINEER REQUIRED

Figure 5.1 ***(cont.)***
Inspection Guidelines - Upstream Slope

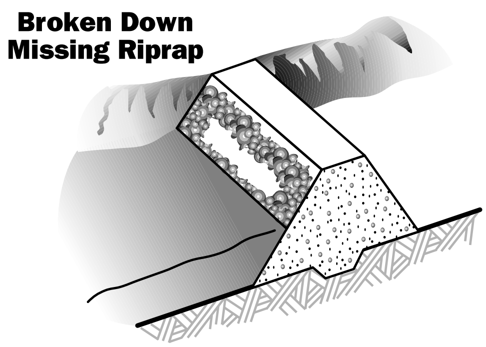


Figure 5.1d

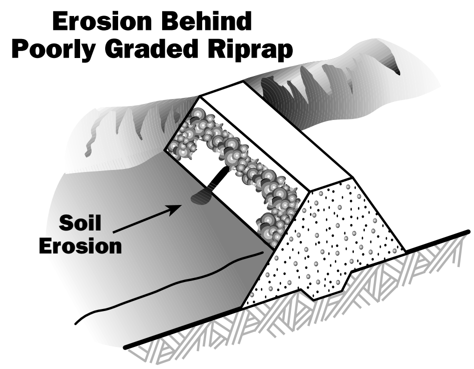


Figure 5.1e

Problem	Probable Cause and Possible Consequences	Recommended Actions
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). (See Chapter 7.)
Broken Down, Missing Riprap *(Figure 5.1d)*	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. (See Chapter 7.)
Erosion Behind Poorly Graded Riprap *(Figure 5.1e)*	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. ENGINEER REQUIRED for design—for graduation and size for rock for bedding and riprap. A qualified engineer should inspect the conditions and recommend further actions.

Figure 5.2
Inspection Guidelines - Downstream Slope

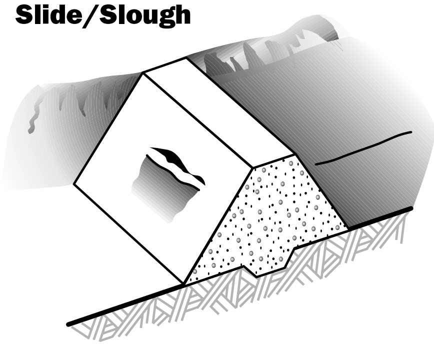


Figure 5.2a

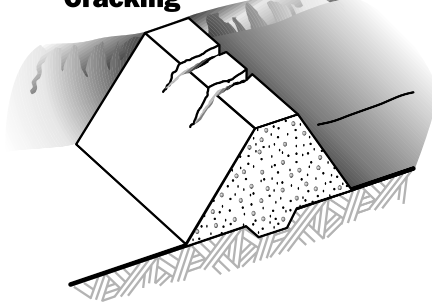


Figure 5.2b

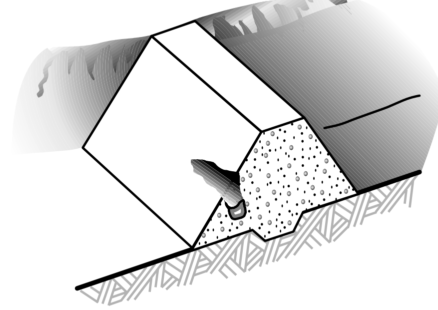


Figure 5.2c

Problem	Probable Cause and Possible Consequences	Recommended Actions
Slide or Slough *(Figure 5.2a)*	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	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. ENGINEER REQUIRED
Transverse Cracking *(Figure 5.2b)*	1. Uneven movement between adjacent segments of the embankment. 2. Deformation caused by structural stress or instability. 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	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. ENGINEER REQUIRED
Cave-in or Collapse *(Figure 5.2c)*	1. Lack of adequate compaction. 2. Rodent hole below. 3. Piping through embankment or foundation. 4. Presence of dispersive soils. Indicates possible washout of embankment.	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. ENGINEER REQUIRED

Figure 5.2 ***(cont.)***
Inspection Guidelines - Downstream Slope

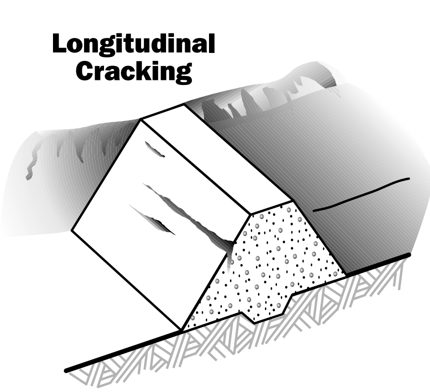


Figure 5.2d

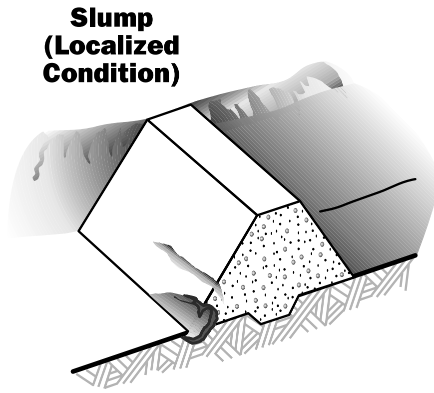


Figure 5.2e

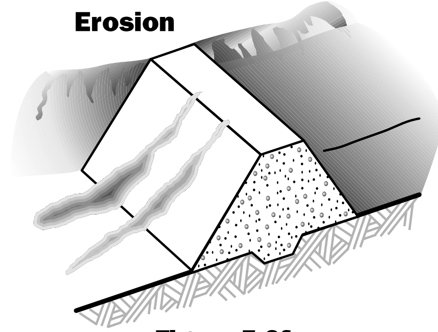


Figure 5.2f

Problem	Probable Cause and Possible Consequences	Recommended Actions
Longitudinal Cracking ***(Figure 5.2d)***	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. ENGINEER REQUIRED
Slump ***(localized condition)*** ***(Figure 5.2e)***	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. ENGINEER REQUIRED
Erosion ***(Figure 5.2f)***	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.

Figure 5.2 *(cont.)*
Inspection Guidelines - Downstream Slope

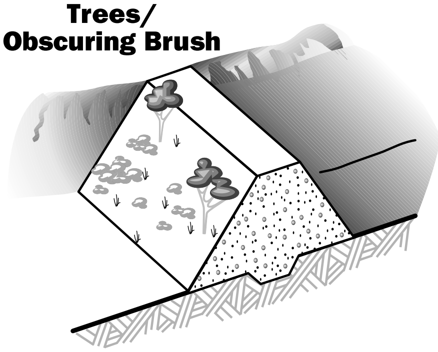


Figure 5.2g

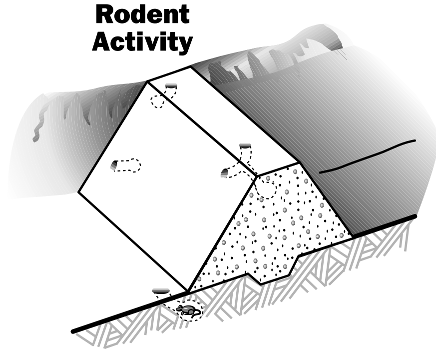


Figure 5.2h

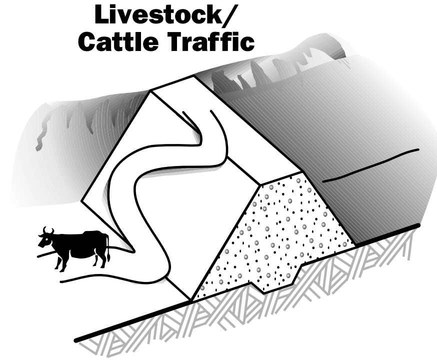


Figure 5.2i

Problem	Probable Cause and Possible Consequences	Recommended Actions
Trees, Obscuring Brush *(Figure 5.2g)*	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. Remove all brush and trees less than 4" in diameter. Larger trees may be allowed to stay until they die. At that time, the tree, with its root system, should be removed and the void properly filled with compacted soil. (See Chapter 7.) 2. Control vegetation on the embankment that obscures visual inspection. (See Chapter 7.)
Rodent Activity *(Figure 5.2h)*	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. (See Chapter 7.)
Livestock ***(such as cattle)*** **Traffic** *(Figure 5.2i)*	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.

Figure 5.3
Inspection Guidelines - Embankment Crest

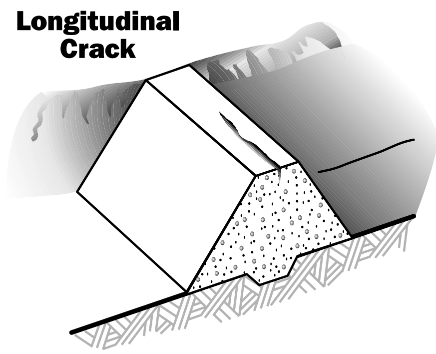


Figure 5.3a

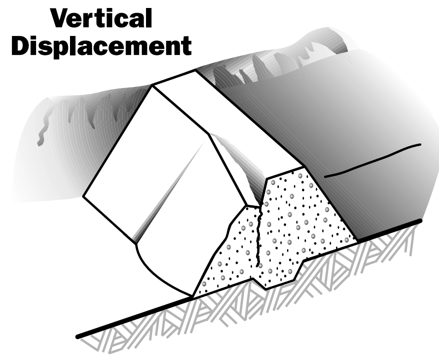


Figure 5.3b

Problem	Probable Cause and Possible Consequences	Recommended Actions
Longitudinal Crack *(Figure 5.3a)*	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. 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.	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. ENGINEER REQUIRED
Vertical Displacement *(Figure 5.3b)*	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. 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.	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. (See Chapter 6.) ENGINEER REQUIRED

Figure 5.3 *(cont.)*
Inspection Guidelines - Embankment Crest

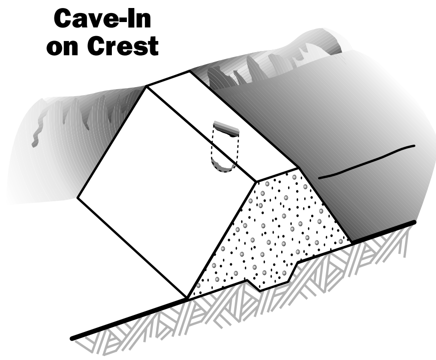


Figure 5.3c

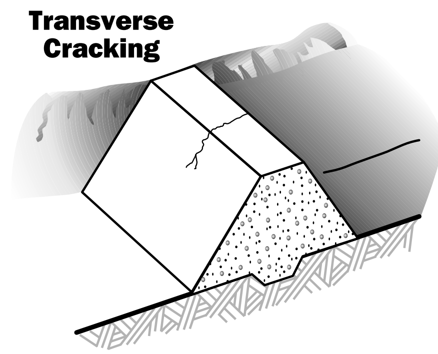


Figure 5.3d

Problem	Probable Cause and Possible Consequences	Recommended Actions
Cave-in On Crest ***(Figure 5.3c)***	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. 1. Void within dam could cause localized caving, sloughing, instability or reduced embankment cross-section. 2. Entrance point for surface water.	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. (See Chapter 7.) This should be supervised by engineer. ENGINEER REQUIRED
Transverse Cracking ***(Figure 5.3d)***	1. Uneven movement between adjacent segments of the embankment. 2. Deformation caused by structural stress or instability. 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.	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. (See Chapter 7.) This should be supervised by engineer. 4. Continue to monitor crest routinely for evidence of future cracking. (See Chapter 4.) ENGINEER REQUIRED

Figure 5.3 ***(cont.)***
Inspection Guidelines - Embankment Crest

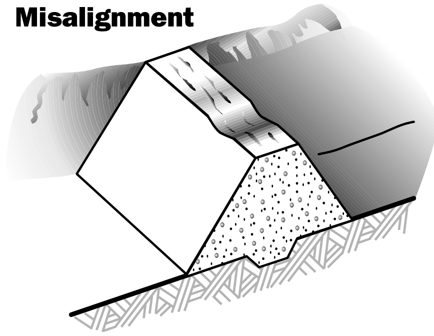


Figure 5.3e

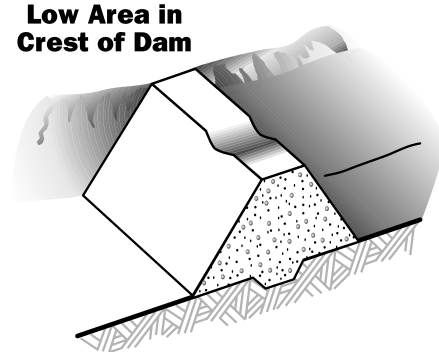


Figure 5.3f

Problem	Probable Cause and Possible Consequences	Recommended Actions
Crest Misalignment *(Figure 5.3e)*	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. 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. (See Chapter 6.) ENGINEER REQUIRED
Low Area in Crest *(Figure 5.3f)*	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. ENGINEER REQUIRED

Figure 5.3 *(cont.)*
Inspection Guidelines - Embankment Crest

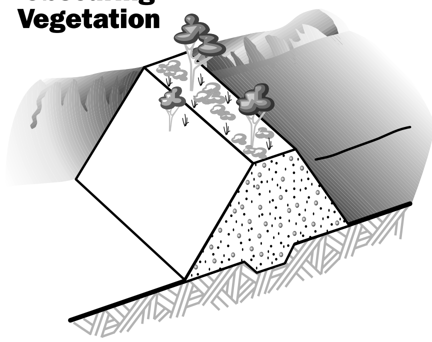


Figure 5.3g

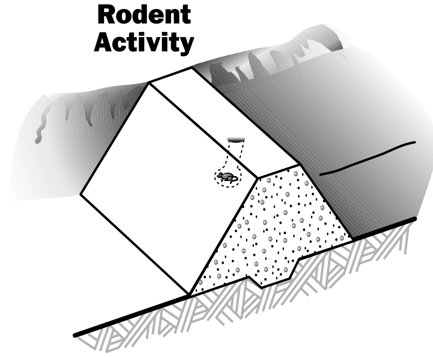


Figure 5.3h

Problem	Probable Cause and Possible Consequences	Recommended Actions
Obscuring Vegetation *(Figure 5.3g)*	Neglect of dam and lack of proper maintenance procedures. 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.	1. Remove all damaging growth from the dam. This would include removal of trees (4-inches or less in diameter), bushes, brush, conifers and growth other than grass. Grass should be encouraged on all segments of the dam to prevent erosion by surface runoff. Root systems should also be removed to the maximum practical extent. The void which results from removing the root system should 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. (See Chapter 7.) 3. All cutting or debris resulting from the vegetative removal should be immediately taken from the dam and properly disposed of outside the reservoir basin. An engineer should be involved if the tree removal process poses a threat to the dam.
Rodent Activity *(Figure 5.3h)*	Burrowing animals. 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.	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. (See Chapter 7.)

Figure 5.3 *(cont.)*
Inspection Guidelines - Embankment Crest

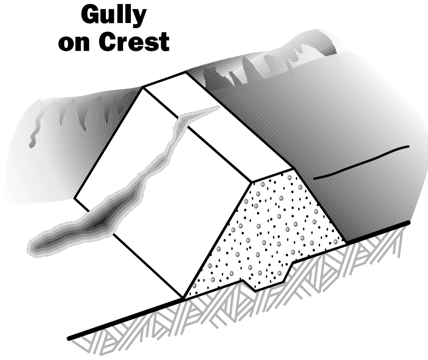


Figure 5.3i

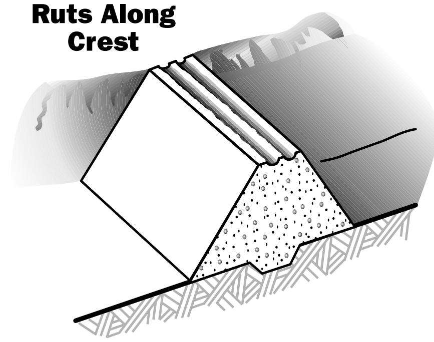


Figure 5.3j

Problem	Probable Cause and Possible Consequences	Recommended Actions
Gully on Crest *(Figure 5.3i)*	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. 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.	1. Restore freeboard to dam by adding fill material to low area, using proper construction techniques. (See Chapter 7.) 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.
Ruts Along Crest *(Figure 5.3j)*	Heavy vehicle traffic without adequate or proper maintenance or proper crest surfacing 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.	1. Drain standing water from ruts. 2. Regrade and re-compact crest to restore integrity and provide proper drainage to upstream slope. (See Chapter 7.) 3. Provide gravel or roadbase material to accommodate traffic. 4. Periodically maintain and regrade to prevent ruts reforming.

Figure 5.3 *(cont.)*
Inspection Guidelines - Embankment Crest

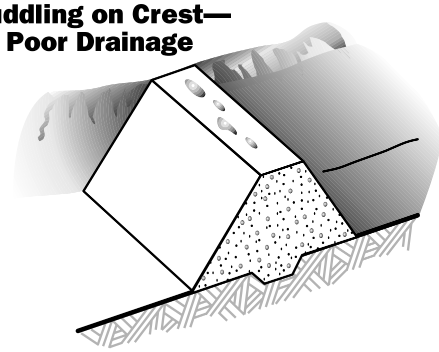


Figure 5.3k

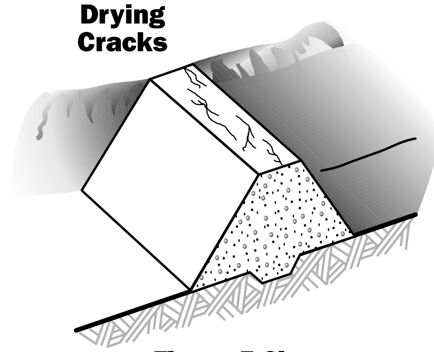


Figure 5.3l

Problem	Probable Cause and Possible Consequences	Recommended Actions
Puddling on Crest—Poor Drainage *(Figure 5.3k)*	1. Poor grading and improper drainage of crest. 2. Localized consolidation or settlement on crest allows puddles to develop. 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.	1. Drain standing water from puddles. 2. Regrade and re-compact crest to restore integrity and provide proper drainage to upstream slope. (See Chapter 7.) 3. Provide gravel or roadbase material to accommodate traffic. 4. Periodically maintain and regrade to prevent low areas reforming.
Drying Cracks *(Figure 5.3l)*	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.	1. Seal surface cracks with a tight, impervious material. (See Chapter 7.) 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.

Figure 5.4
Inspection Guidelines - Embankment Seepage Areas

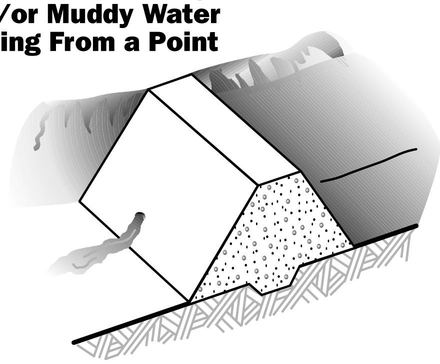


Figure 5.4a

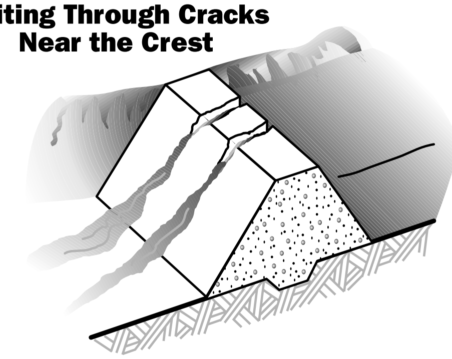


Figure 5.4b

Problem	Probable Cause and Possible Consequences	Recommended Actions
Excessive Quantity and/or Muddy Water Exiting From a Point *(Figure 5.4a)*	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. 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.	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. ENGINEER REQUIRED
Stream of Water Exiting Through Cracks Near the Crest *(Figure 5.4b)*	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.	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. ENGINEER REQUIRED

Figure 5.4 *(cont.)*
Inspection Guidelines - Embankment Seepage Areas

Seepage Water Exiting as a Boil in the Foundation

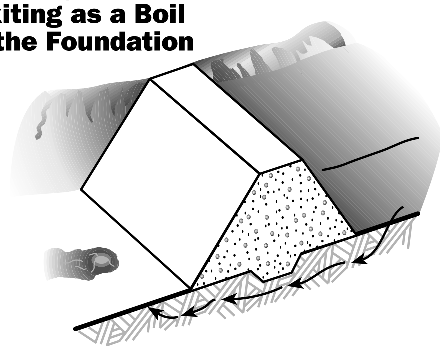


Figure 5.4c

Seepage Exiting at Abutment Contact

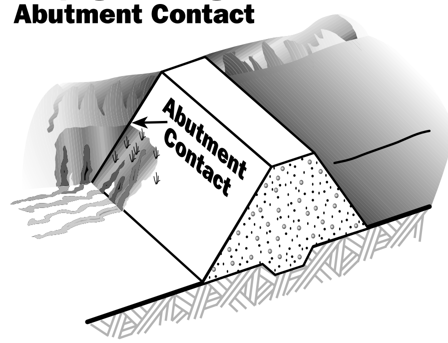


Figure 5.4d

Problem	Probable Cause and Possible Consequences	Recommended Actions
Seepage Water Exiting as a Boil in the Foundation *(Figure 5.4c)*	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.	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. ENGINEER REQUIRED
Seepage Exiting at Abutment Contact *(Figure 5.4d)*	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.	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. ENGINEER REQUIRED

Figure 5.4 *(cont.)*
Inspection Guidelines - Embankment Seepage Areas

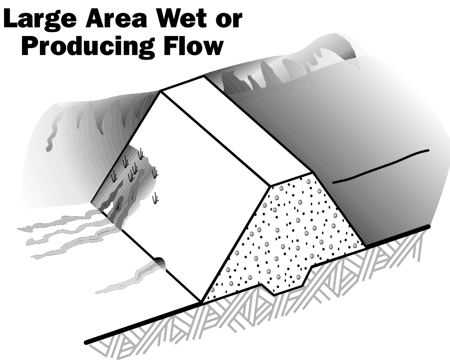


Figure 5.4e

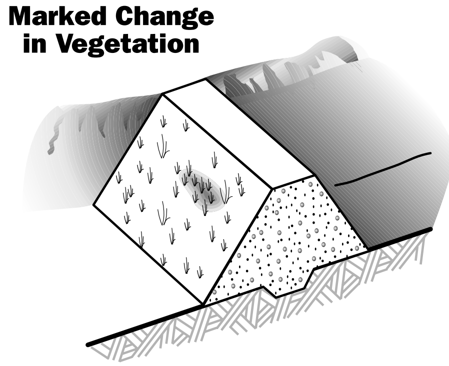


Figure 5.4f

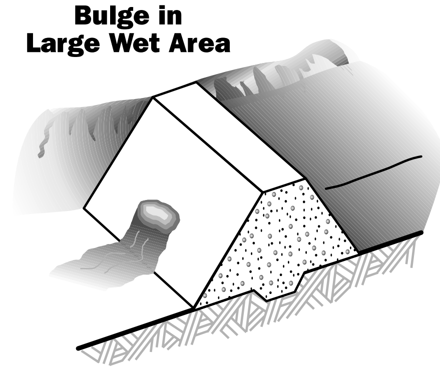


Figure 5.4g

Problem	Probable Cause and Possible Consequences	Recommended Actions
Large Area Wet or Producing Flow *(Figure 5.4e)*	A seepage path has developed through the abutment or embankment materials and failure of the dam can occur. 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.	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. ENGINEER REQUIRED
Marked Change in Vegetation *(Figure 5.4f)*	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.	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. ENGINEER REQUIRED
Bulge in Large Wet Area *(Figure 5.4g)*	Downstream embankment materials have begun to move. Failure of the embankment resulting from massive sliding can follow these early movements.	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. ENGINEER REQUIRED

Figure 5.4 *(cont.)*
Inspection Guidelines - Embankment Seepage Areas

Trampoline Effect in Large Soggy Area

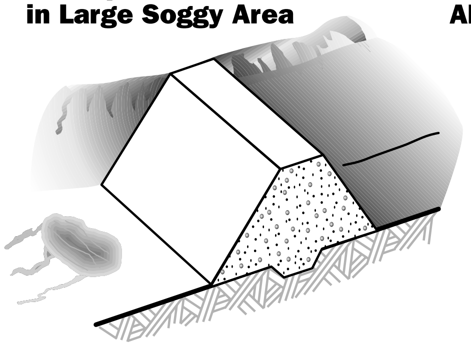


Figure 5.4h

Leakage From Abutments Beyond the Dam

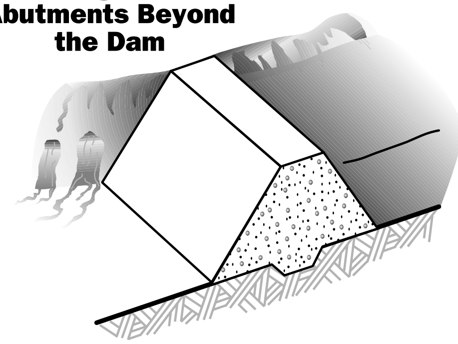


Figure 5.4i

Wet Area in Horizontal Band

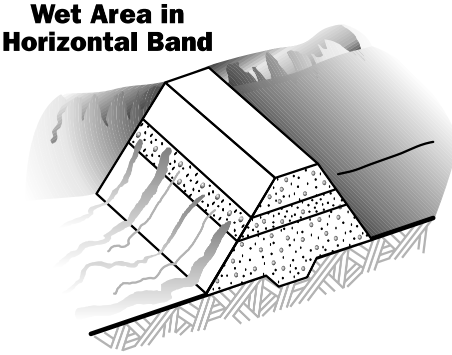


Figure 5.4j

Problem	Probable Cause and Possible Consequences	Recommended Actions
Trampoline Effect ***(bouncy when jumped on)*** **in Large Soggy Area** ***(Figure 5.4h)***	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.	1. Carefully inspect the area for outflow quantity and any transported material. 2. A qualified engineer should inspect the condition and recommend further actions. ENGINEER REQUIRED
Leakage From Abutments Beyond the Dam ***(Figure 5.4i)***	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.	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. ENGINEER REQUIRED
Wet Area in Horizontal Band ***(Figure 5.4j)***	Frost layer or layer of sandy material in original construction. 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.	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 further actions. ENGINEER REQUIRED

Figure 5.5
Inspection Guidelines - Concrete Upstream Slope

Large Increase in Flow or Sediment in Drain Outfall

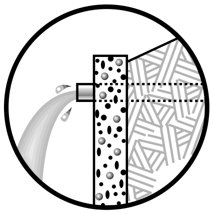


Figure 5.5a

Cracked Deteriorated Concrete Face

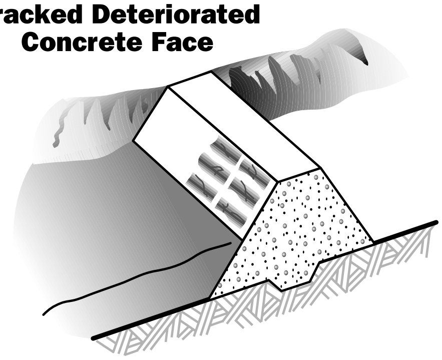


Figure 5.5b

Cracks Due to Drying

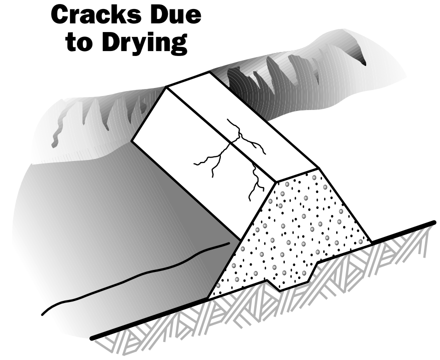


Figure 5.5c

Problem	Probable Cause and Possible Consequences	Recommended Actions
Large Increase in Flow or Sediment in Drain Outfall ***(Figure 5.5a)***	Shortened seepage path or increased storage levels. 1. Higher-velocity flows can cause erosion of drain, then embankment materials. 2. Can lead to piping failure.	1. Accurately measure outflow quantity and determine amount of increase over previous flow. 2. Collect jar samples to compare turbidity. 3. If either quantity or turbidity has increased by 25%, a qualified engineer should evaluate the condition and recommend further actions. ENGINEER REQUIRED
Cracked Deteriorated Concrete Face ***(Figure 5.5b)***	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.	1. Determine cause. Either patch with grout or contact engineer for permanent repair method. 2. If damage is extensive, a qualified engineer should inspect the condition and recommend further actions. ENGINEER REQUIRED
Cracks Due to Drying ***(Figure 5.5c)***	Soil loses its moisture and shrinks, causing cracks. *Note:* Usually limited to crest and downstream slope. Heavy rains can fill cracks and cause small parts of embankment to move along internal slip surface.	1. Monitor cracks for increases in width, depth , or length. 2. A qualified engineer should inspect condition and recommend further actions. ENGINEER REQUIRED

Figure 5.6
Inspection Guidelines - Spillways

Excessive Vegetation or Debris in Channel

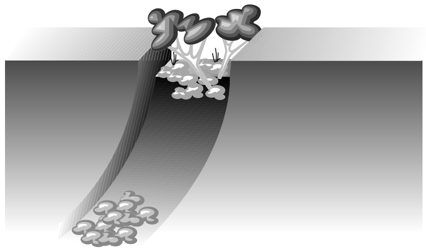


Figure 5.6a

Erosion Channels

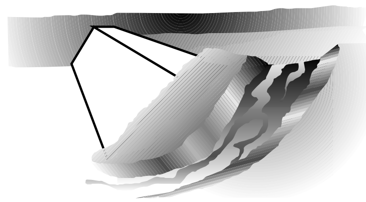


Figure 5.6b

Excessive Erosion in Earth-Slide Causes Concentrated Flows

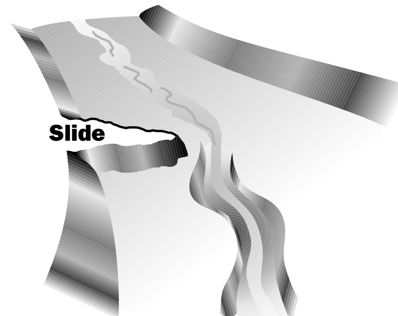


Figure 5.6c

Problem	Probable Cause and Possible Consequences	Recommended Actions
Excessive Vegetation or Debris in Channel *(Figure 5.6a)*	Accumulation of slide materials, dead trees, excessive vegetative growth, etc., in spillway channel. Reduced discharge capacity; overflow of spillway, overcropping of dam. Prolonged overtopping can cause failure of the dam.	Clean out debris periodically; control vegetative growth in spillway channel. Install log boom in front of spillway entrance to intercept debris.
Erosion Channels *(Figure 5.6b)*	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. 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.	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.
Excessive Erosion in Earth-Slide Causes Concentrated Flows *(Figure 5.6c)*	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. 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.	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.

Figure 5.6 *(cont.)*
Inspection Guidelines - Spillways

End of Spillway Chute Undercut

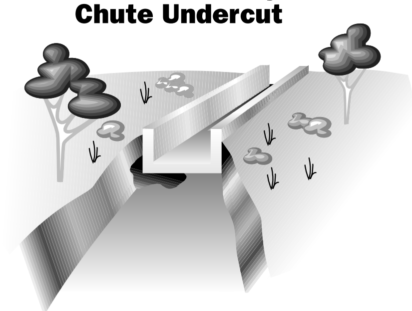


Figure 5.6d

Wall Displacement

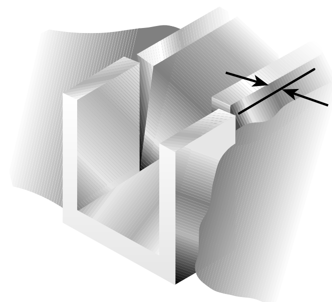


Figure 5.6e

Large Cracks

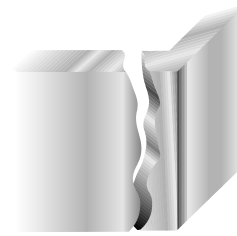


Figure 5.6f

Problem	Probable Cause and Possible Consequences	Recommended Actions
End of Spillway Chute Undercut *(Figure 5.6d)*	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 *(Figure 5.6e)*	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.	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 present further displacement. Install struts between spillway walls. Clean out and backflush drains to assure proper operations. Consult an engineer before actions are taken. ENGINEER REQUIRED
Large Cracks *(Figure 5.6f)*	Construction defect; local concentrated stress; local material deterioration; foundation failure, excessive backfill pressure. Disturbance in flow patterns; erosion of foundation and backfill; eventual collapse of structure.	Large cracks without large displacement should be repaired by patching. Surrounding areas should be cleaned or cut out before patching material is applied. (See Chapter 7.) Installation of weep holes or other actions may be needed.

Figure 5.6 *(cont.)*
Inspection Guidelines - Spillways

Open or Displaced Joints

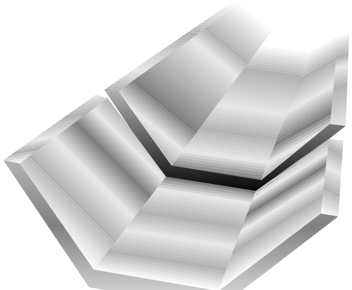


Figure 5.6g

Breakdown and Loss of Riprap

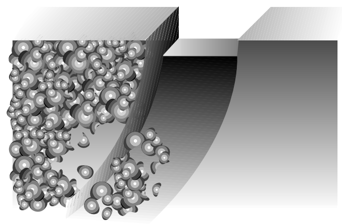


Figure 5.6h

Material Deterioration— Spalling and Disintegration of Riprap, Concrete, Etc.

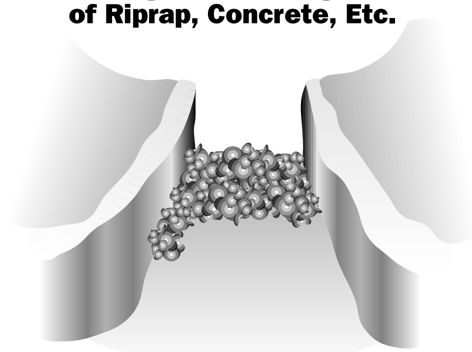


Figure 5.6i

Problem	Probable Cause and Possible Consequences	Recommended Actions
Open or Displaced Joints *(Figure 5.6g)*	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. ENGINEER REQUIRED
Breakdown and Loss of Riprap *(Figure 5.6h)*	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. ENGINEER REQUIRED
Material Deterioration— Spalling and Disintiegration of Riprap, Concrete, Etc. *(Figure 5.6i)*	Use of unsound or defective materials; structures subject to freeze-thaw cycles; improper maintenance practices; harmful chemicals. Structure life will be shortened; premature failure.	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.

Figure 5.6 *(cont.)*
Inspection Guidelines - Spillways

Poor Surface Drainage

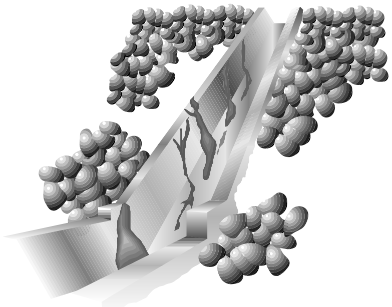


Figure 5.6j

Concrete Erosion, Abrasion, and Fracturing

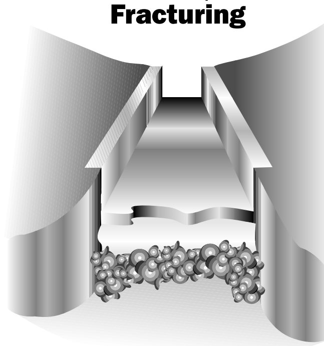


Figure 5.6k

Leakage in or Around Spillway

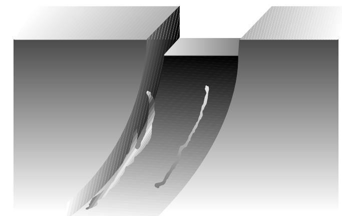


Figure 5.6l

Problem	Probable Cause and Possible Consequences	Recommended Actions
Poor Surface Drainage *(Figure 5.6j)*	No weep holes; no drainage facility; plugged drains. 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.	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. Backflush and rehabilitate drain system under the supervision of an engineer. ENGINEER REQUIRED
Concrete Erosion, Abrasion, and Fracturing *(Figure 5.6k)*	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. Pockmarks and spalling of concrete surface may progressively worsen; small hole may cause undermining of foundation, leading to failure of structure.	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. ENGINEER REQUIRED
Leakage in or Around Spillway *(Figure 5.6l)*	1. Cracks and joints in geologic formation at spillway are permitting seepage. 2. Gravel or sand layers at spillway are permitting seepage. 1. Could lead to excessive loss of stored water. 2. Could lead to a progressive failure if velocities are high enough to cause erosion of natural materials.	1. Examine exit area to see if type of material can explain leakage. 2. Measure flow quantity 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. ENGINEER REQUIRED

Figure 5.6 *(cont.)*
Inspection Guidelines - Spillways

Too Much Leakage From Spillway Under Drains

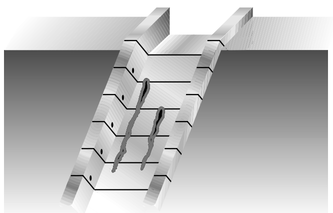


Figure 5.6m

Seepage From a Construction Joint or Crack in Concrete Structure

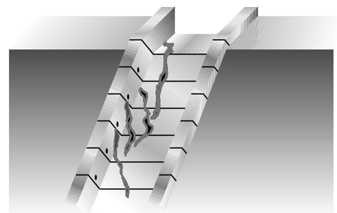


Figure 5.6n

Problem	Probable Cause and Possible Consequences	Recommended Actions
Too Much Leakage From Spillway Under Drains *(Figure 5.6m)*	Drain or cutoff may have failed. 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.	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. ENGINEER REQUIRED
Seepage From a Construction Joint or Crack in Concrete Structure *(Figure 5.6n)*	Water is collecting behind structure because of insufficient drainage or clogged weep holes. 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.	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. ENGINEER REQUIRED

Figure 5.7
Inspection Guidelines - Inlets, Outlets, and Drains

Outlet Pipe Damage

Crack

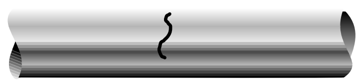


Figure 5.7a-1

Hole

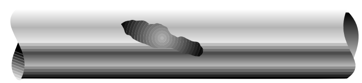


Figure 5.7a-2

Joint Offset

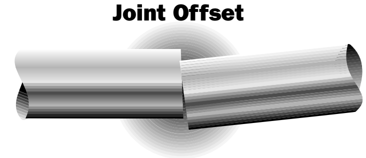


Figure 5.7a-3

Problem	Probable Cause and Possible Consequences	Recommended Actions
Outlet Pipe Damage: Crack ***(Figure 5.7a-1)***	Settlement; impact. Excessive seepage, possible internal erosion.	Check for evidence of water either entering or exiting pipe at crack, hole, etc.
Outlet Pipe Damage: Hole ***(Figure 5.7a-2)***	Rust (steel pipe); erosion (concrete pipe); cavitation. Excessive seepage, possible internal erosion.	Tap pipe in vicinity of damaged area, listening for hollow sound which indicates a void has formed along the outside of the conduit.
Outlet Pipe Damage: Joint Offset ***(Figure 5.7a-3)***	Settlement or poor construction practice. Provides passageway for water to exit or enter pipe, resulting in erosion of internal materials of the dam.	If a progressive failure is suspected, request engineering advice.

Figure 5.7 *(cont.)*
Inspection Guidelines - Inlets, Outlets, and Drains

Control Works

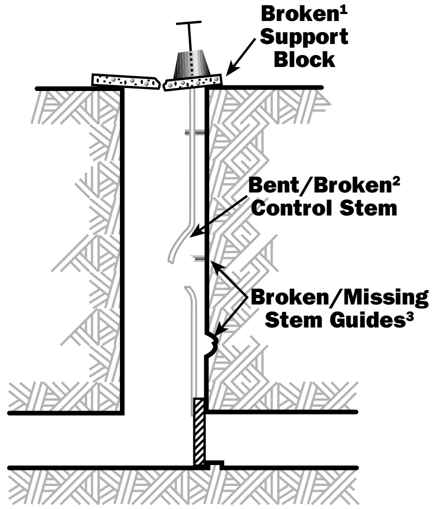


Figure 5.7b

Problem	Probable Cause and Possible Consequences	Recommended Actions
Damage to Control Works *(Figure 5.7b)*	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.

Figure 5.7 *(cont.)*
Inspection Guidelines - Inlets, Outlets, and Drains

Failure of Concrete Outfall Structure

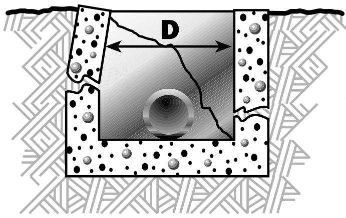


Figure 5.7c

Outlet Releases Eroding Toe of Dam

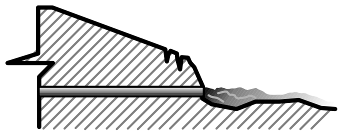


Figure 5.7d

Valve Leakage

Debris Stuck Under Gate

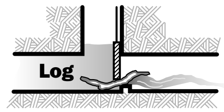


Figure 5.e-1

Cracked Gate Leaf

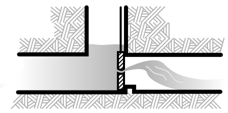


Figure 5.e-2

Damage Gate Seat or Guides

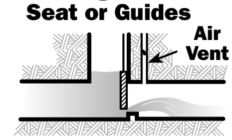


Figure 5.e-3

Problem	Probable Cause and Possible Consequences	Recommended Actions
Failure of Concrete Outfall Streucture *(Figure 5.7c)*	Excessive side pressures on nonreinforced concrete structure. Poor concrete quality. Loss of outfall structure exposes embankment to erosion by outlet releases.	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.
Outlet Releases Eroding Toe of Dam *(Figure 5.7d)*	Outlet pipe too short. Lack of energy-dissipating pool or structure at downstream end of conduit. Erosion of toe oversteepens downstream slope, causing progressive sloughing.	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.
Valve Leakage: Debris Stuck Under Gate *(Figure 5.7e-1)*	Trashrack missing or damaged. Gate will not close. Gate or stem may be damaged in effort to close gate.	Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trashrack.
Valve Leakage: Cracked Gate Leaf *(Figure 5.7e-2)*	Ice action, rust, affect vibration, or stress resulting from forcing gate closed when it is jammed. Gate-leaf main fail completely, evacuating reservoir.	Use valve only in fully open or closed position. Minimize use of valve until leaf can be repaired or replaced.
Valve Leakage: Damaged Gate Seat or Guides *(Figure 5.7e-3)*	Rust, erosion, cavitation, vibration or wear. Leakage and loss of support for gate leaf. Gate may bind in guides and become inoperable.	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.

Figure 5.7 ***(cont.)***
Inspection Guidelines - Inlets, Outlets, and Drains

Seepage Water Exiting From a Point Adjacent to the Outlet

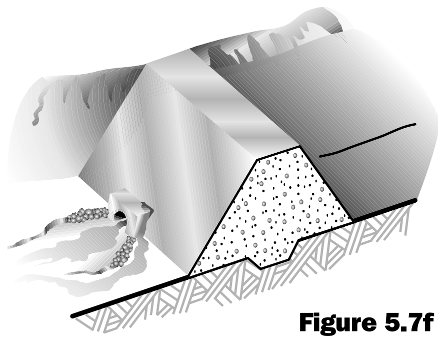


Figure 5.7f

Problem	Probable Cause and Possible Consequences	Recommended Actions
Seepage Water Exiting From a Point Adjacent to the Outlet ***(Figure 5.7f)***	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. ENGINEER REQUIRED