

**P**roperly maintaining a dam not only protect the dam and its owner, but the general public as well. A good maintenance program will protect a dam against deterioration, prolong its life, and greatly reduce the chance of failure. Nearly all the components of a dam and its materials are susceptible to damage and deterioration if not well maintained. Moreover, the cost of a proper maintenance program is small compared to the costs of major repairs, loss of life and property, and litigation.

### O & M Plans

All dam owners should develop written Operation and Maintenance (O&M) plans providing each of the following (if applicable):

#### **Step by step instructions for operating all mechanisms associated with the dam**

Typically, these instructions will include operation of the outlet conduit control valve, flashboards, or the spillway gates if applicable. Proper sequences should be emphasized using diagrams or photographs to aid in identifying specific control panels, levers or other devices. A description of the correct method of opening and closing valves or gates, gate usage during low and high flow conditions, operating problems peculiar to a specific valve or gate, and maximum lake drawdown rate should also be included.

#### **Operation of the lake, including the inflow and outlet devices**

Instructions should also describe operation of the outlet to limit or prevent excessive spillway

flow as well as the method for periodic drainage of the lake to permit thorough inlet, outlet, and upstream slope inspection.

#### **Release rate instructions and schedules for maintaining any required downstream flows**

Downstream flows may include irrigation, power generation, or other purposes. Release rates and dates should be recorded and placed in the owner's project files.

#### **Safety and security measures deployed at the site**

Locations of fences and locks and contact information for key-holders should be included. Specific areas at the dam and around the lake that present a potential safety concern for site visitors and maintenance personnel should be listed or illustrated, as well as zones posted with "no-trespassing" or "warning" signs. This also includes zones that present a danger to visitors such as slippery, steep or rip-rap covered slopes.

#### **Maintenance instructions**

Detailed instructions and schedules for performing periodic maintenance work at the dam, the appurtenant works, and the lake areas, including both routine preventive maintenance and repair of problems identified during safety inspections.

Preventive maintenance assures that the dam and lake are in good working condition and precludes more harmful conditions from developing. This includes such tasks as mowing, repairing eroded areas, and removal of burrowing animals. Individual maintenance tasks should be itemized on a list, with a description of the area where the maintenance is to be performed, the schedule for performing the tasks, and reporting procedures. Typical routine maintenance tasks performed at most dams include mowing grass, removing brush and trees, removing litter and other debris, regrading the crest and/or access roads, repairing fencing to keep livestock off the dam, removing



*Well maintained dam*

burrowing animals, operating and lubricating gates, adding riprap when needed, sealing joints in concrete facings, cleaning spillway and outlet conduits, maintaining monitoring points, maintaining security of operating equipment, and reseeding and fertilizing grass.

Work due to findings from an inspection should be planned out and listed in similar detail as required for preventive maintenance. Dam repairs should be scheduled based on severity of the problem, available resources, and weather

conditions. For example, if a severe settlement problem is identified on the crest of the dam, it should have a high priority since further degradation could lead to dam breaching. Correcting minor rill erosion on the downstream slope, however, could be assigned a low priority since it is not a dam safety concern. This type of repair will also be weather dependent, since grass can only be planted during specific times of the year, and the embankment should be relatively dry so that additional damage is not inflicted to the embankment slopes.

Other maintenance that may need to be performed varies from dam to dam and is usually the result of weathering and other destructive forces. This includes such things as repair of embankment sloughs and slides, seepage problems, severe erosion, displaced riprap, shoreline wave erosion, embankment settlement, and concrete cracking and disintegration.

**The key to a successful maintenance program is the establishment of a task schedule and strict adherence to it.**



*Vertical crack in dam allowing seepage*

## Maintenance Priorities

Maintenance should never be neglected. The following outline lists, by relative priority, the various problems or conditions that might be encountered when routine maintenance has been neglected.

### Immediate Maintenance

The Emergency Action Plan should be activated when any of the following conditions are noted:

- The dam is in danger of being overtopped.
- The dam is about to be breached (by progressive erosion, slope failure, or other circumstances).
- The dam shows signs of piping or internal erosion, indicated by increasingly cloudy seepage or other symptoms.
- The spillway is blocked or otherwise inoperable or has normal discharge restricted.
- There is evidence of an increasing volume of excessive seepage seen anywhere at the dam site (e.g., an embankment becoming saturated or seepage exiting on the downstream face of a dam).



With the exception of the blocked spillway, the problems listed above usually require the services of a professional engineer familiar with the construction and maintenance of dams.

### Required Maintenance at Earliest Possible Date

- Remove all underbrush and trees from the dam, and establish a good grass cover.
- Fill animal burrows.
- Repair livestock trails and fences to keep livestock off dam.
- Restore and reseed eroded areas and gullies on embankment dams.
- Repair defective spillways, gates, valves, and other appurtenant features.
- Repair any concrete or metal parts that have deteriorated.



*Erosion of dam embankment*

### Continuing Preventive Maintenance

- Routine mowing and general maintenance.
- Maintenance and filling of any cracks and joints on concrete dams and in concrete spillways.
- Observation of any springs or areas of seepage, comparing quantity and quality (clarity) with prior observations.
- Routine technical inspection of the dam.
- Monitoring of development in the watershed that would materially increase runoff from storms.
- Monitoring of development downstream and updating the emergency notification plan to include new houses or other occupied structures within the area.

### Erosion on Embankments

Erosion is one of the most common maintenance problems at embankment structures. Erosion is a natural process and its continuous forces will eventually wear down almost any surface or structure. Periodic and timely maintenance is essential to prevent continuous deterioration and possible failure.

Sturdy sod, free from weeds and brush, is an effective means of preventing erosion. Embankment slopes are normally designed and constructed so that surface drainage will be spread out in thin layers (sheet flow) on the grassy cover. When embankment sod is in poor condition or flows are concentrated at any location, the resulting erosion will leave rills and gullies in the embankment slope. An owner should look for such areas and be aware of the

problems that may develop. Eroded areas must be promptly repaired to prevent more serious damage to the embankment.

Rills and gullies should be filled with suitable soil (the upper four inches should be topsoil, if possible), compacted, and then seeded. The local Natural Resources Conservation Service office can help select the types of grass to use for protecting dam surfaces. Erosion in large gullies can be slowed by stacking bales of hay or straw across the gully until permanent repairs can be made.

Eroded areas should be repaired and their cause determined to prevent a continuing maintenance problem. Possible causes may be improper drainage, settlement, pedestrian traffic, animal burrows, or other factors. The source of the erosion will have a direct bearing on the type of repair needed.



*Longitudinal crack*



**S**ome common areas of erosion include the following:

**Paths due to pedestrian, livestock, or vehicular traffic (two- and four-wheeled)**

If a path has become established, vegetation will not provide adequate protection. More durable cover

will be required unless traffic is eliminated. Small stones, asphalt, or concrete may be used effectively to cover footpaths. In addition, railroad ties or other beams of treated wood can be embedded into an embankment slope to form an inexpensive stairway. All vehicular traffic, except for maintenance,

should be prohibited from the embankments of the dam.

**Areas where the embankment meets the spillway or other structure**

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

**Areas where the downstream face of an embankment contacts the abutments**

Runoff from rainfall can concentrate in gutters constructed in these areas and can reach erosive velocities because of relatively steep slopes.

## Repairing Embankments

The surfaces of an earthen dam may deteriorate for several reasons. For example, wave action may cut into the upstream slope, vehicles may cause ruts in the crest or slopes, trails left by livestock on the dam can result in erosion of the embankments, or runoff waters may leave erosion gullies on the downstream slope. Other special problems, such as shrinkage cracks or rodent damage, may also occur. Damage of this nature must be repaired continually.

The following maintenance procedures should not be used to solve serious problems. Conditions such as embankment slides, structural cracking, and sinkholes threaten the safety of a dam and require immediate repair under the direction of a professional engineer.



*Embankment slide moves guardrail*



*Longitudinal crack displaces guardrail*



## Material Selection

The material selected for repairing embankments should depend upon the purpose of the earthwork. Generally, earth should be free from vegetation, organic materials, trash, and large rocks. Most of the earth should be fine-grained soils or earth clods that easily break down when worked with compaction equipment. The intent is to use a material that, when compacted, forms a firm, solid mass, free from excessive voids. If flow-resistant portions of an embankment are being repaired, materials that are high in clay or silt content should be used. If the area is to be free draining or highly permeable (such as riprap bedding) the material should have a higher percentage of sand and gravel. It is usually satisfactory to replace or repair damaged areas with soils similar to those originally in place. An important soil property affecting compaction is moisture content. Soils that are too dry or too wet do not compact well. One may roughly test repair material by squeezing it into a tight ball. If the sample maintains its shape without cracking and falling apart (too dry) and without depositing excess water onto the hand (too wet), the moisture content should be acceptable.

## Preparing the Repair Area

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

## Shaping and Dressing the Repair Area

Shape and dress the affected area so that the new fill can be compacted and will properly tie into the

existing fill. If possible, trim slopes and roughen surfaces by scarifying or plowing to improve the bond between the new and existing fill and to provide a good base to compact against. Grade the slopes in a direction such that the soil ridges are parallel to the length of the dam—this will help to minimize or reduce rill erosion. Roughening in the wrong direction will likely increase rill erosion.

## Placing and compacting soils

Place soils in loose layers up to eight inches thick and compact manually or mechanically to form a dense mass free from large rock or organic material. Maintain soil moisture in the proper range. The fill should be watered and mixed to the proper wetness or scarified and allowed to dry if too wet. During backfilling, take care that the fill does not become too wet from rainstorm runoff. Direct runoff away from the work area and overfill repair areas so that the fill maintains a crown that will shed water.

As mentioned earlier, occasionally minor cracks will form in an earthen

dam because of surface drying. These are called desiccation (drying) cracks and should not be confused with structural or settlement cracks. Drying cracks are usually parallel to the main axis of the dam, typically near the upstream or downstream shoulders of the crest. These cracks often run intermittently along the length of the dam and may be up to four feet deep. Drying cracks can be distinguished from more serious structural cracks because the former are usually no wider than a few inches and have edges that are not offset vertically.

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

These cracks should close as climatic or soil moisture conditions change.



*Large slide on embankment with prominent slope*

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

## Maintaining & Repairing Spillways

Many dams have pipes (or conduits) that serve as principal spillways. These conduits are required to carry normal stream and small flood flows safely past the embankment throughout the life of the structure. Pipes through embankments are difficult to construct properly, can be extremely dangerous to the embankment if problems develop after construction, and are usually difficult to repair because of their location and size.

It is imperative to install pipe with pressure tight joints that can withstand minor deflections. The use

of pipe whose joints are not designed to handle pressure flows, such as corrugated metal pipe, should be avoided when replacing or repairing existing pipe. The joints in a pipe can be affected by differential settlement of the embankment, bedding failure, positive and negative pressures within the pipe, and slides and seepage through the embankment.

Conduits should be inspected thoroughly once a year. Conduits which are 36 inches or more in diameter can be entered and visually inspected. Common issues are improper alignment (sagging), separation and displacement at joints, cracks, leaks, surface wear, loss of protective coatings, corrosion, and blockage.

Problems with conduits occur most often at the joints. Hence, special attention should be given them during the inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint-filler material. Open joints can permit erosion of embankment material or cause leakage of water

into the embankment during pressure flow. The outlet should be checked for signs of water seeping along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

Effective repair of the internal surface or joint of a conduit is difficult and should not be attempted without careful planning and proper professional supervision.

Listed below are common concerns regarding pipe repairs:

- Asphalt mastic is not recommended for other than temporary repairs. Asphalt mastic used as joint filler becomes hard and brittle, is easily eroded, and will generally provide a satisfactory seal for only about five years. Mastic should not be used if the pipe is expected to flow under pressure.
- The instructions on the label should be followed when using thermosetting plastics (epoxy). Most of these products must be applied to a very clean and dry surface to establish an effective bond.
- Material used as joint filler should be impervious to water and should be flexible throughout the range of expected air and water temperatures.
- The internal surfaces of the conduit should be made as smooth as possible when repairs are made so that high-velocity flow will not damage the repair material.
- Hairline cracks in concrete are not generally considered a dangerous problem. Repair is not necessary unless the cracks widen or transmit water.



*Outlet Pipe and Plunge Pool*



Corrosion is a common problem with metal pipe spillways and conduits. Metal pipes are not recommended and should be upgraded to concrete when repairs are required. Exposure to moisture, acid conditions, or salt will accelerate the corrosion process. Only metal pipes precoated with epoxy, aluminum, or zinc (galvanized) should be used. Coatings applied to pipes in service are generally not very effective because of the difficulty in establishing a bond and bituminous coatings cannot be expected to last more than two years.

Corrosion can be controlled or arrested by installing cathodic protection. A metallic anode such as magnesium is buried in the soil and is connected to the metal pipe by wire. Natural voltage causes current to flow from the magnesium (anode) to the pipe (cathode) and will cause the magnesium to corrode and not the pipe. Corrosion of metal parts of operating mechanisms can be effectively treated and prevented by keeping these parts oiled and/or painted.

### Spillway Outlets

Erosion at the spillway outlet, whether it be a pipe or overflow spillway, is one of the most common spillway problems encountered. Severe undermining of the outlet can displace sections of pipe, cause slides in the downstream slope of the dam as erosion continues, and eventually lead to complete failure of a dam. Water must be conveyed safely from the lake to a point downstream of the dam without endangering the spillway or embankment. Often the spillway outlet is adequately protected for normal flow conditions, but not for extreme flows. It is easy to underestimate the energy and force of flowing water or overestimate the resistance of the outlet material (earth, rock, concrete, etc). The required level of protection should be

determined by hydraulic calculations performed by a professional engineer.

Structures that provide complete erosion control at a spillway outlet are usually expensive to construct, but often necessary. Less expensive types of protection can be effective, but require more extensive periodic maintenance. As areas of erosion and deterioration develop, repairs must be promptly initiated. To properly correct the problem, the cause of the damage must be determined.

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

1. **Outlet at an elevation above the stream channel:** If the outlet flows emerge at the correct elevation, tailwater in the stream channel can absorb a substantial amount of the high velocity flow.
2. **Sediment Carrying Capacity:** Flows emerging from the spillway are generally free of sediment and therefore have substantial sediment-carrying capacity. In obtaining the potential sediment load, the moving water will scour soil material from the channel and leave eroded areas. Such erosion is difficult to estimate and requires that the outlet be protected for a safe distance downstream from the dam.
3. **Cavitation/Negative Pressure:** Flows leaving the outlet at high velocity can create negative pressures that can cause material to be loosened and removed from the floor and walls of the outlet channel. This action is known as "cavitation" and can also affect concrete or metal surfaces. Venting can sometimes be used to relieve negative pressures; however, the size and location of a vent should be determined by a professional engineer.

**4. Weakened Soil Structure Around The Pipe:** 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 the structure during construction and the absence of sand diaphragms will compound the problem.

Large riprap placed below spillway outlets can often be a solution to undermining and erosion. Stones should however, weigh in excess of 500 pounds at 18 to 24 inches in diameter. Such riprap can be expensive and is not guaranteed to solve the problem.

Gabions have been used successfully in areas where the velocity is low turbulence is not expected. Gabions require careful foundation preparation and experienced personnel for installation.

Plunge pools may be an acceptable alternative but can require frequent maintenance.

In many cases, professional help should be sought for complete redesign and construction of the outlet.

### Auxiliary (Emergency) Spillways

The function of an auxiliary spillway is to convey flood flows past the dam in a manner that will ensure that the dam is not overtopped. Vegetated-earth, rock, and concrete spillways are commonly used as an economical means to provide emergency spillway capacity. Normal flows are carried by the principal spillway, and infrequent, large flood flows pass primarily through the auxiliary spillway. For dams with pipe conduit as their principal spillways, an auxiliary spillway is almost always

required as a back-up in case the pipe becomes plugged. These spillways are often neglected because the owner rarely, if ever, sees them flow. Auxiliary spillways usually are designed to flow only once every 25 to 100 years or more; however, maintenance is still very important.

Obstructions in the spillways should be removed immediately after their discovery. For earthen spillways trees and woody vegetation are one of the more common maintenance concerns. Trees and brush should always be kept under control in emergency spillways so that flows will not be impeded.

Permanent structures (buildings, fences, etc.) should not be constructed in auxiliary spillways. If fences are absolutely necessary, they should cross the spillway far enough away from the crest (control section) so they do not interfere with flow. After flows occur, the fences should be cleared of all debris, trees, and brush. Maintenance of rock spillways should include the periodic removal of trees, brush, and debris from flood flows and rock slides.

Rock slides can be a major problem in areas where open channel spillways have been cut into weathered or highly fractured rock. Large rock that has fallen into the channel can partially block an emergency spillway and reduce its discharge capacity and should be cleared as quickly as possible.

Many spillways are constructed adjacent to the dam and founded partially in rock and partially in natural soil or fill material. In these cases, a training berm is required to direct flows away from the dam. This berm and the channel side next to the dam should be inspected for erosion whenever the spillway is used.

Erosion protection consisting of riprap or concrete and designed to hold up under design flood velocities should be provided and maintained. Maintenance of concrete spillways should include keeping the channel clear of debris, filling joints and cracks, keeping drains open and maintaining the structural stability of the concrete.

Concrete spillways must be inspected for cracks or displacements caused by settlement, foundation failure, uncontrolled seepage, and frost action. Voids created by the settlement of compressible soils beneath spillways and uncontrolled seepage may cause the concrete to crack or displace due to lack of support. It is important to provide adequate drainage for concrete located on soil. Drains under concrete must be kept clear. Clogged or plugged drains and inadequate filter systems can cause saturated conditions beneath the concrete.

## Maintaining & Repairing Gutters

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

Care should be taken when replacing failed gutters or designing new gutters to assure that the channel has adequate capacity, adequate erosion protection and a satisfactory filter have been provided, surface runoff can easily enter the gutter, and the outlet is adequately protected from erosion.

Berms on the downstream face that collect surface water and empty into these gutters add to the runoff volume. Sod surfaced gutters may not adequately prevent erosion in these areas. Paved concrete gutters may not be desirable because they do not slow the water and can be undermined by erosion. Also, small animals often construct burrows underneath these gutters, adding to the erosion potential.



*Wave erosion on upstream slope of dam.*



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

## Maintaining & Repairing Dam Slopes with Riprap

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

The upstream face of a dam is commonly protected against wave erosion and resultant benching by placement on the face of a layer of rock riprap over a layer of filter material. Sometimes, materials such as bituminous or concrete facing, bricks, or concrete blocks are used for this upstream slope protection. Protective benches are sometimes actually built into small dams by placing a berm (8 - 10 ft wide) along the upstream face a short distance below the normal pool level, supplying a surface on which wave energy can dissipate. Generally, however, rock riprap offers the most economical and effective protection.

Nonetheless, benching can occur in existing riprap if the embankment surface is not properly protected by a filter. Water running down the slope under the riprap can erode

the embankment. Sections of riprap that have slumped downward are often signs of this kind of benching.

Similarly, concrete facing used to protect slopes may fail because waves wash soil from beneath the slabs through joints and cracks. Detection is difficult because the voids are hidden, and failure may be sudden and extensive. Effective slope protection must prevent soil from being removed from the embankment.

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

A riprap layer should extend a minimum of 3 ft below the lowest expected normal pool level. Otherwise, wave action

during periods of low lake level will undermine and destroy the protection. If rock riprap is used, it should consist of a heterogeneous mixture of irregular shaped stone placed over a sand and gravel filter. The biggest rock must be large and heavy enough to break up the energy of the maximum expected waves and hold smaller stones in place. (An engineer may have to be consulted to determine the proper size.).

The smaller rocks help to fill the spaces between the larger pieces and to form a stable mass. The filter prevents soil particles on the embankment surface from being washed out through the spaces between the rocks in the riprap. If the filter material itself can be washed out through these voids and benching develops, two layers of filters may be required. The lower layer should be composed of sand or filter fabric to protect the soil surface and the upper layer should be composed of coarser materials.

When deficiencies prevent riprap from providing erosion protection,



*Trees and Woody Brush Growing on the Dam.*

the soil embankment beneath the riprap is exposed to erosion damage. Undercutting by wave action, slides, and slope failure can lead to failure of the upstream slope, a spillway channel, a plunge pool, or, if erosion continues unchecked, the breaching of the embankment. The inspector should look closely for signs of soil erosion and undercutting in all riprap areas.

A dam owner should expect some riprap deterioration because of weathering. Freezing and thawing, wetting and drying, abrasive wave action and other natural processes will eventually break down the material. Therefore, allocate sufficient funds for the regular replacement of riprap. The useful life of riprap varies depending on the characteristics of the stone used. Thus, stone for riprap should be rock that is dense and well cemented. When riprap breaks down, and erosion and breaching occur more often than once every three to five years, professional advice should be sought to design more effective slope protection.



*Cattle on Embankment of Dam*

## Controlling Vegetation

It is vital to keep the entire dam clear of unwanted vegetation such as brush or trees. Excessive growth may cause several problems:

- Obscured view of the surface of an embankment, preventing thorough inspection of the dam.
- Large holes due to uprooting of trees by high wind or erosion, which could lead to a dam breach.
- The creation of passageways for water by root systems that decay and rot.
- Lifting of concrete slabs or structures by growing root systems.
- Prevention of the growth of desirable grasses.
- Development of rodent habitats.

When brush is cut down, it should be removed to permit a clear view of the embankment. Following removal of large brush or trees, leftover root systems must also be removed.

Resulting holes must be properly filled and compacted. In cases where trees and brush cannot be removed, root systems must be treated with herbicide (properly selected and applied) to retard further growth. A licensed firm should be consulted regarding effective herbicides for control of vegetation on dam structures.

After the removal of brush, cuttings may need to be burned. The local fire department, forest service, or other agencies responsible for fire control should be notified. If properly maintained, grass is not only an effective means of controlling erosion, but also enhances the appearance of a dam and provides a surface that can be easily inspected. Grass roots and stems tend to trap fine sand and soil particles, forming an erosion-resistant layer once the plants are well established. Grass is least effective in areas of concentrated runoff or in areas subjected to wave action.

## Controlling Livestock

Livestock should not be allowed to graze on an embankment surface. When soil is wet, livestock can damage vegetation and disrupt the uniformity of the surface. Moreover, they tend to walk in established paths and thus can promote severe erosion. Such paths should be regraded and seeded, and the livestock permanently fenced out of the area.

## Controlling and Repairing Animal Damage

Burrowing animals (beaver, muskrat, groundhogs, and others) are naturally attracted to the habitats created by dams and lakes; however, their presence can endanger the structural integrity and proper performance of embankments and spillways.



The burrows and tunnels of these animals generally weaken earthen embankments and serve as pathways for seepage from the lake. This kind of damage has resulted in several failures of dams. Controlling burrows is an essential maintenance item.

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

Large burrows on an embankment should be filled by “mud-packing”. This simple, inexpensive method involves placing one or two lengths of metal stove or vent pipe vertically over the entrance of the den with a tight seal between the pipe and den. A mud-pack mixture is then poured into the pipe until the burrow and pipe are filled with the earth-water mixture. The pipe is removed and more dry earth is tamped into the den. The mud-pack mixture is made by adding water to a mixture of 90 percent earth and 10 percent cement until a slurry of thin cement is obtained. Plug all entrances with well-compacted earth and reestablish vegetation. Eliminate dens promptly. One burrow can lead to failure of a dam.

For extensive tunneling or large rodent activity, excavate the

area around the entrance and then backfill it with impervious material, plugging the passage entrance so that lake water is prevented from saturating the dam’s interior. This should be considered a temporary repair. Excavation and backfilling of the entire tunnel or filling of the tunnel

with cement grout are possible long-term solutions, but pressure cement grouting is an expensive and sometimes dangerous procedure and can cause hydraulic fracturing. Grouting should be performed only under the direction of an engineer.

*Trash Rack Over Inlet Pipe*



*Trash Rack With Debris*

## Controlling Damage from Traffic

Vehicles, except for maintenance, should be banned from dam slopes and kept out by fences or barricades. Vehicles driving across an embankment dam can create ruts in the crest if it is not surfaced with roadway material. Ruts can then collect water and cause saturation and softening of the dam. Repair any ruts as soon as possible. Maintenance vehicles should only travel on the soil and grass portions of the dam when the surface is dry unless necessitated by an emergency.

## Installing and Maintaining Trash Racks

In Oklahoma, many principal spillways consist of pipe and riser. Pipe spillway inlets that become plugged with debris or trash reduce spillway capacity. As a result, the potential for overtopping the dam is greatly increased, particularly if the emergency spillway is inadequate or blocked. A constricted or plugged principal spillway will cause more frequent and greater flow in the emergency spillway. Emergency spillways are generally designed for infrequent flows of short duration. Therefore serious damage to the emergency spillway is more likely to result from more frequent and greater flows. For these reasons, trash racks or collectors should be installed over the inlet.

A well-designed trash rack will stop large debris that could plug the pipe but allow unrestricted passage of water and smaller debris. Some of the most effective trash racks allow flow to pass beneath the trash rack into the riser inlet as the pool level rises. Trash racks usually become plugged because the openings are too small or the head loss at the rack causes material and sediment to settle and accumulate. Small

openings will stop small debris such as twigs and leaves, which in turn cause a progression of larger items to build up, eventually blocking the inlet. Trash rack openings should be at least 6 inches across regardless of the pipe size. The larger the principal spillway conduit, the larger the trash rack opening should be. The largest possible openings should be used, up to a maximum of about 12 inches.

The trash rack should be properly attached to the riser inlet and strong enough to withstand the hammering forces of debris being carried by high-velocity flow, a heavy load of debris, and ice. If the riser is readily accessible, vandals may throw riprap and debris into it. To prevent such vandalism, the size of the trash rack openings should not be decreased, but rock that is larger than the openings, too large to handle, or covered with concrete slurry should be used.

Maintenance should include periodic inspections for rusted and broken sections and repairs made as needed. The trash rack should be checked frequently during and after storms to ensure it is functioning properly and to remove accumulated debris.

## Maintaining Outlet Gates

The simplest procedure to ensure the smooth operation of outlet gates is to operate all gates through their full range at least once and preferably twice annually. In fact, many manufacturers recommend operating gates as often as four times a year. Because operating gates under full lake pressure can result in large outlet discharges, schedule gate testing during periods of low storage. Or during periods of low stream flow. If a large release is expected, coordinate with the local floodplain administrator and other downstream operators. Also notify downstream residents and water users.

If routine inspection of the outlet works indicates the need for maintenance, the work should be completed as soon as access can be gained. Postponing maintenance could result in damage to the installation, significantly reduce the useful life of the structure, and result in more extensive and more costly repairs when finally carried out. More importantly, failure to maintain an outlet system can lead directly to dam failure.

When inspecting/operating outlet gates, it is important to do the following:

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

Note rough, noisy, or erratic movement of the gates. Investigate and correct immediately if a problem is found.

It should not be difficult to raise or lower a gate. Most hoisting mechanisms are designed to operate satisfactorily with a maximum force of 40 pounds on the operating handle or wheel. If it is difficult, something may be binding the mechanical system. Such force may result in additional binding of the gate or damage to the outlet works. If there is undue resistance, the gate should be worked up and down repeatedly in short strokes until the binding ceases or the cause of the problem should be investigated.



To test a valve or gate without lowering the lake, the drain inlet upstream from the valve must be physically blocked. Some drain structures have been designed with this capability and have dual valves or gates, or slots for stoplogs (sometimes called bulkheads) located upstream of the drain valve.

Other problems may be encountered when operating the reservoir drain. Sediment can build up and block the drain inlet. Debris can be carried into the valve chamber, thereby hindering its function if an effective trash rack is not present. The potential that these problems will occur is greatly reduced if the valve or gate is operated and maintained periodically. The best location for drain valves is upstream from the centerline of the dam. Older dams often have drains with valves at the downstream end. This design results in the entire conduit being under the constant pressure of the reservoir when the valve is closed.

If a gate does not properly seal when closed, debris may be lodged under or around the gate leaf or frame. Raise the gate at least two to three inches to flush the debris; then have the operator attempt to reclose the gate. This procedure should be repeated until proper sealing is achieved. However, if this problem or any other problem persists, consult a manufacturer's representative or engineer experienced in gate design and operation.

An outlet gate's operating mechanism should always be well-lubricated in accordance with the manufacturer's specifications. Proper lubrication will not only reduce wear in the mechanism, but also protect it against adverse weather. Gates with oil-filled stems (i.e., stems encased in a larger surrounding pipe) should be checked semiannually to assure the proper oil level is maintained. If such

mechanisms are neglected, water could enter the encasement pipe through the lower oil seal and could cause failure of the upper or lower seals, which in turn could lead to the corrosion of both the gate stem and the interior of the encasement pipe.

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

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

## Electrical Maintenance

Electricity is typically used at a dam for lighting and to operate outlet gates, spillway gates, recording equipment, and other miscellaneous equipment. It is important that an electrical system be well maintained, including a thorough check of fuses and a test of the system to ensure that all parts are properly functioning. The system should be free from moisture and dirt, and wiring should be checked for corrosion and mineral deposits. Carry out any necessary repairs immediately,

and keep records of the work. Maintain generators used for auxiliary emergency power—change the oil, check the batteries and antifreeze and make sure fuel is readily available.

## Cleaning

Regularly clean and remove debris from spillways, sluiceways, approach channels, inlet and outlet structures, stilling basins, discharge conduit, dam slopes, trash racks, and debris-control devices. Cleaning is especially important after upstream storms, which tend to send more debris into the lake.

## Maintaining Concrete

Concrete is most easily repaired in its early stages. Deterioration can accelerate and, if left unattended, can result in serious problems or dam failure. Consult an experienced engineer to determine both the extent of deterioration and the proper method of repair. Seal joints and cracks in concrete structures to avoid damage beneath the concrete.

Knowledge of the locations and change in widths of cracks and joints in concrete dams, in concrete spillways, and other concrete appurtenances of embankment dams are important because of the potential for seepage through those openings. Various crack and joint measuring devices are available, and most allow very accurate measurement.

The measurement of the crack widths and lengths is an indication of the amount of movement. Concrete cracks can be measured with a clear plastic card printed with lines of various thicknesses. Crack movement can be measured with a crack measuring device

which is attached to the concrete structure at the crack. This device gives direct readings of crack displacement and rotation.

## Maintaining Metal Components

All exposed, bare ferrous metal on an outlet installation, whether submerged or exposed to air, will tend to rust. To prevent corrosion, exposed ferrous metals must be either appropriately painted (following the paint manufacturer's directions) or heavily greased. When areas are repainted, ensure that paint does not get on gate seats, wedges, or stems (where they pass through the stem guides), or on other friction surfaces where paint could cause binding. Use heavy grease on surfaces where binding can occur. Because rust is especially damaging to contact surfaces, remove existing rust before the periodic application of grease.

## Vandalism

Vandalism is a common problem for all dam owners. Particularly susceptible to damage are the vegetated surfaces of the embankment, mechanical equipment, manhole covers, and rock riprap. Every precaution should be taken to limit access to the dam by unauthorized persons and vehicles. "No trespassing" signs are commonly used to restrict access.

Dirt bikes (motorcycles), off-road-vehicles, and four-wheel drive vehicles can severely damage the vegetation on embankments. Worn areas can lead to erosion and more serious problems. Constructed barriers such as fences, gates, and cables strung between poles are effective ways to limit access of these vehicles to the dam. A highway metal guardrail constructed immediately adjacent

to the toe of the downstream slope is an excellent means for keeping vehicles off embankments.

Fishing from embankments can also create problems. Fishermen will often build fires which can kill adjacent vegetation. Fishermen also create paths and may tend to kill the vegetation in areas of repeated use.

Mechanical equipment and its associated control mechanisms should be protected. Buildings containing mechanical equipment should be sturdy, have protected windows and heavy-duty doors, and should be secured with dead bolt locks or padlocks.

Detachable controls such as handles and wheels should be removed when not in use and stored inside. Other controls should be secured with locks and heavy chains, where possible. Manhole covers are subject to removal and are often thrown into the lake or spillway by vandals.

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

## Public Safety

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

During high flow conditions areas around spillways can be deceptive to a boater who can quickly get

into trouble. Warning buoys, signs, or cable with warning signs stretched across the stream or above the spillway can be effective in discouraging boaters, but these are often ignored and are difficult to maintain.



REQUIRED MAINTENANCE:											
FEATURE:	Earthwork Maintenance	Riprap Maintenance & Repair	Vegetation Maintenance	Livestock Damage Maintenance	Rodent Damage Maintenance	Traffic Damage Maintenance	Mechanical Maintenance	Electrical Maintenance	Cleaning	Concrete Maintenance	Metal Components Maintenance
<b>Embankment Dam</b>											
Upstream slope	X	X	X	X	X				X		
Downstream slope	X		X	X	X	X					
Left/Right abutments	X	X	X	X	X	X					
Crest	X		X	X	X	X					
Internal drainage system										X	X
Relief drains							X		X	X	X
Riprap & slope protection		X	X	X	X	X				X	
<b>Concrete Dams</b>											
Upstream face									X	X	
Downstream face										X	
Left/Right abutments	X	X	X	X	X	X					
Crests										X	
Internal drainage system											X
Relief drains							X		X		X
Galleries								X		X	
Sluiceways/Controls							X	X	X	X	X
<b>Spillways</b>											
Approach channel	X	X	X	X	X				X	X	
Inlet/Outlet structure							X	X	X	X	X
Stilling basin		X							X	X	
Discharge conduit/channel	X	X	X				X	X	X	X	X
Control features							X	X	X	X	X
Erosion protection	X	X	X	X	X	X				X	
Side slopes	X	X	X	X	X	X				X	
<b>Inlets, Outlets, and Drains</b>											
Inlet & Outlets							X	X	X	X	X
Stilling basin							X	X	X	X	X
Discharge channel		X	X	X	X	X			X	X	
Trash Racks/Debris control							X	X	X		X
Emergency systems											
<b>General Areas</b>											
Reservoir surface									X		
Shoreline		X	X		X				X		
Mechanical systems								X	X		X
Electrical systems								X	X		X
Upstream watershed		X	X						X		
Downstream channel	X	X							X	X	



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