Dam Ownership **Fact Sheets**

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TOPIC:

OWNERSHIP RESPONSIBILITY & LIABILITY

Dams are owned and operated by individuals, private and public organizations, and the government. The responsibility for maintaining a safe dam rests with the owner. A dam failure resulting in an uncontrolled release of the reservoir can have a devastating effect on persons and property downstream. Tens of thousands of public and private dam owners in the United States have exposure to liability for the water stored behind their dams. Safely maintaining a dam is a key element in preventing a failure and limiting the liability that an owner could face.

Public safety around dams is also the responsibility of the owner. Dams can create a hazardous environment and dangerous hydraulic features. Dam owners need to consider issues with accessibility by the public to the dam and the surrounding area.

DAM FAILURE

The failure of a dam has the potential for loss of life and catastrophic impact on communities, private property and public works downstream. The data shows that there are approximately 10 to 20 failures per year involving uncontrolled release of reservoirs. Failure of even small dams can result in serious injuries, fatalities, disruption of business operations, damage to critical infrastructure and other extensive property damage.

"In today's litigious society it is safe to assume that in the case of catastrophic dam failure, extensive litigation will ensue. Any competent lawyer, representing the victims, will sue all possible wrong doers in seeking redress...including...the owners and operators of the facility, and...architects, engineers, contractors, sub-contractors, and consultants involved in the original construction and any subsequent modifications...."

— Denis Binder, Professor of Law, Chapman University

LOSS FROM FAILURE

The cost of dam failure is difficult to assess because flooding can affect large areas, often beyond the floodplain areas where flood insurance is required. The dam owner loses a valuable asset and faces reconstruction costs and possible liability for downstream damages. Local communities may be directly impacted due to building damage, injuries, fatalities, lost water supply, damaged transportation systems and infrastructure, and lost recreational assets.

Common law holds that the storage of water is a hazardous activity.

COMPLIANCE

Compliance with government or professional standards does not absolve an owner from liability, but it does establish a minimum standard of care to be used by owners. The extent of liability in any situation depends on the facts of the case and how those facts are interpreted by a judge or jury.

Consequently, actions that result in owner liability in one state may not result in liability in different states. In general, a dam owner is required to use “reasonable care” in the operation and maintenance of a dam and reservoir.

STRICT LIABILITY AND NEGLIGENCE

The extent of an owner’s liability will vary from state to state, depending on the statutes and case law precedents. The concept of strict liability imposes liability on a dam owner for damages that occur regardless of the cause of failure. The alternative theory of negligence considers the degree of care employed by the owner in constructing, operating and maintaining a dam. Historically, courts have sought to compensate those injured by a dam failure. When assessing liability, the standard of care exercised by an owner will be closely examined. The standard of care should be in proportion to the downstream hazards involved. Where the risk is great, owners must be especially cautious. In many cases, a dam regulated by the federal government or a state dam safety program must be designed to withstand an unprecedented flood or earthquake.

RISK MANAGEMENT

An essential and logical part of an organization’s management program is the control of potential losses that may arise. To manage risks, an owner can utilize a combination of standard operating procedures, employee training, regular maintenance, emergency preparedness and liability insurance.

A dam owner can take several actions to protect against financial loss. Technical guidance and information is available from your state’s Dam Safety office.

Each dam should have:

- A state dam safety permit (if applicable).
- An operation plan, documented regular maintenance plan and emergency action plan.
- Documented periodic inspections.
- Warning signs and controlled access.

RESOURCES

ASDSO Resources
The ASDSO website houses national guidelines on dams. Go to:
DamSafety.Org/ManualsandGuidelines

For more information, videos and tools for dam owners go to:
DamOwner.Org

Access your state’s Dam Safety Program by clicking your state at:
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State Attorney General’s Office
State Office of Emergency Services

Dam Ownership **Fact Sheet**

TOPIC:

HOW TO PROCURE THE SERVICES OF A PROFESSIONAL ENGINEER

DAM MAINTENANCE & OWNER RESPONSIBILITY

The responsibility for maintaining a safe dam rests with its owner. The owner must understand the laws and regulations associated with proper dam maintenance and the procedures for keeping these structures safe. Dam owners are also responsible for maintaining safety at and around their dam. It is important to limit trespassing including considering fencing alternatives along high spillway walls and reducing access around dangerous water hydraulics. Proper operation, maintenance, repair and rehabilitation of a dam are key elements in preventing a failure, limiting your liability and maintaining your water resource. One of the most important procedures for ensuring proper maintenance of the dam is procuring the services of a Professional Engineer. A Professional Engineer is one who has been certified by the state and the industry according to their tested ability, schooling and experience.

WHY DO I NEED AN ENGINEER?

All dams meeting government regulatory definitions – no matter what their size or level of engineering – will deteriorate with time. Periodic inspection, proper maintenance and occasional repair and rehabilitation are inevitable. An owner needs the expertise of an engineer to perform inspections or evaluate and undertake corrective measures at a dam. An engineer can investigate the problem and recommend a course of action which may include the design of corrective measures and the preparation of construction plans and specifications. The engineer also can assist in selecting a contractor and will provide valuable construction inspection services.

QUESTIONS TO ASK WHEN HIRING

It is essential to select someone with a Professional Engineer (P.E.) license, with a background in civil engineering, who is competent and experienced in the field of dam safety.

Important criteria to look for in a prospective engineer include the following:

- ✓ A licensed Professional Engineer in your state;
- ✓ A minimum of 10 years of experience in dam design, maintenance, safety and construction;
- ✓ A knowledge of the rules and regulations governing dam design and construction in the state where the dam is located;
- ✓ Specific experience in the problem area—hydrology, hydraulics, structural, soils, seismic, seepage, and geotechnical engineering.

HOW DO I CHOOSE AN ENGINEER WHO IS BEST FOR MY NEEDS?

It is important to use the *Qualification-Based* approach to selecting an engineer. *Qualification-Based* means that the knowledge, experience and ingenuity of the engineer are the determining factors in making the selection. This strategy is advantageous when the owner is uncertain about the exact problem or the best solution to the problem. When *Qualification-Based* selection is used, several engineering firms submit their technical qualifications, experience with similar projects, reputation with existing clients and any other factors pertaining to the specific project. The owner then selects the three to five most qualified firms to make brief presentations outlining a cost-effective and innovative approach to the problem. Based upon these presentations, the owner chooses the most qualified engineer to develop a scope of work. When agreement on the scope of work is achieved, the engineer and the owner negotiate a price that is fair and reasonable to both parties. If an agreement cannot be reached, negotiations start with the second-ranked engineer. In this selection process, price is a factor, but only after the most qualified engineer has been identified.

Fee-Based selection means the engineer's fee is the only determining factor in making the selection. This is not the recommended selection procedure. It is only advantageous when the owner, in conjunction with their State Dam Safety Program, knows exactly what is needed and can clearly define the scope of work before meeting with an engineer. In this case, the engineer is requested to prepare the designs and bid documents or conduct investigations as the owner specifies. A strict *Fee-Based* selection often means the engineer selected may not be qualified to do the work, especially if the bidding is open to anyone and/or the scope of work is poorly defined.

Carefully consider your selection of an engineer. A little work on your part in selecting the engineer may save you money in the future.

FOR YOUR CONSIDERATION

Request references and a portfolio from the engineer. Contact the references of owners and contractors to discuss the engineer's performance. Look at projects that have been completed under the engineer's leadership. Request to review state files of projects an engineer has undertaken to see if the process went smoothly. Maintain an open line of communication with regulatory agencies, particularly your State Dam Safety Program. They may be unable to recommend one engineer over another but they can give an assessment of their previous work. Discuss an engineer's recommended course of action to verify that regulatory requirements will be satisfied. Educate yourself in the basics of dam safety and be knowledgeable regarding the laws you must meet.

RESOURCES

ASDSO Resources

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Dam Ownership **Fact Sheet**

TOPIC:
EMERGENCY ACTION PLANNING

Emergency Action Plans Help Dam Owners as Well As People Downstream.

WHAT IS AN EMERGENCY ACTION PLAN?
An Emergency Action Plan (EAP) is a written document that identifies incidents that can lead to potential emergency conditions at a dam, identifies the areas that can be affected by the loss of reservoir and specifies pre-planned actions to be followed to minimize property damage, potential loss of infrastructure and water resource and potential loss of life because of failure or mis-operation of a dam.

The dam owner is responsible for development, maintenance, and exercise of the EAP; however, there are guidelines, tools and assistance available to help owners. City, county and state emergency management directors and state dam safety officials stand ready to partner with dam owners to create and exercise EAPs. An owner can tap into this technical and emergency management expertise and can get additional support by using state and national educational materials, EAP forms and examples, and step-by-step guidelines.

An EAP takes time, focus and dedication. The time is now. The focus is on saving lives. The dedication is to public safety.

The dam owner initiates the EAP process and both emergency responders and owners will be users of the EAP. The completed document should have had input from emergency managers, state dam safety officials, leaders of downstream communities and, directly or indirectly, everyone who may be responsible for the proper implementation of the EAP. It is important that the dam owner stays involved throughout the entire process.

Emergency Action Plans are a public safety benefit for all citizens.

KEY POINTS ABOUT EAPS

- An EAP must clearly specify the dam owner's responsibilities to ensure timely and effective action. Responsibilities of dam owners include: surveillance (monitoring the condition of the dam) and notification (phoning local or state emergency management agency officials in charge of emergency response).
- EAPs are developed by dam owners working with local emergency response managers, dam safety engineers, and state dam safety officials.
- Inundation maps are a key component of the EAP. Inundation maps show areas that may have to be evacuated in a dam emergency. The maps facilitate notification by displaying flood areas and estimated travel times for the floodwaters. New, two-dimensional technologies are available to create inundation maps of areas below dams.
- Dam owners and local emergency responders are primary users of EAPs. A Standard Operating Plan (SOP) is a related document that outlines the normal, non-emergency operation of a dam and is a document for the dam owner and his staff and not a public emergency document.
- Public awareness is a critical component of emergency planning. Many people do not know they may live or work near a dam. Public awareness of an EAP will enhance its effective implementation.
- The EAP defines events that trigger emergency actions.
- An EAP includes a notification flowchart with names and numbers of who will call whom and in what priority.
- Emergency events at dams are infrequent. Training and exercises of EAPs help maintain readiness.
- EAPs should be updated at least once per year and following any changes or new information such as changes in downstream development or new contact information. EAPs should be exercised at least every five years.

DAM OWNER RESPONSIBILITIES

All potentially hazardous dams benefit from some type of an Emergency Action Plan. Obviously dams with a potential for loss of life or damage to infrastructure or high value property in the event of failure (typically identified by regulators as High-Hazard Potential) would be a higher priority and would require a more sophisticated and detailed plan. The regulatory agency responsible for dam safety will probably have criteria for the type and detail of EAP required and the required priority if major repairs are also needed (in many states, dam owners are legally obligated to provide EAPs for certain dam hazards). Regardless of the requirement for a recorded or documented EAP by the Dam Safety Regulatory Program, every dam owner is strongly encouraged to develop some type of EAP that can be used to implement emergency action response in the event of a dam incident.

Regardless of state or federal regulatory requirements, dam owners are responsible and liable for dam operations and any related incidents. EAPs can actually limit a dam owner's liability in the field and in the courtroom because it shows the proper diligence and reasonable actions expected by the law and the dam industry.

Time and effort must be devoted to creating an EAP, filing it appropriately with state and local officials, updating plan details, testing the plan's assumptions and functionality, and following its procedures in an emergency. Completion of an EAP demonstrates that a dam owner is actively attempting to prevent and mitigate harm to persons and property.

HOW TO GET STARTED

Contact your state dam safety regulatory office and your consulting engineer.

You can locate your state's office by visiting the ASDSO website (www.damsafety.org/states). ASDSO can point you toward its industry membership to assist in locating a consulting engineer.

Contact the state and local emergency management coordinator.

The primary means of notification to the public is the National Weather Service (NWS). The NWS has the Congressional mandate for issuing flood warnings, which include dam failure. The NWS has a well-established warning infrastructure that includes access to the Emergency Alert System, Weather Radio network, and Internet-based mechanisms.

Know your:
State Dam Safety Officials &
State and Local Emergency
Management Coordinator

TYPICAL EAP COMPONENTS

- Basic Dam Characteristics
- EAP Plan Overview
- Roles & Responsibilities
- Event Detection
- Emergency Level Determination
- Notification & Communication Flowcharts
- Expected Actions
- Termination
- EAP Maintenance Plan (Review, Exercise & Update)
- Appendices including Inundation Maps for Evacuations

WHO IS RESPONSIBLE?

Dam Owners/Operators

- Identification of emergency at dam
- Initial notifications
- Implementation of repairs
- Security and technical assistance on site

Local Emergency Management and Responders

- Public warning
- Possible evacuation
- Shelter plan activated
- Rescue and recovery
- State of Emergency declaration
- Termination of emergency status

State Emergency Management

- Aid affected area when requested
- Coordinate specialized assistance
- Notify appropriate state agencies
- Determine who does what in an emergency

RESOURCES

ASDSO Resources

The ASDSO website houses the national guidelines on EAP development. Go to DamSafety.Org/ManualsandGuidelines

For more information, videos and tools for dam owners go to: DamOwner.Org

Watch for training in your area sponsored by ASDSO or your State Dam Safety Office.

DHS/FEMA Resources

DHS and FEMA make several publications and videos available to dam owners through FEMA.gov and DHS.gov (search "dam safety")

Dam Ownership **Fact Sheet**

TOPIC:
EARTH DAM FAILURES

Owners of dams, operating personnel, and maintenance personnel must be knowledgeable of the potential problems which can lead to dam failure. These people regularly view the structure and, therefore, need to be able to recognize potential problems so that failure can be avoided. If a problem is noted early enough, an engineer experienced in dam design, construction, and inspection can be contacted to recommend corrective measures, and such measures can be implemented.

IF THERE IS ANY QUESTION AS TO THE SERIOUSNESS OF AN OBSERVATION, AN ENGINEER EXPERIENCED WITH DAMS SHOULD BE CONTACTED.

Acting promptly may avoid possible dam failure and the resulting catastrophic effect on downstream areas.

Since only superficial inspections of a dam can usually be made, it is imperative that owners and maintenance personnel be aware of the prominent types of failure and their telltale signs. Earth dam failures can be grouped into three general categories: overtopping failures, seepage failures, and structural failures. A brief discussion of each type follows.

OVERTOPPING FAILURES

Overtopping failures result from the erosive action of water on the embankment. Erosion is due to uncontrolled flow of water over, around, and adjacent to the dam. Earth embankments are not designed to be overtopped and therefore are particularly susceptible to erosion. Once erosion has begun during overtopping, it is almost impossible to stop. A well vegetated earth embankment may withstand limited overtopping if the dam's crest is level, the downstream slope of the dam is uniform with a consistent slope gradient, and there are no bare areas or undulations along the surface of the dam. The owner should closely monitor the reservoir pool level during severe storms.

SEEPAGE FAILURES

All earth dams leak to some extent and this is known as seepage. This is the result of water moving slowly through the embankment and/or percolating slowly through the dam's foundation. This is normal and usually not a problem with most earthen dams if measures are taken to control movement of water through and under the dam. If uncontrolled, seepage can progressively erode soil from the embankment or its foundation, resulting in failure of the dam. Typically, erosion of embankment soil begins at the downstream side of the dam and progressively works toward the reservoir eventually developing a path to the reservoir which is referred to as "piping." Piping action can be recognized by an increased seepage flow rate, the discharge of muddy or discolored water, sinkholes on or near the embankment, and possibly a whirlpool at the surface of the reservoir. Once a whirlpool (eddy) is observed, failure of the dam may follow. As with overtopping, fully developed piping is virtually impossible to control and will likely cause failure.

Seepage can also cause dam failure by saturating the embankment, thus weakening the dam, or by increasing internal pressure within the embankment. Saturation and internal pressure within the dam are difficult to determine without proper instrumentation.

STRUCTURAL FAILURES

Structural failure typically refers to the collapse of non-earthen embankment dams such as those made from concrete, masonry, or other materials not consisting of a soil matrix. In addition, failure of a dam's appurtenant structures such as a concrete chute spillway slab, gate structures and components, or other such features may lead to failure of the dam itself. Earthen dams do not tend to collapse or fail catastrophically on their own except where earthquakes of significant magnitude are prevalent or other erosive forces weaken the structure. Large cracks in an earthen embankment, major settlement, and major slides may require emergency measures to ensure safety, especially if these problems occur suddenly. If this type of situation occurs, the lake level should be lowered, the appropriate state and local authorities notified, and professional advice sought. If the observer is uncertain as to the seriousness of the problem, a qualified professional engineer with experience in dam safety should be contacted immediately.

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

Minor defects such as cracks in the embankment may be the first visual sign of a major problem which could lead to failure of the structure. The seriousness of all deficiencies should be evaluated by someone experienced in dam design and construction. A qualified professional engineer can recommend appropriate permanent remedial measures.

RESOURCES

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TOPIC:
EMBANKMENT INSTABILITIES

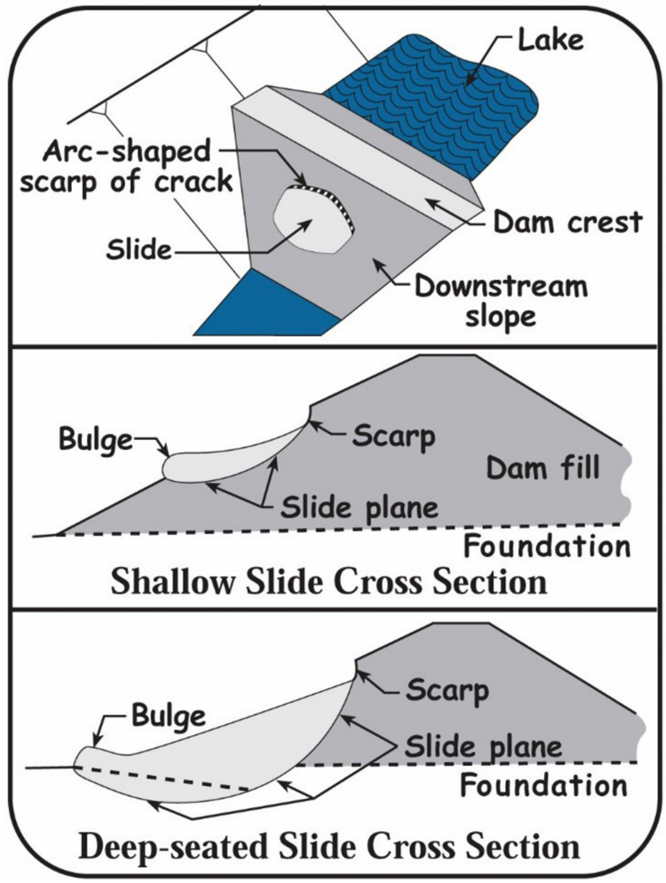
The dam embankment and any appurtenant dikes must safely contain the reservoir during normal and flood conditions. Cracks, slides, and depressions are signs of embankment instability and should indicate to the owner that maintenance or repair work may be required. When one of these conditions is detected, the owner must retain an experienced professional engineer to determine the cause of the instability. A rapidly changing condition or the sudden development of a large crack, slide, or depression indicates a very serious problem, and the state dam safety agency should be contacted immediately. A professional engineer must investigate these types of embankment stability problems because a so-called “home remedy” may cause greater and more serious damage to the embankment and eventually result in unneeded expenditures for unsuccessful repairs.

CRACKS

Short, isolated cracks are commonly due to drying and shrinkage of the embankment surface and are not usually significant. They are usually less than 1 inch wide, propagate in various directions, and occur especially where the embankment lacks a healthy grass cover. Larger (wider than 1 inch), well-defined cracks may indicate a more serious problem. There are generally two types of these cracks: longitudinal and transverse. Longitudinal cracks extend parallel to the crest of the embankment and may indicate the early stages of a slide on either the upstream or downstream slope of the embankment. They can create problems by allowing runoff to enter the cracks and saturate the embankment which in turn can cause instability of the embankment. Transverse cracks extend perpendicular to the crest and can indicate differential settlement within the embankment. Such cracks provide avenues for seepage through the dam and could quickly lead to piping, a severe seepage problem that will likely cause the dam to fail. If the owner finds small cracks during inspection of the dam, they should document the observations, and seal the cracks to prevent runoff from saturating the embankment. The documentation should consist of detailed notes (including the location, length, approximate elevation, and crack width), photographs, sketches, and possibly monitoring stakes. The crack must then be monitored during future inspections. If the crack becomes longer or wider, a more serious problem such as a slide may be developing. Large cracks indicate serious stability problems. If one is detected, the owner should contact the state dam safety agency and retain an engineer to investigate the crack and prepare plans and specifications, if necessary, for repairs. When muddy flow discharges from a crack, the dam may be close to failure. The emergency action plan should be initiated immediately and the state dam safety agency contacted.

SLIDES

A slide in an embankment or in natural soil or rock is a mass movement of material. Some typical characteristics of a slide are an arc-shaped crack or scarp along the top and a bulge along the bottom of the slide (see drawing). Slides may develop because of poor soil compaction, the gradient of the slope being too steep for the embankment material, seepage, sudden drawdown of the lake level, undercutting of the embankment toe, or saturation and weakening of the embankment or foundation.



Slides can be divided into two main groups: shallow and deep-seated. Shallow slides generally affect the top 2 to 3 feet of the embankment surface. Shallow slides are generally not threatening to the immediate safety of the dam and often result from wave erosion, collapsed rodent burrows, or saturated top soil. Deep-seated slides are serious, immediate threats to the safety of a dam. They can extend several feet below the surface of the embankment, even below the foundation. A massive slide can initiate the catastrophic failure of a dam. Deep-seated slides are the result of serious problems within the embankment.

Small slides can be repaired by removing the vegetation and any unsuitable fill from the area, compacting suitable fill and adding topsoil to make the embankment uniform, and establishing a healthy grass cover. If a shallow or deep-seated slide is discovered, the state dam safety agency should be contacted and an engineer retained to investigate the slide. Plans and specifications may need to be prepared for its repair depending on the findings of the investigation.

DEPRESSIONS

Depressions are sunken areas of the abutment, toe area, or embankment surface. They may be created during construction, or may be caused by decay of buried organic materials, thawing of frozen embankment material, internal erosion of the embankment, or settlement (consolidation) of the embankment or its foundation. To a certain degree, minor depressions are common and do not necessarily indicate a serious problem. An embankment with several minor depressions may be described as hummocky. However, larger depressions may indicate serious problems such as weak foundation materials, poor compaction of the embankment during construction, or internal erosion of the embankment fill.

Depressions can create low areas along the crest, cracks through the embankment, structural damage to spillways or other appurtenant structures, damage to internal drainage systems, or general instability of the embankment. They can also inhibit maintenance of the dam and make detection of stability or seepage problems difficult. The owner should monitor depressions during the regular inspection of the dam. All observations should be documented with detailed notes, photographs, and sketches. Minor depressions can be repaired by removing the vegetation and any unsuitable fill from the area, adding fill and then topsoil to make the embankment uniform, and finally establishing a healthy grass cover. An engineer should be retained to investigate large depressions or settlement areas. Plans and specifications may need to be prepared for its repair depending on the findings of the investigation.

IMPORTANCE OF INSPECTION

Stability problems can threaten the safety of the dam and the safety of people and property downstream. Therefore, stability problems must be detected and repaired in a timely manner. The entire embankment should be routinely and closely inspected for cracks, slides, and depressions. To do this thoroughly, proper vegetation must be regularly maintained on the embankment. Improper or overgrown vegetation can inhibit visual inspection and maintenance of the dam. Accurate inspection records are also needed to detect stability problems. These records can help determine if a condition is new, slowly changing, or rapidly changing. A rapidly changing condition or the sudden development of a large crack, slide, or depression indicates a very serious problem, and the state dam safety agency should be contacted immediately.

RESOURCES

ASDSO Resources
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TOPIC:

SEEPAGE THROUGH EARTHEN DAMS

Areas downstream from dams are not usually natural springs, but most likely seepage exiting from the dam's embankment. Even if natural springs exist, they should be treated with suspicion and carefully observed. Flows from ground-water springs in existence prior to the reservoir would probably increase due to the pressure caused by the pool of water behind the dam.

All dams have some seepage as the impounded water seeks paths of least resistance through the dam and its foundation. Seepage must, however, be controlled to prevent erosion of the embankment or foundation materials or damage to concrete structures.

DETECTION

Seepage can emerge anywhere on the downstream face, beyond the toe, or on the downstream abutments at elevations below normal pool. Seepage may vary in appearance from a "soft," wet area to a flowing "spring." It may show up first as an area where the vegetation is lush and darker green. Cattails, reeds, mosses, and other marsh vegetation often become established in a seepage area. Another indication of seepage is the presence of rust-colored iron bacteria. Due to their nature, the bacteria are found more often where water is discharging from the ground than in surface water. Seepage can make inspection and maintenance difficult. It can also saturate and weaken portions of the embankment and foundation, making the embankment susceptible to earth slides.

If the seepage forces are large enough, soil will be eroded from the foundation and be deposited in the shape of a cone around the seepage outlet. If these "boils" appear, professional advice should be sought immediately. Seepage flow which is muddy and carrying sediment (soil particles) is evidence of "piping," and could very possibly cause failure of the dam. Piping can occur along a spillway and other conduits through the embankment, and these areas should be closely inspected. Sinkholes may develop on the surface of the embankment as internal erosion takes place. A whirlpool in the lake surface may follow and then likely a rapid and complete failure of the dam. Emergency procedures, including downstream evacuation, should be implemented if this condition is noted.

Seepage can also develop behind or beneath concrete structures such as chute spillways or headwalls. If the concrete structure does not have a means such as weep holes or relief drains to relieve the water pressure, the concrete structure may heave, rotate, or crack. The effects of the freezing and thawing can amplify these problems. It should be noted that the water pressure behind or beneath structures may also be due to infiltration of surface water or spillway discharge.

A continuous or sudden drop in the normal lake level is another indication that seepage is occurring. In this case, one or more locations of flowing water are usually noted downstream from the dam. This condition, in itself, may not be a serious problem, but will require frequent and close monitoring and professional assistance.

CONTROL

The need for seepage control will depend on the quantity, content, and location of the seepage. Reducing the quantity of seepage that occurs after construction is difficult and expensive. It is not usually attempted unless the seepage has lowered the pool level or is endangering the embankment or appurtenant structures. Typical methods used to control the quantity of seepage are grouting or installation of an upstream blanket. Of these methods, grouting is probably the least effective and is most applicable to leakage zones in bedrock, abutments, and foundations. These methods must be designed and constructed under the supervision of a qualified professional engineer experienced with dams. Controlling the volume of the seepage or preventing seepage flow from removing soil particles from the embankment is extremely important. Modern design practice incorporates this control into the embankment through the use of cutoffs, internal filters, and adequate drainage provisions. Control at points of seepage exit can be accomplished after construction by installation of toe drains, relief wells, or inverted filters. Weep holes and relief drains can be installed to relieve water pressure or drain seepage from behind or beneath concrete structures. These systems must be designed to prevent migration of soil particles but still allow the seepage to drain freely. The owner must retain a professional engineer to design toe drains, relief wells, inverted filters, weep holes, or relief holes.

MONITORING

Regular monitoring is essential to detect seepage and prevent a potential dam failure. Knowledge of the dam's history is important to determine whether the seepage condition is in a steady or changing state. It is important to keep written records of points of seepage exit, quantity and content of flow, size of wet area, and type of vegetation for later comparison. Photographs provide invaluable records of seepage.

All records should be kept in the operation, maintenance, and inspection manual for the dam. The inspector should always look for increases in flow and evidence of flow carrying soil particles, which would indicate that a more serious problem is developing. Instrumentation can also be used to monitor seepage. V-notch weirs can be used to measure flow rates, and piezometers may be used to determine the saturation level (phreatic surface) within the embankment.

Regular surveillance and maintenance of internal embankment and foundation drainage outlets is also required. The rate and content of flow from each pipe outlet for toe drains, relief wells, weep holes, and relief drains should be monitored and documented regularly. Normal maintenance consists of removing all obstructions from the pipe to allow for free drainage of water from the pipe. Typical obstructions include debris, gravel, sediment, and rodent nests. Water should not be permitted to submerge the pipe outlets for extended periods of time. This will inhibit inspection and maintenance of the drains and may cause them to clog.

RESOURCES

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TOPIC:

INTERNAL EROSION OF EARTH DAMS

WHAT IS INTERNAL EROSION?

Internal erosion (called "piping" by dam engineers) of an earth dam takes place when water that seeps through the dam carries soil particles away from the embankment, filters, drains, foundation or abutments of the dam.

If the seepage that discharges at the downstream side of the dam carries particles of soil, an elongated cavity or "pipe" may be eroded backward (working upstream) toward the reservoir through the embankment, foundation or abutment. When a backward-eroding pipe reaches the reservoir, a catastrophic breaching of the dam can occur. Internal erosion usually takes place in episodes of erosion and discharge of muddy water interspersed with periods of clear-water discharge or no discharge at all depending on head and flow. Internal erosion may be taking place even if there is no visible discharge of water or if the water that is discharging from the soil on the downstream side of a dam is not muddy. Chemicals, salts, dissolved and suspended solids and dispersive clays can also erode unnoticed from the inside of a dam. The only way to monitor this, in the absence of visible erosion or sand boil deposits, is to send samples to a lab for testing.

Failure at a dam caused by internal erosion of the soil abutment.

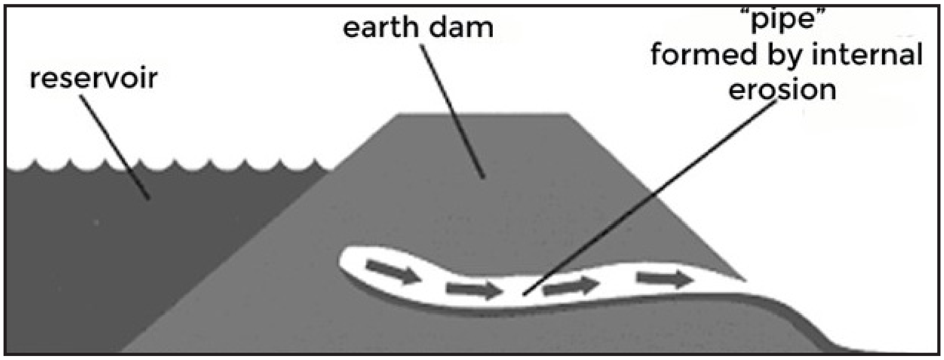

Illustration of internal erosion (piping) in an earth dam embankment.

INTERNAL EROSION BASICS

Internal erosion is one of the most common causes of failure of earth dams.

There may be no external evidence, or only subtle evidence, that it is taking place.

A dam may breach within a few hours after evidence of the internal erosion becomes obvious. Internal erosion may develop the first time water is impounded behind a dam, or it may develop slowly over many years.

Higher water surface elevations and pressure may exacerbate or initiate internal erosion.

You cannot assume that your dam is safe against internal erosion just because it has performed satisfactorily for many years.

Internal erosion failures are often associated with “penetrations” of dams, such as outlet pipes buried in the embankment, rodent activity, and concrete spillways that cross the embankment.

An experienced dam engineer may be able to detect the subtle signs of internal erosion during routine periodic inspections, but you should be aware of what signs to look for between inspections.

If you do observe signs of internal erosion, you should get help from an experienced dam engineer.

Above: Seepage that developed where the root ball of a tree pulled out of the ground near the downstream toe of the dam.

Above: Sinkhole on the crest of an earth dam. The reservoir was lowered and a cavity was found under the sinkhole.

Above: Corroded corrugated-metal outlet pipe removed from a dam that had developed large sinkhole.

Left: Failure of an earth dam by internal erosion along concrete outlet pipe.

SIGNS OF A DEVELOPING SITUATION

What to Look For:

- ✓ Water discharging on the downstream slope of an earth dam or within a few hundred feet downstream from the dam. Look for any accumulation of sediment downstream from the discharge.
- ✓ Water flowing along the outside of a pipe, concrete spillway, or other structure that penetrates the embankment.
- ✓ Water discharging near the roots of a living or dead tree.
- ✓ Corrosion or deterioration of the visible portion of a low-level outlet pipe or other structure that penetrates the embankment.
- ✓ Trees that are uprooted on the embankment or abutments or in the valley bottom immediately downstream from the dam.
- ✓ Water emanating from animal borrows.
- ✓ Dead trees (the rotting roots of which may become avenues of internal erosion) on the embankment or abutments or in the valley bottom immediately downstream from the embankment.

WHAT TO DO

As soon as possible, contact your qualified Professional Engineer or dam safety consultant to inspect the dam and then call your state dam safety engineer.

Research the history of seepage in previous dam inspection and monitoring reports. Look for changes of flow quality and quantity.

SIGNS OF IMMINENT DANGER

What to Look For:

- ✓ Muddy water or large flow of clear water discharging (1) from soil anywhere on the downstream side of the dam, (2) next to a spillway, pipe or other structure that penetrates the embankment or abutments, or (3) from drain pipes in the embankment. Muddy water discharging from the downstream side of a dam or from a drain or low-level outlet pipe, which may indicate that the dam is failing.
- ✓ Sinkholes or subsidence anywhere on the embankment or an abutment. Water flowing into a sinkhole below the reservoir surface on the upstream slope of a dam is especially dangerous.

WHAT TO DO

Immediately call your emergency management, public safety officials or 911 for imminent dangers.

Activate your Emergency Action Plan and call your engineer and the State Dam Safety Program.

RESOURCES

All guidelines and tools for owners are available at the ASDSO website for owners: ***DamOwner.org***

To view an animation of a piping failure, go to ASDSO's YouTube site.

Dam Ownership **Fact Sheet**

TOPIC:

GROUND COVER

The establishment and control of proper vegetation are an important part of dam maintenance. Properly maintained vegetation can help prevent erosion of embankment and earth channel surfaces, and aid in the control of groundhogs and muskrats. The uncontrolled growth of vegetation can damage embankments and concrete structures and make close inspection difficult. Grass vegetation is an effective and inexpensive way to prevent erosion of embankment surfaces. If properly maintained, it also enhances the appearance of the dam and provides a surface that can be easily inspected. Roots and stems tend to trap fine sand and soil particles, forming an erosion-resistant layer once the plants are well established.

Grass vegetation may not be effective in areas of concentrated runoff, such as at the contact of the embankment and abutments, or in areas subjected to wave action.

COMMON PROBLEMS

Bare Areas

Bare areas on an embankment are void of protective cover (e.g. grass, asphalt, riprap etc.). They are more susceptible to erosion which can lead to localized stability problems such as small slides and sloughs. Bare areas must be repaired by establishing a proper grass cover or by installing other protective cover. If using grass, the topsoil must be prepared with fertilizer and then scarified before sowing seed. Types of grass vegetation that have been used on dams are bluegrass, fescue, ryegrass, alfalfa, clover, and redtop. One suggested seed mixture is 30% Kentucky Bluegrass, 60% Kentucky 31 Fescue, and 10% Perennial Ryegrass. Once the seed is sown, the area should be mulched and watered regularly.

Erosion

Embankment slopes are normally designed and constructed so that the surface runoff will be spread out in a thin layer as “sheet flow” over the grass cover. When the sod is in poor condition or flow is concentrated at one or more locations, the resulting erosion will leave rills and gullies in the embankment slope. The erosion will cause loss of material and make maintenance of the embankment difficult. Prompt repair of the erosion is required to prevent more serious damage to the embankment. If erosion gullies are extensive, a registered professional engineer may be required to design a more rigid repair such as riprap or concrete. Minor rills and gullies can be repaired by filling them with compacted cohesive material. Topsoil should be a minimum of 4 inches deep. The area should then be seeded and mulched. Not only should the eroded areas be repaired, but the cause of the erosion should be addressed to prevent a continued maintenance problem.

Footpaths

Paths from animal and pedestrian traffic are problems common to many embankments. If a path has become established, vegetation in this area will not provide adequate protection and a more durable cover will be required unless the traffic is eliminated. Gravel, asphalt, and concrete have been used effectively to cover footpaths. Embedding railroad ties or other treated wood beams into an embankment slope to form steps is one of the most successful and inexpensive methods used to provide a protected pathway.

Vehicle Ruts

Vehicle ruts can also be a problem on the embankment. Vehicular traffic on the dam should be discouraged especially during wet conditions except when necessary. Water collected in ruts may cause localized saturation, thereby weakening the embankment. Vehicles can also severely damage the vegetation on embankments. Worn areas could lead to erosion and more serious problems. Ruts that develop in the crest should be repaired by grading to direct all surface drainage into the impoundment. Bare and eroded areas should be repaired using the methods mentioned in the above sections. Constructed barriers such as fences and gates are effective ways to limit access of vehicles.

Improper Vegetation

Vegetation that hides the embankment surface, preventing early detection of cracks and erosion, is not recommended. Crown vetch is an example of this type of vegetation. It is a perennial plant with small pink flowers. It is also not effective in preventing erosion.

Vines and woody vegetation such as trees and brush also hide the embankment surface preventing early detection of cracks and erosion. Tall vegetation also provides a habitat for burrowing animals.

All improper vegetation must be removed from the entire embankment surface. Any residual roots that are larger than 3 inches in diameter must be removed. All roots should be removed down to a depth of at least 6 inches and replaced with a compacted clay material; then 4 inches of topsoil should be placed on the disturbed areas of the slope. Finally, these areas must be seeded and mulched to establish a proper grass cover.

MAINTENANCE

Embankments, areas adjacent to spillway structures, vegetated channels, and other areas associated with a dam require continual maintenance of the vegetal cover. Removal of improper vegetation is necessary for the proper maintenance of a dam, dike or levee. All embankment slopes and vegetated earth spillways should be mowed at least twice a year. Reasons for proper maintenance of the vegetal cover include unobstructed viewing during inspection, maintenance of a non-erodible surface, discouragement of burrowing animal habitation, and aesthetics. Common methods for control of vegetation include the use of weed trimmers or power brush-cutters and mowers. Chemical spraying to kill small trees and brush is acceptable if precautions are taken to protect the local environment. Some chemical spraying may require proper training prior to application.

RESOURCES

ASDSO Resources

The ASDSO website houses national guidelines on dams. Go to: *DamSafety.Org/ManualsandGuidelines*

For more information, videos and tools for dam owners go to: *DamOwner.Org*

Watch for training in your area sponsored by ASDSO or your State Dam Safety Office.

Access your state's Dam Safety Program by clicking your state at: *DamSafety.Org/States*

Dam Ownership **Fact Sheet**

TOPIC:

TREES AND BRUSH

The establishment and control of proper vegetation is an important part of dam maintenance. Properly maintained vegetation can help prevent erosion of embankment and earth channel surfaces and aid in the control of groundhogs and muskrats. The uncontrolled growth of vegetation can damage embankments and concrete structures and make close inspection difficult.

TREES AND BRUSH

Trees and brush should not be permitted on embankment surfaces or in vegetated earth spillways. Extensive root systems can provide seepage paths for water. Trees that blow down or fall over can leave large holes in the embankment surface that will weaken the embankment and can lead to increased erosion. Brush obscures the surface limiting visual inspection, providing a haven for burrowing animals, and inhibiting the growth of grass vegetation. Tree and brush growth adjacent to concrete walls and structures may eventually cause damage to the concrete and should be removed.

STUMP REMOVAL & SPROUT PREVENTION

Stumps of cut trees should be removed so vegetation can be established and the surface mowed. Small stumps may be entirely removed if removal does not require extensive excavation into the embankment which could compromise the structural integrity of the dam. If the stump is of sufficient size where complete removal would require significant excavation into the embankment, then the stump should be ground down to about 6 inches below the surface. All other woody material should also be removed or ground down to about 6 inches below the ground surface. The cavity should be filled with well-compacted clay soil with a surface dressing of top soil to promote a vigorous grass cover.

Stumps of trees in riprap should be cut as close to the rock layer as possible and then chemically treated so they will not form new sprouts. Certain herbicides are effective for this purpose and can even be used at water supply reservoirs if applied by licensed personnel. These products should be applied in strict coherence with local and state herbicide regulations. Other instructions found on the label should be strictly followed when handling and applying these materials. Only a few commercially available chemicals can be used along shorelines or near water.

Tree roots growing into the dam's earth embankment causing failure.

EMBANKMENT MAINTENANCE

Embankments, areas adjacent to spillway structures, vegetated channels, and other areas associated with a dam require continual maintenance of the vegetal cover. Grass mowing, brush cutting, and removal of woody vegetation (including trees) are necessary for the proper maintenance of a dam, dike, or levee. All embankment slopes and vegetated earth spillways should be mowed at least twice per year: once in the late spring and then during fall when the growing season subsides. Aesthetics, unobstructed viewing during inspections, maintenance of a non-erodible surface, and discouragement of burrowing animal habitation are reasons for proper maintenance of the vegetal cover.

Methods used in the past for control of vegetation but now are considered unacceptable include chemical spraying and burning. Acceptable methods include the use of weed whips or power brush-cutters and mowers. Chemical spraying to first kill small trees and brush is acceptable if precautions are taken to protect the local environment.

It is important to remember not to mow when the embankment is wet. It is also important to use proper equipment for the slope and type of vegetation to be cut. Also, always follow the manufacturer's recommended safe operation procedures.

Slope Mower

Properly maintained embankment.

RESOURCES

ASDSO Resources

The ASDSO website houses national guidelines on plant impacts on dams.
DamSafety.Org/ManualsandGuidelines

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DamSafety.Org/States

DHS / FEMA Resources

DHS and FEMA make several publications and videos available to dam owners through:
FEMA.gov and *DHS.gov*
(search "dam safety")

TOPIC:

RODENT CONTROLS

Rodents such as the groundhog (woodchuck), muskrat, and beaver are attracted to dams and reservoirs, and can be quite dangerous to the structural integrity and proper performance of the embankment and spillway. Groundhog and muskrat burrows weaken the embankment and can serve as pathways for seepage. Beavers are attracted to running water and may try to plug the spillway and raise the pool level. Rodent control or eradication is essential in preserving a well-maintained dam.

GROUNDHOG

The groundhog is the largest member of the squirrel family. Its coarse fur is a grizzled grayish brown with a reddish cast. Typical foods include grasses, clover, alfalfa, soybeans, peas, lettuce, and apples. Breeding takes place during early spring (beginning at the age of one year) with an average of four or five young per litter, one litter per year. The average life expectancy is two or three years with a maximum of six years.

Occupied groundhog burrows are easily recognized in the spring due to the groundhog's habit of keeping the burrow "cleaned out." Fresh dirt is generally found at the mouth of active burrows. Half-round mounds, paths leading from the den to nearby fields, and clawed or girdled trees and shrubs also help identify inhabited burrows and dens.

When burrowing into an embankment, groundhogs stay above the phreatic surface (upper surface of seepage or saturation) to stay dry. The burrow is rarely a single tunnel. It is usually forked, with more than one entrance and with several side passages or rooms from 1 to 12 feet long.

GROUNDHOG CONTROL

Control methods should be implemented during early spring when active burrows are easy to find, young groundhogs have not scattered, and there is less likelihood of damage to other wildlife. In later summer, fall, and winter, game animals will scurry into groundhog burrows for brief protection and may even take up permanent abode during the period of groundhog hibernation. Groundhogs can be controlled by using fumigants or by shooting. Fumigation is the most practical method of controlling groundhogs. Around buildings or other high fire hazard areas, shooting may be preferable. Groundhogs will be discouraged from inhabiting the embankment if the vegetal cover is kept mowed.

Gas cartridges may be purchased at garden supply and hardware stores. Information about the use and availability of gas cartridges may be obtained from county extension offices, or the U.S. Department of Agriculture.

MUSKRAT

The muskrat is a stocky rodent with a broad head, short legs, small eyes, and rich dark brown fur. Muskrats are chiefly nocturnal. Their principal food includes stems, roots, bulbs, and foliage of aquatic plants. They also feed on snails, mussels, crustaceans, insects, and fish. Usually three to five litters, averaging six to eight young per litter, are produced each year. Adult muskrats average one foot in length and three pounds in weight. The life expectancy is less than two years, with a maximum of four years.

Muskrats can be found wherever there are marshes, swamps, ponds, lakes and streams having calm or very slowly moving water with vegetation in the water and along the banks. Muskrats make their homes by burrowing into the banks of lakes and streams or by building “houses” of bushes and other plants. Their burrows begin from 6 to 18 inches below the water surface and penetrate the embankment on an upward slant. At distances up to 15 feet from the entrance, a dry chamber is hollowed out above the water level. Once a muskrat den is occupied, a rise in the water level will cause the muskrat to dig farther and higher to excavate a new dry chamber. Damage (and the potential for problems) is compounded where groundhogs or other burrowing animals construct their dens in the embankment opposite muskrat dens.

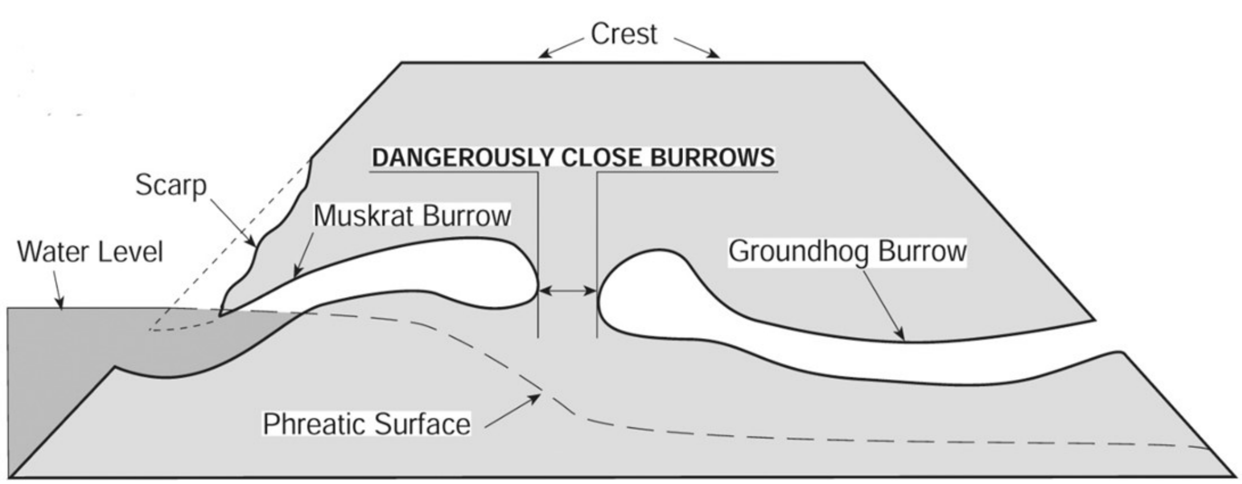
MUSKRAT CONTROL

Barriers to prevent burrowing offer the most practical protection to earthen structures. A properly constructed riprap and filter layer will discourage burrowing. The filter and riprap should extend at least 3 feet below the water line. As the muskrat attempts to construct a burrow, the sand and gravel of the filter layer caves in and thus discourages den building.

Heavy wire fencing laid flat against the slope and extending above and below the water line can also be effective. Eliminating or reducing aquatic vegetation along the shoreline will discourage muskrat habitation. Where muskrats have inhabited the area, trapping is usually the most practical method of removing them.

ELIMINATING A BURROW

The recommended method of backfilling a burrow in an embankment is mud-packing. This simple, inexpensive method can be accomplished by placing one or two lengths of metal stove or vent pipe in a vertical position over the entrance of the den. Making sure that the pipe connection to the den does not leak, the mud-pack mixture is then poured into the pipe until the burrow and pipe are filled with the earth-water mixture. The pipe is removed and dry earth is tamped into the entrance. The mud-pack is made by adding water



to a 90 percent earth and 10 percent cement mixture until a slurry or thin cement consistency is attained. All entrances should be plugged with well-compacted earth and vegetation reestablished. Dens should be eliminated without delay because damage from just one hole can lead to failure of a dam or levee.

BEAVER

Beaver do not necessarily burrow into dams but they will try to plug any spillways, outlets and channels with running water with their cuttings, mud, rocks and debris. Routinely removing the cuttings is one way to alleviate the problem but beaver can rebuild their obstructions overnight. Beaver may also establish large intrusive lodges on the banks or lakes formed by dams. Trapping beaver may be done by the owner during the appropriate season but beaver can migrate up and down a stream or river system and proliferate where habitat is good.

HUNTING AND TRAPPING REGULATIONS

Because hunting and trapping rules and regulations vary from state to state the appropriate State Wildlife Agency should be consulted to ensure compliance with state regulations.

RESOURCES

FEMA #473: FEMA Technical Manual For Dam Owners, "Impact of Animals on Earthen Dams"

FEMA Flyer, "Dam Owner's Guide to Animal Impacts on Earthen Dams," FEMA #L-264.NA

ASDSO Resources
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Dam Ownership **Fact Sheet**

TOPIC:

SPILLWAY CONDUIT SYSTEM PROBLEMS

Many dams have conduit systems that serve as principal spillways. These conduit systems are required to carry normal stream and small flood flows safely past the embankment throughout the life of the structure. Conduits through embankments are difficult to construct properly and can be extremely dangerous to the embankment if problems develop after construction. Conduits are usually difficult to repair because of their location within the embankment. Also, replacing conduits requires extensive excavation. In order to avoid difficult and costly repairs, particular attention should be directed to maintaining these structures. The most common problem noted with spillway conduit systems is undermining of the conduit. This condition typically results from water leaking through pipe joints, seepage along the conduit or inadequate energy dissipation at the conduit outlet. The typical causes of seepage and water leaking through pipe joints include any one or a combination of the following factors: loss of joint material, separated joints, misalignment, differential settlement, conduit deterioration, and pipe deformation. Problems in any of these areas may lead to failure of the spillway system and possibly dam failure.

UNDERMINING

Undermining is the removal of foundation material surrounding a conduit system. Any low areas or unexplained settlement of the earthfill in line with the conduit may indicate that undermining has occurred within the embankment. As erosion continues, undermining of a conduit can lead to displacement and collapse of the pipe sections and cause sloughing, sliding or other forms of instability in the embankment. As the embankment is weakened, a complete failure of the conduit system and, eventually the dam may occur.

Seepage along the conduit from the reservoir can occur because of poor compaction around the conduit. If seepage control devices have not been installed, the seepage may remove foundation material from around the conduit and eventually lead to undermining.

In addition, undermining can occur as the result of erosion due to inadequate energy dissipation or inadequate erosion protection at the outlet. This undermining can be visually observed at the outlet of a pipe system and can extend well into the embankment. In this case, undermining can lead to other conduit problems such as misalignment, separated joints and pipe deterioration. An extensive discussion on outlet erosion control as it relates to undermining of the pipe outlet can be found in the “Outlet Erosion Control Structures” fact sheet.

Installation of seepage control devices is required as a preventative measure to control seepage along the conduit and undermining. Regular monitoring of conduit systems must include visual observation and notation of any undermining or any precursors. These precursors usually include pipe deformation, misalignment and differential settlement, pipe deterioration, separated joints and loss of joint material.

PIPE DEFORMATION

Pipe deformations are typically caused by external loads that are applied on a pipe such as the weight of the embankment or heavy equipment. Collapse of the pipe can cause failure of the joints and allow erosion of the supporting fill. This may lead to undermining and settlement. Pipe deformation may reduce or eliminate spillway capacity. Pipe deformation must be monitored on a regular basis to ensure that no further deformation is occurring, that pipe joints are intact and that no undermining or settlement is occurring.

SEPARATED JOINTS AND LOSS OF JOINT MATERIAL: JOINT DETERIORATION

Conduit systems usually have construction and/or section joints. In almost every situation, the joints will have a water stop, mechanical seal and/or chemical seal to prevent leakage of water through the joint. Separation and deterioration can destroy the watertight integrity of the joint. Joint deterioration can result from weathering, excessive seepage, erosion or corrosion. Separation at a joint may be the result of a more serious condition such as foundation settlement, undermining, structural damage or structural instability. Deterioration at joints includes loss of gasket material, loss of joint sealant and spalling around the edges of joints. Separation of joints and loss of joint material allow seepage through the pipe. This can erode the fill underneath and along the conduit causing undermining, which can lead to the displacement of the pipe sections. Separated pipe joints can be detected by inspecting the interior of the conduit. A regular monitoring program is needed to determine the rate and severity of joint deterioration. Joint separations should be monitored to determine if movement is continuing.

CONDUIT DETERIORATION

Deterioration of conduit material is normally due to the forces of nature such as wetting and drying, freezing and thawing, oxidation, decay, ultra-violet light, cavitation and the erosive forces of water. Deterioration of pipe materials and joints can lead to seepage through and along the conduit and eventually failure of conduit systems. Additional information on deterioration can be found on the “Problems with Concrete Materials”, “Problems with Metal Materials”, and “Problems with Plastic (Polymer) Materials” fact sheets.

DIFFERENTIAL SETTLEMENT

Removal or consolidation of foundation material from around the conduit can cause differential settlement. Inadequate compaction immediately next to the conduit system during construction would compound the problem. Differential settlement can ultimately lead to undermining of the conduit system. Differential settlement should be monitored with routine inspections and documentation of observations.

MISALIGNMENT

Alignment deviations can be an indication of movement, which may or may not be in excess of design tolerances. Proper alignment is important to the structural integrity of conduit systems. Misalignment can be the direct result of internal seepage flows that have removed soil particles or dissolved soluble rock. Misalignment can also result from poor construction practices, collapse of deteriorated conduits, decay of organic material in the dam, seismic events or normal settlement due to consolidation of embankment or foundation materials. Excessive misalignment may result in other problems such as cracks, depressions, slides on the embankment, joint separation and seepage. Both the vertical and horizontal alignment of the conduit should be monitored on a regular basis.

MONITORING AND REPAIR

Frequent inspection is necessary to ensure that the pipe system is functioning properly. All conduits should be inspected thoroughly once a year. Conduits that are 24 inches or more in diameter can be entered and visually inspected with proper ventilation and confined space precautions. Small inaccessible conduits may be monitored with video cameras. The conduits should be inspected for misalignment, separated joints, loss of joint material, deformations, leaks, differential settlement and undermining. Problems with conduits occur most often at joints, and special attention should be given to them during the inspection. The joint should be checked for separation caused by misalignment or settlement and loss of joint-filler material. The outlet should be checked for signs of water seeping along the exterior surface of the conduit. Generally, this is noted by water flowing from under the conduit and/or the lack of foundation material directly beneath the conduit. The embankment surface should be monitored for depressions or sinkholes. Depressions or sinkholes on the embankment surface above the spillway conduit system develop when the underlying material is eroded and displaced. Photographs along with written records of the monitoring items performed provide invaluable information.

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. Various construction techniques can be applied for minor joint repair and conduit leakage, but major repairs require a plan be developed by a professional engineer experienced in dam spillway construction.

RESOURCES

ASDSO Resources

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DHS/FEMA Resources

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(search "dam safety")

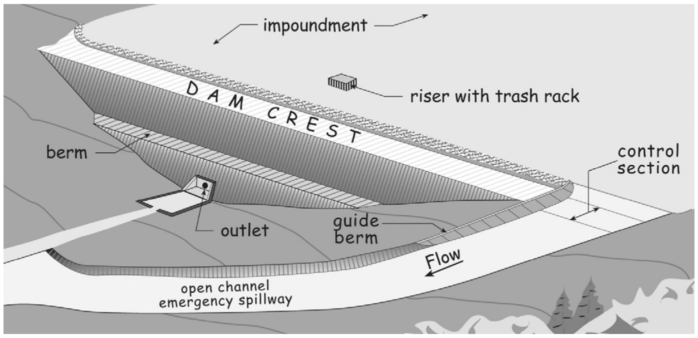
Dam Ownership **Fact Sheet**

TOPIC:
OPEN CHANNEL SPILLWAYS (EARTH AND ROCK)

Open channels are often used as the emergency spillway and sometimes as the principal spillway for dams. A principal spillway is used to pass normal inflows, and an emergency spillway is designed to operate only during large flood events, usually after the capacity of the principal spillway has been exceeded.

For dams with pipe conduit principal spillways, an open channel emergency spillway is almost always required as a backup in case the pipe becomes clogged. Open channels are usually located in natural ground adjacent to the dam and can be vegetated, rocklined, or cut in rock.

DESIGN
Flow through an emergency spillway does not necessarily indicate a problem with the dam, but high velocity flows can cause severe erosion and result in a permanently lowered lake level if not repaired. Proper design of an open channel spillway will include provisions for minimizing any potential erosion. One way to minimize erosion is to design a flatter channel slope to reduce the velocity of the flow. Earthen channels can be protected by a good grass cover, an appropriately designed rock cover, concrete or various types of erosion control matting. Rock-lined channels must have adequately sized riprap to resist displacement and contain an appropriate geotextile fabric or granular filter beneath the rock. Guide berms are often required to divert flow through open channels away from the dam to prevent erosion of the embankment fill. If an open channel is used for a principal spillway, it must be rock-lined or cut in rock due to more frequent or constant flows.



Downstream View of Open Channel Spillway

Many States have requirements, based on hazard classification, for how often an earth (grass-lined) or a rock-lined emergency spillway should be used prior to maintenance procedures. It is important to check the guidelines or regulations in your State.

MAINTENANCE
Maintenance should include, but not be limited to, the following items:

Grass-covered channels should be mowed at least twice per year to maintain a good grass cover and to prevent trees, brush and weeds from becoming established. Poor vegetal cover can result in extensive and rapid erosion when the spillway flows. Repairs can be costly. Reseeding and fertilization may be necessary to maintain a vigorous growth of grass.

One suggested seed mixture is 30% Kentucky Bluegrass, 60% Kentucky 31 Fescue, and 10% Perennial Ryegrass.

Trees and brush must be removed from the channel. Tree and brush growth reduces the discharge capacity of the spillway channel. This increases the lake level during large storm events which can lead to overtopping and failure of the dam.

Erosion in the channel must be repaired quickly after it occurs. Erosion can be expected in the spillway channel during high flows, and can also occur because of rainfall and runoff, especially in areas of poor grass cover. Terraces or drainage channels may be necessary in large spillway channels where large amounts of rainfall and runoff may concentrate and have high velocities. Erosion of the side slopes may deposit material in the spillway channel, especially where the side slopes meet the channel bottom. In small spillways, this can significantly reduce the discharge capacity. This condition often occurs immediately after construction before vegetation becomes established. In these cases, it may be necessary to reshape the channel to provide the necessary capacity.

All obstructions should be kept out of the channel. Open channel spillways often are used for purposes other than passage of flood flows. Among these uses are reservoir access, parking lots, boat ramps, boat storage, pasture and cropland. Permanent structures (buildings, fences, etc.) should not be constructed in these spillways. If fences, bridges or other such structures are absolutely necessary, they should cross the spillway far enough upstream or downstream from the control section so that they do not interfere with the flow Construction of any structures in or across the channel may require prior approval from the State.

Weathering of rock channels can be a serious problem and is primarily due to freeze/thaw action. Deterioration because of sun, wind, rain, chemical action and tree root growth also occurs. Weathered rock is susceptible to erosion and displacement during high flows; therefore, rock channels are often designed with 1 to 3 feet of earth with a grass cover over the rock surface to help insulate the rock from the effects of freeze/thaw action.

MONITORING

Open channel spillways should be monitored for erosion, poor vegetal cover, growth of trees and brush, obstructions, and weathering and displacement of rock. Monitoring should take place on a regular basis and after large flood events. It is important to keep written records of observations. Photographs provide invaluable records of changing conditions. All records should be kept in the operation, maintenance, and inspection manual for the dam.

RESOURCES

ASDSO Resources

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Dam Ownership **Fact Sheet**

TOPIC:

OPEN CHANNEL SPILLWAYS (CONCRETE CHUTES AND WEIRS)

Concrete chutes and weirs are used for principal spillways and emergency spillways. The principal spillway is used to pass normal flows, and the emergency spillway provides additional flow capacity during large flood events. If the principal spillway for a dam is a concrete weir and/or chute, the flow capacity may be large enough that an emergency spillway is not needed. Unlike grass-lined channel spillways that should always be located on natural ground, a concrete weir or chute may be located on the dam, but must be properly designed so that the integrity of the dam is not endangered.

The main components of a concrete chute spillway are the inlet structure, control section, discharge channel, and outlet erosion control structure. The inlet structure conveys water to the control section. The control section is the highest point in the channel and regulates the outflow from the reservoir. It is usually located on or near the crest of the dam. The control section may consist of a concrete weir or may simply be the most elevated slab in the floor of the chute. The discharge channel is located downstream of the control section and conveys flow to the outlet erosion control structure. This structure is designed to dissipate most of the erosive energy of the flow before it enters the downstream channel.

OVERALL DESIGN AND SAFETY CONSIDERATIONS

Alignment

For good hydraulic performance, abrupt changes should be avoided. This applies to sudden changes in vertical elevation of the chute floor, abrupt widening or narrowing of the chute, and sharp turns in the chute. Anything that will abruptly disrupt or change the direction of the flow in the chute will reduce flow capacity and will place more stress on the concrete. The best performance is obtained when the distribution of flow is even across the channel.

Settlement and Movement

Abnormal settlement, heaving, deflections, and lateral movement of the sidewalls or floor slabs of the spillway can occur. Movements are usually caused by a loss of underlying material, excessive settlement of the fill, or the buildup of water pressure behind or under the structure. Any abnormal settlement, heaving, deflections or lateral movement in the concrete spillway should be immediately investigated by a registered professional engineer knowledgeable about dam safety. As necessary, plans and specifications for repair to the spillway should also be promptly developed and implemented by a registered professional engineer.

The concrete sidewalls and floor of the chute must have enough strength to withstand water loads, soil/fill loads, uplift forces, weathering, and abrasion. The forces of weathering, movement of abrasive materials by water flowing in the spillway, or cavitation may cause surface defects or more serious concrete deterioration.

The freeze-thaw cycle is the most damaging weathering force acting on exposed concrete. The concrete's durability and resistance to weathering and deterioration will be determined by the concrete mix, age of the concrete, and proper sealing of the joints. Typical problems with concrete structures include scaling, spalling, honeycombing, bugholes, and popouts. Please refer to the "Problems with Concrete Materials" fact sheet for further explanation of these problems and more details about concrete durability and design. Plans and specifications for repair of structural cracks, or other structural problems, should be developed and implemented by a registered professional engineer so that the integrity of the spillway and/or embankment is not jeopardized.

Undermining

Undermining of the chute may occur at any point along its length. The chute may become undermined at the inlet and/or outlet due to an inadequate cutoff wall or erosion protection. Erosion beneath and alongside the spillway may also be caused by seepage and inadequate drainage. Undermining and erosion will lead to settlement of the undermined portions of the chute. If the concrete spillway is located on the embankment, undermining and collapse of portions of the chute will jeopardize the safety of the dam. If the spillway is located in the abutment, erosion and lowering of the lake level may result. A registered professional engineer should be hired to develop plans and specifications to repair undermining of the chute.

Cutoff Wall and Endwall

A cutoff wall should be placed at the entrance to the concrete chute to prevent the flow approaching and entering the chute from flowing beneath and undermining the floor slabs. Undermining of the chute can cause cracking and collapse of the slabs as the underlying material is eroded away. In addition, a cutoff wall is necessary at the downstream end of the chute to prevent undermining by flows exiting the chute and entering the downstream channel. The cutoff wall or endwall should be founded on bedrock or have adequate support to provide stability and prevent undermining of the wall itself.

Outlet Erosion Control Structure

The discharge at the outlet may exit the chute at a high velocity. Based on the anticipated velocity, energy, and volume of flow, a structure may be needed to protect the spillway and/or dam from erosion and undermining. Please refer to the "Outlet Erosion Control Structures" fact sheet for more detailed information.

Seepage

The rate and content of flow from weep holes and relief drains must be monitored and documented regularly. Muddy flow may indicate erosion of fill material along the spillway or piping through the embankment. The presence of soil particles or muddy flow from the drains indicates that the filter or underdrainage is not functioning properly and is allowing the migration of soil particles from the embankment. Sudden increases in flow, or muddy flow from the drains should be immediately investigated by a registered professional engineer to determine the cause and severity of the problem. Plans and specifications to properly control the seepage and repair the drain(s) and embankment should also be developed and carried out under the direction of a registered professional engineer.

In addition to monitoring the amount of flow, normal maintenance consists of removing all obstructions from drain holes and pipes to allow free drainage. Typical obstructions include debris, gravel, sediment and rodent nests. Water should not be permitted to submerge the pipe outlets for extended periods of time. This will inhibit inspection and maintenance and may cause the drains to clog. Also see the “Seepage Through Earthen Dams” fact sheet for more information.

Underdrainage and Weep Holes

Weep holes, relief drains and underdrains must be included with the concrete chute to relieve excessive water pressure or infiltration from behind the walls and floor. The drainage system for the chute should consist of correctly placed and sized drainage holes, perforated pipes, and filter and bedding materials, such as sand and gravel. Seepage can occur through the dam, along the contact between the embankment and the concrete chute, or through open joints and cracks. Uncontrolled seepage flow along the structure can erode the underlying fill material (undermining) which may cause cracking or buckling of the slabs. Excessive pressure behind the walls and floor of the chute can cause cracking and heaving of the concrete. The freeze-thaw cycle can increase the amount of stress and strain on the concrete and can also cause heaving, cracking and additional serious damage to the structure. Weep holes, relief drains, and underdrainage for a concrete chute spillway should be designed by a registered professional engineer.

RESOURCES

ASDSO Resources

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Dam Ownership **Fact Sheet**

TOPIC:

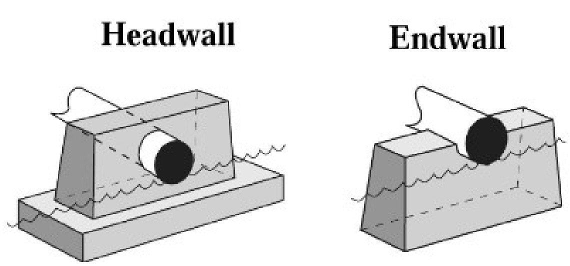
OUTLET EROSION CONTROL STRUCTURES (STILLING BASINS)

Water moving through the spillway of a dam contains a large amount of energy. This energy can cause erosion at the outlet which can lead to instability of the spillway. Failure to properly design, install, or maintain a stilling basin could lead to problems such as undermining of the spillway and erosion of the outlet channel and/or embankment material. These problems can lead to failure of the spillway and ultimately the dam. A stilling basin provides a means to absorb or dissipate the energy from the spillway discharge and protects the spillway area from erosion and undermining. An outlet erosion control structure such as a headwall/endwall, impact basin, United States Department of the Interior, Bureau of Reclamation Type II or Type III basin, baffled chute, or plunge pool is considered an energy dissipating device. The performance of these structures can be affected by the tailwater elevation. The tailwater elevation is the elevation of the water that is flowing through the natural stream channel downstream during various flow conditions.

A headwall/endwall, impact basin, Type II or Type III basin, and baffled chute are all constructed of concrete. Concrete structures can develop surface defects such as minor cracking, bugholes, honeycombing, and spalling. Concrete structures can have severe structural defects such as exposed rebar, settlement, misalignment and large cracks. Severe defects can indicate structural instability.

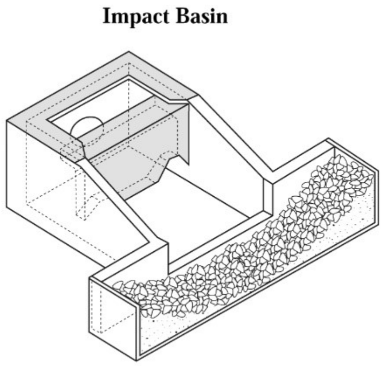
HEADWALL/ENDWALL

A headwall/endwall located at or close to the end of the discharge conduit will provide support and reduce the potential for undermining. A headwall/endwall is typically constructed of concrete, and it should be founded on bedrock or have an adequate foundation footing to provide support for stability. A headwall/endwall can become displaced if it is not adequately designed and is subject to undermining. Displacement of the headwall/endwall can lead to separation of the spillway conduit at the joints which could affect the integrity of the spillway conduit. If a concrete structure develops the structural defects mentioned in the opening paragraphs, or if the discharge spillway conduit does not have a headwall/endwall, then a registered professional engineer should be contacted to evaluate the stability of the outlet.



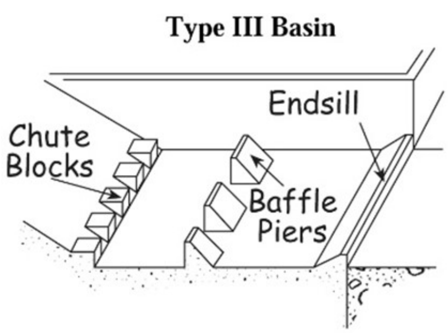
IMPACT BASIN

A concrete impact basin is an energy dissipating device located at the outlet of the spillway in which flow from the discharge conduit strikes a vertical hanging baffle. Discharge is directed upstream in vertical eddies by the horizontal portion of the baffle and by the floor before flowing over the endsill. Energy dissipation occurs as the discharge strikes the baffle, thus, performance is not dependent on tailwater. Most impact basins were designed by the United States Department of Agriculture, Natural Resources Conservation Service and the United States Department of Interior, Bureau of Reclamation. If any of the severe defects that are referenced in the opening paragraphs are observed, a registered professional engineer should be contacted to evaluate the stability of the outlet.



U.S. DEPARTMENT OF INTERIOR, BUREAU OF RECLAMATION TYPE II AND TYPE III BASINS

Type II and Type III basins reduce the energy of the flow discharging from the outlet of a spillway and allow the water to exit into the outlet channel at a reduced velocity. Type II energy dissipators contain chute blocks at the upstream end of the basin and a dentated (tooth-like) endsill. Baffle piers are not used in a Type II basin because of the high velocity water entering the basin.



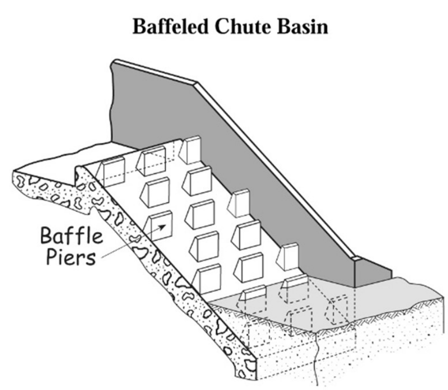
Type III energy dissipators can be used if the entrance velocity of the water is not high. They contain baffle piers which are located on the stilling basin apron downstream of the chute locks. Located at the end of both the Type II and Type III basins is an endsill. The endsill may be level or sloped, and its purpose is to create the tailwater which reduces the outflow velocity. If any of the severe defects associated with concrete structures are observed, a registered professional engineer should be contacted to evaluate the stability of the basin.

BAFFLED CHUTE

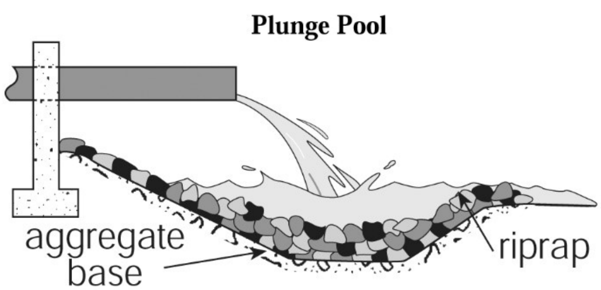
Baffled chutes require no initial tailwater to be effective and are located downstream of the control section. Multiple rows of baffle piers on the chute prevent excessive acceleration of the flow and prevent the damage that occurs from a high discharge velocity. A portion of the baffled chute usually extends below the streambed elevation to prevent undermining of the chute. If any of the severe problems associated with concrete that are referenced in the opening paragraphs are observed, a registered professional engineer should be contacted to evaluate the stability of the outlet.

PLUNGE POOL

A plunge pool is an energy dissipating device located at the outlet of a spillway. Energy is dissipated as the discharge flows into the plunge pool. Plunge pools are commonly lined with rock riprap or other material to prevent excessive erosion of the pool area. Discharge from the plunge pool should be at the natural streambed elevation. Typical problems may include movement



of the riprap, loss of fines from the bedding material and scour beyond the riprap and lining. If scour beneath the outlet conduit develops, the conduit will be left unsupported and separation of the conduit joints and undermining may occur. Separation of the conduit joints and undermining may lead to failure of the spillway and ultimately the dam. A registered professional engineer should be contacted to ensure that the plunge pool is designed properly.



RESOURCES

Additional information about related topics can be found on the following fact sheets:

- Inspection of Concrete Structures
- Spillway Conduit System Problems
- Open Channel Spillways (Concrete Chutes and Weirs)
- Problems with Concrete Materials

ASDSO Resources
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DHS/FEMA Resources
DHS and FEMA make several publications and videos available to dam owners through:
FEMA.gov and *DHS.gov*
(search “dam safety”)

Dam Ownership **Fact Sheet**

TOPIC:
LAKE DRAINS

TYPES OF DRAINS

Common types of drains include the following:

- A valve located in the spillway riser.
- A conduit through the dam with a valve at either the upstream or downstream end of the conduit.
- A siphon system (often used to retrofit existing dams).
- A gate, valve, or stoplogs located in a drain control tower.

USES OF DRAINS

The following situations make up the primary uses of lake drains:

Emergencies

Should serious problems ever occur to threaten the immediate safety of the dam, drains may be used to lower the lake level to reduce the likelihood of dam failure. Examples of such emergencies are as follows: clogging of the spillway pipe which may lead to high lake levels and eventually dam overtopping, development of slides or cracks in the dam, severe seepage through the dam which may lead to a piping failure of the dam, and partial or total collapse of the spillway system.

Maintenance

Some repair items around the lake and dam can only be completed or are much easier to perform with a lower than normal lake level. Some examples are: slope protection repair, spillway repairs, repair and/or installation of docks and other structures along the shoreline, and dredging the lake.

Winter Drawdown

Some dam owners prefer to lower the lake level during the winter months to reduce ice damage to structures along the shoreline and to provide additional flood storage for upcoming spring rains. Several repair items are often performed during this winter drawdown period. Periodic fluctuations in the lake level also discourage muskrat and beaver habitation along the shoreline. Muskrat burrows in earthen dams can lead to costly repairs.

In addition to providing means of regulating normal pool level, typical riser structures include means to operate a reservoir drain.

COMMON MAINTENANCE PROBLEMS

Common problems often associated with the maintenance and operation of lake drains include the following:

- Deteriorated and bent control stems and stem guides.
- Deteriorated and separated conduit joints.
- Leaky and rusted control valves and sluice gates.
- Deteriorated control towers.
- Deteriorated ladders in control towers.
- Clogging of the drain conduit inlet with sediment and debris.
- Inaccessibility of the control mechanism to operate the drain.
- Seepage along the drain conduit.
- Erosion and undermining of the conduit discharge area because the conduit outlets significantly above the elevation of the streambed.
- Vandalism.
- Development of slides along the upstream slope of the dam and the shoreline caused by lowering the lake level too quickly.

OPERATION AND MAINTENANCE TIPS

All gates, valves, stems and other mechanisms should be lubricated according to the manufacturer's specifications. If you do not have a copy of the specifications and the manufacturing company cannot be determined, then a local valve distributor may be able to provide assistance.

The lake drain should be operated at least twice a year to prevent the inlet from clogging with sediment and debris and to keep all movable parts working easily. Most manufacturers recommend that gates and valves be operated at least four times per year. Frequent operation will help to ensure that the drain will be operable when it is needed. All valves and gates should be fully opened and closed at least twice to help flush out debris and to obtain a proper seal. If the gate gets stuck in a partially opened position, gradually work the gate in each direction until it becomes fully operational. Do not apply excessive torque as this could bend or break the control stem, or damage the valve or gate seat. With the drain fully open, inspect the outlet area for flow amounts, leaks, erosion and anything unusual.

All visible portions of the lake drain system should be inspected at least annually, preferably during the periodic operation of the drain. Look for and make note of any cracks, rusted and deteriorated parts, leaks, bent control stems, separated conduit joints, or unusual observations.

A properly designed lake drain should include a headwall near the outlet of the drain conduit to prevent undermining of the conduit during periods of flow. A headwall can be easily retro-fitted to an existing conduit if undermining is a problem at an existing dam. A properly designed layer of rock riprap or other slope protection will help reduce erosion in the lake drain outlet area.

Drain control valves and gates should always be placed upstream of the centerline of the dam. This allows the drain conduit to remain depressurized except during use, therefore reducing the likelihood of seepage through the conduit joints and saturation of the surrounding earth fill.

For accessibility ease, the drain control platform should be located on shore or be provided with a bridge or other structure. This becomes very important during emergency situations if high pool levels exist.

Vandalism can be a problem at any dam. If a lake drain is operated by a crank, wheel or other similar mechanism, locking with a chain or other device or off-site storage may be beneficial. Fences or other such installations may also help to ward off vandals. The recommended rate of lake drawdown is one foot or less per week, except in emergencies.
Fast drawdown causes a build-up of hydrostatic

pressures in the upstream slope of the dam which can lead to slope failure. Lowering the water level slowly allows these pressures to dissipate.

MONITORING

Monitoring of the lake drain system is necessary to detect problems and should be performed at least twice a year or more frequently if problems develop. Proper ventilation and confined space precautions must be considered when entering a lake drain vault or outlet pipe. Items to be considered when monitoring a lake drain system include the stem, valve, outlet pipe and related appurtenances. Monitoring for surface deterioration (rust), ease of operation, and leakage is important to maintain a working lake drain system. If the stem or valve appears to be inoperable because of deterioration or if the operability of the lake drain system is in question, because the valve does not completely close (seal) and allows an excessive amount of leakage, then a registered professional engineer or manufacturer's representative should be contacted. Photographs along with written records of the monitoring items performed provide invaluable information.

CONCLUSION

An operable lake drain accomplishes the following:

1. Makes for a safer dam by providing a method to lower the lake level in an emergency situation.
2. Allows the dam owner to have greater control of the lake level for maintenance, winter drawdown and emergency situations.
3. Meets the requirements of state dam safety laws.

RESOURCES

For further information on evaluating the condition of the lake drain systems see the "Spillway Conduit System Problems," "Problems with Metal Materials," "Problems with Plastic (Polymer) Materials," and "Problems with Concrete Materials" fact sheets.

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Dam Ownership **Fact Sheet**

TOPIC:

DESIGN AND MAINTENANCE OF TRASHRACKS FOR PIPE AND RISER SPILLWAYS

The principal spillway for dams can be one of several designs. The proper operation of these spillways is an important part of maintaining the overall safety of the dam. Pipe and riser, drop inlet, and slant pipe spillways are susceptible to obstruction and damage by floating debris such as leaves, branches, and logs. One device used to ensure that these spillways operate correctly is a trashrack. Trashracks are designed to keep trash and other debris from entering the spillway and causing damage.

COMMON PROBLEMS

Trashracks usually become plugged because the openings are too small or the head loss at the inlet causes material and sediment to settle out and accumulate. Small openings will cause debris such as twigs and leaves to accumulate on the trashrack bars. This buildup will cause progressively larger debris to accumulate against the trashrack bars. Ultimately, this will result in the complete blockage of the spillway inlet.

Pipe and riser spillways can also become blocked by a buildup of debris in the spillway. This type of blockage occurs when no trashrack is in place, or if the openings are too large.

In many spillway systems, the size of the outlet conduit is smaller than the size of the inlet. Therefore, it is incorrect to assume that debris which passes through the inlet will not obstruct the flow through the outlet. Large debris, such as logs and tree limbs, can become lodged in the transitions in the spillway. This reduces the capacity of the spillway and could cause damage. An obstructed outlet pipe can be a major problem because removal of large debris from inside the spillway can be very difficult.

A partially blocked spillway reduces the capacity of the spillway and may also create a higher than normal pool level. The combination of these two factors can dramatically reduce the discharge & storage capacity of the dam. A reduction in the discharge & storage capacity of a dam increases the likelihood that the dam will be overtopped during a severe storm event. Overtopping, for even a short period of time, can cause damage to the embankment and possibly failure of the dam. If the dam has an emergency spillway, a blocked principal spillway will cause more frequent flows in the emergency spillway. Since emergency spillways are usually grass lined channels designed for infrequent flows of short duration, serious damage is likely to result.

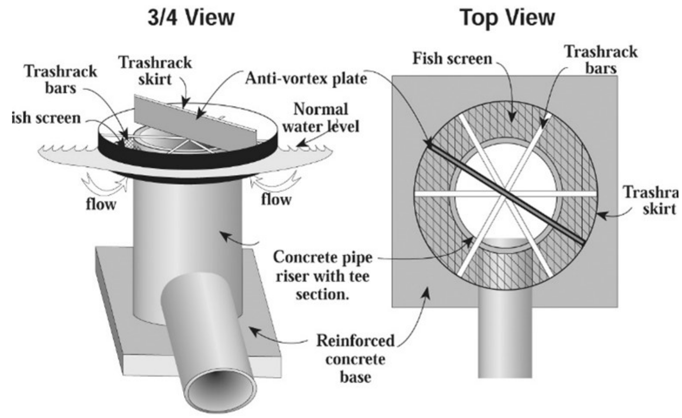
TRASHRACK DESIGN

A well-designed trashrack will stop large debris that could plug the conduit, but allow unrestricted passage of water and smaller debris. The larger the outlet conduit, the larger the trashrack opening should be. In the design of a trashrack, the openings should be sized so that they measure one-half the nominal dimension of the outlet conduit.

For example, if the outlet pipe is 18 inches in diameter, the trashrack openings should be the effective equivalent of 9 inches by 9 inches; if the outlet conduit is 3 feet by 5 feet, the trashrack openings should be the effective equivalent of 18 inches by 18 inches. This rule applies up to a maximum trashrack opening of two feet by two feet. For an outlet conduit with a nominal dimension of 12 inches or less, the trashrack openings should be at least 6 inches by 6 inches. This prevents large debris from passing through the inlet and blocking the outlet conduit while allowing smaller debris (leave, sticks, etc.) to flush through the spillway system. The trashrack should be securely fastened to the inlet. The connection must be strong enough to withstand the hydrostatic and dynamic forces exerted on the trashrack during periods of high flow.

FISH PROTECTION

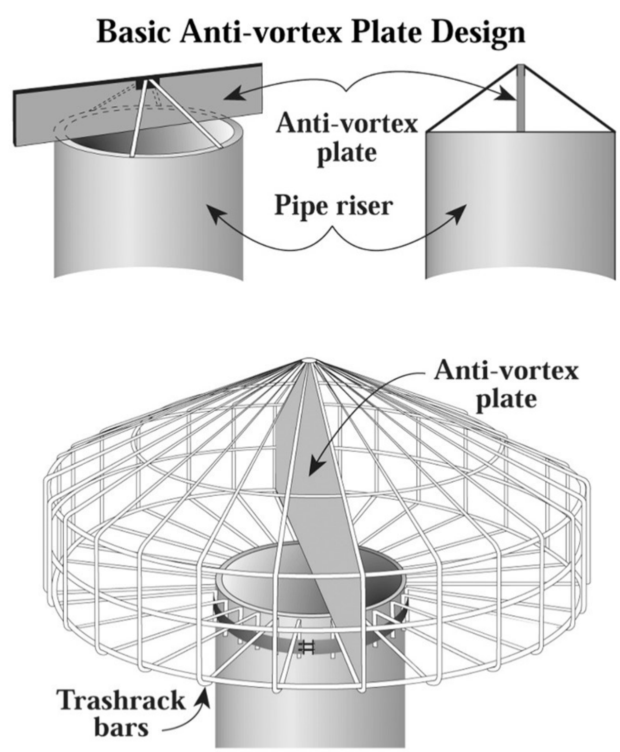
Many owners are concerned about losing fish through trashracks that have large openings. If this is a concern, a metal plate surrounding the riser or drop inlet which extends above and below the normal pool level should be installed. See Figure below. On the bottom of the plate, a metal screen should be attached and connected to the riser pipe. The solid plate at the water level will prevent the fish and floating debris from passing over the crest of the riser. The underwater screen will keep the fish from moving under the metal plate and through the spillway. The underwater screen will not become blocked because most of the debris floats on the water surface. If this design is used, the area between the inside of the cylinder and the outside of the riser must be equal to or greater than the area inside the riser.



Trash Rack Design with Fish Protector Screen

ANTI-VORTEX DEVICES

An anti-vortex device can easily be incorporated into most trashrack designs. A common anti-vortex device is a flat metal plate which is placed on edge and attached to the inlet of the spillway. See Figure above. The capacity of the spillway will be increased by equipping the trashrack with an anti-vortex plate. The anti-vortex plate increases capacity by preventing the formation of a flow inhibiting vortex during periods of high flow.



MAINTENANCE

Maintenance should include periodic checks of the trashrack for rusted and broken sections and repairing as needed. Trashracks should be checked frequently during and after storm events to ensure they are functioning properly and to remove accumulated debris. Extreme caution should be used when attempting to remove accumulated debris during periods of high flow.

CONCLUSION

The benefits of a properly designed and maintained trashrack include the following:

- ✓ Efficient use of the existing spillway system that will maintain the design discharge/storage capacity of the dam and prevent overtopping.
- ✓ Prevention of costly maintenance items such as the removal of debris from the spillway, repair or replacement of damaged spillway components, and the repair of erosion in emergency spillway.
- ✓ A reduction in the amount of fish lost through the spillway system if a fish screen is used.

RESOURCES

ASDSO Resources
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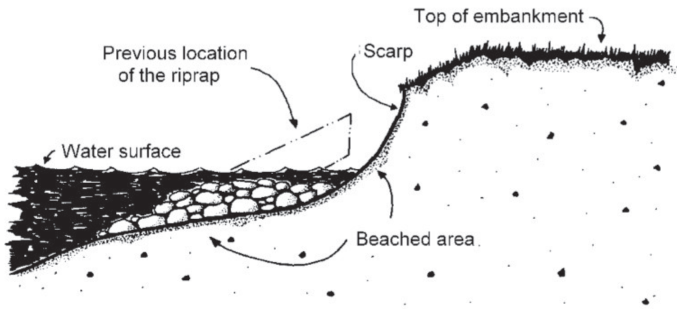
Dam Ownership **Fact Sheet**

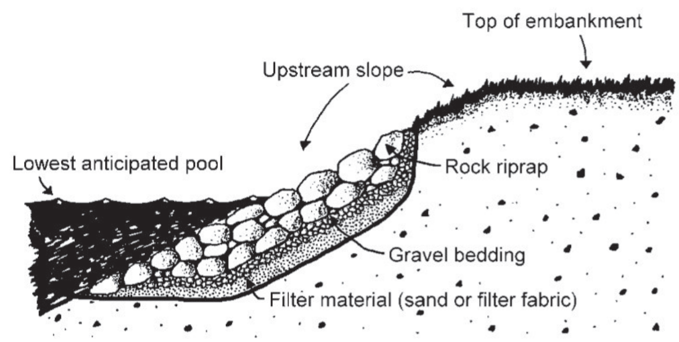
TOPIC:

UPSTREAM SLOPE PROTECTION

Slope protection is usually needed to protect the upstream slope against erosion due to wave action. Without proper slope protection, a serious erosion problem known as "beaching" can develop on the upstream slope.



Beaching



Rock Riprap

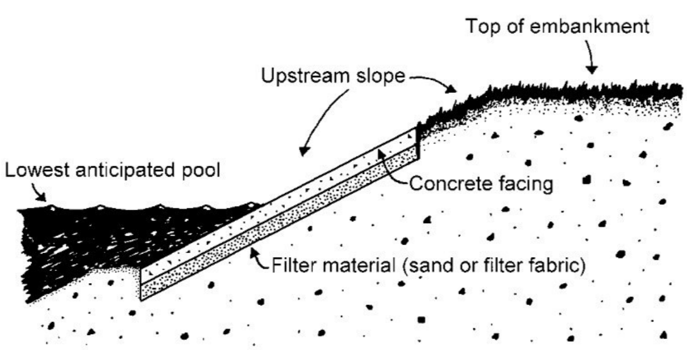
The repeated action of waves upon a vegetated embankment surface over time may erode embankment material and deposit it farther down the slope, creating a "beach." The amount of erosion depends on the predominant wind direction, the orientation of the dam, the steepness of the slope, water level fluctuations, boating activities, and other factors. Further erosion can lead to cracking and sloughing of the slope which can extend into the crest, reducing its width. When erosion occurs and beaching develops on the upstream slope of a dam, repairs should be made as soon as possible. The upstream face of a dam is commonly protected against wave erosion by placement of a layer of rock riprap over a layer of bedding and a filter material. Other material such as concrete facing, soil-cement, fabri-form bags, slush grouted rocks, steel sheet piling, and articulated concrete blocks can also be used. Vegetative protection combined with a berm on the upstream slope can also be effective.

ROCK RIPRAP

Rock riprap consists of a heterogeneous mixture of irregular shaped rocks placed over gravel bedding and a sand filter or geotextile fabric. The smaller rocks help to fill the spaces between the larger pieces forming an interlocking mass. The filter prevents soil particles on the embankment surface from being washed out through the spaces (or voids) between the rocks. The maximum rock size and weight must be large enough to break up the energy of the maximum anticipated wave action and hold the smaller stones in place. If the rock size is too small, it will eventually be displaced and washed away by wave action. If the riprap is sparse or if the filter or bedding material is too small, the filter material will wash out easily, allowing the embankment material to erode. Once erosion has started, beaching will develop if remedial measures are not taken.

The dam owner should expect some deterioration (weathering) of riprap. Freezing and thawing, wetting and drying, abrasive wave action, and other natural processes will eventually break down riprap. Its useful life varies with the characteristics of the stone used. Stone for riprap should be rock that is dense, well cemented, abrasion resistant, and angular in shape to resist deterioration and create an interlocking barrier. Vegetative growth within the slope protection is undesirable because it can displace stone and disturb the filter material. Heavy undergrowth prevents an adequate inspection of the upstream slope and may hide potential problems. For additional information, see the “Trees and Brush” fact sheet.

Sufficient maintenance funds should be allocated for the addition of riprap and the removal of vegetation. Severe erosion or reoccurring problems may require a registered professional engineer to design a more effective slope protection.



Soil-Cement

SOIL-CEMENT

Soil-Cement consists of a well compacted mixture of soil, Portland cement, and water compacted to a high density. The relative proportions of soil, cement and water in the soil-cement mixture are based on the results of laboratory tests on specially prepared specimens to determine its durability and strength properties over a range soil gradations and cement contents. A soil-cement mixture of adequate durability and strength can be designed, and slope protection constructed, using almost any type of soil. Soil-cement can be placed by either the “plating” or “stair-step” method. The plating method of placement consists of one or more lifts of soil-cement placed parallel to the slope. The plating method can be considered for use on small dams where wave action is not severe. Even for small dams this method is not considered for areas where significant wave action is expected.

The stair-step method of construction consists of placing the soil-cement in horizontal lifts of 6 to 9 inches. An approximate 9-inch spread thickness results in a 6-inch compacted thickness. The width of each lift is generally 8 to 10 feet to accommodate placing and compaction equipment. See Figure. Use of pneumatic-tired rollers or steel drum rollers is the most common used compact soil-cement in the stair-stop method.

RCC (roller compacted concrete) has also been used as slope protection and is designed and installed similar to soil cement. Consideration should be given that other methods maybe more appropriate in freeze-thaw regions of the country. *Bureau of Reclamation Design Standard No. 13, Embankment Dams, Chapter 17: Soil Cement Slope Protection* and the Portland Cement Association Soil -Cement Construction Handbook are good references for design engineers.

INSPECTION AND MONITORING

Regular inspection and monitoring of upstream slope protection is essential to detect any problems. It is important to keep written records of the location and extent of any erosion, undermining, or deterioration of the riprap, wave berm or other slope protection. Photographs provide invaluable records of changing conditions. A rapidly changing condition may indicate a very serious problem, and appropriate dam safety officials should be contacted. All records should be kept in the operation, maintenance, and inspection manual for the dam.

RESOURCES

The ASDSO website houses guidelines on dams. Go to:
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Dam Ownership **Fact Sheet**

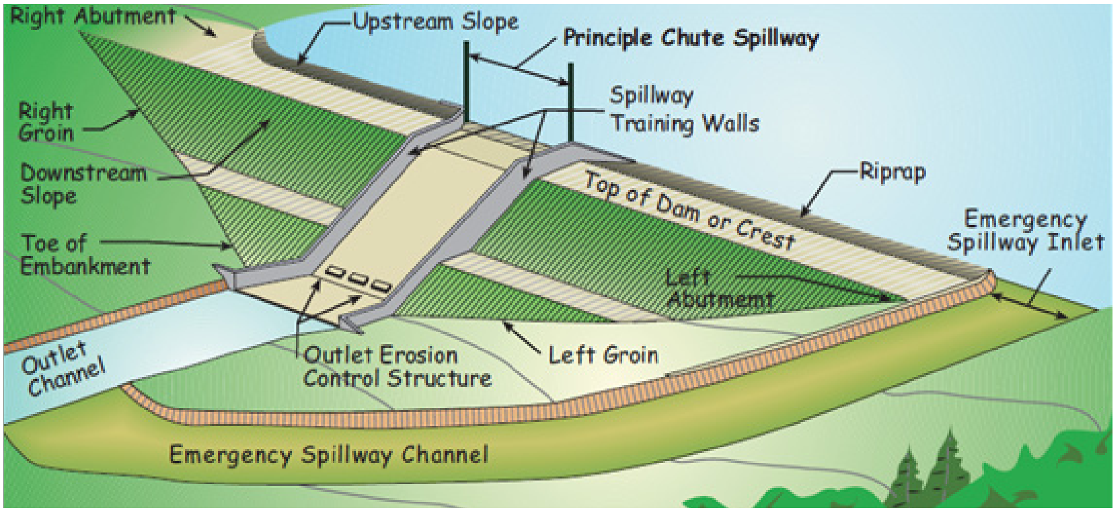
TOPIC:

COMMON PROBLEMS FOR SMALL DAMS WITH CONCRETE CHANNEL SPILLWAYS

The State Dam Safety Program has inspection requirements for state regulated dams. A dam, like any man-made structure, will change and deteriorate over time. Keeping a dam in good condition will allow better inspections and easier maintenance. Proper inspection and maintenance will help prevent small problems from turning into larger, more costly repairs. The following paragraphs and pictures address common problems that have been noted during inspections.

EARTHEN EMBANKMENTS

The establishment and control of proper vegetation is an important part of dam maintenance. Properly maintained vegetation can help prevent erosion of embankment and earth channel surfaces, and aid in the control of groundhogs and muskrats. Embankment slopes are normally designed and constructed so that the surface drainage will be spread out in a thin layer as “sheet flow” over the grass cover. When the sod is in poor condition or flow is concentrated at one or more locations, the resulting erosion will leave rills and gullies in the embankment slope.



A dam safely passes a flood event by a combination of storing water in the lake and passing water through its spillways. Earthen embankments are not designed to have floodwaters overtop them. An emergency spillway should not pass over the crest of the dam; it should be located in the abutment area.

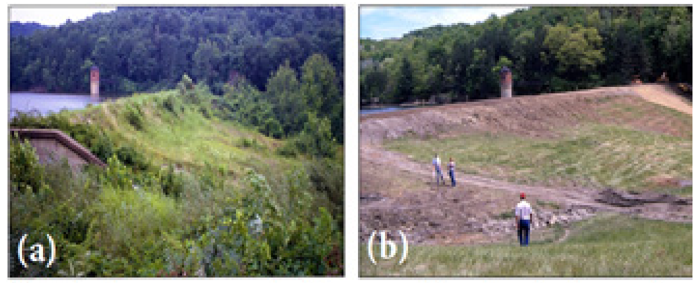
TREES AND BRUSH

Trees and brush must not be permitted on embankment surfaces or in vegetated earth spillways. Extensive root systems can provide seepage paths for water. Trees that blow down or fall can leave large holes in the embankment. Brush hinders visual inspection, provides a haven for burrowing animals, and retards growth of grass vegetation.

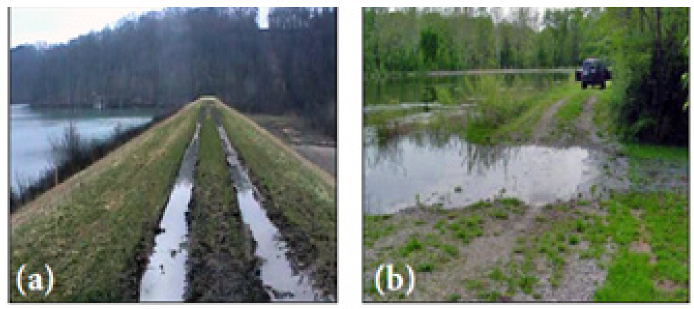
UPSTREAM SLOPE

Slope protection may be needed to protect the upstream slope against erosion. Erosion can lead to cracking and sloughing, which can extend into the crest. Muskrats and groundhogs can also damage the slope. The upstream face of the dam is commonly protected against wave erosion by placement of a layer of rock riprap over a layer of bedding and a filter material.

An excellent grass cover will reduce erosion and is easily maintained.



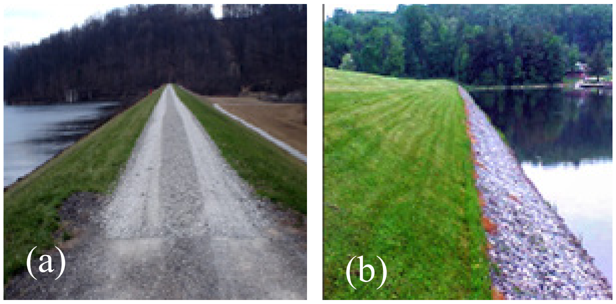
(a) Embankments covered with trees and brush makes inspections difficult. (b) Cleared of trees and brush, this embankment is much easier to inspect, but needs a good vegetal cover.



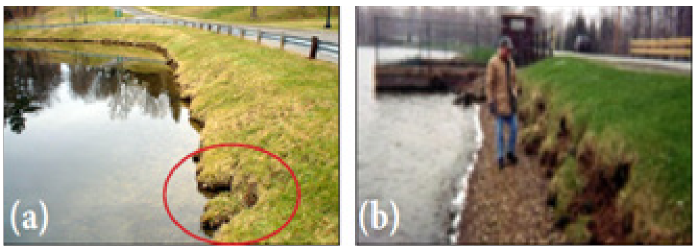
(a) Embankment crests with vehicle ruts will collect water and weaken the embankment. (b) Crest beginning to overtop in low area. This could lead to erosion and failure of the dam.

CREST

Vehicular traffic should be discouraged, especially during wet conditions, to avoid ruts. Water collected in ruts may cause localized saturation, thereby weakening the embankment. Ruts can develop into low areas. Low areas on the crest increase the likelihood that a dam will be overtopped during severe floods. Earthen embankments are not designed to be overtopped. Should the dam overtop, floodwaters will concentrate in the low area, increasing the likelihood of erosion of the crest and downstream slope. Severe erosion can lead to failure of the embankment. A well-vegetated earth embankment may withstand limited overtopping if its crest is level and water flows over the crest and downstream slope as an evenly distributed sheet without becoming concentrated.



(a) Crest with a good cover that will reduce the effects of vehicular traffic.
(b) This slope is well maintained with rock riprap along the shoreline.



(a) Collapsed muskrat burrows increase shoreline erosion and sloughing. (b) This shoreline has eroded due to lack of proper erosion protection leading to sloughing and cracking of the slope.

(a) A spillway outlet area as originally constructed. (b) Severe erosion has undermined the spillway outlet and threatens the overall structural safety of the spillways.

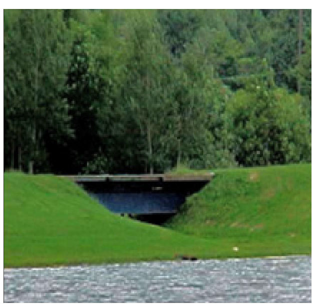
CONCRETE SPILLWAYS

A concrete weir or chute is often used as a principal spillway for dams. The principal spillway is the first spillway to experience flow after a storm when the pool rises above the normal pool level. For the spillway to be effective, it must be clear of obstructions, in good structural condition, and on a solid foundation. A spillway must remain unobstructed to maintain its flow capacity. Obstructions such as fish screens, walkways, vegetation, and bridge piers should be cleared from the spillway inlet. Loss of flow capacity could cause the dam to overtop and fail. The spillway must remain in good structural condition to ensure that spillway flow stays within the spillway and does not cause erosion that could cause the spillway to fail. Concrete surfaces should be visually examined for structural problems due to weathering, stress, chemical attack, erosion, and other destructive forces. Structural problems are indicated by cracking, exposure of reinforcing bars, and large areas of spalled concrete. Even if the spillway is in good structural condition, seepage under the spillway or erosion at the outlet or along the sides can cause the spillway to fail. Spillway floor slabs and walls should be checked for erosion of underlying base material known as undermining. Indicators of problems with seepage and erosion under the spillway include misalignment at joints and large cracks.

EMERGENCY AKA AUXILIARY SPILLWAYS

The emergency or auxiliary spillway is the second spillway to experience flow during a flood event. For many common dams, the emergency spillway consists of a grass-lined, earthen open channel. An open channel can convey much more flow than a pipe spillway, so it is important to keep the spillway free of obstructions. Obstructions reduce the flow capacity and could cause the dam to overtop and fail. Permanent structures including buildings, fences, and roadway embankments for access across the spillway should not be constructed in the spillway. Earthen channels should be protected by a good grass cover, an appropriately designed rock cover, concrete, or other various types of erosion control matting. Grass-lined channels should be mowed at least twice per year to maintain a good grass cover and to prevent trees, brush, and weeds from becoming established. Poor vegetal cover can result in extensive and rapid erosion when the spillway flows.

Left: A tree is obstructing this spillway.
Right: Notice the landscaping directly behind the table. Obstructions in the spillway reduce the capacity to convey water. They also can collect debris, further diminishing the capacity of the spillway.



This bridge blocks much of the spillway, reducing its ability to convey water.

RESOURCES

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(search "dam safety")

This open-channel emergency spillway is clear of trees, brush and other obstructions. Also note the good grass cover.

Dam Ownership **Fact Sheet**

TOPIC:

INSPECTION OF CONCRETE STRUCTURES

Dams, dikes, and levees must not be thought of as part of the natural landscape, but as manmade structures which must be designed, inspected, operated, and maintained accordingly. Routine maintenance and inspection of dams and appurtenant facilities should be an ongoing and active process to ensure that structural failures do not occur which can threaten the overall safety of the dam. The information provided in this fact sheet pertains entirely to the inspection of concrete structures used at dams. The intention is to help dam owners become more aware of common problems that are typically encountered with concrete so that they can more readily address the seriousness of a condition whenever it arises.

STRUCTURAL INSPECTIONS

Concrete surfaces should be visually examined on a periodic basis for spalling and deterioration due to weathering, unusual or extreme stresses, erosion, cavitation, vandalism, and other destructive forces. Structural problems are indicated by cracking, exposure of reinforcing bars, large areas of broken-out concrete, misalignment at joints, undermining and settlement in the structure. Rust stains that are noted on the concrete may indicate that internal corrosion and deterioration of reinforcement steel is occurring. Spillway floor slabs and upstream slope protection slabs should be checked for erosion of underlying base material otherwise known as undermining. Concrete walls and tower structures should be examined to determine if settlement and misalignment of construction joints has occurred.

WHAT TO LOOK FOR

Cracking

Concrete structures can exhibit many different types of cracking. Deep, wide cracking is due to stresses which are primarily caused by shrinkage and structural loads. Minor or hairline surface cracking is caused by weathering and the quality of the concrete that was applied. The results of this minor cracking can be the eventual loss of concrete, which exposes reinforcing steel and accelerates deterioration. Generally, minor surface cracking does not affect the structural integrity and performance of the concrete structure. Cracks through concrete surfaces exposed to flowing water may lead to the erosion or piping of embankment or foundation soils from around and/or under the concrete structure. In this case, the cracks are not the result of a problem but are the detrimental condition which leads to piping and erosion.

Example of cracking.

Structural cracking of concrete is usually identified by long, single or multiple diagonal cracks with accompanying displacements and misalignment. Cracks extending across concrete slabs which line open channel spillways or provide upstream slope wave protection can indicate a loss of foundation support resulting from settlement, piping, undermining, or erosion of foundation soils. Piping and erosion of foundation soils are the result of inadequate underdrainage and/or cutoff walls. Items to consider when evaluating a suspected structural crack are the concrete thickness, the size and location of the reinforcing steel, the type of foundation, and the drainage provision for the structure.

Seepage

Seepage at the discharge end of a spillway or outlet structure may indicate leakage of water through a crack. Proper underdrainage for open channel spillways with structural concrete floors is necessary to control this leakage. Flows from underdrain outlets and pressure relief holes should also be observed and measured. Cloudy flows may indicate that piping is occurring beneath or adjacent to the concrete structure. This could be detrimental to the foundation support.
Concrete surfaces adjacent to contraction joints and subject to flowing water are of special concern especially in chute slabs. The adjacent slabs must be flush or the downstream one slightly lower to prevent erosion of the concrete and to prevent water from being directed into the joint during high velocity flow.

Poor Drainage

All weep holes should be checked for the accumulation of silt and granular deposits at their outlets. These deposits may obstruct flow or indicate loss of support material behind the concrete surfaces. Tapping the concrete surface with a hammer or some other device will help locate voids if they are present as well as give an indication of the condition and soundness of the concrete. Weep holes in the concrete are used to allow free drainage and relieve excessive hydrostatic pressures from building up underneath the structure. Excessive hydrostatic pressures underneath the concrete could cause it to heave or crack which increases the potential for accelerated deterioration and undermining. Periodic monitoring of the weep hole drains should be performed and documented on a regular and routine basis to ensure that they are functioning as designed.

Inspection of intake structures, trash racks, upstream conduits, and stilling basin concrete surfaces that are below the water surface is not readily feasible during a regularly scheduled inspection. Typically, stilling basins require the most regular monitoring and major maintenance because they are holding ponds for rock and debris, which can cause extensive damage to the concrete surfaces during the dissipation of flowing water. Therefore, special inspections of these features should be performed at least once every five years by either dewatering the structure or when operating conditions permit. Investigation of these features using experienced divers is also an alternative.

Weep holes with screens to control seepage.

PREPARING FOR AN INSPECTION

Before an inspection of the dam's concrete facilities is performed, it is recommended that a checklist be developed that includes all the different components of the spillway and/or outlet works. The checklist should also include a space for logging any specific observations about the structure and the state of its condition. Photographs provide invaluable records of changing conditions. A rapidly changing condition may indicate a very serious problem and documentation of prior inspections is very helpful in making this determination If there are any questions as to the seriousness of an observation the state dam safety agency, or a registered professional engineer experienced with dams, should be contacted.

RESOURCES

ASDSO Resources

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Dam Ownership **Fact Sheet**

TOPIC:

PROBLEMS WITH CONCRETE MATERIALS

Visual inspection of concrete will allow for the detection of distressed or deteriorated areas. Problems with concrete include construction errors, disintegration, scaling, cracking, efflorescence, erosion, spalling, and popouts.

CONSTRUCTION ERRORS

Errors made during construction can include adding improper amounts of water to the concrete mix, inadequate consolidation, and improper curing can cause distress and deterioration of the concrete. Proper mix design, placement, and curing of the concrete, as well as an experienced contractor are essential to prevent construction errors from occurring. Construction errors can lead to some of the problems discussed later in this fact sheet such as scaling and cracking. Honeycombing and bugholes can be observed after construction.

Honeycombing can be recognized by exposed coarse aggregate on the surface without any mortar covering or surrounding the aggregate particles. The honeycombing may extend deep into the concrete. Honeycombing can be caused by a poorly graded concrete mix, by too large of a coarse aggregate, or by insufficient vibration at the time of placement. Honeycombing will result in further deterioration of the concrete due to freeze-thaw cycles because moisture can easily work its way into the honeycombed areas. Severe honeycombing should be repaired to prevent further deterioration of the concrete surface.

Bugholes is a term used to describe small holes (less than about 0.25 inch in diameter) that are noticeable on the surface of the concrete. Bugholes are generally caused by too much sand in the mix, a mix that is too lean or excessive amplitude of vibration during placement. Bugholes may cause durability problems with the concrete and should be monitored.

DISINTEGRATION AND SCALING

Disintegration can be described as the deterioration of the concrete into small fragments and individual aggregates. *Scaling* is a milder form of disintegration where the surface mortar flakes off. Large areas of crumbling (rotten) concrete, areas of deterioration which are more than about 3 to 4 inches deep (depending on the wall/slab thickness), and exposed rebar indicate serious concrete deterioration. If not repaired, this type of concrete deterioration may lead to structural instability of the concrete structure. A registered professional engineer must prepare plans and specifications for repair of serious concrete deterioration. For additional information, see the “Concrete Repair Techniques” fact sheet.

Disintegration can be a result of many causes such as freezing and thawing, chemical attack, and poor construction practices. All exposed concrete is subject to freeze-thaw cycles, but the concrete’s resistance to weathering is generally determined by the concrete mix and the age of the concrete.

Concrete with the proper amounts of air, water, and cement, and a properly sized aggregate, will be much more durable. In addition, proper drainage is essential in preventing freeze-thaw damage. When critically saturated concrete (when 90% of the pore space in the concrete is filled with water) is exposed to freezing temperatures, the water in the pore spaces within the concrete freezes and expands, damaging the concrete. Repeated cycles of freezing and thawing will result in surface scaling and can lead to disintegration of the concrete. Hydraulic structures are especially susceptible to freeze-thaw damage since they are more likely to be critically saturated. Older structures are also more susceptible to freeze-thaw damage since the concrete was not air entrained. In addition, acidic substances in the surrounding soil and water can cause disintegration of the concrete surface due to a reaction between the acid and the hydrated cement.

CRACKS

Cracks in the concrete may be structural or surface cracks. Surface cracks are generally less than a few millimeters wide and deep. These are often called hairline cracks and may consist of single, thin cracks, or cracks in a craze/map-like pattern. A small number of surface or shrinkage cracks is common and does not usually cause any problems. *Surface cracks* can be caused by freeze-thaw cycles, poor construction practices, and alkali-aggregate reactivity. Alkali-aggregate reactivity occurs when the aggregate reacts with the cement causing crazing or map cracks. The placement of new concrete over old may also cause surface cracks to develop. This occurs because the new concrete will shrink as it cures. Surface cracks in the spillway should be monitored and will need to be repaired if they deteriorate further. Structural cracks in the concrete are usually larger than 0.25 inch in width. They extend deeper into the concrete and may extend all the way through a wall, slab, or other structural member. *Structural cracks* are often caused by settlement of the fill material supporting the concrete structure, or by loss of the fill support due to erosion. The structural cracks may worsen in severity due to the forces of weathering. A registered professional engineer knowledgeable about dam safety should investigate the cause of structural cracks and prepare plans and specifications for repair of any structural cracks.

EFFLORESCENCE

A white, crystallized substance, known as efflorescence, may sometimes be noted on concrete surfaces, especially spillway sidewalls. It is usually noted near hairline or thin cracks. Efflorescence is formed by water seeping through the pores or thin cracks in the concrete. When the water evaporates, it leaves behind some minerals that have been leached from the soil, fill, or concrete. Efflorescence is typically not a structural problem. Efflorescence should be monitored because it can indicate the amount of seepage finding its way through thin cracks in the concrete and can signal areas where problems (i.e. inadequate drainage behind the wall or deterioration of concrete) could develop. Also, water seeping through thin cracks in the wall will make the concrete more susceptible to deterioration due to freezing and thawing of the water.

EROSION

Erosion due to *abrasion* results in a worn concrete surface. It is caused by the rubbing and grinding of aggregate or other debris on the concrete surface of a spillway channel or stilling basin. Minor erosion is not a problem but severe erosion can jeopardize the structural integrity of the concrete. A registered professional engineer should prepare plans and specifications for repair of this type of erosion if it is severe.

Erosion due to cavitation results in a rough, pitted concrete surface. Cavitation is a process in which subatmospheric pressures, turbulent flow and impact energy are created and will damage the concrete. If the shape of the upper curve on the ogee spillway is not designed close to its ideal shape, cavitation may occur just below the upper curve, causing erosion. A professional engineer should prepare plans and specifications for repair of this type of erosion if the concrete becomes severely pitted which could lead to structural damage or failure.

SPALLING AND POPOUTS

Spalling is the loss of larger pieces or flakes of concrete. It is typically caused by sudden impact of something dropped on the concrete or stress in the concrete that exceeded the design. Spalling may occur on a smaller scale, creating popouts. Popouts are formed as the water in saturated coarse aggregate particles near the surface freezes, expands, and pushes off the top of the aggregate and surrounding mortar to create a shallow conical depression. Popouts are typically not a structural problem. However, if a spall is large and causes structural damage, a registered professional engineer should prepare plans and specifications to repair the spalling.

INSPECTION AND MONITORING

Regular inspection and monitoring is essential to detect problems with concrete materials. Concrete structures should be inspected a minimum of once per year and after any significant weather event. The inspector should also look at the interior condition of concrete spillway conduit. Proper ventilation and confined space precautions must be considered when entering a conduit. It is important to keep written records of the dimensions and extent of scaling, disintegration, efflorescence, honeycombing, erosion, spalling, popouts, and the length and width of cracks. Structural cracks should be monitored more frequently and repaired if they are a threat to the stability of the structure or dam. Photographs provide invaluable records of changing conditions. A rapidly changing condition may indicate a very serious problem, and the State Dam Safety Agency should be contacted immediately. All records should be kept in the operation, maintenance, and inspection manual for the dam.

RESOURCES

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Dam Ownership
Fact Sheet

TOPIC:

CONCRETE REPAIR TECHNIQUES

Concrete is an inexpensive, durable, strong and basic building material often used in dams for core walls, spillways, stilling basins, control towers, and slope protection. However, poor workmanship, construction procedures, and construction materials may cause imperfections that later require repair. Any long-term deterioration or damage to concrete structures caused by flowing water, ice, or other natural forces must be corrected. Neglecting to perform periodic maintenance and repairs to concrete structures as they occur could result in failure of the structure from either a structural or hydraulic standpoint. This in turn may threaten the continued safe operation and use of the dam.

CONSIDERATIONS

Floor or wall movement, extensive cracking, improper alignments, settlement, joint displacement, and extensive undermining are signs of major structural problems. In situations where concrete replacement solutions are required to repair deteriorated concrete, it is recommended that a registered professional engineer be retained to perform an inspection to assess the concrete's overall condition and determine the extent of any structural damage and necessary remedial measures.

Typically, it is found that drainage systems are needed to relieve excessive water pressures under floors and behind walls. In addition, reinforcing steel must also be properly designed to handle tension zones and shear and bending forces in structural concrete produced by any external loading (including the weight of the structure). Therefore, the finished product in any concrete repair procedure should consist of a structure that is durable and able to withstand the effects of service conditions such as weathering, chemical action, and wear. Major structural repairs that require professional advice are not addressed here.

REPAIR METHODS

Before any type of concrete repair is attempted, it is essential that all factors governing the deterioration or failure of the concrete structure are identified. This is required so that the appropriate remedial measures can be undertaken in the repair design to help correct the problem and prevent it from occurring in the future. The following techniques require expert and experienced assistance for the best results. The method of repair will depend on the size of the job and the type of repair required

1. The Dry-Pack Method: The dry-pack method can be used on small holes in new concrete which have a depth equal to or greater than the surface diameter. Preparation of a dry-pack mix typically consists of about 1-part portland cement and 2-1/2-parts sand to be mixed with water. You then add enough water to produce a mortar that will stick together. Once the desired consistency is reached, the mortar is ready to be packed into the hole using thin layers.

2. Concrete Replacement: Concrete replacement is required when one-half to one square foot areas or larger extend entirely through the concrete sections or where the depth of damaged concrete exceeds 6 inches. When this occurs, normal concrete placement methods should be used. Repair will be more effective if tied in with existing reinforcing steel (rebar). This type of repair will require the assistance of a professional engineer experienced in concrete construction.
3. Replacement of Unformed Concrete: The replacement of damaged or deteriorated areas in horizontal slabs involves no special procedures other than those used in good construction practices for placement of new slabs. Repair work can be bonded to old concrete by use of a bond coat made of equal amounts of sand and cement. It should have the consistency of whipped cream and should be applied immediately ahead of concrete placement so that it will not set or dry out. Latex emulsions with portland cement and epoxy resins are also used as bonding coats.
4. Preplaced Aggregate Concrete: This special commercial technique has been used for massive repairs, particularly for underwater repairs of piers and abutments. The process consists of the following procedures: 1) Removing the deteriorated concrete, 2) forming the sections to be repaired, 3) prepacking the repair area with coarse aggregate, and 4) pressure grouting the voids between the aggregate particles with a cement or sand-cement mortar.
5. Synthetic Patches: One of the most recent developments in concrete repair has been the use of synthetic materials for bonding and patching. Epoxy-resin compounds are used extensively because of their high bonding properties and great strength. In applying epoxy-resin patching R 07/08/99 mortars, a bonding coat of the epoxy resin is thoroughly brushed onto the base of the old concrete. The mortar is then immediately applied and troweled to the elevation of the surrounding material.

Before attempting to repair a deteriorated concrete surface, all unsound concrete should be removed by sawing or chipping and the patch area thoroughly cleaned. A sawed edge is superior to a chipped edge, and sawing is generally less costly than mechanical chipping. Before concrete is ordered for placing, adequate inspection should be performed to ensure that (1) foundations are properly prepared and ready to receive the concrete, (2) construction joints are clean and free from defective concrete, (3) forms are grout-tight, amply strong, and set to their true alignment and grade, (4) all reinforcement steel and embedded parts are clean, in their correct position, and securely held in place, and (5) adequate concrete delivery equipment and facilities are on the job, ready to go, and capable of completing the placement without addition unplanned construction.

CONCRETE USE GUIDELINES

In addition to its strength characteristics, concrete must also have the properties of workability and durability. Workability can be defined as the ease with which a given set of materials can be mixed into concrete and subsequently handled, transported, and placed with a minimal loss of homogeneity. The degree of workability required for proper placement and consolidation of concrete is governed by the dimensions and shape of the structure and by the spacing and size of the reinforcement. The concrete, when properly placed, will be free of segregation, and its mortar is intimately in contact with the coarse aggregate, the reinforcement, and/or any other embedded parts or surfaces within the concrete. Separation of coarse aggregate from the mortar should be minimized by avoiding or controlling the lateral movement of concrete during handling and placing operations. The concrete should be deposited as nearly as practicable in its final position. Placing methods that cause the concrete to flow in the forms should be avoided. The concrete should be placed in horizontal layers, and each layer should be thoroughly vibrated to obtain proper compaction.

All concrete repairs must be adequately moist-cured to be effective. The bond strength of new concrete to old concrete develops much more slowly, and the tendency to shrink and loosen is reduced by a long moist-curing period. In general, the concrete repair procedures discussed above should be considered on a relative basis and in terms of the quality of concrete that one wishes to achieve for their construction purpose. In addition to being adequately designed, a structure must also be properly constructed with concrete that is strong enough to carry the design loads, durable enough to withstand the forces associated with weathering, and yet economical, not only in first cost, but in terms of its ultimate service. It should be emphasized that major structural repairs to concrete should not be attempted by the owner or persons not experienced in concrete repairs. A qualified professional engineer experienced in concrete construction should be obtained for the design of large scale repair projects.

CRACK REPAIR

The two main objectives when repairing cracks in concrete are structural bonding and stopping water flow. For a structural bond, epoxy injection can be used. This process can be very expensive since a skilled contractor is needed for proper installation. The epoxy is injected into the concrete under pressure, welding the cracks to form a monolithic structure. This method of repair should not be considered if the crack is still active (moving). For a watertight seal, a urethane sealant can be used. This repair technique does not form a structural bond; however, it can be used on cracks that are still active. Cracks should be opened using a concrete saw or hand tool prior to placing the sealant. A minimum opening of 1/4 inch is recommended since small openings are hard to fill. Urethane sealants can be reapplied since they are flexible materials and will adhere to older applications. All of the factors causing cracking must be identified and addressed before repairing the concrete to prevent the reoccurrence of cracks.

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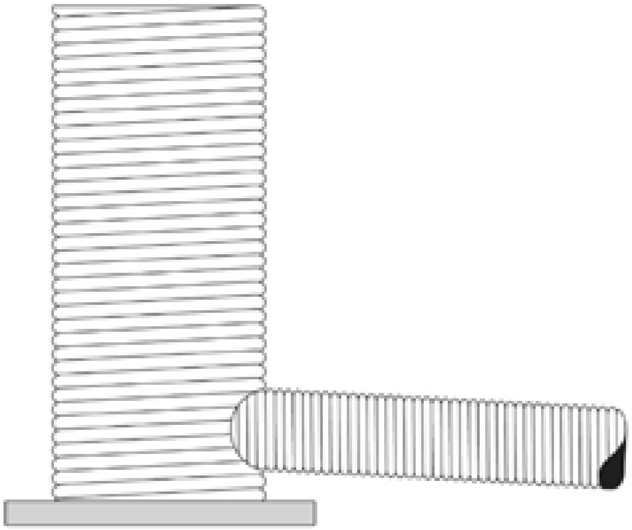
Dam Ownership **Fact Sheet**

TOPIC:

PROBLEMS WITH METAL MATERIALS

Corrosion is a common problem for spillway conduits and other metal appurtenances. Corrosion is the deterioration or breakdown of metal because of a reaction with its environment. Exposure to moisture, acidic conditions, or salt will accelerate the corrosion process. Acid runoff from strip-mined areas will cause rapid corrosion of metal conduits. In these areas, conduits made of less corrodible materials such as concrete or plastic should be used. Soil types also factor into the amount of corrosion. Clayey soils can be more corrosive than sandy soils since they are poorly drained and poorly aerated. Silts are somewhere in between clays and sands. Some examples of metal conduits include ductile iron, smooth steel, and corrugated metal.



Example of a corrugated metal pipe and riser spillway.

Corrugated metal pipe is not recommended for use in dams since the service life for corrugated metal is only 25 to 30 years, whereas the life expectancy for dams is much longer.

In areas of acidic water, the service life can be much less. Therefore, corrugated metal spillway conduits typically need to be repaired or replaced early in the dam's design life, which can be very expensive.

Conduit coating is an effective way of controlling corrosion of metal conduits if used properly. It is relatively inexpensive and extends the life of the conduit. Some examples of coatings include cement-mortar, epoxy, aluminum, or polyethylene film. Asphalt (bituminous) coatings are not recommended since their service life is usually only one or two years. Coatings must be applied to the conduit prior to installation and protected to ensure that the coating is not scratched off. Coatings applied to conduits in service are generally not very effective because of the difficulty in establishing an adequate bond.

Corrosion can also be controlled or arrested by installing cathodic protection. A metallic anode such as magnesium (or zinc) is buried in the soil and is connected to the metal conduit by wire. Natural voltage current flowing from the magnesium (anode) to the conduit (cathode) will cause the magnesium to corrode and not the conduit. However, sufficient maintenance funds should be allocated for the regular inspection of this active system.

If corrosion is allowed to continue, metal conduits will rust out. The spillway must be repaired before water flows through the rusted-out portion of the conduit and erodes the fill material of the embankment. Continued erosion can lead to failure of the dam. Sliplining can be an economical and effective method of permanently restoring deteriorated spillways. During sliplining, a smaller diameter pipe is inserted into the old spillway conduit and then grout is used to fill in the void between the two pipes. If sliplining the spillway is not feasible, the lake may need to be drained and a new spillway must be installed. A registered professional engineer should be retained to develop and submit plans and specifications for any major modifications such as spillway sliplining or replacement.

Corrosion of the metal parts of the operating mechanisms such as lake drain valves and sluice gates can be effectively treated by keeping these parts lubricated and /or painted. If the device has not been operated in several years, a qualified person (i.e. manufacturer's representative or registered professional engineer) should inspect it to determine its operability. Caution must be used to prevent the mechanism from breaking. A registered professional engineer may be needed to prepare plans and specifications for repair if the device is determined to be inoperable.
Regular inspection and monitoring is essential to detect any problems with metal materials. Coatings on metal pipes should be inspected for scratched and worn areas. The inspector should also look for corrosion inside the spillway conduit. Proper ventilation and confined space precautions must be considered when entering the spillway conduit system. If using cathodic protection, regular inspections are required to verify that the system is working properly. It is important to keep written records of the amount of surface rust, pitting, and corrosion on any metal surface. Areas of thin metal should be monitored more frequently and repaired or replaced if they rust out. Photographs provide invaluable records of changing conditions. A rapidly changing condition may indicate a very serious problem, and the State Dam Safety Agency should be contacted immediately. All records should be kept in the operation, maintenance, and inspection manual for the dam.

RESOURCES

ASDSO Resources
The ASDSO website houses national guidelines on dams. Go to:
DamSafety.Org/ManualsandGuidelines

For more information, videos and tools for dam owners go to:
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Dam Ownership **Fact Sheet**

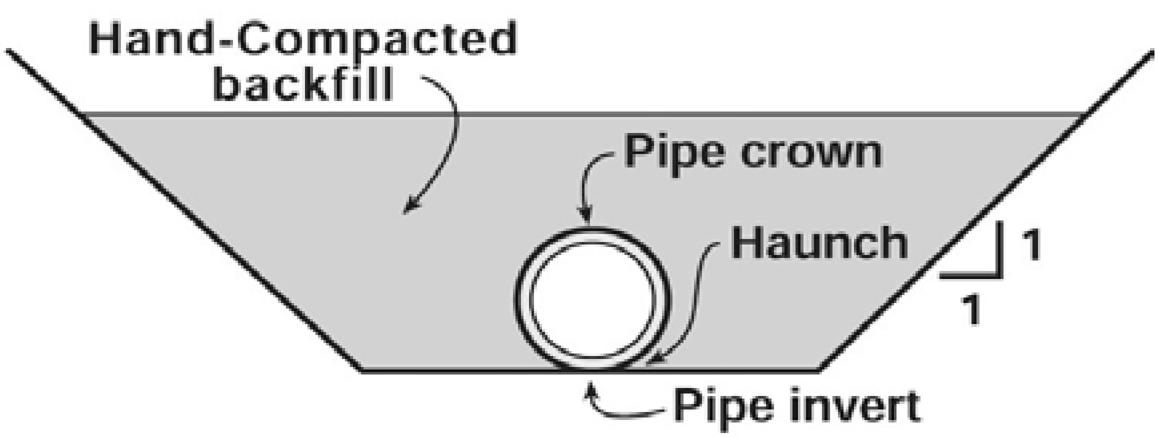
TOPIC:

PROBLEMS WITH PLASTIC (POLYMER) MATERIALS

Plastics are often used as spillway and lake drain pipes in dam construction and repair. The most common plastic pipes are high-density polyethylene (HDPE) and polyvinyl chloride (PVC). The advantages of using plastic pipe include excellent abrasion resistance, chemical corrosion resistance, low maintenance, and long-life expectancy. Naturally occurring chemicals in soils will not degrade plastic pipe and cause it to rot or corrode. Plastic pipes are also much easier to handle and install compared to heavier concrete and steel pipes.

Plastic pipes are considered flexible, and they get their strength from the material and the surrounding backfill whereas rigid pipes, such as concrete, get their strength from the material and the pipe structure. Backfill around plastic pipes must be properly compacted and in full contact with the pipe. It is important to take special care in the haunch area to prevent the pipe from lifting off the subgrade and disrupting vertical alignment.

Symmetric backfilling is also required to prevent the pipe from being out of lateral alignment. When designing a new spillway system, a registered professional engineer will be required to specify the correct type of pressurized plastic pipe that can be used. The pipe must be able to withstand the pressures from the weight of the embankment without crushing or buckling. The joints must also be watertight. Not all plastic pipe will meet these requirements.



Cross-section of plastic pipe in trench.

As with other plastic materials, ultraviolet light degradation can be a problem. Photo-degradation can cause plastic to become brittle and crack.

Carbon black is the most effective additive to enhance the photo-degradation resistance of plastic materials. Pipes containing carbon black can be safely stored outside in most climates for many years without damage from ultraviolet exposure.

Plastic pipes can be affected by liquid hydrocarbons such as gasoline and oil. If hydrocarbons come in contact with plastic pipe, they will permeate the pipe wall causing swelling and loss of strength. However, if the hydrocarbons are removed, the effects are reversible.

Regular inspection and monitoring is essential to detect any problems with plastic materials. Plastic pipes should be inspected for deformation and cracking. The inspector should also look at the interior condition of the spillway pipe. Proper ventilation and confined space precautions must be considered when entering the spillway pipe system. It is important to keep written records of pipe dimensions to note deformation and the length and width of cracks. Photographs provide invaluable records of changing conditions. A rapidly changing condition may indicate a very serious problem, and the State Dam Safety Agency should be contacted immediately. All records should be kept in the operation, maintenance, and inspection manual for the dam.

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Dam Ownership **Fact Sheet**

TOPIC:

CONCRETE GRAVITY DAM FAILURES

This fact sheet will discuss failure modes for concrete gravity dams. Similar dam types, such as concrete buttress, arch, and slab, may have similar failure modes.

As the nation's dams age, the potential for dam failures grows. These failures can cause immense property and environmental damage and threaten thousands of lives. Owners of dams and operating and maintenance personnel must be knowledgeable of the potential problems and failure modes that can lead to dam failure. If a problem is noted early enough, corrective measures can be implemented.

If there is any question as to the seriousness of an observation, an engineer experienced with dams should be contacted.

GRAVITY DAM FAILURE MODES

Gravity dam failures can be grouped into three general categories: sliding failures, overturning failures, and structural failures.

Sliding Gravity Dam Failure

When the dam slides over its foundation or one part of the dam slides over a part of itself, it is called a sliding failure. It occurs when the net horizontal forces acting on the gravity dam exceed the frictional resistance produced between the body of the dam and the foundation. The resistance may be due to friction alone, or it may be due to a combination of friction and shear strength, depending on how the dam was constructed. The ability of the dam to resist a sliding failure is commonly calculated by dividing the resistance to movement by the horizontal forces acting on the dam. Its value varies by loading condition, but generally, the result should vary between 1.3 and 1.5.

Overturning Gravity Dam Failure

Horizontal and vertical forces such as water pressure, wave pressure, silt pressure, ice pressure, and uplift pressure can act against a gravity dam, creating overturning force or rotation of the structure. The structure resists this rotation by having adequate weight. If the sum of all the forces acting on a dam acts, either through or outside of the downstream toe of the dam, the dam will rotate and overturn. While a structure can rotate about the toe, it is more likely that the overturning forces would increase stresses to such a level at the toe of the dam that structural failure would occur.

Structural Failure of Gravity Dams
Structural failure occurs when the tensile or compressive stresses in the dam exceed the strength of the materials that compose the dam. Masonry and concrete are weak in tension, so masonry and concrete gravity dams are designed to minimize tension in the structure. Steel bars, known as rebar, are incorporated within the concrete during construction to resist anticipated tensile forces. As the structure ages, rebar can corrode or deteriorate, and tensile forces can develop where rebar is not present or weakened. This, coupled with overturning forces, can redistribute stresses in the dam that could cause cracking. In severe cases of the redistribution of stresses, the dam can lose contact with the bottom foundation, increasing uplift forces on the dam. This can significantly increase loading at the toe of the dam leading to a compression failure. If the compressive stresses exceed the allowable stresses of the masonry or concrete, the materials may be crushed, leading to dam failure.

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Bureau of Reclamation
Technical Reference: Design of Small Dams:
https://on.doi.gov/3eUMQoz

US Army Corps of Engineers
Engineer Manual: Gravity Dam Design (EM 1110-2-2200)
https://bit.ly/3MQbIQe

Dam Ownership **Fact Sheet**

TOPIC:

Dam Removal

There are more than 90,000 dams in the United States. Many of these dams continue to provide safe and reliable social and economic benefits, such as water supply, flood control, hydropower, and recreation. However, thousands of dams no longer serve a viable purpose or provide significant benefits. Many have exceeded the average life expectancy of a dam, become structurally unsound and unsafe to the public, and require costly repairs to bring them into compliance with state or federal safety regulations. All repairs are the responsibility of the dam owner. The cost to repair and rehabilitate a dam can exceed the owner's financial abilities. Many dam owners choose to remove their dams to eliminate ongoing maintenance costs and public safety concerns and reduce financial and legal liability.

CONSIDERATIONS FOR REMOVAL - IMPACTS

Before a dam owner can consider the removal of their dam, they must first evaluate the feasibility of all possible alternatives, such as:

- Altering the dam's operation (e.g., reducing reservoir levels)
- Rehabilitating or repairing the dam
- Removing the dam

When removing a dam, consideration must be given to identifying and assessing the diverse changes created by the dam's removal. These significant changes may vary in importance to the dam owner(s) vs. other parties who may have very different vested interests, i.e., the general public, community leaders, state fish and wildlife departments, state historic preservation offices, environmental restoration organizations, abutting property owners upstream and downstream, etc.

Consideration must be given to the following:

- **Public Safety** – potential increased flood risk downstream; removal of dam failure hazard
- **Fish Passage** – greater fish diversity; invasive species
- **Stream Restoration** – improved aquatic habitat
- **Sediment Management** – costly removal if contaminated
- **Recreation** – navigable waterways; shoreline revitalization
- **Property Value** – loss of lakefront properties
- **Historical Significance**
- **Existing Infrastructure** – groundwater availability; loss of reservoir/changes in river flow can cause adverse effects on bridges, submerged utility lines, etc.

CONSIDERATIONS FOR REMOVAL - COSTS

The financial cost associated with the removal of a dam is case-specific and depends on numerous variables, some of which are listed below:

- Dam's composition – concrete, masonry, timber, earthen
- Dam's material condition
- Dam's size – height, length
- Good or limited site access
- Sediment issues – contamination, removal, disposal
- Proper removal and disposal of materials
- Restoration of site
- Consulting engineer costs – project planning, design, permitting, construction oversight

Dam removal costs can range from tens of thousands (of dollars) to millions, depending on size and condition. Removal costs are primarily the dam owner's responsibility; however, private, local, state, or federal funding may be available. Funding is dependent on site-specific cases and the financial ability of the dam owner. It is important to research potential funding sources that could contribute to the project.

WHERE TO START

For specific guidance on the dam removal process in your state, talk to:

- The State Dam Safety Regulatory Office
- The State Environmental Protection Office
- State Historic Preservation Office
- ASDSO – similar project case studies
- American Rivers – provides dam removal and restoration guidance and funding options

GENERAL STEPS FOR DAM REMOVAL

The following are general steps in a dam removal project. Steps can vary, from project to project, due to site-specific engineering, environmental, and community issues. The expected timeframe of a dam removal project is typically two to three years from conception to completion. In some cases, not all steps will be necessary. Therefore evaluate each step presented here to determine if it is necessary for your project.

1) Site Reconnaissance

- Determine the approximate age of the dam, history of modifications
- Review current use, legal rights (dam and impoundment)
- Research land ownership (around impoundment, dam)
- List infrastructure impacts (utilities, roads, bridges, etc.)
- Identify critical biological resources (habitats, wetlands)
- Identify support/funding opportunities
- Assess historical land use (gauge sediment quality)
- Assess community interests/concerns

2) Feasibility Study

- Collect existing data, survey existing conditions
- Assess sediment quantity, quality, mobility
- Assess hydrology and hydraulics
- Develop conceptual plans (removal/modification of structures, sediment management, channel / riparian habitat restoration)
- Analyze other site-specific issues (utilities, wetlands, rare/endangered species, historical sites, etc.)
- Identify required federal, state, and local permits (complete necessary calculations)
- Develop cost estimates
- Develop conceptual drawings (dam removal and channel restoration)

3) Work with the Community

- Hold stakeholder/community meeting(s) - review alternatives, obtain local support for preferred alternative
- Hold pre-permitting meeting(s) – contact or meet with local, state, and federal planners, environmental regulators, dam safety officials, etc. to clarify/confirm regulatory review requirements

4) Final Engineering Design & Permitting

- Develop design plans for the preferred alternative (modifications, dam removal, and stream restoration)
- Develop project specifications (specify construction equipment, material specs and quantities, project sequencing, staging areas, and site access)
- Provide an Engineer's Cost Estimate for construction
- File all regulatory permits
- Attend public hearings
- Address public and regulatory agency comments and permitting conditions

5) Project Implementation and Construction

- Hire contractors
- Drawdown impoundment
- Address impoundment sediments, as necessary
- Modify/remove dam structure
- Stream channel restoration
- Impoundment revegetation

RESOURCES

ASDSO Resources
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Funding Resources
American Rivers:
americanrivers.org/river-restoration-funding-sources

Dam Ownership
Fact Sheet

TOPIC:

PUBLIC SAFETY AT DAMS

Dams are becoming public destinations for a wide range of recreational activities. Many of these activities make use of dam features for extreme sports and other unauthorized and unsafe actions for which they were not intended. In addition, not all accidents and fatalities are from public use of the sites but from unsafe operations by owners and operators. Several incidences are the result of carelessness during routine maintenance, inspection, or observation. Many accidents and fatalities are due to first responders and good samaritans succumbing to the hazard(s) while attempting to rescue victims or by maintenance staff and others working around dams.

Safety at Dams is a term used to describe the identification, management, and treatment of all risks to the public around existing dams, except those risks associated with dam failure. This includes all access and uses, permitted or not permitted, on or near a dam and its accompanying water bodies, hydraulics, accessories, and facilities.

WHO NEEDS TO KNOW THE HAZARDS AROUND DAMS?

This concerns the following stakeholders:

- Owners
- Operators
- Engineers
- Regulators
- Recreationists, hikers, bikers, runners, campers
- Boaters, kayakers, canoeists
- Swimmers, tubers, floaters
- Fishermen, campers, wildlife
- Ice users, skiers, skaters
- Outdoor and water enthusiasts

HAZARDS AROUND DAMS

Public Safety at Dams includes hazards that mthe public may encounter at and around all dams, such as those associated with:

- Swift and turbulent currents near intakes and spillways,
- Changes in flows and water levels associated with the operation of gates,
- Falls from slippery surfaces and heights, or
- Accidental contact with the mechanical and electrical components of the facility

Although the most significant hazard and cause of fatalities is the transient submerged hydraulic jump or hydraulic roller that is often attributed to flow over low-head run-of-the-river dams, many other hazards exist at dams that have contributed to accidents and fatalities. Dozens of fatalities resulting from mostly boating accidents occur immediately downstream from larger conventional dam spillways and turbine releases. Other hazardous conditions produced by and around dams include strainers, sudden releases with rapidly increasing flow conditions, confined spaces, unpredictable currents, submerged structures, hidden dam crests, watercraft over spillways, entrapment, stranding, bridge, and box culvert apron drop-offs, and steep slopes and slippery surfaces.

LIMITING LIABILITY

Some ways to limit liability and accidents short of removal, repair, or mitigation of the hazard are:

- Signage
- Fencing portage and bypass channels
- Safety booms and marker buoys
- Audible sirens and visual alerts (e.g. strobes)
- Stepped opening of spillway gates and other operational considerations
- Pre-release warning patrols and site security
- Video surveillance and other techniques
- Public education

Coordination and communication with stakeholders and partners such as rafting and fishermen groups are important, along with police, fire and emergency management, dam owners, engineers and operators, and the general public.

DAM OWNER SOLUTIONS

Several steps have been identified for dam owners to pursue to reduce the hazard and liability of HHS and to proceed with the 'actions of a reasonable person that is the legal litmus and precedent. Here is a list of common, but not comprehensive, steps:

1. Identify, inventory, and recognize all low head dams in their portfolio and jurisdiction

2. Identify all potential co-owners, partners, stakeholders, funding sources, and authorities

3. Contact State and Federal Dam Safety authorities for help in dam inventory, ownership, and use quantification and hazard assessment

4. Identify existing programs for mitigation and public education assistance with local and national emergency response agencies, police and fire departments, and wildlife and boating organizations

5. Promote a public education campaign using social media, web pages, signs, pamphlets, interpretive displays, public service announcements and warnings, newspapers, and magazines

6. Develop non-structural mitigation strategies such as signage, fences, log booms, or barriers creating portages and exclusion zones

7. With your engineer, quantify the flow ranges when these low head dams are most hazardous using models and simulations

8. Develop structural mitigation solutions or removal options for the low head dams and funding sources

RESOURCES

FEMA National Dam Safety Program
Dam Safety Warning Signs Best Practices: *bit.ly/3ONF5No*

ASDSO Resources
Public Safety At Dams Webpage: *Damsafety.org/public-safety*

Government of Ontario
Public Safety for Dam Owners Webpage: *ontario.ca/page/public-safety-dam-owners*