Inspection and Maintenance of Your Earthen Dam

Version 1.6, 2024

An informational booklet for dam owners in Nebraska

Inspection and Maintenance of Your Earthen Dam

Dams provide many benefits across Nebraska, from water for irrigation and livestock, to flood control, to countless recreation opportunities. This booklet has been developed by the Nebraska Department of Natural Resources (NeDNR) as a guide to help you inspect and maintain your dam.

Dams require maintenance

Routine maintenance assures your dam will operate as intended, help prevent costly repairs or even dam failure, and preserve the many benefits it provides. Information about common problems found at dams and repair recommendations can be found on pages 6 to 16 of this booklet.

Dams can cause catastrophic damage

In Nebraska, at least one dam fails almost every year, putting lives at risk and causing damage to downstream property. Even a small dam can release large quantities of water and sediment capable of causing catastrophic damage for miles downstream, destroying crops, roads, highways, bridges, buildings, and homes.

Dam owners can be held liable for downstream damage

Nebraska statutes specifically state the owner of a dam shall be liable for all damages arising from the failure of their dam (46-241(5)). Proper maintenance reduces the potential liability associated with your dam.

The most deadly dam failure in U.S. history occurred in Pennsylvania in 1889. The failure of the South Fork Dam killed 2,209 people and caused $450 million in damage (adjusted for inflation). Poor maintenance and alterations to the dam that reduced its spillway capacity contributed to the dam being overtopped by flood water, resulting in the worst man-made disaster in the United States prior to September 11, 2001.

Left: Destruction downstream of South Fork Dam following its failure in 1889.

Kaloko Dam Failure, Hawaii—A private dam owner pled no contest to reckless endangerment for causing the deaths of seven people after his dam failed in 2006. He was charged with seven counts of manslaughter. He was also charged with $12 million in restitution and fees. The EPA portion of the fine—$7.5 million—was the largest penalty against an individual polluter in U.S. history.

Hadlock Pond Dam Failure, New York—A municipally owned dam failed in 2005 and was the subject of litigation. There have been 11 different lawsuits involving 119 plaintiffs. The town and the designers of the failed dam have all been sued. In addition, the town spent more than $4 million replacing the failed dam.

Taum Sauk Dam Failure, Missouri—A private power company paid more than $170 million in restitution and clean-up costs after one of its dams failed in 2005.

Flooding in North Loup, NE following the failure of a dam in 2010. (Photo Source: NWS)

A Dam Owner Needs to:

- Inspect dam routinely
- Ensure proper design, construction, maintenance, and operation
- Invest in repair and routine maintenance
- Know what to do in an emergency
- Know the area that could be affected if dam were to fail
- Design to Industry and State Guidelines
- Recognize Responsibility and Liability
- Avoid short-term “band aid” repairs
- Adhere to State regulations
- Receive NeDNR approval prior to constructing, removing, or modifying a dam

Definitions of common dam-related terms used in this booklet can be found on Page 18.

Inspection of Dams

You should inspect your dam at least three times a year and following any major rainfall to assure:

- Spillways are not plugged or obstructed
- Seepage from the dam has not emerged or increased
- Soil erosion has not developed
- Holes or cracks in the dam have not appeared

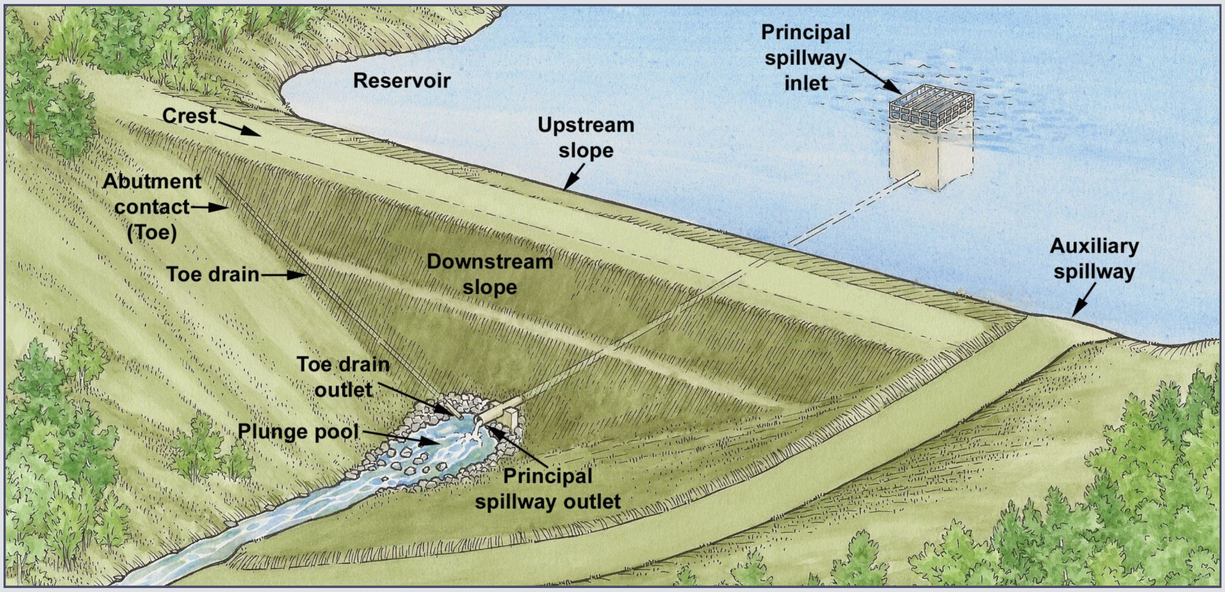
A sample dam inspection checklist can be found on page 4 or downloaded at https://dnr.nebraska.gov/dam-safety/dam-owners. It is a good idea to take photos during inspections to help monitor changes over time.

State Inspections

State law requires NeDNR to conduct routine inspections of all dams in Nebraska with a height of 25 feet or more or a maximum storage capacity of 50 acre-feet or more. Following each inspection, an inspection report is sent to the dam owner. Each report includes:

- A checklist listing all the features that were inspected – see page 4 for sample checklist
- Basic Information about the dam – see page 5
- A list of deficiencies requiring attention. Common problems and maintenance recommendations can be found on pages 6 to 16 of this booklet. These correspond to numbered items in the dam inspection checklist on page 4.
- An overall condition assessment rating for the dam of satisfactory, fair, poor, or unsatisfactory
- Photos of the dam

Typical Dam Configuration in Nebraska



Know What to Do in an Emergency

Signs of a Dam-Related Emergency

- Water is about to flow over the crest of the dam
- Erosion in auxiliary spillway that is progressing upstream and is likely to break through into the reservoir
- Uncontrolled seepage from the dam that is cloudy/muddy and rapidly increasing in flow
- Boil with cloudy/muddy discharge and increasing in flow
- Cracks or sinkholes on dam with increasing downstream discharge
- Sudden rapidly proceeding slides of the dam embankment slopes with seepage emerging from the slide area

What to do in an Emergency

- Notify local law enforcement by calling 911. Be prepared to tell them the location of the dam, the severity and nature of the problem, and the downstream area that may be affected.
- Do whatever is necessary to bring people in immediate danger to safety.
- If time allows, take immediate action to delay, moderate or prevent the failure of the dam. See page 19 for emergency measures to save the dam.
- Call NeDNR at 402-471-2363 for technical advice.

DAM INSPECTION CHECKLIST

DAM NAME:	INSPECTED BY: DATE:

Yes	No	NA	General Conditions	Remarks (References to "left" or "right" are made as if facing downstream)
			1. Recent High Water Marks	
			2. Development in Downstream Floodplain	
			3. Inadequate Vegetative Cover	
			4. Unapproved Alterations to Dam	
Yes	**No**	**NA**	**Crest**	
			5. Settlements or Cracks	
			6. Erosion	
			7. Trees	
			8. Rodent Holes	
Yes	**No**	**NA**	**Upstream Slope**	
			9. Settlements, Slides, or Cracks	
			10. Erosion	
			11. Trees	
			12. Rodent Holes	
			Principal Spillway Inlet	**Water Surface El.:** **Est. Flow Rate:**
Yes	**No**	**NA**	**Size and Type:**	**Drawdown:**
			13. Spalling, Cracking, or Scaling	
			14. Leakage	
			15. Inadequate Trash Rack	
			16. Obstructions	
Yes	**No**	**NA**	**Auxilliary Spillway**	**Type and location:**
			17. Obstructions	
			18. Erosion	
			19. Rodent Holes	
			20. Vegetation Condition Inadequate	
Yes	**No**	**NA**	**Downstream Slope**	
			21. Settlements, Slides, or Cracks	
			22. Erosion	
			23. Trees	
			24. Rodent Holes	
			25. Problems at Drain or Well Outlet	Est. Flow Rate:
			26. Seepage or Boils	Est. Flow Rate:
Yes	**No**	**NA**	**Principal Spillway Outlet**	**Size and Type** **Est. Flow Rate:**
			27. Spalling, Cracking, or Scaling	
			29. Leakage	
			29. Obstruction	
			30. Erosion	
Yes	**No**	**NA**	**Plunge Pool/Stilling Basin**	
			31. Concrete or Riprap Deterioration	
			32. Outlet Channel Obstruction	
			33. Erosion	

Condition Assessment:

Additional Comments:

Basic Information About Your Dam

State-issued inspection reports include basic information specific to each dam. Here is an example:

DAM NAME: CATAMARAN DAM	NID #: NE99999 PLAN #: P-55555 APP #: A-77777 DAM APPROVAL STATUS: Approved
PRIMARY OWNER: Samantha Johnstone Irrevocable Trust % Preston Johnstone 43324 N.W. Second Circle Beaver Crossing, NE 68595	LOCATION: QRT: NW SEC: 36 TWP: 30N RGE: 20E COUNTY: Washington STREAM: Trib. To Norweigen Creek HAZARD CLASS: Low HYDRAULIC CAPACITY: Inadequate
ADDITIONAL OWNERS: John Smith Muddy River Excavating LLC	DAM HEIGHT: 32 feet DRAINAGE AREA: 2.685 acres MAX. STORAGE: 322 acre-ft DAM TYPE: RE-Earthfill NORMAL STORAGE: 62 acre-ft DAM LENGTH: 1,565 ft INSPECTED BY: John Johnson, Jane Miller, George Smith INSPECTED: 05/12/2015 REVIEWED BY: Steve Smitherson, PE

Dam Name: Name of the dam as it appears on the Nebraska Dam Inventory.

Primary Owner: The primary owner of the dam based on NeDNR records.

Additional Owners: If there is more than one owner of the dam, the additional owners will be listed here.

NID #: National Inventory of Dams identification number.

Plan#: NeDNR plan identification number for the dam.

App #: Surface water appropriation number. All dams are required to have appropriation from the State if they have a normal storage capacity of 15 acre-feet or more, or the water in the reservoir is pumped or released for irrigation or some other beneficial purpose. If an appropriation number is listed, it indicates a surface water appropriation has been issued or is pending.

Dam Approval Status: Dams in Nebraska must be approved by NeDNR (*Neb. Rev. Stat. 46-1646 and 46-1670*). The current approval status of the dam is provided here. If a dam is listed as unapproved, it means the dam was constructed or modified without the required permits and approvals.

Location: The legal description for the location of the dam listed by quarter section, section, township, and range.

County: County where dam is located.

Stream: Stream on which dam is located or into which discharge from the dam flows.

Hazard Class: Dams are classified into four hazard classifications based on the potential for loss of life and damage to downstream property if the dam were to fail. The four hazard classifications are high, significant, low, and minimal. The hazard classification is not based on the condition of the dam, only the potential consequences if it were to fail. As the hazard class increases, the design standards and the frequency of inspections increase.

Year Completed: Year in which construction of the dam was completed. If the year is followed by (E), the year listed is an estimate of when the dam was constructed.

Hydraulic Capacity: The hydraulic capacity of a dam is based on its hazard class and its ability to safely pass flood events without overtopping. The number one cause of dam failure is overtopping during a flood. The hydraulic capacity of dams are classified into four categories based on the dam's ability to pass flood water without overtopping:

- Adequate - An engineering evaluation has shown the dam can safely pass an extreme flood event. Nevertheless, an exceptionally rare flood event may still overtop the dam.
- Fair – The dam is capable of passing standard flood events; however, an extreme flood event could result in dam overtopping. Consideration should be given to improving the spillway capacity of the dam.
- Inadequate – An engineering evaluation has shown the dam does not meet the minimum standard to safely pass flood events for the dam's hazard class. A professional engineer should evaluate the dam and determine the best way to increase the spillway capacity of the dam.
- Severely Inadequate – The dam's spillway is severely inadequate and the dam is likely to fail. The reservoir should be drained until a professional engineer can design improvements to the spillway.
- Unknown – There is not enough information available to rate the hydraulic capacity of the dam. Consideration should be given to having a professional engineer evaluate the dam.

Dam Height: Height of the dam from the bed of the stream to the crest of the dam.

Max. Storage: Storage capacity of the reservoir in acre-feet at the crest of the dam.

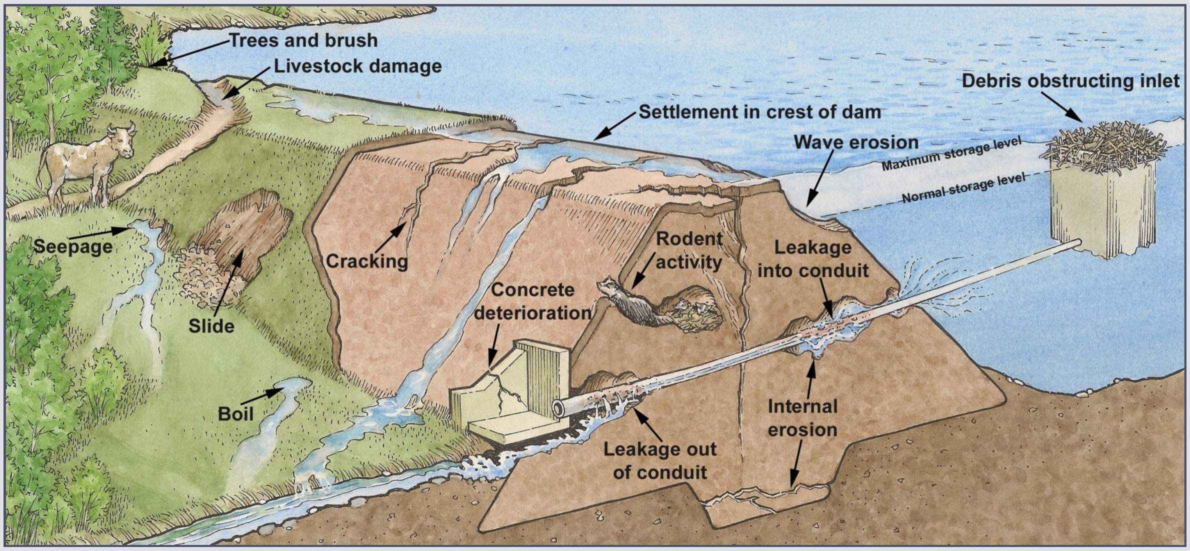
Normal Storage: Storage capacity of the reservoir in acre-feet at the lowest open overflow/spillway or the maximum operating pool if there is no spillway.

Drainage Area: The area of land (in acres) on which runoff from rainfall flows to the dam.

Dam Type: The primary building material that was used to construct the dam.

What is an acre-foot? An acre-foot is a unit of measure commonly used for large quantities of water. One acre-foot of water covers 1 acre of land to a depth of 1 foot. One acre-foot is equal to 43,560 cubic feet or 325,850 gallons of water.

Common Inspection and Maintenance Issues



✓1. Recent High Water Marks. Tree branches, crop residue, or other debris are left behind following high reservoir levels after heavy rainfall. By itself, high reservoir levels are not an indication of a problem at the dam, it is just an indication that the dam was tested by a flood event. It is best to remove storm debris from the dam as it accumulates so it does not damage grass vegetation on the dam or become an obstruction to flow at the spillway inlet.

✓2. Development in Downstream Floodplain. Note downstream buildings and infrastructure that may be damaged if the dam were to fail. New development downstream of a dam, such as the construction of a new home, may result in a change of a dam's hazard class that could result in the need to upgrade the dam to meet higher design standards.

✓3. Inadequate Vegetative Cover.

Probable Causes and Possible Consequences

- Overgrazing, poor weed control, and wave erosion are all common causes for poor vegetative cover on a dam.
- Areas with bare soil or sparse vegetative cover are especially susceptible to damage and erosion.
- Heavy rainfall, high winds, and flood events can cause extensive damage and costly repairs to un-vegetated areas.

Recommended Actions

- Areas of sparse vegetation should be reseeded with perennial grasses each spring or fall.
- It is best to keep livestock from grazing on earthen dams and in vegetated earthen spillways. At a minimum, livestock grazing should be extremely limited.
- Control weeds by mowing or application of herbicides.

A healthy stand of grass is the best defense against soil erosion.

Erosion in auxiliary spillway where grass cover was removed and planted to crops.

✓4. Unapproved Alterations to Dam.

Probable Causes and Possible Consequences

- Unapproved alterations have been made to the dam.
- The approval of NeDNR is required before modifying a dam (*Neb. Rev. Stat. 46-1646*).
- The dam may be susceptible to failure if it is not properly constructed with the right materials, if there is inadequate storage capacity, or if spillways are under-sized.

Recommended Actions

- If possible, remove alterations and return spillways back to the original, approved design.
- Otherwise, have the dam evaluated by a qualified professional engineer.
- The engineer will need to develop updated engineering plans for the dam and submit them with an application for approval to NeDNR.
- If necessary, implement modifications recommended by the engineer and approved by NeDNR.

Alterations to state-regulated dams* that require NeDNR approval include:

- Installing, replacing, or reducing flow capacity of spillways
- Installing new pipes or conduits through the dam
- Raising the crest elevations of spillways so more water is held in the reservoir
- Raising or lowering the crest of the dam
- Placing fill in the reservoir area below the crest elevation of the dam
- Excavations into the dam or spillway
- Reconstructing a dam after it has breached
- Other alterations that increase the normal water storage level in the reservoir, decrease the hydraulic capacity of spillways, or alter the structural integrity of the dam embankment or spillways

*State statutes require NeDNR to regulate all dams in Nebraska with a height of 25 feet or more or a maximum storage capacity of 50 acre-feet or more.

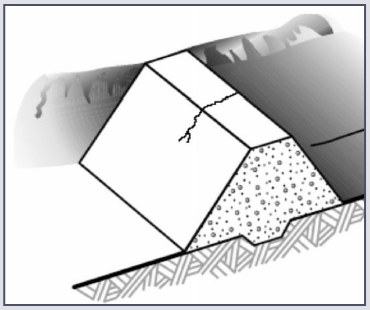
✓5. Settlements or Cracks in Crest

Probable Causes and Possible Consequences

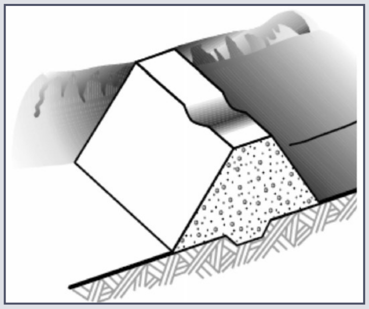
- Uneven movement between adjacent segments of the dam embankment may cause settlements and/or transverse cracking.
- Cracks, settlements, and sinkholes create a point for water to flow through or flow over the dam. When reservoir levels reach the crack, settlement or sinkhole, it can lead to erosion and rapid failure of the dam.
- Embankment slopes that are too steep or saturated soils can cause longitudinal cracking and slides to develop causing serious damage to large sections of a dam.

Recommended Actions

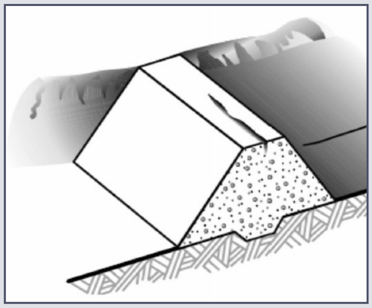
- Shallow settlements should be filled with topsoil and reseeded.
- Shallow cracks should be filled with mud-pack. Mud-pack is made by adding water to a 90-percent earth and 10-percent cement mixture until a slurry of thin cement consistency is attained.
- Deep or reoccurring settlements, cracks, sinkholes and large slides are all potentially serious issues that should be evaluated by a qualified engineer to determine the cause and supervise all steps necessary to reduce danger to the dam and correct the condition.



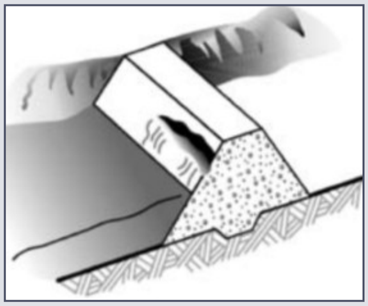
Transverse Cracking



Settlement



Longitudinal Crack



Slide

✓6. Erosion in Crest

Probable Causes and Possible Consequences

- Lack of grass cover, livestock trails, concentrated runoff, waves, and dam overtopping can all lead to erosion of the dam.
- Erosion can lead to deterioration and eventual failure of the dam, especially if the dam is overtopped during an extreme flood event.

Recommended Actions

- Fill eroded areas with soil and establish protective grass vegetation which may resolve the problem.
- It is best to keep livestock from grazing on earthen dams and in vegetated spillways. At a minimum, livestock grazing should be extremely limited. Protect areas by installing fencing. Fences should not be installed across vegetated spillways where the flow velocities could be high.
- Redirect surface runoff away from steep areas by constructing swales and terraces.
- See section 10 on page 10 for more information.

It is best to prevent livestock from grazing on dams and in spillways. (Photo source: USDA)

Dam embankment damaged by livestock.

Failure to address erosion issues as they develop leads to costly repairs.

✓7. Trees on Crest

Probable Causes and Possible Consequences

- Trees and other brush obscure visual inspection of the dam.
- Large tree roots can create seepage paths through earthen dams.
- Large trees can blow over during a storm and damage the dam, which may cause the dam to fail.
- Trees and other brush provide attractive habitat for burrowing animals.

Recommended Actions

- Do not allow trees to grow on the dam. Remove trees and other brush annually. Treat the stumps of deciduous trees with herbicide to prevent regrowth.
- Remove large trees (8-inch diameter trunk or greater) and their roots and backfill holes with well compacted soil. Before removing the roots, the reservoir should be gradually lowered to reduce the risk of serious seepage problems developing during removal.
- If possible, remove trees at the toe of the dam to provide at least a 15-foot buffer around the dam.

Uprooted trees can remove a significant portion of a dam.

Trees make inspecting the dam difficult and provide attractive habitat for burrowing animals.

Seepage through dam damaged by tree roots. Trees should not be allowed to grow on dams. (Photo: ASDSO)

✓8. Rodent Holes in Crest

Probable Causes and Possible Consequences

- Areas of trees, brush, and open water provide ideal habitat for burrowing animals.
- An overabundance of rodents increases the chance of animal burrowing, which creates holes, tunnels, and caverns.
- Tunnels can lead to the collapse of the dam crest and may cause dam failure.
- Tunnels shorten seepage paths which can lead to internal erosion of the dam (see figure in Section 12 on page 10).

Recommended Actions

- Remove trees and brush from the dam and surrounding areas to reduce attractive habitat.
- Start a rodent control program to reduce the population and prevent future damage to the dam.
- Backfill existing rodent holes with mud-pack. Mud-pack is made by adding water to a 90-percent earth and 10-percent cement mixture until a slurry of thin cement consistency is attained.
- Large holes may need to be excavated and backfilled with compacted soil.

To repair damage, large rodent burrows may need to be excavated and backfilled with compacted soil.

Looking inside a rodent hole that extended from upstream to downstream, entirely through a dam (Note daylight in center of photo).

✓9. Settlements, Slides, or Cracks in Upstream Slope

See section 5. on page 7 for more information about settlements, slides, sinkholes, and cracking of dams.

Large slide extending into the crest of a dam. Slides are typically caused by unstable steep slopes and saturated soil conditions following heavy rainfall. Slides can also be caused by rapid draining of the reservoir. (Photo Source: USDA)

A transverse crack is believed to be the cause of this dam failure in Hitchcock County. Poorly compacted soil in the dam or in the foundation is the most common cause of transverse cracking.

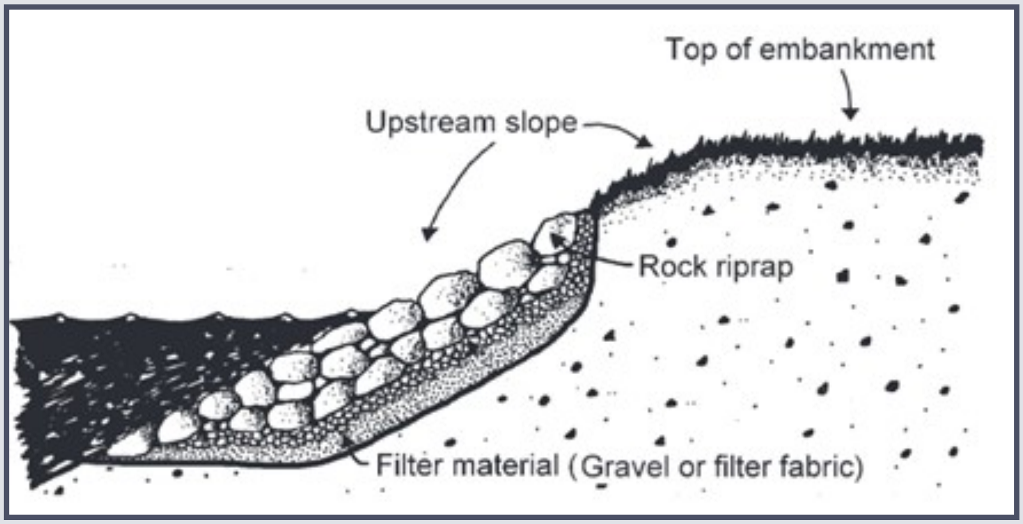
✓10. Erosion of Upstream Slope

Probable Causes and Possible Consequences

- Over time, wave action will erode unprotected earthen slopes decreasing the width of the dam.
- Waves can reach and erode soil through holes between large pieces of riprap.
- See section 6 on page 8 for more information about erosion on dams.

Recommended Actions

- Reestablish the normal embankment slope by placing compacted soil in eroded areas.
- Place filter material such as crushed rock, gravel, or filter fabric under rock riprap to prevent the movement of soil through the riprap.
- Place rock riprap to protect against wave action. Riprap with an equal mix of stones ranging in diameter from 6 to 24 inches is suitable for most situations.
- See section 6 on page 8 for more recommendations to address erosion problems.



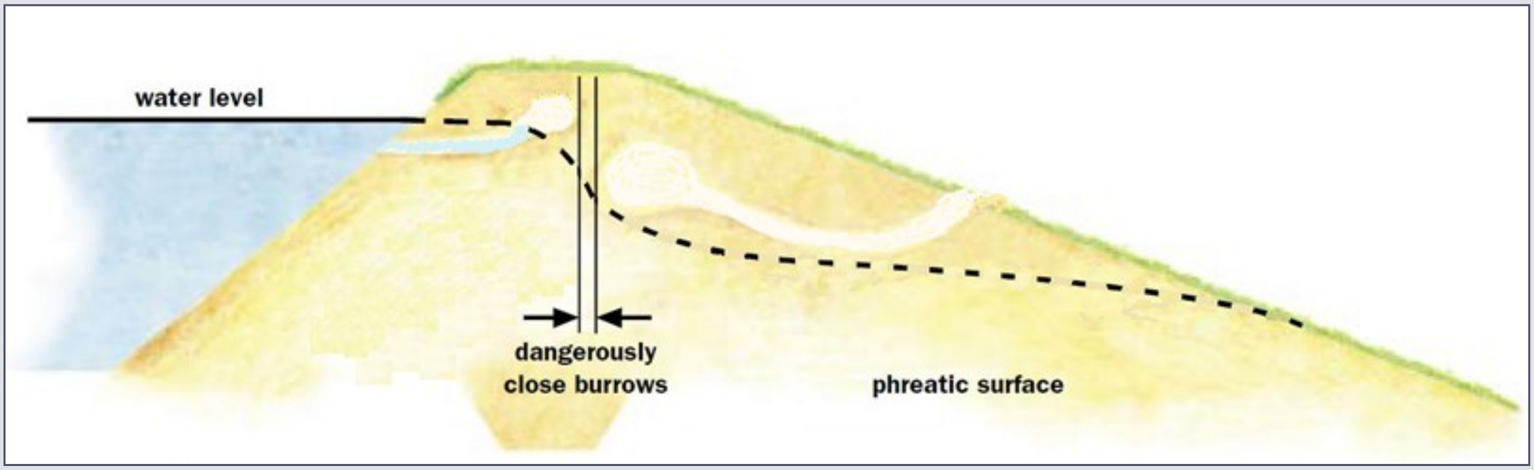
Rock riprap wave protection over filter material such as gravel or filter fabric on upstream slope. The size of the riprap needed depends of many factors, but rocks that are 24 inches in diameter are suitable for most situations. To fill the holes between the larger rocks, it is important to include a mixture of smaller stones ranging in size from 6 to 24 inches. (Diagram source: North Carolina DEQ)

✓11. Trees on Upstream Slope

See section 7 on page 8 for information about trees on dams.

✓12. Rodents holes in Upstream Slope

See section 8. on page 9 for information about controlling rodents on dams.



Upstream and downstream rodent burrows can become dangerously close, making the dam more susceptible to seepage and internal erosion problems that can lead to dam failure. (Diagram source: FEMA)

✓13. Spalling, Cracking, or Scaling of Principal Spillway Inlet

Probable Causes and Possible Consequences

- Natural weathering will cause deterioration of poor quality concrete and corrosion of metals.
- Poorly designed structures will crack, deform, or fail when subjected to excessive pressures and forces.
- Water can infiltrate cracks leading to corrosion of reinforcing steel and breakdown of concrete during freeze-thaw cycles.
- Deterioration can lead to costly repairs.
- Deformation of the inlet can lead to inadequate spill-way capacity and result in dam overtopping.

Recommended Actions

- Small cracks in concrete structures should be sealed with a high quality polyurethane caulk.
- Maintain protective galvanization, paints and coatings on metal structures and reinforcing steel.
- Apply concrete sealers or topcoats to protect slightly weathered concrete.
- Severely deteriorated structures should be evaluated by a qualified engineer to determine the best course of action.

✓14. Leakage into Principal Spillway Inlet

Probable Causes and Possible Consequences

- Leakage can be an early sign of deterioration of the structure.
- Leaks can develop through poorly sealed joints in pipes and concrete structures.
- Leaks can lead to erosion of the soil surrounding the inlet.

Recommended Actions

- Leakage into the intake structure should be monitored to assure other problems do not develop within the dam.
- If desired, small leaks can be sealed with professionally-injected hydrophobic polyurethane foam.
- Severely deteriorated structures should be evaluated by a qualified engineer to determine the best course of action.

✓15. Inadequate Trash Rack on Principal Spillway Inlet

Probable Causes and Possible Consequences

- Without a trash rack, spillways can become plugged with branches, logs, and other debris.
- Trash rack openings that are too small will plug with leaves, weeds, and corn stalks.
- Reduced discharge capacity will cause the reservoir to rise and possibly overtop the dam. Prolonged overtopping can cause dam failure.
- Trash racks are also important to prevent children and livestock from falling into spillways.

Recommended Actions

- The openings of a trash rack should be half the diameter of the spillway outlet pipe.
- Trash racks should be sturdy, constructed of metal, and capable of withstanding the weight of several large logs.
- Install a metal trash rack that has been approved for use in Nebraska. For more information, visit dnr.nebraska.gov/dam-safety/dam-owners.

A properly designed trash rack prevents debris from entering a spillway that are too large to freely pass through, while at the same time, facilitating the passage of smaller trash. Trash racks are also important to prevent children and livestock from falling into spillways.

dnr.nebraska.gov/dam-safety/dam-owners

✓16. Obstructions to Principal Spillway Inlet

Probable Causes and Possible Consequences

- Branches, logs, crop residue, and other debris accumulate at spillway inlets.
- Beavers can plug spillway inlets with debris.
- Reduced discharge capacity will cause the reservoir to rise and possibly overtop the dam. Prolonged overtopping can cause dam failure.

Recommended Actions

- Inspect spillways after large flood events.
- Remove debris in or around spillways and dispose of offsite, away from the dam and reservoir.
- Keep your distance when removing debris so that you do not become trapped in flowing water when the flow increases. The blockage may break loose at any time.
- Remove woody vegetation around inlets to discourage beaver activity.

Spillway inlets must be kept free of obstructions. Trash racks will become plugged if the openings of the trash rack are too small to allow small debris, such as leaves, grass and twigs, to pass. The openings in a trash rack should be about half the diameter of the spillway outlet pipe. A fence to prevent fish passage may be added around an inlet as long as it is kept at least 5 feet from the inlet on all sides, it does not extend more than 2 feet above the normal water level, and it is not placed over the top of the inlet.

✓17. Obstructions in Auxiliary Spillway

Probable Causes and Possible Consequences

- Trees, hay bales, and farm equipment are all common obstructions to flow in auxiliary spillways.
- Fence lines in spillways can catch debris and become a major obstruction to flow.
- Obstructions reduce spillway capacity and cause flow turbulence, scouring, and erosion.

Recommended Actions

- Do not allow trees to grow in the spillway. Remove trees and other brush annually. Treat the stumps of deciduous trees with herbicide to prevent regrowth.
- Do not store equipment or materials in the spillway.
- Relocate fence lines so they do not pass through the high velocity flow areas of a auxiliary spillway. The high velocity flow areas are typically at the spillway crest and areas downstream of the crest.

✓18. Erosion in Auxiliary Spillway

Probable Causes and Possible Consequences

- Lack of grass cover, obstructions in the spillway, concentrated runoff, ruts, and trails can lead to erosion.
- Once erosion begins in the vegetated earthen spillway, the eroded area can grow quickly in size during a large flood, progress upstream, and result in dam failure.

Recommended Actions

- Protect grass vegetation in spillways from damage.
- Replace eroded materials with compacted soil to repair damaged areas and reseed with perennial grasses.
- Check for erosion in vegetated earthen spillways after major storm events.

✓19. Rodent Holes in Auxiliary Spillway

Probable Causes and Possible Consequences

- Rodent holes make earthen spillways more susceptible to erosion when flow passes through the spillway.
- Rodent activity can spread to other areas on the dam.

Recommended Actions

- See section 8 on page 9 for information about controlling rodent damage.

Auxiliary spillway flowing at a dam in Wheeler County. Spillways should be kept free of obstructions such as trees, posts, fence lines, and equipment that will catch debris and cause turbulent flow.

Vehicle paths in the auxiliary spillway led to failure of this dam in Kansas. Vehicle ruts and cattle trails in earthen spillways must be repaired and reseeded to prevent erosion. (Photo source: Darrel Temple)

✓20. Vegetation Condition Inadequate in Auxiliary Spillway

Probable Causes and Possible Consequences

- Farming the spillway, livestock grazing, and vehicle paths remove protective grass cover in vegetated earthen spillways.
- Lack of grass cover can lead to massive erosion and dam failure when water flows through the spillway.
- One imperfection in a vegetated spillway, such as a small patch of dead grass, can be the starting point for erosion.

Recommended Actions

- Do not plant crops in vegetated earthen spillways.
- Seed bare areas with perennial grasses.
- Do not create paths by repeatedly driving vehicles over the same path through the spillway.
- Do not allow cattle to graze in earthen spillways. Fences should not be installed across spillways where the flow velocities could be high. The high velocity flow areas are typically at the spillway crest and areas downstream of the crest.

A well-maintained vegetated earthen spillway has a healthy, dense grass cover (no crops, vehicle ruts, or cattle paths) and smooth slopes (no abrupt transitions). Earthen spillways also must be kept free of obstructions that can collect debris and cause flow turbulence such as trees, fence lines, hay bales, and farm equipment.

Failure of dam in Dixon County due to erosion in the vegetated earthen auxiliary spillway. A healthy, uniform grass cover is critical. One imperfection in a vegetated spillway, such as a small patch of dead grass, can be the starting point for erosion. Once erosion begins, the eroded area can quickly grow in size and breach the dam.

✓21. Settlements, Slides, or Cracks in Downstream Slope

See section 5 on page 7 for more information about settlements, slides, sinkholes, and cracking on dams.

✓22. Erosion on Downstream Slope

See section 6 on page 8 for information about erosion on dams.

✓23. Trees on Downstream Slope

See section 7 on page 8 for information about trees on dams.

✓24. Rodent Holes in Downstream Slope

See section 8 on page 9 for information about rodent holes in dams.

✓25. Problems with Drain or Well Outlets

Probable Causes and Possible Consequences	Recommended Actions
• Some dams have drains or relief wells to control seepage. Over time, the drain/well outlets can become plugged, submerged, or buried and lose their effectiveness in controlling seepage through the dam. • Cloudy or muddy flow from a drain/well could be a sign that water is causing erosion inside the dam. This may be a serious condition that could lead to sudden failure of the dam.	• Mark the location of drain outlets with T-posts so they are easy to locate during inspections. • Conduct routine inspections of drain/well outlets to assure drains have not plugged, water can freely flow from the drain, and water from drain is flowing clear. • Notify NeDNR (402-471-2363) and lower the reservoir level if flow from drain is cloudy, muddy, or if sand particles are flowing from the drain.

✓26. Seepage or Boils along Downstream Slope

Probable Causes and Possible Consequences	Recommended Actions
• Water flowing through or under the dam can cause seepage and boils to develop along or just downstream of a dam. • Seepage and boils can lead to erosion of the dam. • If seepage is cloudy or muddy, or if soil particles are flowing out of a boil; the water is eroding the dam. This may be a serious condition that could lead to sudden failure of the dam.	• Inspect seepage areas frequently, especially when the reservoir level is high. Carefully measure seepage flow so increases in flow can be detected. • Consider having a qualified engineer design corrective measures to control seepage and boils. • If seepage is cloudy or muddy, or if soil particles are flowing out of a boil; lower the reservoir level and notify NeDNR (402-471-2363). See page 19 for emergency remedial actions to save dam.

Sandbags surrounding a boil on the downstream side of a dam to pond water and create back pressure. (Photo source: USDA)

Severe example of a boil and seepage with significant cloudy flow. Cloudy flow is a sign that erosion is occurring inside a dam (Photo source: FEMA)

Cloudy seepage emerging from the downstream slope of dam in Frontier County, an indication that internal dam erosion was occurring. (Photo source: NRCS)

✓27. Spalling, Cracking, or Scaling at Principal Spillway Outlet

Probable Causes and Possible Consequences

- Natural weathering will cause deterioration of poor quality concrete and corrosion of metals.
- Poorly designed outlet conduits and structures will crack, deform, or fail when subjected to excessive pressures and forces.
- Water can infiltrate cracks leading to corrosion of reinforcing steel and breakdown of concrete during freeze-thaw cycles.
- Deterioration can lead to costly repairs, leakage, and erosion of the dam.
- Deformation can lead to inadequate spillway capacity and result in dam overtopping.

Recommended Actions

- Small cracks in concrete structures should be sealed with a quality polyurethane caulk.
- Maintain protective galvanization, paints and coatings on metal structures and reinforcing steel.
- Apply concrete sealers or topcoats to protect slightly weathered concrete.
- Slipline corroded corrugated metal pipes with pressure-tight plastic pipe that is grouted in place or line the pipe with cured-in-place pipe.
- Severely deteriorated outlet conduits and structures should be evaluated by a qualified engineer to determine the best course of action.

Corrosion of the corrugated metal principal spillway pipe led to this dam failure in Adams County.

Rusty corrugated metal pipes can be sliplined with pressure-tight, solid-wall, HDPE pipe. Grout is injected into the space between the old and new pipes. (Photo source: FEMA)

✓28. Leakage in Principal Spillway Outlet

Probable Causes and Possible Consequences

- Leakage is a serious sign of deterioration of outlet conduits and structures.
- Leaks can develop through poorly sealed joints in pipes and concrete structures.
- Water leaking from or into outlet conduits will erode the dam, eventually leading to dam failure.

Recommended Actions

- Poorly sealed joints in conduits can be sealed by professionally-injected hydrophobic polyurethane foam.
- Severely deteriorated structures should be evaluated by a qualified engineer to determine the best course of action.
- Corroded corrugated metal pipes with holes should be replaced. Plans for replacement must be prepared by a qualified engineer and submitted to NeDNR for approval.

✓29. Obstructions in Principal Spillway Outlet

Probable Causes and Possible Consequences

- Branches, logs, crop residue, sediment, and rocks can accumulate in spillway outlets.
- Reduced discharge capacity will cause the reservoir to rise and possibly overtop the dam. Prolonged overtopping can cause dam failure.

Recommended Actions

- Inspect spillways after large flood events.
- Remove debris in or around spillway outlets.
- Keep your distance when removing debris so that you do not become trapped in flowing water when the flow increases. The blockage may break loose at any time.

✓30. Erosion at Principal Spillway Outlet

Probable Causes and Possible Consequences

- The outlet pipe may be too short, causing the discharge to erode the surrounding dam embankment.
- No energy-dissipating plunge pool or stilling basin at the downstream end of the outlet can cause a large scour hole to develop.
- Erosion of the toe of the dam makes the downstream slope too steep and causes progressive sloughing.
- An erosion hole under or next to the pipe outlet may be an indication that the pipe is leaking.

Recommended Actions

- Extend the outlet and drain pipes (match the existing materials and sizes of pipe). Form a watertight connection to the existing pipe(s).
- Stabilize the slope by placing compacted soil.
- Use riprap to protect the dam. Place filter material such as crushed rock, gravel, or filter fabric under riprap to prevent the movement of soil through the riprap.
- See section 28 on page 15 if it is suspected that the erosion is being caused by a leaky pipe.

✓31. Concrete or Riprap Deterioration in Plunge Pool/Stilling Basin

Probable Causes and Possible Consequences

- Natural weathering will cause deterioration of poor quality concrete and riprap.
- Deterioration of plunge pool or stilling basin can lead to erosion and costly repairs.
- A poorly designed plunge pool or stilling basin will fail during high flows and be ineffective in preventing erosion.

Recommended Actions

- See section 27 on page 15 for maintenance of concrete structures.
- Supplement deteriorated and missing riprap with additional rock riprap.
- Severely deteriorated plunge pools and stilling basins should be evaluated by a qualified engineer to determine the best course of action.

A well-designed plunge pool (left, right) or stilling basin (center) can prevent erosion at the outlet of spillway pipes.

✓32. Outlet Channel Obstructed

Probable Causes and Possible Consequences

- Beaver dams, accumulated sediment, and other obstructions placed in outlet channels can back water up into spillway outlets, reducing their capacity.
- Reduced discharge capacity will cause the reservoir to rise and possibly overtop the dam. Prolonged overtopping can cause dam failure.
- Standing water in corrugated metal pipes accelerates corrosion.

Recommended Actions

- Remove beaver dams, sediment, and other obstructions in outlet channels so water does not back up into spillway pipes.
- Use extreme caution when attempting to remove accumulated debris during periods of high flow.
- Keep your distance when removing debris so that you do not become trapped in flowing water when the flow increases. The blockage may break loose at any time.

✓33. Erosion in plunge pool/stilling basin

See section 30 above for information about erosion in plunge pool/stilling basin.


Spillway outlets must be free flowing to discharge water as designed.


Severely corroded principal spillway pipe in Jefferson County.


Standing water in outlet pipes accelerates corrosion of metal pipes and reduces spillway capacity.

Fact or Fiction – Common Beliefs about Dams

FICTION	FACT
"Dams are like roads and bridges; the government takes care of them."	Most dams in Nebraska are privately owned. Dam owners are responsible for maintenance and operation. Private dam owners are responsible for 56% of the dams in Nebraska.
"That dam has been here for years; it's not going anywhere."	Advancing age can make dams more susceptible to failure. As dams get older, deterioration increases and repair costs rise. Some common problems of older dams are: • Deteriorating metal and concrete – after 40 years, metal rusts and fails – concrete cracks and breaks. • Undersized spillways – the spillways at many older dams were not designed to modern standards • Years of neglect can leave dams riddled with rodent holes, rotting tree roots, and severe surface erosion.
"I have lived here for 30 years and the water doesn't get that high."	Personal observations alone are unreliable in predicting the potential for future flooding. As a general rule, it can always rain more; there can always be a bigger flood. Every year, there are stories of unprecedented flooding somewhere in the United States. Consider a few recent examples of record flooding in Nebraska: • The 2008 flood on Shell Creek near Columbus was 40% larger than any previous flood dating back to 1947. • Record flooding occurred up and down the Elkhorn River in 2010. The record flow set at the Norfolk Gage, which has been in place since 1897, was more than double the previous record. • An unprecedented volume of flooding occurred along the Missouri River in 2011, far exceeding what had been seen in the previous 114 years of record.
"Trees are good for dams; they help reinforce the soil."	Trees have extensive root systems that penetrate deep into the soil. In an earthen dam, tree roots can extend entirely through the dam, providing seepage paths for water. After a tree dies, the tree roots will decay, leaving a hole for water to flow through the dam.
"The Army Corps of Engineers is responsible for most of the dams in Nebraska."	The Nebraska Department of Natural Resources regulates all dams in Nebraska that are 25 feet or more in height or have a maximum storage capacity of 50 acre-feet or more. The Army Corps of Engineers has responsibility for only 16 of the more than 2,900 regulated dams in Nebraska.

Dam-Related Terminology

(See Page 5 for more dam-related terms)

Abutment—The natural ground on either end of the dam.

Auxiliary spillway—Secondary spillway through which flow is discharged from the reservoir in excess of what can pass through the principal spillway. Also commonly used to refer to any vegetated earthen spillway channel through which flow is discharged over or around the dam.

Berm—A nearly horizontal step in the upstream or downstream slope of a dam.

Boil— A disturbance downstream of a dam where water is escaping under pressure. The boil may be accompanied by deposition of soil particles in the form of a conical-shaped mound (miniature "volcano").

Breach—An opening through a dam that allows the uncontrolled draining of a reservoir. A controlled breach is a constructed opening. An uncontrolled breach is an unintentional opening caused by discharge from the reservoir.

Channel—A general term for any natural or artificial facility for conveying water.

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

Crest of dam—See "Top of dam."

Crest of spillway— The level at which water can begin to flow over the spillway.

Dam—Any artificial barrier with the ability to impound water, wastewater, or other liquid-borne materials.

Drainage Area—The area of land on which runoff from rainfall flows to the dam.

Drawdown—A low-level conduit or opening used to empty or nearly empty a reservoir.

Embankment—A bank, mound, wall, or dike built from soil or rock to hold water.

Emergency Spillway—See Auxiliary Spillway.

Foundation—The soil or rock upon which a dam is constructed.

Hazard Potential Classification—The classification given to a dam based on its potential to cause loss of life and damage to downstream property due to failure or misoperation of the dam.

High Hazard Potential— A hazard potential classification given to dams where failure or misoperation of the dam would result in probable loss of human life.

Inlet—The location where flow enters a pipe or spillway.

Internal Erosion—The gradual loss of soil within or under an earthen dam due to seepage or flowing water.

Low Hazard Potential—A hazard potential classification given to dams where failure or misoperation of the dam would result in no probable loss of human life and in low economic loss.

Minimal Hazard Potential—A hazard potential classification given to dams where failure or misoperation of the dam would likely result in no economic loss beyond the cost of the structure itself and losses principally limited to the owner's property.

Outlet—The location where flow exits a pipe or spillway.

Outlet Channel—The open stream or channel that carries water downstream, away from a dam.

Orifice—A small opening built in the wall of a riser or spillway that allows water to enter.

Overtopping—The rising of the reservoir level to where water is flowing over the top of the dam.

Phreatic surface— The upper surface of seepage in an embankment. All the soil below this surface in a dam will be saturated with water.

Plunge Pool—A natural or artificially created pool at a spillway outlet that dissipates the energy of free falling water and prevents erosion.

Principal Spillway—The lowest open structure over or through which flow is discharged from a reservoir.

Riprap—Broken rock or concrete of varying size that is placed to provide protection from erosion.

Riser—A vertical pipe or box constructed at the principal spillway inlet to set or control the discharge through the dam and the water level in a reservoir.

Seepage—The movement of water through the interior of a dam, the foundation, or the abutments.

Settlement—The vertical downward movement of a dam, a structure, or its foundation.

Significant Hazard Potential—A hazard potential classification given to dams where failure or misoperation of the dam would result in no probable loss of human life but could result in major economic loss, environmental damage, or disruption of lifeline facilities.

Slide—The movement of a large mass of earth or soil down a slope.

Sinkhole—A depression caused by collapse of surface materials due to movement of water removing underlying soil.

Slipline—Lining of a deteriorated spillway pipe with a smaller diameter pipe to provide water-tightness, prevent erosion, and provide structural support, and then filling the space between the two pipes with cement grout.

Stilling Basin—A concrete structure that dissipates the energy of rapidly flowing water from a spillway to prevent erosion.

Toe Drain—A system of pipe and/or pervious material along the downstream toe of a dam used to collect seepage and convey it to an outlet.

Toe of the dam—The junction of the slope or face of a dam with the natural ground surface.

Top of dam—The elevation of the uppermost surface of a dam.

Trash rack—A device located at an inlet to prevent large debris from entering and plugging a spillway.

Weir—The part of a spillway consisting of a wall or barrier over which water flows. It controls the discharge through the dam and the water level in a reservoir.

Well Outlet—The location where flow exits a vertical shaft or well installed on the downstream side of a dam to collect and control seepage through or under the dam.

Emergency Actions to Save a Dam

If dam failure is imminent, call 911 and do whatever is necessary to bring people in immediate danger to safety

Emergency Condition Observed at Dam	Emergency Remedial Actions to Save Dam (call NeDNR at 402-471-2363 for technical advice)
• Water is about to flow over the crest of the dam	• Place sandbags along the low areas of the top of the dam to control wave action, reduce the likelihood of flow concentration during minor overtopping, and to safely direct more water through the auxiliary spillway. • Cover the weak areas of the top of the dam and downstream slope with riprap, sandbags, plastic sheets, or other materials to provide erosion-resistant protection.
• Erosion in auxiliary spillway that is progressing upstream and is likely to break through into the reservoir	• Place rockfill or sandbags upstream of the eroded area to slow/redirect the flow of water. • Excavate a long, shallow ditch around the other end of the dam to safely lower the reservoir level.
• Uncontrolled seepage from the dam that is cloudy/muddy and rapidly increasing in flow • Boil with cloudy/muddy discharge and increasing in flow • Cracks or sinkholes on dam with increasing downstream discharge	• Open spillway gate and set up pumps or siphons to lower the reservoir level. • Plug the entrance to the seepage origination point with readily available materials such as hay bales, bentonite, soil, sand, rockfill, or plastic sheeting. • Cover the seepage exit area(s) with several feet of sand, gravel, and rock to hold fine-grained embankment materials in place. • Construct sandbag or other types of ring dikes around seepage exit areas to retain a pool of water, providing backpressure and reducing the erosive nature of the seepage. (see photo on page 14)
• Sudden rapidly proceeding slides on the dam embankment slopes with seepage emerging from the slide area	• Open spillway gate and set up pumps or siphons to lower the reservoir level. • Repair settlement of the crest by placing sandbags or earth and rockfill materials in the damaged area. • Stabilize slides by placing a soil or rockfill buttress against the toe of the slide.

The Nebraska Dam Safety Program
-Protecting Nebraskans from Dam Failures-

Nebraska Department of Natural Resources (NeDNR)
Dam Safety Section
402-471-2363

Want more information?
Visit: dnr.nebraska.gov/dam-safety
or damowner.org

This booklet was written and designed for a wide audience and covers the most common problems and deficiencies found at small earthen dams in Nebraska. If you have a deficiency that is not addressed in this booklet, you may need to contact a professional engineer for assistance. A list of professional engineers with dam-related experience is available by calling NeDNR at 402-471-2363. NeDNR may also have specific requirements and recommendations for your dam that are not included in this booklet based on its condition, size, and hazard class.

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