

SPECIAL EDITION

# KANSAS DAMS

2014

## OPERATION & MAINTENANCE



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This publication was written and designed by C. A. Higgins in compliance with the public awareness objective of the federal Dam Safety Act from funding provided by the U.S. Department of Homeland Security, Federal Emergency Management Agency.



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## DAM OPERATION AND MAINTENANCE WORKSHOPS



Division of Water Resources dam safety staff routinely offer workshops on dam maintenance and inspection throughout the state of Kansas. In the last decade, for example, staff offered 25 on-site workshops, in addition to conference sessions and on-site consultation.

In the past year, the USDA-Natural Resource Conservation Service along with the Kansas Department of Agriculture's Division of Conservation and DWR co-sponsored workshops focusing on the annual dam inspection form used by DOC and NRCS, which lists similar criteria to DWR forms. After each presentation and lunch, attendees journeyed to a nearby dam to practice using inspection forms.



The 2013 workshops in Eureka, Holton, and Little River were attended by individuals from watershed districts and the local NRCS conservations. Additional 2014 workshops took place in Lincoln, El Dorado, and Holton.



## WHY INSPECT?

Early identification can reduce later repair bills, be a funding agency requirement, and prevent dam failure. Inspections should be done every year and after extreme storm events or other events that can cause damage to a dam.

Regular inspections as well as inspections done after unusual events such as heavy rains or windstorms prolong a dam's lifespan, reduce costly repairs, and safeguard downstream property and lives.

When inspecting a dam, prepare first by reviewing design criteria, operation records, and past reports. Know the location of the dam's parts such as drains or instrumentation and have necessary instructional manuals.

Document observations and measurements for each inspection because an inspection is basically a comparative analysis of the dam's present and past condition. For instance, after taking a photograph, indicate in notes the location from where the photograph was taken and the direction faced for reference. Also, if photographing a depression, it may not be as obvious where it is without a sketch indicating location.

Besides using a camera for documentation, other useful items to take on an inspection are a checklist to remember what to look for, pen and paper to make a dam sketch showing problem areas, surveying rods, measuring tape, bucket and a timer for seepage, surveying equipment, lights for pipes or hard-to-see areas, machete to clear vegetation, and a shovel for drains that have been plugged.



## STATE OF KANSAS O & M REGULATIONS

With the goal of reducing risks to life and property from dam failure, Kansas has enacted regulations monitored by the Dam Safety Program



State of Kansas regulations require the inspection of high-hazard dams Class C every three years and significant hazard dams Class B every five years. These hazard classifications indicate the possible downstream impact of dam failure and do not refer to a dam's condition.

From 2007 to 2010, Division of Water Resources engineers inspected high hazard and significant hazard dams and contacted owners if they observed any deficiencies. These state-funded inspections now must be done by licensed engineers at the owner's expense and submitted to DWR for review within 60 days after the inspection.

DWR provides a voluntary list of engineers who offer services related to DWR's regulatory duties. This list does not constitute an endorsement or guarantee of the accuracy, timeliness, or completeness of the information provided, nor does it imply an endorsement or recommendation for the services these engineers provide.

If an owner fails to submit an inspection report by a licensed engineer with at least five years of experience, DWR will do the inspection and charge its cost to the landowner.

Current law does not require low hazard dams to be inspected.



Besides safety inspections, Division of Water Resources dam inspections include:

- Pipe inspection (new construction and replacement)
- Core trench inspection
- Final construction inspection



Typical danger signs that state inspectors have noted include blocked trash screens, excessive woody vegetation, and excessive erosion of slopes or spillway.

Regular maintenance helps correct these problems before they become dam failure causes.

# DWR DAM INSPECTION FORMS

Having a checklist ensures required inspection data is recorded, said Kim Hunninghake, P.E., who developed an inspection checklist in compliance with Division of Water regulations.

Each dam safety inspection report required by K.S.A. 82a-303b and amendments documents an engineer's observations made during the inspection and includes the engineer's opinion of the dam condition. Submitting the report is in compliance with regulation K.A.R. 5-40-90 requirements.

Kimberly Hunninghake, who manages the dam safety program at Division of Water Resources, said staff have been reviewing dam safety inspections and prepared a checklist for engineers to ensure they are submitting required information.

The checklist, *Dam Safety Inspection Report Requirements and Guidelines*, is not required by regulation, but is recommended by the Chief Engineer as a report supplement.

"Because items have been missing from reports, we made this form to help engineers have a checklist to submit with reports," Hunninghake said. "It helps us review inspection reports quicker and makes sure all is submitted as by K.A.R. 5-40-90. If certain items are not in the report, we could reject the report and send back to for corrections."

Hunninghake said that while regulations do not require email addresses, she suggests including the email address of the submitting engineer for quicker responses in communications. Including email addresses for

dam owners is advised, too, so when owners are sent emails, engineers can be copied the same information pertaining to dams. In addition, although dam owner information is stored in DWR databases, ownership changes and other factors can make it difficult to verify and contact owners, so owner contact information inclusion in a report is recommended for accurate communication.

"Hazard class is what we have identified it as. It's also what you think. Expand upon your hazard classification identification and on what you based your conclusion.

For example, if two homes are identified as reasons for the hazard classification, you could restate both homes are still there with no further developments, and expand on that. Or you might disagree with the classification and explain why."

Check boxes on the form that apply. For example, three spillways are indicated on the form; however, depending on the dam, it may have only one. Add information such as water level at the time of inspection and other relevant findings, Hunninghake said.

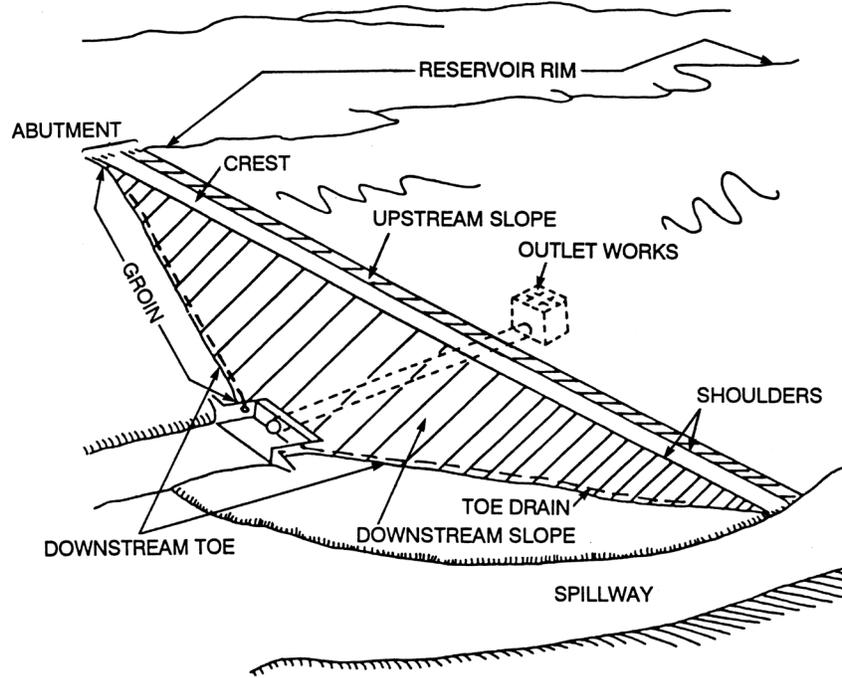
Or if there aren't any drains, identify that. If there are, tell how many, where they are located, any discharge, color of discharge, and other relevant information. Is there a drawdown valve?

Often, engineers fail to mention if one is there and whether it is operable or has deficiencies. Note, too, whether the dam needs an emergency action plan. If it has one, which is required for significant and high hazard dams, indicate the last time it was updated.

The appendix, which is required by regulations, should contain deficiencies, hazard location map and identification as well as other needed items.

Hunninghake, pictured below, through the years has done many dam inspections in all parts of the state.





## WHAT'S WHAT ON A DAM

Know the parts of a dam and terms associated with dams to make inspections more effective.

**Abutment:** Valleyside part against which dam is constructed

**Berm:** Nearly horizontal step (bench) in embankment.

**Crest:** Uppermost elevation of embankment dam.

**Conduit:** Closed channel that conveys water through, around, or under dam.

**Drain, toe, or foundation:** Water collection system of sand and gravel to collect seepage and convey it to a safe outlet.

**Foundation:** Natural soil or rock on which the dam is placed.

**Freeboard:** Vertical distance between stated water level in reservoir and dam top.

**Gate:** Operable, watertight valve to manage discharge of water.

**Groin:** Area along intersection of dam face and abutment.

**Outlet works:** Appurtenant structure that provides for controlled passage of normal water flows through the dam.

**Reservoir:** Body of water impounded or potentially impounded by dam.

**Riprap:** Layer placed on an embankment as protection against wave action, erosion, or scour.

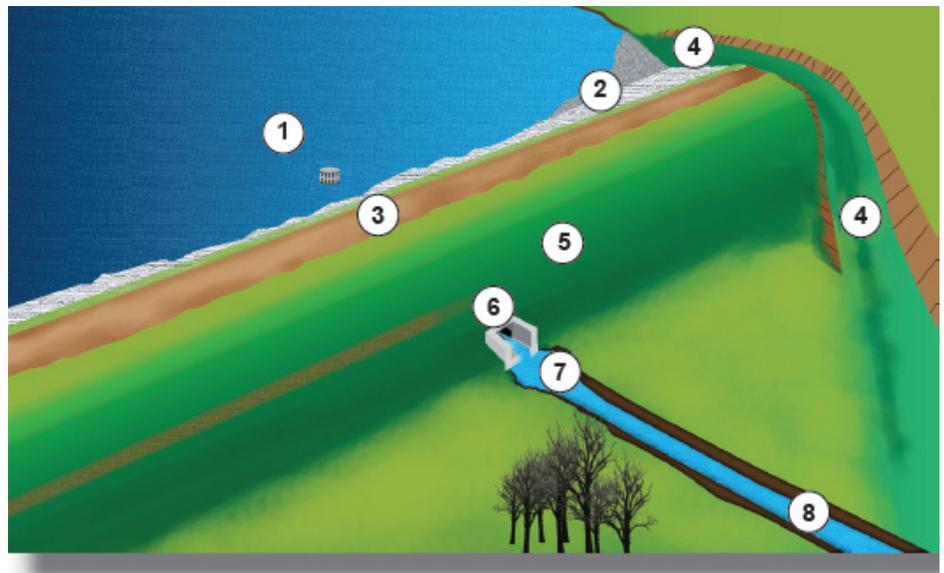
**Slope:** Side of an embankment

**Spillway (auxiliary or emergency):** Appurtenant structure that provides controlled conveyance of excess water through, over, or around dam.

**Stilling basin:** Area constructed to dissipate energy of fast-flowing water to prevent erosion.

**Toe of dam:** Junction of the upstream or downstream face of an embankment with ground surface.

**Trashrack:** Device located at an intake to prevent floating or submerged debris from entering intake.



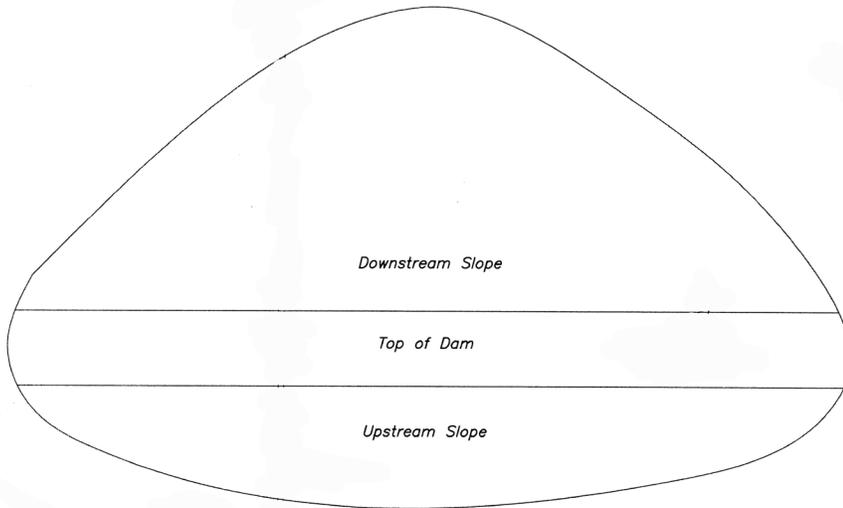
**Note:** Individual dams vary in design and not all dams have the same features.

- 1. Intake Structure and Reservoir
- 2. Upstream Embankment
- 3. Crest
- 4. Auxiliary Spillway

- 5. Downstream Embankment
- 6. Conduit and Outlet
- 7. Plunge Pool
- 8. Outlet Channel

Image courtesy of Nebraska Department of Natural Resources

## SYSTEMATIC VISUAL INSPECTION

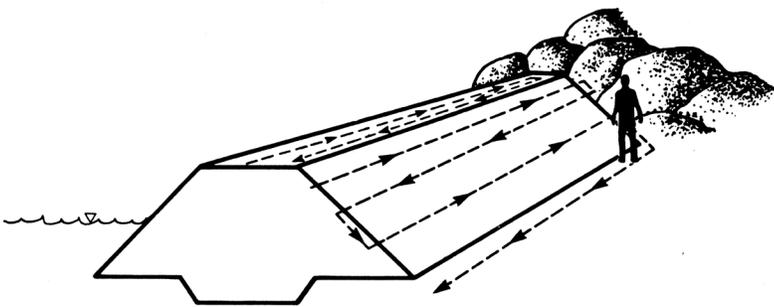


Visual inspection on a regular basis is a cost-savings measure that easily can be done in a day. With guidelines, visual inspection is straightforward procedure that anyone can do to make a reasonably accurate assessment of a dam's condition.

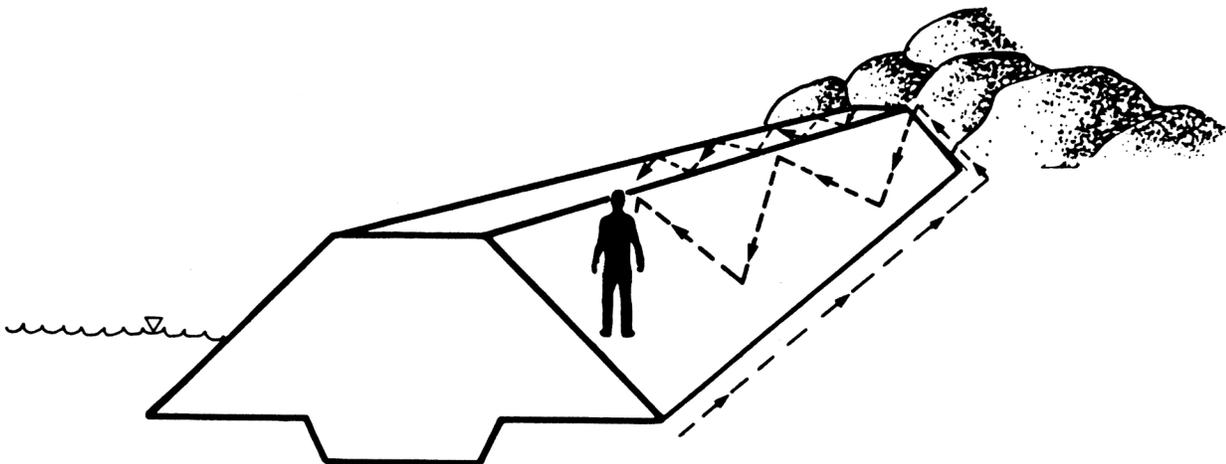
Experienced dam inspectors recommend walking across the crest from abutment to abutment, walking across the slope in an up-and-down or zigzag pattern from abutment to abutment, and walking the entire length of the embankment-abutment contacts (groin).

It's also advisable to check conduits and the entire length of the spillway. Because maps and existing information may not be sufficiently updated regarding locations of residences and property that can be affected by dam failure, inspections should be done in person and far enough downstream to cover the area that could be affected by a dam failure.

Developing problems most frequently appear on downstream slopes. Top of dam (which is called "crest") problems such as misalignment should be studied from either abutment and by sighting the upstream and downstream edges of



Inspection involves careful examination of all dam sections and areas that could be affected by a dam failure.



A zig-zag inspection path is recommended to more easily identify structural problems.

## CHECKLIST SPOTLIGHT

These Kansas dam examples illuminate problems that can be discovered with diligent inspection.

### Sloughing, sliding, slumping

A slow or sudden movement of embankment slope, which is known as slumping as well as sloughing or sliding, indicates instability and needs immediate response.

Two forces act upon soil mass: the driving force of soil weight and gravity that tends to move soil mass downward. Resisting gravity is the slope's material strength and cohesiveness that holds soil mass in place.

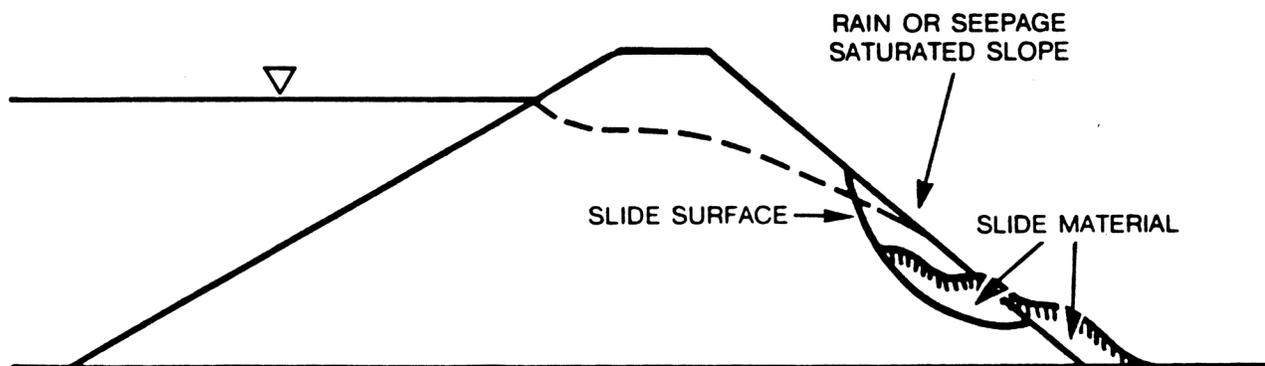
If the driving force is greater than the resisting force, a soil mass will slide along the slip surface and a slope stability failure will occur.

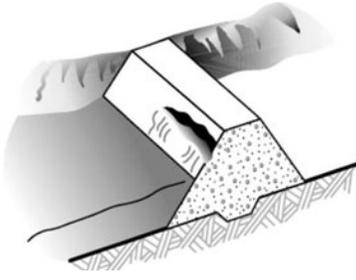


DWR dam inspectors note the slide condition and take measurements as seen in these photographs. When inspecting, evaluate slide extent, monitor slide, draw down the reservoir level if dam threatened, and have qualified engineer inspect the conditions and recommend further actions.



Fill compaction can be a factor in slope failure. A dam should be built with compacted soil that is added in layers, and then compacted before adding another soil layer for optimum stability. *Photo below and left from Leavenworth County.*





Slides can be difficult to detect because slopes may not be uniformly graded. They also might be subtle, which is why dated photographs can be helpful in detecting changes.



Another stability factor is the side slope angle, which shouldn't be any steeper than 3:1. Thus, for every foot in height, the slope must go out 3 foot to the side. If built at a steeper angle, the embankment may lack stability.



Erosion, which can be internal or external, is the one dam potentiality that must be examined carefully during every inspection before it is too late for corrective actions as seen in these photographs that include Butler County and Marshall County.

**Seepage**

Water leaking or passing through or underneath a dam's downstream embankment is seepage. All dams leak; however, the quantity of leakage can be problematic and needs monitoring.



Wetness on a dam, may be evident with springs; water plants such as cattails, or reeds. Watch for increased seepage, especially when reservoirs are at a high level because seepage can lead to embankment erosion. *Left, Douglas County and right, Bourbon County*

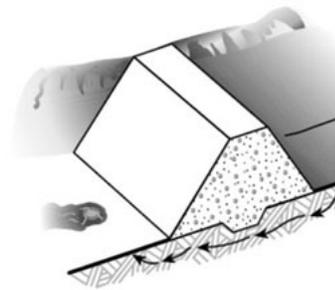
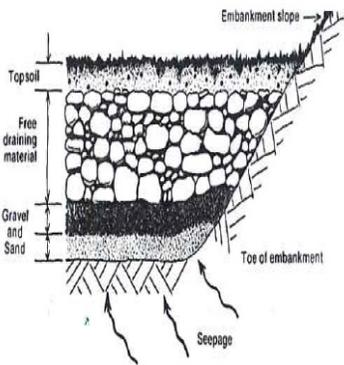


Above and also right, Atchison County seepage evident on left abutment. Above left, Jefferson County seepage.



Look for presence of soil particles. Soil can indicate internal erosion known as piping.

**Boils**



This Doniphan County boil is piping evidence. If a vortex develops, the dam in danger of immediate failure.

Drain systems are often incorporated into dams to collect and control seepage water. These systems prevent erosion and slope saturation leading to embankment slides. At the dam toe, for example, reverse weighted filters can be installed.

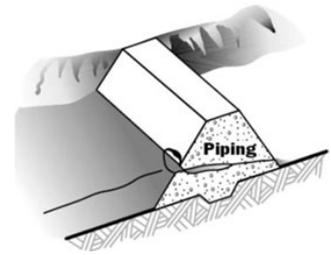


Above, Atchison County

### Sinkholes

Internal erosion, especially piping, can cause a sinkhole evident on a dam's surface.

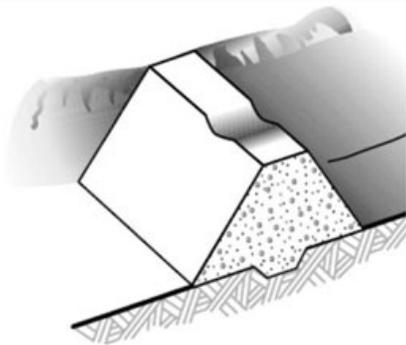
If a sinkhole is evident, report existence to Division of Water Resources if a significant or high hazard dam. Contact a qualified engineer to recommend further actions.



### Fill settlement

An elevation decrease in part of all of a dam indicates a loss of material or inadequate material compression known as settlement. This condition also can result from erosion or inadequate grading and reduces freeboard when at dam top.

If noted, determine the amount and extent of settlement in the crest. Fill in low areas for uniform elevation after consultation with a qualified engineer. Routinely survey for additional settlement.



Settlement above in Brown County is not the same as this Jefferson County sinkhole.



## Cracking

A crack is the place where something has come apart.

If there is something wrong in the material, for example, uneven movement between segments, that might make it easier for cracks to start. Cracks allow water to enter the embankment, and water working to go downstream forces cracks to grow and open.

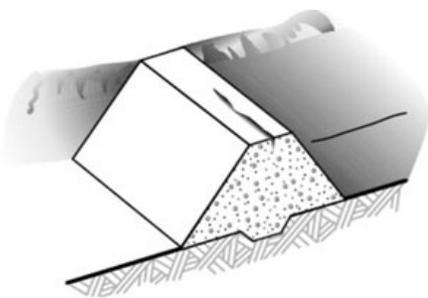
Record location, depth, and width and look for patterns.

When checking for cracks, note whether they are perpendicular or parallel to the dam.

### LONGITUDINAL CRACKS

During the building of a dam, longitudinal cracking that runs parallel with the dam length may happen because of insufficient vegetation with roots to hold the soil.

It also can indicate instability that may require excavation, soil replacement, and slope grading.



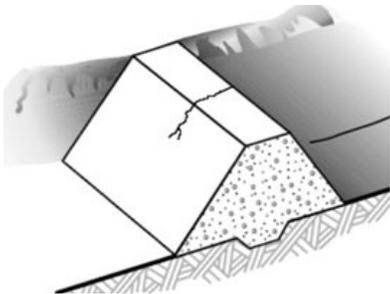
Bourbon County dam

Always measure cracking for comparison purposes.



DWR inspectors measured this transverse crack in their inspection report.

**TRANSVERSE CRACKS**



Transverse cracking is perpendicular to the centerline of the dam. It can indicate differential settlement within the embankment or foundation. This cracking can result in high seepage rates and piping through a dam, especially if the cracks extend into the dam's core.

Corrective recommendations typically include crest excavation along and beneath the crack, and then backfilling using suitable material to seal the crack. This prevents surface water infiltration.



Desiccation cracking will generally be shallow and is caused by drying and wetting of the embankment (especially drying). If this is serious, remove the material and backfill. Most often, a little rain will solve this type of cracking.



## SLOPE PROTECTION



An example of desirable riprap can be seen, left, at this Hodgeman County dam. Below, view eroded riprap needing replacement.



Rock riprap, a common cover material for embankment dams, prevents erosion of dams' upstream faces and may protect during dam overtopping. Consisting of a mix of irregular shaped rocks placed over gravel or geotextile fabric, it absorbs and deflects wave action from the dam. Smaller rocks fill in the spaces between the larger pieces, and a filter prevents soil particles on the embankment surface from washing out between the rock spaces.

For optimum endurance, use dense riprap stone. In Kansas, limestone and hard sandstone are acceptable for riprap. But most sandstone and shale found in Kansas do not provide the long-term protection needed on dams. Larger rocks have to be big enough to break the maximum anticipated wave action and also hold the smaller stones. If too small, the rocks will be washed away by waves. If insufficient, the filter material will wash out causing the embankment to erode.

Freezing and thawing, wetting and drying, waves, and other natural processes will eventually break down the riprap, which will then have to be replaced. Vegetative growth can displace stone and can disturb the filter material. If a dam has severe erosion or reoccurring riprap problems, contact a registered professional engineer to design more effective slope protection.



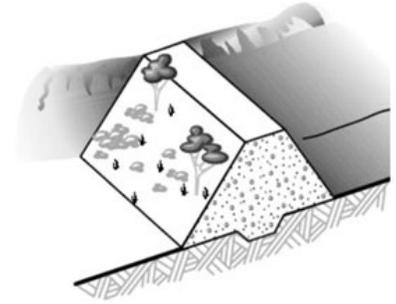
Seeding a dam with a uniform cover of healthy sod-forming grass species not only reduces erosion and makes inspection easier, it filters water entering the reservoir.

Developing a grass groundcover consists of site preparation; choosing the optimum species (and adhering to its seeding methods, rates, and dates); and then maintaining the grass. A thick standing cover crop creates a surface mulch. This mulch, ideally kept damp, minimizes erosion and prevents seed from washing out and down the slopes during rains. When planting surface mulch, consider referring to the Kansas Department of Agriculture's Kansas Certified Weed Free Forage Producers found on the Certified Weed Free Forage and Mulch Program web page.



## Trees

Tree roots can lead to piping. When uprooted, trees also can physically damage a dam by leaving a void. Their presence makes dam inspection difficult and restricts desirable grass growth.



Cut any vegetation less than a foot in diameter at the ground as close as possible. Treat it or paint the stump. Kansas State Extension recommends Pathfinder Two in general and specific solutions for certain trees, for example Milestone for young honey locusts. Remedy in varying concentrations works well in pasture area but not closer to a reservoir.



Photographs on this page show voids made in Kansas dams as a result of tree root damage. While roots may increase soil shear and tensile strength, which increases resistance to mass failure on unstable dam slope embankments, the impact is minimal. Because of their safety magnitude, trees of substantial size should be removed under the direction of a qualified professional engineer. Any questions regarding tree removal may be directed toward DWR because a permit may be required.



### Vegetation

Grass vegetation slows erosion by trapping soil particles, provides an easily inspected surface, and discourages burrowing animals.

Maintenance consists of mowing at least twice a year with recommendations to delay until mid-July to avoid destroying nesting wildlife.

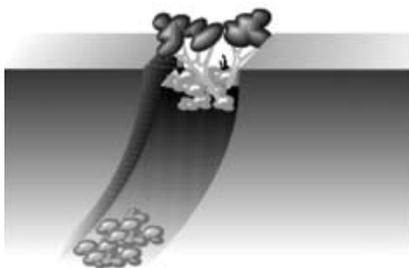


Other maintenance tasks include brush and broadleaf removal, eroded area repair, and annual application of fertilizer to maintain vegetative growth.



Fill joints and cracks with appropriate filler.

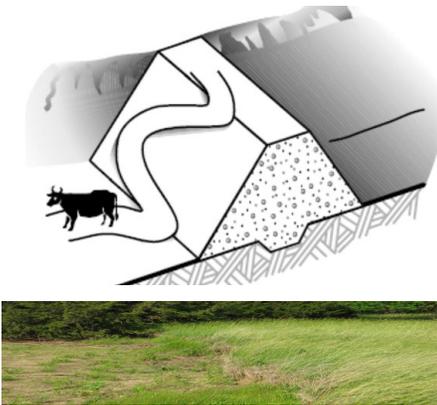
Mowing before inspection, as seen above on Mission Lake in Brown County, makes potential dam safety problems easier to spot. Right, conduits and spillway need to be free of vegetation to properly function.



Reseeding helps establish a desirable surface that prevents erosion.



Unprotected embankment subject to wave action can erode into vertical face to form into a benching condition, which diminishes a dam's maximum storage.



Livestock grazing and livestock paths often cause diminished vegetative cover. Thin grass cover also result from vehicular traffic. If vehicles are allowed on a dam crest, proper road material should be installed.



Fences keep livestock off the dam and away from the waterline onl if they are kept closed and maintained.

**Fencing**

DWR inspectors have found most fences on Kansas dams are made of barbwire and usually are on the front slope to keep livestock off the dam. Check posts to see whether loose, bent, or broken and also wire tension and condition.

Often, a spur fence that goes across the reservoir to keep livestock from getting on the dam during low water can be found, too, and needs to be cleaned of high water debris.



Vegetative growth is hard to maintain in the fence line because it's hard to mow around but still requires diligent maintenance. Signage discourages trespassers and assist dam owners in minimizing exposure to liability.

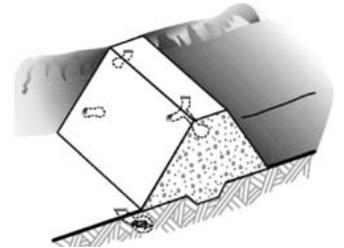
## Rodents

Rodent burrows can result in erosion and possible dam failure. Muskrats, for example, build below the water surface in upward slanting burrows that have a dry chamber above the waterline. Woodchucks and groundhogs burrow into the downstream face of a dam above the phreatic surface. Burrow signs include fresh dirt at burrow openings and paths.

Mowing, riprap, waterline fencing, and water vegetation elimination discourage den building. Natural control often can be achieved by providing perch sites for predatory birds such as hawks, owls, and eagles.



This path on an Atchison County dam indicates the presence of burrowing animals.



Fill holes with compacted material. A common suggested recommendation is to backfill burrows with a slurry mix of water, soil (90%), and cement (10%).

After compaction, reseed disturbed area to discourage additional burrowing and erosion.

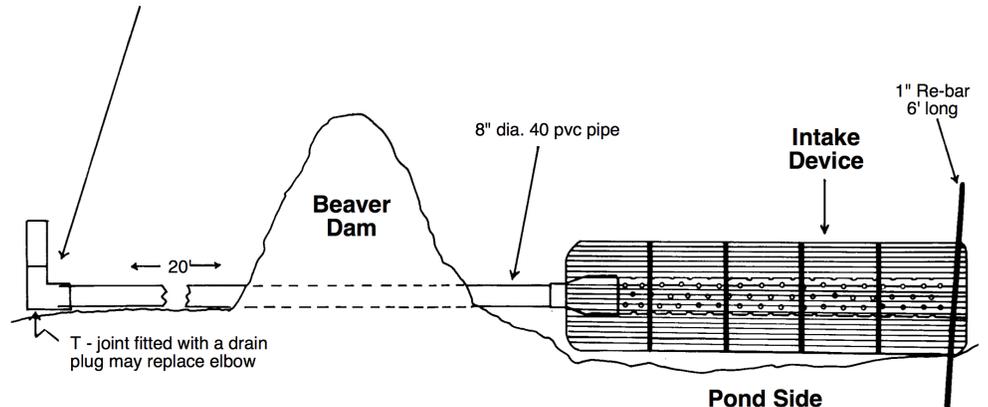




Beaver burrows often run deep below the dam surface causing hydraulic alteration and structural integrity loss. Beavers can lock a dam's spillway and intake structure with building materials, which raises the reservoir water level in a reservoir and impairs spillway integrity. Besides trapping, devices such as The Clemson University Beaver Pond Leveler, seen below, can retain beaver building benefits and maintain a dam's structure.



Elbow and stand pipe are optional. Needed only to manage water level if maintaining pond is an objective



**PRIMARY SPILLWAY**



The above photograph shows evidence of erosion by the pipe that needs to be corrected. Below, corrugated metal pipe in Pottawatomie County has outlived its lifespan and needs replacement.



Spillways provide a safe exit for reservoirs' excess water. Spillways should be kept free of obstructions, have the ability to resist erosion, and be protected from deterioration.

Primary problems with a principal spillway include:

- Inadequate capacity
- Obstructions
- Erosion
- Deterioration
- Cracks
- Undermining
- Observable horizontal or vertical misalignment of pipe
- Condition of concrete in riser
- Leaky pipe joints



Check for damage, obstruction, or corrosion of trash rack.

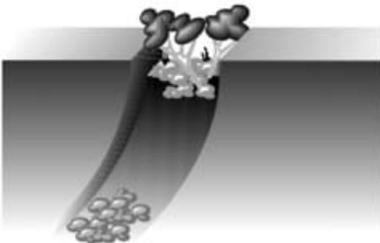


### AUXILLIARY SPILLWAY

Check auxilliary spillways for adequacy of grass vegetation; sloughing, sliding, or erosion of slopes; damage by livestock, vehicles, or poor drainage; and obstructions by woody plants, fences, and debris. Obstructions impede flow because discontinuities cause higher stress during flow making them the first areas to erode during spillway flow.



Permanent structures such as fences should not be constructed in auxiliary spillways. If fences are absolutely necessary, they should cross the spillway far enough away from the crest.



### VALVES



Valve should be operated annually to ensure functionality. Cleans dirt and debris within valve.



Damaged control section in auxilliary spillway at Cedar Lake by Garnett

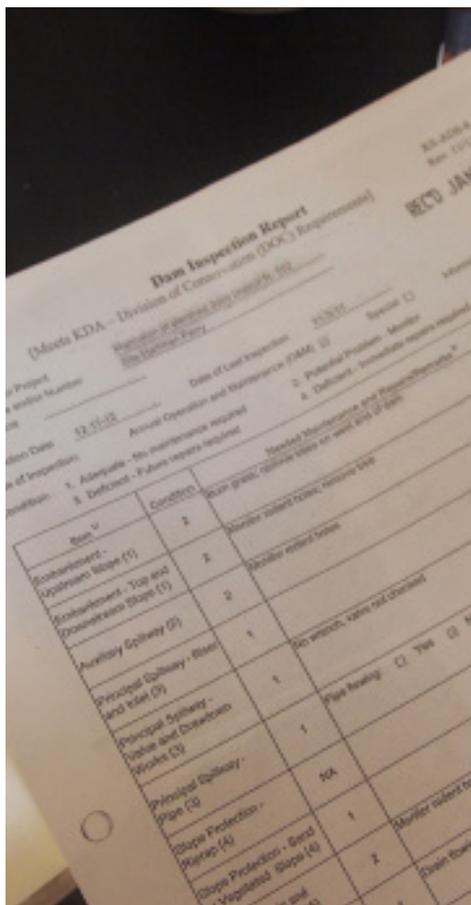
### DOWNSTREAM IMPROVEMENTS



Check for any new houses, road, utilities, etc., downstream that will affect the dam hazard classification.

## INSPECTION ADVICE FOR ENGINEERS

Kevin Shamburg, KLA Environmental Services Inc., spoke at the 2012 Dam Safety Conference on dam inspections from an engineer’s perspective.



The Natural Resources Conservation Service requires dams constructed with funding from the Watershed Protection and Flood Prevention Act of 1954 (P/L? 83-566) and Flood Control Act of 1944 (P.L. Law 78-534) to have annual inspections as part of their Operation and Maintenance Agreements.

NRCS has inspection report forms that can be used to document a dam inspection and can provide dam inspection training.



A professional engineer licensed in Kansas, Nebraska and Oklahoma, Kevin Shamburg said professional engineers have three clients: owners who pay the engineering fees; Division of Water Resources, the regulatory agency overseeing engineering work; and individuals living downstream of a dam.

He began by defining the term “inspection”—“an inspection is relied upon by others as a guarantee of conformance with a standard” — and the consequences of that term.

The dam inspector, he noted, must be qualified to meet Kansas regulations that require inspectors to be a licensed professional engineer experienced with dam design, construction, and operation.

“Lastly, engineers are required to perform to an industry standard of care. In case of dam safety inspections in Kansas, that’s the dam design and inspection criteria. To protect people downstream from the dams, we shouldn’t overlook other standards of care.”

His engineering firm begins its inspection process by reviewing all available documentation regarding the design of a dam, particularly the dam’s hydraulic and hydrologic capacity. This entails looking at land use changes in the watershed and impacts on the design hydrology and also changes in reservoir and spillway capacities.

Next, a physical inspection is done of the dam, spillway, and other features and changes documented since the dam was designed. “We evaluate inspection results and summarize findings. This is where we use our engineering experience to identify the consequences of the observations we made.”

After organizing all pertinent technical documentation, a comprehensive report is prepared consistent with the standard: K.A.R. 5-40-90.

Included in the report are maps, drawings, photographs, and any specific deficiencies. Shamburg stressed the importance of using a checklist while doing an inspection, saying plenty were available, for example, from the Association of State Dam Safety Officials and other dam regulating authorities. A checklist should record and document observations that violate the permit or approved plans, modify the permit or approved plans, or threaten the structural dam integrity and safety of the people or property.

Take color photographs of violations or changes while documenting the condition of dam appurtenances, embankments, and observed deficiencies, he said, and include a plan view sketch showing the location and direction of each photograph.

Of deficiencies Shamburg has observed on Kansas dams, the first is seepage that can range from minimal to a major concern. To identify seepage, he said, use the basic conservation equation: Inflow – outflow = change in storage. “We can apply this throughout the project – whether it be reservoir, outlet channel, stilling basin,” he said.

“If no water is coming out of pipe, anticipate any discharge in channel downstream from the pipe that water is coming from some place other than conduit. If you see an accumulation of cattails, you can conclude pretty significant seepage that should be identified and communicated to the dam owner.”

Shamburg specializes in designing major feedyard expansion projects, water right permit development, feedyard compliance issues and construction contracting.