BURGESS & NIPLE

Operation, Maintenance, and Inspection Manual

Roaming Rock Shores Lake Dam

Village of Roaming Shores

October 2008

ROAMING SHORES
A PRIVATE LAKE COMMUNITY

OPERATION, MAINTENANCE, AND INSPECTION MANUAL
ROAMING ROCK SHORES LAKE DAM

PREPARED FOR

VILLAGE OF ROAMING SHORES
ASHTABULA COUNTY, OHIO

OCTOBER 2008

BURGESS & NIPLE, INC.
Engineers and Architects
5085 Reed Road
Columbus, Ohio 43220

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I. INTRODUCTION

This manual was prepared in accordance with Section 1501:21-15-06 of the Ohio Laws and Administrative Rules for Issuing Construction Permits for and Making Periodic Inspections of Dams, Dikes, and Levees. It is intended to assist the owner in regular operation, maintenance, and inspection activities.

The Roaming Rock Shores Lake Dam has been conservatively designed and carefully constructed; however, small problems can develop over time. Experience has shown that some of these small problems can become major problems if corrective measures are not promptly taken. The main intent of this manual, therefore, is to provide the guidelines for a regular operation, maintenance, and inspection program that will detect problems at an early stage so that they can then be corrected.

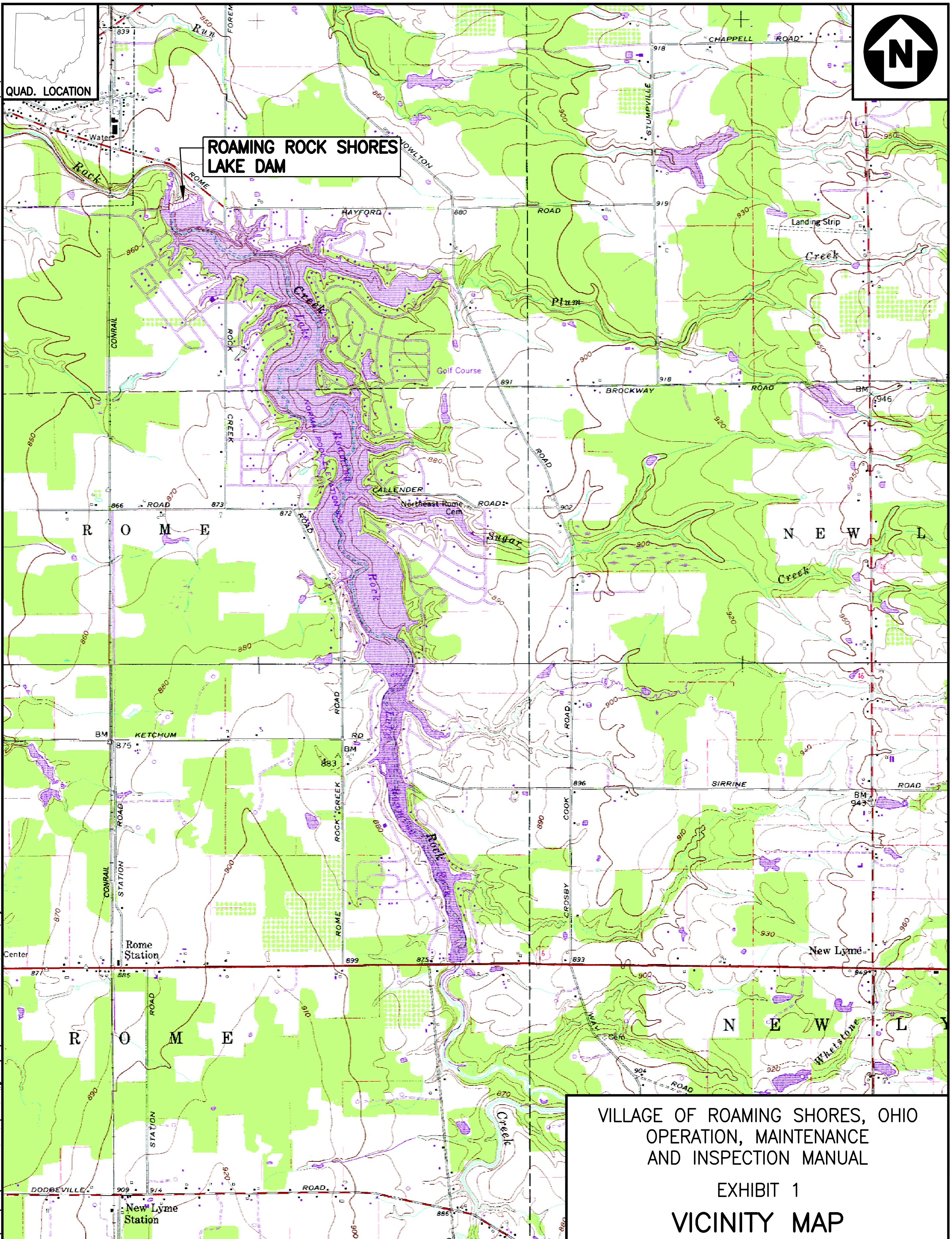
Much of the information in this manual has been based on a publication issued by the Ohio Department of Natural Resources (ODNR), Division of Water, Dam Inspection Section. The title of this publication is *Operation, Maintenance and Inspection Manual for Dams Dikes and Levees*. In addition to providing basic recommendations for operation, maintenance, and inspection procedures, the publication gives a great deal of background information, including causes of dam failures, common problems and solutions, a glossary of dam-related terms, and reference to organizations and bureaus which can provide information and advice. It is a valuable publication to have as an adjunct to this manual.

A. **Project Description**

Roaming Rock Shores Lake Dam is owned by the Village of Roaming Shores, Ohio and is located in southwest Ashtabula County, Ohio. Exhibit 1 shows the location of the dam. The dam is approximately 0.4 mile upstream of the Village of Rock Creek and controls a drainage area of 73.5 square miles. Roaming Rock Shores Lake is the largest private lake in Ohio with more than 19 miles of shoreline.

The dam is a 45-foot high, 730-foot long earthfill embankment dam constructed in 1967. Exhibit 2 is a plan view of the dam. The outlet works consists of a principal, auxiliary, and emergency spillway, as well as a 30-inch lake drain. The principal spillway is a 180-foot concrete ogee weir located on the left end of the embankment with a crest elevation of 850.0, corresponding to 6,091-acre-feet of storage. The auxiliary spillway is a 110-foot concrete ogee weir located on the right end of the embankment with a crest elevation of 852.0, corresponding to 7,200-acre-feet of storage. The emergency spillway is an 80-foot wide open channel located to the right of the auxiliary spillway, with a crest elevation of 854.0, and corresponding 8,300-acre-feet of storage. The top of the dam is at Elevation 861.0 with a capacity of 12,000-acre-feet of storage. The outflow discharges into Rock Creek and flows 2.4 miles before joining the Grand River. Three piezometers, identified as P-1, P-2, and P-3, are located on the downstream side of the dam for monitoring seepage through the earthen embankment dam.

PLOTTED: 10/23/2008 2:50:55 PM VanZandt, Ryan 10/16/2008 2:54:55 PM P:\PR41636\cadd\EAP\EXHIBIT 1 Vin Map OMI.dwg



SOURCE: JEFFERSON/ORWELL OHIO
7.5 MINUTE U.S.G.S. QUADRANGLE MAP

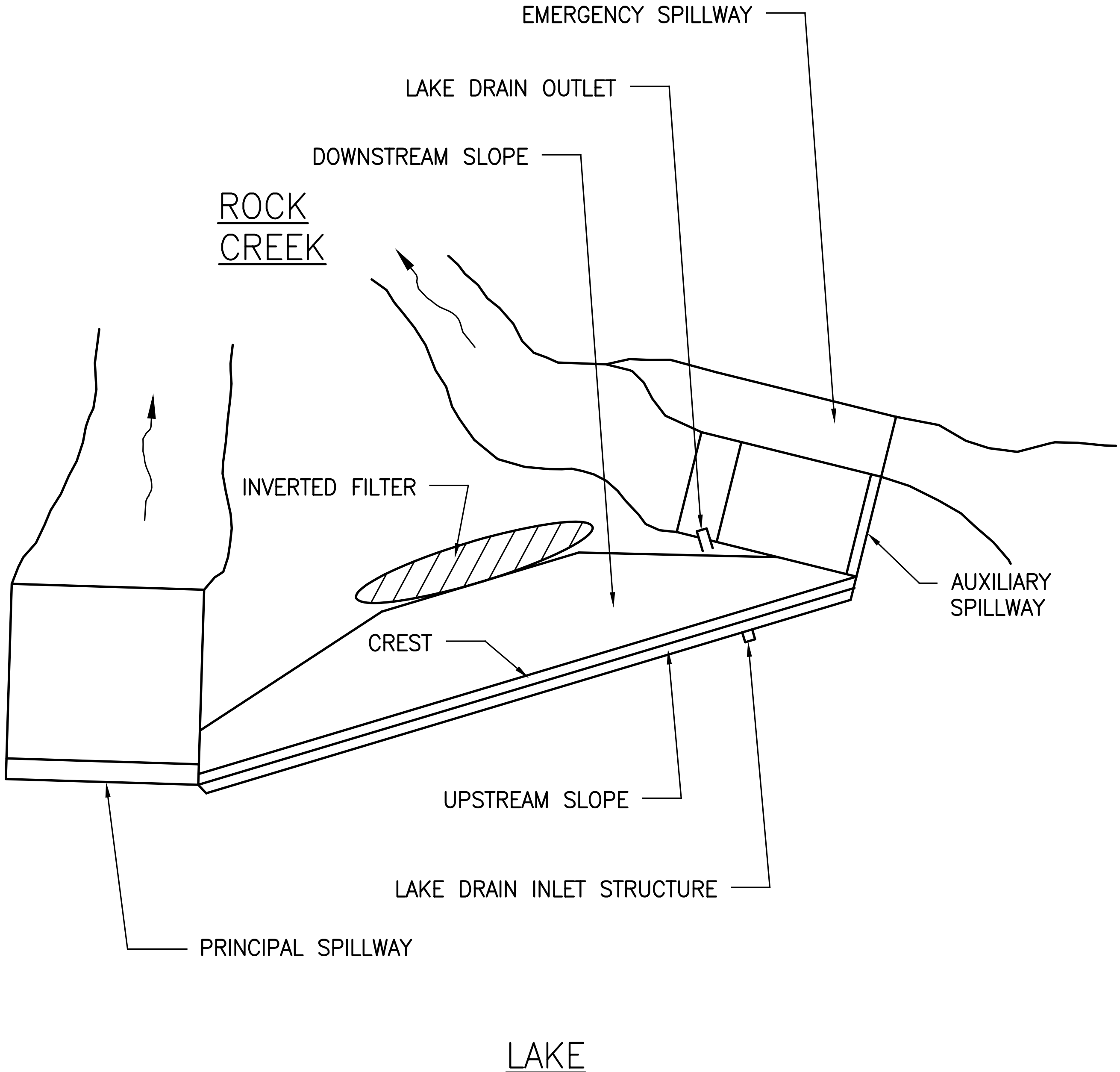
VILLAGE OF ROAMING SHORES, OHIO
OPERATION, MAINTENANCE
AND INSPECTION MANUAL

EXHIBIT 1

VICINITY MAP

BURGESS AND NIPLE, INC.

SCALE: 1"=3000'
DATE: OCT. 2008



VILLAGE OF ROAMING SHORES, OHIO
OPERATION, MAINTENANCE
AND INSPECTION MANUAL

EXHIBIT 2

SITE PLAN

NOT TO SCALE
DATE: OCT. 2008

BURGESS AND NIPLE, INC.

II. OPERATION PLAN

A. Emergency Conditions

If any of the following conditions occur or appear imminent, the Emergency Action Plan (separate document) should be implemented immediately.

1. Overtopping or nearly overtopping.
2. Piping through the embankment, spillway, or foundation.
3. A large slide in the embankment.

B. Records

Accurate records should be kept of the following items:

1. Maintenance and major repairs (see Appendix A).
2. Specific observations and changes recorded and photographs taken during normal inspection periods (see Appendix B).
3. Daily reservoir water level gage readings.
4. Date, hour, and maximum elevation of extreme high water occurrences and the associated rainfall.
5. Amount, rate, and reasons for drawdown.
6. Monthly and flood event piezometer readings.
7. Complete and up-to-date set of as-built plans and specifications which show all changes made since the completion of the dam.

8. Visual observation of the horizontal and vertical alignment on an annual basis. If needed, the alignments should be surveyed to verify any changes.

9. Seepage location, quantity (if possible), content of flow, and size of wet area for later comparison. V-notch weirs can usually be constructed to collect and measure flow rates.

10. Erosion location and extent of erosion for later comparison.

C. **Reservoir Level Monitoring**

1. The Village has installed reservoir level staff gages on the principal and auxiliary spillways at locations that can be read during all types of weather and flow conditions. The gage "zero" reading is at the crest of the principal spillway.

2. The reservoir level staff gage(s) shall be read daily and the reading shall be recorded on a copy of the forms included in Appendix A.

3. The reservoir level staff gage shall be read and recorded hourly when the depth of water over the principal spillway exceeds three feet.

D. **Piezometers**

1. Three piezometers, which are generally located along the center of the dam, have been designated P-1, P-2, and P-3; with P-1 located near the crest of the dam, P-2 located at the middle of the dam, and P-3 located near the dam's toe.

   All of the piezometers consist of 1-inch diameter aluminum risers, which are protected by an iron pipe cover. The presence of hollow plastic tubing adjacent to the riser pipes at each location is a likely indication that some type of multiple-tip hydraulic or pneumatic piezometer was installed adjacent to, or possibly within, the aluminum standpipes. Based on the condition of the plastic tubing, the hydraulic or pneumatic piezometers are not believed to be functional.

2. Water levels in the piezometers should be determined and recorded on a monthly basis to monitor changes in the pore pressures within the dam. Water levels should be measured to the nearest tenth of a foot. A form for recording the piezometer readings is provided in Appendix A.

3. In addition to monthly monitoring, the piezometers should be monitored during and after periods of high reservoir levels (greater than 1 foot of water over the principal spillway). If levels within the dam rise more than 2 feet during a flood event, contact a Professional Engineer for evaluation of the recorded data.

4. All piezometer monitoring must be done with regard to the safety of the personnel performing the monitoring. Personnel shall cease monitoring activities if weather conditions become hazardous (i.e., lightning), if failure of the dam is imminent, or if safe exit from the embankment will be cut off by flood flows.

E. Drainage Scheme

1. The lake drain should be opened and closed at least twice a year to ensure it remains operative.

2. Operating instructions should be checked for clarity and maintained in a secure, but readily accessible, location.

3. Leakage has been observed from the lake drain. Village staff indicates that the seepage is from the outlet gate valve and that the valve generally seals tightly about a week after closure. The leakage will be monitored as a part of semi-annual inspections.

F. Safe Rate of Reservoir Drawdown

1. Deliberate drawdown beyond normal operational requirements should typically not exceed 1 foot per week, except for emergency situations. Because the lake drain is capable of draining approximately 2 feet of water per week, the drain should be monitored to limit the rate of drawdown to 1 foot per week. Faster

drawdown rates could cause sloughing of the embankment's upstream slope or valley walls and may be required under emergency conditions.

G. **Vandalism**

1. "No Trespassing" signs should be posted where appropriate. Railings or fences and warning signs should be erected around dangerous areas.

III. MAINTENANCE PLAN

A. Vegetation

1. Grass areas should be mowed at least twice per year; however, it is desirable to mow more frequently to reduce the amount of cut.

2. Paths created by pedestrian, vehicular, or animal traffic should be minimized, and any barren areas which develop should be seeded.

3. Any cracks and/or erosion gullies which develop should be completely filled with thoroughly compacted soil. The area should be resodded if less than 100 square feet (sf), and reseeded if larger than 100 sf.

4. Trees and brush should not be permitted to grow on the embankment. Remove any trees or brush from the embankment before it becomes established and restore the embankment and grass cover. ODNR Fact Sheet 94-28, Trees and Brush, in Appendix D, outlines the importance of properly maintained embankment vegetation.

5. Vegetation should not be permitted to grow in cracks or joints in concrete portions of the principal and auxiliary spillways and their discharge chutes.

6. Tree and brush growth in the creek channel downstream of the plunge pool should be minimized.

B. Erosion

1. Promptly repair any eroded areas on the embankment to prevent more serious damage to the embankment (see Section III.A. Vegetation).

2. Erosion in large gullies can be slowed by stacking bales of hay across the gully until permanent repairs can be made.

3. Eroded areas in the valley wall should be repaired to prevent more serious damage (see Section III.A. Vegetation).

4. Causes of erosion should be eliminated. Surface drainage should be spread out in thin layers as sheet flow.

C. **Seepage**

1. Any areas of seepage should be noted and observed for evidence of piping erosion. Seepage containing soil is a sign of potential serious damage to the dam which may lead to failure of the dam and should be promptly addressed. Professional engineering assistance for control of any seepage problems should be obtained.

2. Prior inspections by ODNR have noted seepage at weep holes, a wet area downstream of the inverted filter, and at the end of the auxiliary spillway chute.

3. Maintain written records of seepage (see Section II.B. Records).

D. **Cracks, Slides, Sloughing, and Settlement**

1. Cracks, slides, sloughing, and settlement are signs of embankment distress and indicate that maintenance or remedial work is necessary.

2. A Professional Engineer should determine the cause of stress before any repairs are made. Maintain written records of repairs (see Section II.B. Records).

E. **Rodent Control**

1. Activities of rodents, such as the groundhogs, muskrats, and beavers can endanger the structural integrity and proper performance of an embankment. Groundhogs and muskrats burrow into an embankment, thereby weakening it and creating seepage paths. Rodent control is therefore essential for a well-maintained dam. Refer to ODNR Fact Sheet 94-27, Rodent Control, in Appendix D, for further information.

2. The damage caused by burrows should be immediately repaired by backfilling the burrow. A method for backfilling by mud packing is described in ODNR Fact Sheet 94-27, Rodent Control, in Appendix D.

3. Groundhogs may be controlled by fumigants. More detailed information on rodent control is contained in ODNR Fact Sheet 94-27, Rodent Control, in Appendix D.

F. **Debris**

1. Debris should be removed from the principal, auxiliary and emergency spillways and their discharge channels. Caution should be used during high lake levels.

2. Debris should be removed from near the lake drain intake to minimize the likelihood of debris entering the drain.

G. **Mechanical Equipment**

1. All mechanical equipment should be checked periodically and maintained in proper working order.

2. The lake drain operating mechanism should be lubricated one time per year.

3. The lake drain should be inspected and then entirely opened and reclosed two times per year (i.e., once in the spring and once in the fall) to assure its proper operation.

4. It is known that the lake drain sluice gates leak. It is important to maintain documentation regarding the amount of seepage occurring and whether it has changed with respect to previous inspections.

H. **Concrete Structures**

1. All deteriorated concrete surfaces (i.e., spalling, cracking, pitting, etc.) shall be repaired.

2. Replace sealant missing from construction/expansion joints along the dam, the discharge chutes, and associated concrete structures.

3. Clean out weep holes on vertical concrete walls of the principal and auxiliary spillways annually to assure that they remain able to flow freely.

4. Movement of concrete walls or spillway chute concrete slabs should be evaluated by a Professional Engineer to determine the cause and to develop corrective measures.

I. **Piezometers**

1. In a January 23, 2006 letter to the ODNR, Burgess & Niple, Inc. (B&N) stated that the piezometers are "functional and responsive to some degree" and recommended that they not be abandoned or rehabilitated. It is recommended the Village replace the old iron covers with locking lid protective covers in order to preserve the integrity of the piezometers in their current state. This will prevent the aluminum standpipes from exposure, damage from lawn-mowing equipment, and potential vandalism.

IV. INSPECTION PROGRAM

A. Purpose

The purpose of this inspection program is to detect any changes in condition of the dam. When a change in condition is detected, a Professional Engineer should be contacted to identify any necessary remedial repair or maintenance work. For clear identification, a pictorial representation of potential problems and resolutions has been excerpted from Federal Emergency Management Agency (FEMA) 145, Dam Safety: An Owner's Guidance Manual, August 1987, and is contained in Appendix C for your reference.

B. Personnel

The same personnel should perform all regular semi-annual dam inspections to maintain consistency in reporting as well as familiarity with the structure.

C. Informal Inspections

A brief, informal inspection to ensure that the principal, auxiliary, and emergency spillways and their discharge chutes are unobstructed, no earth slide has occurred, and no seepage is present should be made at least twice per month and after every significant rainfall event.

D. Periodic Inspections

1. Periodic inspection of the dam is extremely important. An inspection should be made at least twice a year by Village personnel, once in the summer and once in the winter, and by a Professional Engineer at least once every 5 years.

2. Inspection instructions and a checklist are found in Appendix B.

3. The inspection procedures and findings must be documented in writing. These semi-annual inspection reports should be maintained for a minimum of 10 years.

4. If problems are found during a period inspection that may affect the integrity of the dam, the Emergency Action Plan for the dam shall be followed for the appropriate emergency condition (A, B, or C) and the indentified problems shall be placed under increased surveillance and scheduled for repair as appropriate. See also Appendix C for additional guidance.

V. OWNER'S REVIEW

This Operation, Maintenance, and Inspection Manual was prepared for Roaming Rock Shores Lake Dam. I have read the Manual on behalf of the Village of Roaming Shores and understand the actions that will be required of the Village, and acknowledge that the information contained herein is accurate as of the date of my signature.

______________________________	______________________________
(Signature)	Date

Chip Laugen
Fire Safety Officer

APPENDIX A
DAM AND MAINTENANCE MONITORING RECORDS

ROAMING ROCK SHORES LAKE DAM
DAM MAINTENANCE RECORD
FOR YEAR ____________

Maintenance	Date	Initials	Comments[a]
1. Cut/mow grass and clear brush			
2. Cut/mow grass and clear brush			
3. Cut/mow grass and clear brush			
4. Cut/mow grass and clear brush			
5. Lubricate lake drain operator			
6. Operate lake drain mechanism			
7. Operate lake drain mechanism			
8. Remove debris from principal, auxiliary, and emergency spillways			
9. Repair eroded areas			
10. Clean out weep holes			
11. Concrete repair (describe)			
12. Repair rodent damage			
13. Other (Piezometer)			
14. Other (specify)			
15. Other (specify)			

[a]Use additional sheets if necessary.

____
Signature

APPENDIX B

DAM INSPECTION INSTRUCTIONS

AND

DAM INSPECTION CHECKLIST

A. **Dam Inspection Instructions**

1. **Checklist**

a. Inspectors and others should include names and affiliations.

b. Weather and site conditions should include weather conditions and the condition of the ground surface (i.e., wet, snow covered, dry, etc.), at the time of the inspection.

c. The lake level should be the pool level recorded at the time of the inspection.

d. The water level measurement in the piezometers should be read each time the dam is inspected, both formally and informally. The overall physical condition and any sediment present should be recorded for each of the piezometers. To measure the water level, remove the iron cap and measure the water level from the bottom of the piezometer. The three piezometers, their approximate locations, and depth are listed below:

- Piezometer P-1- Located approximately 8 vertical feet below the crest of the dam. The bottom of the piezometer has been recorded at -29.4 feet below the top of the riser pipe.

- Piezometer P-2- Located approximately 10 vertical feet above the toe of the dam. The bottom of the piezometer has been recorded at -13.3 feet below the top of the riser pipe.

- Piezometer P-3- Located in the relatively flat, rip-rapped area approximately 25 feet from the toe of the dam. The bottom of the piezometer has been recorded at -8.7 feet below the top of the riser pipe.

e. Check the appropriate box along the left-hand side as that item is inspected.

f. Check the appropriate box for the REQUIRED ACTION. Obvious problems will require maintenance. Monitoring will be recommended if there is potential for a problem to occur in the future. An engineer is necessary if the reason the problem is occurring is not obvious. More than one box can be checked.

2. **Notes**

a. A brief description of any noted irregularities, needed maintenance, or problems for each item checked should be made. Abbreviations and short descriptions are recommended.

3. **Sketches and Field Measurements**

a. Explanatory sketches, measurements of cracks, settlement, and additional explanation of observations should be placed on these pages.

b. Definitions:

U/S	Upstream
D/S	Downstream
Groin	Intersection of embankment face with the valley abutment.

INSPECTION CHECKLIST

ROAMING ROCK SHORES LAKE DAM
DAM CLASSIFICATION: I
ODNR FILE NO. 1506-001
VILLAGE OF ROAMING SHORES, OHIO
ASHTABULA COUNTY, MORGAN TOWNSHIP

Date: ______________________________

Time: ______________________________

Weather and Site Conditions: ______________________________

Inspectors: ______________________________

Others: ______________________________

Lake Level (Normal Pool El. = 850.00) ______________________________

Piezometer Readings:

ID	Location	Reading	Sediment Present?	
Piezometer P-1	8 vertical feel below crest of dam	____________	Y	N
Piezometer P-2	10 vertical feet above toe of dam	____________	Y	N
Piezometer P-3	Flat rip-rapped area 25' from toe of dam	____________	Y	N

(a) Use additional sheets if necessary.

ROAMING ROCK SHORES LAKE DAM

Date: ______________________

		SPILLWAYS-DRAINS-OUTLETS		Actions		
Check Area as Inspected		Check/Circle Condition Noted	Observations[a]	Repair	Monitor	Investigate
Principal Spillway						
☐ Spillway		Debris buildup at weir				
		Cracks/deterioration/spalling				
		Tilting/movement of sidewalls				
☐ Outlet Channel and Stilling Basin		Cracks/deterioration				
		Seepage/piping				
		Tilting/movement of sidewalls				
		Undercutting				
		Erosion				
		Debris				
☐ Auxiliary Spillway		Debris buildup at weir				
		Cracks/deterioration/spalling				
		Tilting/movement of sidewalls				
		Tilting/movement of sidewalls				
Emergency Spillway						
☐ All Areas		Vegetation/cover				
		Erosion				
		Obstructions				
Lake Drain						
☐ 30-inch Diameter Lake Drain		Gates/valves				
		Outlet area				
		Operability				
		Seepage				
		Flow amounts				
		Flow clear/muddy				
Other Outlets						
		Gates/valves				
		Outlet area				
		Operability				
☐ Toe Drain		Flow amounts				
		Flow clear/muddy				
General Comments, Sketches & Field Measurements						

(a) Use additional sheets if necessary.

ROAMING ROCK SHORES LAKE DAM

Date: ______________________

		EARTHEN EMBANKMENT		Actions		
Check Area as Inspected		Check/Circle Condition Noted	Observations[a]	Repair	Monitor	Investigate
☐ Upstream Slope		Vegetation/erosion				
		Sloughs/beaching/slides/cracks				
		Undermining/erosion				
☐ Crest		Vegetation/erosion				
		Ruts/erosion				
		Cracks/settlement				
☐ Downstream Slope		Vegetation/erosion				
		Rodent burrows				
		Sloughs/slides/cracks				
		Seepage wetness				
☐ Groins		Erosion				
		Seepage/wetness				
☐ Toe		Cracks/slumps				
		Seepage/wetness				
☐ Weep Hole-Immediately downstream of inverted filter		Approximate size				
		Flow amounts? Increased?				
		Flow clear/muddy				
		Instability on/near embankment				
☐ Weep Hole-Seepage at end of auxiliary spillway		Approximate size				
		Flow amounts? Increased?				
		Flow clear/muddy				
		Instability on/near embankment				
☐ New Weep Holes		Approximate size				
		Flow amounts? Increased?				
		Flow clear/muddy				
		Instability on/near embankment				

General Comments, Sketches & Field Measurements

(a) Use additional sheets if necessary.

APPENDIX C

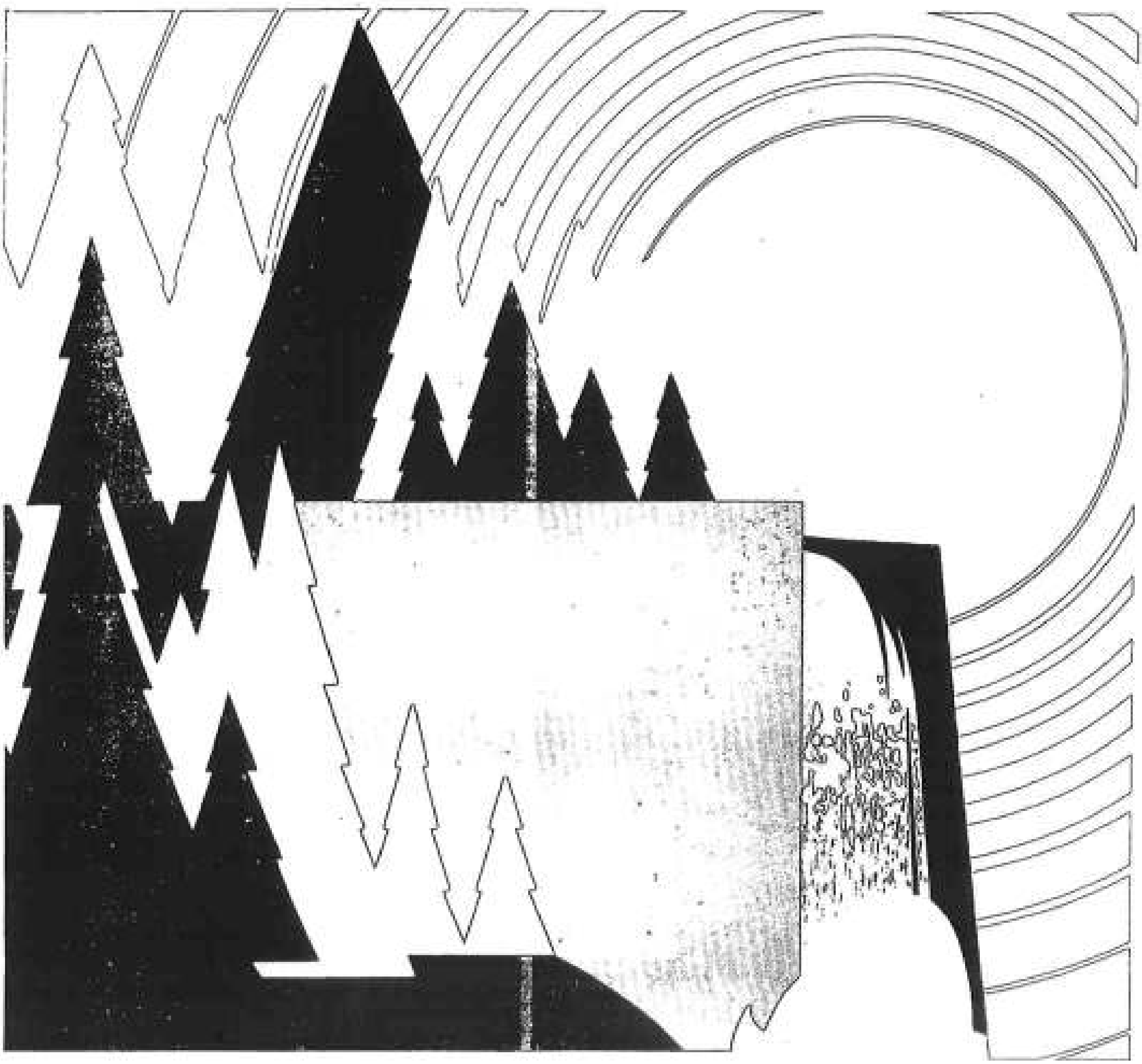
DAM INSPECTION GUIDELINES

APPENDIX C
DAM INSPECTION GUIDELINES

The following Dam Inspection Guidelines are taken from the FEMA document, Dam Safety: An Owner's Guidance Manual, FEMA 145, August 1987. This excerpt is included in this manual for informational purposes so that potential problems are more easily identified and resolved.

FEMA 145 / August 1987

DAM SAFETY:
AN OWNER'S GUIDANCE MANUAL



DAM SAFETY: AN OWNER'S GUIDANCE MANUAL

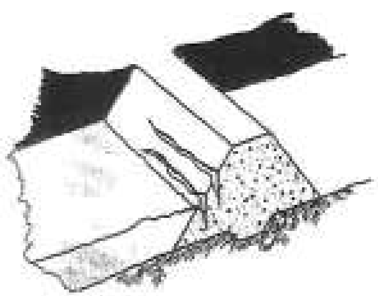
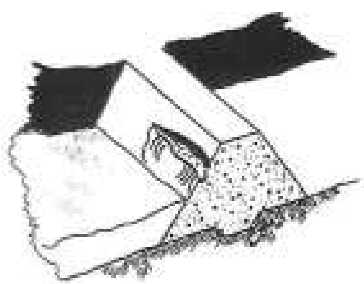
By The Colorado Division of Disaster Emergency Services (DODES)

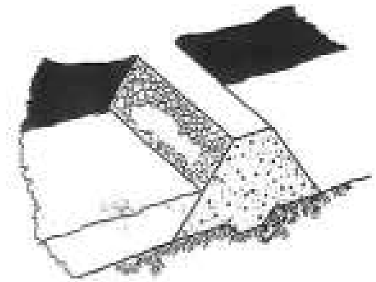
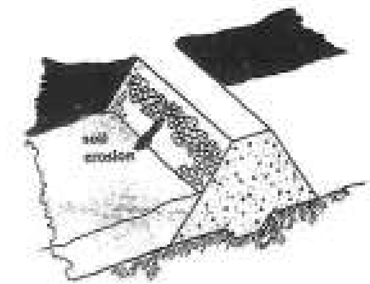
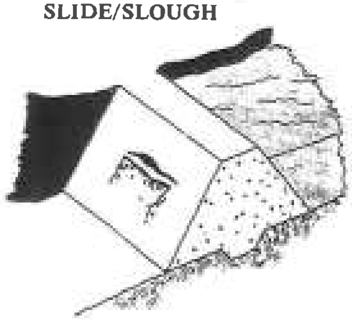
Funded By
Federal Emergency Management Agency
State and Local Programs and Support Directorate

Under
Comprehensive Cooperative Agreement #EMD-K-0089

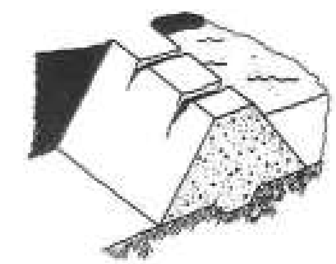
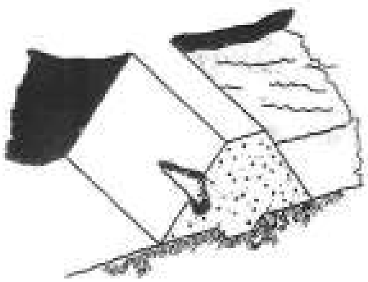
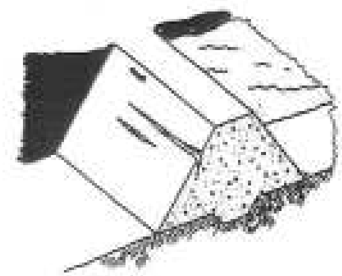
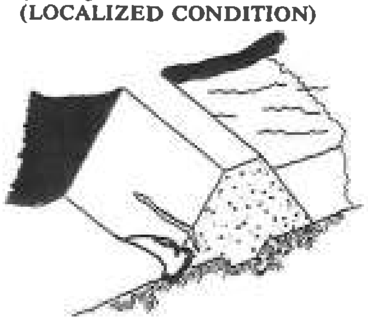
July 1987

FIC 5 5.3.1
INSPECTION GUIDELINES -
EMBANKMENT UPSTREAM SLOPE

PROBLEM	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIONS
SINKHOLE 	Piping or internal erosion of embankment materials or foundation causes a sinkhole. The cave-in of an eroded cavern can result in a sink hole. A small hole in the wall of an outlet pipe can develop a sink hole. Dirty water at the exit indicates erosion of the dam.	HAZARDOUS Piping can empty a reservoir through a small hole in the wall or can lead to failure of a dam as soil pipes erode through the foundation or a pervious part of the dam.	Inspect other parts of the dam for seepage or more sink holes. Identify exact cause of sink holes. Check seepage and leakage outflows for dirty water. A qualified engineer should inspect the conditions and recommend further actions to be taken. ENGINEER REQUIRED
LARGE CRACKS 	A portion of the embankment has moved because of loss of strength, or the foundation may have moved, causing embankment movement.	HAZARDOUS Indicates onset of massive slide or settlement caused by foundation failure.	Depending on embankment involved, draw reservoir level down. A qualified engineer should inspect the conditions and recommend further actions to be taken. ENGINEER REQUIRED
SLIDE, SLUMP OR SLIP 	Earth or rocks move down the slope along a slippage surface because of too steep a slope, or the foundation moves. Also, look for slides movement in reservoir basin.	HAZARDOUS A series of slides can lead to obstruction of the outlet or failure of the dam.	Evaluate extent of the slide. Monitor slide. (See Chapter 6.) Draw the reservoir level down if safety of dam is threatened. A qualified engineer should inspect the conditions and recommend further actions to be taken. ENGINEER REQUIRED
SCARPS, BENCHES, OVERSTEEP AREAS	Wave action, local settlement, or ice action cause soil and rock to erode and slide to the lower part of the slope forming a bench.	Erosion lessens the width and possible height of the embankment and could lead to increased seepage or overtopping of the dam.	Determine exact cause of scarps. Do necessary earthwork, restore embankment to original slope and provide adequate protection (bedding and riprap). See Chapter 7.

PROBL.	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMEND ACTIONS
BROKEN DOWN MISSING RIPRAP 	Poor quality riprap has deteriorated. Wave action or ice action has displaced riprap. Round and similar-sized rocks have rolled downhill.	Wave action against these unprotected areas decreases embankment width.	Re-establish normal slope. Place bedding and competent riprap. (See Chapter 7.)
EROSION BEHIND POORLY GRADED RIPRAP 	Similar-sized rocks allow waves to pass between them and erode small gravel particles and soil.	Soil is eroded away from behind the riprap. This allows riprap to settle, providing less protection and decreased embankment width.	Re-establish effective slope protection. Place bedding material. ENGINEER REQUIRED for design for gradation and size for rock for bedding and riprap. A qualified engineer should inspect the conditions and recommend further actions to be taken.
SLIDE/SLOUGH 	1. Lack of or loss of strength of embankment material. 2. Loss of strength can be attributed to infiltration of water into the embankment or loss of support by the foundation.	**HAZARDOUS** Massive slide cuts through crest or upstream slope reducing freeboard and cross section. Structural collapse or overtopping can result.	1. Measure extent and displacement of slide. 2. If continued movement is seen, begin lowering water level until movement stops. 3. Have a qualified engineer inspect the condition and recommend further action. ENGINEER REQUIRED

Figures 5.3.2 Inspection Guidelines - Downstream Slope

PROBL	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIO.
TRANSVERSE CRACKING 	Differential settlement of the embankment also leads to tranverse cracking (e.g., center settles more than abutments).	**HAZARDOUS** Settlement or shrinkage cracks can lead to seepage of reservoir water through the dam. Shrinkage cracks allow water to enter the embankment. This promotes saturation and increases freeze-thaw action.	1. If necessary, plug upstream end of crack to prevent flows from the reservoir. 2. A qualified engineer should inspect the conditions and recommend further actions to be taken. ENGINEER REQUIRED
CAVE IN/COLLAPSE 	1. Lack of adequate compaction. 2. Rodent hole below. 3. Piping through embankment or foundation.	**HAZARDOUS** Indicates possible wash out of embankment.	1. Inspect for and immediately repair rodent holes. Control rodents to prevent future damage. 2. Have a qualified engineer inspect the condition and recommend further action. ENGINEER REQUIRED
LONGITUDINAL CRACKING 	1. Drying and shrinkage of surface material. 2. Downstream movement of settlement of embankment.	1. Can be an early warning of a potential slide. 2. Shrinkage cracks allow water to enter the embankment and freezing will further crack the embankment. 3. Settlement or slide showing loss of strength in embankment can lead to failure.	1. If cracks are from drying, dress area with well-compacted material to keep surface water out and natural moisture in. 2. If cracks are extensive, a qualified engineer should inspect the conditions and recommend further actions to be taken. ENGINEER REQUIRED
SLUMP (LOCALIZED CONDITION) 	Preceded by erosion undercutting a portion of the slope. Can also be found on steep slopes.	Can expose impervious zone to erosion and lead to further slumps.	1. Inspect area for seepage. 2. Monitor for progressive failure. 3. Have a qualified engineer inspect the condition and recommend further action. ENGINEER REQUIRED

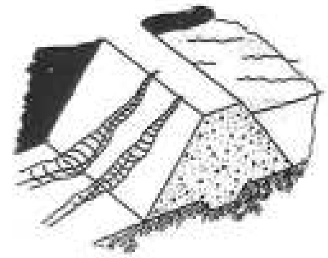
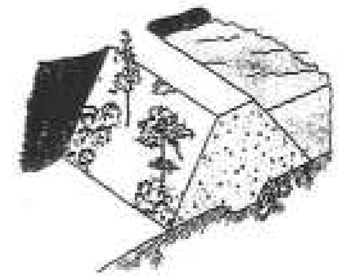
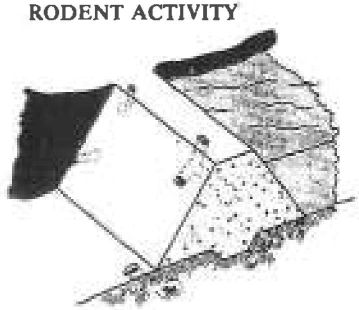
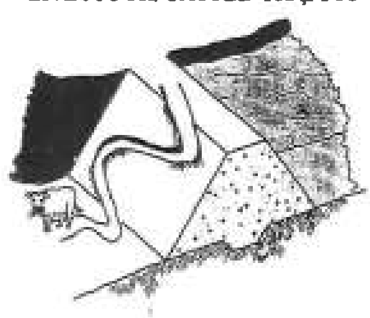
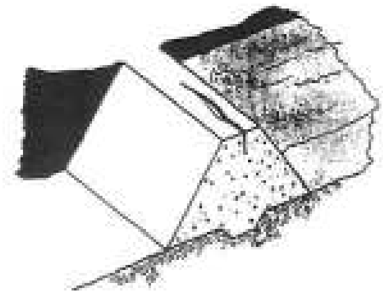
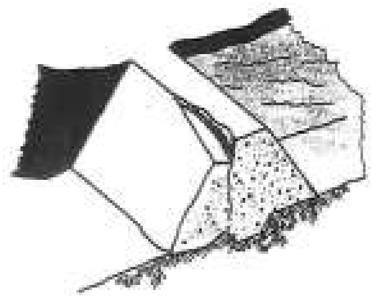
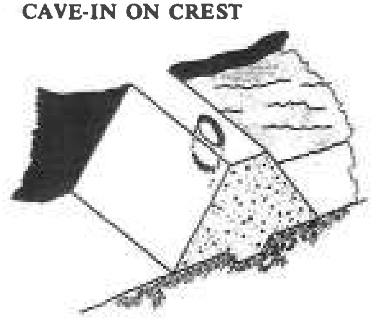
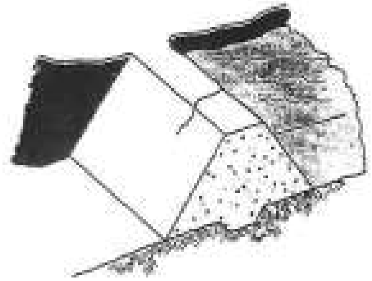
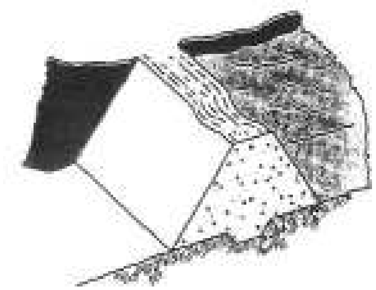
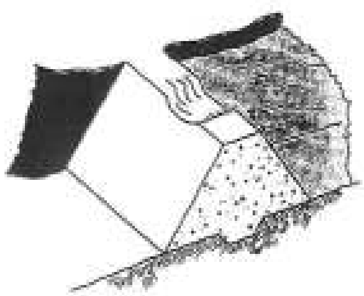
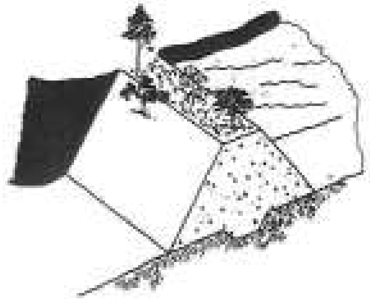
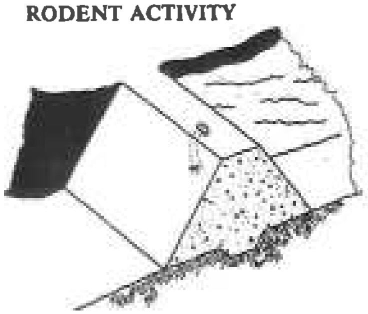
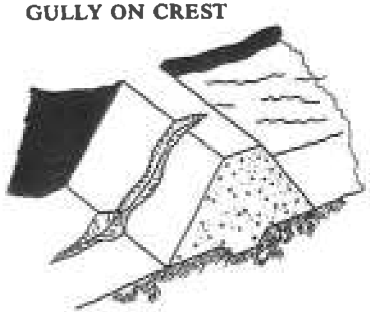
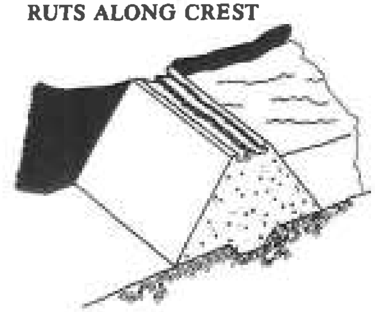
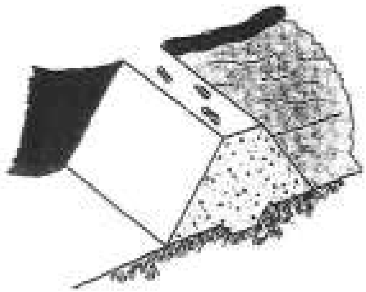
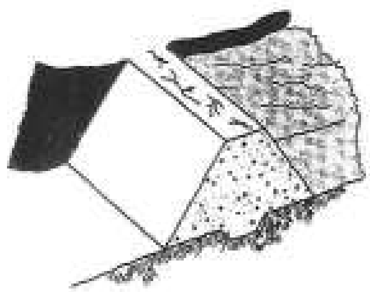
PROBL	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIO
EROSION 	Water from intense rainstorms or snow-melt carries surface material down the slope, resulting in continuous troughs.	Can be hazardous if allowed to continue. Erosion can lead to eventual deterioration of the downstream slope and failure of the structure.	1. The preferred method to protect eroded areas is rock or riprap. 2. Re-establishing protective grasses can be adequate if the problem is detected early.
TREES/OBSCURING BRUSH 	Natural vegetation in area.	Large tree roots can create seepage paths. Bushes can obscure visual inspection and harbor rodents.	1. Remove all large, deep-rooted trees and shrubs on or near the embankment. Properly backfill void. (See Chapter 7.) 2. Control vegetation on the embankment that obscures visual inspection. (See Chapter 7.)
RODENT ACTIVITY 	Over-abundance of rodents. Holes, tunnels and caverns are caused by animal burrowings. Certain habitats like cattail type plants and trees close to the reservoir encourage these animals.	Can reduce length of seepage path, and lead to piping failure. If tunnel exists through most of the dam, it can lead to failure of the dam.	1. Control rodents to prevent more damage. 2. Backfill existing rodent holes. 3. Remove rodents. Determine exact location of digging and extent of tunneling. Remove habitat and repair damages. (See Chapter 7.)
LIVESTOCK/CATTLE TRAFFIC 	Excessive travel by livestock especially harmful to slope when wet.	Creates areas bare of erosion protection and causes erosion channels. Allows water to stand. Area susceptible to drying cracks.	1. Fence livestock outside embankment area. 2. Repair erosion protection, i.e., riprap, grass.

Figure 5.3.3
Inspection Guidelines - Embankment Crest

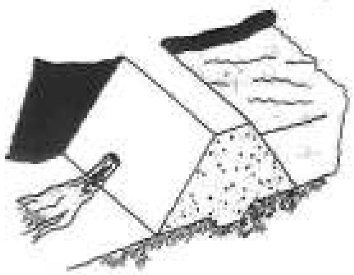
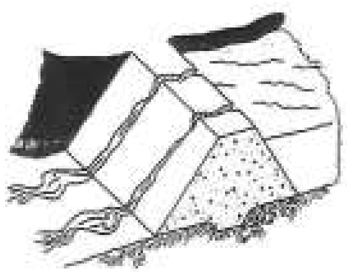
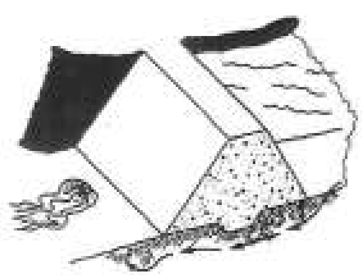
PROBLEM	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIONS
LONGITUDINAL CRACK 	1. Uneven settlement between adjacent sections or zones within the embankment. 2.Foundation failure causing loss of support to embankment. 3. Initial stages of embankment slide.	HAZARDOUS 1. Creates local area of low strength within embankment. Could be the point of initiation of future structural movement, deformation, or failure. 2. Provides entrance point for surface run-off into embankment, allowing saturation of adjacent embankment area, and possible lubrication which could lead to localized failure.	1. Inspect crack and carefully record location, length, depth, width, alignment, and other pertinent physical features. Immediately stake out limits of cracking. Monitor frequently. 2. Engineer should determine cause of cracking and supervise steps necessary to reduce danger to dam and correct condition. 3. Effectively seal the cracks at the crest's *surface to prevent infiltration by surface* water. 4. Continue to routinely monitor crest for evidence of further cracking. ENGINEER REQUIRED
VERTICAL DISPLACEMENT 	1. Vertical movement between adjacent sections of the embankment. 2. Structural deformation or failure caused by *structural stress or instability*, or by failure of the foundation.	HAZARDOUS 1. Provides local area of low strength within embankment which could cause future movement. 2. Leads to structural instability or failure. 3. Provides entrance point for surface water that could further lubricate failure plane. 4. Reduces available embankment cross section.	1. Carefully inspect displacement and record its location, vertical and horizontal displacement, length, and other physical features. Immediately stake out limits of cracking. 2. Engineer should determine cause of displacement and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate area to the bottom of the displacement. Backfill excavation using competent material and correct construction techniques, and under supervision of engineer. 4. Continue to monitor areas routinely for evidence of future cracking or movement. (See Chapter 6.) ENGINEER REQUIRED
CAVE-IN ON CREST 	1. Rodent activity. 2. Hole in outlet conduit is causing erosion of embankment material. 3. Internal *erosion or piping of embankment* material by seepage. 4. Breakdown of dispersive clays within embankment by seepage waters.	HAZARDOUS 1. Void within dam could cause localized caving, sloughing, instability, or reduced embankment cross section. 2. Entrance point for surface water.	1. Carefully inspect and record location and physical characteristics (depth, width, length) of cave in. 2. Engineer should determine cause of cave in and supervise all steps necessary to reduce threat to dam and correct condition. 3. Excavate cave in, slope sides of excavation, and backfill hole with competent material using proper construction techniques. (See Chapter 7.) This should be supervised by engineer. ENGINEER REQUIRED

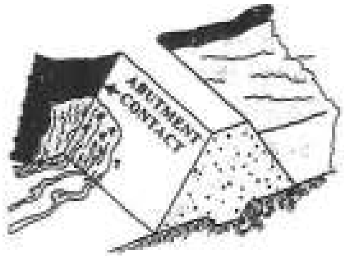
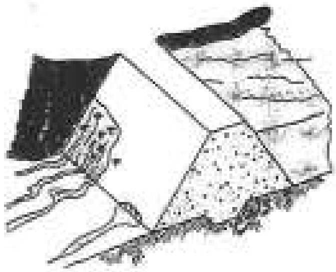
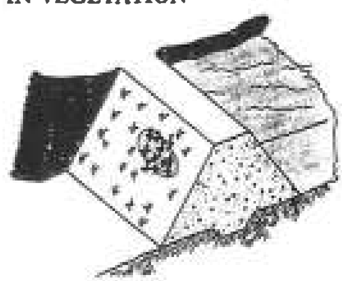
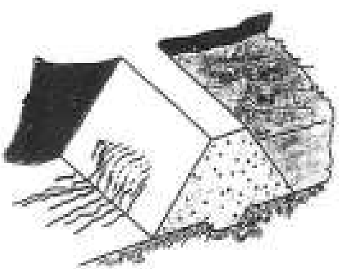
PROBL.	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTION
TRANSVERSE CRACKING 	1. Uneven movement between adjacent segments of the embankment. 2. Deformation caused by structural stress or instability.	HAZARDOUS 1. Can provide a path for seepage through the embankment cross section. 2. Provides local area of low strength within embankment. Future structural movement, deformation or failure could begin. 3. Provides entrance point for surface runoff to enter embankment.	1. Inspect crack and carefully record crack location, length, depth, width, and other pertinent physical features. Stake out limits of cracking. 2. Engineer should determine cause of cracking and supervise all steps necessary to reduce danger to dam and correct condition. 3. Excavate crest along crack to a point below the bottom of the crack. Then backfilling excavation using competent material and correct construction techniques. This will seal the crack against seepage and surface runoff. (See Chapter 7.) This should be supervised by engineer. 4. Continue to monitor crest routinely for evidence of future cracking. (See Chapter 6.) ENGINEER REQUIRED
CREST MISALIGNMENT 	1. Movement between adjacent parts of the structure. 2. Uneven deflection of dam under loading by reservoir. 3. Structural deformation or failure near area of misalignment.	1. Area of misalignment is usually accompanied by low area in crest which reduces freeboard. 2. Can produce local areas of low embankment strength which may lead to failure.	1. Establish monuments across crest to determine exact amount, location, and extent of misalignment. 2. Engineer should determine cause of misalignment and supervise all steps necessary to reduce threat to dam and correct condition. 3. Monitor crest monuments on a scheduled basis following remedial action to detect possible future movement. (See Chapter 6.) ENGINEER REQUIRED
LOW AREA IN CREST OF DAM 	1. Excessive settlement in the embankment or foundation directly beneath the low area in the crest. 2. Internal erosion of embankment material. 3. Foundation spreading to upstream and/or downstream direction. 4. Prolonged wind erosion of crest area. 5. Improper final grading following construction.	Reduces freeboard available to pass flood flows safely through spillway.	1. Establish monuments along length of crest to determine exact amount, location, and extent of settlement in crest. 2. Engineer should determine cause of low area and supervise all steps necessary to reduce possible threat ot the dam and correct condition. 3. Re-establish uniform crest elevation over crest length by placing fill in low area using proper construction techniques. This should be supervised by engineer. 4. Re-establish monuments across crest of dam and monitor monuments on a routine basis to detect possible future settlement. ENGINEER REQUIRED

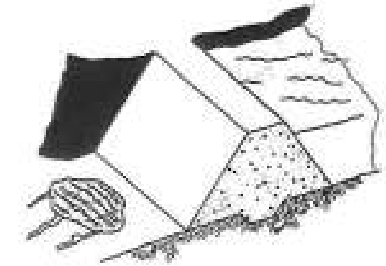
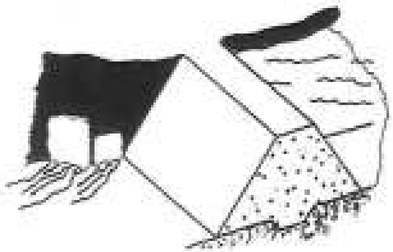
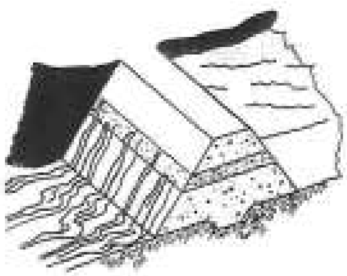
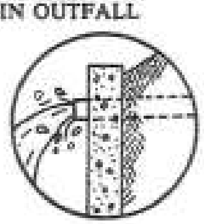
PROBL	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIO.
OBSCURING VEGETATION 	Neglect of dam and lack of proper maintenance procedures.	1. Obscures large parts of the dam, preventing adequate, accurate visual inspection of all parts of the dam. Problems which threaten the integrity of the dam can develop and remain undetected until they progress to a point that threatens the dam's safety. 2. Associated root systems develop and penetrate into the dam's cross section. When the vegetation dies, the decaying root systems can provide paths for seepage. This reduces the effective seepage path through the embankment and could lead to possible piping situations. 3. Prevents easy access to all parts of the dam for operation, maintenance, and inspection. 4. Provides habitat for rodents.	1. Remove all damaging growth from the dam. This would include removal of trees, bushes, brush, conifers, and growth other than grass. Grass should be encouraged on all segments of the dam to prevent erosion by surface runoff. Root systems should also be removed to the maximum practical extent. The void which results from removing the root system should be backfilled with wellcompetent, well-compacted material. 2. Future undesirable growth should be removed by cutting or spraying, as part of an annual maintenance program. (See Chapter 7.) 3. All cutting or debris resulting from the vegetative removal should be immediately taken from the dam and properly disposed of outside the reservoir basin.
RODENT ACTIVITY 	Burrowing animals.	1. Entrance point for surface runoff to enter dam. Could saturate adjacent portions of the dam. 2. Especially dangerous if hole penetrates dam below phreatic line. During periods of high storage, seepage path through the dam would be greatly reduced and a piping situation could develop.	1. Completely backfill the hole with competent, well-compacted material. 2. Initate a rodent control program to reduce the burrowing animal population and to prevent future damage to the dam. (See Chapter 7.)
GULLY ON CREST 	1. Poor grading Xand improper drainage of crest. Improper drainage causes surface runoff to collect and drain of crest at low point in upstream or downstream shoulder. 2. Inadequate spillway capacity which has caused dam to overtop.	1. Can reduce available freeboard. 2. Reduces cross-sectional area of dam. 3. Inhibits access to all parts of the crest and dam. 4. Can result in a hazardous condition if due *to overtopping.*	1. Restore freeboard to dam by adding fill material in low area, using proper construction techniques. (See Chapter 7.) 2. Regrading crest to provide proper drainage of surface runoff. 3. If gully was caused by overtopping, provide adequate spillway which meets current design standards. This should be done by engineer. 4. Re-establish protective cover.
RUTS ALONG CREST 	Heavy vehicle traffic without adequate or proper maintenance or proper crest surfacing.	1. Inhibits easy access to all parts of crest. 2. Allows continued development of rutting. 3. Allows standing water to collect and saturate crest of dam. 4. Operating and maintenance vehicles can get stuck.	1. Drain standing water from ruts. 2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope. (See Chapter 7.) 3. Provide gravel or roadbase material to accommodate traffic. 4. Do periodic maintenance and regrading to prevent reformation of ruts.

PROBL	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIOI
PUDDLING ON CREST-POOR DRAINAGE 	1. Poor grading and improper drainage of crest. 2. Localized consolidation or settlement on crest allows puddles to develop.	1. Cause localized saturation of the crest. 2. Inhibits access to all parts of the dam and crest. 3. Becomes progressively worse if not corrected.	1. Drain standing water from puddles. 2. Regrade and recompact crest to restore integrity and provide proper drainage to upstream slope. (See Chapter 7.) 3. Provide gravel or roadbase material to accommodate traffic. 4. Do periodic maintenance and regrading to prevent reformation of low areas.
DRYING CRACKS 	Material on the crest of dam expands and contracts with alternate wetting and drying of weather cycles. Drying cracks are usually short, shallow, narrow, and many.	Provides point of entrance for surface runoff and surface moisture, causing staturation of adjacent embankment areas. This statura-tion, and later drying of the dam, could cause further cracking.	1. Seal surface of cracks with a tight, imper-vious material. (See Chapter 7.) 2. Routinely grade crest to provide proper drainage and fill cracks. -OR 3. Cover crest with non-plastic (not clay) material to prevent large moisture content variations.

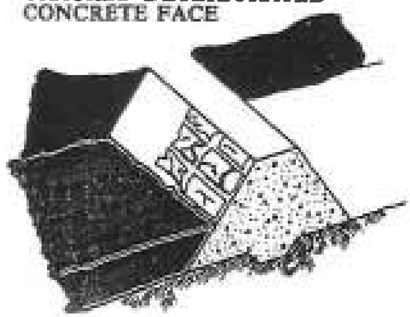
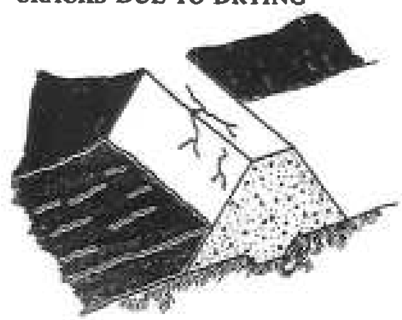
Fi ,s 5.3.4
Inspection Guidelines - Embankment Seepage Areas

PROBLEM	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIONS
EXCESSIVE QUANTITY AND/OR MUDDY WATER EXITING FROM A POINT 	1. Water has created an open pathway, channel, or pipe through the dam. The water is eroding and carrying embankment material. 2. Large amounts of water have accumulated in the downstream slope. Water and embankment materials are exiting at one point. Surface agitation may be causing the muddy water. 3. Rodents, frost action or poor construction have allowed water to create an open pathway or pipe through the embankment.	HAZARDOUS 1. Continued flows can saturate parts of the embankment and lead to slides in the area. 2. Continued flows can further erode embankment materials and lead to failure of the dam.	1. Begin measuring outflow quantity and establishing whether water is getting muddier, staying the same, or clearing up. 2. If quantity of flow is increasing the water level in the reservoir should be lowered until the flow stabilizes or stops. 3. Search for opening on upstream side and plug if possible. 4. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
STREAM OF WATER EXITING THROUGH CRACKS NEAR THE CREST 	1. Severe drying has caused shrinkage of embankment material. 2. Settlement in the embankment or foundation is causing the transverse cracks.	HAZARDOUS Flow through the crack can cause failure of the dam.	1. Plug the upstream side of the crack to stop the flow. 2. The water level in he reservoir should be lowered until it is below the level of the cracks. 3. A qualified engineer should inspect the condition and recommend further actions to be taken.
SEEPAGE WATER EXITING AS A BOIL IN THE FOUNDATION 	Some part of the foundation material is supplying a flow path. This could be caused by a sand or gravel layer in the foundation.	HAZARDOUS Increased flows can lead to erosion of the foundation and failure of the dam.	1. Examine the boil for transportation of foundation materials. 2. If soil particles are moving downstream, sandbags or earth should be used to create a dike around the boil. The pressures created by the water level within the dike may control flow velocities and temporarily prevent further erosion. 3. If erosion is becoming greater, the reservoir level should be lowered. 4. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED

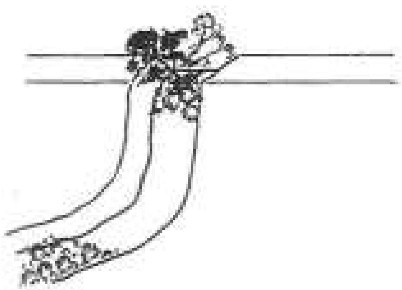
PROBLEM	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTION
SEEPAGE EXITING AT ABUTMENT CONTACT 	1. Water flowing through pathways in the abutment. 2. Water flowing through the embankment.	**HAZARDOUS** Can lead to erosion of embankment materials and failure of the dam.	1. Study leakage area to determine quantity of flow and extent of saturation. 2. Inspect daily for developing slides. 3. Water level in reservoir may need to be lowered to assure the safety of the embankment. 4. A qualified engineer should inspect the conditions and recommend further actions to be taken. ENGINEER REQUIRED
LARGE AREA WET OR PRODUCING FLOW 	A seepage path has developed through the abutment or embankment materials and failure of the dam can occur.	**HAZARDOUS** 1. Increased flows could lead to erosion of embankment material and failure of the dam. 2. Saturation of the embankment can lead to local slides which could cause failure of the dam.	1. Stake out the saturated area and monitor for growth or shrinking. 2. Measure any outflows as accurately as possible. 3. Reservoir level may need to be lowered if saturated areas increase in size at a fixed storage level or if flow increases. 4. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
MARKED CHANGE IN VEGETATION 	1. Embankment material aré supplying flows paths. 2. Natural seeding by wind. 3. Change in seed type during early post construction seeding.	Can show a saturated area.	1. Use probe and shovel to establish if the materials in this area are wetter than surrounding areas. 2. If areas shows wetness, when surrounding areas do not, a qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
BULGE IN LARGE WET AREA 	Downstream embankment materials have begun to move.	**HAZARDOUS** Failure of the embankment result from massive sliding can follow these early movements.	1. Compare embankment cross section to the end of construction condition to see if observed condition may reflect end of construction. 2. Stake out affected area and accurately measure outflow. 3. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED

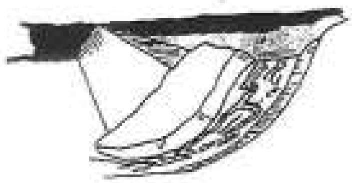
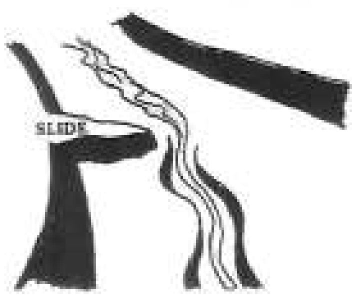
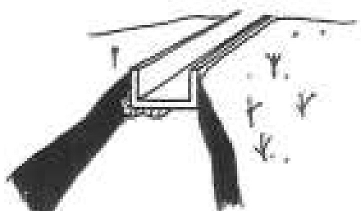
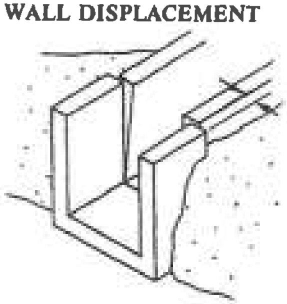
PRO. .M	PROBABLE CAUSE.	POSSIBLE CONSEQUENCES	RECOMMENDED ACT. S
TRAMPOLINE EFFECT IN LARGE SOGGY AREA 	1. Water moving rapidly through the embankment or foundation is being controlled or contained by a well-established turf root system.	Condition shows excessive seepage in the area. If control layer of turf is destroyed, rapid erosion of foundation materials could result in failure of the dam.	1. Carefully inspect the area for outflow quantity and any transported material. 2. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
LEAKAGE FROM ABUTMENTS BEYOND THE DAM 	Water moving through cracks and fissures in the abutment materials.	Can lead to rapid erosion of abutment and evacuation of the reservoir. Can lead to massive slides near or downstream from the dam.	1. Carefully inspect the area to determine quantity of flow and amount of transported material. 2. A qualified engineer or geologist should inspect the condition and recommend further actions to be taken.
WET AREA IN HORIZONTAL BAND 	Frost layer or layer of sandy material in original construction.	HAZARDOUS 1. Wetting of areas below the area of excessive seepage can led to localized instability of the embankment. (SLIDES) 2. Excessive flows can lead to accelerated erosion of embankment materials and failure of the dam.	1. Determine as closely as possible the flow being produced. 2. If flow increases, reservoir level should be reduced until flow stabilizes or stops. 3. Stake out the exact area involved. 4. Using hand tools, try to identify the material allowing the flow. 5. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
LARGE INCREASE IN FLOW OR SEDIMENT IN DRAIN OUTFALL 	A shortened seepage path or increased storage levels.	HAZARDOUS 1. Higher velocity flows can cause erosion of drain then embankment materials. 2. Can lead to piping failure.	1. Accurately measures outflow quantity and determine amount of increase over previous flow. 2. Collect jar samples to compare turbidity. 3. If either quantity or turbidity has increased by 25%, a qualified engineer should evaluate the condition and recommend further actions. ENGINEER REQUIRED

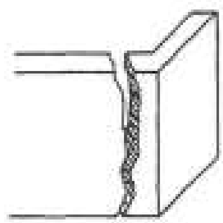
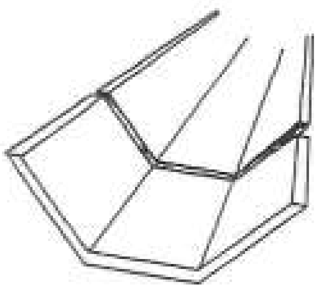
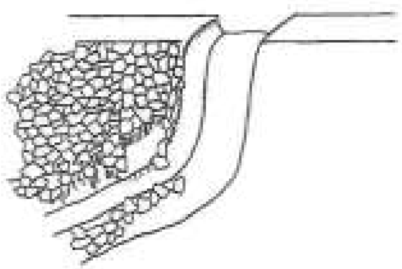
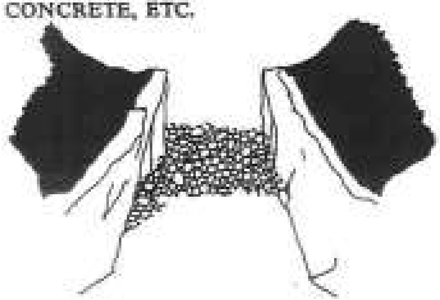
Figur[illegible] 4
Inspection [illegible]delines - Concrete Upstream Slope

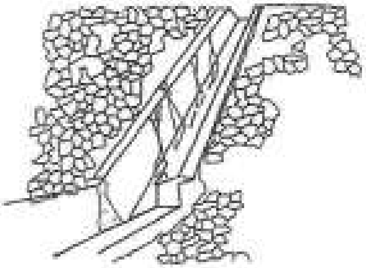
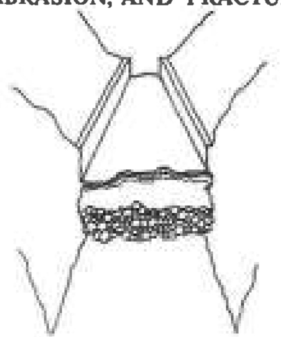
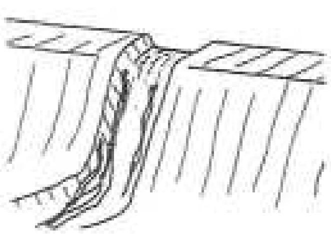
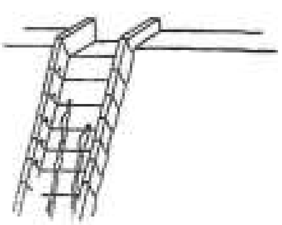
PROBLEM	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIONS
CRACKED DETERIORATED CONCRETE FACE 	Concrete deteriorated resulting from weathering. Joint filler deteriorated or displaced.	Soil is eroded behind the face and caverns can be formed. Unsupported sections of concrete crack. Ice action may displace concrete.	Determine cause. Either patch with grout or contact engineer for permanent repair method. 2. If damage is extensive, a qualified engineer should inspect the conditions and recommend further actions to be taken. ENGINEER REQUIRED
CRACKS DUE TO DRYING 	The soil loses its moisture and shrinks, causing cracks. NOTE: Usually seen on crest and downstream slope mostly.	Heavy rains can fill up cracks and cause small parts of embankment to move along internal slip surface.	1. Monitor cracks for increases in width, depth, or length. 2. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED

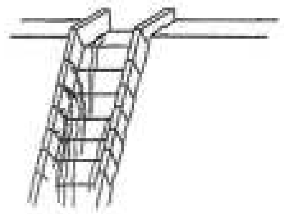
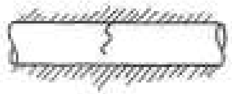
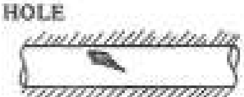
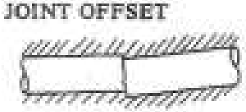
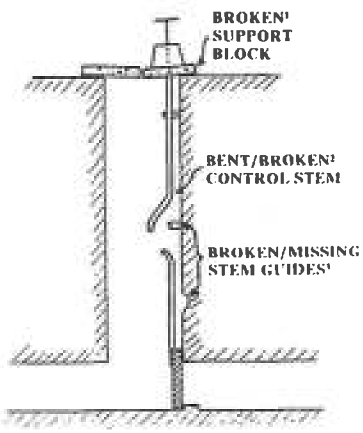
Figures 5.5
Inspection Guidelines - Spillways

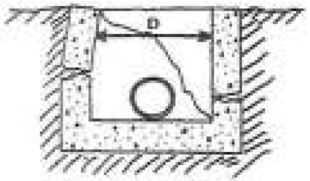
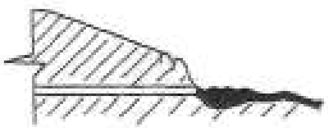
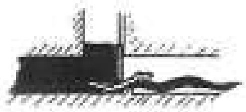
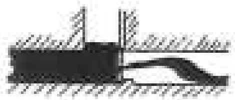
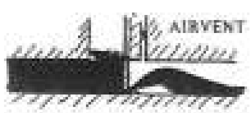
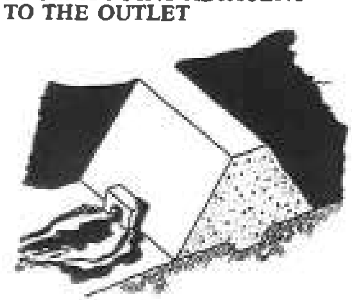
PROBLEM	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTIONS
EXCESSIVE VEGETATION OR DEBRIS IN CHANNEL 	Accumulation of slide materials, dead trees, excessive vegetative growth, etc., in spillway channel.	Reduced discharge capacity; overflow of spillway; overtopping of dam. Prolonged overtopping can cause failure of the dam.	Clean out debris periodically; control vegetative growth in spillway channel. Install log boom in front of spillway entrance to intercept debris.

PROBLEM	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTI
EROSION CHANNELS 	Surface runoff from intense rainstorms or flow from spillway carries surface material down the slope, resulting in continous troughs. Livestock traffic create gullies where flow concentrates varies.	Unabated erosion can lead to slides, slumps or slips which can result in reduced spillway capacity. Inadequate spillway capacity can lead to embankment overtopping and result in dam failure.	Photograph condition. Repair damaged areas by replacing eroded material with compacted fill. Protect areas against future erosion by installing suitable rock riprap. Revegetate area if appropriate. Bring condition to the attention of the engineer during next inspection.
EXCESSIVE EROSION IN EARTH-SLIDE CAUSES CONCENTRATED FLOWS 	Discharge velocity too high; bottom and slope material loose or deteriorated; channel and bank slopes too steep; bare soil unprotected; poor construction protective surface failed.	Disturbed flow pattern; loss of material, increased sediment load downstream; collapse of banks; failure of spillway; can lead to rapid evacuation of the reservoir through the severely eroded spillway.	Minimize flow velocity by proper design. Use sound material. Keep channel and bank slopes mild. Encourage growth of grass on soil surface. Construct smooth and well-compacted surfaces. Protect surface with riprap, asphalt, or concrete. Repair eroded part using sound construction practices.
END OF SPILLWAY CHUTE UNDERCUT 	Poor configuration of stilling basin area. Highly erodible materials. Absence of cutoff wall at end of chute.	HAZARDOUS Structural damage to spillway structure; collapse of slab and wall lead to costly repair.	Dewater affected area; clean out eroded area and properly backfill. Improve stream channel below chute; provide properly sized riprap in stilling basin area. Install cutoff wall.
WALL DISPLACEMENT 	Poor workmanship; uneven settlement of foundation; excessive earth and water pressure; insufficent steel bar reinforcement of concrete.	Minor displacement will create eddies and turbulence in the flow, causing erosion of the soil behind the wall. Major displacement will cause severe cracks and eventual failure of the structure.	Reconstruction should be done according to sound engineering practices. Foundation should be carefully prepared. Adequate weep holes should be installed to relieve water pressure behind wall. Use enough reinforcement in the concrete. Anchor walls to prevent further displacement. Install struts between spillway walls is needed. Clean out and backflush drains to assure proper operations. Consult an engineer before actions are taken. ENGINEER REQUIRED

PROBLE	PROBABLE CAUSE	'OSSIBLE CONSEQUENCES	RECOMMENDED ACTION
LARGE CRACKS 	Construction defect; local concentrated stress; local material deterioration; foundation failure, excessive backfill pressure.	**HAZARDOUS** Disturbance in flow patterns; erosion of foundation and backfill; eventual collapse of structure.	Large cracks without large displacement should be repaired by patching. Surrounding areas should be cleaned or cut out before patching material is applied. (See Chapter 7.) Installation of weep holes or other actions may be needed.
OPEN OR DISPLACED JOINTS 	Excessive and uneven settlement of foundation; sliding of concrete slab; construction joint too wide and left unsealed. Sealant deteriorated and washed away.	**HAZARDOUS** Erosion of foundation material may weaken support and cause further cracks; pressure induced by water flowing over displaced joints may wash away wall or slab, or cause extensive undermining.	Construction joint should be no wider than 1/2 inch. All joints should be sealed with asphalt or other flexible materials. Waterstops should be used where feasible. Clean the joint, replace eroded materials, and seal the joint. Foundations should be properly drained and prepared. Underside of chute slabs should have ribs of enough depth to prevent sliding. Avoid steep chute slope. ENGINEER REQUIRED
BREAKDOWN AND LOSS OF RIPRAP 	Slope too steep; material poorly graded; failure of subgrade; flow velocity too high; improper placement of material; bedding material or foundation washed away.	**HAZARDOUS** Erosion of channel bottom and banks; failure of spillway.	Design a stable slope for channel bottom and banks. Riprap material should be well graded (the material should contain small, medium, and large particles). Sub-grade should be properly prepared before placement of riprap. Install filter fabric if necessary. Control flow velocity in the spillway by proper design. Riprap should be placed according to specification. Services of an engineer are recommended. ENGINEER REQUIRED
MATERIAL DETERIORATION- SPALLING AND DISINTEGRATION OF RIPRAP, CONCRETE, ETC. 	Use of unsound or defective materials; structures subject to freeze-thaw cycles; improper maintenance practices; harmful chemicals.	Structure life will be shortened; premature failure.	Avoid using shale or sandstone for riprap. Add air-entraining agent when mixing concrete. Use only clean good quality aggregates in the concrete. Steel bars should have at least 1 inch of concrete cover. Concrete should be kept wet and protected from freezing during curing. Timber should be treated before using.

PROl I	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTI
POOR SURFACE DRAINAGE 	No weep holes; no drainage facility; plugged drains.	Wet foundation has lower supporting capacity; uplift pressure resulting from seepage water may cause damage to spillway chute; accumulation of water may also increase total pressure on spillway walls and cause damage.	Install weep holes on spillway walls. Inner end of hole should be surrounded and packed with graded filtering material. Install drain system under spillway near downstream end. Clean out existing weep holes. Backflush and rehabilitate drain system under the supervision of an engineer. ENGINEER REQUIRED
CONCRETE EROSION, ABRASION, AND FRACTURING 	Flow velocity too high (usually occurs at lower end of chute in high dams); rolling of gravel and rocks down the chute; cavity behind or below concrete slab.	Pock marks and spalling of concrete surface may progressively become worse; small hole may cause undermining of foundation, leading to failure of structure.	Remove rocks and gravels from spillway chute before flood season. Raise water level in stilling basin. Use good quality concrete. Assure concrete surface is smooth. ENGINEER REQUIRED
LEAKAGE IN OR AROUND SPILLWAY 	1. Cracks and joints in geologic formation at spillway are permitting seepage. 2. Gravel or sand layers at spillway are permitting seepage.	HAZARDOUS 1. Could lead to excessive loss of stored water. 2. Could lead to a progressive failure if velocities are high enough to cause erosion of natural materials.	1. Examine exit area to see if type of material can explain leakage. 2. Measure flow quantity and check for erosion of natural materials. 3. If flow rate or amount of eroded materials increases rapidly, reservoir level should be lowered until flow stabilizes or stops. 4. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED
TOO MUCH LEAKAGE FROM SPILLWAY UNDER DRAINS 	Drain or cutoff may have failed.	HAZARDOUS 1. Excessive flows under the spillway could lead to erosion of foundation material and collapse of parts of the spillway. 2. Uncontrolled flows could lead to loss of stored water.	Same as above.

PROBLE[M]	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTION
SEEPAGE FROM A CONSTRUCTION JOINT OR CRACK IN CONCRETE STRUCTURE 	Water is collecting behind structure because of insufficient drainage or clogged weep holes.	1. Can cause walls to tip in and over. Flows through concrete can lead to rapid deterioration from weathering. 2. If the spillway is located within the embankment, rapid erosion can lead to failure of the dam.	1. Check area behind wall for puddling of surface water. 2. Check and clean as needed; drain outfalls, flush lines, and weep holes. 3. If condition persists a qualified engineer should inspect the condition and recommend further actions to be taken.
Figures 5.6 Inspection Guidelines - Inlets, Outlets and Drains			
OUTLET PIPE DAMAGE			
CRACK 	Settlement; impact.	Excessive seepage, possible internal erosion.	Check for evidence of water either entering or exiting pipe at crack/hole/etc.
HOLE 	Rust (steel pipe) Erosion (concrete pipe) Cavitation	**HAZARDOUS** Excessive seepage, possible internal erosion.	Tap pipe in vicinity of damaged area, listening for hollow sound which shows a void has formed along the outside of the conduit.
JOINT OFFSET 	Settlement or poor construction practice.	**HAZARDOUS** Provides passageway for water to exit or enter pipe, resulting in erosion of internal materials of the dam.	If a progressive failure is suspected, request engineering advice.
CONTROL WORKS 	1. BROKEN SUPPORT BLOCK Concrete deterioration. Excessive force exerted on control stem by trying to open gate when it was jammed. 2. BENT/BROKEN CONTROL STEM Rust. Excess force used to open or close gate. Inadequate or broken stem guides. 3. BROKEN/MISSING STEM GUIDES Rust. Inadequate lubrication. Excess force used to open or close gate when it was jammed.	Causes control support block to tilt: control stem may bind. Control head works may settle. Gate may not open all the way. Support block may fail completely, leaving outlet inoperable. **HAZARDOUS** Outlet is inoperable. Loss of support for control stem. Stem may buckle and break under even normal use, (as in this example).	Any of these conditions can mean the control is either inoperable or at best partly operable. Use of the system should be minimized or discontinued. If the outlet system has a second control valve, consider using it to regulate releases until repairs can be made. Engineering help is recommended.

PROBL	PROBABLE CAUSE	POSSIBLE CONSEQUENCES	RECOMMENDED ACTION
FAILURE OF CONCRETE OUTFALL STRUCTURE 	Excessive side pressures on nonreinforce concrete structure. Poor concrete quality.	HAZARDOUS Loss of outfall structure exposes embankment to erosion by outlet releases.	1. Check for progressive failure by monitoring typical dimension, such as "D" shown in figure. 2. Repair by patching cracks and supplying drainage around concrete structure. Total replacement of outfall structure may be needed.
OUTLET RELEASES ERODING TOE OF DAM 	Outlet pipe too short. Lack or energy-dissipating pool or structure at downstream end of conduit.	HAZARDOUS Erosion of toe oversteepens downstream slope, causing progressive sloughing.	1. Extend pipe beyond toe (use a pipe of same size and material, and form watertight connection to existing conduit). 2. Protect embankment with riprap over suitable bedding.
VALVE LEAKAGE			
DEBRIS STUCK UNDER GATE 	Trashrack missing or damaged.	Gate will not close. Gate or stem may be damaged in effort to close gate.	Raise and lower gate slowly until debris is loosened and floats past valve. When reservoir is lowered, repair or replace trashrack.
CRACKED GATE LEAF 	Ice action, rust, affect vibration, or stress resulting from forcing gate closed when it is jammed.	Gate-leaf main fail completely, evacuating reservoir.	Use valve only in fully open or closed position. Minimize use of valve until leaf can be repair or replaced.
DAMAGE GATE SEAT OR GUIDES 	Rust, erosion, cavitation, vibration, or wear.	Leakage and loss of support for gate leaf. Gate may bind in guides and become inoperable.	Minimize use of valve until guides/seats can be repaired. If cavitation is the cause, check to see if air vent pipe exist, and is unobstructed.
SEEPAGE WATER EXITING FROM A POINT ADJACENT TO THE OUTLET 	1. A break in the outlet pipe. 2. A path for flow has developed along the outside of the outlet pipe.	HAZARDOUS Continued flows can lead to raid erosion of embankment materials and failure of the dam.	1. Thoroughly investigate the area by probing and/or shovelling to see if the cause can be determined. 2. Determine if leakage water is carrying soil particles. 3. Determine quantity of flow. 4. If flow increases, or is carrying embankment materials, reservoir level should be lowered until leakage stops. 5. A qualified engineer should inspect the condition and recommend further actions to be taken. ENGINEER REQUIRED

APPENDIX D
ODNR FACT SHEETS

APPENDIX D
ODNR FACT SHEETS

The following ODNR Fact Sheets are included in this manual for information purposes. Additional Fact Sheets are available at the ODNR website or from ODNR.

Fact Sheet No.	Title
93-26	Lake Drains
94-27	Rodent Control
94-28	Trees and Brush
94-30	Earth Dam Failures
94-31	Seepage through Earthen Dams
94-32	Concrete Repair Techniques
94-33	Inspection of Concrete Structures
98-49	Open Channel Spillways (Earth and Rock)
99-51	Outlet Erosion Control Structures (Stilling Basins)
99-52	Upstream Slope Protection
99-53	Embankment Instabilities
99-54	Ground Cover
99-55	Spillway Conduit System Problems
99-56	Problems with Concrete Materials
99-57	Problems with Metal Materials
99-59	Open Channel Spillways (Concrete Chutes and Weirs)
02-63	Remediation Alternatives

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 93–26

Dam Safety: Lake Drains

A lake drain is a device to permit draining a reservoir, lake or pond. Division of Water Administrative Rule 1501:21-13-06 requires that all Class I, Class II and Class III dams include a lake drain.

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.

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 ladders in control towers.
- Deteriorated 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

A. 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 can not be determined, then a local valve distributor may be able to provide assistance.

B. 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

Continued on back!

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.

C. 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.

D. 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.

E. 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.

F. 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.

G. 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.

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

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 the Ohio Dam Safety Laws.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–27

Dam Safety: Rodent Control

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 may plug the spillway and raise the pool level. Rodent control 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 them "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 at the following address:

The USDA
Animal and Plant Health Inspection Service
Wildlife Services
6929 Americana Parkway
Reynoldsburg, OH 43068-4116
Phone: (614) 861-6087 FAX: (614) 861-9018
Toll-Free Number: 1-866-4USDAWS 1-866-487-3297
Web site: http://www.aphis.usda.gov/wildlife_damage/

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.

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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 from a pond.

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 re-established. Dens should be eliminated without delay because damage from just one hole can lead to failure of a dam or levee.

Beaver

Beaver will try to plug spillways with their cuttings. Routinely removing the cuttings is one way to alleviate the problem. Trapping beaver may be done by the owner during the appropriate season; however, the nearest ODNR, Division of Wildlife, District Office or state wildlife officer should be contacted first.

Hunting and Trapping Regulations

Because hunting and trapping rules change from year to year, ODNR, Division of Wildlife authorities at one of the following offices should be consulted before taking any action.

Wildlife District One
1500 Dublin Road
Columbus, Ohio 43215
Phone: (614) 644-3925
FAX (614) 644-3931

Wildlife District Two
952 Lima Avenue
Findlay, Ohio 45840
Phone: (419) 424-5000
FAX (419) 422-4875

Wildlife District Three
912 Portage Lakes Drive
Akron, Ohio 44319
Phone: (330) 644-2293
FAX (330) 644-8403

Wildlife District Four
360 E. State Street
Athens, Ohio 45701
Phone: (740) 589-9930
FAX (740) 589-9999

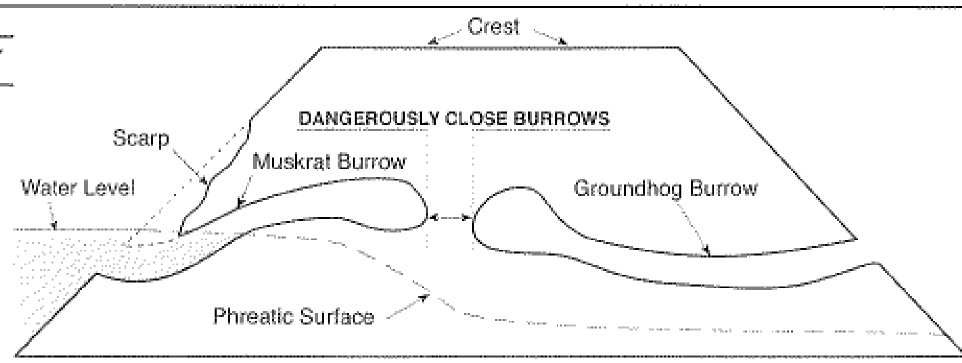
Wildlife District Five
1076 Old Springfield Pike
Xenia, Ohio 45385
Phone: (937) 372-9261
FAX (937) 376-3011

In Fairport Harbor
1190 High Street
Fairport Harbor, Ohio 44077
Phone: (440) 352-4199
FAX (440) 352-4182

Additional questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

Rodent Burrow



Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–28

Dam Safety: 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, provides a haven for burrowing animals, and retards 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. Stumps can be removed either by pulling or with machines that grind them down. All woody material should be removed to about 6 inches below the ground surface. The cavity should be filled with well-compacted soil and grass vegetation established.

Stumps of trees in riprap cannot usually be pulled or ground down, but can be chemically treated so they will not continually form new sprouts. Certain herbicides are effective for this purpose and can even be used at water supply reservoirs if applied by licensed personnel. For product information and information on how to obtain a license, contact the Ohio Department of Agriculture at the following address:

Ohio Department of Agriculture
Pesticide Regulation
8995 E. Main Street
Reynoldsburg, Ohio 43068
Telephone Number (614) 728-6987

These products should be painted, not sprayed, on the stumps. 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.

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. Aesthetics, unobstructed viewing during inspections, maintenance of a non-erodible surface, and discouragement of groundhog habitation are reasons for proper maintenance of the vegetal cover.

Methods used in the past for control of vegetation, but are now considered unacceptable, include chemical spraying, and burning. More 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.

Any other questions, comments, concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–30

Dam Safety: Earth Dam Failures

Owners of dams and operating and maintenance personnel must be knowledgeable of the potential problems which can lead to failure of a dam. 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. Engineers from the Division of Water, Dam Safety Engineering Program of the Department of Natural Resources are available at any time to inspect a dam if a serious problem is detected or if failure may be imminent. Contact the division at the following address and telephone number:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6605
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

In an emergency, call (614) 799-9538.

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 its crest is level and water flows over the crest and down the face as an evenly distributed sheet without becoming concentrated. **The owner should closely monitor the reservoir pool level during severe storms.**

Seepage Failures

All earth dams have seepage resulting from water permeating slowly through the dam and its foundation. Seepage must be controlled in both velocity and quantity. If uncontrolled, it can progressively erode soil from the embankment or its foundation, resulting in rapid failure of the dam. Erosion of the soil begins at the downstream side of the embankment, either in the dam proper or the foundation, progressively works toward the reservoir, and eventually develops a direct connection to the reservoir. This phenomenon is known 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, or a whirlpool in the reservoir. Once a whirlpool (eddy) is observed on the reservoir surface, complete failure of the dam will probably follow in a matter of minutes. As with overtopping, fully developed piping is virtually impossible to control and will likely cause failure.

Seepage can cause slope failure by creating high pressures in the soil pores or by saturating the slope. The pressure of seepage within an embankment is difficult to determine without proper instrumentation. A slope which becomes saturated and develops slides may be showing signs of excessive seepage pressure.

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Structural Failures

Structural failures can occur in either the embankment or the appurtenances. Structural failure of a spillway, lake drain, or other appurtenance may lead to failure of the embankment. Cracking, settlement, and slides are the more common signs of structural failure of embankments. Large cracks in either an appurtenance or the embankment, major settlement, and major slides will 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, the Division of Water 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.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–31

Dam Safety: Seepage Through Earthen Dams

Contrary to popular opinion, wet areas down stream from dams are not usually natural springs, but seepage areas. 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 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 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 will 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 professional engineer experienced with dams.

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Controlling the content of the seepage or preventing seepage flow from removing soil particles is extremely important. Modern design practice incorporates this control into the embankment through the use of cut-offs, 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 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.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–32

Dam Safety: 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. Because of their complex nature, 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 particular 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 that 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

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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 particular 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. As previously noted, all of the factors causing cracking must be identified and addressed before repairing the concrete to prevent the reoccurrence of cracks.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 94–33

Dam Safety: Inspection of Concrete Structures

Dams, dikes, and levees must not be thought of as part of the natural landscape, but as man-made structures which must be designed, inspected, operated, and maintained accordingly. Routine maintenance and inspection of dams and appurtenant facilities should be an ongoing 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 particular condition whenever it arises.

Structural Inspections

Concrete surfaces should be visually examined for spalling and deterioration due to weathering, unusual or extreme stresses, alkali or other chemical attack, 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

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. 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. 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.

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

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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.

Inspection of intake structures, trashracks, 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.

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. If there are any questions as to the seriousness of an observation the Dam Safety Engineering Program, or a registered professional engineer experienced with dams, should be contacted.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

In an emergency, call
(614) 265-6731 or (614) 799-9538

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 98–49

Dam Safety: 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, rock-lined, 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.

Ohio Administrative Code Rule 1501:21-13-04 requires that the frequency of use for an earth (grass-lined) or a rock-lined emergency spillway be less than:

- Once in 50 years for Class I dams;
- Once in 25 years for Class II dams; and
- Once in 10 years for Class III dams.

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 as a result 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

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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 requires prior approval from the Division of Water.

•**Weathering of rock channels can be a serious problem and is primarily due to freeze/thaw action.** Deterioration due to the effects 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.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

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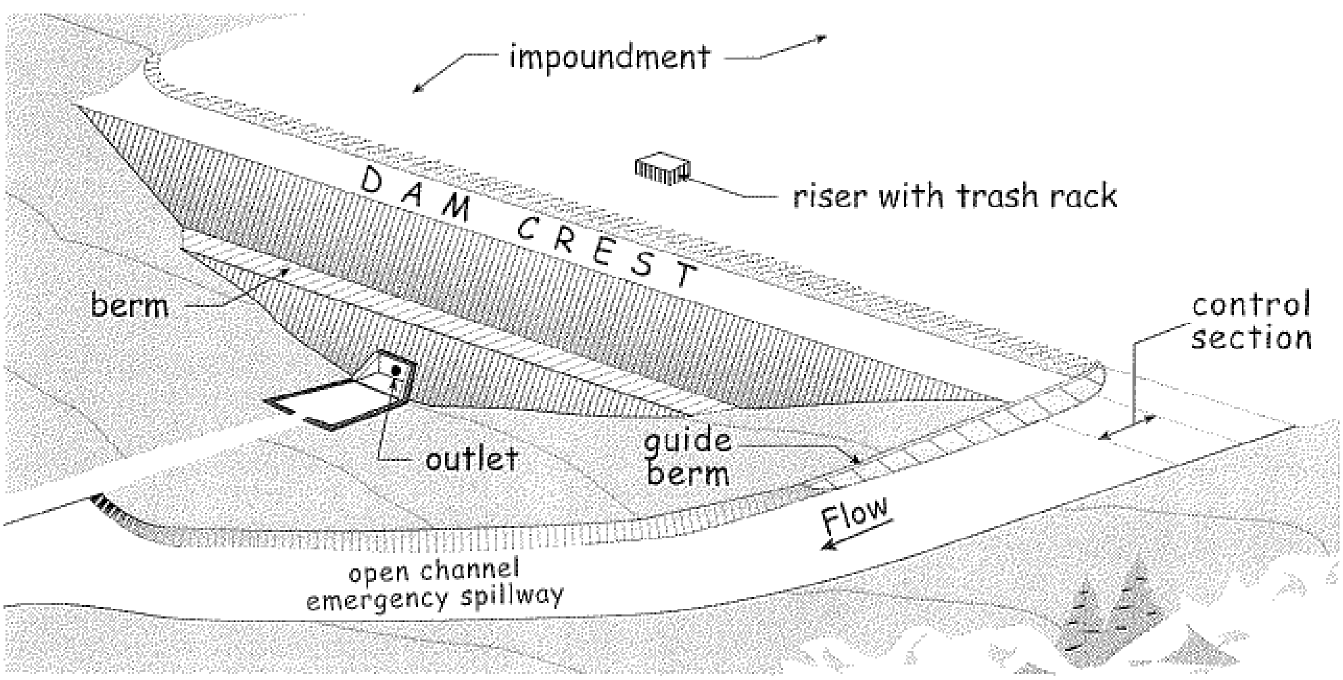
Downstream View of Open Channel Spillway



Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–51

Dam Safety: Outlet Erosion Control Structures
(Stilling Basins)

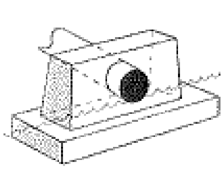
Water moving through the spillway of a dam contains a large amount of energy. This energy can cause erosion at the outlet which can lead to instability of the spillway. Failure to properly design, install, or maintain a stilling basin could lead to problems such as undermining of the spillway and erosion 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.

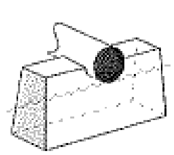
Headwall/Endwall

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.

Headwall



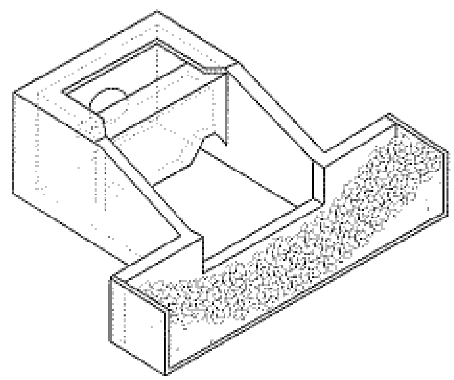
Endwall



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.

Impact Basin



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.

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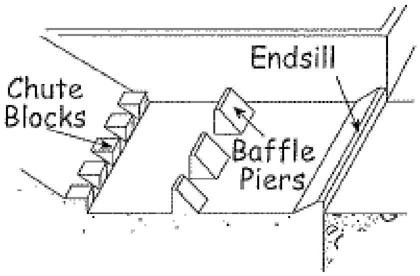
Type III Basin

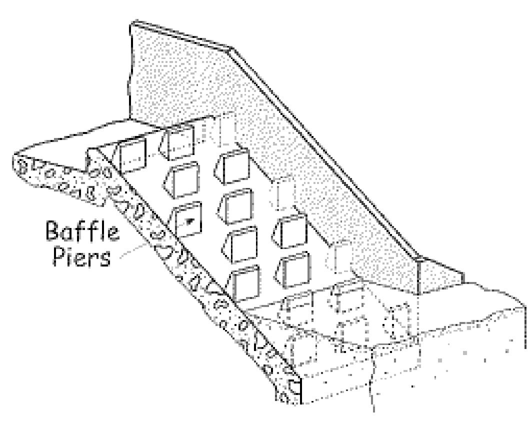


Type III energy dissipators can be used if the entrance velocity of the water is not high. They contain baffle piers which are located on the stilling basin apron downstream of the chute blocks. Located at the end of both the Type II and Type III basins is an endsill. The endsill may be level or sloped, 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.

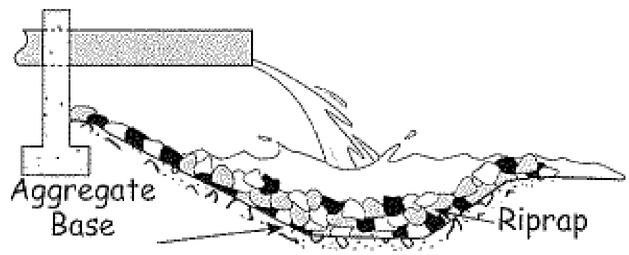
Baffeled Chute Basin



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.

Plunge Pool



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)," and "Problems with Concrete Materials."

Any questions, comments, concerns, or fact sheet requests should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
Voice: (614) 265-6731 Fax: (614) 447-9503
Website: http://www.dnr.state.oh.us/water

Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99-52

Dam Safety: 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.

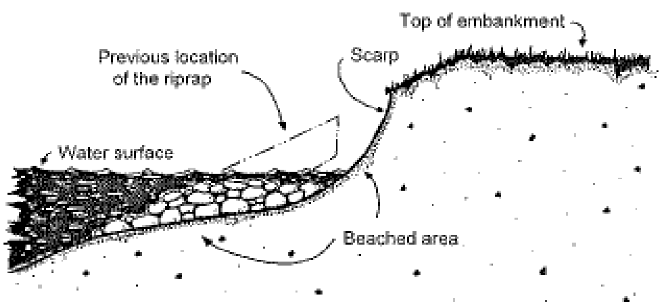


Figure 1 - Beaching

The repeated action of waves striking the embankment surface erodes fill material and displaces 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. However, an erosion scarp less than 1 foot high may be stable and not require repair.

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 the erosion has started, beaching will develop if remedial measures are not taken. Technical Release No. 69 developed by the USDA, Natural Resources Conservation Service can be used to help design engineers develop a preliminary or detailed design for riprap slope protection.

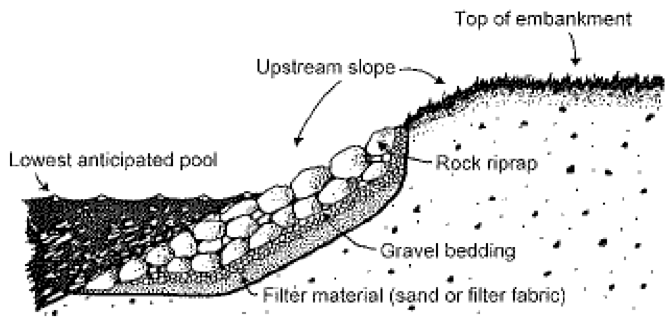


Figure 2 - Rock Riprap

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 the riprap. Its useful life varies with the characteristics of the stone used. Stone for riprap should be rock that is dense and well cemented. In Ohio, glacial cobbles or boulders, most limestone, and a few types of sandstone are acceptable for riprap. Most sandstones and shales found in Ohio do not provide long-term protection. Due to the high initial cost of rock riprap, its durability should be determined by appropriate testing procedures prior to installation. 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.

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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.

Vegetated Wave Berm

Vegetated wave berms dissipate wave energy and protect the slope from erosion. Berms are constructed on the upstream slope at the normal pool level and should be no less than 20 feet wide. This method of slope protection will not work well where the water surface fluctuates regularly from normal pool. If improper or sparse vegetation is present, the wave berm may not adequately dissipate the wave energy, allowing erosion and beaching to develop on the upstream slope. Technical Release No. 56 developed by the USDA, Natural Resources Conservation Service provides design and layout information.

The vegetation on the wave berm should be monitored regularly to verify adequate growth. Sufficient funds should be allocated for the regular maintenance of the vegetation. Severe erosion or reoccurring problems may require a registered professional engineer to design a more effective slope protection.

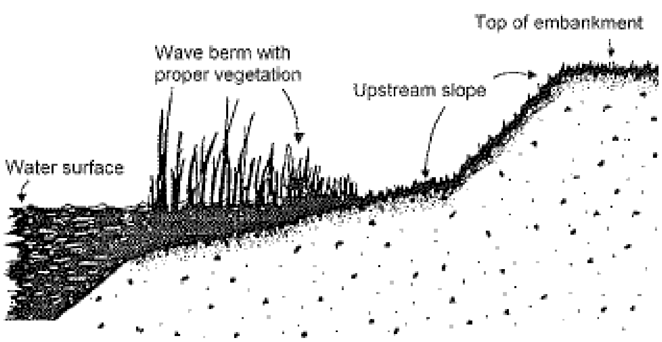

Figure 3 - Vegetated wave berm

Concrete Facing

Concrete facing can be used if severe wave action is anticipated, however, settlement of the embankment must be insignificant to insure adequate support for the concrete facing. A properly designed and constructed concrete facing can be expensive. This slope protection should extend several feet above and below the normal pool level. It should terminate on a berm or against a concrete curb or header. Granular filter or filter fabric (geotextile) is required under the concrete facing to help reduce the risk of undermining.

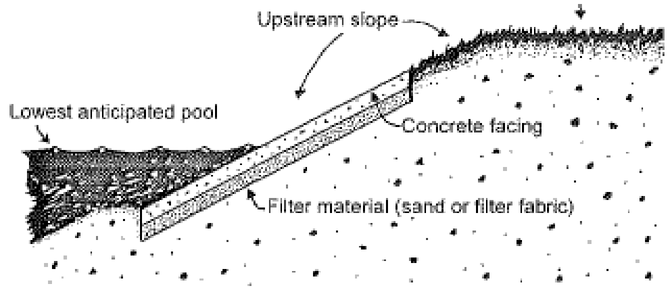

Figure 4 - Concrete facing

As with any type of slope protection, problems will develop if the concrete facing has not been properly designed or installed. Concrete facing often fails because the wave action washes soil particles from beneath the slabs through joints and cracks. This process is known as undermining, which will continue until large voids are created. Detection of voids is difficult because the voids are hidden. Failure of the concrete facing may be sudden and extensive. Concrete facing should be monitored for cracks and open joints. Open joints should be sealed with plastic fillers and cracks should be grouted and sealed. For additional information, see the "Problems with Concrete Materials" fact sheet.

Inspection and Monitoring

Regular inspection and monitoring of the 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 the Dam Safety Engineering Program should be contacted immediately. All records should be kept in the operation, maintenance, and inspection manual for the dam.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

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Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–53

Dam Safety: 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 Dam Safety Engineering Program 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.

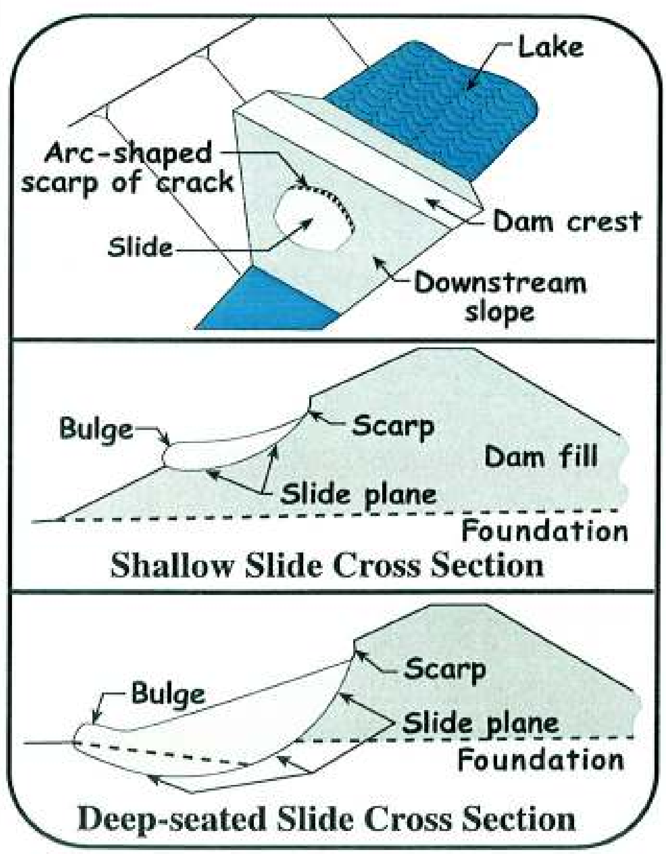
Cracks

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, he/she 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 Dam Safety Engineering Program and/or retain an engineer to investigate the crack and prepare plans and specifications 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 Dam Safety Engineering Program 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



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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 Dam Safety Engineering Program 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 Dam Safety Engineering Program must be contacted immediately.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
Division of Water
Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
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Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99-54

Dam Safety: 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 in Ohio 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 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. 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

Crown vetch, a perennial plant with small pink flowers, has been used on some dams in Ohio but is not recommended (see Figure 1). It hides the embankment surface, preventing early detection of cracks and erosion. It is not effective in preventing erosion.

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Figure 1: Crown Vetch
(Source: http://www.vg.com)

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. Additional information can be found on the Trees and Brush Fact Sheet.

Any other questions, comments concerns, or fact sheet requests, should be directed to the Division of Water at the following address:

Ohio Department of Natural Resources
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Dam Safety Engineering Program
2045 Morse Road
Columbus, Ohio 43229-6693
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Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–55

Dam Safety: 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 as a result 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

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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.

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Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–56

Dam Safety: 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 such as 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 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, but the concrete's resistance to weathering is 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 freezing and thawing, 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 cause surface cracks to develop. This occurs

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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 must investigate the cause of structural cracks and prepare plans and specifications for repair of any structural cracks. For additional information, see the "Concrete Repair Techniques" fact sheet.

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 must 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 registered professional engineer must 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 of the structure.

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 must 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. 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 Dam Safety Engineering Program should be contacted immediately. All records should be kept in the operation, maintenance, and inspection manual for the dam.

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Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–57

Dam Safety: 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. 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.

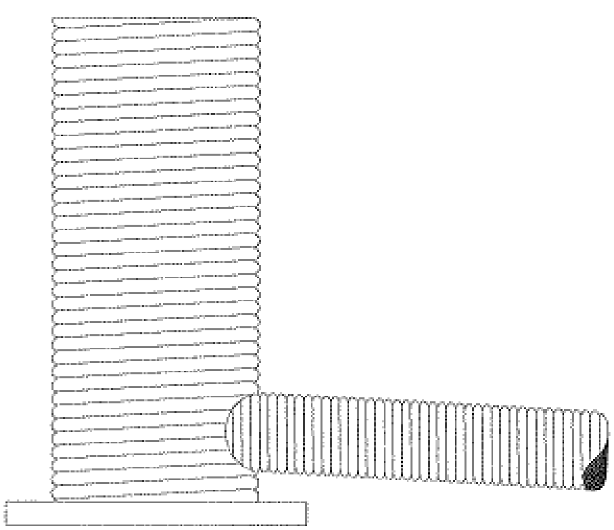

Figure 1 – Example of a corrugated metal pipe and riser spillway.

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 must 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

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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 Dam Safety Engineering Program should be contacted immediately. All records should be kept in the operation, maintenance, and inspection manual for the dam.

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Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 99–59

Dam Safety: 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.

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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 in order 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 in order 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.

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Ohio Department of Natural Resources
Division of Water Fact Sheet

Fact Sheet 02-63

Remediation Alternatives

The Division of Water, Dam Safety Engineering Program, has the statutory responsibility to ensure that human life, health, and property are protected from dam failures. The program regulates dams meeting certain height and storage criteria based on the provisions of the Ohio Revised Code (ORC) and Ohio Administrative Code (OAC). These criteria are listed in the ORC and OAC and in the Division of Water's Construction Permit and Dam Classification fact sheets. For all dams meeting these criteria, the program regulates their construction, operation, and repair to ensure that dams meet the required safety standards set forth in the ORC and OAC.

When the program finds that a dam has been constructed without a permit or that an existing dam does not meet the required safety standards, the Division of Water directs the owner to bring the dam into compliance. For a dam built without a construction permit, the owner would receive a letter that directs the owner to obtain a construction permit by following the construction permit requirements listed in the OAC and ORC. For an existing dam, the owner would receive a dam safety inspection report that lists required remedial measures. The owner must accomplish all of these required remedial measures. As alternatives to obtaining a construction permit or to accomplishing the required remedial measures listed in the inspection report, the owner may (a) remove the dam, (b) breach the dam, (c) modify the height of the dam to make it exempt from all or a portion of the construction permit and periodic inspection requirements, or (d) modify the purpose of the structure so that it does not meet the definition of a dam. Additional information about each of these alternatives is listed below.

Remove the Dam

Description: Dam removal consists of complete removal of the dam embankment to restore the original relief of the site. Removing the dam alleviates the need to obtain a construction permit or to accomplish the required remedial measures listed in the inspection report.

Requirements: The following items must be prepared by a registered professional engineer and submitted to the Division of Water for review and approval: a plan for lowering the lake level, construction plans and specifications for removing the embankment, plans and specifications for controlling sediment in the impoundment, a description of erosion protection in the breach and dam embankment foundation areas, and a construction schedule. Other items may be required in certain circumstances. It is the responsibility of the owner to hire a qualified registered professional engineer.

Breach the Dam

Description: A breach is defined as an opening in a dam that prevents the dam from impounding a significant amount of water (see photograph). A breach extends from the upstream side of the embankment to the downstream side and typically has mild side slopes. A dam breach could be considered partial removal of a dam. Breaching the dam alleviates the need to obtain a construction permit or to address the required remedial measures listed in the inspection report.

Photograph of dam breach from downstream. White line shows former dam crest, and arrow shows center of breach.

Requirements: The following items must be prepared by a registered professional engineer and submitted to the Division of Water for review and approval: a plan for lowering the lake level, construction plans and specifications for constructing the breach, plans and specifications for controlling sediment in the impoundment, calculations or justification for sizing the breach, a description of erosion protection in the breach area, and a schedule for construction. Other items may be required in certain circumstances. It is the responsibility of the owner to hire a qualified registered professional engineer.

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Modify the Height of the Dam

Description: Reducing the height of a dam reduces the dam's storage volume. This can make the dam exempt from the construction permit and periodic inspection requirements of the ORC or change the classification of the structure. Refer to the ORC for a complete description of the height and storage volume criteria. In summary, a dam is exempt from the construction permit and periodic inspection requirements when (a) it is not more than 6 feet high, or (b) it has not more than 15 acre-feet of storage volume at the top of dam elevation, or (c) it is not more than 10 feet high and has not more than 50 acre-feet of storage volume at the top of dam elevation. For reference, a dam that is 15 feet high and impounds a 2.5-acre lake has a storage volume of about 15 acre-feet. Modifying the dam to meet the above criteria alleviates the need to obtain a construction permit or to accomplish the required remedial measures listed in the inspection report.

The classification of a dam is based on three factors: the dam's height, storage capacity, and potential downstream hazard. Each factor is evaluated, and the final classification of the dam is based on the highest individual factor (Class I being the highest and Class IV being the lowest). When the classification based on downstream hazard is lower than the classification based on height and storage capacity, it is possible for the final classification of the dam to be changed if the height of the dam is reduced. In addition, reducing the height of a dam could change the potential impact of a dam failure on the downstream area, and thereby change the hazard classification. Changing the classification could alleviate the need to accomplish some or all of the required remedial measures listed in the inspection report. It should also be noted that Class IV dams do not require a construction permit; however, they do require submittal of the preliminary design report to the Division of Water for approval.

Requirements: The following items must be prepared by a registered professional engineer and submitted to the Division of Water for review and approval: a plan for lowering the lake level, detailed storage volume calculations, construction plans and specifications for lowering the dam crest, and supporting justification and calculations showing that the modified dam will operate safely. Other items such as a dam failure analysis may be required in certain circumstances. It is the responsibility of the owner to hire a qualified registered professional engineer.

Modify the Purpose of the Structure

Description: In accordance with OAC Rule 1501:21-3-01, the definition of a dam is "any artificial barrier together with any appurtenant works, which either does or may impound water or other liquefied material...A fill or structure intended solely for highway or railroad use that does not permanently impound water or other liquefied material as determined by the Chief is not considered a dam." It is possible to modify the dam so that it no longer meets the definition above. For example, draining the lake and installing a culvert at the streambed elevation or modifying the existing spillway to be a culvert may be acceptable. This alleviates the need to obtain a construction permit or to address the required remedial measures listed in the inspection report.

Requirements: The following items must be prepared by a registered professional engineer and submitted to the Division of Water for review and approval: a plan for lowering the lake level, construction plans and specifications for the modification, plans and specifications for controlling sediment in the impoundment, calculations or justification for design, and a schedule for construction. Other items may be required in certain circumstances. It is the responsibility of the owner to hire a qualified registered professional engineer.

As a temporary measure, the lake level of a dam may be lowered and maintained at a lower level. A lower lake level makes the dam safer by reducing water pressure on the dam and its foundation, reducing the volume of water that would be released during a failure, and providing more flood storage capacity. Maintaining the lake at a lower lake level could allow for a less stringent time schedule for obtaining a construction permit, accomplishing required remedial measures, or modifying the size of the dam.

Other local, state, and federal approval may be required for the construction activities listed above. It is recommended that the owner contact the Ohio Environmental Protection Agency, Division of Surface Water - 401 Certification at (614) 644-2135, the local floodplain administrator, and the U.S. Army Corps of Engineers district office. You may also refer to the Division of Water web site to review "Stream Management Guide, Permit Checklist for Stream Modification Projects, Guide No. 6" for more information regarding other agency approval or to review all of the Division of Water fact sheets.

For additional information please contact:

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