UTAH

DAM SAFETY GUIDE

TO

ROUTINE MAINTENANCE

OF DAMS

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FORWARD

A primary goal of the State of Utah's Dam Safety Program is to protect the public against the possibilities and consequences of dam failure. This goal is accomplished, in large measure, by establishing and enforcing adequate construction, operation, and maintenance standards for dams. This guidebook contains recommended maintenance and repair techniques that should be implemented to correct deficiencies noted during inspections of the dam and reservoir by representatives of the Division of Water Rights.

This document is intended as an elaboration of the State of Utah, Dam Safety Administrative Rules and Regulations. This documentation should serve as a guide, and in no way is it to be considered absolute or comprehensive. Professional engineering assistance will often be required to address technical maintenance needs.

This manual is intended as a general guide for routine maintenance, but allowances must be made for site-specific conditions of each dam and drainage. Every dam is unique with its own set of problems and solutions.

Additional guidance and site-specific detail is available from the Division of Water Rights, Dam Safety Section. Please do not hesitate to call if you need assistance in determining specific maintenance requirements for your dam.

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TABLE OF CONTENTS

1.0 INTRODUCTION

1.1 PURPOSE

The purpose of this guidebook is to promote dam safety and to better inform dam owners of their responsibility to safely operate, maintain, and repair their dams. This guidebook is intended to assist owners by providing practical information regarding dam maintenance. To assist dam owners in understanding dams and related facilities and to assist us in communicating the data presented herein, some dam terminology is presented in Appendix I of this guidebook in the form of a glossary.

1.2 AUTHORITY OF STATE ENGINEER

Dams in Utah, with the exception of those owned and operated by the U.S. Bureau of Reclamation or the U.S. Army Corps of Engineers, are inspected by the Utah Division of Water Rights (State Engineer's Office). Under Section 73-5a of the Utah Code, the State Engineer is directed to inspect and regulate dams. Currently, the Division of Water Rights inspects high hazard dams annually, moderate hazard dams biannually, and low hazard dams every five years. Each dam's hazard rating is not related to its likelihood to fail, but is associated with the probability of loss of life or significant property damage downstream in the event of a failure. The Division of Water Rights is strictly a regulatory agency. No funds are available from this agency for construction loans, grants or other assistance. By virtue of performing routine inspections, the Division assumes no liability for the safety of dams. Liability for all aspects of safety of the structure and related facilities rests with the owner.

2.0 VEGETATION CONTROL

All types of woody, deep-rooted vegetation and brush growing on dam embankments or in the spillway are considered a problem and should be controlled. Some of the problems associated with excessive vegetation growth on the dam are:

- Heavy vegetation obstructs the view of the dam inspector and obscures any cracking, seepage and other surficial indications of a problem with the dam.

- After trees and brush die, the root systems can decay, leaving behind

a tunnel through which water can pass (piping).

- Large trees blown over during windstorms can have their root systems uprooted, leaving behind a large hole in the embankment that could lead to breaching.

- Vegetation on the embankment provides habitat for burrowing animals, whose presence further endangers the dam.

Taking early action to remove vegetation before it becomes established is a critical part of dam maintenance.

Common types of vegetation detrimental to dams are willows, saltcedar (tamarisk), Russian olives, cottonwoods, sagebrush, aspens, poplars, pine, spruce, fir, and juniper.

Evergreen species are the easiest to eradicate since most of them die when cut and do not regenerate from roots. Deciduous trees are generally more difficult to control because many are capable of reproducing from roots and do not die from cutting. Some form of poisoning is an integral part of a program to control this type of vegetation.

As a general statement for all trees whether evergreen or deciduous, killing trees over about 6 feet tall on the dam must also be accompanied by excavating the roots and recompacting clean fill material into the excavation. This should be done in a radius extending from the trunk equal to the height of the tree or until the laterally extending roots are less than about a half inch in diameter.

POLICY - Only grasses which do not obscure observation of the embankment should be allowed to grow on the dam itself (contact your county agricultural agent for information on appropriate grasses for your area). All brush and trees should be prevented from growing: 1) on the dam itself and within 50 feet of the dam for deciduous trees and 25 feet for evergreens, 2) in the spillway and within 50 feet of the spillway for deciduous trees and 25 feet for evergreens, 3) near the spillway or outlet channels such that flow through those structures is reduced or water backs up on the embankment.

2.1 HERBICIDE APPLICATION

Several formulations of herbicides suitable for tree and brush control are available. They can be foliar applied or soil applied and consist of liquid spray solutions, granules;

2.1.1 Foliar applications consist of spraying the chemical directly on to the target plant, especially the leaves. It is necessary to thoroughly cover all above ground vegetation on the plant to the point of runoff. Foliar applications need to be made in the late spring or early summer when plants are actively growing and *new growth is young and succulent. In many plants, the heat of summer causes the tree to develop a waxy layer on the leaves which inhibits absorption of foliar applied herbicides into the plant. Also, the tree may become coated with dust as the summer progresses. Both of these factors reduce the effectiveness of foliar applied herbicides. Many foliar herbicides are neutralized in the soil.*

2.1.2 Soil treatment consists of applying the herbicide directly to the soil around the target plant. These treatments are intended to be moved into the soil by precipitation and can remain active for several years. If significant quantities of low lying vegetation exist around the target plant, it may be necessary to remove that vegetation and perhaps scarify the soil to obtain acceptable results. Time of year of these applications is not as critical as with foliar sprays since the herbicide is taken into the plant through the roots. However, do not apply soil treatments to frozen ground. These chemicals are often restricted from use where they may come into contact with irrigation waters, and all precautions and instructions on the labels of herbicides should be followed. They should not be used around the upstream side of the dam nor areas where surface water could move the chemical into conveyance structures.

2.1.3 <u>Frill method</u> consists of making cuts at a convenient height in a circle completely around a tree with downward axe strokes. These cuts should extend well into the sapwood and the sapwood be continuously exposed around the tree. The frilled area is then saturated with herbicide.

2.1.4 <u>Notch or cup method</u> consists of forming one or more notches or cups on the tree with two downward axe cuts, one above the other, and prying out the chips. Notches should be at the base of the tree as near the ground as possible and on the main roots if any show. Two notches are recommended for trees up to 6 inches in diameter, and notches spaced every 10 to 16 inches around larger trees are recommended. Again, the herbicide is applied into the notched areas.

2.1.5 <u>Cut stump method</u> consists of cutting the tree and spraying or painting herbicide onto the remaining stump. Best results are obtained by treating the stump immediately following cutting. Care should be taken to ensure thorough coverage of the area just inside of the bark of the tree.

2.2 HERBICIDE SELECTION

Translocated herbicides (herbicides which are moved from the place of application to other parts of the plant e.g., moved from the leaves to the roots.) are the main type which are useful for control of vegetation *detrimental to dams. These herbicides should be applied when the vegetation is growing and is not dormant. One commonly used herbicide which is not translocated is glyphosate (tradename Roundup). It is <u>not</u> recommended for the uses described herein; particularly, it is not effective in trunk or stump treatments. Translocated foliar sprays which are applied to the leaves (foliage) of plants destroy the plant by being translocated or moved by the plant into its roots. Only plants which are contacted by the chemical are affected. Foliar sprays are normally neutralized in the soil. Soil treatments are applied to the ground rather than directly to the vegetation. They remain active in the soil where they kill plant roots. A single treatment of soil sterilant can remain effective for several years. Choice of a specific herbicide will normally be dictated by where it is to be applied and the proximity of this area to irrigation water rather than the type of vegetation targeted. Extra care needs to be taken in selecting a herbicide for application to vegetation on the upstream side of the dam since some herbicides may contaminate the irrigation supply and result in damage to crops. A complete and thorough discussion of herbicides and the laws controlling their use is beyond the scope of this publication and the reader is referred to the following publications:*

UTAH WEED CONTROL HANDBOOK 1989
compiled by Steven A. Dewey
Utah State University
available through any county extension office

Herbicide Manual
by Gary W. Hansen, Floyd E. Oliver, N. E. Otto
U. S. Department of the Interior
Bureau of Reclamation

Applying Pesticides Correctly
A Guide for Private and Commercial Applicators
U. S. Department of Agriculture
U. S. Department of Environmental Protection
distributed by the Utah Department of Agriculture

2.2.1 <u>Willows</u> do not have a large taproot although sinker roots on large trees can be 6 to 8 feet deep. These trees are commonly found around water and reproduce from roots, seeds or from cuttings. Application of a foliar herbicide, such as 2-4-D, will kill young willows if properly applied. Repeat applications are normally required because 2-4-D does not affect the seeds. A soil sterilant, such as tebuthiuron (available from Elanco as SPIKE), is probably the easiest way to control willows, especially large ones. However, it may only be used on areas of the dam where the chemical will not be washed into irrigation waters. Always carefully read and follow the instructions on the labels of these chemicals.

Small, brushy willows have shallow, spreading roots which should not *require excavation to repair their damage. Large willows will require <u>extensive</u> excavation to successfully remove spreading roots. For this reason it is imperative that willows be controlled while they are small.*

2.2.2 <u>Saltcedar (tamarisk)</u> trees are becoming more of a problem on Utah dams. One of the best and easiest to control saltcedar is the cut stump application. The tree is first cut and the stump is then sprayed or painted with the herbicide picloram plus 2-4-D (available from Dow Chemical as Tordon RTU). It is essential that the entire cut stump surface be coated with the herbicide, especially the area next to the bark. Application of the herbicide should be done immediately following cutting of the tree. A good kill should be obtained using this procedure. Young, new growth of saltcedar can be handled by applying a foliar spray such as imazapyr (available from American Cyanamid as Arsenal). Foliar applications of 2-4-D are not effective on saltcedar.

2.2.3 <u>Russian olive</u> trees have a shallow root system spreading laterally some 3 to 4 feet or more beyond their limb width. Applications of 2-4-D as a foliar spray is not effective. However, the cut stump treatment recommended for saltcedar above or a notch method using a translocated herbicide should be effective. Soil sterilant treatments should also work well to control Russian olives. If controlled when they are young, roots of Russian olives do not need to be excavated. If they are allowed to reach a height of 6 feet or more, roots need to be excavated and soil recompacted in the excavation.

2.2.4 <u>Cottonwoods</u> do not have a taproot but do have sinker roots which grow downward from a lateral root and may be 3 or 4 feet in depth. Lateral roots can extend 150 feet or more from the tree. These trees are very sensitive to water drawdown and can be a significant deadfall problem at reservoirs which have them growing around the edge of the water. Because of their extreme lateral root growth, clearance zones around dams should be increased for cottonwoods. Cutting small cottonwoods will probably cause sprouting of new growth from roots, and herbicide treatments need to be incorporated into small cottonwood removal. Cutting of large cottonwoods should also be accompanied with painting the stump as recommended under saltcedar.

2.2.5 <u>Aspen</u> trees also do not have a taproot. and reproduce by root suckers or seeds. Any of the methods described above should effectively kill aspens. Simply cutting the offending trees will result in additional new growth from root suckers, making herbicidal treatment a necessity. Roots from all but the smallest aspens should be removed from the embankment.

2.2.6 <u>Pine and Spruce</u> trees have extremely shallow root systems. The width of the lateral radial spread of the roots can be equal to the height of the tree and more. Pines do have taproots which may reach 10 feet deep for large trees. Usually, with the exception of firs, simply cutting these evergreens is all that is required for control. Firs may re-sprout after cutting and their stumps should be poisoned.

For assistance in selecting and implementing a vegetation control program, we recommend that the local Utah State University County Extension Agent be contacted. Each county (except Daggett) has a local extension agent and a county weed supervisor who can assist or advise you in herbicide application programs.

3.0 BURROWING ANIMAL CONTROL

The information on rodents used in this guidebook has been taken from Field Rodent Damage Control Booklet by Ray H. Piggott and Donald W. Hawthorne, developed by the U. S. Fish and Wildlife Service cooperating with the Utah State Department of Agriculture. Some of the typical burrowing animals which damage dams in Utah are squirrels, prairie dogs, rock chucks, badgers, beaver and muskrat. Proper maintenance of embankment dams require that these animals be prevented from burrowing on the dam and that they be eradicated if they are present on a dam. Repair of rodent damages will be discussed in this section.

3.1 CONTROL METHODS

3.1.1 Control of ground squirrels can be accomplished by using strychnine-treated oats at 0.50% concentration. This bait should be scattered thinly in teaspoonful quantities near the burrow openings or in areas where feeding is evident. Do not place the bait inside the burrows. Thorough, systematic coverage will produce the best results. A pre-bait appetizer of clean oats may help gain bait acceptance. Treatment should be done just after the animals become active after coming out of hibernation.

3.1.2 Small burrowers can attract badgers which dig for them and create very large holes in dams. Under R608-11-3 General Rules, Section (J) Depredation, Utah Proclamation of the Wildlife Board For Taking, Possessing, Selling, Purchasing and Disposing of Furbearers, 1989-90, it is stated, "Badgers ... may be taken without a license when creating a nuisance or causing damage and these animals or parts of them are not being commercialized." Badgers can be shot under this depredation exemption. Employment of a professional trapper may be the best way to rid a site of badgers. It is recommended that dam owners having problems with badgers contact the Utah State Division of Wildlife Resources office or conservation officer nearest them. The addresses and phone numbers of these offices are found in the Appendix.

3.1.3 Beaver may also pose problems on dams and water conveyance *structures. As discussed above for badgers, the Proclamation for Furbearers regulates taking beaver. Also in Section (J) Depredation, it states, "Beaver doing damage may be taken or removed by an individual during closed seasons. A "Beaver Nuisance Permit" to remove damaging beaver must first be obtained from Division offices or conservation officers." If beaver are a problem, the Division of Wildlife Resources should be contacted for a permit and assistance.*

3.1.4 Rock chucks (marmots) can also damage dams. No toxic chemicals are registered for use on rock chucks. Shooting can provide some control. If the den can be located, gas cartridges can be used. This is done by lighting the cartridge, placing it inside the den opening, and sealing the opening. The acrid gas released by the cartridge then displaces the air inside the burrow. A profess- ional trapper may also be the best solution to deal with rock chucks.

3.1.5 Muskrat can also be a particularly troublesome problem for dam owners since the only viable means for removing them is to trap them. Muskrats can be seen swimming in the reservoir but are seldom seen on land. Employing a professional trapper is also recommended to rid a reservoir of muskrat.

3.1.6 The Utah Division of Wildlife Resources, Proclamation of the Wildlife Board for Nongame Mammals sets forth rules governing certain nongame mammals. Among these is the Utah Prairie Dog which is a protected species in Beaver, Garfield, Iron, Kane, Piute, Sevier, and Wayne Counties. On sites in these counties where the prairie dog is present, assistance from the Division of Wildlife Resources should be requested to remove the offending animals. A certificate of registration from DWR must first be obtained before taking action against the prairie dog.

3.2 REPAIR OF DAMAGE

Repair of rodent burrows on dams should be made by digging out the holes and recompacting clean fill into the excavation. This work can usually be done by hand.

3.3 PESTICIDE LICENSING

The Utah State Department of Agriculture licenses and regulates pesticide applications. Individuals desiring to use pesticides on their own private property can do so by obtaining a private applicator's license from the Department of Agriculture. Irrigation companies should have an individual in the company obtain a noncommercial applicator's license for using rodenticides on irrigation company facilities. Both of these licenses can be obtained from the Department *of Agriculture at various local offices around the state which are listed in the Appendix.*

4.0 OTHER EMBANKMENT MAINTENANCE

Deterioration of the surfaces of an earth dam may occur for several reasons. For example, wave action may cut into the upstream slope, vehicles may cause ruts in the crest or slopes, or runoff waters may leave erosion gullies on the downstream slope. Damage of this nature must be repaired on a continuing basis. The maintenance procedures described below are effective in repairing minor earthwork problems.

The material selected for repairing embankments depends upon the purpose of the earthwork. Generally, earth should be free from vegetation, organic materials, trash, or large rock. Most of the earth should be fine-grained soils or earth clods which easily break down when worked with compaction equipment. The intent is to use a material which, when compacted, forms a firm, solid mass, free from excessive voids.

If flow-resistant portions of an embankment are being repaired, materials which are high in clay or silt content should be used. If the area is to be free draining or highly permeable (i.e., riprap bedding, etc.) the material should have a higher percentage of sand and gravel. As a general rule, it is usually satisfactory to replace or repair damaged areas with soils similar to those originally in place.

4.1 CREST OF DAM

A dam's crest usually provides the primary access for inspection and maintenance. Because surface water will pond on a crest unless that surface is well maintained, this part of a dam usually requires periodic regrading. However, problems found on the crest should not be simply graded over or covered up. When a questionable conditon is found, the state's dam safety engineers should be notified immediately.

4.1.1 <u>Surface runoff</u> should be directed toward the upstream face of the dam by having the crest graded toward the reservoir. Less erosion will result since the upstream face of the dam is usually armored with riprap, the slope is normally flatter and the distance from the crest to the reservoir level is less that from the crest to the downstream toe.

4.1.2 <u>Traffic damage control</u> - As mentioned earlier, vehicles driving across an embankment dam can create ruts in the dam crest if the crest is not surfaced with a suitable roadbase material. The ruts can then collect water and cause saturation and softening of the *dam. Other ruts may be formed by vehicles driving up and down a dam face. These ruts can collect runoff and result in severe erosion. Vehicles should be banned from dam slopes and kept out by fences or barricades. Any ruts should be repaired as soon as possible.*

4.1.3 Excessive <u>settlement</u> of the embankment or foundation can result in a low area in the dam crest and <u>loss of the freeboard</u> (vertical distance between the top of the spillway and the top of the dam) nescessary to pass flood flows safely through the spillway. The dam crest should be surveyed, the probable cause for the formation of the low spot determined by an engineer, remedial action taken to correct the problem and then a uniform crest should be re-established by placing fill in low areas using proper construction techniques.

4.2 SLOPES OF THE DAM

4.2.1 <u>Livestock</u> access to the dam embankment should be controlled through installation of proper fencing. The main problem associated with livestock on the embankment is erosion caused by: excessive travel by livestock, especially during periods of wet weather, overgrazing of protective grasses and disruption of riprap. Increased erosion maintenance would be necessary if grazing is allowed.

4.2.2 Runoff should be directed away from the <u>abutment contacts</u> through the use of deflecting berms. Sources of excess runoff should be identified, e.g. access roads, parking areas, and runoff intercepted and redirected before it reaches the embankment. The abutment contacts should be kept clear of any obstructing vegetation so that the area can be properly inspected for seepage, etc.

4.2.3 Effective <u>slope protection</u> must prevent soil from being removed from the embankment. Slope protection will require routine maintenance to assure satisfactory long term operaton. Weathering can deteriorate poor quality riprap, breaking it into sizes which are too small to resist wave action. Rounded, similar size rocks have a tendency to roll downhill. Similiar sized rocks allow waves to pass between them washing out the finer gravels and sand, causing the riprap to settle. Riprap needs to be replaced anytime the finer material of the bedding is exposed. When riprap breaks down and erosion and beaching occur more often than once every three to five years, it may be necessary to place new bedding and riprap material which has been designed with the gradation and size that will assure its stability when subjected to wave action and weathering.

4.3 DRAINS, PIEZOMETERS AND WEIRS

4.3.1 <u>Drains</u> should be maintained open, this may require occasional reaming and cleaning. Rodent screens should be placed over the downstream end of the drain to protect them from nesting rodents. The drain outfall channel should be sloped to prevent ponding. PVC piping should be buried to protect it from deterioration due to sunlight.

4.3.2 <u>Piezometers</u> should be equipped with a surface casing and locking lid to protect them from vandalism. The piezometer pipe should have a cap to keep soil or water from entering it. Piezometers casings located in or near traffic areas should be protected from vehicular damage.

4.3.3 <u>Weirs</u> and Weir Ponds should be maintained free from weeds and trash. Sediments accumulating behind weirs installed to measure seepage should be monitored with their quantities measured and noted at the time they are cleaned out. The crest of the weir should be checked periodically to assure that it is level and should also be checked with reference to the zero of the gage. The downstream channel should be adequately sloped to prevent water ponding at the base of the weir. The downstream toe of the weir should be protected against erosion by placement of rock of adequate size.

5.0 OUTLET MAINTENANCE

A dam's inlet and outlet works are essential to the operation of a dam. Pool level drawdown should not exceed about 1 foot per day for slopes of clay or silt materials except in emergency situations. Very flat slopes or slopes with free-draining upstream soils can, however, withstand more rapid drawdown rates. The low level outlet must always be operable so that the pool level can be drawn down in case of an emergency or for repairs. Outlet controls must be accessible during periods when the reservoir is spilling. All valves and gates should be operated at least once a year. Valves or gates that have not been operated for a long time can present a special problem for owners. If the valve cannot be closed after it is opened, the impoundment could be completely drained. An uncontrolled and rapid drawdown could also cause more serious problems such as slides along the saturated upstream slope of the embankment or downstream flooding. Therefore, when a valve or gate is operated, it should be inspected and all appropriate parts lubricated and repaired. It is also prudent to advise downstream residents of large and/or prolonged discharges.

5.1 SEDIMENTS

Sediments can build up and block the drain inlet, or debris can enter the valve chamber, hindering its function. The likelihood of these problems *is greatly decreased if the valve or gate is operated and maintained conscientiously.*

5.2 CORROSION

Corrosion is a common problem of metal conduits. Exposure to moisture, acid conditions, or salt will accelerate corrosion. In particular, acid runoff from strip mine areas will cause rapid corrosion of steel pipes. In such areas, pipes made of noncorrosive materials such as concrete or plastic should be used. Metal pipes which have been coated to resist accelerated corrosion are also available. The coating can be of epoxy, aluminum, zinc, asbestos or mortar. Coatings applied to pipes already in service are generally not very effective because of the difficulty of establishing a bond with the pipe. Similarly, bituminous coatings cannot be expected to last more than one or two years on flowways. Of course, corrosion of metal parts of operating mechanisms can be effectively treated and prevented by keeping those parts greased and/or painted.

Corrosion of metal conduits can also be controlled or arrested by installing cathodic protection. A metallic anode made out of a material such as magnesium is buried in the soil and is connected to the metal pipe by wire. An electric potential is established which causes the magnesium to corrode and not the pipe.

5.3 CAVITATION

Cavitation is another potential outlet problem. When water flows through an outlet system and passes restrictions (e.g. valves), a pressure drop may occur. If localized water pressures drop below the vapor pressure of water, a partial vacuum is created and the water actually boils, causing shockwaves which can damage the outlet pipes and control valves. Cavitation may be minimized if a ventilating pipe is connected just downstream of the restriction. Cavitation can be a serious problem for large dams where discharge velocities through the outlets are high.

5.4 EXERCISING VALVES

All valves should be fully opened and closed at least once per year. This not only limits corrosion buildup on control stems and gate guides, but also provides an opportunity to check for smooth operation of the system. Jerky or erratic operation could signal problems and indicate a need for more detailed inspection.

5.5 GATE OPERATION

The full range of gate settings should be checked. The person performing the inspection should slowly open the valve, checking for *noise and vibration - certain valve settings may result in greater turbulence. He should also listen for noises which sound like gravel being rapidly transported through the system. This sound indicates that cavitation is occuring, and the gate settings at which the noises occur should be avoided. The operation of all mechanical and electrical systems, backup electric motors, power generators, and power and lighting wiring associated with the outlet should also be checked.*

5.5.1 Electricity is often used on dams to operate the outlet gates, provide lighting and operate other electrical equipment. Thus, it is important that the electrical system be well maintained.

Maintenance should include a thorough check of the fuses and a test of the system to be sure everything is properly functioning. Moisture and dust should be kept away from the electrical system, and wiring should be checked for corrosion and mineral deposits. Any necessary repairs should be completed immediately, and records of the repair work should be kept.

In addition, generators kept for back-up emergency power must be maintained. Maintenance should include oil changes, battery checks, antifreeze checks, and making sure that fuel is readily available.

5.5.2 A hydraulic control system is often used to open and close the sliding gates of the outlet or intake works. The hydraulic system usually has long hoses and pipelines to transmit hydraulic fluid to the gate operating cylinders, and there are gauges to indicate hydraulic pressure in the system. Routine checks should be performed on the hydraulic cylinders, hoses and pipelines as required.

5.6 OUTLET INSPECTIONS

Inspecting the outlet system should be done by entering all accessible portions of the structure including the conduit if it is large enough. While inside the conduit it should be tapped with a hammer to help locate possible voids behind the pipe. All joints, connections and vents should be checked for leakage, offsets or damage. Any material obstructing the conduit should be removed. Conduits which are too small to enter should be periodically inspected by remote video camera. If possible, the entire length of the conduit should be inspected for any obvious holes, cavitation damage, vertical and horizontal alignment.

6.0 SPILLWAY MAINTENANCE

The main function of a spillway is to provide a safe exit for excess water in a reservoir. If a spillway is of inadequate size, a dam could be overtopped and fail. Defects in a spillway can cause failure by rapid erosion of the underlying soils. A spillway should always be kept clear of obstructions, have the ability to resist erosion, and be protected from deterioration.

6.1 OBSTRUCTIONS

Obstructions of a spillway may result from excessive growth of grass, weeds, brush, trees, debris, landslide deposits, or rocks placed in the spillway by recreationists. Any of these obstructions can reduce the capacity of a spillway and lead to overtopping of the dam. The installation of log booms can help to prevent floating debris from entering the spillway. Only low-lying grasses should be permitted to grow in the spillway and any obstructions in the spillway should be promptly removed so that the spillway can pass its design capacity. Also, medium sized rocks which can be carried by swift flowing water in a spillway can damage spillway concrete.

6.2 CRACKS

Cracks in the concrete lining of a spillway are commonly encountered. Hairline cracks are usually of no real consequence, but large cracks are of concern. These cracks may be caused by loss of foundation support, shrinkage, movement of the structure, or excessive earth or water pressure. Large cracks may allow earth materials behind the structure to be washed out, causing erosion and perhaps more cracks. It is even possible for the structure to become dislodged and washed away. A severely cracked spillway should be examined by and repaired under the supervision of an engineer. The Division may require monitoring of cracks or other deficiencies such as tilting walls and will assist owners in setting up a monitoring program if the owner so desires.

6.3 EROSION RESISTANCE

It is essential that the spillway be erosion resistant. Erosion protection is very important for spillways in sandy soils, deteriorated granite, clay or silt deposits. Low lying grasses, rip rap, and concrete structures usually are used to armor spillways.

6.4 SPILLWAY SURFACE

Spillway surfaces exposed to freeze-thaw cycles often suffer from surface spalling. Chemical action, contamination, and unsound aggregates can also cause spalling. If spalling is extensive, the spalled area should be sketched or photographed, showing the length, width, and depth of the area. The problem should be examined closely to see if the remaining concrete is sound and if reinforcing bars are exposed. The concrete should be tapped with a rock hammer to determine *whether voids exist below the surface of the concrete. The condition should be periodically examined to determine if it is worsening.*

6.5 WEEP HOLES

Vertical walls of a spillway are usually equipped with "weep holes". These holes are intended to drain water from the soil behind the walls and help to prevent damage to the walls from freezing and water pressure. If all weep holes in a wall are dry, then it is probable that the soil behind the wall is dry. If some weep holes flow but others do not, it possible that those which do not flow may be plugged. Any mud, mineral deposits or other obstructions accumulated in weep holes should be removed. Properly functioning weep holes can prolong the life of all concrete walls. Rodent screens should be installed if necessary.

6.6 EXPOSURE TO SUNLIGHT

Making sure the spillway is exposed to sunlight on high mountain dams will prevent the accumulation of drifted snow and ice in the spillway entrance that could obstruct the early spring runoff and result in overtopping of the dam. In new dams exposing the spillway to sunlight should be considered in the design phase. In existing dams any vegetation that shades the spillway should be removed. A visit to the dam prior to heavy runoff should be scheduled to determine if the spillway is blocked by snow or ice, if that is the case, the blockage should be removed either by excavating a starter channel or spreading coal dust on the surface of the snow to aid in its melting.

6.7 FLASHBOARDS AND STOPLOGS

The placing of flashboards or stoplogs on the crest of the spillway to raise the water retention level is considered a poor practice by this office. In the event of a flood, stoplogs can be very difficult to remove due to the additional water force acting upon them and wooden flashboards may not fail as designed. Either of these problems could lead to overtopping of the dam.

6.8 DISCHARGE CHANNEL

The spillway discharge channel should be aligned so that it directs water away from the toe of the dam. The channel should be maintained free of obstructing vegetation and debris. Erosional damage should be repaired as soon as possible.

7.0 RESERVOIR BASIN

7.1 FLOATING DEBRIS

Floating debris can obstruct and damage spillways and outlets and should be removed from the reservoir basin and dam embankment as a part of routine maintenance.

7.2 LANDSLIDES

Landslides entering the reservoir basin greatly contribute to the sediment load and may drastically shorten the useful life of a reservoir. Landslides entering a reservoir displace the impounded water, if this displacement is large enough it can lead to overtopping of the dam.

Landslides into a reservoir are often due to the reservoir slopes becoming saturated with water and then the reservoir being rapidly drawn down. Avoiding rapid drawdowns, blanketing unstable soils with clay, and directing runoff away from unstable soil areas are effective methods to prevent landslides.

7.3 SEDIMENT

Sediment buildup in the reservoir is usually due to destabilization of upstream drainages. A comprehensive basin management plan which emphasizes erosion control, retention of vegetation and environmentally sound stream channel stabilizations practices would be the most effective solution to the sediment problems. Dredging of the reservoir would forestall the loss of capacity but removing the sediment source would be much more effective.

7.4 SINKHOLES

Sinkholes in the reservoir basin, especially adjacent to the embankment, should be cause for concern. They may be indicative of internal erosion (piping) of the embankment material. Away from the upstream toe of the embankment sinkholes may form due to seepage through the foundation material. If the foundation material is erodable the seepage could lead to failure of the dam. All sinkholes should be brought to the attention of the Dam Safety Office and monitored for any significant changes.

8.0 SIGNS OF EMBANKMENT DISTRESS

Structural problems with the embankment may be exhibited in the embankment itself, the foundation of the dam, or the abutments. Many of these types of problems become evident early in the life of the dam, often during the first reservoir filling. Symptoms of structural problems are seepage, cracking, *movement, settlement, sinkholes and erosion.*

8.1 SEEPAGE

Seepage may be evidenced by water emerging in a concentrated location or wet areas. Seepage may occur through joints in the bedrock or zones of low permeability in the foundation or abutments. Seepage may also be attributed to improper construction. In modern dams, seepage flows through the embankment are usually intercepted by permeable drain materials and carried away by pipes from the drain. Excessive drain flows or embankment seepage occuring outside of the drain outlets indicates serious problems. Any evidence of seepage will be discussed with the owner during inspections by the Division. It may be necessary to measure seepage flows and maintain a written historical record of the flows. Physically measuring flows allows a correlation of seepage flow to reservoir elevation and eliminates guesswork from estimating those quantities. Increases will be apparent. Another benefit from using weirs to measure flows is that soils which are possibly being moved by the water may settle out in the pool behind the weir. This allows estimates of sediments being removed and observation of potentially dangerous piping. Piping consists of the progressive erosion and removal of soil by concentrated seepage flows through a dam, its foundation, or its abutments. Seepage which is causing piping may create a sand boil where the water emerges. If new seepage areas develop, an increase in existing seepage occurs, or sand boils develop, the Dam Safety Section of the Division of Water Rights should immediately be contacted.

8.2 CRACKING

Cracking can occur in a variety of places on the dam. Transverse cracks, those which occur perpendicular to the crest, usually indicate that stresses in the dam are being created by unequal settlement of the fill or foundation material. Longitudinal cracks, which are parallel to the crest, can occur anywhere from the upstream toe to the downstream toe. Foundation problems or an embankment weakness can be manifested by cracks. Emptying the reservoir quickly can cause cracks on the upstream side of the dam. Randomly oriented, shallow cracks are usually attributable to drying of the surface soils on the dam. Cracks of any sort should be reported to the Dam Safety Section of the Division of Water Rights.

8.3 MOVEMENT

Movement of the embankment can occur as a slough or slide. These problems are usually initiated by a period of unusually high moisture in the ground and are aggravated by seepage flows. Cracks at the top and bulging at the bottom, or toe, of the moving material frequently accompanies a slope failure. Establishing survey monuments allows the extent of movement to be accurately measured. If any movement of *embankment or abutment material occurs, the Dam Safety Section of the Division of Water Rights should be contacted.*

8.4 SINKHOLES

Sinkholes are created by piping of material by seepage flows. They can occur directly on the dam but usually occur along the upstream toe of the dam. During low reservoir levels, the reservoir basin, the abutments, and the upstream face of the dam should be examined closely for sinkhole depressions. Sinkholes may indicate serious deficiencies with the dam and should be remedied quickly. Corrective action will need to be designed by a professional engineer.

8.5 EROSION

Erosion of the embankment can result from inadequate protection of the dam from wave action or from rain collecting and running down the face of the dam. Waves create steps, sometimes called beaches and benches, along the upstream face of dams not properly protected by riprap. Surface runoff should be directed toward the upstream face of the dam by having the crest graded toward the reservoir. Less erosion will result since the upstream face of the dam is usually armored with riprap and the distance from the crest to the reservoir level is less than from the crest to the downstream toe. Erosion of the upstream face of the dam should be corrected by placing an adequate layer of properly graded riprap.

APPENDICES

I. GLOSSARY

***ABUTMENT** - That part of a valley side against which a dam is constructed. Right and left abutments are those on the right and left sides respectively of an observer facing downstream.*

***AIRVENT PIPE** - A pipe designed to provide air to the outlet conduit to reduce turbulence during release of water. Extra air is usually necessary downstream of constrictions.*

***BEACHING or BENCHING** - The removal, by wave action, of a portion of the upstream (reservoir) side of the embankment and the resultant deposition of this material farther down the slope. Such deposition creates a relatively flat beach area.*

***BOIL** - A disturbance in the surface layer of soil caused by water escaping under pressure. The boil may be accompanied by deposition of soil particles (usually sand) in a circle around the point at which the water exits.*

***BREACH** - An opening or a breakthrough of a dam sometimes caused by rapid erosion of a section of earth embankment by water.*

***CAVITATION** - Wear on hydraulic structures where a high hydraulic gradient is present. Cavitation is caused by the abrupt change in direction and velocity of the water so the pressure at some points is reduced to the vapor pressure and vapor pockets are created. These pockets collapse with great impact when they enter areas of higher pressure, producing very high impact pressures over small areas that eventually cause pits and holes in the surface. Noises and vibrations may be evident during high flows.*

***CONDUIT** - A closed channel to convey the discharge through or under a dam.*

***CORE** - A zone of material of low permeability, usually clayey soils, in an embankment dam.*

***CREST LENGTH** - The length of the dam, from one abutment to the other, along the top of the dam. This includes the spillway width if it is adjacent to the embankment.*

***CUTOFF** - An impervious construction or material which reduces seepage or prevents it from passing through foundation material.*

***CUTOFF TRENCH** - An excavation into the foundation later to be filled with impervious material to form a cutoff below the dam.*

***CUTOFF WALL** - A wall of impervious material (usually concrete) built into the foundation to reduce seepage under the dam.*

***DRAINS** - Permeable vertical or horizontal sections in the dam which collect water to prevent saturation of the downstream portion of the embankment. This water is frequently piped from the drainage layer to daylight outside the embankment.*

***DRAINAGE AREA** - Land above the damsite from which surface waters naturally drain to the dam.*

***FILTER** - A band or zone of granular material that is incorporated into a dam and is graded so as to allow seepage to flow into the filter without allowing the migration of soils from zones adjacent to the filter.*

***FLASHBOARDS** - A length of timber, concrete, or steel placed on the crest of a spillway to raise the water level, but that may be quickly removed in the event of a flood either by a tripping device or by deliberately designed failure of the flashboard or its supports.*

***FLOODPLAIN** - An area adjoining a body of water or natural stream that has been or may be covered by flood water.*

***FLOWLINE** - The path that a particle of water follows in its course of seepage under laminar flow conditions.*

***FLUME** - A flow measuring device*

***FOUNDATION OF DAM** - The natural material on which the dam structure is placed.*

***FREEBOARD** - The vertical distance between a stated water level and the top of a dam. Usually, this term is used to denote the difference in elevations between the flowline of the spillway, which is considered to be the maximum normal water surface, and the top of the dam.*

***GATE or VALVE** - In general, a device in which a member is moved across the waterway to control or stop the flow.*

***HEIGHT OF DAM** - Hydraulic height refers to the height that water can rise to behind a dam. It is the difference between the elvations of the lowest point in the original streambed at the downstream toe of the dam and the maximum controllable water surface. Structural Height is the same as hydraulic height except that it is measured to the top of the dam.*

***INSTRUMENTATION** - Permanent devices which are installed in/near a dam to allow monitoring of the dam and impoundment. These devices may include a staff gage for measuring the reservoir level, piezometers and/or observation wells to determine the phreatic surface through the dam , weirs or flumes, and survey monuments. Each of these terms is defined in this glossary.*

INTAKE - A structure which is designed to guide water into another, such as the intake structure for the outlet conduit.

LIQUIFACTION - The sudden large decrease of the shearing resistance of a cohesionless soil. It is caused by a collapse of the structure by shock or other type of strain and is associated with a sudden but temporary increase of the pore-filled pressure. It involves a temporary transformation of the soil into a fluid mass.

LOG BOOM - A device intended to prevent large floating debris from being carried into the spillway and possibly clogging it. Typically, it is constructed out of logs which are hinged together and anchored on either side of the spillway so that the floating debris catches on the log boom and is kept in the reservoir basin.

OUTLET - A conduit through which controlled releases can be made from the reservoir.

PHREATIC SURFACE - The upper surface of saturation within an embankment.

PIEZOMETER - A device for measuring internal water pressures or levels in the dam, its foundation, or the abutments. Most piezometers are wells with small diameter pipes installed through which the water level is measured. Observation wells are similar to piezometers but are often larger in diameter than piezometers.

PIPING - The progressive development of internal erosion by seepage, appearing downstream as a hole or seam discharging water that contains soil particles.

PLUNGE POOL - A natural or sometimes artificially created pool that dissipates the energy of free-falling water. The pool is located at a safe distance downstream of the structure from which water is being released. Also called STILLING BASIN.

RIPRAP - A layer of non-erodable large stones, broken rock or precast blocks placed in a random fashion on the upstream slope of an embankment dam, on a reservoir shore, or on the sides of a channel as a protection against wave and ice action.

SLUMP AREA - A portion of earth embankment which moves downslope, sometimes suddenly, often with cracks and bulges developing.

SPALLING - the seperation and deterioration of a thin surface layer of concrete or rock.

SPILLWAY SYSTEM - A structure over or through which excess reservoir water is discharged. If the flow is controlled by gates, it is considered a controlled spillway; if the elevation of the spillway crest cannot be adjusted and is the only control, it is considered an uncontrolled spillway.

EMERGENCY SPILLWAY - A secondary spillway designed to operate only during extreme floods.

PRINCIPAL SPILLWAY - The main spillway for normal operations and flows.

STILLING BASIN - A basin constructed to dissipate the energy of fast-flowing water from a spillway or outlet to protect the river bed from erosion.

STOPLOGS - Removable logs or timbers, steel or concrete beams placed on top of each other with their ends held in guides on each side of a channel to raise the reservoir level.

SURVEY MONUMENTS - Surveyed monuments are sometimes installed on dams to allow monitoring of movement of the dam.

TOE OF EMBANKMENT - The intersection of the face of a dam with the ground surface.

TRASH RACK - A structure of metal or concrete bars located in the waterway at an intake to prevent the entry of floating or submerged debris.

WATERSTOP - A strip of metal, rubber, or other material used to prevent leakage through joints between adjacent sections of concrete.

WEEPHOLES - Holes in concrete walls or slabs intended to drain water from the soil behind the wall.

WEIR - A low dam or wall built across a stream to raise the upstream water level or a structure built across a stream or channel for the purpose of measuring flow. Sometimes described as measuring weir or gauging weir. Types of weirs include broadcrested weir, sharp-crested weir, ogee weir, and V-notched weir.