Maryland Dam Safety Manual

1996 Edition

(rev. November 2003)

PREFACE

This manual was developed by the Maryland Department of the Environment, Water Management Administration, Dam Safety Division, in order to assist owners in the regular operation, inspection, and maintenance of their dam. The information presented should also be valuable to many engineers who are preparing construction documents for a proposed structure. It is intended to serve as an information resource and educational tool for the dam owner and includes six basic sections: Owner Responsibilities, Operation, Maintenance and Repair, Inspections, Construction, and Emergency Procedures. It is hoped that this manual will be of assistance to the dam owner in becoming familiar with the general principles and features of their facility as well as developing adequate skills of observation and safety inspection. Timely maintenance can reduce expensive safety repairs at a later date.

Dam owners must maintain their facility in a safe condition. For this reason the main focus of this manual is directed towards developing an operation and maintenance program for the dam owner. Throughout the manual, it is recommended that the owner contact an engineer experienced with dams when certain observations are made. The importance of this recommendation cannot be overemphasized. Dams are complex structures and the causes and remedies of certain problems may not be obvious to a layperson.

This manual was prepared and revised under the guidance of the Maryland Dam Safety Division including Brad Iarossi, Harald Van Aller, Bruce W. Harrington, M.Q. (Cas) Taherian, Gene Gopenko, Robert S. Norton, Brian S. Clevenger, and Tona Ives. The manual was modeled after similar publications developed by the Ohio Department of Natural Resources, Division of Water, Dam Inspection Section; the North Carolina Department of Natural Resources and Community Development, Division of Land Resources, Land Quality Section; and the Commonwealth of Pennsylvania, Department of Environmental Resources, Division of Dam Safety. In addition, similar publications from many other states were also of considerable assistance. Funds for the development and distribution of this manual were provided by the Association of State Dam Safety Officials through a grant from the Federal Emergency Management Agency.

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INTRODUCTION

A dam is defined as any obstruction, wall, or embankment, together with its abutments and appurtenant works, constructed for the purpose of storing water. Dams may be constructed of earth, concrete, wood or rock. Most dams in Maryland consist of an earthen embankment to store water and a combination of spillways designed to pass water safely around or through the facility.

Millions of Marylanders are dependent on dams for water supply, flood control, power generation, recreation and irrigation. High standards including proper design and construction of dams, properly operated and well maintained dams and effective emergency warning plan can help prevent dam failures, save lives and property and enable us to continue to enjoy the benefit that dams provide.

Dams represent a potential danger. With the exception of a nuclear power plant, few manmade structures have the potential to cause catastrophic disaster as dams do if they fail. This country has witnessed some tremendous tragedies caused by dam failures including:

1) The South Fork Dam failure (Johnson Flood) of 1889 which took the lives of 2,209 people in Johnstown, Pennsylvania;

2) The Buffalo Creek Dam failure in 1972 killed 125 people in West Virginia;

3) The Teton Dam failure of 1976 caused 14 deaths and over $400 million in damages;

4) The Laurel Run Dam failure in 1977 killed 40 people in Pennsylvania; and

5) The Kelly Barns Dam failure in 1977 killed 39 people and $2.5 million in damages.

For centuries, dams have provided mankind with the essential benefits associated with water. Modern dams are often integrated into new communities to such a degree that they become a part of the landscape and are forgotten as an engineering structure that needs periodic maintenance. However, a well documented operation and maintenance program is necessary for every dam in order to detect symptoms of deterioration and plan for timely maintenance. Every program should include:

1) periodic technical inspections,
2) periodic maintenance inspections, and
3) informal observations by the dam owner.

BUFFALO CREEK DAM FAILURE FEBRUARY 26, 1972

The following accounts of this tremendous tragedy are excerpted from Everything in Its Path written by Kai T. Erikson, 1976.

> *"I walked to the back porch and saw my neighbors running and screaming. I heard one say 'the dam.' I then came running through the house and told my wife to head for the hills. When I got to the living room I saw the water rolling by the window. I knew then there was no way out of the house, and all hope just vanished. My wife started crying and praying. I saw a housetop going by with a friend of mine on top. Then I heard a big crash and saw the big wave of water coming with houses and trash in it. There was nothing we could do but watch and pray for the best and wonder how long our house would stand."*

> *"And we stood there so helpless, couldn't do nothing. We were there watching people trying to get out of the way, and the water just swept them right down."*

> *"One of our very close friends stayed drunk for almost five months because he could still hear his brother and sister screaming for their mother and his mother screaming 'God help us' when the water hit them. Sometimes he talks with me about it and I get the impression that he feels bad because he lived through it all. He is only twenty years of age, but I guess sometimes he feels like a thousand years old."*

> *"I looked up the road and saw it coming, the water. I said, 'Here comes a big old doll.' But when it got to me, I said 'Lord, that's a kid,' and I took off down the creek after it."*

> *"I can't forget the horrible expression in her eyes and on her face. She looked as though she was scared to death, not drowned."*

OWNER RESPONSIBILITIES

The investment in safety must be accepted as an integral part of any existing or proposed dam, and not an extra item that can be eliminated if the budget is tight. This concept of safety applies throughout all phases of the project, from planning through design and construction, and most importantly throughout the life of the structure. A typical dam is <u>not</u> constructed to last indefinitely. As dams age they typically require increased efforts to operate and maintain them.

JOHNSTOWN FLOOD OF MAY 31, 1889

The following personal accounts, described by observers and survivors of this tragic dam failure which killed 2,209 people, were selected from The Johnstown Flood of 1889, The Tragedy of the Conemaugh, by Paula and Carl Degen, Eastern Acorn Press, 1984.

> *"It came like a thief, and was upon us before we were aware. Already when it reached us it had numbered its victims by the hundreds. Mineral Point and East Conemaugh were gone, a passenger train was engulfed. Woodvale was swept away. Conemaugh Borough was shaved off as if by the sharp surface of an avalanche; in a moment Johnstown was tumbling all over itself; houses at one end nodded to houses at the other end and went like a swift, deceitful friend to meet, embrace, and crush them. Then on sped the wreck in a whirl, the angry water baffled for a moment, running up the hill with the town and the helpless multitude on its back, the flood shaking with rage, and dropping here and there a portion of its burden--crushing, grinding, pulverizing all. Then back with the great frame buildings, floating along like ocean steamers, upper decks crowded, hands clinging to every support that could be reached, and so on down to the great stone bridge, where the houses, piled mountain high, took fire, and burned with all the fury of hell you read about."*

> *"Everything about us was in inextricable confusion, showing the effects of the terrific convulsion through which nature and humanity had passed. Here were uprooted trees, houses upturned or demolished, furniture of every description--hardware, woodenware, parlor ornaments and kitchen utensils, mattresses, bodies of horses, cattle and swine, corpses of men, women, and children, railroad cars and locomotives--overturned or on end, and pressing down upon the half-buried bodies of the drowned." [The Reverend David J. Beale]*

> *"The flood showed no mercy: it struck down young and old, man, woman, and child. One of the saddest stories is that of the Fenn family. The flood claimed the father and seven children. If God had spared me one I could have been resigned. But all, all! Father in Heaven, is not my cross heavier than I can bear?"*

> *"Death by violence due to the flood caused by the breaking of the dam of the South Fork Reservoir. We find the owners of said dam were culpable in not making it as secure as it should have been, especially in view of the fact that a population of many thousands were in the valley below; and we hold that the owners are responsible for the fearful loss of life and property resulting from the breaking of the dam. (The Cambria County coroner's inquest)."*

OWNER LIABILITY

The dam owner is liable for the damages resulting from a dam's misoperation or failure that would result in a sudden release of water downstream. In assessing the legal liability for a dam failure, there are two basic theories that are used, strict liability and negligence.

Earth Dam Failure

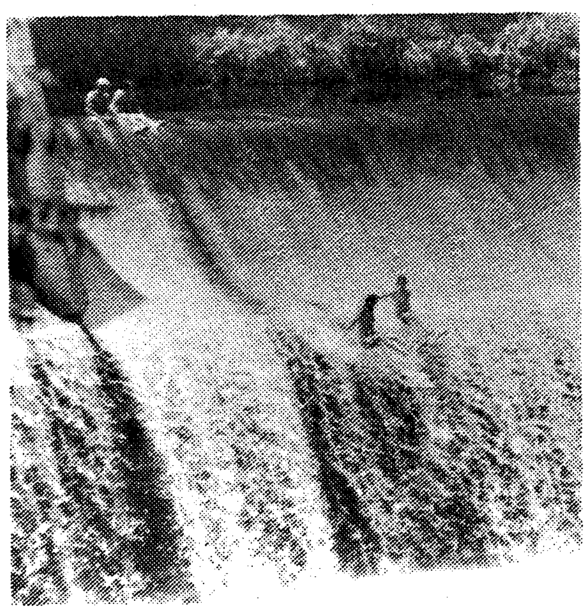
Strict Liability

The theory of strict liability essentially imposes liability as a risk of doing business and is derived from the old English case of Rylands v. Fletcher. In this case, a dam and reservoir were constructed by the defendants on a parcel of property with the owner's permission. A shaft gave way and caused the impounded water to destroy the plaintiff's property. The court ruled for the plaintiff, holding that when one brings onto his land, and collects and keeps there anything likely to do mischief, if it escapes, and it is a non-natural use of the land, he must keep it at his peril. The rule is that a defendant is liable when he damages another by a thing or activity unduly dangerous, in light of the place and its surroundings.

The concept of strict liability has been extended widely to activities that are considered abnormally dangerous. The basis for this is the risk of harm and potential magnitude of that harm. Factors to be considered in strict liability include the degree of risk, the potential gravity of harm should the risk materialize, the exercise of reasonable care, whether or not the activity is one of common usage, the appropriateness of the activity to the locality, and its value to the community.

Negligence

The alternative theory of liability is one of negligence, which is the most commonly utilized cause of action in tort litigation. Negligence is generally defined in terms of failure to exercise the standard of care of a reasonable person under similar circumstances. This standard in turn is based on the reasonable foreseeability of the risk. It is important to emphasize that the ultimate question though is, whether in light of that forseeability, how a reasonable person would have acted taking into account the potential magnitude of harm and the alternatives available. Thus, negligence can consist of a failure to act, or the failure to act in a reasonable manner.



Keep Off!

In Maryland, the General Assembly has added statutory requirements on top of the common law strict liability and negligence doctrines. Construction and repair of dams require state permits and those permits contain specific conditions for maintenance. Size, location, design, and public safety are all issues addressed by State law and regulations. The Administration may order structures built without permission to be drained or removed.

It is the owner's responsibility and obligation to act in a reasonable manner to inspect and maintain the dam and its appurtenances. Additionally, the Dam Safety Division of the Water Management Administration performs periodic safety inspections of Maryland dams. After each inspection, the owner is presented with a summary of findings and maintenance recommendations. These recommendations should be implemented to insure the dam's continuing safety.

Public Safety

In addition to the responsibility for dam maintenance, owners should also be aware of their responsibility for public safety. This includes the safety of people not authorized to use the facility. "No Trespassing" signs should be posted and fences and warning signs should be erected around dangerous areas. Liability insurance can also be purchased to protect the owner in the event of accidents.

In conclusion, dam owners have both the legal and moral obligation to keep their dam in repair. The following guidelines should be followed:

- Periodically monitor the condition of the dam and correct any deficiencies. Depending on the size of the structure and its operational history, this could mean anything from a occasional casual site inspection to a full scale annual evaluation by a professional engineer experienced in dam design.

- When the dam is inspected by the State Dam Safety Division, recommendations should be carefully reviewed and repairs made shortly thereafter.

- If abnormal conditions develop at the dam, or the dam shows signs of potential failure, the owner must be prepared to notify local and state authorities so every action possible can be taken to protect lives and property downstream, as well as the dam itself.

Riparian Rights

Care should be taken by owners when releasing or impounding water to protect the rights of downstream property owners. The system of riparian rights has been established through the courts, and permits each riparian owner to make a "reasonable" use of the water, having regard to the same rights existing for the other downstream riparian owners.

Professional Assistance

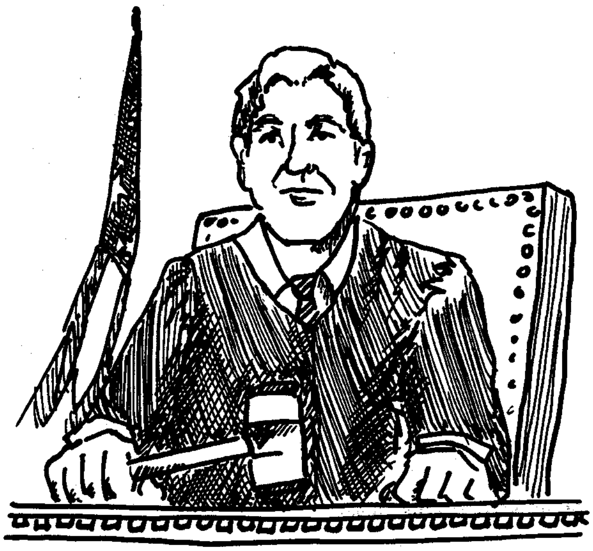
A dam with its associated works is a complex structure. Engineers who are experienced in the design, construction, and inspection of dams should be consulted for many of the operation guidelines and maintenance techniques identified in this manual.

The owner or operator of the dam should always keep in mind that each structure is unique in its construction and operation. When contacting a professional for assistance, there can be no substitute for the availability of historical records and documentation on the operation of the facility. Therefore, it is extremely important to follow the guidelines suggested in this manual.

Assistance in the form of technical advice and historical records is available from the Maryland Department of the Environment, Water Management Administration, Dam Safety Division, 1800 Washington Blvd., Suite 440, Baltimore, Maryland 21230-1718, Phone (410) 537-3538, Fax (410) 537-3553

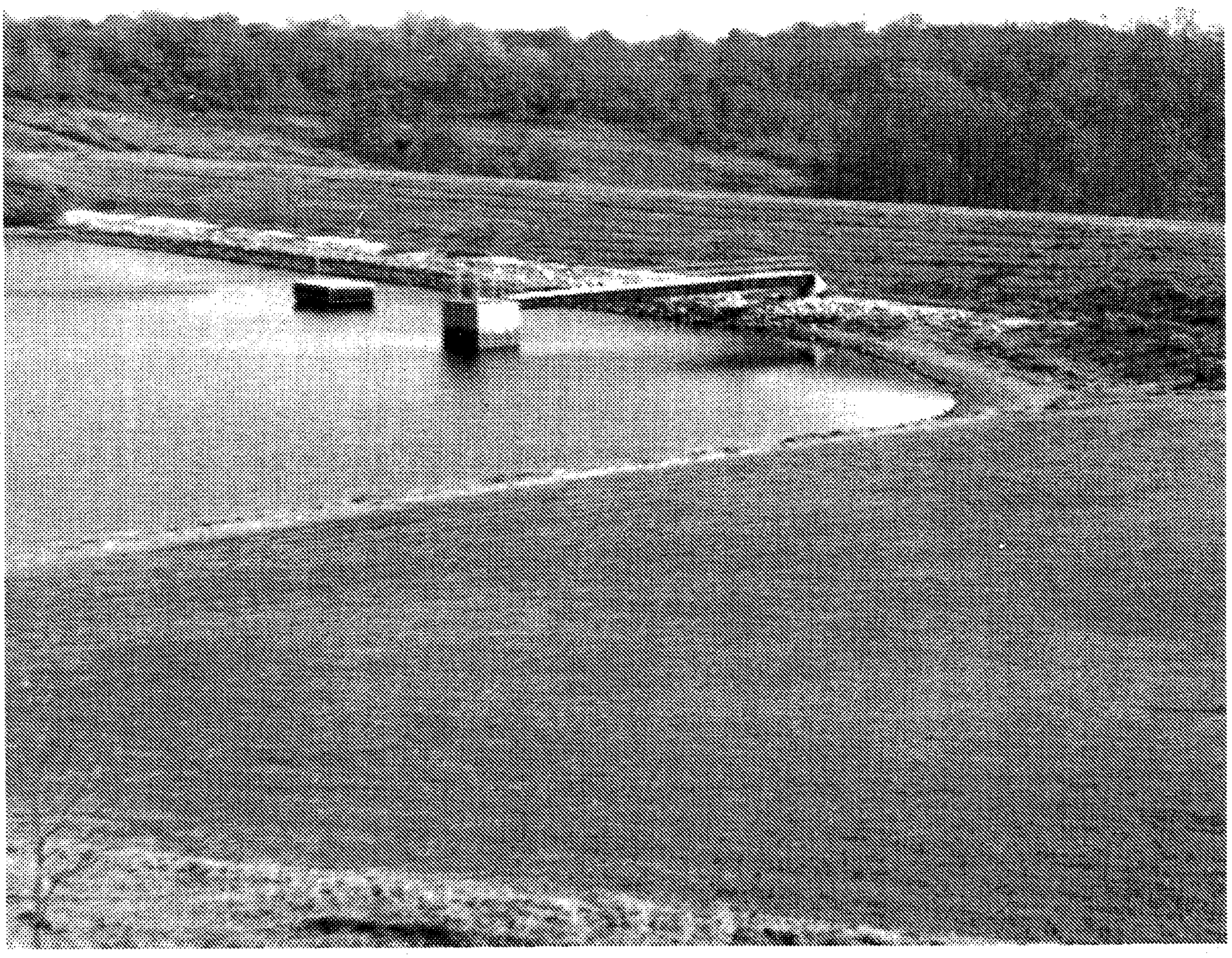
DAM SAFETY LAWS

Maryland laws and regulations place upon the dam owner the responsibility of constructing and maintaining a safe facility. These laws have been in existence since 1933 and are updated periodically in order to keep pace with changing engineering technology.



The Maryland Dam Safety Division issues permits to construct new dams or make major alterations to existing structures. The major emphasis of the administrative permit process is placed on the safety and longevity of the dam. In addition, the capabilities of the owner to operate and maintain the facility are also considered.

A chronology of the legislative history of Maryland's Dam Safety Program can be found in the Appendix. In addition, the most current Rules and Regulations governing the construction of dams are included to provide guidance to the dam owner.

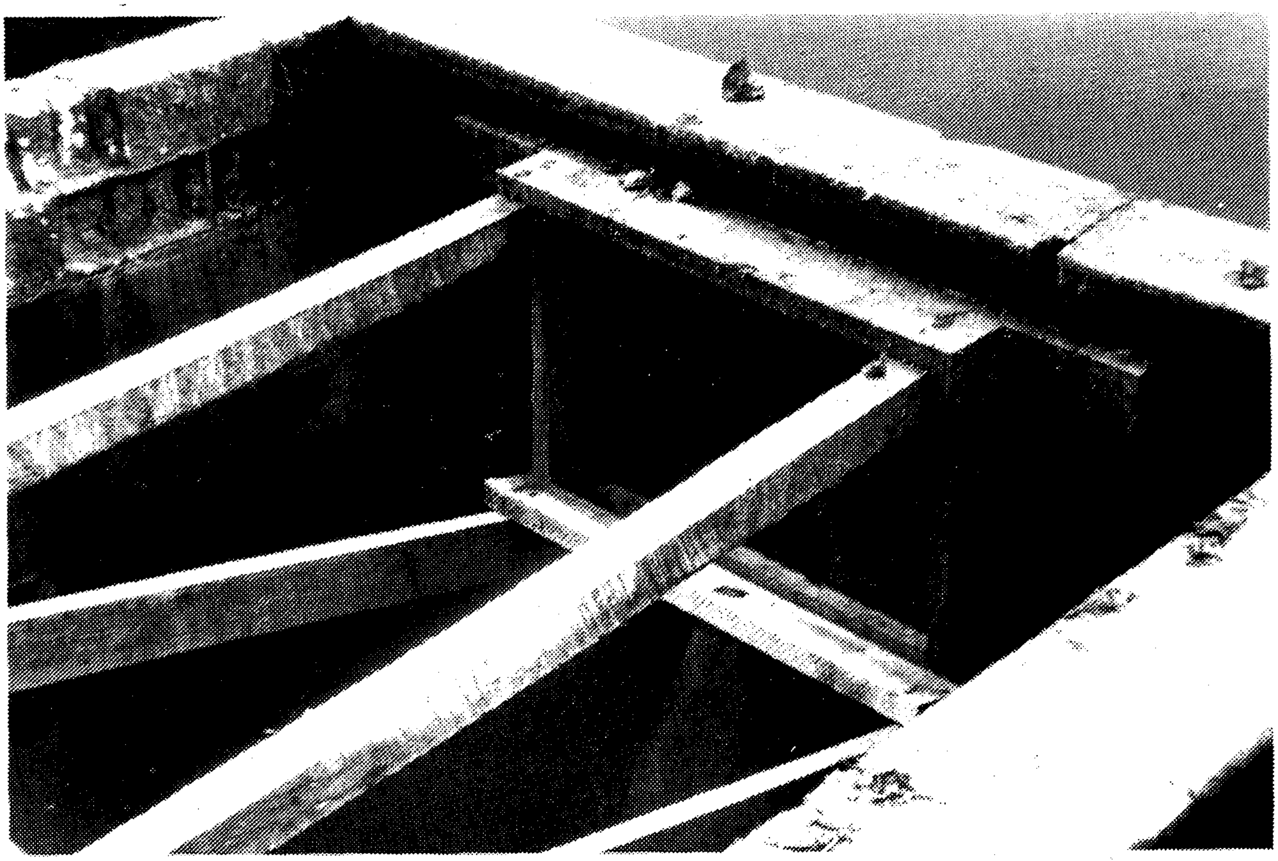


UNAUTHORIZED CONSTRUCTION

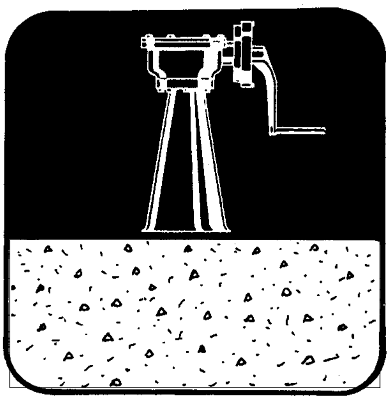
The modification of a dam or spillway without adequate engineering design and supervision could result in the spillway or dam being inadequate in capacity or function. This could lead to a costly repair or complete failure of the structure.

One of the more common errors made by dam owners is raising the normal pool elevation by permanently elevating the crest of the principal spillway. This action not only results in a decrease in storage available during a flood event, but also restricts the capacity of the spillway by reducing the total depth available to "push" water through the spillway. Raising the normal pool will usually cause the emergency spillway to flow more frequently than its design allows, thus increasing the overall maintenance cost. Furthermore, raising the normal pool without a state permit is a violation of Maryland dam safety laws.

It is important for the dam owner to realize that each part of the dam is equally important to the safety of the entire structure. Seemingly minor changes to the dam can cause misoperation or reduce the margin of safety that has been designed into the structure. For this reason, any proposed modifications to the dam require a state permit and should be discussed with the Dam Safety Division.



Unauthorized raising of the lake level with the addition of cinder blocks to this spillway structure. This modification resulted in the necessity to brace the spillway. If heavy rains were to occurr, the spillway would not be able to handle the incoming flows.



OPERATION

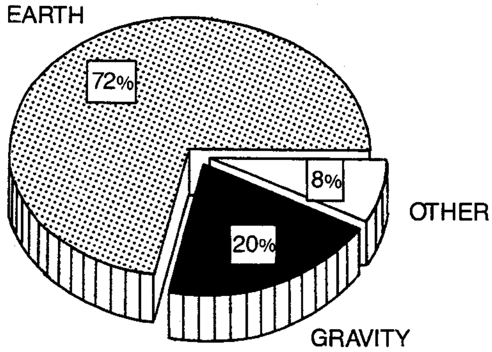
The types of dams discussed in this manual are normally used to store water for irrigation, water supply, recreation, and to provide stormwater management and flood control. Operation of these types of dams will rarely "push" water through the spillway. Raising the normal pool will usually cause the emergency spillway to flow more frequently than its design allows, thus increasing the overall maintenance cost. Furthermore, raising the normal pool without a state permit is a violation of Maryland dam safety laws.

It is important for the dam owner to realize that each part of the dam is equally important to the safety of the entire structure. Seemingly minor changes to the dam can cause misoperation or reduce the margin of safety that has been designed into the structure. For this reason, any proposed modifications to the dam require a state permit and should be discussed with the Dam Safety Division.

COMMON DAM ELEMENTS

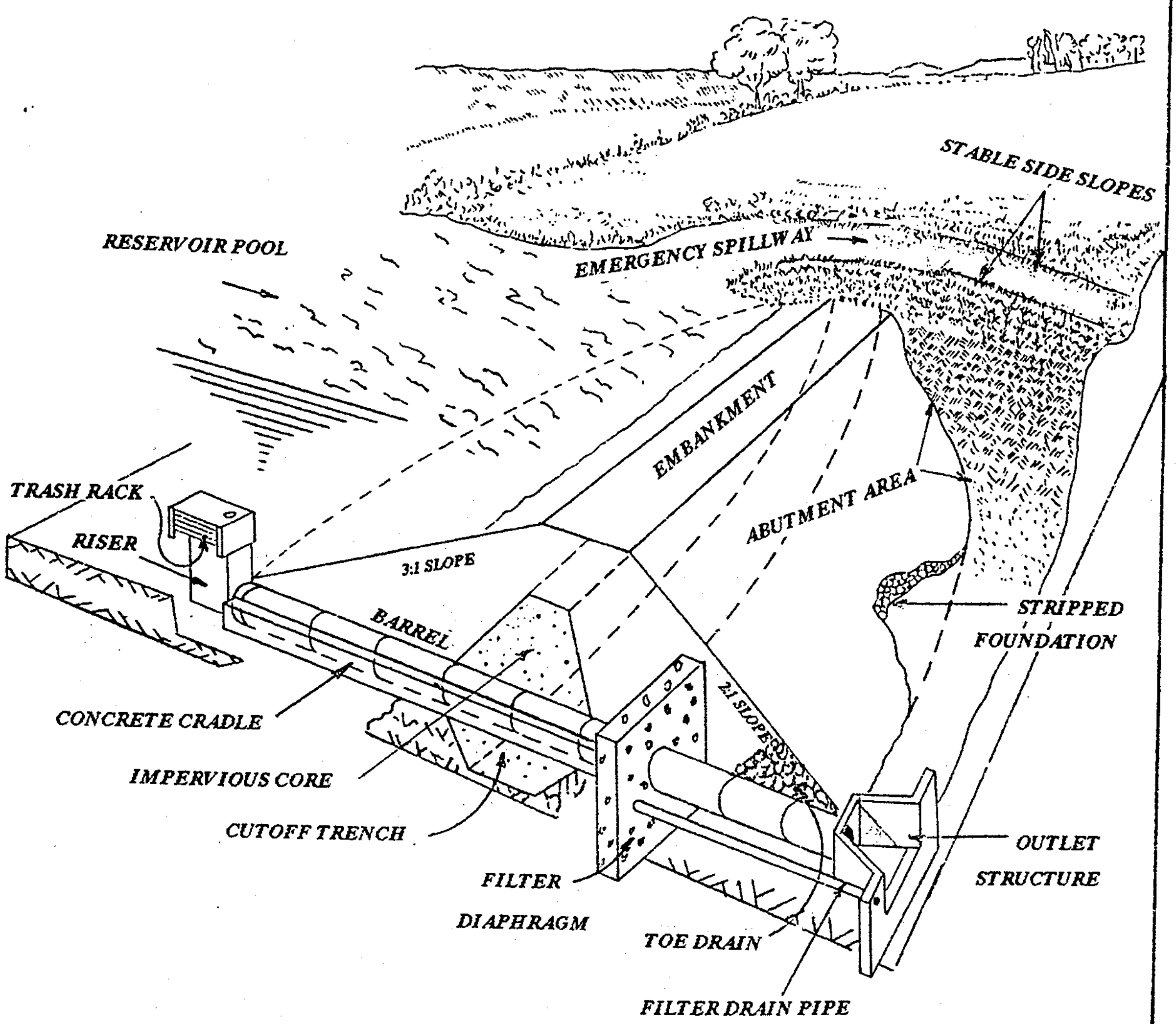
Dams can be constructed of various materials such as concrete, earth, rock, and wood. Many of the common dam types are listed in the glossary. In Maryland, the different types of dams are listed in the adjacent chart:

As one can see, the majority of dams are constructed of earth. Therefore, the primary focus of this manual will be toward this type of dam. The figure below illustrates the common elements of an earthen dam.



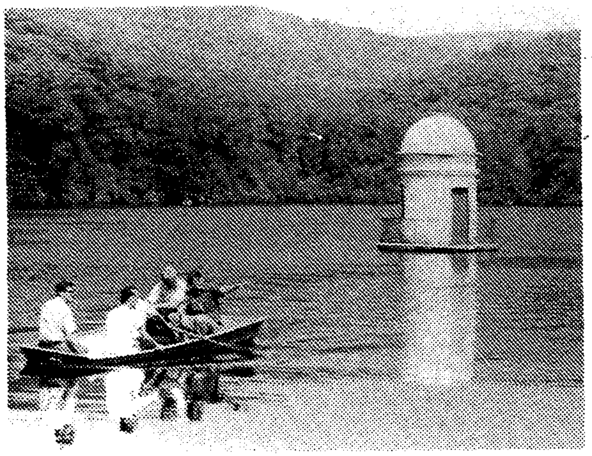
Maryland Dams
By Type

PRINCIPAL FEATURES
of an EARTH DAM



OPERATION PLANS

The owner of each dam should adhere to a prescribed operation and maintenance program in order to insure the safety welfare of his investment. An effective operation program provides all of the necessary information for the owner to perform the tasks routinely required to operate and maintain the dam. The extent of the operation plan depends on the complexity of the dam itself. Regardless of the size of the structure there are many similarities between operation plans. The most effective plans are usually the simplest.



Site Inspection

The principal elements of an effective operation plan are presented below:

Background Data A typical dam owner possesses a good deal of information about his facility. Very often the information is scattered about or reviewed so rarely that it is of little use. This section of the operation plan serves to organize available background data to make it more accessible.

Schedule of Routine Tasks A schedule that includes both day-to-day tasks as well as tasks performed less frequently throughout a given year is important. The schedule serves to formalize inspection and maintenance procedures such that the owner could determine when a task is to be performed by merely consulting the schedule.

Emergency Procedures Perhaps the most important section contains a formal plan for reacting to dam emergencies. It involves coordination between the dam owner/operator, local agencies, and downstream residents.

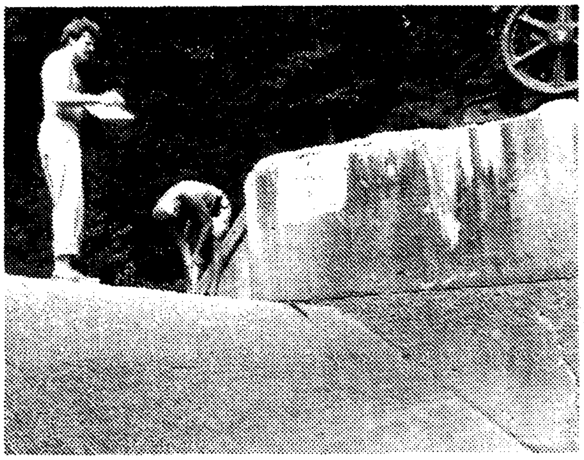
Record Keeping

The owner should maintain a complete and up-to-date set of plans and specifications ("as-built" drawings) for the dam, which should show all changes made over time. Knowing how a dam, its spillways, and other appurtenances were constructed or modified is very helpful in diagnosing problems.

Operation of a dam should include keeping accurate records of the following:

Observations: All observations should be recorded. Of particular importance is the periodic observation of existing seepage to detect any changes in flow. Photographs are valuable for recording observations and changes.

Maintenance: Written records of maintenance and major repairs will be important in periodic safety evaluations of the dam.

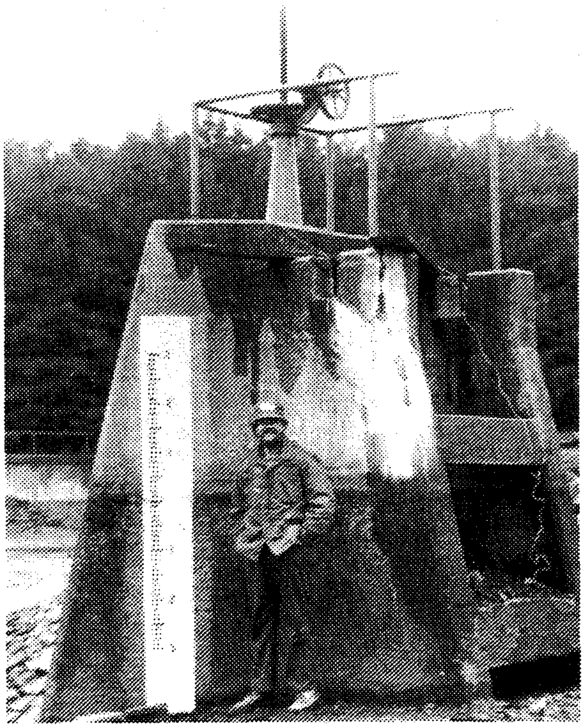


Record Keeping

Rainfall and Pool Levels: A record of the date, hour, and maximum elevation of extreme high water events and the associated rainfall is especially helpful in evaluating the performance of the dam and its spillway system. Rain gauges are available at any local farm or garden store. Lake level staff gauges can be easily made, or measurement numbers can be painted on existing structures in the pool area.

Drawdown: A record should be kept of the amount, rate, and reason for pool level drawdown.

Other Operational Procedures: A complete listing of operational procedures should be maintained.



Reservoir Staff Gauge

General Instructions

The form on the following page is provided for the convenience of the dam owner or operator in keeping monthly records. This periodic monitoring program will help to develop a well documented history of the operation and performance of the facility. Guidelines in recording information are as follows:

Rainfall and Pool Level - Spaces have been provided for one month's records if daily readings are made. At a minimum, rainfall and pool level records should be kept of significant (very large) rainfall events. Weather conditions should include: rainfall duration and intensity estimates; temperature; ice and snow cover conditions; etc. General observations of the spillway performance and condition of the dam should be made.

Maintenance Performed - Maintenance and operation of equipment can be recorded under these headings. For example, if the lake drain is operated periodically, the date can be recorded here. Minor repairs, such as patching of spillway concrete or joints should also be recorded.

Flow Amounts - Records can be kept of any flows which are being periodically observed. Others could apply to seepage flow estimates of a certain area. Weather conditions during the observation are important to note.

OPERATION AND MAINTENANCE RECORDS

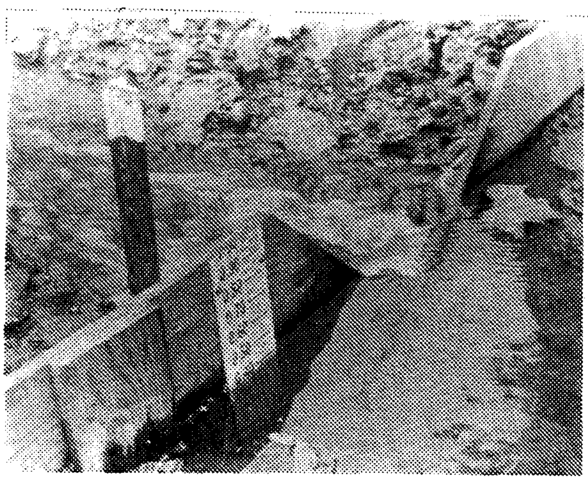
DATE	TIME	RAIN (inches)	POOL LEVEL	WEATHER CONDITIONS	GENERAL OBSERVATIONS OR COMMENTS	RECORDED BY

	MAINTENANCE PERFORMED	COMMENTS	RECORDED BY

FLOW AMOUNTS					WEATHER AND COMMENTS	RECORDED BY
DATE	LEFT	RIGHT	WEIRS	OTHER		

MONITORING DEVICES

Various devices such as weirs, piezometers, and settlement monuments are used to monitor earth embankments and concrete gravity structures. These devices can be used to determine if the structure is performing as designed, to detect signs of serious problems, or to provide further information after a problem has been detected. The use of extensive instrumentation is usually limited to large dams or those structures for which little design and construction documentation is available. A full-scale monitoring and instrumentation program requires professional design.



V-notch Weir for Seepage Monitoring

Monitoring by a private owner is usually limited to visual observation. It is very important that the observations be made periodically and accurately recorded. Several checklists for this purpose have been included in this manual. Owners are encouraged to use photographs with identifying dates and labels as a permanent record. These photos should be kept with the other dam records.

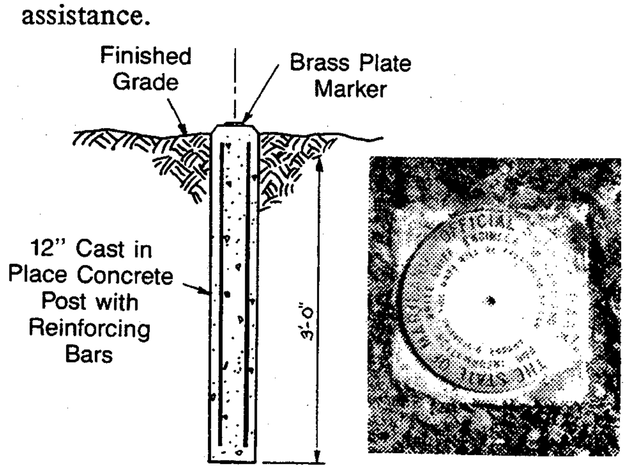
The following devices can easily be used by owners to monitor their embankments:

Weirs, Flumes, and Buckets Flow rates for weirs and flumes are obtained from a calibration chart that relates the depth of flow to gallons per minute of flow. The flow from pipe outlets can be measured by timing how long it takes to fill a bucket of known capacity. In order for the readings to be meaningful, they must be taken at regular intervals that are frequent enough to establish trends of seasonal variations in pool and groundwater levels as well as other factors that can affect the seepage rate. Many times after installation, weirs and flumes are neglected and good readings become useless for lack of comparative data. The v-notch weir is probably the most commonly used device to measure flow rates of seepage.

Yardstick or Folding Rule This portable monitoring device is not only inexpensive but has a number of uses. It can be used to measure cracks, scarps, erosion gullies, settlement, trees, wet areas, and slab or wall movement. Again, records should be kept of all observations for comparative purposes.

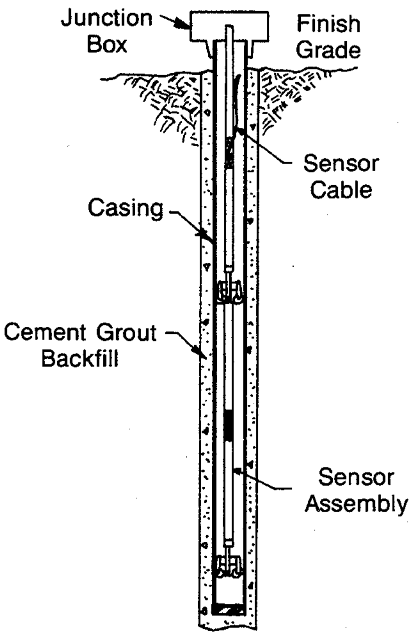
Camera Photographs which have been dated and labeled provide an excellent record of existing conditions, and if taken periodically from the same locations, can be used for comparison. Photographs should be taken during all inspections to supplement written and visual observations. They are valuable in documenting the location and severity of wet areas, erosion, and concrete deterioration.

Settlement monuments, piezometers, observation wells, and inclinometers are often found on large dams and are described briefly. Their installation requires professional assistance.



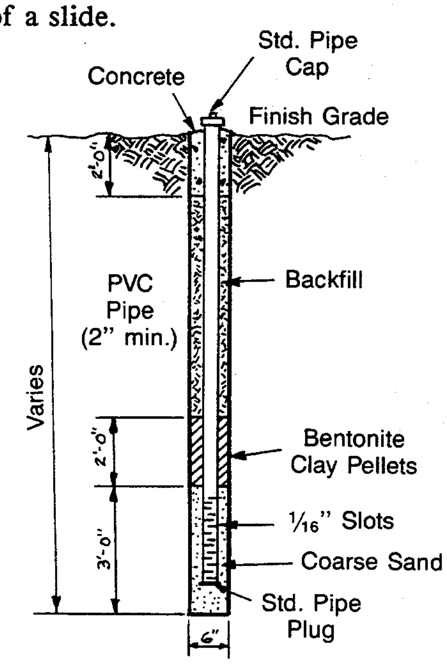
Survey Monument Detail

Settlement Monuments are usually installed along the crest of the dam to check its vertical and horizontal alignment (with known reference points and elevations). Measurements of these monuments must be precise and are obtained using surveying instruments.



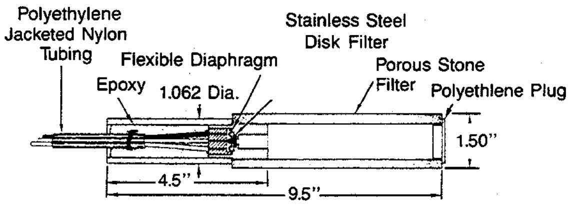
Slope Inclinometer

Inclinometers are instruments that are lowered into a vertical casing and measure horizontal deflection of the embankment. Inclinometers are often used to determine the rate of movement of a slide.

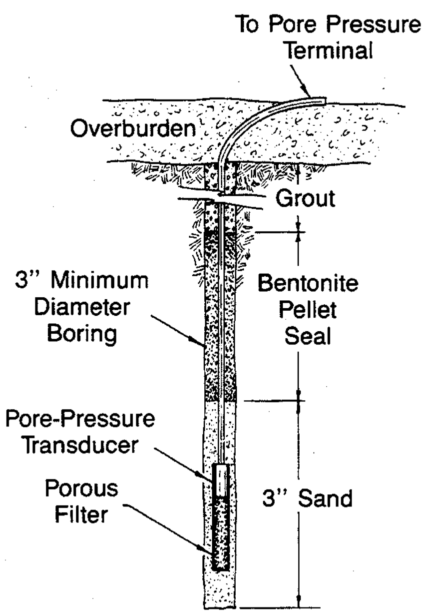


Open Pipe

Observation Wells (technically known as open standpipe piezometers) can be installed in the embankment and are used to determine the water levels. Measurements are made with a water level indicator that is lowered into the well.



SINCO Pore-Pressure Transducer



Pneumatic Piezometers

Piezometers are instruments used to measure the water pressure in the embankment and foundation. Pore pressure within the embankment can be determined from these readings.

MAINTENANCE AND REPAIR

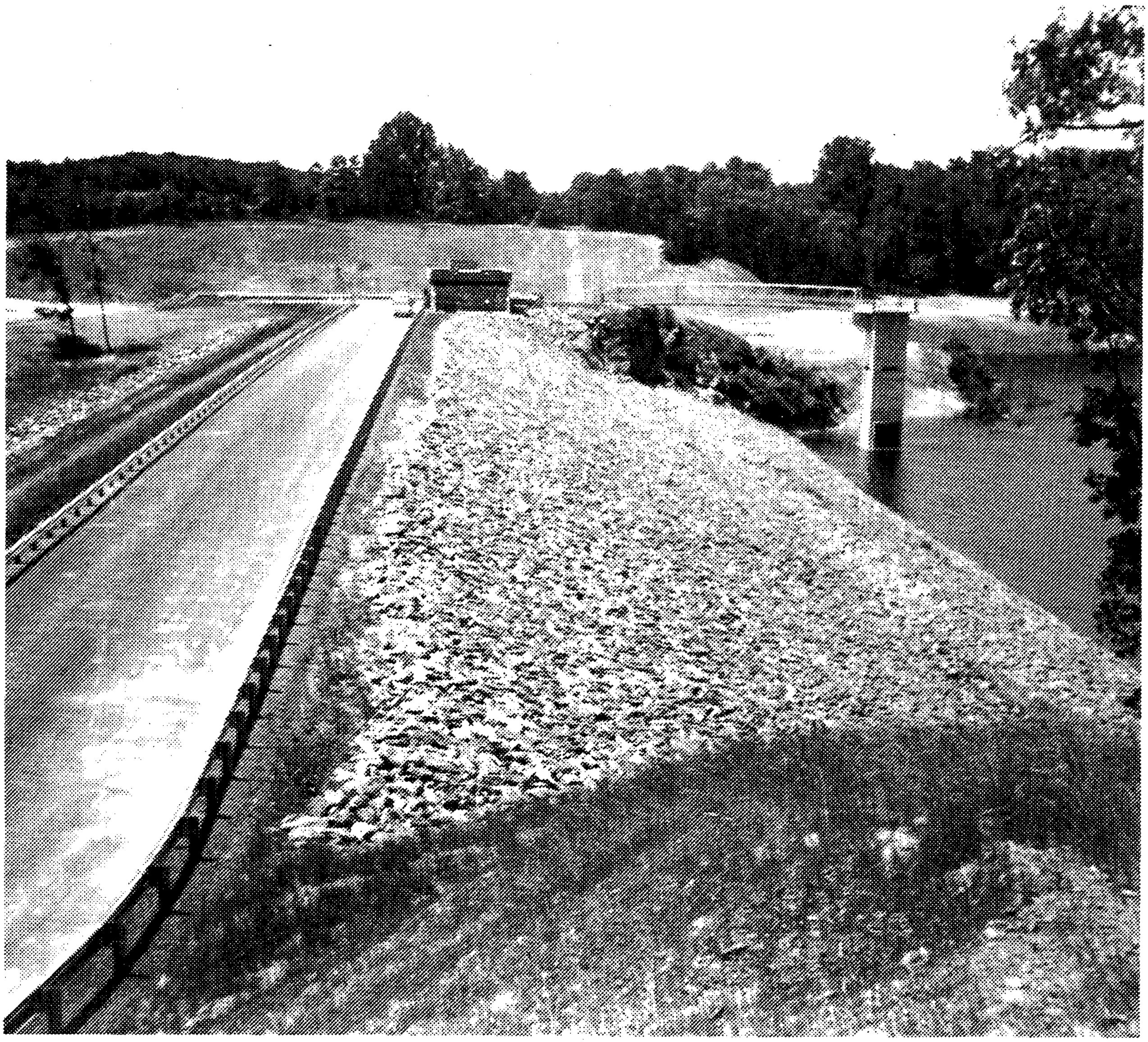
The importance of proper dam maintenance cannot be overemphasized. A regular program of inspection and care will help to keep many major problems from developing and avoid more costly repairs at a later date. The Water Management Administration requires all dam owners to maintain their facility in a safe condition so that it may not endanger human life or property located above or below the facility. Routine maintenance is defined as minor maintenance that does not modify the original design parameters of the facility. The Water Resources Administration requires the issuance of a Maintenance and Repair Permit for any repairs or maintenance that involves the modification of the dam or spillway from its original design and specifications. A permit is also required for any repairs or reconstruction that involve a substantial portion of the structure.

In general, maintenance items are required for the following major areas:

EMBANKMENT
SPILLWAY AND OUTLET WORKS
RESERVOIR

EMBANKMENT

The embankment section of the dam is usually constructed of earth or rock. Embankment dams are built with different design sections. Internal zoning of material ranges from simple to intricate. Practical experience suggests that embankment slopes should be easily maintainable while providing an adequate factor of safety against failure. Because the embankment is the main feature of the dam, the owner should provide for routine maintenance of the slopes and crest.



VEGETATION

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. Proper maintenance also ensures a healthy stand of vegetation that can withstand extreme climatic conditions and pest, weed, or disease infestation better than poorly maintained vegetation. The uncontrolled growth of vegetation will damage embankments and concrete structures and make close inspection of the dam difficult. Aesthetics, unobstructed viewing during inspections, maintenance of a nonerodible surface, and discouragement of burrowing animal habitation are reasons for proper maintenance of the vegetative cover.

NO TREES ALLOWED!

Ground Covers

Grass is the most common type of vegetation found on an embankment. Grass 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 sod is well established. Grass vegetation is least effective in areas of concentrated runoff, such as the contact of the embankment and abutments, or in areas subjected to wave action. In these areas a riprap channel is recommended.

Types of vegetation that have been used on dams in Maryland are tall fescue, red fescue, clover, redtop, and sericea lespedeza. Deep rooted grasses should be planted in vegetated earth spillways. One hundred percent Kentucky 31 Fescue is excellent for erosion protection. Seeding should be accomplished between optimum planting dates. Seeding late in the year may result in winterkill of young seedings. The following spring an inspection of the seeded area should be made to determine if plant survival is satisfactory.

Before seeding, fertilizer and lime should be applied. Exact quantities necessary will vary with soil type and condition, and can be determined by having the soil tested. The fertilizer and lime should be raked, disced, or harrowed into the soil to a depth of not less than 4 inches. Periodic fertilization is necessary to maintain vigorous vegetation. Immediately following seeding, the area should be mulched. Mulching materials should be kept in place with a mulchanchoring device or with asphalt emulsion.

Additional information on the proper selection of grasses and legume mixtures, seeding rates, optimum planting dates, and vegetation maintenance is available in the "Maryland Standards and Specifications for Sediment and Erosion Control."

Trees and Brush

The presence of trees and brush is the most common form of neglect in the area of embankment maintenance. Uninformed owners will often allow trees and brush on their dams. **Woody vegetation is, however, one of the dam's worst enemies, and will lead to more serious maintenance problems if not controlled.**

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 and limits visual inspection, provides a haven for 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 and should be removed.

Failure Due to Root System

Trees that have been allowed to grow on the dam should be removed so desirable vegetation can be established and the surface can be mowed. The stumps can be removed either by pulling or with machines that grind them down. For trees greater than eight inches in diameter, all woody material should be removed to about 24 inches below the ground surface. The cavity should be filled with well compacted soil and grass vegetation established.

Stumps less than eight inches in diameter may be left in place if cut flush with the ground and treated with a silvicide.

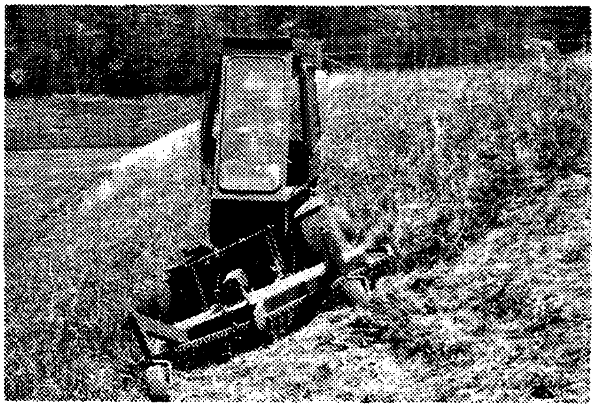
Stumps of trees in riprap cannot easily be removed, but should be chemically treated so they will not continually form new sprouts. The removal of large trees and stumps is expensive and usually requires the use of heavy construction equipment.

Mowing and Brush Removal

Embankments, areas adjacent to spillway structures, vegetated channels, and other areas associated with a dam require periodic maintenance of the vegetative cover. Grass mowing, brush cutting, and removal of woody vegetation (including trees) is necessary for the proper maintenance of a dam. All embankment slopes and vegetated earth spillways should be mowed or trimmed at least once a year. Brush removal is also important beyond the downstream toe of the dam in order to allow inspection for "boils" (see Seepage).

Methods used in the past for control of vegetation that now may be considered unacceptable include chemical spraying and burning. More acceptable methods include the use of weed whips, power brush-cutters and mowers. It is important to remember to use the proper equipment for the slope and type of vegetation to be cut, and to always follow the manufacturer's recommended safe operation procedures.

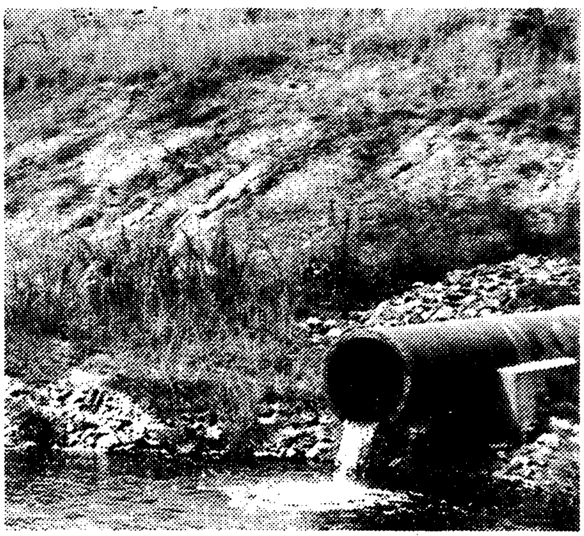
Tree/Stump Removal



Mowing Embankment With Special Equipment

EROSION

Whether on a slope or at a spillway outlet, erosion is a common maintenance problem on the embankment structure. Erosion is a natural process and its continuous forces will eventually wear down almost any surface. The rate of erosion is directly related to the lack of vegetation. Periodic and timely maintenance is essential in preventing continuous deterioration, more costly repairs at a later date, and possible failure of the dam.



Embankment Erosion

Vegetated Surfaces

A sturdy sod, free of weeds and brush, is one of the most effective means of erosion protection. Embankment slopes are normally designed and constructed so that the surface drainage will be spread out in thin layers as "sheet flow" on the grassy cover. When the sod is in poor condition or flows are concentrated at one or more locations, the resulting erosion will leave rills and gullies in the embankment slope. The owner should look for these areas and be aware of the problems that may develop.

Prompt repair of eroded areas is required to prevent more serious damage to the embankment. Rills and gullies should be filled with suitable soil (the upper 4 inches should be topsoil, if available), compacted, and then seeded. Methods described in the section on vegetation should be used to properly establish the grassed surface. Erosion in large gullies can be slowed by stacking bales of hay or straw across the gully until permanent repairs can be made.

Erosion Left Unattended

Repairs of the eroded areas should also address the cause of the erosion in order to prevent a continuing maintenance problem. Erosion may be aggravated by improper drainage, settlement, pedestrian traffic, animal burrows, or other factors. The cause of the erosion will have a direct bearing on the type of repair needed.

Paths from pedestrian traffic are problems common to many embankments. If a path has become established, vegetation in this area will not provide adequate protection and more durable cover will be required unless the traffic is eliminated. Small stones, asphalt, or 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.

Worn areas also result from unwanted two and four-wheel vehicle traffic. Control of these vehicles is discussed in the section on vandalism.

Another area where erosion commonly occurs is the contact between the embankment and the concrete walls of the spillway or other structures. Poor compaction adjacent to the wall during construction and subsequent settlement could leave an area lower than the grade of the embankment. Runoff often concentrates along these structures, resulting in erosion. Possible solutions include regrading the area to slope away from the wall, adding more resistant surface protection, or constructing wood beam steps.

Pedestrian Path Erosion

Abutment Contacts

Adequate erosion protection is required along the contact between the downstream face of the embankment and the abutments. Runoff from rainfall concentrates in these gutter areas and can reach erosive velocities because of the steep slopes. Berms on the downstream face that collect surface water and empty into these gutters add to the runoff volume. Sod gutters may not adequately prevent erosion in these areas. A well graded mixture of rock with stones that are 9 to 12 inches in diameter, or larger, placed on a stone filter or filter fabric provides the best protection on small dams.

Paved concrete gutters do not hold up well, will not slow the velocity of the water, can become undermined, and therefore are not recommended. Groundhogs often construct burrows underneath these gutters, possibly since burrowing is easier due to existing undermining.

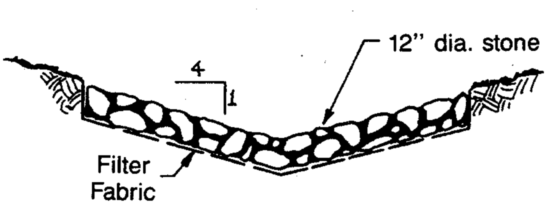
Erosion adjacent to gutters results from improper construction or design where the finished flow line of the gutter is too high with respect to adjacent ground. This condition prevents all or much of the runoff

water from entering the gutter. The flow concentrates alongside the gutter, erodes a gully, and may eventually undermine the gutter.

Care should be taken when replacing failed gutters or designing new gutters to assure that:

1. The channel has adequate capacity,
2. Adequate protection and a satisfactory filter have been provided,
3. Surface runoff can enter the gutter, and
4. The outlet is adequately protected from erosion.

Riprap Gutter Construction



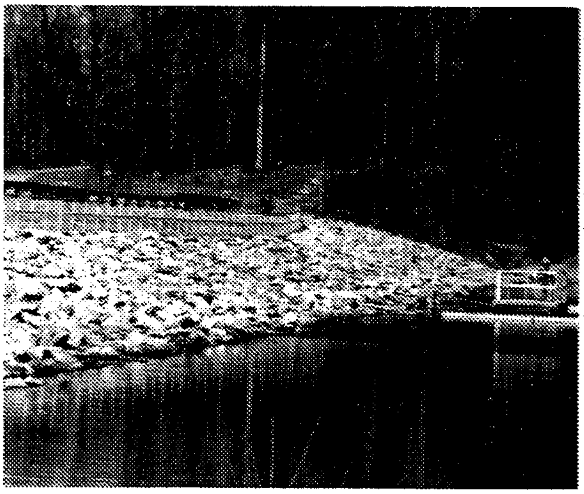
Riprap Ditch Detail

SLOPE PROTECTION

The upstream face of a dam is commonly protected against wave erosion by placement of a layer of rock riprap over a layer of filter material. This provides a surface on which the wave energy can dissipate.

Riprap should consist of a heterogeneous mixture of irregular shapes placed over a filter material. The maximum rock size and weight must be large enough to break up the energy of the anticipated wave action and hold the smaller stones in place. Generally, the largest stones should be at least 12 inches in diameter. The smaller rocks help to fill the spaces (or voids) between the rocks in the riprap. If the filter material can be washed out through these voids two filter layers will be required. The lower layer should be composed of sand or filter fabric to protect the soil surface. The second layer should be composed of coarser materials that prevent washout through the voids in the riprap.

A 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. The useful life of riprap varies with the characteristics of the stone used. Stone for riprap should be rock that is dense and well cemented.

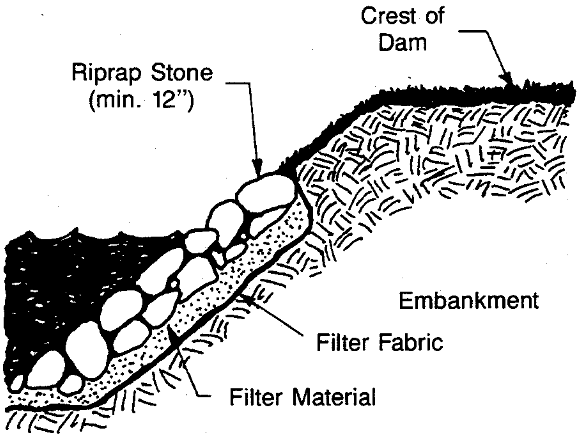


Properly Installed Protection

Another erosion problem which can develop on the upstream slope of the dam is "beaching." Waves caused by winds or power boats can erode the exposed face of the embankment. This action displaces the soil material farther down the slope, creating a "beach". Effective slope protection must prevent the soil particles from being removed from the embankment.

When beaching develops on the upstream slope of a dam, repairs should be made as soon as possible. The pool level should be lowered and the surface of the dam prepared for replacement of the slope protection. A small berm or "bench" should be made across the face of the dam to help hold the protective layer in place. The bench should be placed at the base of the new layer of protection. Depth of the bench will depend on the thickness of the protective layer. The layer should extend a minimum of 3 feet below the lowest anticipated pool level. Otherwise, wave action during periods when the lake level is drawn down can undermine and destroy the protective layer.

Sufficient maintenance funds should be allocated for the regular replacement of riprap. When riprap breaks down, erosion and beaching will occur more often than once every three to five years, professional advice should be sought to design more effective slope protection.



Slope Protection Detail

SEEPAGE

Contrary to popular opinion, wet areas downstream from dams are not usually natural springs but seepage areas. Even if natural springs exist in the area, they should be treated with suspicion and carefully observed. Flows from groundwater springs in existence prior to the reservoir usually increase in flow due to the pressure caused by a pool of water behind the dam.

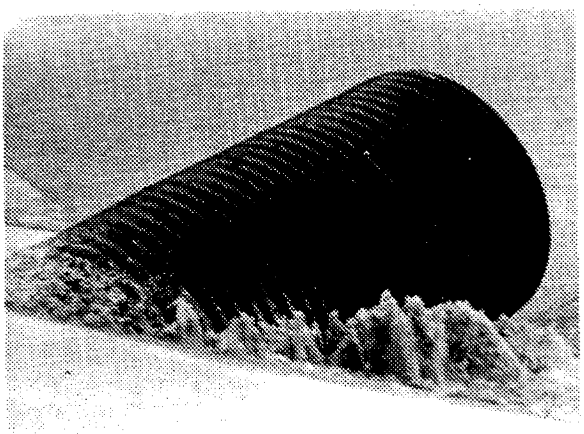
All dams have some seepage as the impounded water seeks paths of least resistance through the dam and its foundation. However, seepage must be controlled in both velocity and quantity to minimize damage to the structure.

Evidence of Seepage

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 more lush and darker green. Cattails, reeds, mosses, and other marsh vegetation often become established in a seepage area. In the winter, seepage areas may be evidenced by areas of ice buildup or areas of melted snow on the embankment. Downstream abutment contact areas should always be inspected closely for signs of seepage. Seepage can also occur along the contact between the embankment and a conduit spillway, drain, or other appurtenance. Slides on the embankment may be the result of seepage causing soil saturation or pressures in the soil pores.

At most dams, some water will seep from the reservoir through the foundation. Where it is not intercepted by a subsurface drain, the seepage will emerge downstream from or at the toe of the embankment. If the seepage forces are large enough, soil will be eroded from the foundation and be deposited in the shape of a cone around the seepage outlet. If these "boils" appear, professional advice should be sought immediately. Seepage flow which is muddy and carrying soil particles is evidence of "piping," and complete failure could occur within hours.



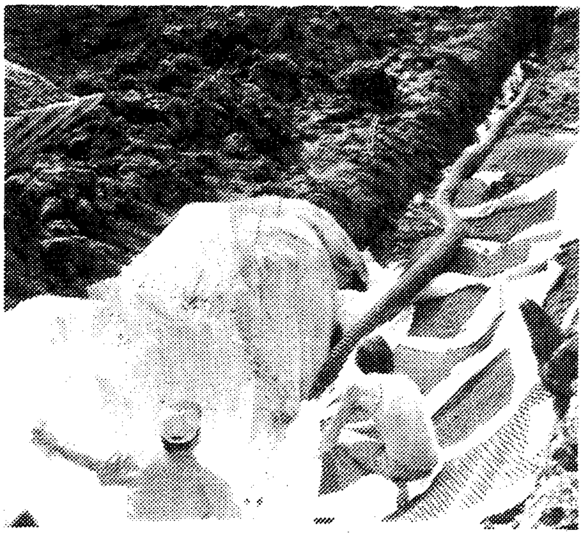
Piping Along Spillway Conduit

Piping can occur along a spillway and other conduits through the embankment, and these areas should be closely inspected. Sinkholes that develop on the embankment are signs that piping has begun, and may soon be followed by a failure of the dam. Emergency procedures, including downstream evacuation, must be implemented if this condition is noted. (See section on Emergency Procedures.)

A continuous or sudden drop in the normal lake level may be an 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 seepage. Controlling the quantity of seepage that occurs after construction is difficult, quite expensive, and not usually attempted unless the seepage is endangering the embankment or appurtenant structures. Typical methods used to control the quantity of seepage are installation of an upstream blanket, or the installation of relief wells or drainage trenches and drains. **All of these methods must be designed and constructed under the supervision of a professional engineer experienced with dams and require a state permit.**



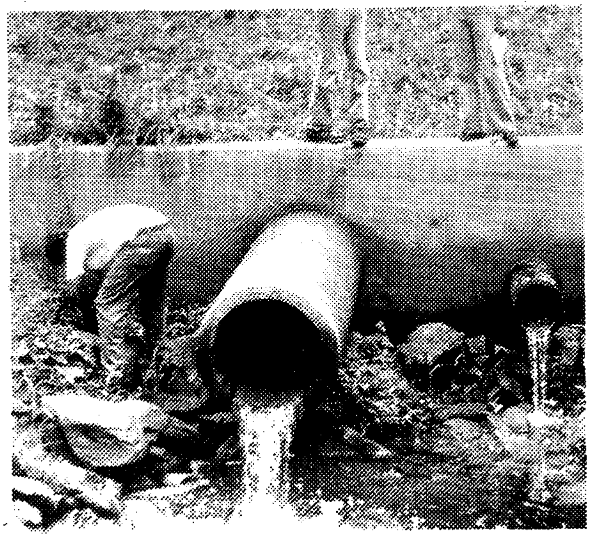
Toe Drain Installation

Preventing loss of soil particles by seepage is extremely important. Modern design practice incorporates this control into the embankment through the use of cutoffs, internal filters, and adequate drainage provisions. Control of seepage at the downstream toe can be accomplished by using properly graded filters and providing proper drainage. The filter and drainage system should be designed to prevent migration of soil particles and still provide for passage of the seepage flow.

The location of a seepage or wet area on the embankment or abutment is often a primary concern. Excessive seepage pressure or soil saturation can threaten the stability of the downstream slope of the dam or the abutments. Seepage control can sometimes be accomplished by installing trench drains.

Monitoring

Regular monitoring is essential to detect seepage and prevent failure. Without knowledge of the dam's history, the owner has no idea whether the seepage condition is in a steady state (constant) or fluctuating condition. It is important to keep written records of points of seepage, quantity of flow, soil particle content, size of wet area, and type of vegetation for later comparison. The rate and content of flow emerging from these outlets should be monitored regularly and recorded. Photographs provide valuable records of seepage. The owner should always look for increases in flow and evidence of flow carrying soil particles.



Monitoring Internal Drain Seepage

Regular surveillance and maintenance of internal embankment and foundation drainage outlets is also recommended. Normal maintenance consists of removing any soil or other material that obstructs flow. Internal repair is complicated and often impractical and should not be attempted without professional advice.

STABILITY

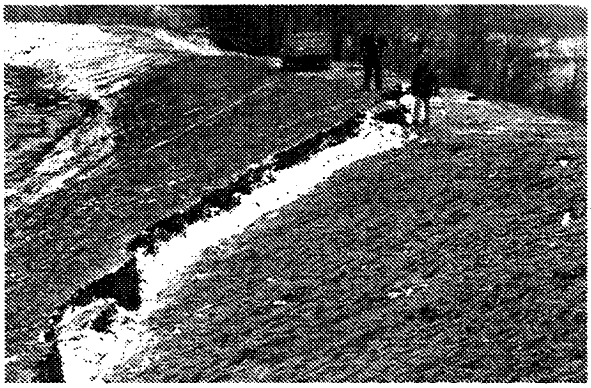
The embankment must safely contain the reservoir. Cracks, slides, sloughing, and settlement are signs of embankment distress and should indicate to the owner that maintenance or remedial work is required. The cause of the distress must be determined by an experienced engineer before undertaking repairs. This step is important because poorly conceived repairs may cause greater and more serious damage to the embankment and can cause failure of the dam.

Cracks

The entire embankment must be closely inspected for cracks. Short, isolated cracks are not usually significant, but larger well-defined cracks indicate a serious problem. There are two types of cracks that occur on the embankment surface - transverse and longitudinal.

Transverse cracks appear perpendicular to the dam axis and indicate differential settlement within the embankment. Such cracks provide avenues for seepage and the piping of embankment material could develop quickly.

Longitudinal cracks run parallel to the dam axis and may signal the early stages of a slide or slump on either face of the embankment. In recently built structures, these cracks may indicate inadequate compaction of the embankment or inadequate foundation preparation during construction.



Transverse Crack

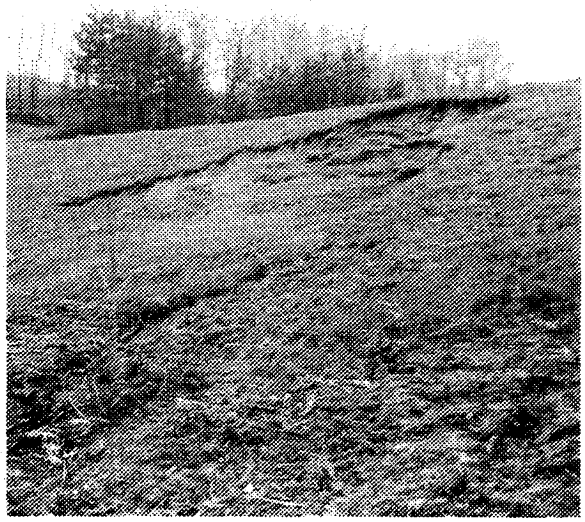
Small cracks, as they appear, should be documented, immediately examined by a professional engineer or the Dam Safety Division, and then sealed. The seal will prevent surface water from entering the cracks and causing saturation of embankment material. Saturation could possibly trigger a slide or other serious problems.

Sealing can be accomplished by compacting clay in the cracks. After the cracks have been sealed, the areas should be monitored frequently to determine if movement is still occurring. Slides or crack locations can be documented with photographs and sketches or diagrams. Continued movement is an indication of a more serious problem such as a slide.

Slides

Slides and slumps are serious threats to the safety of a dam and can initiate catastrophic failure. The need for immediate professional assistance to determine the cause of cracks and slides and to recommend remedial action cannot be overemphasized.

Slides can be detected easily unless obscured by tall vegetation. Arc-shaped cracks are indications that a slide or slump is beginning. These cracks can develop into a large scarp in the slope at the top of the slide.



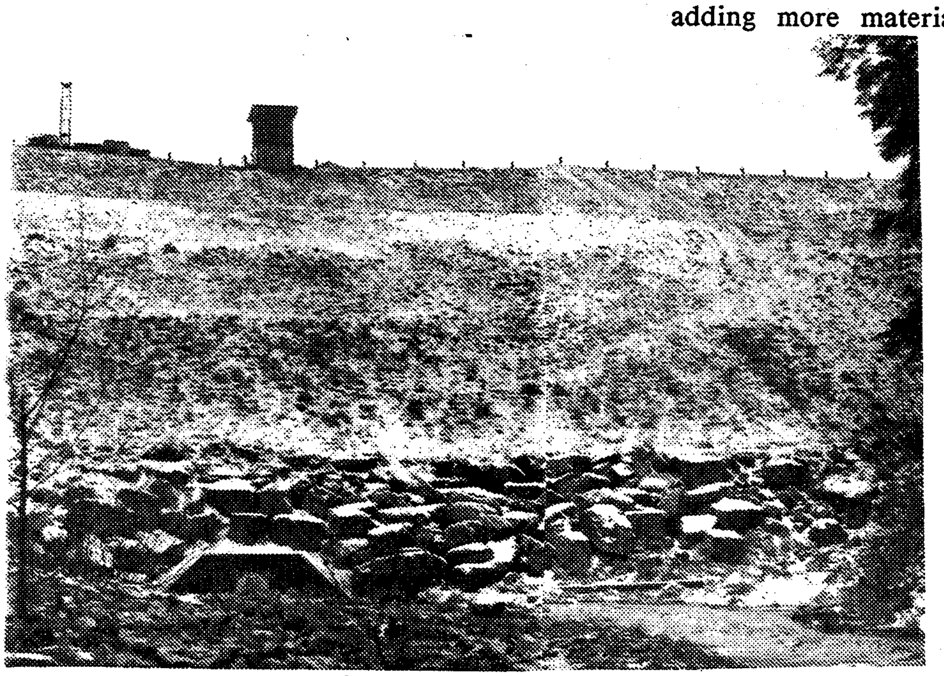
Slide Failure

If a slide develops, the reservoir should be drained. The scarp should be sealed to prevent rainfall and surface runoff from lubricating the interior slide surface, saturating the embankment, and causing future sliding. Sealing the scarp is only a temporary measure and should include contacting the Dam Safety Division.

Slide material in spillway and outlet areas should be removed immediately since its presence reduces the flow capacity. Shallow surface slides can be repaired by removing the slide material and rebuilding the slope to original grade with well compacted pervious material. The cause for any slide should be fully determined before permanent repairs are made to the slope.

Settlement

Settlement occurs both during construction and after the embankment has been completed and placed in service. To a certain degree, this is normal and should be expected. It is usually most pronounced at locations of maximum foundation depth or embankment height. Excessive settlement will reduce the freeboard (the difference in elevation between the water surface and the top of the dam) and may increase the probability of overtopping during a flood.



Excessive Settlement

Any areas of excessive settlement should be restored to original design elevations to reduce the risk of overtopping. A relatively large amount of settlement within a small area could indicate serious problems in the foundation or perhaps in the lower part of the embankment. Settlement accompanied by cracking often precedes failure. When either condition is observed, professional advice should be sought immediately. Settlement can be monitored by measuring the differences in elevation between the problem area and permanent reference monuments located away from the dam. Land surveying instruments are required to make these measurements.

Repair

Soil added to restore an embankment must be properly "keyed" into the base material. This is accomplished by removing the vegetation and all unsuitable material until a good firm base of undisturbed soil is uncovered. Unsuitable materials include wet, soft, porous, organic, and improperly compacted soils. The surface should then be roughened with a disc or similar device to obtain a good bond between "old" and "new" materials. The new soil should be successively placed in thin layers (6 to 8 inches thick) and each layer compacted before adding more material. Filters and drains may also be necessary to correct stability problems.

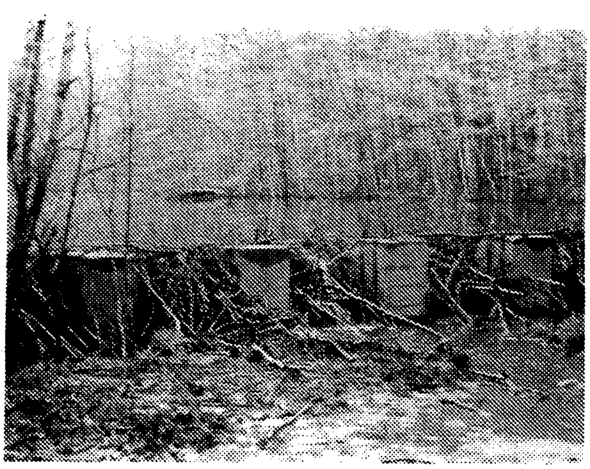
Repair of cracks, slides, and settlement is not considered routine maintenance and must be done under the supervision of a registered engineer who is experienced in the design and repair of dams. A permit must also be obtained from the Water Management Administration's Dam Safety Division.

RODENT CONTROL

Rodents such as the beaver, groundhog, and muskrat are attracted to dams and reservoirs, and can be quite dangerous to the structural integrity and 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.

Beaver

Beavers will try to plug spillways with their cuttings. Routinely removing the cuttings is one way to alleviate the problem. Another successful remedy is the placement of electrically charged wires around the spillway inlet. Trapping beaver may be done by the owner during the appropriate season.



Beaver Dam Blockage in Spillway

Groundhog

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 2 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 nesting 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 vegetation cover is properly maintained.

Muskrat

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 rushes and other plants. Their burrows begin from 6 to 18 inches below the water surface and penetrate the embankment on an upwards 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 higher to excavate a new dry chamber in the embankment. Damage (and the potential for problems) is compounded where groundhogs or other burrowing animals construct their dens on the opposite side of the embankment.

Muskrat Control

Barriers to prevent burrowing offer the most practical protection to earth structures. A properly constructed riprap and filter layer may 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 cave in and thus discourage den building. Heavy wire fencing laid flat against the slope and extending above and below the waterline can also be effective. Eliminating or reducing aquatic vegetation along the shoreline will discourage muskrat habitation.

Eliminating a Burrow

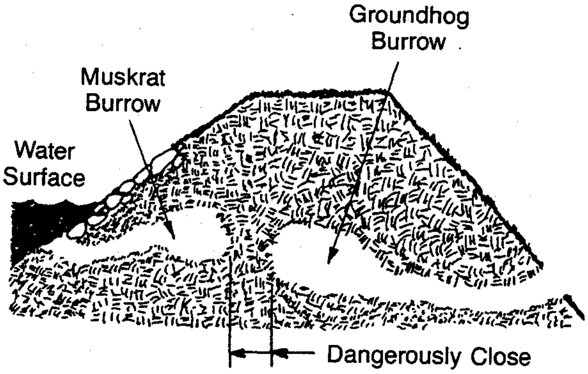
A method of backfilling a burrow on an embankment is "mudpacking." Lowering of the reservoir pool level may be necessary to accomplish this work. This simple, inexpensive method can be accomplished by placing one or two lengths of metal stove or vent pipe in a vertical position over the entrance of the den. After making sure that the pipe connection to the den does not leak, the mudpack mixture is then poured into the pipe until the burrow and pipe are filled with the mixture. The pipe is removed and dry earth is tamped into the entrance. The mudpack is made by adding water to a 90 percent earth and 10 percent cement mixture until slurry or thin cement consistency is attained. All entrances should be plugged with well compacted earth, and vegetation reestablished. Dens should be eliminated without delay because damage from just one hole can lead to failure of the dam.

Burrow Under Slab

Hunting and Trapping Regulations

Because state regulations change from year to year, hunting and trapping or other methods used to eliminate animals from the dam may have certain restrictions. For more information, the dam owner should contact:

Maryland Department of Natural Resources
Wildlife Administration
Tawes State Office Building
Annapolis, Maryland 21401
(410) 974-3195.



Rodent Burrows

CREST OF THE DAM

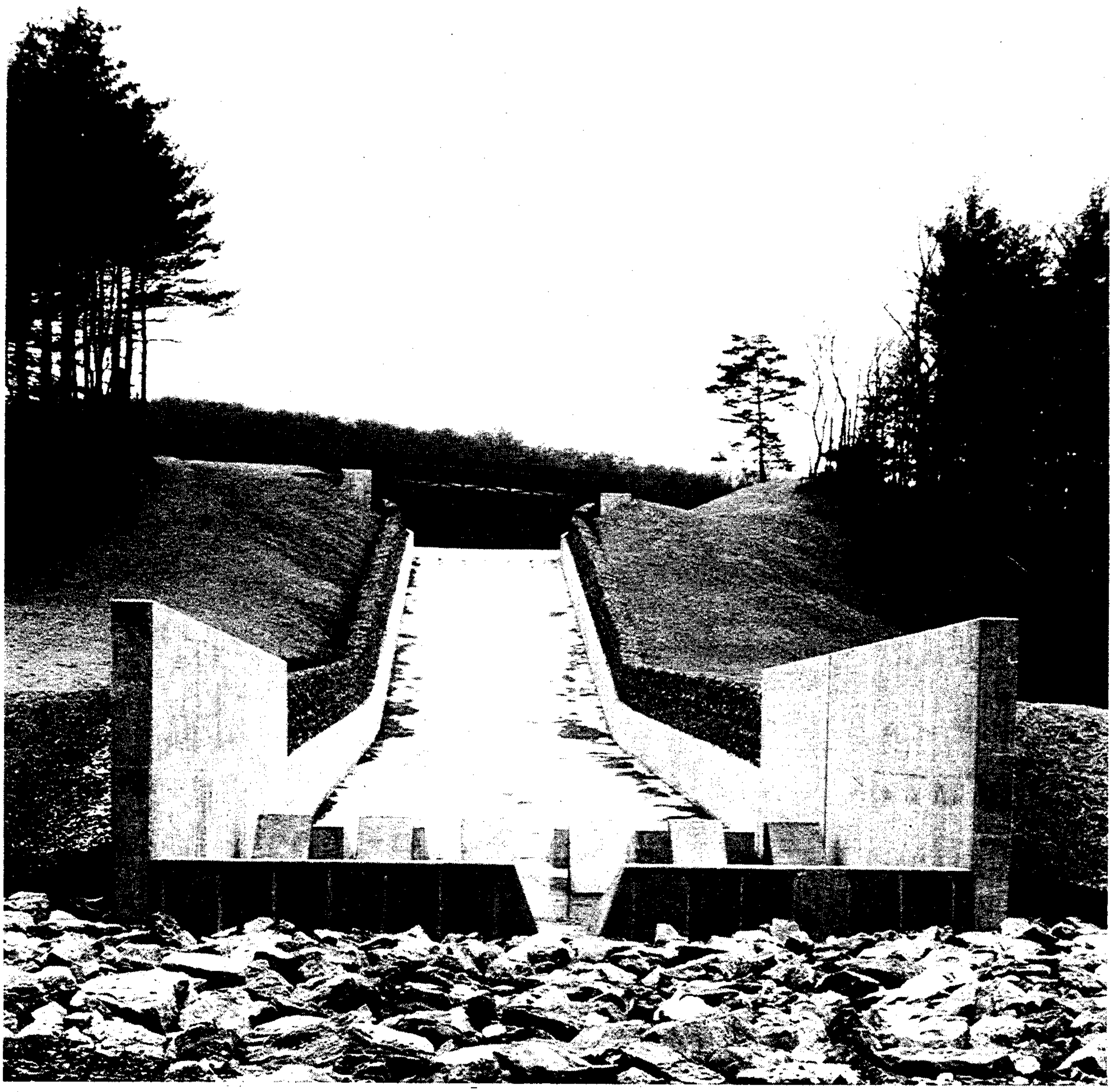
The crest, or top of the dam also requires attention and maintenance. The dam crest is usually constructed with a camber because some settlement of the embankment is anticipated.

Roads are often constructed along the dam crest in order to gain access to the other side of the dam or to simply gain access to the dam itself. Roads along or on the crest of dams should be maintained not only to keep the road in passable condition, but, more importantly, to prevent damage to the embankment. A road on the dam should be constructed with the proper base and wearing surface. If a well designed wearing surface has not been provided, traffic should not be allowed on the crest during wet conditions. Water collected in ruts may cause localized saturation, thereby weakening the embankment. Ruts that develop in the crest should be repaired as soon as possible. The crest of the dam should be graded to direct all surface drainage into the impoundment. Road drainage should not be concentrated at one location.

Heavily traveled paved roads may require special means for collection and drainage of surface water. If properly designed and constructed, guard rails, curbs, gutters, and rigid pavement may also be located on the crest of the dam.

SPILLWAY AND OUTLET WORKS

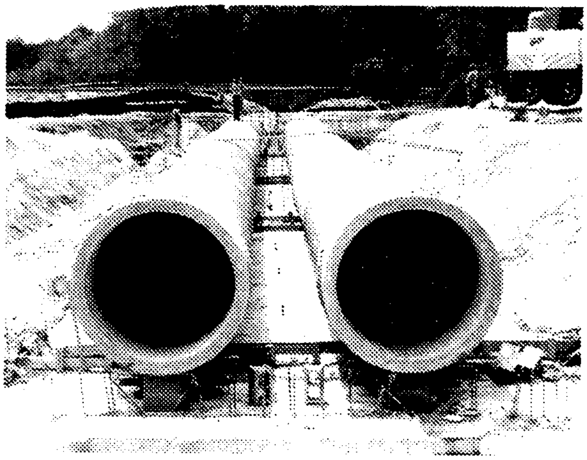
Many dams have a principal spillway that consists of a riser and conduit pipe. This spillway system carries the normal stream and small flood flows safely past the embankment. The emergency spillway will supplement the passage of larger flood flows around the dam to prevent major damage. Conduits are constructed of metal pipe or concrete depending on the size of the dam. Pipes through embankments are difficult to construct properly, can be extremely dangerous to the embankment if problems develop after construction, and are usually difficult to repair because of their location and size. These structures should not be neglected during the course of maintenance.



Principal Spillway • Edgemont Dam • City of Hagerstown, 1993
photo courtesy of Whitman, Requardt and Associates.

CONDUITS

Frequent inspection is necessary to ensure the spillway conduit is functioning properly. All conduits should be inspected thoroughly once a year. Conduits which are 36 inches or more in diameter can be entered and visually inspected. The conduits should be inspected for improper alignment (sagging), elongation and displacement at joints, cracks, leaks, surface wear, loss of protective coatings, corrosion, and blockage.

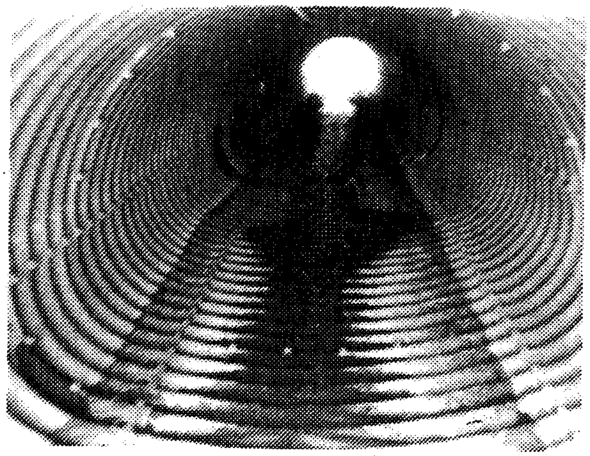


Concrete Conduit

Problems with conduits occur most often at joints, and special attention should be given to them during the inspection. The joints should be checked for gaps caused by elongation or settlement and loss of joint filler material. Open joints can permit erosion of embankment material into the pipe, or cause leakage of water into the embankment when the pipe is flowing full and under pressure. The outlet should be checked for signs of water seeping along the exterior surface of the pipe. A depression in the soil surface over the pipe may be a sign that soil is being removed from around the pipe.

Corrosion

Corrosion is a common problem of metal pipe spillways and other conduits. Exposure to moisture, acid conditions, or salt will accelerate the corrosion process. Metal pipes are available which have been coated to resist corrosion. Coatings can be of epoxy, aluminum, zinc (galvanized), or bituminous asphalt. These coatings are generally applied at the time the pipe is manufactured. Coatings applied to pipes in service are generally not very effective because of the difficulty in establishing a lasting bond.



Metal Conduit Deterioration

Repair

Effective repair of the internal surface or joint of a metal or concrete conduit is difficult, and should not be attempted without careful planning and proper professional supervision. Listed below are comments regarding common methods used in minor pipe repairs.

1. Asphalt mastic used as joint filler becomes hard and brittle, is easily eroded, and will generally provide a satisfactory seal for only about five years. Mastic should not be used if the pipe is expected to flow under pressure. For these reasons asphalt mastic is not recommended for other than temporary repairs.

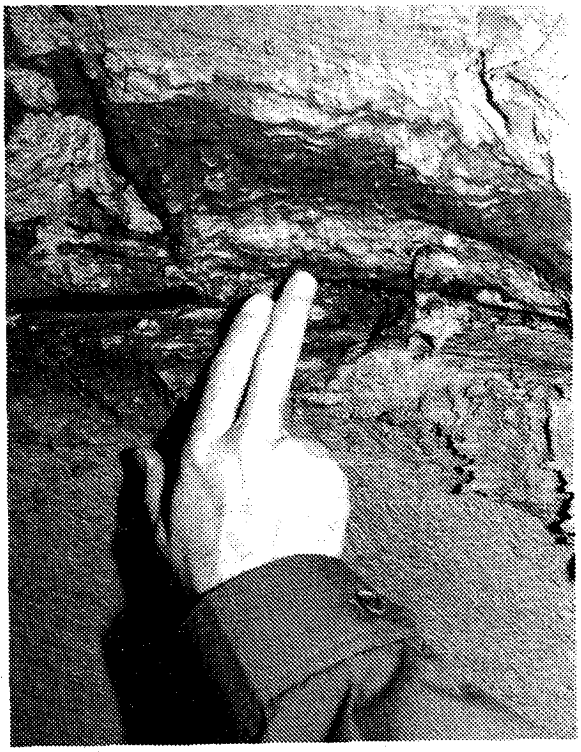
2. The instructions on the label should be followed when using thermosetting plastics (epoxy). Most of these products must be applied to a very clean and dry surface to establish an effective bond.

3. Joint filler compounds should be impervious to water, and should be flexible throughout the range of expected air and water temperatures.

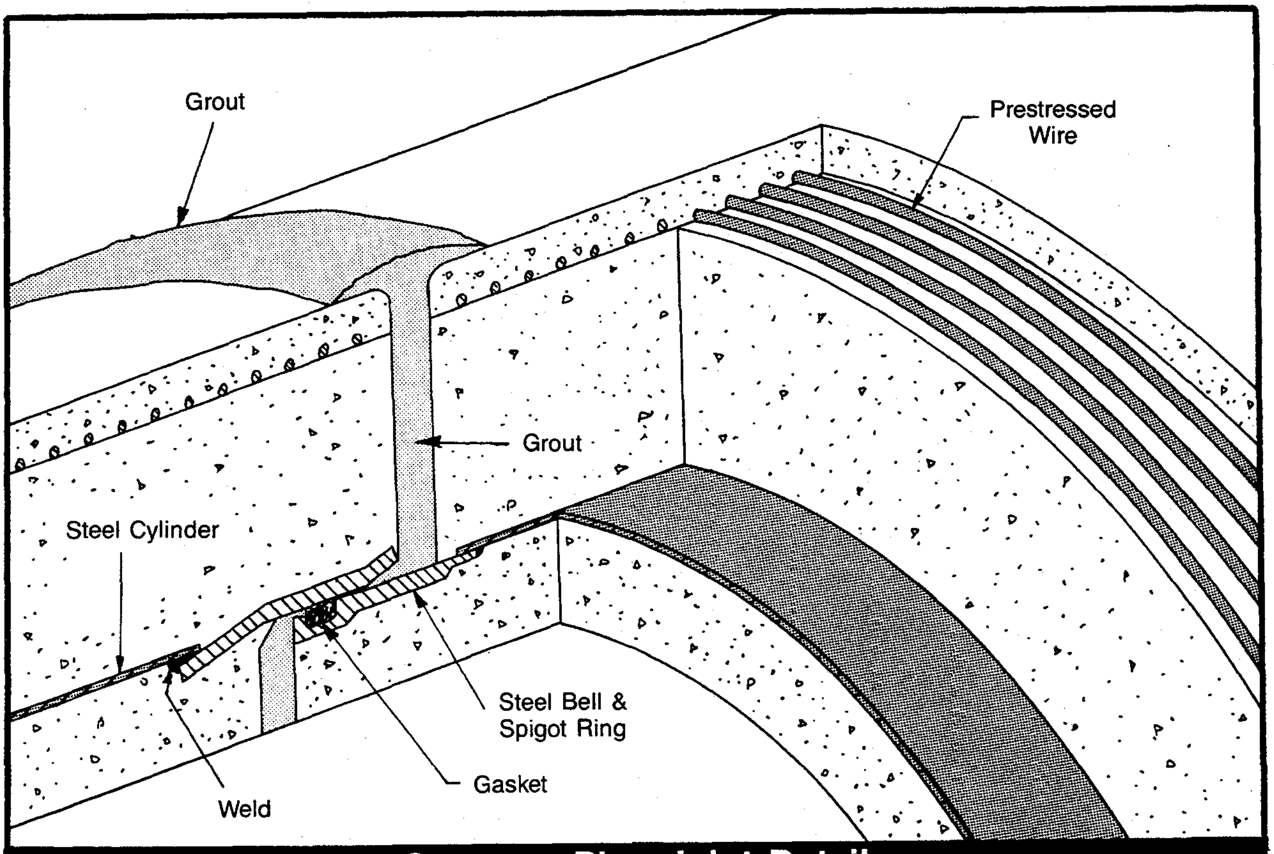
4. The internal surfaces of the conduit should be made as smooth as possible when repairs are made so that high-velocity flow will not damage the repair material.

5. Oakum or gasket-type material can be hammered, jacked, or forced into an open crack or joint and is one of the most effective methods used to repair large openings.

6. Hairline cracks in concrete are not generally considered a dangerous problem, and repair is not needed unless the cracks open up. Cracks are generally repaired with an epoxy compound.



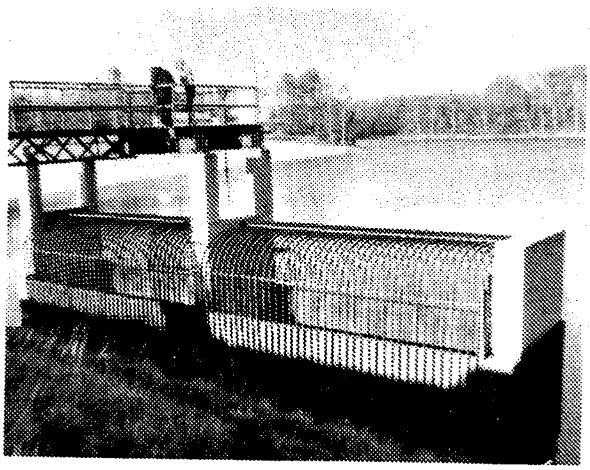
Severe Joint Deterioration



Concrete Pipe Joint Detail

TRASH RACKS

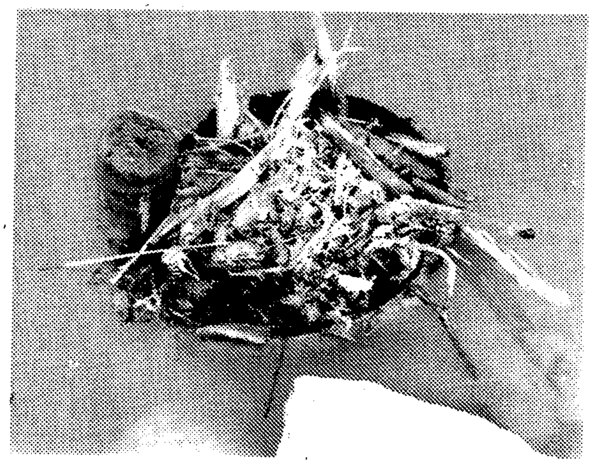
The importance of a safe spillway cannot be overemphasized. Pipe spillways should always contain some type of trash rack in order to prevent accumulation of debris and possible misoperation during a flood event. Even though the emergency spillway is available to pass excess flows, it is generally designed to operate on a very infrequent basis and will sustain some damage during operation.



Welded Bar Trash Rack

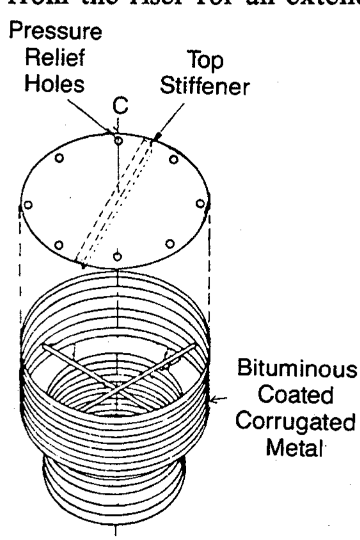
A properly designed riser structure includes a trash rack that will allow passage of smaller debris yet not become clogged as larger debris accumulates around it. There are generally two types of trash rack designs: welded bar and hood. In a welded bar trash rack, the recommended minimum spacing of steel bars is 6 inches on center. Hooded trash racks are generally one piece units and contain either anti-vortex plates or a top plate to prevent debris from entering the conduit. A hooded trash rack is generally installed on a corrugated metal pipe riser, whereas a welded cross-bar trash rack is bolted over the openings of a concrete riser. Both types of trash racks are designed to prevent:

a) accumulation of small debris,
b) development of a whirlpool around the riser, and
c) damage from the hammering forces of debris.



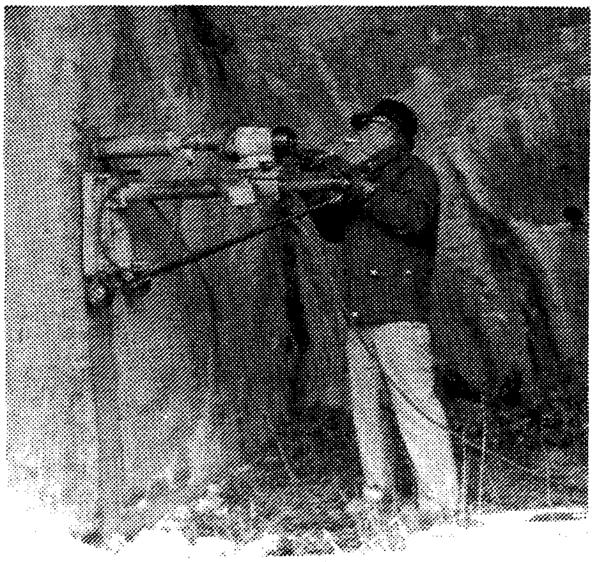
Debris Accumulation

The trash rack unit should be checked periodically, especially after storm events, to ensure that it is functioning properly. Accumulated debris should be removed and maintenance performed if necessary. Under no circumstances should the unit be removed from the riser for an extended period.



CONCRETE

Concrete is a widely used material in dam construction. When made of quality materials and constructed properly, concrete is durable and strong. However, maintenance problems eventually develop in nearly all concrete structures. These problems are caused by design errors, construction errors, chemical attack, and natural forces.



Testing Concrete Strength

Inspection

Concrete surfaces should be inspected for cracking, spalling, displacement or movement, and deterioration by weathering, chemical reactions or leaching. Rust stains may indicate internal rusting and deterioration of reinforcing steel. Expansion and contraction joints should be inspected for signs of deterioration of the joint filler material, leakage, or abnormal movement. Drains designed to relieve water pressure beneath slabs and behind walls should be functional.

Repair Techniques

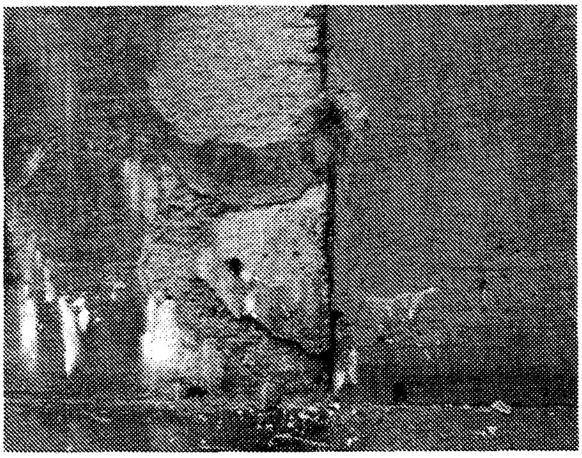
Concrete problems are structural problems that require structural solutions in order to be long lasting. Concrete repairs can be broken down into several categories as follows:

Patching	**Joint Repair**
Grouting	**Strengthening**
Coatings	**Crack Repair**

Concrete repair techniques are specialized, and depend on the concrete problems encountered. Dam owners are encouraged to consult with a professional in order to select the most appropriate repair method.

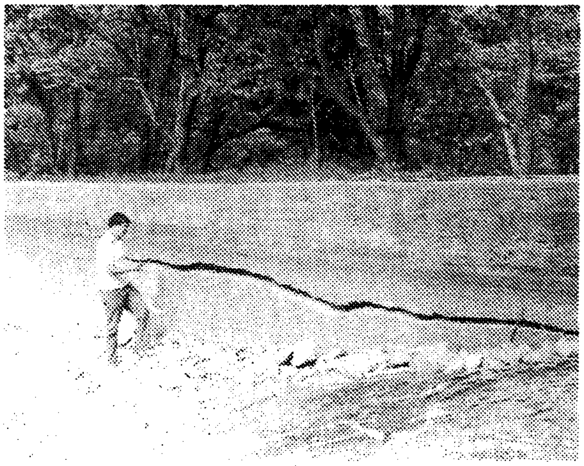
Extensive cracking, slab or wall movement, large areas of exposed reinforcing steel, and severe undermining are examples of structural problems which require professional advice and a permit from the Dam Safety Division before repairs can be made. These repairs, not addressed here, are generally expensive and require a custom designed solution.

Minor repairs, as outlined below, can be performed during routine maintenance. Although these repairs are seldom a permanent solution to concrete problems, minor repairs may help to prolong the useful life of the structure.



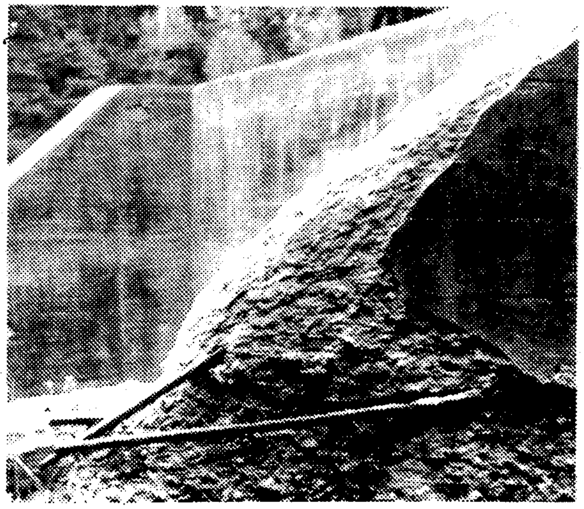
Concrete Spalling

Spalled concrete. Spalling is the loss of surface concrete and can expose the reinforcing steel. Patching is the process of replacing this material. All loose and unsound concrete should be removed from the spalled area and beneath the reinforcing bars if they are exposed. The edges of the area to be repaired, should be saw cut to about 3/4" deep. An appropriate bonding agent may be applied prior to patching with new concrete. If the spalled area is large enough, anchors must be installed to hold the replacement concrete in position. This work should be done by an experienced contractor.



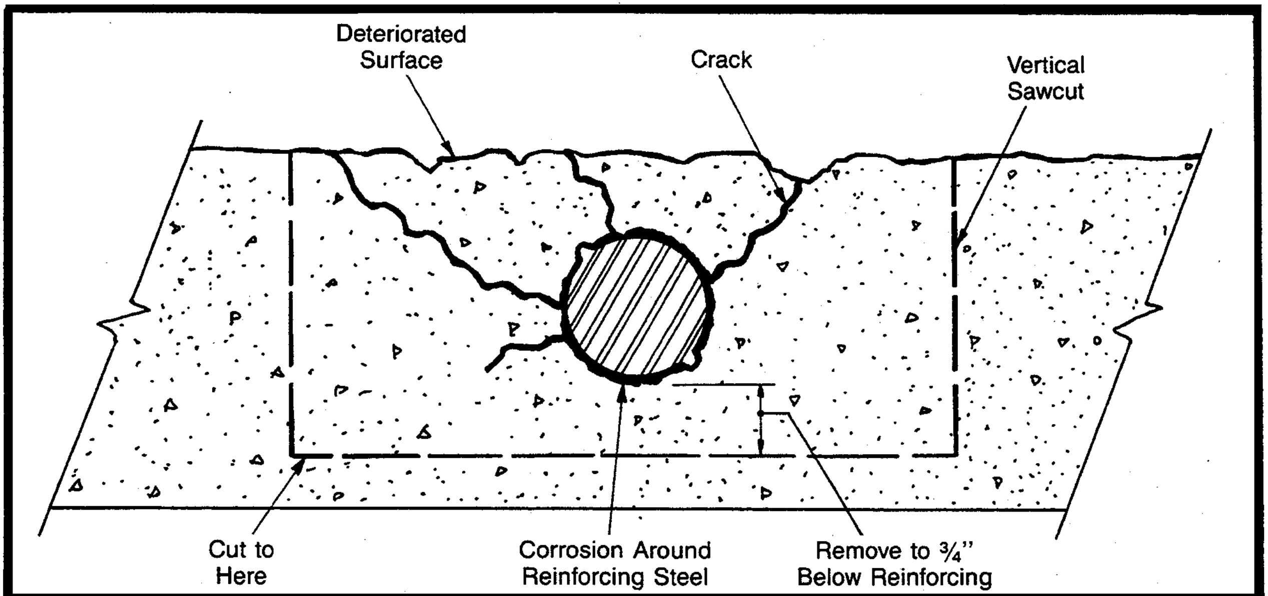
Abutment Wall Crack

Cracks. Small cracks may be repaired by surface sealing with an appropriate adhesive. Epoxy injection, and sawcut and seal techniques are used for larger cracks. Surface sealing is used to stop water flows or as a temporary measure until more permanent crack repairs can be made.



Concrete Deterioration

Surface deterioration. Concrete deterioration on dams is accelerated by the presence of chemicals in the water as well as the freeze-thaw process. Many types of commercial coatings are available to make the concrete resistant to this deterioration. The selection of an appropriate sealer is difficult and must be carefully matched to the specific problem. A specialty contractor should perform the repairs and apply the coating.



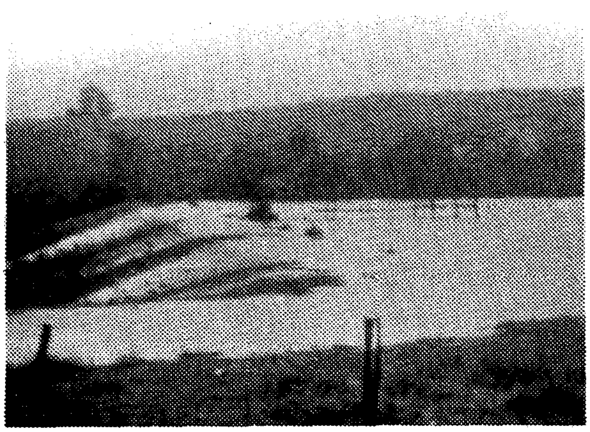
Concrete Crack Repair

VEGETATED SPILLWAYS

Dams are designed to safely pass a certain "inflow design flood." This flow is in excess of what is considered the normal operating range for the dam. A concrete dam that consists of a single monolithic structure is generally designed to pass the full range of flows anticipated. However, an earthen structure would most certainly be washed away if flow were to pass over top. Therefore, it is impractical, and economically unfeasible, to size the principal spillway to pass the inflow design flood. For this reason an earthen type of dam must allow flood flows to pass around the embankment section through an emergency spillway.

Emergency Spillway

It is extremely important that the dam owner understand the purpose and function of the emergency, or auxiliary, spillway. This area of the dam is often neglected because the owner rarely sees flow in the spillway. It is a common perception of the dam owner that his structure is fail-safe.



Emergency Spillway In Operation

The emergency spillway is designed to pass flood flows around the dam on an infrequent basis. This type of spillway usually consists of a vegetated earthen channel that is precisely dimensioned to convey water without overtopping the dam. A certain amount of erosion and damage to the spillway is anticipated into the overall design.

A typical spillway section consists of the inlet, control section, and outlet channel.

Spillway Inspection

Vegetated earth spillways are usually the most economical means to provide emergency spillway capacity. Normal flows are carried by the principal spillway, and infrequent large flood flows pass primarily through the emergency spillway. For dams with pipe-conduit spillways, an emergency spillway is almost always required as a back-up in case the pipe becomes plugged.

Maintenance and Repair of Vegetated Earth Spillways

Since the vegetated emergency spillway is used on an infrequent basis, maintenance of the channel should not be a burdensome task. As in the case of the embankment maintenance, there are certain items that need to be attended to that include:

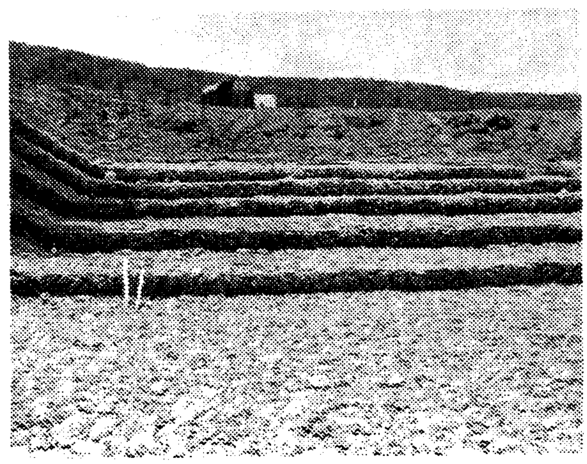
1. **Maintenance of vegetation.** Periodic mowing to prevent trees, brush, and weeds from creating a flow obstruction,particularly at the control section. A poor vegetative cover will usually result in extensive, rapid erosion when the spillway flows, and require more costly repairs. The vegetative cover should be given the same care and maintenance as the embankment of the dam. Reseeding and fertilization is necessary to maintain a vigorous growth of vegetation. Kentucky 31 fescue is an excellent grass for erosion protection (see section on vegetation).

2. **Prompt repair of damage.** Repair of erosion damage, particularly after high flows. Erosion can be expected in the spillway channel during high flows, and can also occur as a result of rainfall and local runoff. The

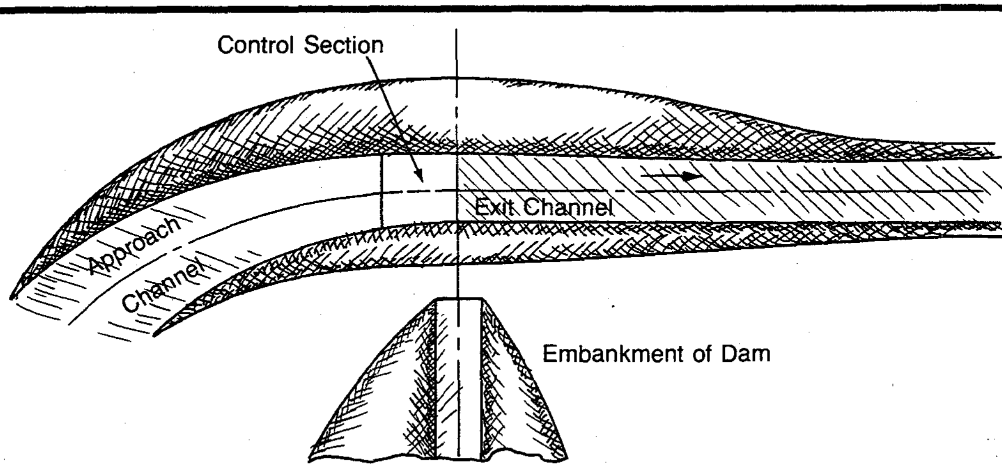
latter is more of a problem in large spillways, and may require special treatment, such as terraces or drainage channels. Erosion of the side slopes will deposit material in the spillway channel, especially where the side slopes meet the channel bottom. In small spillways, this can significantly reduce the spillway 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 flow capacity.

3. **Removal of flow obstructions.** Emergency spillways are often used for purposes other than the passage of flood flows. Among these uses are reservoir access, parking lots, boat ramps, boat storage, pasture and cropland. Permanent structures (buildings, fences, etc.) should not be constructed in these spillways. If fences are absolutely necessary, they should cross the spillway far enough away from its control section (at the highest point in the channel) so they do not interfere with flow. Any change to the dimensions of the spillway channel will alter its capacity to carry flood flows and could cause failure of the dam.

Eroded Spillway



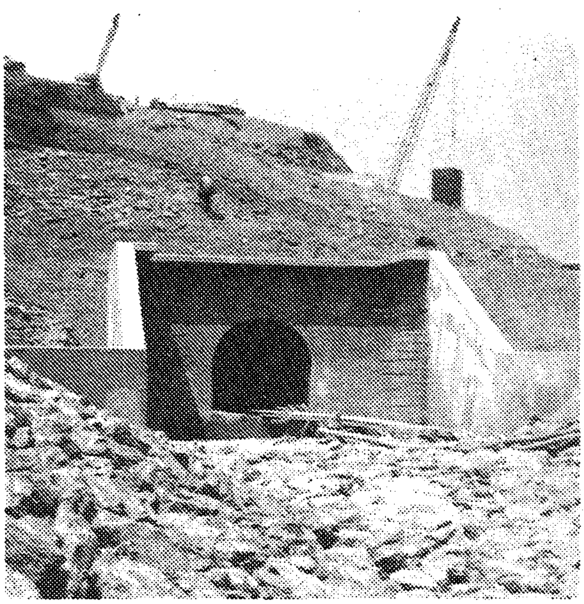
Spillway After Repair



Emergency Spillway - Plan View

OUTLET

Erosion at the spillway outlet, whether it be a pipe or overflow spillway, is one of the more common spillway problems encountered in the maintenance of a dam. Severe undermining of the outlet can displace sections of pipe, cause slides in the downstream slope as erosion continues, and eventually lead to complete failure of the dam. Water must be conveyed safely from the lake to a point downstream of the dam without endangering the spillway or embankment. Often the spillway outlet is adequately protected for normal flow conditions, but not for extreme flows. It is easy to underestimate the energy and force of flowing water and overestimate the resistance of the outlet material (earth, rock, concrete, etc). The required level of protection is hard to establish by visual inspection, but can usually be determined by hydraulic calculations performed by a professional engineer.



Properly Constructed Outlet

Structures that provide for complete erosion control at a spillway outlet are usually expensive to construct, but often necessary. These structures consist of some type of impact basin to reduce flow velocities at the outlet. A concrete overflow section contains a bucket dissipator to deflect water away from the toe of the dam. The most common types of conduit outlet structures are the stilling basin and plunge pool. The major difference between these two designs is that the stilling basin is a concrete structure, whereas the plunge pool is an excavated pool that is armored with riprap for protection against scour. As areas of erosion and deterioration develop, repairs must be promptly initiated.

The following four factors, often interrelated, contribute to erosion and scour at the spillway outlet:

1. Flows emerging from the spillway are generally of high velocity such that the moving water will scour soil material from the outlet channel and leave eroded areas. This erosion is difficult to design for, and requires the outlet be protected for a safe distance downstream from the dam.

Erosion Under Outlet Slab

2. Flows emerging from the outlet are at an elevation above the stream channel. If the outlet flows emerge at the correct elevation, tailwater in the stream channel can be used to absorb a substantial amount of the high velocity flow.

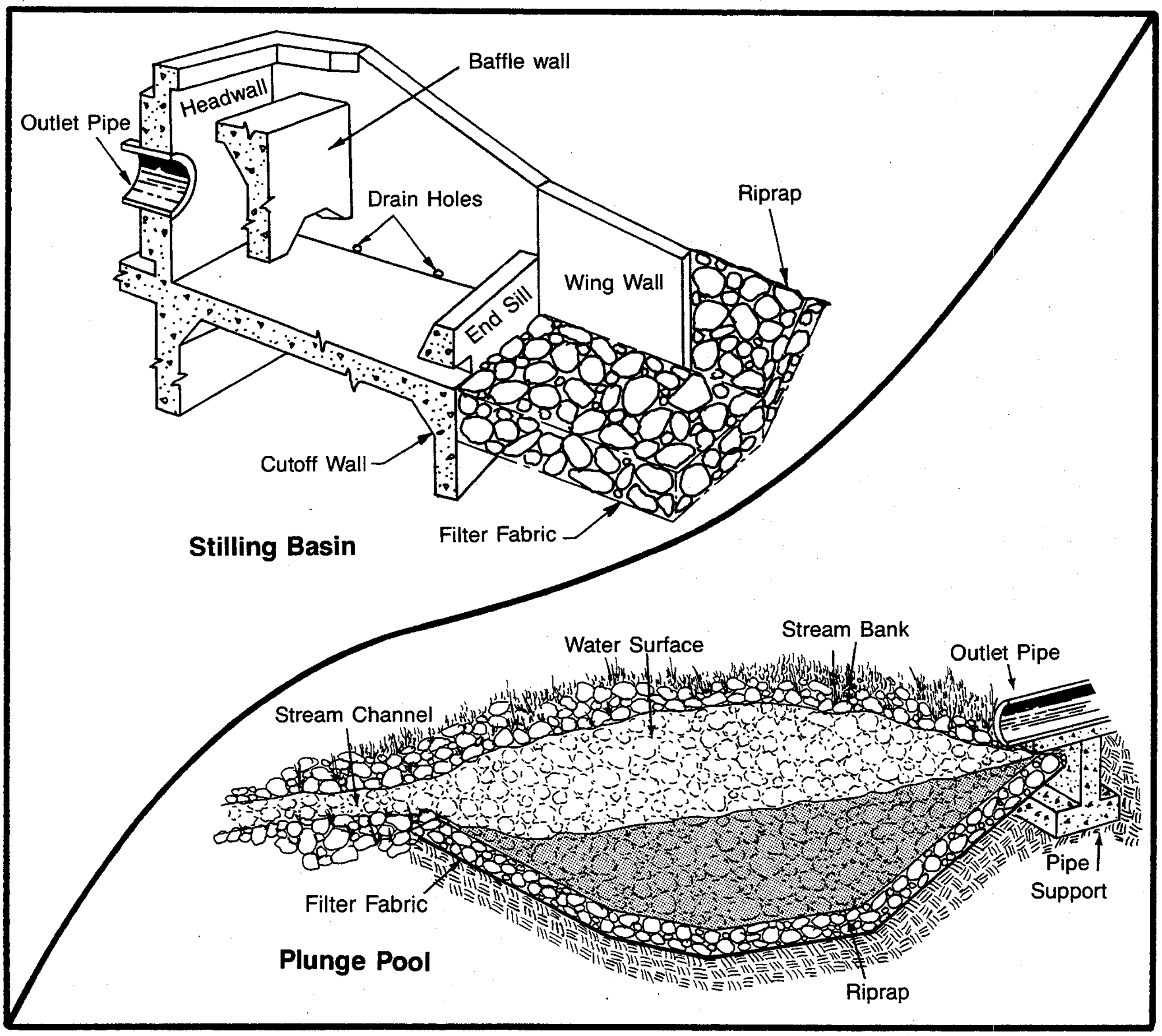
3. Flows leaving the outlet at high velocity can create negative

pressures that can cause material to be loosened and removed from the floor and walls of the outlet channel. This action is called "cavitation" when it occurs on concrete or metal surfaces. Venting can sometimes be used to relieve negative pressures.

4. Water leaking through pipe joints or flowing along a pipe from the reservoir may weaken the soil structure around the pipe outlet. Inadequate compaction adjacent to the conduit during construction adds to the problem.

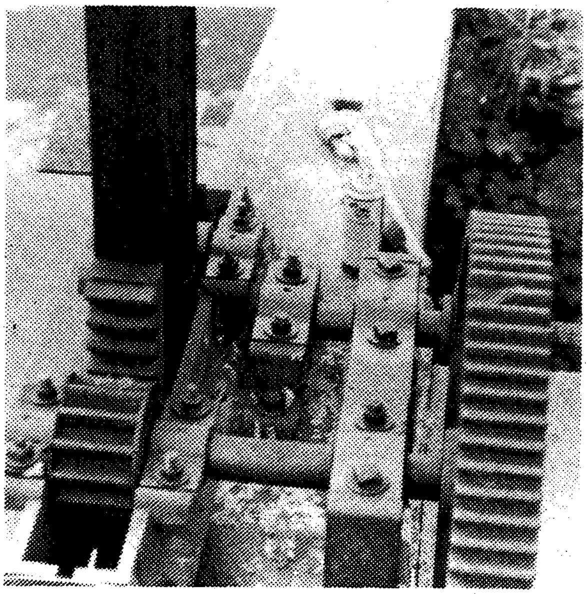
Eroded and undermined areas at spillway outlets can sometimes be repaired by filling these areas with large stone. Stone that is large enough to be effective needs to weigh at least 500 pounds (18 to 24 inches in diameter). Often stone this size is not available or is expensive to buy and haul. Concrete slurry can be used to bind smaller stones together to increase their effective size and weight. Gabions have been used successfully in areas where the velocity is low, but should be used cautiously where high velocity and turbulence are expected. Gabions require careful foundation preparation and experienced personnel for installation.

In many cases, professional help should be obtained for the design and construction of the outlet protection.



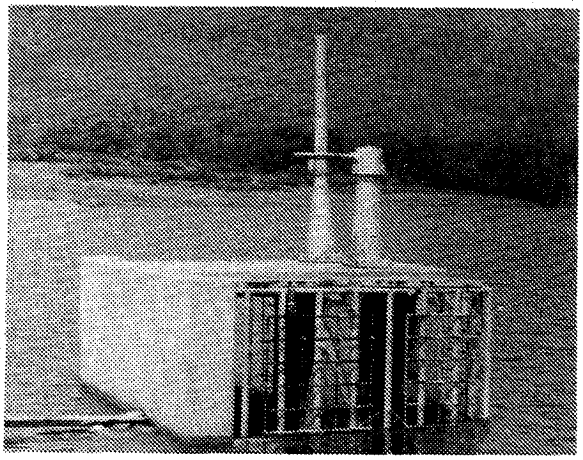
MECHANICAL EQUIPMENT

Mechanical equipment includes spillway gates, sluice gates valves for lake drains or water supply pipes, stoplogs, sump pumps, flashboards, relief wells, emergency power sources, siphons, and other devices. The owner should have copies of all manufacturers' literature for the mechanical equipment. All mechanical and associated electrical equipment should be tested according to the manufacturer's recommendations. Recommended maintenance should be performed at that time. The equipment test should be conducted through the full operating range under actual operating conditions to determine whether the equipment performs satisfactorily. Operating instructions should be checked for clarity, and maintained in a secure but readily accessible location. Each operating device should be permanently marked for easy identification. All equipment controls should be checked for proper security to prevent vandalism.

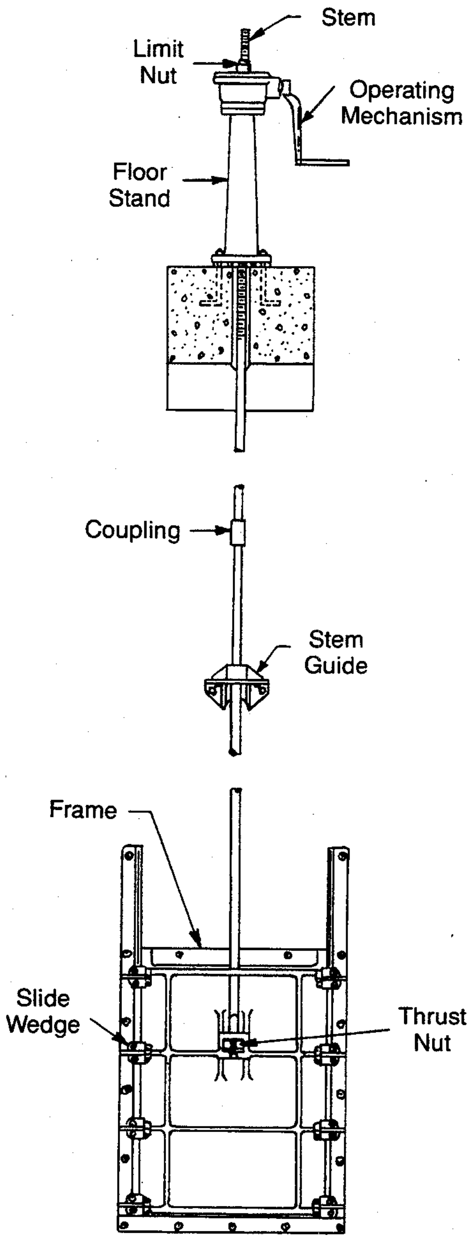


Protecting Metal Parts

Corrosion of metal parts of operating mechanisms can be effectively prevented at the time maintenance is performed by keeping these parts greased or painted.



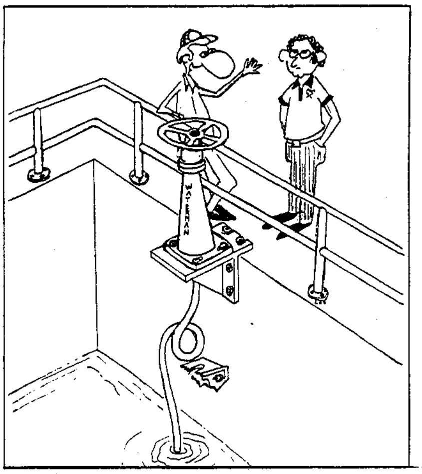
Mechanical Gate Lift



Water Control Gate

LAKE DRAINS

The lake drain should always be operable in order for the pool level to be drawn down in case of an emergency or for necessary repairs. Lake drain valves or gates that have not been operated for a long time present a special problem for dam owners. If the valve cannot be closed after it is opened, the impoundment could be completely drained. Therefore, before operating a valve or gate, it should be carefully inspected and all appropriate parts lubricated and repaired.



I turned it too hard!

An uncontrolled and rapid drawdown of the lake level could induce more serious problems such as slides in the saturated upstream slope of the embankment or reservoir area. Drawdown rates should not exceed 1 foot per week for slopes of clay or silt material except for emergency situations. Very flat slopes or slopes with free-draining upstream zones can withstand more rapid drawdown rates. It is prudent to advise downstream residents of large or prolonged discharges because of the possibility of downstream flooding.

If problems are encountered during the exercising of the drain valve, the operator should stop the test immediately. A professional engineer or the Dam Safety Division should be contacted for advice and assistance in properly exercising a questionable drain gate. Before testing a gate that is suspected to be faulty, the drain inlet upstream from the valve should be physically blocked. Some drain structures have been designed with this capability and have dual valves or gates, or slots for stoplogs (sometimes called bulkheads) located upstream of the drain valve. Divers can be hired to inspect the drain inlet, and may be able to construct a temporary block at the inlet for testing purposes.

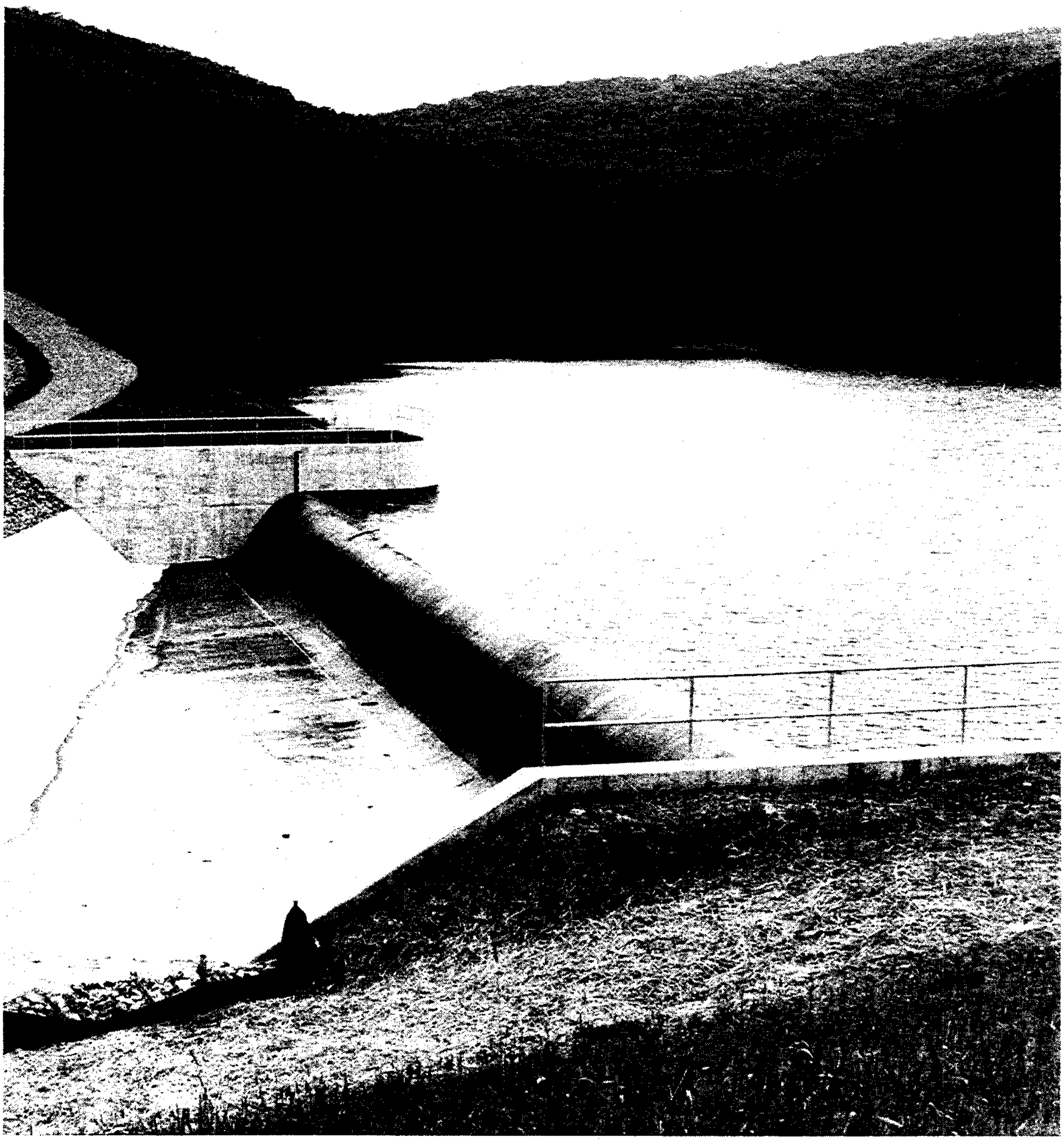
Other problems may be encountered when operating the lake drain. Sediment can build up and block the drain inlet. Debris can be carried into the valve chamber, hindering its function if an effective trash rack is not present. These problems can be minimized if the valve or gate is operated and maintained periodically. The gate or valve controlling the lake drain should be operated from the fully closed to fully opened position as recommended by the manufacturer or at least once each year. Early detection of equipment problems or breakdowns, and confidence in equipment operability, are the benefits of periodic operation.

Some older dams have drains with valves at the downstream toe. If the valve is located at the downstream end of a pressurized conduit extending through the embankment, the conduit is under the constant pressure of the reservoir. If a leak in the conduit develops within the embankment, saturation, erosion, and possibly failure of the embankment could occur. A depression in the soil surface over the pipe may be a sign that soil is being removed from around it. These older structures should be monitored closely and owners should plan to relocate the valve upstream or install a new drain structure. Inspectors should closely examine the drain outlet for signs of possible problems.

Reservoir Lake Drain

RESERVOIR

A well documented operation and maintenance program for the dam will include periodic attention to the reservoir pool. The amount of attention needed will generally depend on the size of the facility as well as its intended use. The most frequent maintenance will include the removal of debris entering the reservoir in order to prevent clogging of the spillway section.



Edgemont Dam • City of Hagerstown, 1993
photo courtesy of Whitman, Requardt and Associates.

POOL LEVELS

Reservoir pool levels are often controlled by a combination of spillway gates, flashboards, and lake drain and release structures. The drawdown rate of the pool level should be made over a gradual period of time. Rapid drawdown of the lake could cause a failure of the embankment slope. The dam owner should follow the drawdown guidelines described in the Mechanical Equipment section under Spillway and Outlet Works.

Listed below are conditions or instances in which the pool level might be permanently or temporarily lowered.

1. Maintenance or repair activity requires the pool to be lowered. Drawdown is temporary until the work is accomplished.

2. Water is released to the downstream channel, supplementing streamflow during dry conditions. This may temporarily lower the lake level if there is little inflow to the lake.

3. Water supply reservoir levels will fluctuate according to the service area's demand for water. Flashboards are sometimes used to permanently or temporarily raise the pool level of water supply reservoirs. Flashboards should not be installed or allowed unless there is sufficient freeboard remaining to safely pass the inflow design flood. The installation of flashboards requires a permit from the Dam Safety Division.

4. The pool level is drawn down in the winter to facilitate repair of boat docks, to retard growth of aquatic vegetation along the shoreline, or to allow additional storage for spring runoff.

5. Pool levels are sometimes adjusted for recreation, hydropower, or waterfowl and fish management.

AQUATIC VEGETATION

Control of most aquatic vegetation can be accomplished through the use of chemical herbicides. Aquatic vegetation is classified into three major groups: **floating growth**, **submerged growth**, and **emergent growth**.

Floating growth is a floating dense mat of hair-like fibers. The most common form is filamentous planktonic algae. Most species can be controlled with very low concentrations of copper sulfate or <u>Cutrine-Plus</u>. Application instructions can be found on the product label. Caution should be exercised as copper sulfate can kill new hatches of fish if applied when fish are spawning.

Submerged growth is attached to the lake bottom and has most of its growth below the water surface. It grows mostly in clear, calm, shallow water. Herbicides for submerged weeds are available as liquids, wettable powders (to be mixed with water), and granules. Liquids and wettable powders release their active ingredients immediately and work best when used in spring through midsummer. Granular herbicides release their active ingredients more slowly and should be used early in the growing season or on a spot treatment basis.

Emergent growth is found along the shoreline and in shallow water where the stems and leaves extend out of the water. Cattails, bulrushes, and spatterdock are examples frequently found in these areas. A non-chemical method of control is to increase the water depth in the area of growth by maintaining a steep slope, at least 3H:1V, along the shore. Most herbicides used for land weed control can also be used for emergent growth if combined with a wetting and sticking agent. In addition to commercially available wetting and sticking agents, two tablespoons of liquid household detergent per gallon of herbicide may be used. The mixture is then sprayed until a thin film covers the leaves. Common herbicides include 2-4-D products and <u>Diquat</u>.

Chara, **duckweed**, and **watermeal** are growths that do not fit the above categories. **Chara (muskgrass, stonewart)** grows in dense clumps in shallow areas and is an advanced form of algae. **Duckweed**, a floating weed, has small three-lobed leaves with rootlets that hang down in the water. **Watermeal** consists of small green grains floating in the water.

The use of herbicides for aquatic management is controlled by the Department of Health and Mental Hygiene. These herbicides are classified as either "restricted use" or "general use" products and are identified as such on the product container. Maryland regulations require a <u>permit</u> for the use of **ANY** toxic material for aquatic life management. In addition, the application of a restricted use product requires <u>certification</u> by the Maryland Department of Agriculture. General use products may be applied by an individual property owner without the certification requirement.

With most general use commercial herbicides, application instructions, environmental precautions, and a list of weeds controlled will be found on the label. Always **READ THE LABEL CAREFULLY** and **NEVER** mix different herbicides. Herbicides can be purchased from a local agricultural supply center.

For information on obtaining a permit for the application of herbicides contact the Maryland Department of the Environment at 1-800-633-6101.

For a more complete discussion of aquatic weed control, contact the Maryland Department of Agriculture, Pesticide Regulation Branch, 50 Harry S. Truman Parkway, Annapolis, MD 21401, phone (410) 841-5710, or your local Cooperative Extension Office.

SEDIMENTATION

Sediment is the end product of erosion, which is the naturally occurring process of the wearing away of the earth's land surface. In addition to this natural process, erosion is worsened by man's activities that include construction, foresting, and agricultural practices. The sediment resulting from the entire erosion process in a watershed shows up as physical damage downstream such as:

a) filling in of stream channels and bridges,
b) environmental damage,
c) damage to recreational facilities, and
d) filling of reservoirs.

Sediment Damage

Damages

The damage resulting from sedimentation amounts to millions of dollars annually. These costs can have a significant impact on the useful life of a reservoir. The portion of eroded material that travels through the drainage network to the reservoir is referred to as the sediment yield. Old reservoirs, designed without consideration for sediment yield, are often abandoned because the cost to reestablish a desirable lake is prohibitive. New facilities that are permitted by the Dam Safety Division generally include additional reservoir storage capacity to account for sedimentation. This capacity shows up as an increased project cost to the dam owner.

Sediment Yield Rate

The very existence of a dam in a watershed drainage network upsets the natural equilibrium of the stream. Aggradation, or sediment deposition, occurs above the dam, while degradation of the stream channel can result downstream from the dam.

Sediment deposits first become apparent when deltas build up at the mouths of streams entering the lake. The coarser, heavier sediments are deposited at the inflow to the reservoir while finer particles may be carried as far as the upstream face of the dam. Aquatic vegetation, such as cattails and lily pads, soon develops in the shallow water over these deltas. As sediment deposition continues, the delta will rise above the water surface.

Sedimentation Control

Sediments entering the reservoir cannot be totally eliminated. Therefore, the dam owner should take measures to minimize the effects and consider the annual maintenance costs. One method of controlling sediments is to periodically dredge areas of the lake where sediments have accumulated. This method is usually expensive and includes finding a disposal area for the dredged material.

Another method of sediment control is the construction of sediment "forebays" at locations of stream inflow to the lake. While these areas will also have to be dredged periodically,they limit the amount of time and effort the contractor will have to put into the job. This in turn may limit the cost of dredging to the owner.

Another method of controlling sedimentation is to take an active role in community efforts to control erosion runoff from construction sites. Violations of sediment control laws should be reported to the local sediment control inspector.

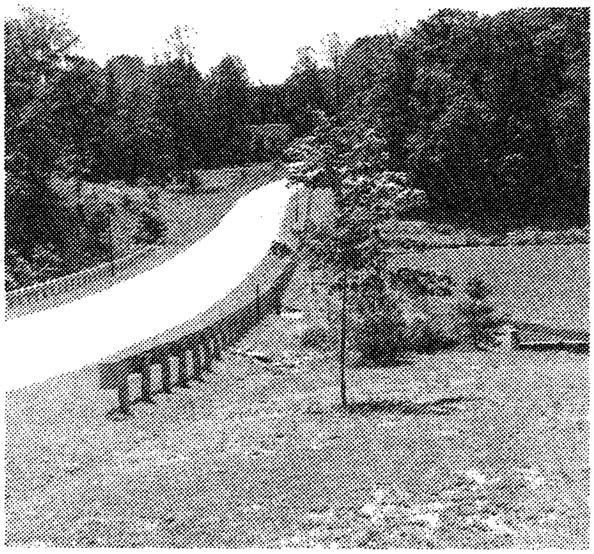
Finally, every method of controlling sediments should include periodically exercising the drain valve to keep sediments from obstructing or burying the inlet.

LAKE PERIMETER AND ACCESS ROADS

The safe operation of a dam also depends on the ability to gain access to all parts of the dam and reservoir. The perimeter of the reservoir can be affected by the fluctuating pool level and is a source of debris and sediments entering the lake.

A function performed during the routine maintenance program should include an inspection of the lake perimeter. Potentially damaging fallen trees, debris, and sediments should be removed.

The access road to the dam itself should also be inspected. The road should be suitable for maintenance equipment to gain access to the structure at all times. Cut-and-fill slopes, both uphill and downhill from the road should be stable. The road surface should be located above the projected high-water elevations of any adjacent streams and the reservoir pool, so access can be maintained during periods of high water.



Paved Access Road

WINTERIZING TECHNIQUES AND PROBLEMS

The pool level of a reservoir is often lowered for the winter months for various reasons: to facilitate repair of boat docks and other structures; to retard growth of aquatic vegetation; to provide additional spring flood storage; or to prevent ice damage. Rapid drawdown of the pool will leave the upstream slope saturated and without support, and could result in sloughs and slides. Unless there is an emergency, the owner should follow the drawdown guidelines described in the Mechanical Equipment section under Spillway and Outlet Works. If there is a question about the allowable drawdown rate, a professional should be contacted. The dam owner should also contact the Dam Safety Division immediately if the pool needs to be drawn down quickly.

Ice can pose problems at spillways and around other structures. Ice formation can be prevented by heaters, aeration equipment, or forced movement of water. Ice in conduit outlets or stilling basins can impair their proper functioning. The owner should be aware of these potential problems and take appropriate action during extended periods of severe cold weather. Ice damage from impact can also occur during thaw when large chunks of ice begin to break free.

Other winterizing activities should include:

1. Seeding bare areas so that vegetation is established before onset of winter.

2. Removing spillway flashboards for providing additional pool storage.

3. Opening valves slightly to provide a small flow to prevent freezing.

VANDALISM

Vandalism is a common problem faced by all dam owners. Particularly susceptible to damage are the vegetated surfaces of the embankment, mechanical equipment, manhole covers, and rock riprap. Every precaution should be taken to limit access to the dam by unauthorized persons and vehicles.

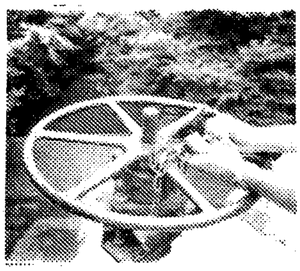
Unauthorized Vehicles

Motorcycles and four-wheel drive vehicles will severely damage the vegetation on embankments. Worn areas could lead to erosion and more serious problems. Barriers such as fences, gates, and cables strung between poles are effective ways to limit access by these vehicles. Fences must not be installed around the emergency spillway area because they can impede the safe discharge of flood waters. A metal or wooden guardrail constructed immediately adjacent to the toe of the downstream slope is an excellent means for keeping vehicles off embankments. However, this may interfere with the operation of mowing equipment.

Damage to Slope

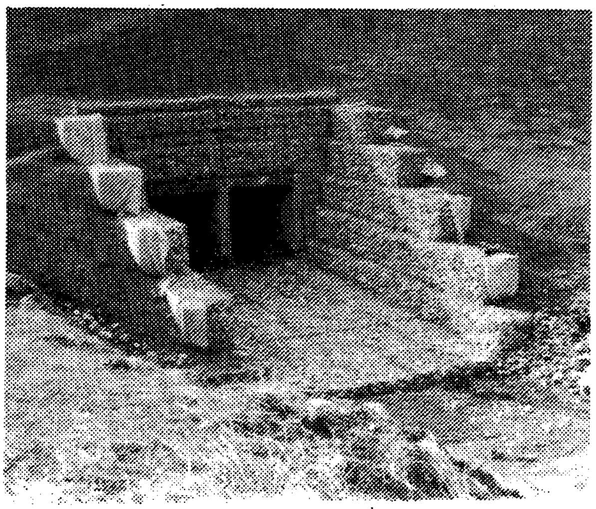
Mechanical Equipment

Mechanical equipment and its associated control mechanism should be protected. Buildings housing mechanical equipment should be sturdy, have protected windows, heavy-duty doors, and should be secured with deadbolt locks or padlocks. Detachable controls such as handles and wheels should be removed when not in use and stored inside. Other controls should be secured with locks and heavy chains where possible. Manhole covers are also subject to removal and are often thrown into the lake or spillway by vandals.



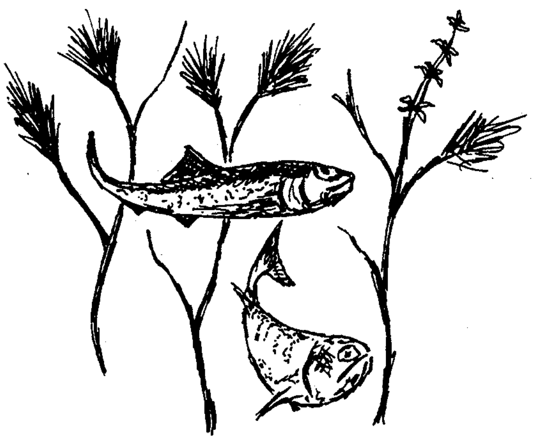
Rock Riprap

Rock used as riprap or inside gabion baskets is often thrown into the lake, spillways, stilling basins, and elsewhere. Riprap is often displaced by fishermen to form benches. The best way to prevent this abuse is to use rock too large and heavy to move easily. Otherwise, the rock must be constantly replenished and other damages repaired.



Removal of Rock Could Endanger Outlet

FISH STOCKING



Pond owners can receive advice on management of the lake for fishing from the Maryland Department of Natural Resources. Fishery management information is available that describes activities such as fertilization, liming, and stocking, as well as common problems associated with ponds, and recommended solutions. For additional information contact:

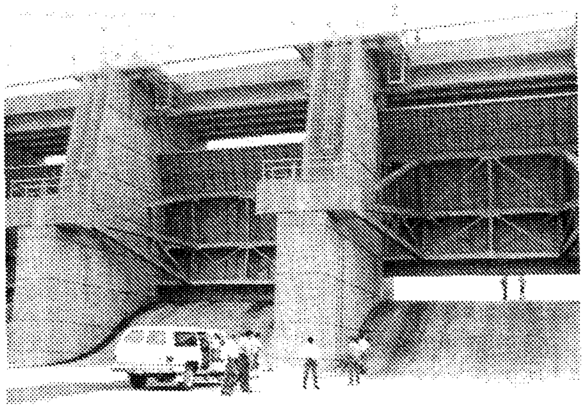
Maryland Department of Natural Resources
Freshwater Fisheries
Tawes State Office Building
Annapolis, Maryland 21401
(410) 974-3061

INSPECTIONS

Periodic inspection is an essential part of dam operation. Owners are encouraged to make a thorough visual inspection of their dams at least twice a year - once in the summer after mowing, and once in the winter when the vegetative cover is dormant. Inspections should also be made after extreme rainfall events. Owners of high hazard (Category I) dams are encouraged to have their dams inspected by a registered professional engineer at least once every 5 years.

INSPECTION GUIDELINES

The external surface of an earth dam can often provide clues to the condition of the interior of the structure. A thorough evaluation of all exposed surfaces of the dam should be made during the inspection. It is important to note changes in the appearance of the structure from one inspection to the next. If any of the following conditions are noted, **emergency procedures** are warranted: muddy water is flowing from the downstream slope or toe; cracks or depressions are forming on the embankment; movement of the embankment is occurring; or flood flow over top of the embankment is imminent.



Inspection of Large Dam

During the inspection, the embankment should be examined for settlement, displacement, cracking, erosion, and adequacy of the vegetative cover. The downstream slope and toe area should also be inspected for signs of seepage such as wet spots, wet ground vegetation, boils, or depressions. Internal drainage systems should be examined for chemical deposits, algae growth, corrosion or other deterioration, and clogging or obstruction. Any instrumentation for the structure should be examined and the appropriate readings and measurements taken. Observation wells, weirs, and water level gages can often be read with simple equipment. Settlement monuments, piezometers and slope inclinometers require specialized equipment for readings and engineering evaluation of the data is necessary.

The Dam Safety Division of the Water Resources Administration also conducts periodic inspections of many dams in an effort to assist owners in the safe operation of their structure. These inspections are made at intervals of one to five years that are determined by the type, size, and importance of the dam as well as its age and overall condition, spillway type, past performance, and potential to cause damage in the event of a failure.

DAM INSPECTION CHECKLIST

To help the dam owner perform periodic safety inspections of the structure, a checklist is provided. Each item of the checklist should be completed. **Repair** is required when obvious problems are observed. **Monitoring** is recommended if there is potential for a problem to occur in the future. **Investigation** is necessary if the reason for the observed problem is not obvious.

A brief description should be made of any noted irregularities, needed maintenance, or problems. Abbreviations and short descriptions are recommended. Space at the bottom of the form should be used for any items not listed.

The following chart may be used as a guide by the dam owner in determining the frequency of inspections for the dam. Each program is dependant on the particular condition of the dam. The Dam Safety Division is available to assist owners in tailoring a program for their facility.

DAM ______________________ **DATE** ______________
OWNER ______________________ **WEATHER** ______________
INSPECTED BY ______________________ **POOL LEVEL** ______________

Item	Comments	Y/N	MONITOR	REPAIR	INVESTIGATE
1. CREST					
a. Visual settlement?					
b. Misalignment?					
c. Cracking?					
2. UPSTREAM SLOPE					
a. Erosion?					
b. Ground cover in good condition?					
c. Trees, shrubs, or other woody vegetation?					
d. Longitudinal/Vertical cracks?					
e. Adequate riprap protection?					
f. Stone deterioration?					
g. Settlements, depressions, or bulges?					
3. DOWNSTREAM SLOPE					
a. Erosion?					
b. Ground cover in good condition?					
c. Trees, shrubs, or other woody vegetation?					
d. Longitudinal/Vertical cracks?					
e. Riprap protection adequate?					
f. Settlements, depressions, or bulges?					
g. Soft spots or boggy areas?					
h. Movement at or beyond toe?					
i. Boils at toe?					
4. DRAINAGE-SEEPAGE CONTROL					
a. Internal drains flowing?	Est. Left ______ gpm Est. Right ______ gpm				
b. Seepage at toe?	Estimated ______ gpm				
c. Does seepage contain fines?					

INSPECTION CHECKLIST - PAGE 2

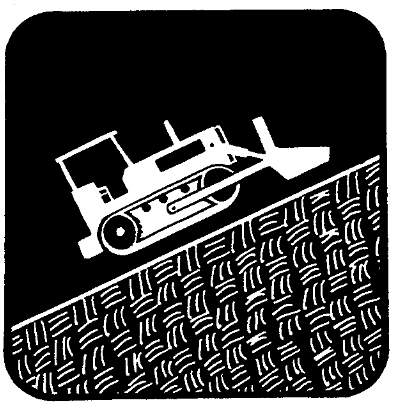
INSPECTED BY ______________ **DATE** ________________

Item	Comments	Y/N	MONITOR	REPAIR	INVESTIGATE
5. ABUTMENT CONTACTS					
a. Erosion?					
b. Differential movement?					
c. Cracks?					
d. Seepage?	Estimated ______ gpm				
e. Adequate erosion protection for ditches?					
6. INLET STRUCTURE	Concrete or Metal Pipe (circle one)				
a. Seepage into structure?					
b. Debris or obstructions?					
c. If concrete, do surfaces show:					
1. Spalling?					
2. Cracking?					
3. Erosion?					
4. Scaling?					
5. Exposed reinforcement?					
6. Other?					
d. If metal, do surfaces show:					
1. Corrosion?					
2. Protective Coating deficient?					
3. Misalignment or split seams?					
e. Do the joints show:					
1. Displacement or offset?					
2. Loss of joint material?					
3. Leakage?					
f. Are the trash racks:					
1. Broken or bent?					
2. Corroded or rusted?					
3. Obstructed?					
4. Operational?					
g. Sluice/Drain gates:					
1. Broken or bent?					
2. Corroded or rusted?					
3. Leaking?					
4. Not seated correctly?					
4. Periodically maintained?					
5. Operational?					

INSPECTION CHECKLIST - PAGE 3

INSPECTED BY ________________ **DATE** ________________

Item	Comments	Y/N	MONITOR	REPAIR	INVESTIGATE
7. PRINCIPAL SPILLWAY PIPE	Concrete or Metal Pipe (circle one)				
a. Seepage into conduit?					
b. Debris present?					
c. Do concrete surfaces show:					
1. Spalling?					
2. Cracking?					
3. Erosion?					
4. Scaling?					
5. Exposed reinforcement?					
6. Other?					
d. Do the joints show:					
1. Displacement or offset?					
2. Loss of joint material?					
3. Leakage?					
8. STILLING BASIN/POOL	Riprap or Concrete (circle one)				
a. If concrete, condition of surfaces?					
b. Deterioration or displacement of joints?					
c. Outlet channel obstructed?					
d. Is released water:					
1. Undercutting the outlet?					
2. Eroding the embankment?					
3. Displacing riprap?					
4. Scouring the plunge pool?					
e. Tailwater elevation and flow condition:					
9. EMERGENCY SPILLWAY					
a. Is the channel:					
1. Eroding or backcutting?					
2. Obstructed?					
b. Trees or shrubs in the channel?					
c. Seepage present?					
d. Soft spots or boggy areas?					
e. Channel slopes eroding or sloughing?					
10. RESERVOIR					
a. High water marks?					
b. Erosion/Slides into pool area?					
c. Sediment accumulation?					
d. Floating debris present?					
e. Adequate riprap protection for ditches?					



CONSTRUCTION

Modern dams are highly complex and exact structures. From the early dams and their failures, a great deal of knowledge has been gained on the design, construction, and safety of dams. Dams require the art of defensive engineering, which means that a wide range of forces and circumstances must be considered. Each project requires an array of different designs to call on because of: (a) unique site conditions, (b) the particular use of the dam, and (c) the hazards inherent to the particular site.

The necessity for the control of dam construction is obvious because of the potential for damage from failure. A safe and well engineered design may be entirely ruined by careless and shoddy construction. Careful attention to the details of construction is therefore as important as the preliminary investigation and design.

ADMINISTRATIVE

An owner contemplating the construction or repair of a dam must engage the service of a registered engineer. The engineer should be familiar with the State's administrative and technical requirements in order to assure that the dam is properly built or repaired. The Dam Safety Division requires an engineer to be licensed in the State and have prior experience in the design and construction of dams. The engineer is referred to as the Engineer-In-Charge (EIC) and is responsible for seeing the entire project through. Among other things, the EIC is responsible for the following throughout the construction process:

* Submitting periodic reports to the Dam Safety Division,

* Submitting design changes to the Dam Safety Division for approval,

* Certification that the structure is ready for filling, and

* Certification of project completion along with project narrative and "as-built" plans.

TECHNICAL

Good construction begins with good design. Decisions made during the design process will affect the cost of construction, operation and maintenance cost and, ultimately the life of the structure. Choices that are made on the basis of available funds often result in the dam owner spending additional monies at a later date to correct problems that arise.

There are short term vs. long term trade-offs that are made by the owner and his engineer throughout the design process. During this process it is important that thought be given to unanticipated problems that will arise during construction as well as the need for future operation, and maintenance, and repair. There are several fundamental questions that the engineer should ask himself throughout the design process:

1. Can the structure be built or repairs made with a minimum of effort and cost or does that project involve practices and procedures the contractors are not familiar with?

2. Are product materials readily available or must they be custom built for the job?

3. Are functioning parts of the dam (appurtenances) readily accessible for maintenance and repair?

All of these items can contribute not only to the increased cost of the project to the owner but to the long term operation and repair problems of the dam.

Plans and Specifications

Plans and specifications set the standard by which a dam is to be built or modified. Deviations from the standard that is prescribed by the designer will tend to weaken the structure, make it less durable or cause operation and maintenance problems. It is through the use of plans and specifications that the quality of the materials being used are described as well as the level of work quality the contractor must meet in placing the materials in the total structure.

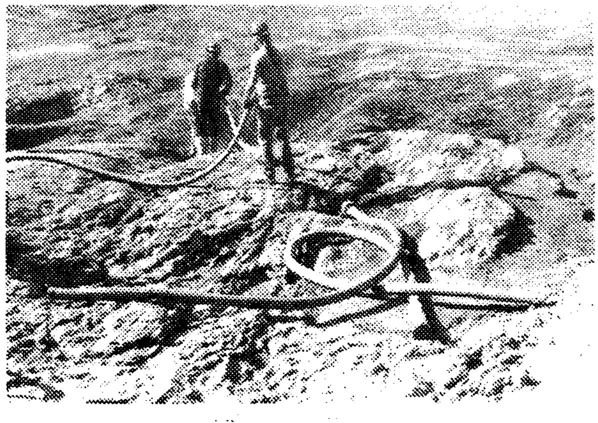
The following is a discussion of typical areas covered by specifications for dams:

Foundation preparation - In order for the dam to be a sound structure it must rest on a solid foundation. Foundation investigations consider the physical features of the site including topography, geology, material availability, and material properties. Specifications for the foundation preparation will address such concerns as:

a. geologic faults,
b. the ability of the foundation material to support the weight of the dam,
c. the control of excessive seepage, and
d. the uniform consolidation of the foundation and fill material.

To address these concerns, specifications may include sections on:

a. removal of unsuitable material,
b. grouting,
c. dental concrete,
d. removal of overhanging or sheer rock surfaces, and
e. core trenches, slurry trenches or other methods of cutting off the excessive seepage of water.

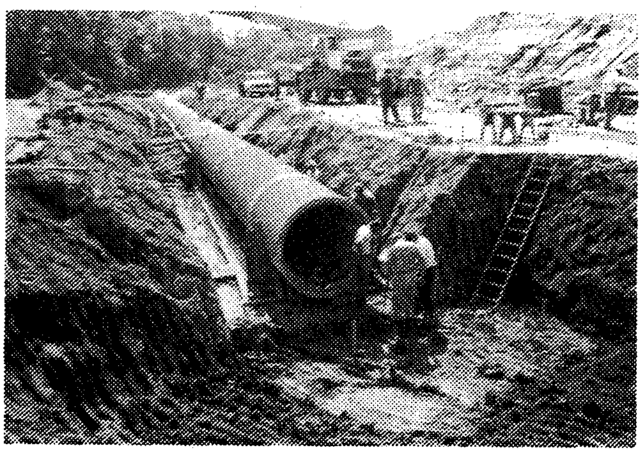


Preparing Rock Foundation

Pipe - Various types of pipe are used for a wide range of purposes in the construction of a dam. Of particular importance are pipes used as principal spillways and any other pipe that goes from the upstream to the downstream side of an earth dam. Pipe is a rigid structure. As such, voids can form around the pipe during consolidation of the embankment. These voids can provide channels for water to escape through the dam, which in turn may cause the dam to fail. For this reason, anti-seep collars are often specified. In addition to conveying water, the pipe must resist the load imposed by the surrounding fill, it must not leak, and joint elongation due to settlement must be accounted for. To accomplish this, pipe specifications will include:

a. size,
b. type,
c. joint design, and
d. load bearing capacity.

The design may include a concrete cradle for additional support. Specifications may also include instructions to the contractor on how to place the pipe and provisions for rejecting damaged pipe.

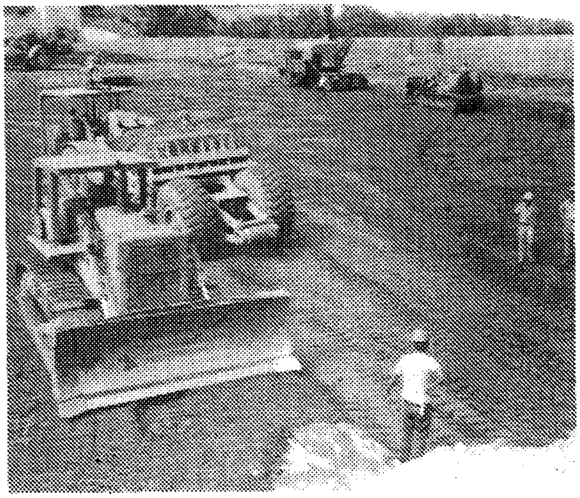


Close Inspection of Installation

Earth and Rock Fill - When a dam is to be built of locally available material, the specifications will address such concerns as: the ability of the embankment to support its own weight under conditions of high water, normal pool and rapid draw down; the degree of consolidation that will occur over time; and, depending upon the availability, a variety of material may be specified to be placed in "zones" of the fill. To address these concerns specifications will include:

a. the grain size distribution of each material to be used,
b. the in-place density of each material,
c. moisture content, and
d. quality of the material in terms contaminants such as organic material.

Specifications may also address how the contractor will do the work by specifying the sequence of construction and type of equipment to be used.



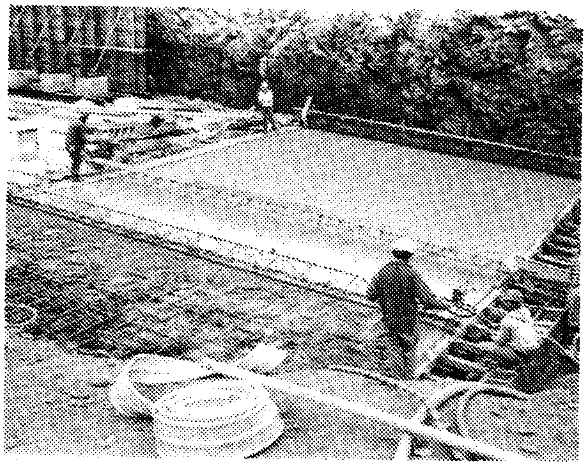
Proper Placement of Embankment Fill

Concrete - Concerns regarding concrete are workability during placement, design strength, appearance of exposed surfaces and durability. To address these concerns specifications for concrete will include;

a. design mix (the ratio of cement, sand, coarse aggregate and water) which is frequently provided by the concrete supplier,
b. compressive strength after 28 days of curing,
c. amount of air entrainment,
d. slump,
e. quality of aggregate, and
f. cement type.

Specifications will also include how the contractor is to perform, including:

a. placement methods (vibrating, limit height of fall, etc.),
b. surface finish,
c. control of cold joints, and
d. repair of faulty areas.


Concrete Pour

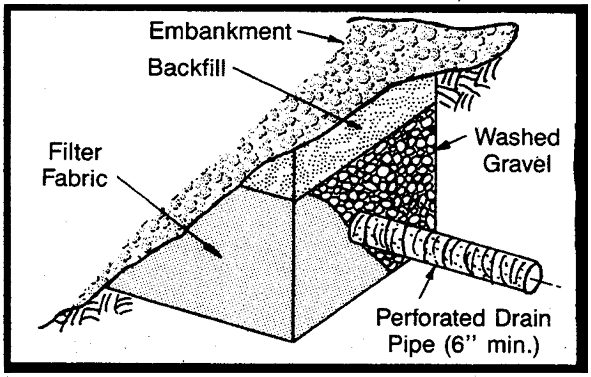
Gates and other mechanical equipment- Gates, valves and other mechanical equipment must operate under adverse conditions. Frequently, mechanical equipment is expected to operate after long periods of idleness. This is one area where a little extra money may be well spent on high quality equipment. Specifications for gates include:

a. size,
b. type,
c. material,
d. operating head,
e. size and type of valve stem,
f. size, type and location of stem guides, and
g. size and type of hoist.

Filter drains - Filter drains are placed in earth dams to provide for the safe passage of seepage from the embankment and foundation to the downstream toe of the dam, thereby preventing piping failures, slope failures and wet conditions on the downstream face. Drains must provide voids of sufficient size to provide for free passage of water and at the same time provide voids that are small enough to prevent migration of the finer fill material surrounding the drain. To accomplish this the specifications will include:

a. grain size distribution, and
b. requirements for durability and hardness.

In some cases drains may be constructed as layers of fine material and coarse material. Specifications may also include a filter fabric defining the transmissibility, type of weave and strength.



Riprap - Areas of the dam and exit channel that are subject to damage by wave action and high velocities are most frequently protected by riprap. The ability of riprap to resist erosion is based upon its size and weight. Therefore specifications for riprap will include:

a. size distribution, and
b. durability.

SUPERVISION

The supervision of construction or repair of a dam by a professional engineer is required. The engineer who designed the project is often required to be the EIC because he is the one individual most familiar with the thinking and interpretation of data made during the design process. If unanticipated conditions are encountered during construction, the design engineer is the one best able to make the necessary adjustments in the design.

Construction Inspections

The amount of supervision required of the EIC depends on the size and complexity of the dam to be constructed. In some cases the EIC, with the assistance of a competent inspector, may only have to make periodic visits to the site. In others, the EIC may have to spend full time at the site with the assistance of other engineers and staff inspectors.

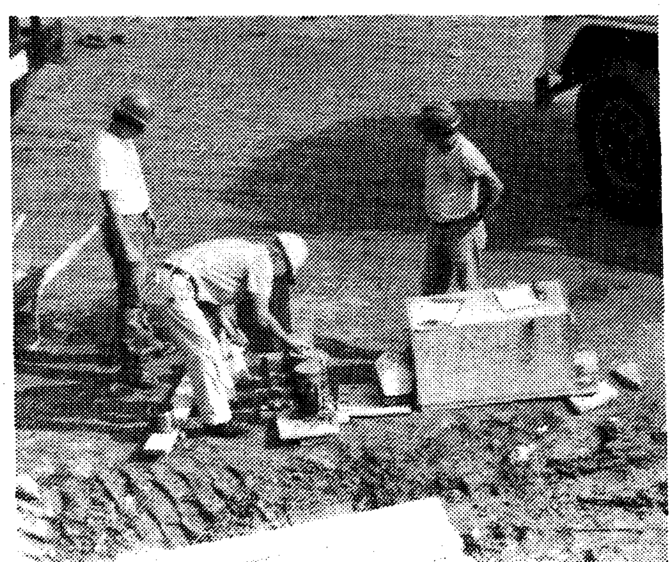
Unanticipated conditions often dictate changes to the plan. These changes must be submitted to the Dam Safety Division for approval prior to the execution of the change. Here is one place where keeping the state field engineer informed can help expedite matters.

The EIC is also responsible for providing to the Dam Safety Division periodic reports that document work progress, problems encountered during construction, and other pertinent information. This report is part of the permit requirements. Upon completion of the project the EIC is responsible for certifying that the project was built in accordance with the plans and specifications. The Dam Safety Division maintains a permanent record of the construction history for future reference. These records are maintained in the event that future structural modifications are required or problems are encountered.

When construction of the dam is substantially complete, contractor or the owner will want to start filling the reservoir. At this time the EIC must prepare a letter stating that the reservoir is ready for filling and request permission from the Dam Safety Division to close the gates. The state field engineer will act on that request.

Within a reasonable period after completion of the dam (usually specified in the permit), a final inspection will be conducted by the EIC, Dam Safety Division and the owner. Thereafter, periodic Operation and Maintenance inspections are required by the owner. The Dam Safety Division will also periodically inspect the structure.

Testing Embankment Compaction



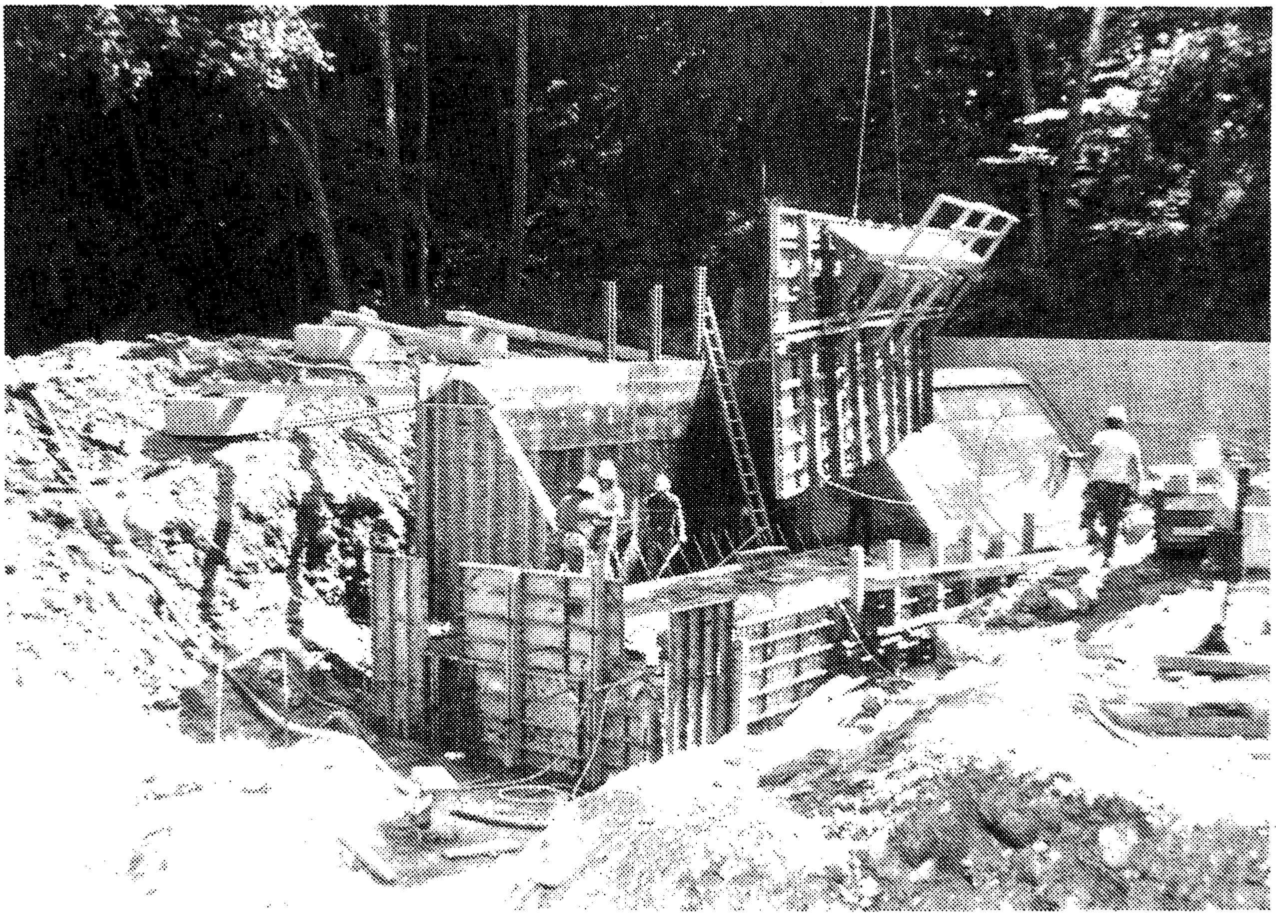
Testing Concrete Quality

State Inspections

Construction progress is closely monitored by a field engineer from the Dam Safety Division. Even though the state representative makes frequent visits to the site, he cannot duplicate or relieve the EIC of his responsibility. The field engineer can provide expeditious handling of temporary permits and requests for modifications to the plans and specifications. Additionally, he can provide an extra pair of eyes in the monitoring of quality control. If the field engineer sees something that appears to be wrong or questionable, he will bring it to the attention of the EIC. The state's field engineer can assist in various decision making processes in order to assure that a safe structure is built.

The best way to work effectively with the field engineer is to keep him advised as to problems encountered and the thought process leading to a solution. That way, when a design change is proposed he can approve it in a timely manner. One very helpful way to keep the field engineer informed is to allow him to participate in progress meetings. Such participation allows him to gain a feeling for the relationships among the EIC, the contractor and the owner.

The contractor should be aware of the fact that he must obtain permits for temporary construction which affects the stream (e.g. waterway crossings and stream diversions). Again the state field engineer can help expedite matters if he knows what is going on. The contractor, the owner and the EIC all want a quality job. However, in the unlikely event that it appears that a dam is not being built according to plans and specifications, the Dam Safety Division will take appropriate administrative and legal actions. These may include revoking the permit and ordering the owner to remove the partially completed obstruction.



CONSTRUCTION PROBLEMS

Construction projects are rarely completed without some delay or problem arising throughout the process. If a project is planned, coordinated, and supervised properly, the chance of major problems is minimized. However, there are several problems that occur with some frequency. When these problems develop there are delays that usually result in increased construction costs.

Scheduling

The first of these problems is the sequence of construction. The engineers should anticipate how the contractor is going to build the job and prepare construction plans that can be followed with a minimum amount of diversions, pumping, and other temporary construction. However, the contractor must also put some thought into the sequence of steps he is going to follow in construction of the dam. This is to insure that he has an efficient operation. Additionally, he must be sure he has the right material, equipment and manpower on the job at the right time.

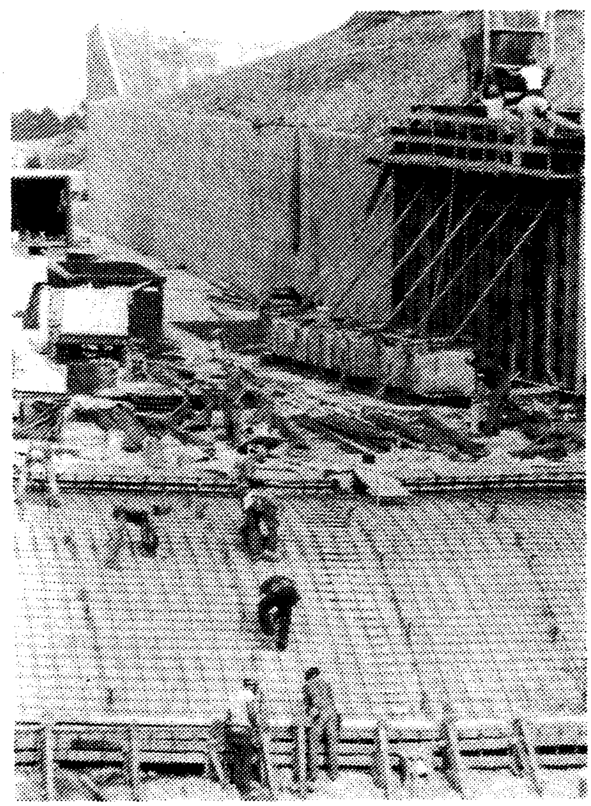
For example, it seems obvious that, in most cases, the outlet works must be completed early in the job, and yet, contractors continually place themselves in the position of having to pour concrete or place gates in the wet. A little forethought would prevent a lot of sand bagging and pumping.

Financial Health

As in any business operation, the contractor's goal is to make money while providing a quality product to his client. Of course, there are justifiable reasons for profit losses on a particular job. However, a contractor that is loosing money on a job may be cause for concern. For these reasons, the contracting process should provide for the elimination of bids that grossly fall short of the engineer's estimated cost. Additionally, throughout the course of the project all parties should periodically meet to discuss all aspects of the job progress. Potential financial problems should be discussed before the quality of the job suffers.

Ordering Supplies & Equipment

One frequent cause of delay is the time required for suppliers to provide mechanical equipment, particularly gates. Ordering mechanical equipment should be done very early in the job. Also, certain types of pipe are special order items. In some instances contractors have found it difficult to find a supplier for a specific product because the order is generally small in quantity.



Proper Scheduling Avoids Delays

Proper Equipment

Having the proper equipment on the job is important. "Making do" often leads to slow production and the correction of inadequate work. The most frequent problems on earth dams, in this regard, are improper or inadequate compaction equipment and a lack of means for providing moisture control.

Natural Hazards

Another problem the contractor must address, especially if it is not considered in the design, is the problem of flooding during construction. At the very least, the contractor should provide for removing equipment to high ground during floods. Other defensive measures may include constructing the upstream portion of the dam to an elevation sufficient to handle frequent events such as a 5 year flood or deliberately leaving a portion of fill low as a "relief plug."

Foul weather will generally upset the construction schedule. Not only can rain shut down a job, but it can cause earth work problems for days. Borrow and fill areas should permitted to drain to avoid saturated material. Cold weather disrupts concrete work and may necessitate costly heating and insulation to protect new pours. Such work is better scheduled in warmer months if possible.

Unapproved Construction

Sometimes, for whatever reason, a contractor will bury work that has not been inspected. If the EIC or his inspector is doing his job, he will require the contractor to uncover the buried work for inspection. The contractor can save himself a lot of grief, expense and delay if he makes sure the inspector is notified of the need for inspection in a timely manner.

Almost all of the above problems can be lumped under the general heading of construction management. Assuming the contract time is realistic, most of the problems that befall a construction job can be avoided by sound management and a cooperative climate between the contractor and the Engineer-In-Charge.

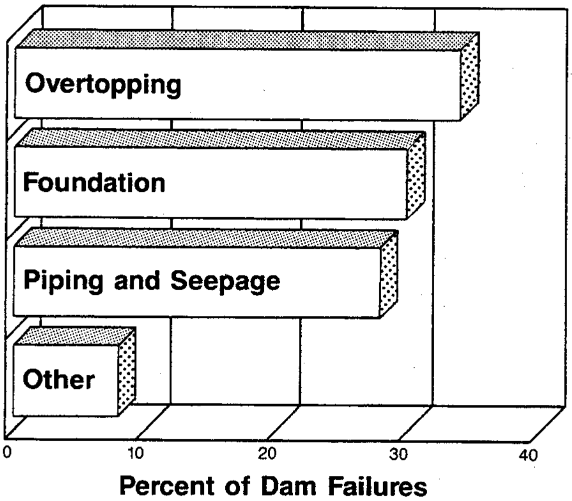
EMERGENCY PROCEDURES

Discussions throughout this manual have concentrated on the safe operation of dams by proper construction, operation and maintenance, and inspection practices. However, the most sophisticated design and construction techniques and a vigorous operation and maintenance program can not prolong the life expectancy of a dam indefinitely. The simple fact is that dams don't last forever. Unforeseen and unanticipated conditions can arise during a dam's existence that can alter the structure's performance and in some instances cause failure.

This section identifies the more common modes of dam failure and how their effects can be mitigated through adequate warning and evacuation planning. Emergency Warning Plans are generally implemented through the local Emergency Management Agency. Included with the discussions is an explanation of the safety hazard classification as it relates to various levels of downstream warning procedures.

TYPES OF FAILURES

In today's technical world, dam failures are rated as a "low probability-high loss" event. However, dams are subject to many forces that can cause failure. A number of studies have been made and suggest the following causes of dam failures:

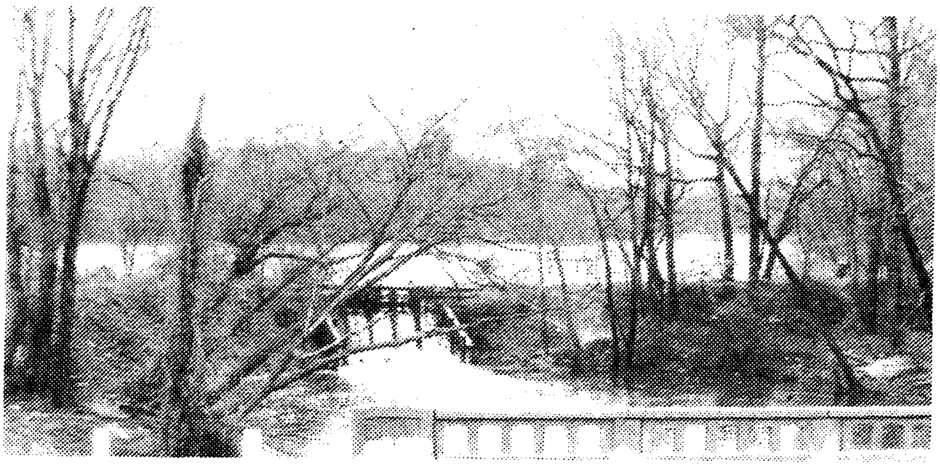


Because dam failures can result from various conditions, a periodic review of all facets of a dam is necessary.

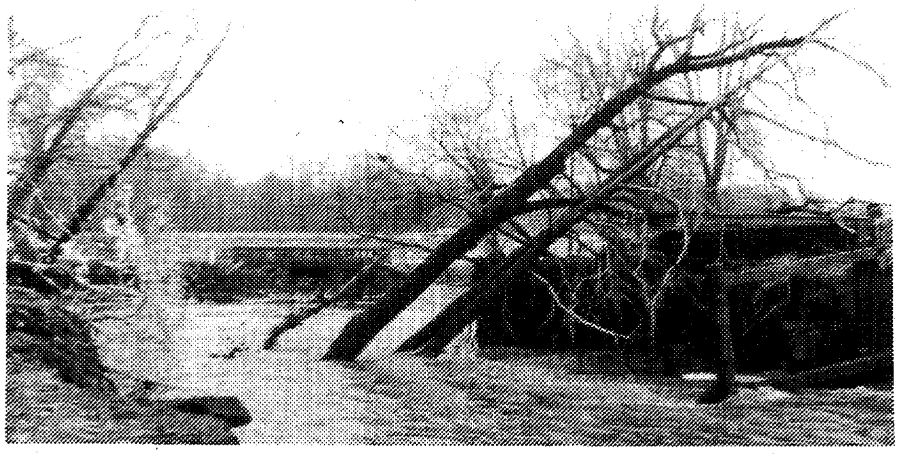
The majority of Maryland dams (75%) are constructed of earth. Therefore, the main discussion of failure types in this section is limited to embankment dams. However, the failures that will be described can be attributed to gravity, buttress, and other types of dams as well.

Overtopping Failures

Overtopping is the most common mode of failure with regard to earth dams and is the result of the structure's inability to safely discharge significant inflows to the reservoir. This causes uncontrolled water to flow over and around the embankment, eroding portions of the dam. Since earth structures are usually not designed to be overtopped, the



Earth dam in poor shape. Inadequate spillway capacity, tree growth, and weak embankment soils are causes for concern.



1 month later - The poor condition of the dam was no match for the heavy rains that overtopped the crest and caused failure.

erosion process begins as soon as water flows over the dam. Inadequate spillway capacity usually causes the overtopping of earth dams and will often lead to a complete breach of the dam. This mode of failure can also be caused by debris accumulation in appurtenances such as the riser and barrel structure or the emergency spillway.

One aspect of overtopping that an earth dam owner should be aware of is the concentration of flow. Where pedestrian paths or poorly maintained vegetative cover have created depressions or low spots along the crest, water will concentrate when overtopping begins, accelerating the erosion process. This problem can be corrected by keeping the dam crest level. Low spots should be filled and adequate vegetation established.

Methods of mitigating the effects of overtopping include providing for adequate spillway capacity or lowering the reservoir pool when flooding is anticipated. Temporary sandbagging can be used to prevent overtopping of the dam crest during a flood. Caution should be used when sandbagging, not only for safety reasons but also because additional water is impounded that could be released should the dam fail. Keeping the spillways free of debris and maintaining a level dam crest is helpful in deterring the effects of overtopping and should be part of the dam owner's regular operation and maintenance activities.

Piping and Seepage Failures

All dams have some quantity of seepage. Methods exist to control and convey seepage safely through the dam. When the volume of seepage exceeds the capacity of the dam's internal drainage system, problems will develop and can eventually cause partial or complete failure of the structure. Uncontrolled seepage can progressively erode portions of the embankment or foundation and cause an internal erosion or "piping" failure of the dam.

Once the "piping" of a dam progresses beyond a certain point it is virtually impossible to stop. Usually signs of uncontrolled seepage indicate a problem exists long before the structural integrity of the dam it threatened. Therefore regular and routine inspection of known seepage areas is essential. Should seepage increase significantly over what is normally observed or the seepage discharge suddenly becomes discolored or muddy, then a professional engineer should be contacted immediately and the Dam Safety Division notified.

Actions taken to delay or prevent complete failure of the dam when "piping" of the embankment has begun include: lowering the pool until the seepage problem has been corrected, covering the seepage area downstream with sand and gravel to prevent erosion of the embankment material, and, should the "pipe" progress to the upstream slope, attempt to plug the upstream end of the "pipe" with gravel, earth, straw or some other suitable material.

Structural Failures

Structural failures can occur in the embankment portion of a dam or its appurtenant structures. Embankment failures are typified by major differential settlement, cracks, or slumps in either the upstream or downstream slopes. These conditions, if left unattended, can lead to complete failure of the dam. They are generally preceded by less severe conditions that indicate a problem exists. Therefore, the point of regular and routine inspections cannot be overemphasized.

Cracks and major settlement in appurtenances can also cause dam failure. Settlement in an outlet pipe can result in loss of embankment material through an open construction joint and eventually lead to failure. Undermining of the pipe's outfall can reduce the conduit's support and cause partial failure of the principal spillway system. Again, these conditions usually do not happen overnight and can be detected long before failure occurs.

Maryland Dam Failures

It is believed that no lives have been lost in Maryland as a direct result of dam failure. However, we have not been without incident. Several dams have partially or completely failed due to various conditions that include: excessive rainfall, structural failures, and failure during

Several dams have partially or completely failed due to various conditions that include: excessive rainfall, structural failures, and failure during construction. Some examples follow that will describe the more recent dam failures.

Lake Waterford Dam

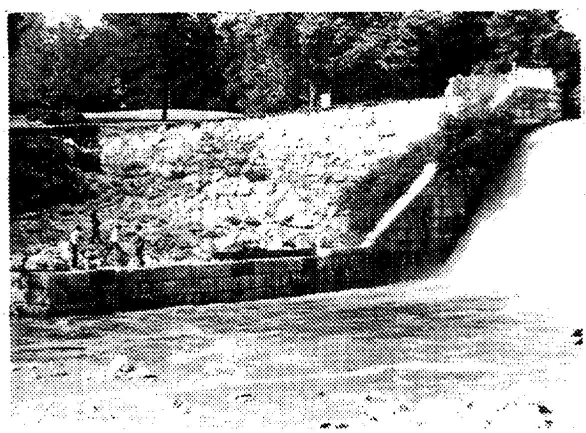
The Lake Waterford Dam is the focal point of a recreational park in Anne Arundel County. The dam, on the Magothy River, is fifteen feet high, 250 feet long, and has an overflow spillway ten feet wide. Believed to have been purchased from a private mill operator in 1925, this earth structure was overtopped and partially failed during Tropical Storm David in September, 1979. An inspection of the dam three months prior to failure revealed sparse vegetation and erosion gullies caused by pedestrian traffic on the crest and downstream slope. The inspection report stated that "In the event of overtopping of the embankment during major storm events, these gullies would be preferential flow paths, susceptible to rapid erosion and could possibly lead to failure of the dam." When overtopping did occur, water flowing in these gullies eroded portions of the embankment to the right of the overflow spillway exposing a concrete core wall.

The Lake Waterford Dam was repaired in 1993. A new principal pipe spillway along with a concrete ogee spillway were installed to safely pass the 100-year storm. In addition a cement bentonite slurry wall was installed and a fish passage was constructed to access the upstream spawning areas.

Lake Roland Dam

The Lake Roland Dam, on the Jones Falls in Baltimore County, has experienced significant structural damages in recent years. This structure, completed in 1861 to supply Baltimore City with water, is an earth and rockfill gravity dam 31 feet high, 310 feet long, and has a 120 foot wide uncontrolled ogee spillway. Lake Roland was retired as a water supplier around 1915 and has been used as a recreational facility since then. Inadequate spillway capacity led to two partial failures during Tropical Storms Agnes in 1972 and David in 1979. Overtopping of the right non-overflow portion of the dam during both storms resulted in erosion of the earth and rockfill, exposing the marble stone block wall. Subsequent repairs involved replacing backfill material consisting of soil and riprap that was surface grouted with mortar.

As of May 1993, the repair of Lake Roland Dam has begun and is scheduled to be completed by the end of 1993. The repairs include enlarging the principal spillway to 170 and construction of two auxillary spillways located on the old abutments. The modifications will enable the dam to safely pass over 90% of the PMF.



Severe Abutment Washout

Loveton

The Loveton Farms Stormwater Management facility is a "dry" pond in Baltimore County. It is a 20-foot high earth dam with a 78-inch diameter corrugated metal pipe spillway conduit. Completed in 1985, it failed by piping during heavy rains in 1989 causing extensive environmental damage. It was rebuilt in 1990.

A review of construction records after failure showed that the pipe was installed in a trench cut through the partially completed embankment fill. It is likely that piping was inititiated by seepage through transverse cracks that formed in the fill due to differential settlement. Other possible causes of failure are: improper compaction under the haunches of the pipe and joints that were not watertight.

HAZARD CLASSIFICATION

Dams are generally classified into usage categories according to their intended function, such as water supply, flood control, or recreation. The Maryland Dam Safety Division also categorizes dams according to their size and potential downstream hazard. Dams are classified as: **high hazard** (Class 1) where loss of life and extensive property damage are probable should the dam fail, **significant hazard** (Class 2) where failure would cause extensive damage to public or private property but the loss of life is very unlikely, and **low hazard** (Class 3) where failure would not cause the loss of life and the damage is within the financial capability of the owner to repair.

The hazard classification of a proposed dam is also used to determine the inflow design flood and the spillway characteristics of the dam itself. Detailed instructions to classifying a Maryland dam can be found in the Rules and Regulations governing Waterway Construction (COMAR 08.05.03.05.).

The National Dam Inspection Program took place between 1978 and 1981. The inventory survey indicated that 68,153 non-federal dams existed nationwide. During the inspection program, U.S. Army Corps of Engineers guidelines were used to assess the downstream hazard characteristics for the dams. The Corps used a system of three terms: high, significant, and low to describe a particular dam's hazard potential with regard to loss of life. No consideration was given to the condition or structural integrity of the dam. It was determined that approximately 13% of the nation's dams were classified as high hazard. Of the nation's high hazard dams, Maryland is responsible for less than 1%.

Danger Reach

In order to mitigate the downstream effects of a dam failure, the area of potential flooding must be known. The "danger reach" below a dam is defined as the area that would be inundated by a flood caused by the sudden release of stored water behind the dam that exceeds the expected amount of flooding had the dam not existed. By identifying those structures affected by the failure of a dam, the owner can determine the amount of warning required to protect those structures. For example, the owner of a Class 2 dam identifies three bridge crossings downstream that would be overtopped from excessive discharge from his dam. From that determination, procedures to prevent vehicle use of those bridges during anticipated high flows or failure can be develop. A Class 3 dam owner, having no permanent structures in the downstream danger reach, may want to warn his neighbor of high discharges caused by a problem at his dam so the neighbor can take necessary precautions (e.g. remove farm equipment and livestock from the downstream area.)

Warning procedures will be more sophisticated for Class 1 dams, but the owners of the less hazardous structures should not discount the necessity of warning downstream interests. Downstream development is another factor that must be considered when proposing a new dam. A dam, for instance, built 30 years ago and designated as a low hazard, Class 3 structure can easily become reclassed as a high hazard dam if development downstream is allowed within the danger reach. The reclassification of a dam to a higher category results in more conservative design parameters. For this reason the dam owner should consider upgrading the structure to provide additional freeboard or spillway capacity.

The danger reach for most of the high hazard dams in Maryland has been defined and can be obtained from the Maryland Dam Safety Division. This information is also available for some of the Class 2 and 3 dams. The ultimate responsibility for implementation of a warning plan that includes the danger reach rests with the dam owner.

EMERGENCY WARNING PLANS

Adequate warning and evacuation planning can prevent extensive property damage and loss of life should the dam fail. An **Emergency Warning Plan** is a non-structural method used to mitigate the effects of dam failure. The Emergency Warning Plan for a dam is based upon the potential for downstream flooding. Every dam owner should have one.

Maryland regulations require an Emergency Warning Plan for all proposed dams that are designated as Class 1 or Class 2 structures. Owners of existing Category 1 dams that were inspected under the Corps of Engineers National Dam Inspection Program were advised to develop a formal flood surveillance and warning plan to protect downstream interests.

Components of a Warning Plan

Much literature is available on the subject of warning systems. Depending on the size of a dam, the warning plan can range from a simple, one page telephone notification list to a sophisticated, telemetered network involving several major public agencies (e.g. - Civil Defense, Police, Fire and Rescue, etc.). Whatever level of warning is determined adequate, the Emergency Warning Plan must accomplish its intended goal: reducing the chance for loss of life and extensive property damage. Warning plans that are too voluminous will not be effective during emergencies if the involved agencies are not familiar with the procedures. Regardless of the size of the dam, an adequate Emergency Warning Plan possesses certain key elements that will ensure effective response. They are:

Surveillance and Mitigation
Communication and Notification
Evacuation

All involved parties should be familiar with the Emergency Warning Plan. The plan should be exercised and updated periodically by verifying personnel responsibilities and phone numbers.

Surveillance and Mitigation

This component of the warning plan is the most important because it identifies any problem that exists at the dam. Through the regular operation, maintenance, and periodic inspection of the dam, the owner should be well aware of problems associated with the structure. Therefore, rapid change in the "normal" condition of the dam should indicate that a problem exists and should be investigated thoroughly with continuous surveillance of the problem if warranted.
Also, advising various agencies that a potential problem exists and corrective action or possibly evacuation maybe required.

If it is known that a particular dam has inadequate spillway capacity and weather forecasters are predicting unusually high rainfall, the owner should maintain constant watch on his structure to insure adequate operation of the dam. Items of importance in this instance are the reservoir level, the rate of pool rise, excessive seepage, debris accumulation in the spillways, and any unusual observations. If the embankment is in danger of being overtopped then the previously discussed procedures for mitigation can be implemented (e.g. sandbagging, lowering the reservoir, etc.).

If time permits, a professional engineer experienced in dam design and operation should be consulted to determine the extent of the problem and assist in deciding whether emergency procedures should be initiated. Local public safety officials like the Civil Defense and Police should be alerted and kept apprised of the situation. Above all, surveillance in times of dam distress should be constant. At unmanned structures, provisions should be included to provide for surveillance of the structure, and travel time will need to be included in the warning plan. Constant communication between the dam owner and those agencies responsible for evacuation is essential. Surveillance should be maintained throughout the emergency and until the decision is made to resume normal operating procedures.

Communication and Notification

Once an emergency has been identified at a dam, communication and notification of individuals and agencies responsible for various tasks is essential to protect life and property downstream. Communication links should be established immediately with those agencies who would provide for the public safety. Normally this link between the dam owner and the public can be established through the local Civil Defense Agency or Emergency Management Office in that particular jurisdiction. The local Civil Defense office has the communications expertise to alert the appropriate agencies so timely action can eventually save lives and property. Civil Defense can, in effect, act as the center for disbursing information to the police, fire and rescue, Red Cross, and the public regarding a developing emergency. It is therefore essential that constant dialogue be maintained with Civil Defense so information can be relayed.

It is prudent to include involved agencies when a warning plan is being developed. For example, if after initial discussions between the dam owner and the local Civil Defense it is determined that the police and fire department will be needed to block roadways and assist in evacuation activities, subsequent meetings should include those agencies to insure that their responsibilities are understood. Once the communications network, including backup, is established, a notification list can be formulated and distributed so all involved individuals understand what is expected of them.

A warning plan also needs to address when and how an emergency is to be terminated and what methods will be used to assure limited access and security in the danger reach. Agreement between involved individuals will dictate termination of an emergency both at the dam and in the downstream areas. Similar methods for evacuation can be used for terminating an emergency. However, all agencies should be involved with the decision.

Evacuation

If it should become necessary to evacuate a portion of a downstream community in the event of dam failure, several items need to be considered.

WHEN is evacuation warranted? Determinations regarding the stability of a dam should be made by an engineer experienced in dam design and operation. Certainly the order to evacuate should not be given if it is not warranted. However, the time involved for failure to occur often governs evacuation procedures. Provisions in a warning plan should account for failure that occurs over an extended period of time (overtopping) and one that occurs almost instantaneously (piping). Also, dams do not always fail between the hours 9 to 5, Monday through Friday. Provisions need to be included for evening and holiday emergencies.

WHO will be evacuated? As discussed above, all dam owners should be well aware of their structure's hazard potential. Danger reach and inundation information should be developed in order to identify those properties and people at risk. The size of the danger reach often determines evacuation procedures. Isolated dams with more than a small number of inhabitable structures will be treated differently than larger dams in major metropolitan areas.

HOW will evacuation occur? Alerting the downstream residents can be accomplished many ways. Methods should be used that are commensurate with the magnitude of evacuees. "Door to Door" evacuation will suffice in isolated areas if time permits but not in more populated areas. Radio and television can be utilized effectively as well as bullhorns or automated sirens. Choose the method best suited for the job at hand.

WHERE will evacuees go? Various civic agencies can assist with housing evacuated individuals. Shelters can be established in most areas and the Civil Defense and Red Cross should be able to assist with relocation.

A sample Emergency Warning Plan is shown on the following pages.

EMERGENCY WARNING PLAN

MONITORING AND EMERGENCY WARNING
PLAN AND PROCEDURES

for the

(Name of Dam)
ID#

Located at

(Town, County, State)

OWNER: ____________________

ISSUE DATE: ______________
REVISED DATE: ______________

Introduction

The purpose of the Emergency Warning Plan is to facilitate the evacuation of downstream residents if there is the possibility of dam failure. The establishment of an effective plan is an essential part of an impounding structure's operation program. Any plan drawn up by the dam owner is subject to review by the local Civil Defense Agency and the Dam Safety Division of the Water Management Administration.

An Emergency Warning Plan is fairly simple to formulate and will be very valuable if ever needed. An effective Plan incorporates several essential elements.

Surveillance

I. Adverse Conditions: When a flood watch or flood warning is issued by the National Weather Service, water levels are recorded and spillways, seepage zones, and discharge water levels are inspected.

1. Continuously monitor and record water levels in the reservoir.

2. Open gates or drains if necessary to lower the reservoir pool and provide additional flood storage.

II. Standby Alert: According to specific on site conditions at the dam; such as depth of spillway flows, cracking, seepage, piping, etc.

1. Constant surveillance by on site personnel.

2. Initial notification of Agencies to advise of status at site.

Notification

I. Adverse Conditions: Communicate data gathered by observers to the dam operator at appropriate intervals. The dam operator shall take the information and make judgement decisions.

II. Standby Alert: Proper authorities are notified of the need to initiate the warning plan or evacuation plan. This can be by telephone, ham radio, CB radio, or police, fire, and other emergency radio systems. It is important that any system chosen have an emergency backup. The Civil Defense Director shall notify: the mayor, police chief, fire chief, city manager, and the public.

Evacuation

Evacuation procedures may include any number of site specific measures such as evacuation of houses within so many vertical feet of a highway, or everyone down to a certain point. These details must be worked out in advance with cooperation between the local Office of Emergency Services. A narrative of these procedures should appear in this section in accordance with the county emergency operations plan. Evacuation areas and location of evacuation receiving centers must be shown on a map attached to this plan.

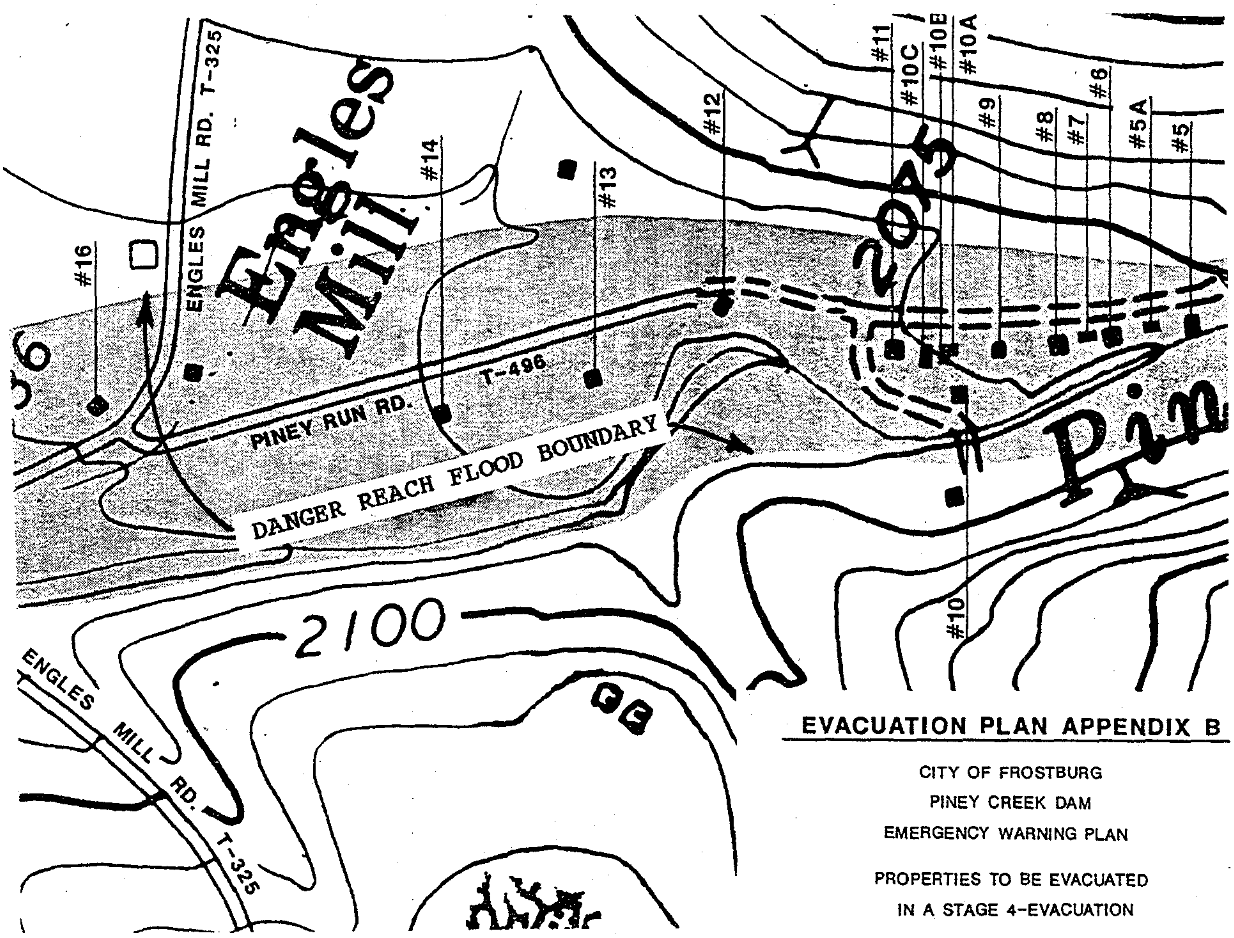
Post Evacuation

Should the Civil Defense Director decide that the emergency condition has passed, the evacuation order shall be cancelled. State dam safety officials shall be alerted and should inspect the facility.

Plan Review

Periodic verification must be made to confirm that the Emergency Warning Plan is adequate. Communication checks, drills, and map up-dates are necessary. An annual review and update is essential to maintain an effective plan.

Evacuation Map



FEDERAL LEGISLATION

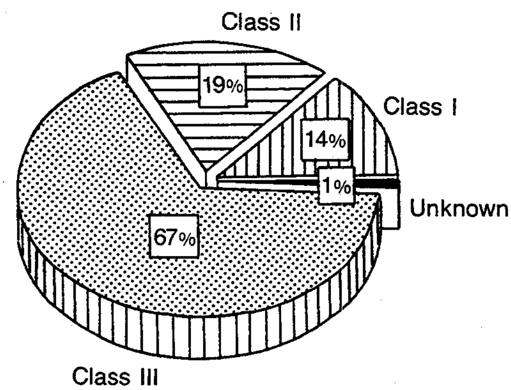
As a result of several dam failures in the United States in the early 1970's, the National Dam Inspection Act of 1972 (Public Law 92-367) was quickly enacted and signed by President Nixon on August 8, 1972. The Secretary of the Army, acting through the Corps of Engineers, was to carry out a national program to inventory and inspect non-federal dams "for the purpose of protecting human life and property." The activities to be carried out under P.L. 92-367 included the inspection of dams posing a threat to human life or property that were 25 feet or more in height or impounded 50 acre-feet or more at maximum water storage elevation. The Secretary of the Army was to report the findings these inspections to the governor of the state in which these dams were located along with recommendations to correct any deficiencies found.

Funding for P.L. 92-367 was limited by Congress and therefore the majority of effort was concentrated on developing a national inventory of dams. By 1975, a total of 49,322 structures comprised the National Dam Inventory.

Dam safety in the United States was given a significant boost in late 1977 in response to renewed public awareness stemming from additional catastrophic dam failures. One of these failures occurred on November 6, 1977 in then President Carter's home state of Georgia. The Kelly Barnes Dam failed, following several days of heavy rain, killing 39 people at a downstream bible college near Toccoa Falls in the northeastern part of the state.

The failure of the Kelly Barnes dam prompted the President, with Congressional appropriations of $15 million in 1978, to direct the Secretary of the Army to immediately begin the inspection of some 9,000 "high" hazard non-federal dams. Funding prior to the December, 1977 "Public Works Appropriation Act" (P.L. 95-96) had been denied by the Office of Management and Budget who observed that such inspections of non-federal dams were the responsibility of the particular states and should be accomplished as part of their normal responsibilities. P.L. 95-96 thus started the four year National Dam Inspection Program.

By the end of 1979 the inspection program was well under way and a total of 4565 high hazard dams had been evaluated. It was determined that 1334 (29%) of the inspected dams were found to be "unsafe". Of these dams it was determined that 5% were found to be in an "emergency" situation, requiring immediate corrective action. The balance of the "unsafe" dams were so designated primarily because of inadequate spillway capacity.



**Non-Federal Dams
Hazard Classification**

In 1979 the responsibility for coordinating non-federal dam safety shifted from the U.S. Corps of Engineers to the Federal Emergency Management Agency (FEMA). FEMA has the responsibility to coordinate the efforts of other federal agencies to implement the Federal Guidelines for Dam Safety. FEMA's current objectives for non-federal dam safety are to:

Assist each state in implementing an effective dam safety program.

Develop public awareness and support

dam safety programs.

Utilize the Interagency Committee on Dam Safety (ICODS) and other federal organizations to develop technical assistance materials for dam safety programs.

To date FEMA has encouraged additional research of dam safety including: funding for repairs, risk analysis, and status updates of the States Dam Safety Programs.

With the assistance and support from FEMA, the Association of State Dam Safety Officials (ASDSO) was formed in 1984. The purpose of the association is to further the safety of non-federal dams and provide a forum for the exchange of ideas and experiences of dam safety issues. The main objectives of the Association are:

Provide information and assistance to state dam safety programs.

Foster interstate cooperation.

Improve efficiency and effectiveness of state dam safety programs.

The Association has been responsible for attracting over 1,600 members including the 50 states. Numerous municipalities, corporations, and individuals have also become members of ASDSO. Support and encouragement of State Dam Safety Programs is provided with the Publication of a quarterly newsletter concerning dam safety. ASDSO also is responsible for:

Assisting states by providing funding and technical assistance towards holding public awareness workshops.

Publication of a <u>Model State Dam Safety Program</u>.

Development of a methodology for maintaining National Dam Inventory.

Offering Regional Technical Services to state dam safety engineers.

Holding an annual ASDSO Dam Safety Conference.

Establishing a Dam Performance Library at Stanford University.

Periodic updating of the national dam inventory which lists 74,464 total non federal dams. The inventory also indicates that high hazard dams represent approximately 9% of the nations total non-federal dams.

Even with the increased emphasis on dam safety nearly 1,915 non federal dams remain unsafe today (ASDSO, 1996).

The most recent federal legislation concerning dam safety was enacted with the passage of Public Law 99-662. Title XII of this law, known as the Dam Safety Act of 1986, includes provisions for:

a) encouragement and assistance in the development of State Dam Safety Programs;

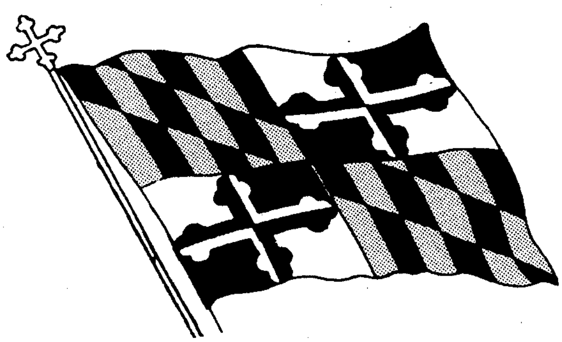
b) establishes a National Dam Safety Review Board;

c) authorizes a program of research into innovative dam safety inspection techniques.

At this time the proposed fiscal budget only includes provisions for the maintenance of a National Dam Inventory only.

MARYLAND LEGISLATION

Maryland recognized the need to regulate the water resources of the State as early as 1931 with the creation of the first "Water Resources Commission of Maryland." Chapter 247 of the Annotated Code of Maryland, enacted on June 1, 1931, authorized the Governor of the State "to appoint a commission of seven persons to review the underground and surface water resources of the State of Maryland in order to determine the most effective plan to preserve and allocate such water supply resources for maximum public benefit and use."



Water Resources Commission

This Commission was charged with the responsibility of developing programs to: measure stream flow; supervise the location, design, and construction of water supply dams and reservoirs; improve rivers of the state to prevent damaging floods; control public water supplies; regulate stream flows by storage reservoirs; and evaluate the necessity for creating water districts. By this Act the Commission was also to present a written report of its findings and recommendations to the General Assembly of 1933 with regard to policy, legislation, and methods of financing.

The Commission submitted its final report to the General Assembly in January 1933, and recommended that, since Maryland had no agency to review the design of dams and had no specific policies with regard to stream gaging, stream discharge regulations, and conservation of water supply uses, there should be created a permanent Water Resources Commission of Maryland. This permanent body would formulate water conservation policies, and provide for continuity of stream gaging and for the supervision of dams.

From those recommendations made by the initial Water Resources Commission, the 1933 State Legislature established Maryland's first comprehensive water resources authority by the approval of Chapter 526 of the Annotated Code. This Act provided for the control of appropriation and use of the state's surface and underground water. Chapter 526 established the Water Resources Commission as a permanent regulatory authority empowered to control the construction and repair of dams, devise a general water conservation program, provide public hearings for permit applications to appropriate state waters, and provide for appeals and penalties for violations of its orders.

Permit Authority Created

Aside from establishing the first permanent regulatory agency for Maryland's water resources, Chapter 526 created permit requirements for the use of State water. Therefore, from January 1, 1934 it became unlawful to use or appropriate any waters of Maryland without written consent of the Water Resources Commission. Plans, drawings, and specifications would be required for projects that "in any manner change or diminish the course, current, or cross-section of any stream or body of water". Chapter 526 also provided for public hearings to give affected individuals the opportunity to voice opinions both for and against the granting of a permit.

Also established in 1933 was the first authority for enforcement type action that could be exercised by the Water Resources Commission. The Commission was given the authority to require the owner of a reservoir, dam, or waterway obstruction to remove or repair said structure should it be determined by outside complaint or investigation that a particular pre-existing or proposed project was judged to be unsafe.

Exclusions from the permit requirement were also provided for in Chapter 526. Structures built before January 1, 1934, as well as those water uses involving domestic and farming purposes, were not required to obtain a permit. Structures ten feet or less in height above the stream were exempt and dams impounding less than one million gallons were also not required to obtain a permit.

The basic legislative intent of the 1933 legislature has remained virtually unchanged through thirteen modifications to the original law. These modifications merely adjusted the exlusionary limits that required written approval from the Water Resources Commission. The following describes those law changes and some of the basic restructuring of the Commission's organization that has taken place since in 1933:

YEAR	LEGISLATION	COMMENTS
1931	Chapter 247, Annotated Code of Maryland	Commission created to investigate a plan to preserve and allocate the water resources of the State.
1933	Chapter 526, Annotated Code of Maryland	Permanent Water Resources Commission established and given regulatory authority.
1939	Article 96B enacted	Chapter 526 renamed to Article 96B
1941	Chapter 508 repealed and reenacted with ammendments as Sections of Article 96B	Creation of "The Board of Natural Resources." Changed all references of the Water Resources Commission to the Department of Geology, Mines and Water Resources.
1950	Chapter 72 repealed and reenacted as Section 5 of Article 96B	Permit exemption provisions were expanded to include muskrat ponds and farm ponds. A farm pond was defined as an all earth dam and spillway impounding nine or less feet, having a surface area of 60,000 square feet, and a contributory drainage area of less than 100 acres. Ponds were not to be built "closer than 500 feet to a place for human habitation or public road."
1951	Article 66C enacted	Previous legislation renamed to Article 66C
1957	Chapter 317 repealed and reenacted as Section 669 of Article 66C	Farm ponds were qualified and expanded to include ponds having a surface area of less than five acres or a depth of water of fifteen feet at the spillway level. Geographical drainage area limitations were added. Ponds exempt would not exceed 400 acres north and west of the B and O Railroad and 700 acres south and east of the B and O Railroad. Some offstream impoundments were also exempt. Some design considerations were also included with regard to minimum freeboard and allowable emergency spillway velocities.
1962	Chapter 18 repealed and reenacted as Section 721 of Article 66C	Waste stabilization lagoons under permit with the Maryland Department of Health and Mental Hygiene were added as exemptions.
1963	Chapter 611 repealed and reenacted as Section 721 of Article 66C	Exemptions for muskrat ponds were qualified to include structures that were less than "four feet in height" and for the propagation of "other wildlife species."
1964	Chapter 73 repealed and reenacted as Sections 15, 16, and 17 of Article 66C	Split Department of Geology, Mines and Water Resources into separate agencies. Created the Department of Water Resources that assumed water related duties.

1965	Chapter 752 repealed and re-enacted as Section 12 of Article 96A	Recreation ponds were added to the exemption list. Requirements of a drop inlet pipe or other mechanical spillway were established for dams draining greater than 5 acres. A minimum freeboard requirement of 1 foot was included and the normal surface area of 5 acres for farm ponds was changed to 12 acres.
1967	Chapter 416 repealed and re-enacted as Section 12 of Article 96A	This act exempted drainage systems built exclusively for the collection, conveyance, or disposal of storm water.
1972	Chapter 521 repealed and re-enacted as Section 12 of Article 96A	Deleted all previously mentioned permit exemptions (farm ponds, muskrat, sewage lagoons, storm water structures, and all size restrictions) and redefined those dams not requiring Administration approval. This exempted small ponds having a contributory drainage area of less than 1 square mile <u>and</u> a normal depth of water less than 15 feet <u>and</u> a normal surface area of less than 12 acres (approval from the Soil Conservation District was required).
1973	Recodification and renumbering as Title 8 of the Natural Resources Article	Restructuring of Departments and the creation of the Department of Natural Resources and the present Water Resources Administration.
1978	Amendments to Natural Resources Article 8-809	Provisions to allow the Department to investigate unsafe dams and repair them if necessary.
1991	Amendments to Natural Resources Article 8-806	Provided for a public informational hearing upon written request, notification of contiguous property owners and written notification of the Department's decision to interested persons. Also provided for requirements to obtain a contested case hearing if aggrieved by Department's decision.
1992	Amendments to Natural Resources Article 8-803(b)	Redefined the "small pond exemption" to be: 1) less than 640 acre drainage area; 2) less than 20 feet in height (measured from the top of the dam to downstream toe); and 3) low hazard structure.
1995	Recodification and renumbering as Title 5 of the Environment Article	Transferred regulatory functions from the Department of Natural Resources to the Department of the Environment.

Present Regulatory Authority

The Maryland General Assembly gives state agencies the authority to promulgate regulations in order to supplement and clarify existing laws. These regulations are found in the Code of Maryland Regulations (COMAR) under Construction on Non-Tidal Waters and Floodplains. The Water Resources Administration has rules and regulations that govern the construction, reconstruction, repair, or alteration of a dam.

Dams and reservoirs are the most stringently regulated of all waterway construction projects. Because of the complexity and cost involved in undertaking this type of project, the Water Resources Administration provides for a two step permit process. The main advantage of this process is that many of the detailed construction plans and specifications for the dam need not be prepared until after a ruling has been made on whether the overall project is in the best interests of the State's Water Resources. The permit and construction process for a new structure can be divided into the following major steps:

1. **Classification of Dam and approval of Engineer-In-Charge**

2. **Plan Development Permit**
   feasibility report
   environmental considerations
   general location and features of dam

3. **Opportunity for Hearing Process**
   public input

4. **Obstruction Permit**
   plans and specifications approval
   operation and maintenance program

5. **Construction of Dam**
   material tests
   construction reports
   design changes
   certification of readiness for filling
   "as built" plans

The Dam Safety Division requires that a registered professional engineer supervise the design and construction of new dams as well as major repairs to existing facilities.

The Engineer-In-Charge is encouraged to serve as the construction manager since he or she is the one person who is keenly aware of the design details. As stated throughout this manual, the overall safety and longevity of the dam is contingent on many factors. The best design program will only serve its purpose if a well prepared construction program is adhered to.

The regulations are intended to provide assistance and guidance in preparing new projects or undertaking major repair to existing facilities.

GLOSSARY

ABUTMENT - That part of the valley side against which the dam is constructed See also Left Abutment and Right Abutment.

ANTI-SEEP COLLAR - A projecting collar built around the outside of a tunnel or conduit to reduce the seepage along the outer surface of the conduit. Filter diaphrams are preferred over antiseep collars.

APPURTENANCES - The associated works of a dam other than the embankment or main impoundment structure, such as the outlet, spillway, outlet conduit, and tunnels.

AS-BUILT DRAWINGS - Plans or drawings portraying the actual dimensions and conditions of a dam, dike, or levee as it was built. Field conditions and material availability during construction often require changes from the original design drawings.

AXIS OF DAM - The plane or curved surface, arbitrarily chosen by a designer, appearing as a line, in plan or in cross section, to which the horizontal dimensions of the dam can be referred.

BASE WIDTH (BASE THICKNESS) - The maximum thickness or width of a dam measured horizontally between upstream and downstream faces and normal to the axis of the dam but excluding projections for outlets, etc.

BEACHING - 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.

BENCH - A horizontal step in the slope of an embankment.

BLANKET DRAIN - A drain that extends in a generally horizontal direction (much like a blanket) under a relatively large area of the downstream portion of the embankment, intercepts seepage through the embankment and the foundation, and prevents further saturation of the downstream toe.

BOIL - A disturbance in the surface layer of soil caused by water escaping under pressure from behind a water-retaining structure such as a dam or a levee. The boil may be accompanied by deposition of soil particles (usually sand) in the form of a cone ring around the area where the water escapes.

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

CAMBER - A slight arch applied to the dam crest to account for embankment settlement.

CAVITATION - Wear on hydraulic structures where a high hydraulic gradient is present. Cavitation is caused by the abrupt change in direction and velocity of water reducing the pressure to vapor pressure and creating vapor pockets. These pockets collapse with great impact, 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.

CONCRETE DAM - Any dam constructed of concrete materials.

ARCH DAM - A concrete or masonry dam that is curved in plan so as to transmit the major part of the water load to the abutments.

BUTTRESS DAM - A dam consisting of watertight upstream face supported at intervals on the downstream side by a series of buttresses. Buttress dams can take many forms, eg. arch buttress dam, multiple arch dam, flat slab or Ambursen dam, solid head buttress dam.

GRAVITY DAM - A dam constructed of concrete and which relies upon its weight for stability. Concrete gravity dams can take several forms, e.g. arch gravity, curved gravity, and hollow gravity.

ROLLER COMPACTED CONCRETE DAM - A concrete dam constructed of a no-slump concrete that can be hauled in dump trucks, spread with a bulldozer or grader, and compacted with a vibratory roller.

CONSTRUCTION JOINT - The interface between two successive placing of pours of concrete where bonding, not permanent separation, is intended.

CONTRACTION JOINT - A joint constructed where shrinkage of the concrete would cause a crack.

CORE - The impervious or relatively impervious material forming the central part of a dam or embankment. Where a dam has a core, the outer zones are usually comprised of more pervious materials. Some dams are constructed entirely of a relatively homogeneous, impervious material with no distinct core. In this case, the entire dam is considered the core.

CORE WALL - A wall of substantial thickness built of impervious materials, usually of concrete or asphaltic concrete, in the body of an embankment to prevent leakage.

CORROSION - The chemical attack on a metal by its environment. Corrosion is a reaction in which metal is oxidized.

CREST LENGTH - The measured length of the top of the dam from abutment to abutment. This includes the length of spillway, powerhouse, navigation lock, fish passage, etc., where these structures from part of the length of the dam. If detached from the dam, these structures should not be included.

CREST OF DAM - The crown of an overflow section of the dam. In the United States, the term "crest of dam" is often used when "top of dam" is intended. To avoid confusion, the terms crest of spillway and top of dam should be used for referring to the overflow section and dam proper, respectively.

CRIB DAM - A gravity dam built up of boxes, cribs, crossed timbers, or gabions and filled with earth or rock.

CULVERT - (a) A drain or waterway structure built transversely under a road, railway, or embankment. A culvert usually comprises a pipe or a covered channel of box section. (b) A gallery or waterway constructed through any type of dam, which is normally dry but is used occasionally for discharging water; hence the terms scour culvert, drawoff culvert, and spillway culvert.

CURTAIN

DRAINAGE CURTAIN - See Drainage Well.

GROUT CURTAIN (GROUT CUTOFF) - A barrier produced by injecting grout into a vertical zone, usually narrow in horizontal width, in the foundation to reduce seepage under a dam. (See Grout)

CUTOFF - An impervious barrier used to reduce or prevent seepage from passing through the foundation under the dam.

CUTOFF TRENCH - The excavation later to be filled with impervious material so as to form the cutoff. Sometimes used incorrectly to describe the cutoff itself.

CUTOFF WALL - A wall of impervious material (e.g., concrete, asphaltic concrete, steel sheet piling) built into the foundation to reduce seepage under the dam.

DAM - Any manmade barrier, together with its abutments and appurtenant works, if any, constructed for the purpose of storing or directing water or for receiving dredge disposal material, as determined by the Administration.

DANGER REACH - That area downstream from a dam within which a sudden release of waters resulting from failure of the dam would cause an artificial flood.

DIKE - See Levee.

DISTRESS - A condition of severe stress, strain, or deterioration indicating possible or potential failure.

DIVERSION CHANNEL, CANAL, OR TUNNEL - A waterway used to divert water from its natural course. The term is generally applied to a temporary arrangement, e.g., to convey water around a dam site during construction. Channel is normally used instead of canal when the waterway is short. Occasionally the term is applied to a permanent arrangement (diversion canal, diversion tunnel, diversion aqueducts).

DRAIN GATE - See Emergency Gate.

DRAINAGE AREA - The area that drains naturally to a particular point on a river or stream.

DRAINAGE LAYER OR BLANKET - A layer of pervious material in a dam to relieve pore pressures or to facilitate drainage of the fill.

DRAINAGE WELL OR RELIEF WELL - Vertical wells or boreholes downstream of, or in the downstream berm of, an embankment to collect and control seepage through or under the dam and so reduce water pressure. A line of such wells forms a drainage curtain.

DRAWDOWN - The resultant lowering of water surface level due to release of water from the reservoir.

EMBANKMENT - Fill material, usually earth or rock, placed with sloping sides and usually with a length greater than its height. An "embankment" is a part of a dam.

EMBANKMENT-ABUTMENT CONTACT - That area at the intersection of either the upstream or downstream slope of an embankment and the valley wall or abutment.

EMBANKMENT DAM - Any dam constructed of excavated natural materials.

EARTH DAM (EARTHFILL DAM) - An embankment dam in which more than 50 percent of the total volume is formed of compacted fine-grained material obtained from a borrow area.

HOMOGENEOUS EARTHFILL DAM - An embankment dam constructed of similar earth material throughout, except for possible inclusion of internal drains or drainage blankets. This term is use to differentiate from a zoned earthfill dam.

HYDRAULIC FILL DAM - An embankment dam constructed of materials, often dredged, that are conveyed and placed by suspension in flowing water.

ROCKFILL DAM - An embankment dam in which more than 50 percent of the total volume comprises compacted or dumped pervious natural or crushed rock.

ROLLED FILL DAM - An embankment dam of earth or rock in which the material is placed in layers and compacted by using rollers or rolling equipment.

ZONED EMBANKMENT DAM - An embankment dam, the thickness of which is composed of zones of selected earth and rock materials having different degrees of porosity, permeability, and density.

EMERGENCY GATE - A standby or reserve gate used only when the normal means of water control is not available; also referred to as a drain gate.

FILTER DIAPHRAGM - A zone of granular material that is constructed around a conduit that passes through an embankment dam or foundation that will allow seepage flow without migration of soil particles. See SCS publication TR-60 "Earth Dams and Reservoirs".

FLASHBOARDS - Lengths of timber, concrete, or steel placed on the crest of a spillway to raise the retention 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 flashboards or their supports.

FLOODPLAIN - An area adjoining a body of water or natural stream that has been or may be covered by flood water. The floodplain is based on the 100 year frequency flood and is included as waters of the State (Annotated Code of Maryland, Natural Resources Article, §8-101(k)).

FLOOD ROUTING - The determination of the attenuating effect of storage on a flood passing through a valley, channel, or reservoir.

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

FREEBOARD - The vertical distance to the crest of a dam above the water surface at the time of maximum design flow over the spillway.

FUSE PLUG SPILLWAY - A form of auxiliary or emergency spillway comprising a low embankment or a natural saddle designed to be overtopped and eroded away during a very rare and exceptionally large flood.

GABION - A hollow cage or basket, usually of heavy wire, filled with stones or rock and used as a revetment or other protective device to sustain a wall or channel.

GROUT - A thin cement mortar used to fill voids, fractures, or joints in masonry, rock, sand and gravel, and other materials. As a verb it refers to filling voids with grout. Grout is usually applied under pressure.

HEIGHT OF DAM - The vertical measurement expressed in feet as measured from the downstream toe of the dam at its lowest point to the elevation of the top of the dam.

INFLOW DESIGN FLOOD - The largest flood that a given project is designed to pass safely. The reservoir inflow discharge hydrograph used to estimate the spillway discharge capacity requirements and corresponding maximum surcharge elevation in the reservoir.

LEFT ABUTMENT - The abutment on the left-hand side of an observer when looking downstream.

LEVEE - A long embankment structure. Usually built along a watercourse to protect land from flooding. If built of concrete or masonry, a levee is usually referred to as a flood wall. Also used to describe embankments that block areas on the reservoir rim that are lower than the top of the main dam and that are quite long.

MASONRY DAM - Any dam constructed mainly of stone, brick, or concrete blocks that may or may not be joined with mortar. A dam having only a masonry veneer facing should not be referred to as a masonry dam.

MAXIMUM CROSS SECTION OF DAM - Cross section of a dam at the point where the height of the dam is the maximum.

MAXIMUM POOL LEVEL - The maximum water level, including the flood surcharge the dam is designed to withstand.

NORMAL DEPTH - The maximum vertical distance from the stream bed invert at the upstream toe of the dam to the normal water surface.

OBSERVATION WELL - Small diameter perforated vertical tube installed within an embankment. Used to measure the height of the internal water surface (phreatic surface) in the embankment at the location of the well.

ONE-HUNDRED YEAR (100-YEAR) FLOOD - The flood magnitude having an exceedence frequency of one percent in any given year. It is often expressed as expected to be equalled or exceeded on the average of one in 100 years.

OUTLET - An opening through which water can be freely discharged from the reservoir to the stream.

OWNER - Any person or persons and their duly authorized agents, owning, operating, maintaining, or proposing to construct a dam, reservoir, or other obstruction, or to change the course, current, or cross section of any body of water in the State.

PERMEABILITY - A material property which defines the capacity to transmit water.

PERVIOUS ZONE - A part of the cross section of an embankment dam comprising material of high permeability.

PHREATIC SURFACE (SEEPAGE SURFACE) - The upper surface of seepage in an embankment. All the soil below the surface will be saturated when the equilibrium condition has been reached.

PIPE CONDUIT - Any tube or hollow channel that conveys water to or from a reservoir.

PIPING - Progressive erosion and removal of soil by concentrated seepage flows through a dam, dike, or levee, its foundation, or its abutment. As material is eroded, the area of the "pipe" increases and the quantity and velocity of flow increase, which in turn erodes more material. The process continues at a progressively faster rate until controlled, or failure occurs.

PLUNGE POOL - An excavated pool at the outlet structure that is designed to withstand erosion from high velocities. The plunge pool is armored with riprap.

PORE PRESSURE - The internal cellular pressure of a fluid (air and water) within the voids of a mass of soil, rock, or concrete.

PROBABLE MAXIMUM PRECIPITATION (PMP) - Theoretically the maximum depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographic location at a certain time of the year.

PROBABLE MAXIMUM FLOOD (PMF) - The most severe flood considered possible in a specific region. This may be:

a) The Probable Maximum Flood as determined by a source acceptable to the Administration; or

b) Calculated using a rational consideration of the chances of simultaneous occurrence of the maximum of several elements or conditions which contribute to the flood.

RANDOM FILL - Earth or rockfill, the grading of which is not specified and that is placed without treatment just as it comes from the excavation.

RESERVOIR - Any basin, either natural or artificial, used for collecting or storing of water. Reservoir capacity is the total volume in reservoir between lowest point in the reservoir and horizontal plane at crest of overflow spillway.

REGULATIONS - Title 26, Subtitle 17, Chapter 05, Regulations .01 thru .13 of the Code of Maryland Regulation (COMAR); also known as Construction on Non-Tidal Waters and Floodplains.

RIGHT ABUTMENT - The abutment on the right-hand side of an observer when looking downstream.

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

SCARP - The nearly vertical, exposed earth surface created at the upper edge of a slide or a beached area along the upstream slope.

SEEPAGE - The slow percolation (or oozing) of a fluid through a permeable material in and under the structure, the depth of water behind the structure, and the length of the path the water must travel through or under the structure.

SETTLEMENT (CONSOLIDATION) - The gradual process of soil compression due to the squeezing out of water, causing a building or embankment to settle.

SHELL - The upstream and downstream parts of the cross section of a zoned embankment dam on each side of the core or core wall.

SLIDE - The movement of a mass of earth and rock down a slope. In embankments and abutments, this involves the separation of a portion of the slope from the surrounding material.

SLOPE PROTECTION - The protection of the embankment slope against wave action and erosion.

SLOUGH - The separation from the surrounding material and downhill movement of a small portion of the slope. Usually a slough refers to a shallow earth slide.

SLUICE GATE - A gate used to control the flow of water through a sluice, or artificial discharge channel. Most sluice gates are used with square openings and are connected to a handwheel lift mechanism by a vertical stem.

SPALLING - Breaking (or erosion) of small fragments from the surface of concrete masonry or stone under the action of weather or abrasive forces.

SPILLWAY - A structure over or through which water is discharged. If the flow is controlled by gates, it is considered a controlled spillway; if the elevation of the spillway crest is the only control, it is considered an uncontrolled spillway.

EMERGENCY SPILLWAY (AUXILIARY SPILLWAY) - A secondary spillway designed to operate only during exceptionally large floods.

OGEE SPILLWAY (OGEE SECTION) - An overflow weir in which in cross section the crest, downstream slope, and bucket have an S or ogee form of curve. The shape is intended to match the underside of the nappe at its upper extremities.

OVERFLOW SPILLWAY - Any operating, emergency, or other spillway which discharges with a free water surface over or around the dam as opposed to a gate, or conduit which discharges through or beneath the dam or nearby ground.

PRINCIPAL SPILLWAY - The principal or first-used spillway that conveys all normal stream flows through the reservoir. The principal spillway generally carries all flows up to the emergency spillway.

RISER SPILLWAY - A principle spillway that consists of a circular or square standpipe that carries normal stream flows through the reservoir. This type of spillway is connected to a conduit that passes through the dam.

SERVICE SPILLWAY - A principal spillway used to regulate reservoir releases additional to or in lieu of the outlet.

SHAFT SPILLWAY (MORNING GLORY SPILLWAY) - A vertical or inclined shaft into which flood water spills and then is conducted through, under, or around a dam by means of a conduit or tunnel. If the upper part of the shaft is splayed out and terminates in a circular horizontal weir, it is termed a bellmouth or morning glory spillway.

SIDE CHANNEL SPILLWAY - A spillway, the crest of which is roughly parallel to the channel immediately downstream of the spillway.

SIPHON SPILLWAY - A spillway with one or more siphons built at crest level. This type of spillway is sometimes used for providing automatic surface-level regulation within narrow limits or when considerable discharge capacity is necessary within a short period of time.

SPILLWAY CHANNEL - A channel conveying water from the spillway crest to the river downstream.

STAFF GAUGE - A device marked in feet used to indicate and measure water levels.

STILLING BASIN - An energy-dissipating device located at the outlet of a spillway to dissipate the high velocity (energy) of the flowing water in order to protect the spillway structure and avoid serious erosion of the outlet channel and subsequent undermining. Stilling basins are generally constructed of concrete.

STORAGE - The retention of water or delay of runoff either by planned operation as in a reservoir, or by temporary filing of overflow areas, as in the progression of a flood crest through a natural stream channel.

SURVEY MONUMENT - A point established on or in the vicinity of an embankment. Provides a set point to survey and, over time, will indicate whether any movement has taken place.

TAILWATER LEVEL - The level of water in the discharge channel immediately downstream of the dam.

TOE OF DAM - The junction of the downstream face of a dam with the ground surface. Also referred to as downstream toe. For an embankment dam, the junction of the upstream face with ground surface is called the upstream toe.

TOE DRAIN - Drains commonly installed along the downstream toe of the dam to collect seepage discharging from the embankment and foundation and lead it to an outfall pipe which discharges away from the dam.

TRANSITION ZONE (SEMI-IMPERVIOUS ZONE) - A part of the cross section of a zoned embankment dam comprising material whose grading is of intermediate size between that of an impervious zone and that of a permeable zone.

TRASH RACK - A structure of metal or reinforced concrete bars located at the intake of a waterway to prevent entrance of floating or submerged debris of a certain size and larger.

TRENCH DRAIN - A drain commonly installed in or along an embankment, abutment, or the foundation of a dam in order to relieve uplift pressures and carry seepage away from dam. Toe drains are generally installed in the bottom of the trench.

UPLIFT - The upward pressure on the base of a structure.

WATERS OF THE STATE - Includes both surface and underground waters within the boundaries of the State of Maryland subject to its jurisdiction, including that portion of the Atlantic Ocean within the boundaries of the State, the Chesapeake Bay and its tributaries, and all ponds, lakes, river, streams, public ditches, tax ditches, and public drainage systems within the State, other than those designed and used to collect, convey, or dispose of sanitary sewage. The floodplain of free-flowing waters determined by the Department on the basis of the 100-year flood frequency is included as waters of the State.

WEIR - A type of spillway in which flow is constricted and caused to fall over a crest. Sometimes specially designed weirs are used to measure flow amounts. Types of weirs are used to measure flow amounts. Types of weirs include "broad-crested" "ogee" and "v-notch."

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JOHNSTOWN FLOOD

A jam at stone bridge caused a 10- to 30-foot lake over Johnstown. The fire there, probably caused by oil and hot coals, burned for 2 days.

As soon as the water receded, rescue workers began searching for survivors and bodies: Some waited days to be rescued.

Survivors lived in army tents and leantos. Prefabricated "Oklahoma" houses, furnished with essentials, were later sold for $250.

Shattered buildings were thrown into piles three stories high, completely filling some blocks.

The flood snapped large trees like sticks and turned them into battering rams that could pierce walls.

Cambria Iron Company's prompt reassurance that mills would be rebuilt heartened the many Johnstown citizens who depended on them.

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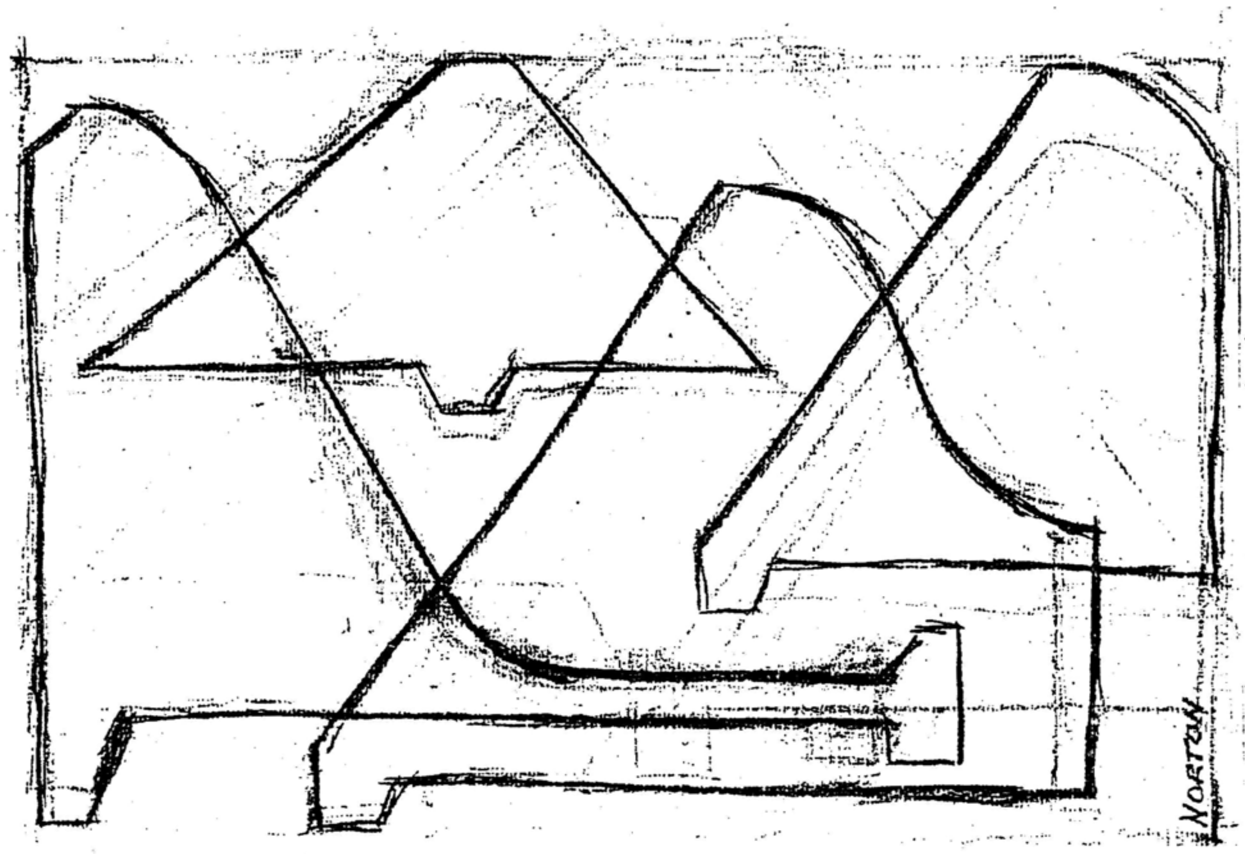

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