Dam Safety

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PDH: 7

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1. AN APPROACH TO DAM SAFETY

1.1 GENERAL

This course is a safety guide for dam owners. There is a critical and continuing need for dam safety because of the thousands of dams now in place and the many new dams built each year. Although these dams are essential elements of the national infra-structure, the risks to the public posed by their possible failure are great; large and growing number of lives and valuable property are at stake. Although there are many who are concerned about dam safety, legal and moral responsibility essentially rests with the dam owner.

1.2 URGENCY FOR SAFETY

The critical need for dam safety is clear. World and national statistics on dam failures show an unacceptable record of losses in both lives and property. The International Commission on Large Dams (ICOLD) reports that more than 8000 people have died so far this century because of the failure of major dams. The record for U.S. losses from major dam failures in recent years, shown in Table 1.1 is also not encouraging. Actual national losses are much higher than indicated because the statistics shown cover neither small dam failures nor many combinations of dam failure and natural flooding events. A more specific examination of the national experience shows that over 18-year period (1965-1983) thirty lesser failures, or serious incidents that almost led to failure, occurred in Colorado. The Johnstown, Pennsylvania disaster of 1889 is regarded as one of the nation’s great catastrophes, and the potential for future similar catastrophes due to dam failure remains strong. Only a cooperative effort in dam safety involving owners and communities can lessen this potential.

1.3 DAM OWNERSHIP AND SAFETY

This course can be applied to dams owned and operated by a wide range of organizations and people, including state and local governments, public and private agencies, and private citizens. Typical reasons for building dams include water storage for human consumption, agricultural production, power generation, flood control, reduction of soil erosion and recreation. Thus, dam owners serve society by meeting important national needs and may also personally profit from dam operations. However, these are not sufficient reasons for building or owning a dam if the owner cannot provide safety for people and property in potential inundation zones.

In both financial and moral terms, successful dam ownership and the maintenance of safety standards go hand in hand. Investment in dam safety should be accepted as an integral part of project costs and not viewed as an expendable item that can be eliminated if a budget becomes tight (Jansen, 1980). The costs of dam safety are small in comparison to those which follow dam failure, particularly in our modern “litigious” society. Liability due to a failure would probably negate years of potential profits. Many different concerns and possible rewards result from dam ownership, but in the end, success will be in large part measured by a continuing record of dam safety.

1.4 THE INCREASING COMPLEXITY OF THE DAM SAFETY PROBLEM

As national needs for water intensify and the value of water increases, more dams are being built. At the same time, many existing dams are reaching or passing their design life spans and, for various reasons, people continue to settle near dams. Further, as builders are forced to use poorer sites for dams, the job of protecting life and property becomes more difficult. Therefore, as dam construction continues and the population grows, exposure of the public to dam failure hazards increases and the overall safety problem becomes more difficult.

Governments across the nation have shown increasing concern for this problem and have enacted laws, statutes and regulations that place an increased burden of responsibility on the dam owner. In most states, dam owners are held strictly liable for losses or damages resulting from dam failure. Concurrently, liability insurance costs have risen rapidly.

Table 1.1: Loss of Life and Property Damage from Notable U.S. Dam Failures, 1963-1983

Name & Location of dam	Date of failure	Number of lives lost	Damages
Mohegan Park, Conn	Mar 1963	6	$3 million
Little Deer Creek, Utah	June 1963	1	Summer cabins damaged.
Baldwin Hills, Calif.	Dec 1963	5	41 houses destroyed, 986 houses damaged. 100 apartment buildings damaged.
Swift, Mont.	June 1964	19	Unknown
Lower Two Medicine, Mont.	June 1968	9	Unknown
Lee Lake, Mass.	Mar 1968	2	6 houses destroyed. 20 houses damaged, 1 manufacturing plant damaged or destroyed.
Buffalo Creek, West Va.	Feb 1972	125	546 houses destroyed, 538. houses damaged.
Lake “O” Hills, Ark.	Apr 1972	1	Unknown.
Canyon Lake, S. Dak.	June 1972	33	Unable to assess damage because dam failure accompanied damage caused by natural flooding.
Bear Wallow, N.C.	Feb 1976	4	1 house destroyed.
Teton, Idaho	June 1976	11	771 houses destroyed, 3,002 houses damaged, 246 business damaged or destroyed.
Laurel Run, Pa.	July 1977	39	6 houses destroyed, 19 houses damaged.

Sandy Run and 5 others, Pa.	July 1977	5	Unknown.
Kelly Barnes, Ga.	Nov 1979	39	9 houses, 18 house trailers and 2 college buildings destroyed; 6 houses, 5 college buildings damaged.
Swimming Pool, N.Y.	1979	4	Unknown.
About 20 dams in Conn.	June 1982	0	Unknown.
Lawn Lake, Colo;	July 1982	3	18 bridges destroyed, 117 businesses and 108 houses damaged. Campgrounds, fisheries, power plant damaged.
DMAD, Utah	June 1983	1	Unknown.

Source: Graham, 1983.

1.5 AN APPROACH TO DAM SAFETY

An owner should be aware of and use both direct and indirect means of achieving dam safety. He can, of course, monitor and work on factors directly in his control (example, structural integrity), and these direct efforts are detailed below. However, the owner may also influence governmental policy and work for positive change in statutes and laws that affect dam safety (example, zoning laws). Such indirect influence by an owner could result in a significant contribution to the reduction of the likelihood and consequences of dam failure and thus, to overall community safety.

Liability, insurance coverage, and the roles of the Federal and state governments should all be well understood by an owner. Additionally, an owner should have a thorough knowledge of a dam's physical and social environment, including knowledge of natural and technological hazards that threaten the dam, misunderstanding of the developing human settlement patterns around the dam, and understanding of other events that can lead to structural failure. These indirect means of achieving dam safety are covered in more detail in Chapters 2, 3 and 10.

Dam owners, can also influence the safety of dams in more direct ways. Owners can and should develop their own safety programs. These programs should include such important elements as inspection, monitoring through instrumentation, maintenance, emergency action planning, and proper operation. Such a program is directly related to a specific dam's structure and its immediate environment and depends on the owner's knowledge of the dam and how it works. Chapter 2 stresses the need for owner's knowledge about the dam, while Chapters 4 through 9 cover the development of a dam owner's safety program.

2. INTRODUCTION TO DAMS

2.1 GENERAL

The purpose of a dam is to impound (store) water for any of several reasons, e.g., flood control, human water supply, irrigation, livestock water supply, energy generation, recreation, or pollution control. This course primarily concentrates on earthen dams which constitute the majority of structures in place and under development.

2.2 THE WATERSHED SYSTEM

Water from rainfall or snowmelt naturally runs downhill into a stream valley and then into larger streams or other bodies of water. The "watershed system" refers to the drainage process through which rainfall or snowmelt is collected into a particular stream valley during natural runoff (directed by gravity). Dams constructed across such a valley then impound the runoff water and release it at a controlled rate. During periods of high runoff, water stored in the reservoir typically increases and overflow through a spillway may occur. During periods of low runoff, reservoir levels usually decrease. The dam owner can normally control the reservoir level to some degree by adjusting the quantity of water released by the dam. Downstream from the dam, the stream continues to exist, but because the quantity of water flowing is normally controlled, very high runoffs (floods) and very low runoffs (drought periods) are avoided.

2.3 TYPES OF DAMS

Dams may be either man-made or exist because of natural phenomena, such as landslides or glacial deposition. The majority of dams are manmade structures normally constructed of earthfill or concrete. Naturally occurring lakes may also be modified by adding a spillway to provide safe, efficient release of excess water from the resulting reservoir.

Dam owners should be aware of the different types of dams, essential components of a dam, how the components function, and important physical conditions likely to affect a dam. This chapter discusses several of these factors.

Man-made dams may be classified according to the type of construction materials used, the methods used in construction, the slope or cross-section of the dam, the way the dam resists the forces of the water pressure behind it, the means used for controlling seepage, and occasionally, according the purpose of the dam.

A. Component Parts - The component parts of a typical dam are illustrated in Figure 2.1. Nearly all dams possess the features shown or variations of these features. Definitions of the terms are given in the glossary of this course, Appendix C. The various dam components are discussed in greater detail later in this course.

B. Construction Materials - The materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, steel, timber, miscellaneous materials (such as plastic or rubber), and any combination of these materials.

1. Embankment Dams - Embankment dams are the most common type of dam in use today. They have the general

The ability of an embankment dam to resist the hydrostatic pressure caused by reservoir water is primarily the result of the mass weight and strength of the materials from which the dam is made.

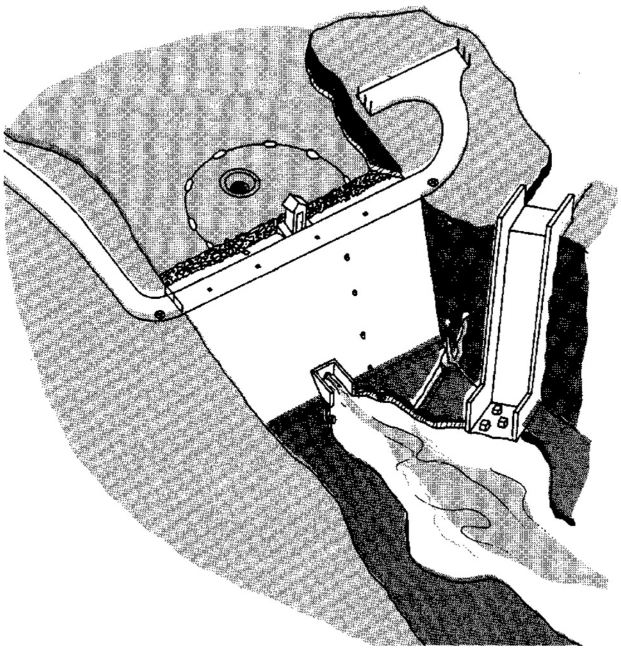

Figure 2.1 Typical Dam Site

2. C*oncrete Dams* - Concrete dams may be categorized into gravity and arch dams ac-cording to the designs used to resist the stress due to reservoir water pressure. A concrete gravity dam (shown in Figure 2.3) is the most common form of concrete dam. In it, the mass weight of the concrete and friction resist the reservoir water pressure. A buttress dam is a specific type of gravity dam in which the large mass of concrete is reduced, and the forces are diverted to the dam foundation through vertical or sloping buttresses. Gravity dams are constructed of non-reinforced vertical blocks of concrete with flexible seals in the joints between the blocks.

shape shown in Figure 2.2. Their side slopes typically have a grade of two to one (horizontal to vertical) or flat-ter. Their water retention capability is due to the low permeability of the entire mass (in the case of a homogeneous embankment) or of a zone of low-permeability material (in the case of a zoned embankment dam).

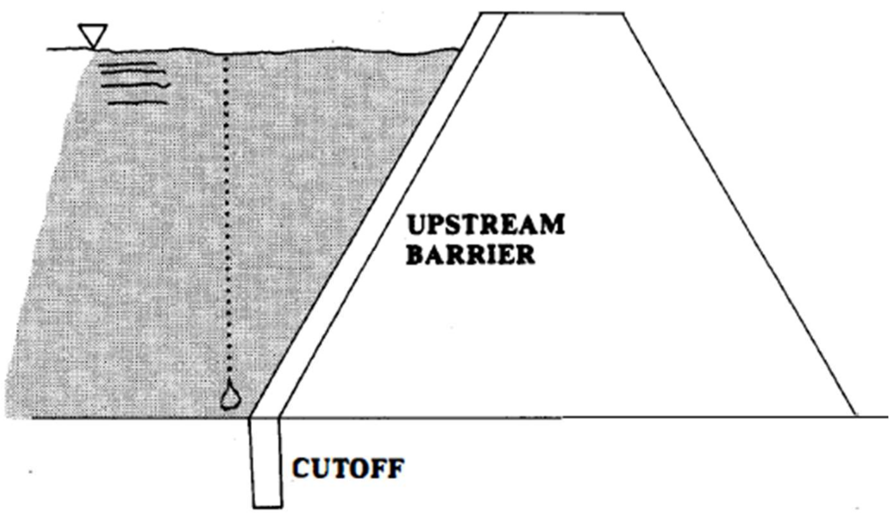

Figure 2.2 Embankment Dam

Materials used for embankment dams include natural soil or rock obtained from borrow areas or nearby quarries, or waste materials obtained from mining or milling operations. If the natural material has a