Chapter 2: Introduction to Dams

2 CHAPTER

2.0 General

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

2.1 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 owner can normally control the reservoir level to some degree by adjusting the quantity of water released. 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.

2.2 Types of Dams

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

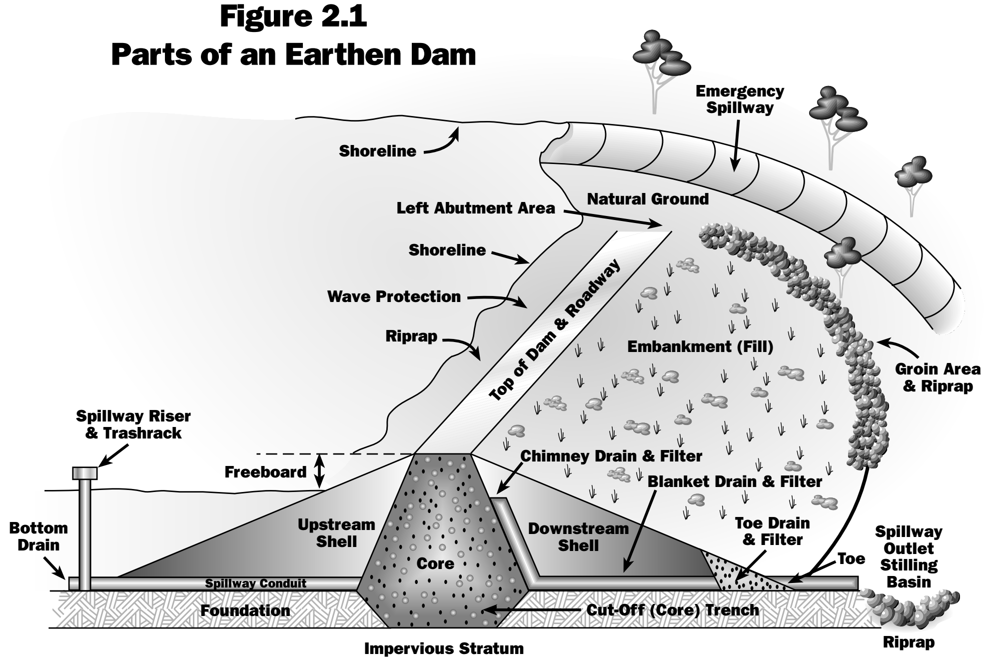
Dam owners should be aware of:

- the different types of dams
- essential components of a dam
- how the components function, and
- important physical conditions likely to affect a dam.

Human-built dams may be classified according to the type of construction materials used, the methods used in construction, their slope or cross-section, the way they resist the forces of the water pressure behind them, the means of controlling seepage, and occasionally, their purpose.

A. **Components—**The components of a typical dam are illustrated in Figure 2.1. Nearly all dams possess the features shown or variations of those features. Definitions of the terms are given in the Glossary. The various dam components are discussed in greater detail later on.

Figure 2.1
Parts of an Earthen Dam



Source: North Carolina Department of Environmental and Natural Resources (1989).

B. Construction Materials— The materials used for construction of dams include earth, rock, tailings from mining or milling, concrete, masonry, steel, and any combination of tho se materials.

1. *Embankment Dams*—Embankment dams, the most common type in use today, have the general shape shown in Figure 2.1. Their side slopes typically have a grade of two to one (horizontal to vertical) or flatter. Their capacity for water retention 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).

   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. If the natural material has a high permeability, then a zone of very-low-permeability material must be included in the dam to retain water.

   An embankment dam is termed an "earthfill" or "rockfill" dam depending on whether it is composed mostly of compacted earth or mostly of compacted or dumped pervious rock.

   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 its materials.

2. *Concrete Dams*—Concrete dams may be categorized into gravity and arch dams according to the designs used to resist the stress due to reservoir water pressure. A concrete gravity dam (shown in Figure 2.2) 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.

   Concrete arch dams are typically rather thin in cross-section (Figure 2.3). The reservoir water forces acting on an arch dam are carried laterally into the abutments. The shape of the arch may resemble a segment of a circle or an ellipse, and the arch may be curved in the vertical plane as well. Such dams are usually built from a series of thin vertical blocks that are keyed together, with water stops between the blocks. Variations of arch dams include multi-arch dams, in which more than one curved section is used, and arch gravity dams, which combine some features of the two types.

   A recently developed method for constructing concrete gravity dams involves the use of a relatively weak concrete mix which is placed and compacted in a manner similar to that used for earthfill dams. Roller-compacted concrete has the advantages of decreased cost and time. In addition, there are no joints where seepage could occur.

3. *Other Types*—Various construction techniques could be used in a single dam. For example, a dam could include an earthen or rockfill embankment as well as a portion made of concrete. In such a case, the concrete section would normally contain the spillway or other outlet works.

   A recent design for low-head dams (with a minimal height of water behind the dam) uses inflatable rubber or plastic materials anchored at the bottom by a concrete slab.

   Some dams are constructed for special purposes, such as diversion of water, or permit construction of

Figure 2.2
Concrete Gravity Dam

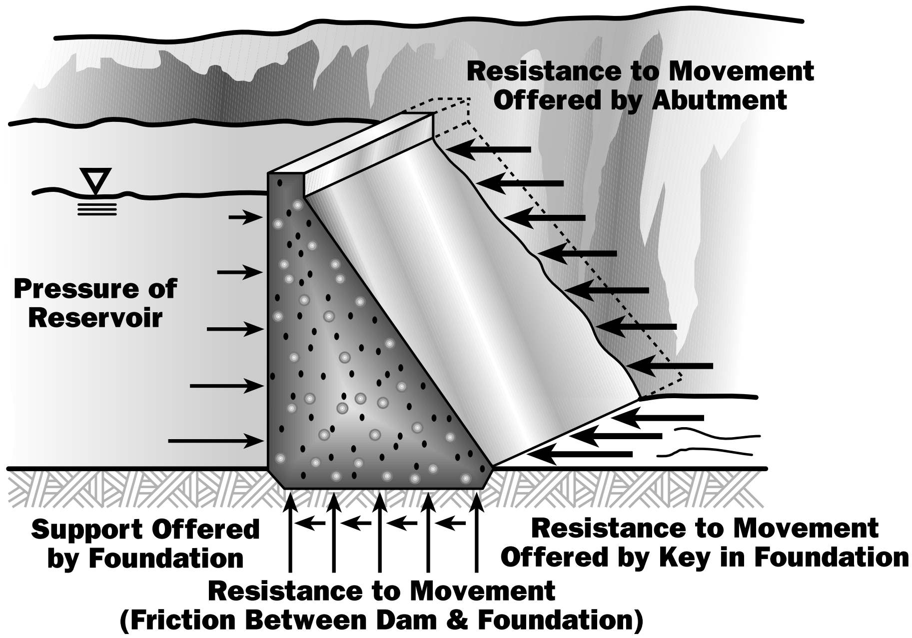
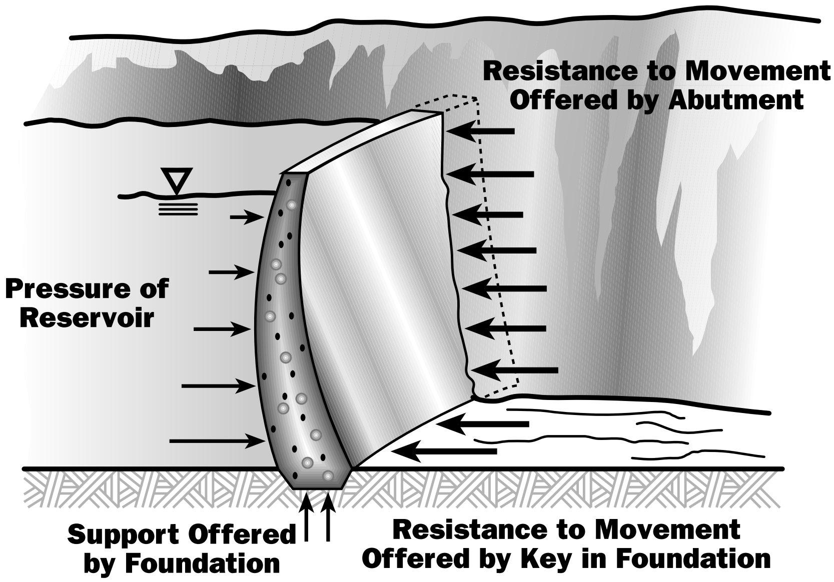


Figure 2.3
Concrete Arch Dam



other facilities in river valleys. These dams are called *diversion dams* and *cofferdams*, respectively.

2.3 Water-Retention Ability

Because the purpose of a dam is to retain water effectively and safely, its water-retention ability is of prime importance. Water may pass from the reservoir to the downstream side of a dam by:

(1) Seeping through the dam.
(2) Seeping through the abutments.
(3) Seeping under the dam.
(4) Overtopping the dam.
(5) Passing through the outlet works.
(6) Passing through or over a service (primary) spillway.
(7) Passing over an emergency spillway.

The first three modes are considered undesirable, particularly if the seepage is not limited in area or volume. Overtopping of an embankment dam is also very undesirable because the embankment material may be eroded away. Additionally, only few concrete dams have been designed to be overtopped. Water normally leaves a dam by passing through an outlet works or a service spillway; it should pass over an emergency spillway only during periods of very high reservoir levels and high water inflow.

A. **Seepage Through a Dam**—All embankment dams and most concrete dams allow some seepage. The earth or other material used to construct embankment dams has some permeability, and water under pressure from the reservoir will eventually seep through. However, it is important to control the quantity of seepage by using low-permeability materials in construction and by channeling and restricting the flow so that embankment materials do not erode.

Seepage through a concrete dam is usually minimal and is almost always through joints between blocks, or through cracks or deteriorated concrete which may have developed. Maintenance of these joints and cracks is therefore essential. The seepage water should be collected and channelized, so that its quantity can be measured and erosion minimized.

B. **Seepage Around a Dam**—Seepage under a dam, through the dam foundation material, or around the ends of a dam through the abutment materials may become a serious problem if the flow is large or of sufficient velocity to cause erosion. Seepage under a dam also creates high hydrostatic uplift (pore-water) pressure, which has the effect of diminishing the weight of the dam, making it less stable.

Seepage through abutments or foundations can dissolve the constituents of certain rocks such as limestone, dolomite, or gypsum so that any cracks or joints in the rock become progressively larger and in turn allow more seepage. Abutment or foundation seepage may also result in "piping" internal erosion, in which the flow of water is fast enough to erode away small particles of soil. This erosion progresses from the water exit point backward to the entrance point. When that point is reached, water may then flow without restriction, resulting in even greater erosion and probable dam failure.

Obviously, large, unrestricted seepage is undesirable. To minimize this possibility, dams are constructed with internal impermeable barriers and internal drainage facilities such as drainpipes or filter systems, or other drainage systems such as toe, blanket, or chimney drains.

Flow through a dam foundation may be diminished by grouting known or suspected highly permeable material, constructing a cutoff wall or trench below a dam, or constructing an upstream impermeable blanket. Figure 2.1 illustrates a cutoff trench.

In summary, the overall water retention ability of a dam depends on its permeability, the abutments, the foundation, and the efforts made to reduce that permeability or restrict the flow of water through these components. Should high permeability occur, seepage can lead to piping, which will likely result in failure.

2.4 Release of Water

Intentional release of water, as stated earlier, is confined to water releases through a service spillway or outlet works or over emergency spillways.

A. **Service (Principal) or Mechanical Spillway**—The service (principal) or mechanical spillway maintains the normal water level in the reservoir. Its function is to pass expected flood flows past the dam safely and without erosion. It may consist of a pipe through the dam or a system of gates that discharge water over the top into a concrete spillway . Either method uses the overflow principle. When the reservoir reaches a certain level, water flows into a standpipe or riser pipe or over a gate. Intake structures for spillways must have systems that prevent clogging by trash or debris.

B. **Drawdown Facility**—All dams should have some type of drawdown facility which can:
   - Quickly lower the water level if failure of the dam is imminent.
   - Serve the operational purposes of the reservoir.
   - Lower the water level for dam repairs.
   - Purposely fluctuate the pool level to kill weeds and mosquitoes.

   The valve regulating the drawdown facility should be on the upstream end of the conduit to minimize the risk to the dam posed by a possible internal rupture of the pipe .

C. **Emergency (Auxiliary) Spillway**—As the name implies, an emergency spillway functions during emergency conditions to prevent overtopping of a dam. A typical emergency spillway is an excavated channel in earth or rock near one abutment of a dam. An emergency spillway should always discharge away from the toe of a dam to avoid its erosion. Furthermore, the spillway should be constructed in such a manner that the spillway itself will not seriously erode when it is in use. Obviously, erosional failure of the spillway could be as catastrophic as failure of the dam itself. An emergency spillway should be sized to convey the so-called "design flood"—the rare, large-magnitude flood used to establish design criteria. The spillways of many existing dams are now considered undersized because standards for the design flood have increased over the years.