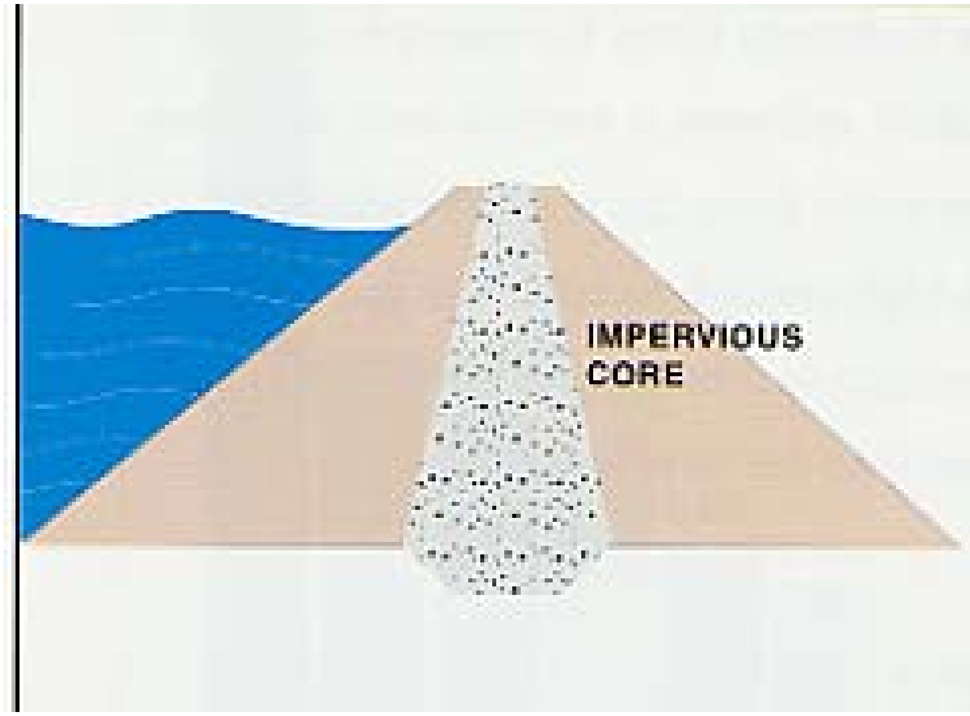
4.7 Dam Failures / Breaches

The purpose of a dam is to impound (store) water, wastewater or liquid borne materials for any of several reasons, e.g. flood control, human water supply, irrigation, livestock water supply, energy generation, containment of mine tailings, recreation, or pollution control. Many dams fulfill a combination of the above functions.

Manmade dams may be classified according to the type of construction material 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 to the purpose of the dam.

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.

Embankment dams are the most common type of dam in use today. They have the general shape shown here.



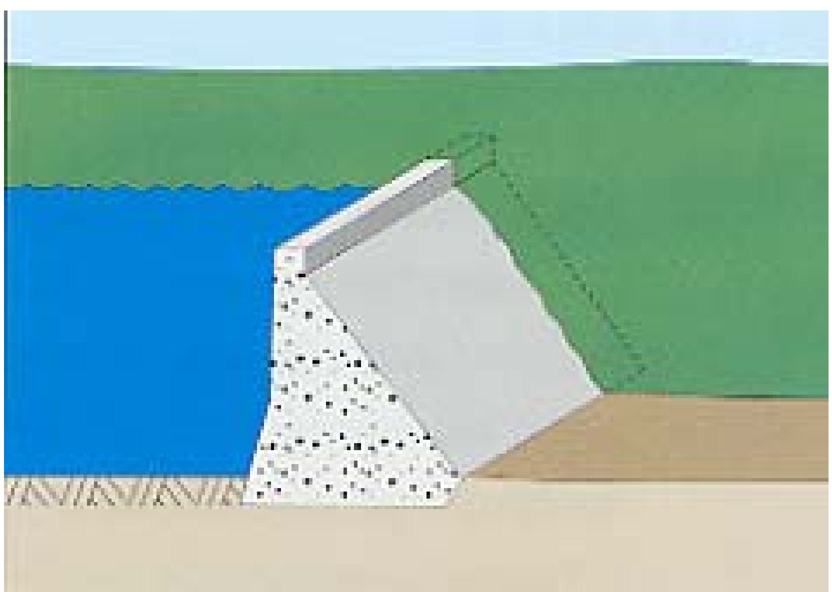
Materials used for embankment dams include natural soil or rock, or waste materials obtained from mining or milling operations. An embankment dam is termed an “earthfill” or “rockfill” dam depending on whether it is comprised of compacted earth or mostly compacted or dumped rock.

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

Concrete dams may be categorized into gravity and arch dams according to the designs used to resist the stress due to reservoir water pressure.

Typical concrete gravity dams are shown here and are the most common form of concrete dam. The mass weight of 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.

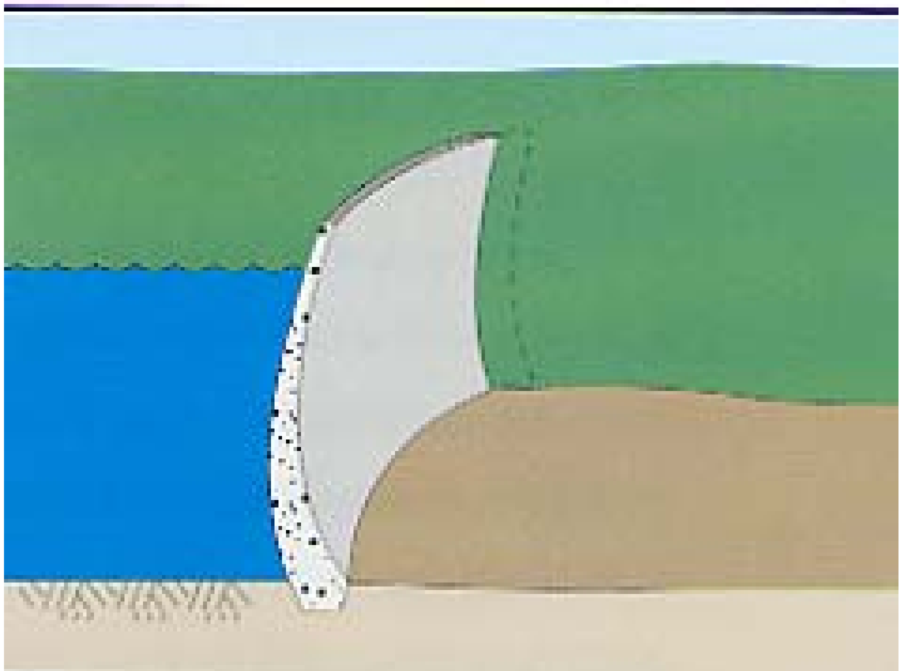


Gravity dams are constructed of vertical blocks of concrete with flexible seals in the joints between the blocks.

Concrete arch dams are typically rather thin in cross-section. 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 constructed of a series of thin vertical blocks that are keyed together; barriers to stop water from flowing are provided between 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 of dams.



All dams have two main jobs, water retention and seepage control. The main purpose of a dam is to retain water effectively and safely. The water retention ability of a dam is of prime importance for dam safety. Water may pass from the reservoir to the downstream side of a dam by:

- Passing through the main spillway or outlet works
- Passing over an auxiliary spillway
- Overtopping the dam
- Seepage through the abutments
- Seepage under the dam

Overtopping of an embankment dam is very undesirable because the embankment materials may be eroded away. Additionally, only a small number of concrete dams have been designed to be overtopped. Water normally passes through the main spillway or outlet works; it should pass over an auxiliary spillway only during periods of high reservoir levels and high water inflow. All embankment and most concrete dams have some seepage. However, it is important to control the seepage to prevent internal erosion and instability. Proper dam construction, and maintenance and monitoring of seepage provide this control.

Intentional release of water is confined to water releases through outlet works and spillways. A dam typically has a principal or mechanical spillway and a drawdown facility. Additionally, some dams are equipped with auxiliary spillways to manage extreme floods.

Outlet Works—In addition to spillways that ensure that the reservoir does not overtop the dam, outlet works may be provided so that water can be drawn continuously, or as needed, from the reservoir. They also provide a way to draw down the reservoir for repair or safety concerns. Water withdrawn may be discharged into the river below the dam, run through generators to provide hydroelectric power, or used for irrigation. Dam outlets usually consist of pipes, box culverts or tunnels with intake inverts near minimum reservoir level. Such outlets are provided with gates or valves to regulate the flow rate.

Spillways—The most common type of spillway is an ungated concrete chute. This chute may be located over the dam or through the abutment. To permit maximum use of storage volume, movable gates are sometimes installed above the crest to control discharge. Many smaller dams have a pipe and riser spillway, used to carry most flows, and a vegetated earth or rockcut spillway through an abutment to carry infrequent high flood flows. In dams such as those on the Mississippi River, flood discharges are of such magnitude that the spillway occupies the entire width of the dam and the overall structure appears as a succession of vertical piers supporting movable gates. High arch-type dams in rock canyons usually have downstream faces too steep for an overflow spillway. In Hoover Dam on the Colorado River, for example, a shaft spillway is used. In shaft spillways, a vertical shaft upstream from the dam drains water from the reservoir when the water level becomes high enough to enter the shaft or riser; the vertical shaft connects to a horizontal conduit through the dam or abutment into the river below.
Causes of Dam Failures

Overtopping of a dam is often a precursor of dam failure. National statistics show that overtopping due to inadequate spillway design, debris blockage of spillways, or settlement of the dam crest account for approximately 34% of all U.S. dam failures.

Foundation defects, including settlement and slope instability, cause about 30% of all dam failures.

Another 20% of U.S. dam failures have been caused by piping (internal erosion caused by seepage). Seepage often occurs around hydraulic structures, such as pipes and spillways; through animal burrows; around roots of woody vegetation; and through cracks in dams, dam appurtenances, and dam foundations.

Other causes of dam failures include structural failure of the materials used in dam construction and inadequate maintenance.[64]

Kentucky Dam Safety starts with KRS 151.293, Section 6, that authorizes the Energy and Environment Cabinet to inspect existing structures that meet the definition of a dam. The Dam Safety and Floodplain Compliance Section of the Water Infrastructure Branch maintain a list of these structures in an inventory database. In determining the frequency of inspection of a particular dam, the cabinet takes into consideration the size and type, topography, geology, soil condition, hydrology, climate, use of the reservoir, the lands lying in the floodplain downstream and the hazard classification of the dam. These factors go into the Dam Classifications of regulated dams.

Table 4.7(1) - KY DOW Dam Safety Classifications

High Hazard (C)	Structures located such that failure may cause loss of life or serious damage to houses, industrial or commercial buildings, important public utilities, main highways or

[64] Association of State Dam Safety Officials, Introduction to Dams; http://www.damsafety.org/news/?p=e4cda171-b510-4a91-aa30-067140346bb2

	major railroads.
Moderate Hazard (B)	Structures located such that failure may cause significant damage to property and project operation, but loss of human life is not envisioned.
Low Hazard (A)	Structures located such that failure would cause loss of the structure itself but little or no additional damage to other property.
High- and moderate-hazard dams are inspected every two years. Low-hazard dams are inspected every five years. If the structure meets all the necessary requirements as outlined in Engineering Memorandum No. 5, a Certificate of Inspection is issued to the owner. Otherwise, the owner is notified of any deficiencies.	

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[65] Division of Water Dam Safety Downloads, Dam Safety Information; http://water.ky.gov/damsafety/Documents/DamSafety.doc

Table 4.7(2) – Kentucky Regulated Dams - Lake Cumberland Region

Dam Name	Hazard Rating	County
Pinewood Country Club Lake Dam	A	Adair
Larry Legg Lake Dam	A	Adair
David Tarter	C	Adair
Hickory Hills Country Club Dam	A	Casey
Devil Harbor Lake	C	Casey
Liberty Reservoir	C	Casey
Keystone Foods Dam (North)	B	Clinton
Keystone Foods Dam (West)	B	Clinton
Stearns Reservoir Dam	A	Mccreary
Laurel Creek Lake Dam	B	Mccreary
Cooper Dam	A	Mccreary
Drexel Campbell Lake (Old)	A	Mccreary
Drexel Campbell Lake (New)	A	Mccreary
Bridge Fork Dam	B	Mccreary
Worley Lake Dam	A	Mccreary
Walter Baird Dam	A	Mccreary
Eagle Falls Resort & Restaurant	B	Mccreary
Somerset Reservoir Dam	A	Pulaski
East Ky Power Corp Ash Storage Dam No 1	A	Pulaski
Mcclellan Prewitt Dam	A	Pulaski
Eagles Nest Dam (Lower)	A	Pulaski
East Kentucky Power Ash Storage Dam (2)	C	Pulaski
Ikerd Farms Lake	A	Pulaski
Eagles Nest Dam (Upper)	A	Pulaski
Parker Delt Lake Dam	A	Pulaski
Mcclure Dam Farm Dam	A	Russell
Clifton Antle	A	Russell
Leo Reader Dam	A	Russell
Ansel Carrender Dam	A	Russell
Oakland Lake Dam	A	Taylor
Ferrill Reservoir Dam	A	Taylor
Porter Reservoir Dam	A	Taylor
Caulk Lake Dam	A	Taylor
Spurlington Lake Dam	A	Taylor
Campbellsville Reservoir Dam	B	Taylor
Glenn Hawkins Lake (Upper)	A	Taylor
Glenn Hawkins Lake (Lower)	A	Taylor

The National Inventory of Dams (NID) is a database of dams in the United States which was developed and is maintained by the USACE. Congress authorized the USACE to inventory dams as part of the 1972 National Dam Inspection Act. Several subsequent acts have authorized maintenance of the NID and provided funding. The USACE collaborates with FEMA and state regulatory offices to collect data on dams. The goal of the NID is to include all dams in the United States which meet at least one of the following criteria:

Table 4.7(3) – National Inventory of Dams (NID) Dam Safety Classifications

High hazard classification	loss of at least one human life is likely if the dam fails
Significant hazard classification	possible loss of human life and likely significant propert y or environmental destruction
Low hazard classification	Equal or exceed 25 feet in height and exceed 15 acre-feet in storage or Equal or exceed 50 acre-feet storage and exceed 6 feet in height, dams which do not meet the criteria specified are not included in the NID even if they are regulated according to state criteria. In some states, the number of these dams is several times the number of dams included in the NID.

[66]

Table 4.7(4) – Kentucky/LCADD NID Dams Over 50'

Dam Name	**NIDID**	**Hazard**	**Own Name**	**Year Completed**	**County**
Liberty Reservoir Dam	ky00820	H	City Of Liberty	1979	Casey
Bridge Fork Dam	ky00568	S	Norfolk Southern Railroad	1930	McCreary
Cumberland Falls Pay Lake Dam	ky00860	S	The Falls Incorporated	1960	McCreary
East Ky. Power Corp Ash Storage Dam (1)	ky00398	L	East Ky Power Coop	1961	Pulaski
Wolf Creek Dam - Lake Cumberland	ky03010	H	Celrn	1951	Russell
Green River Lake Dam	ky03007	H	Celrl	1969	Taylor
Caulk Lake Dam	ky00137	L	Wallace Garrett	1950	Taylor

No record could be found of any previous dam failures in the LCADD region. The only past dam emergency action was taken on Wolf Creek Dam on the Cumberland River. The US Army Corps of Engineers placed Wolf Creek Dam at high risk for failure in 2005-2006.

[66] CorpsMap: The National Inventory of Dams (NID); http://nid.usace.army.mil/cm_apex/f?p=838:1:0::NO

Wolf Creek Dam was designed and constructed during the period 1938-1952, the 5,736 foot-long dam is a combination rolled earth fill and concrete gravity structure. It has a maximum height of 258 feet above founding level. A six- generator-unit power plant, with a capacity of 270,000 KW, is located immediately downstream. US Highway 127 crosses the top of the dam. Lake Cumberland, created by the dam, impounds 6,089,000 acre-feet at its maximum pool elevation of 760. It is the largest reservoir east of the Mississippi and the ninth largest in the United States.

In 1968, muddy flows in the tailrace and two sinkholes near the downstream toe of the embankment signaled serious reservoir seepage problems. Investigations indicated the problems were due to the karst geology of the site characterized by an extensive interconnected network of solution channels in the limestone foundation. Piping of filling materials in these features and collapse of overburden and embankment into the voids caused the problems. The District immediately began an emergency investigation and grouting program between 1968 and 1970 that is generally credited with saving the dam. However, grouting was not a long-term fix and a more permanent solution was sought. After studying numerous alternatives, the District chose to construct a concrete diaphragm wall through the earth embankment into the rock foundation to block the seepage. This wall was constructed between 1975 and 1979.

Since completion of the wall in 1979, Wolf Creek Dam personnel have continued to closely monitor the project. Key instrumentation readings, persistent and increasing wet areas, and investigative borings that encountered soft, wet material at depth in the embankment confirm solution features still exist that have not been cut off. While the original wall interrupted the progression of erosion, seepage has since found new paths under and around the wall and perhaps through defects in the wall itself as erosion of solution features continues.

The U.S. Army Corps of Engineers Nashville District completed a Major Rehabilitation Report to evaluate alternatives to improve the long-term reliability of the Wolf Creek Dam. The recommended alternative will cost about $594 million. The main phase of construction began in March 2006 and was completed in March 2013 when the last concrete was placed for the 4,000-foot-long barrier wall through the dam’s earthen embankment.

In January 2007 a decision was made to lower the lake levels to the 680-foot elevation to reduce pressures on the dam. This lake level was maintained until the spring of 2013 when the barrier wall was completed. The lake was partially raised during 2013 as test on the barrier wall and in 2014 the lake levels returned to historic levels after the barrier wall performed as expected to the higher lake levels.[67]

[67] U.S. Army Corps of Engineers Nashville District, Wolf Creek Dam Safety Rehabilitation Project; http://www.lrn.usace.army.mil/Missions/Current-Projects/Construction/Wolf-Creek-Dam-Safety-Rehabilitation-Project/

Summary

Hazard Location:

- Dam/Levee Failures.
  - The Lake Cumberland Region has 37 dam sites with two major lakes (Cumberland and Green River Lakes) and the remaining being generally small impoundments

Potential Damage (All Hazards):

- Dam/Levee Failures.
  - Low potential with possibility of major damage and flooding below Green River Lake and Lake Cumberland
  - Low potential of damage and flooding on remaining dams

Scale / Extent:

- Dam/Levee Failures.
  - Minor Dam failure could release a wall of water up to 1 foot high, typical of privately owned dams in the Lake Cumberland Region
  - Major Dam failure could release a wall of water greater than 6 feet high, typical of larger high hazard and significant hazard dams in Region
  - A Major Dam failure could cause flooding along Cumberland and Green Rivers causing large injuries and damage to property in cities as far away as Nashville, TN and the Ohio River

Previous Occurrences:

- Dam/Levee Failures.
  - A dam failure within Lake Cumberland has never occurred
  - The repairs to Wolf Creek Dam on Lake Cumberland has caused economic losses to tourism

Likelihood of Future Occurrences:

- Dam/Levee Failures.
  - Possible, however a damaging failure is unlikely