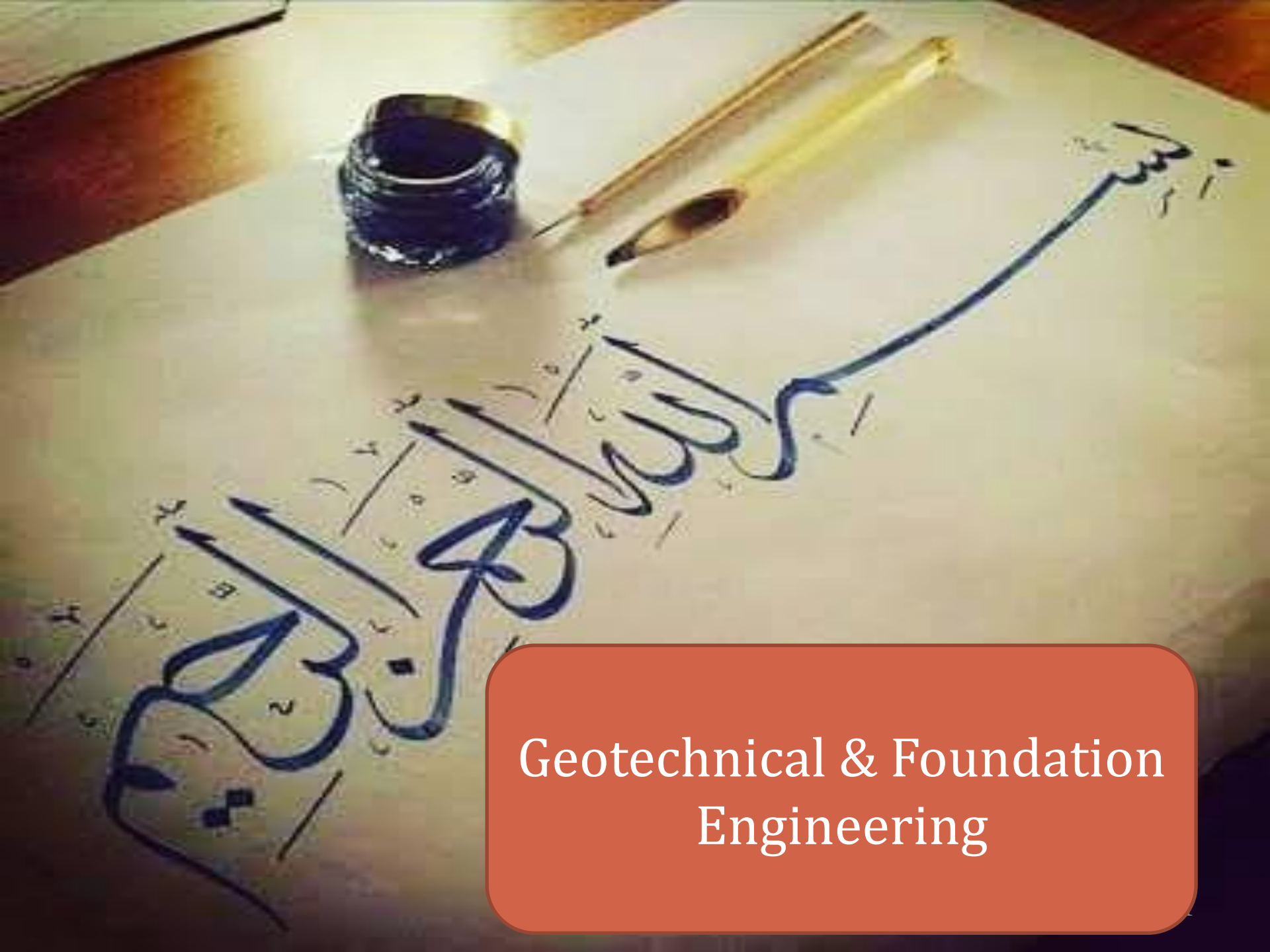

Geotechnical & Foundation Engineering

Geotechnical Engineering in Dams

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What is Geotechnical Engineering?

- Geo = earth
- Technical = having special knowledge
- What do Geotechnical Engineers do?
  - Evaluate soil properties to fully understand the below surface conditions of an area.
  - Design the foundations that structures will be built on.

Geotechnical Engineering in Dams

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Dam Engineering

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Why do we need Geotechnical Engineers?

- Questions Geotechnical Engineers answer:
  - How tall can we make a building on this ground?
  - What kind of foundation will be able to support this structure?
  - Can we build a road, bridge or dam here?
  - If we cut through this mountain, will the slopes collapse down onto the road?

Dam Engineering

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When do we need Geotechnical Engineers?

- In order to have a successful structure, you have to have a successful foundation.
- If the foundation fails then the structure will fail.
- Need to protect against differential settlement, rock slides (slope stability), flooding and many other types of failures.

- So to answer the question…Geotechnical Engineers are needed whenever there is construction!

Dam Engineering

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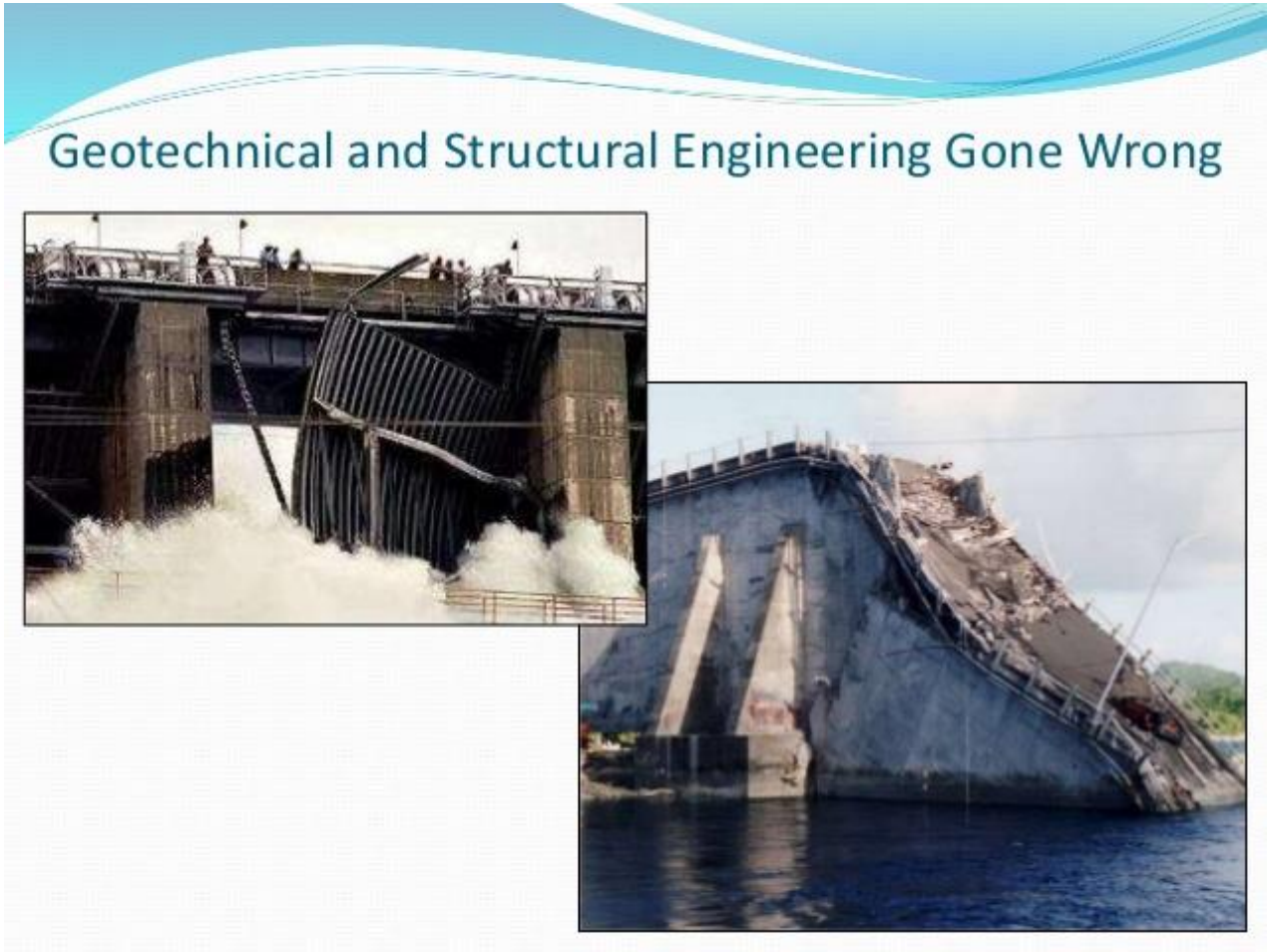

Dam Engineering

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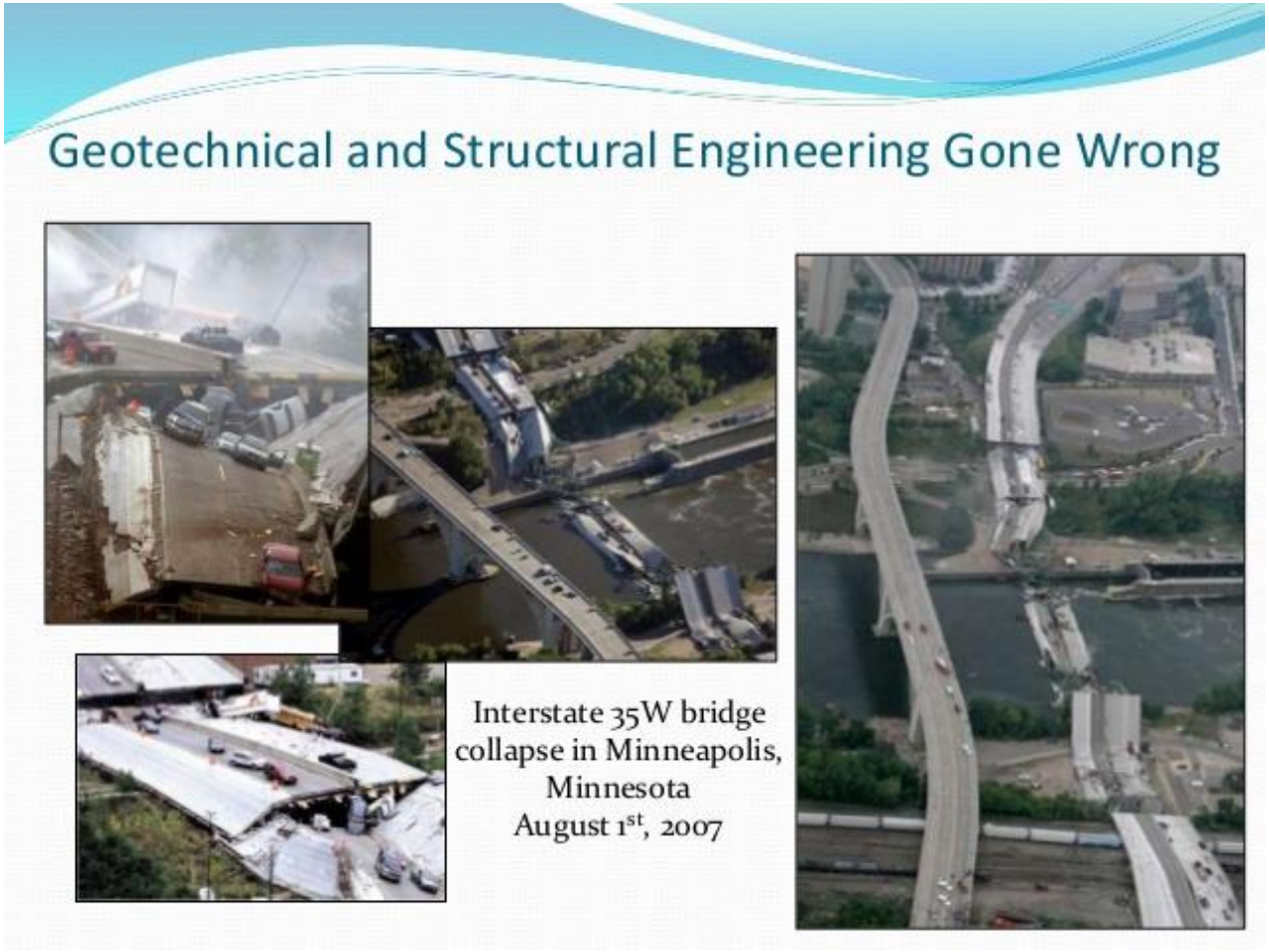
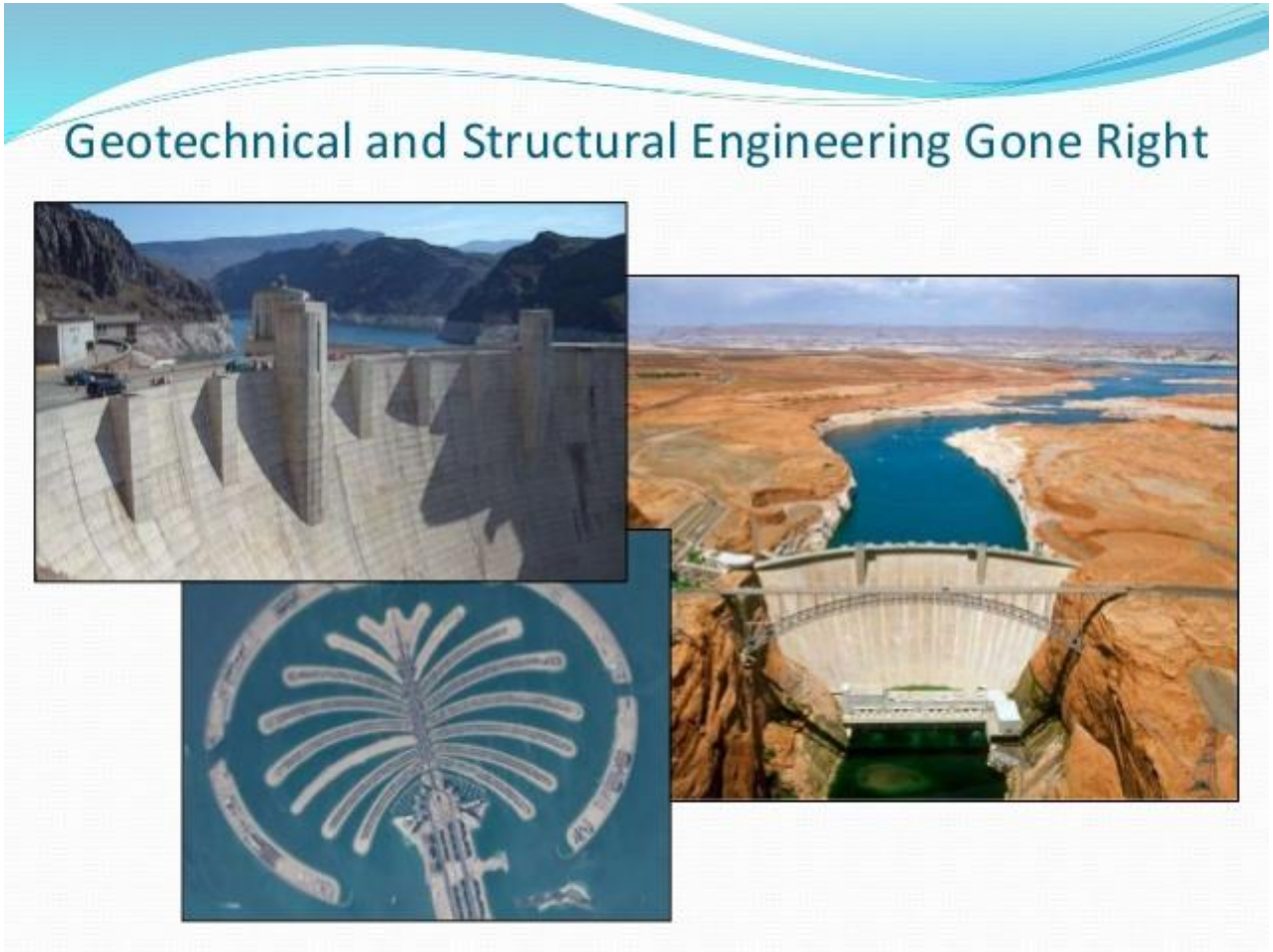


Dam Engineering



Dam Engineering

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What is a Dam?

- A dam is a barrier that impounds water or underground streams; they serve the purpose of retaining water.
- Hydropower and pumped-storage hydroelectricity are often used in conjunction with dams to generate electricity.
- A dam can also be used to collect water or for the storage of water, which can be evenly distributed between locations.

Dam Engineering

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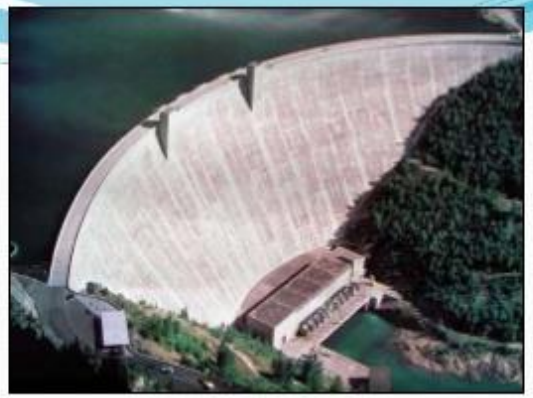
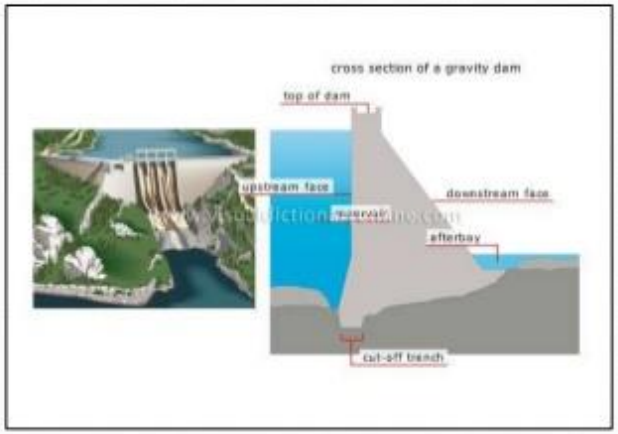
- Arch Dams
  - Distributes force to the walls of the valley or canyon



Types of Dams...



- Gravity Dam
  - Uses the weight of the concrete to absorb the forces of the water

Dam Engineering

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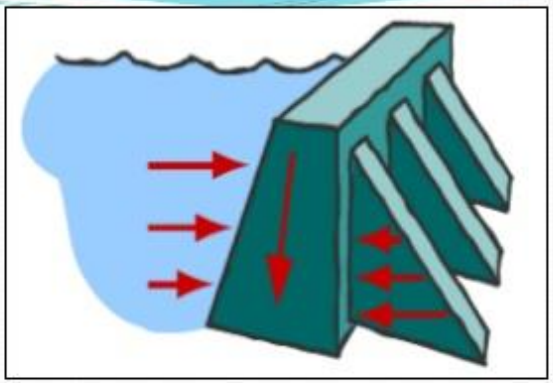
Types of Dams...

- Buttress Dam

-Uses buttresses to transfer the force of the water to the foundation



- Embankment Dam

-Uses mounds of soil or rock with an impervious core to hold the forces of the water

Dam Engineering

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REASONS TO BUILD A DAM

Dams have two main functions.

- The first is to store water to compensate for fluctuations in river flow or in demand for water and energy.
- The second to raise the level of the water upstream to enable water to be diverted into a canal or to increase 'hydraulic head' — the difference in height between the surface of a reservoir and the river downstream.
- The creation of storage and head allow
  - Dams to generate electricity (hydropower provides nearly a fifth of the world's electricity)
  - To supply water for agriculture, industries and households
  - To control flooding
  - To assist river navigation by providing regular flows and drowning rapids.
- Other reasons for building large dams include reservoir fisheries and leisure activities such as boating.

Dam Engineering

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ANCIENT DAMS

- The earliest known dam is the **Jawa Dam** in Jordan, 100 kilometres (62 mi) northeast of the capital Amman.
- This gravity dam featured an originally 9-metre-high (30 ft) and 1 m-wide (3.3 ft) stone wall, supported by a 50 m-wide (160 ft) earth rampart.
- The structure is dated to 3000 BC

Dam Engineering

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ANCIENT DAMS

Sadd-el-Kafara Dam, Egypt
2800-2600 BC

Great Dam of Marib, Yemen
1750-1700 BC

Dam Engineering

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ROMAN ENGINEERING

CHARACTERISTICS

- Larger dam structures
- Large reservoir dams
- Pioneering use of water-proof hydraulic mortar

DESIGNS USED

- Embankment dams
- Masonry gravity dams
- Arch-gravity dams
- Arch dams
- Buttress dams
- Multiple arch buttress dams
- First to build dam bridges
- Hydropower through water wheels
- Water supply

Dam Engineering

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ROMAN ENGINEERING

Remains of the Band-e Kaisar dam, Iran, built by the Romans in the 3rd century AD

The Roman dam at Cornalvo, Spain has been in use for almost two millennia.

Dam Engineering

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EARLY 19th CENTURY

Mir Alam dam, Hyderabad, India
Built in 1804 by Royal Engineers
,British Empire

Jones Falls Dam, Ontario Canada
When completed in 1832, the
Jones Falls dam was the largest dam
in North America

The 75-miles dam near
Warwick, Australia
Built in 1880
World's first concrete arch
dam

Dam Engineering

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LARGE DAMS

- The era of large dams was initiated with the construction of the Aswan Low Dam in Egypt in 1902 by the British.
- When initially constructed between 1899 and 1902, nothing of its scale had ever been attempted
- On completion, it was the largest masonry dam in the world.

Dam Engineering

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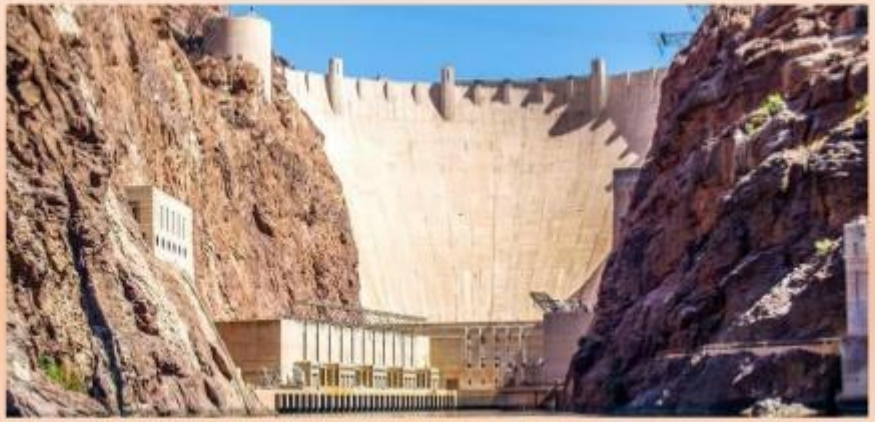
HOOVER DAM

- The Hoover Dam is a massive concrete arch-gravity dam
- Constructed in the black canyon of the Colorado river, on the border between the US states of Arizona and Nevada between 1931 and 1936.
- Such a large concrete structure had never been built before, and some of the techniques were unproven.



Dam Engineering

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DIFFERENT PARTS & TERMINOLOGIES OF DAMS

- **Crest**: The top of the Dam. These may in some cases be used for providing a roadway or walkway over the dam.
- **Parapet walls**: Low Protective walls on either side of the roadway or walkway on the crest.
- **Heel**: Portion of Dam in contact with ground or river-bed at upstream side.
- **Toe**: Portion of dam in contact with ground or river-bed at downstream side.
- **Spillway**: It is the arrangement made (kind of passage) near the top of dam for the passage of surplus/excessive water from the reservoir.
- **Abutments**: The valley slopes on either side of the dam wall to which the left & right end of dam are fixed to.

Dam Engineering

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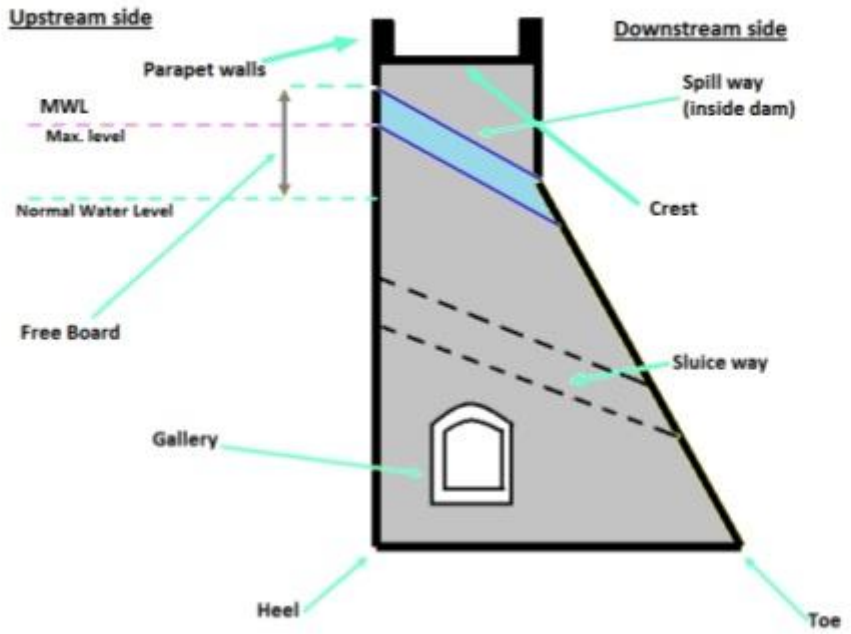

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DIFFERENT PARTS & TERMINOLOGIES OF DAMS

- **Gallery**: Level or gently sloping tunnel like passage (small room like space) at transverse or longitudinal within the dam with drain on floor for seepage water. These are generally provided for having space for drilling grout holes and drainage holes. These may also be used to accommodate the instrumentation for studying the performance of dam.
- **Sluice way**: Opening in the dam near the base, provided to clear the silt accumulation in the reservoir.
- **Free board**: The space between the highest level of water in the reservoir and the top of the dam.
- **Dead Storage level**: Level of permanent storage below which the water will not be withdrawn.
- **Diversion Tunnel**: Tunnel constructed to divert or change the direction of water to bypass the dam construction site. The dam is built while the river flows through the diversion tunnel

Dam Engineering

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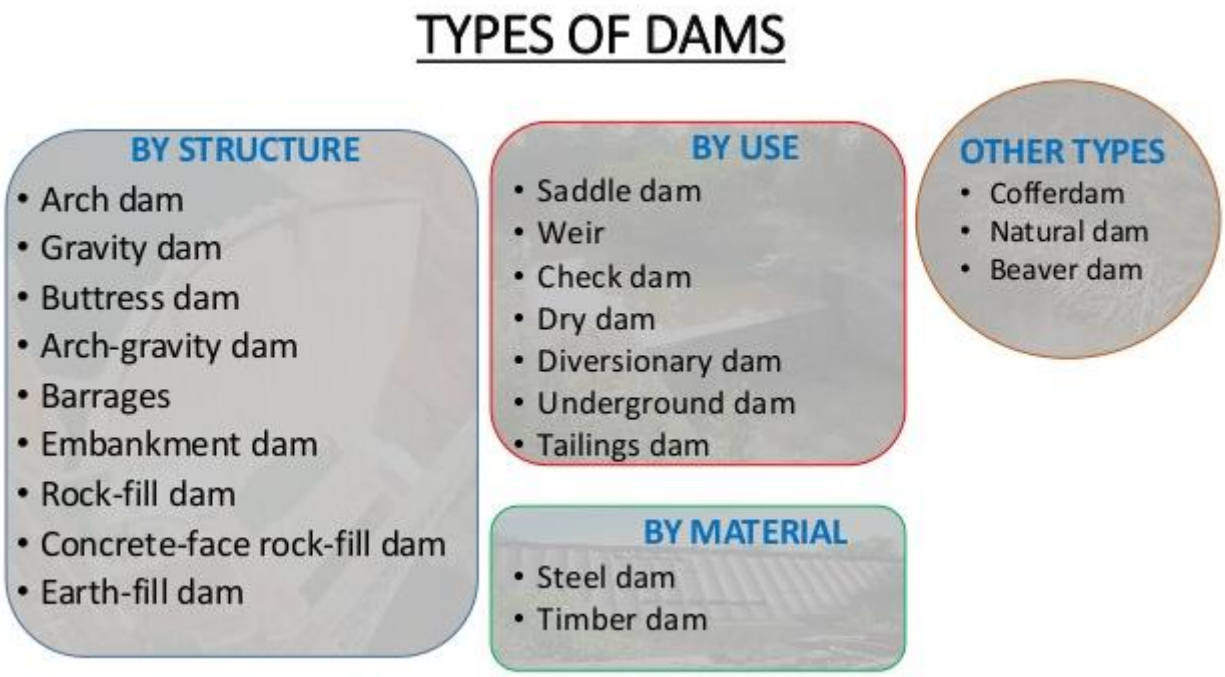

Dam engineering

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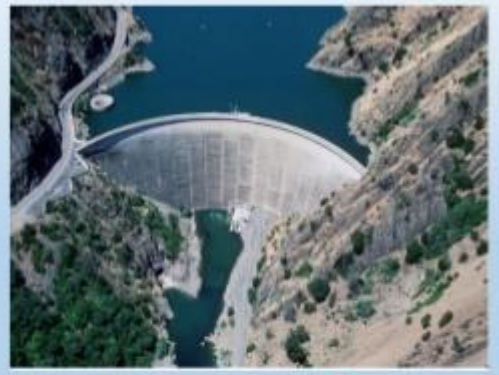
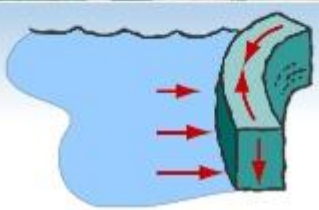
ARCH DAM

- An arch dam is a solid dam made of the bedrock of the surrounding area that is curved upstream in plan.
- The arch dam is designed so that the force of the water against it, known as hydrostatic pressure, presses against the arch, compressing and strengthening the structure as it pushes into its foundation or abutments.
- An arch dam is most suitable for narrow gorges or canyons with steep walls of stable rock to support the structure and stresses.
- Since they are thinner than any other dam type, they require much less construction material, making them economical and practical in remote areas.





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BUTTRESS DAM

- A buttress dam or hollow dam is basically a derivation of a gravity dam with the introduction of intermediate space.
- With a buttress dam, the face of the dam is held by a series of supports or buttresses that are placed at intervals on the downstream side.
- The buttresses work to combat the force of reservoir water from trying to push the dam over.
- The forces or laws of physics working against a buttress dam are exactly the same as those that act on a gravity dam except the vertical load presented by the water on a buttress dam is greater.
- The advantage of a buttress dam is that it typically requires less concrete to construct than a gravity dam.
- The formwork and reinforced steel used in the building of buttresses is expensive, however, and will ultimately offset any costs saved

Dam Engineering

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ARCH-GRAVITY DAMS

- A gravity dam can be combined with an arch dam into an arch-gravity dam for areas with massive amounts of water flow but less material available for a purely gravity dam.
- The inward compression of the dam by the water reduces the lateral (horizontal) force acting on the dam.
- Thus, the gravitation force required by the dam is lessened, i.e. the dam does not need to be so massive.
- This enables thinner dams and saves resources.

Hoover Dam, USA

Dam Engineering

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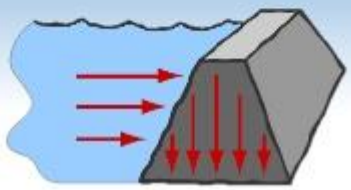
GRAVITY DAM

- A gravity dam is a dam constructed from concrete or stone masonry and designed to hold back water by primarily utilizing the weight of the material alone to resist the horizontal pressure of water pushing against it.
- Gravity dams are designed so that each section of the dam is stable, independent of any other dam section.
- Most gravity dams are straight.
- Some masonry and concrete gravity dams have the dam axis curved to add stability through arch action.



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BARRAGES

- A special kind of dam which consists of a line of large gates that can be opened or closed to control the amount of water passing the dam.
- The gates are set between flanking piers which are responsible for supporting the water load, and are often used to control and stabilize water flow for irrigation systems

Dam Engineering

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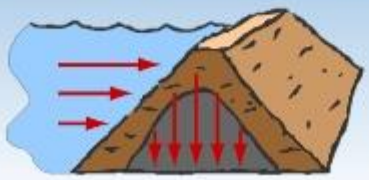
EMBANKMENT DAMS

- They are massive dams made of earth and rock.
- Like gravity dams, embankment dams rely on their heavy weight to resist the force of the water.
- But embankment dams are also armed with a dense, waterproof core that prevents water from seeping through the structure.
- Embankment dams are of two main types, rock-fill and earth-fill dams.



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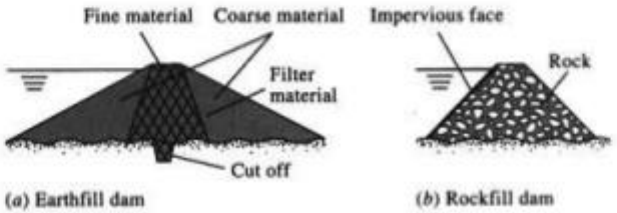
EARTHFILL DAM & ROCK-FILL DAM

- Earthfill dam, also called Earth Dam, or Embankment Dam
- Dam built up by compacting successive layers of earth, using the most impervious materials to form a core and placing more permeable substances on the upstream and downstream sides.
- A facing of crushed stone prevents erosion by wind or rain, and an ample spillway, usually of concrete, protects against catastrophic washout should the water overtop the dam.

- Rock-fill dams are embankments of compacted free-draining granular earth with an impervious zone.
- The earth utilized often contains a high percentage of large particles, hence the term "rock-fill".
- The impervious zone may be on the upstream face and made of masonry, concrete, plastic membrane, steel sheet piles, timber or other material.



Dam Engineering

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Concrete-face Rock-fill Dam (CFRD)

- A concrete-face rock-fill dam (CFRD) is a rock-fill dam with concrete slabs on its upstream face.
- This design provides the concrete slab as an impervious wall to prevent leakage and also a structure without concern for uplift pressure.
- In addition, the CFRD design is flexible for topography, faster to construct and less costly than earth-fill dams.

Mohale Dam, Lesotho

Dam Engineering

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SADDLE DAM & WEIR

Saddle dam is a subsidiary dam of any type constructed across a saddle or low point on the perimeter of a reservoir.

A weir (overflow dam) is a type of small overflow dam that is often used within a river channel to create an impoundment lake for water abstraction purposes and which can also be used for flow measurement or retardation.

Dam Engineering

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CHECK DAM & DRY DAM

- A check dam is a small dam designed to reduce flow velocity and control soil erosion.

- A dry dam, also known as a flood retarding structure, is a dam designed to control flooding.
- It normally holds back no water and allows the channel to flow freely, except during periods of intense flow that would otherwise cause flooding downstream.

Dam Engineering

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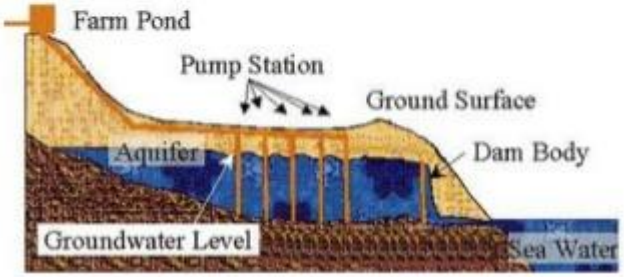
DIVERSIONARY DAM & UNDERGROUND DAM

A diversionary dam is a structure designed to divert all or a portion of the flow of a river from its natural course. The water may be redirected into a canal or tunnel for irrigation and/or hydroelectric power production.

- Underground dams are used to trap groundwater and store all or most of it below the surface for extended use in a localized area.
- In some cases they are also built to prevent saltwater from intruding into a freshwater aquifer.
- Underground dams are typically constructed in areas where water resources are minimal and need to be efficiently stored, such as in deserts and on islands



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TAILINGS DAM

- A tailings dam is typically an earth-fill embankment dam used to store by-products, which are produced during mining operations after separating the valuable fraction from the uneconomic fraction of an ore.

Dam Engineering

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STEEL DAM & TIMBER DAM

- A steel dam is a type of dam briefly experimented with around the start of the 20th century which uses steel plating (at an angle) and load-bearing beams as the structure.
- The steel dams were an (arguably failed) experiment.

- Timber dams were widely used in the early part of the industrial revolution and in frontier areas due to ease and speed of construction.
- Rarely built in modern times because of their relatively short lifespan and the limited height to which they can be built, timber dams must be kept constantly wet in order to maintain their water retention properties and limit deterioration by rot, similar to a barrel.

Dam Engineering

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COFFERDAM & NATURAL DAM

- A cofferdam (also called a coffer) is a temporary enclosure built within, or in pairs across, a body of water and constructed to allow the enclosed area to be pumped out.
- Such structures are typically dismantled after the ultimate work is completed.

- Dams can also be created by natural geological forces
- Natural disasters such as earthquakes and landslides frequently create landslide dams in mountainous regions.
- Natural dams often pose significant hazards to human settlements and infrastructure.

Dam Engineering

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BEAVER DAM

- Beavers create dams primarily out of mud and sticks to flood a particular habitable area.
- By flooding a parcel of land, beavers can navigate below or near the surface and remain relatively well hidden or protected from predators.
- The flooded region also allows beavers access to food, especially during the winter.

Dam Engineering

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POWER GENERATION PLANT

- Hydropower is the leading renewable source for electricity generation globally, supplying 71% of all renewable electricity at the end of 2015.
- Undeveloped potential is approximately 10 000 TWh/y worldwide.
- The global hydropower capacity increased by more than 30% between 2007 and 2015 accounting to a total of 1209 GW in 2015, of which 145 GW is pumped storage.

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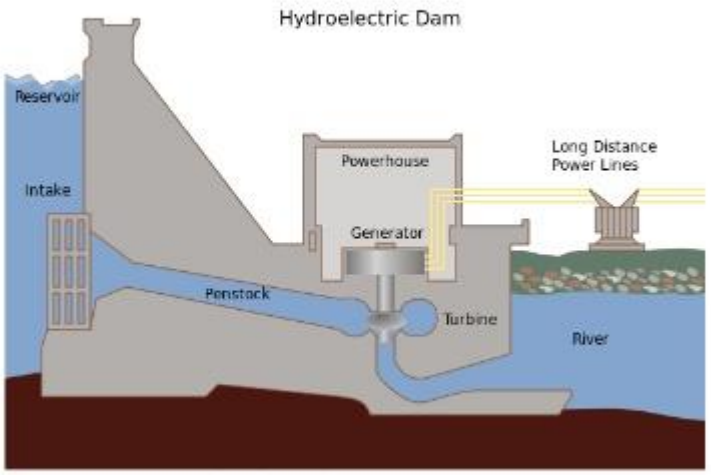
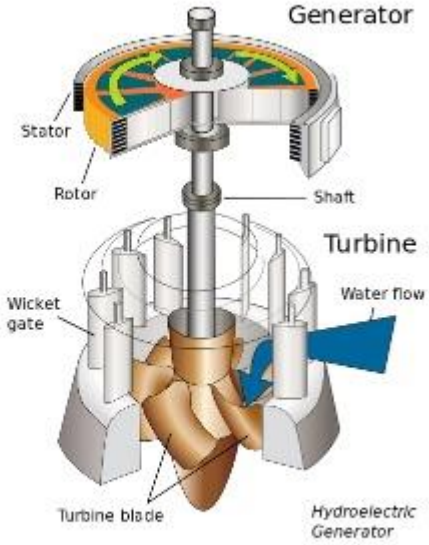


Hydroelectric dam in cross section



Hydraulic turbine and electric generator

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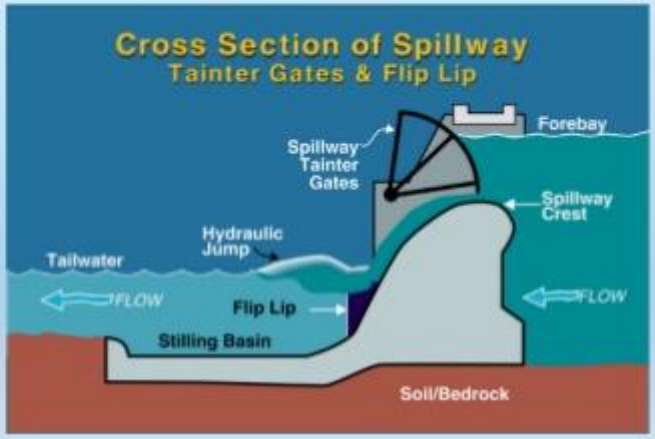
SPILLWAYS

- A spillway is a section of a dam designed to pass water from the upstream side of a dam to the downstream side.
- Many spillways have floodgates designed to control the flow through the spillway.



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THREE GORGES DAM, CHINA

The Three Gorges Dam, the hydroelectric dam is the world's largest power station by installed capacity (22,500 MW)

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ITAIPU DAM (BRAZIL-PARAGUAY)

Itaipu is the hydroelectric plant that produces more energy in the world, setting a new world 103,098,366 megawatt hour (MWh) record in 2016 and had surpassed the Three Gorges Dam plant in 2016 and 2015 in energy production.

Dam Engineering

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FACTORS AFFECTING SELECTION OF TYPE OF DAM

- Topography
- Geology and Foundation Conditions
- Availability of materials
- Spillway size and location
- Earthquake zone
- Height of the Dam
- Other factors such as cost of construction and maintenance, life of dam, aesthetics etc.

Dam Engineering

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SELECTION OF DAM SITE

- Suitable foundation must be available.
- For economy, the length of the dam should be as small as possible, and for a given height, it should store the maximum volume of water.
- The general bed level at dam site should preferably be higher than that of the river basin. This will reduce the height of the dam.
- A suitable site for the spillway should be available in the near vicinity.
- Materials required for the construction of dam should be easily available, either locally or in the near vicinity.
- The value of land and property submerged by the proposed dam should be as low as possible.
- The dam site should be easily accessible, so that it can be economically connected to important towns and cities.
- Site for establishing labor colonies and a healthy environment should be available near the site.

Dam engineering

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ADVANTAGES OF DAMS

- Clean, efficient, and reliable form of energy.
- Does not emit any direct pollutants or greenhouse gases.
- While the initial cost is high, they are very inexpensive to operate.
- Electricity generated by hydro-electric power plants is the cheapest electricity generated.
- Dams prevent floods.
- Dams store water for irrigation in summer seasons and dry months. Many desert areas can now farm due to dams and canals that supply water.
- Dams supply water for local drinking needs.
- Allows for fish farming.

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NEGATIVE IMPACT OF DAMS

- In flat basins large dams cause flooding of large tracts of land, destroying local animals and habitats.
- People have to be displaced causing change in life style and customs, even causing emotional scarring. About 40 to 80 million people have been displaced physically by dams worldwide.
- Large amounts of plant life are submerged and decay anaerobically (in the absence of oxygen) generating greenhouse gases like methane. It is estimated that a hydroelectric power plant produces 3.5 times the amount of greenhouse gases as a thermal power plant burning fossil fuels.
- The migratory pattern of river animals like salmon and trout are affected.
- Dams restrict sediments that are responsible for the fertile lands downstream. Farmers use chemical fertilizers and pesticides to compensate for the loss in productivity.
- Salt water intrusion into the deltas means that the saline water cannot be used for irrigation.
- Large dams are breeding grounds for mosquitoes and cause the spread of disease.
- Farmers downstream who used to wait for the flooding of the fields to plant their seeds are affected.
- Dams serve as a heat sink, and the water is hotter than the normal river water. This warm water when released into the river downstream can affect animal life.
- Peak power operations can change the water level thirty to forty feet in one day and can kill the animals staying at the shorelines.
- Around 400,000 km^2 of land worldwide has been submerged due to the construction of dams.

Dam Engineering

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SOLUTION TO THE PROBLEMS

Negative effects on flora, fauna, and the local population can be reduced by the following methods:

- Fish passages should be created to aid in the migration of the fish.
- New dam sites should be chosen with the environmental impacts in mind.
- Local people should be led into confidence and must be suitably re-settled.
- Proper compensation as per the market rate should be given.
- Religious monuments of historic significance should be shifted.
- Endangered species can be relocated.

If the political will to change and do a good job is there a dam can be constructed in a way to minimize its effects on people and the environment.

Dam Engineering

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CONCLUSION

Dams have made an important and significant contribution to human development, and the benefits derived from them have been considerable. Dam building has been one of the most disputed topics affecting the environment today. The push and pull between the pros and cons have created conflicts among different groups. While dams destroy the nature and people surrounding the area in which they are built, they do provide people with water and products from water. The solutions are minimal, but the damages could be decreased depending on the placement of the dam.


Thank you