WATERPOWER
HYDRO BASICS

JULY
15-16, 2024

COLORADO CONVENTION CENTER
DENVER, COLORADO

CO-LOCATED WITH

HYDROVISION INTERNATIONAL

Waterpower Hydro Basics
Harnessing the Water

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Structure Definitions

- Water Retaining Structures
  - Dams, Spillways, Intakes, Powerhouses, Locks
- Water Conveyance Structures
  - Penstocks, tunnels, flumes, canals & ditches
  - Forebays, balancing reservoirs
- Water Regulating Structures
  - Upstream gates, valves, bulkheads, stoplogs, operators
  - Downstream turbine isolation valves, bypass valves

Water Retaining Structures

Dams

- Gravity
- Fill/Embankment
- Structural

Spillways

- Uncontrolled
- Controlled

Design Considerations

Water Retaining Structures - Dams

- Gravity Structures
  - Rely on mass
  - Concrete, RCC, masonry
- Fill/Embankment Dams
  - Rely on frictional resistance of materials and mass
  - Earthfill, rockfill, hydraulic fill, levees
- Structural
  - Rely on their structural configuration
  - Arch dams, buttress, flood walls

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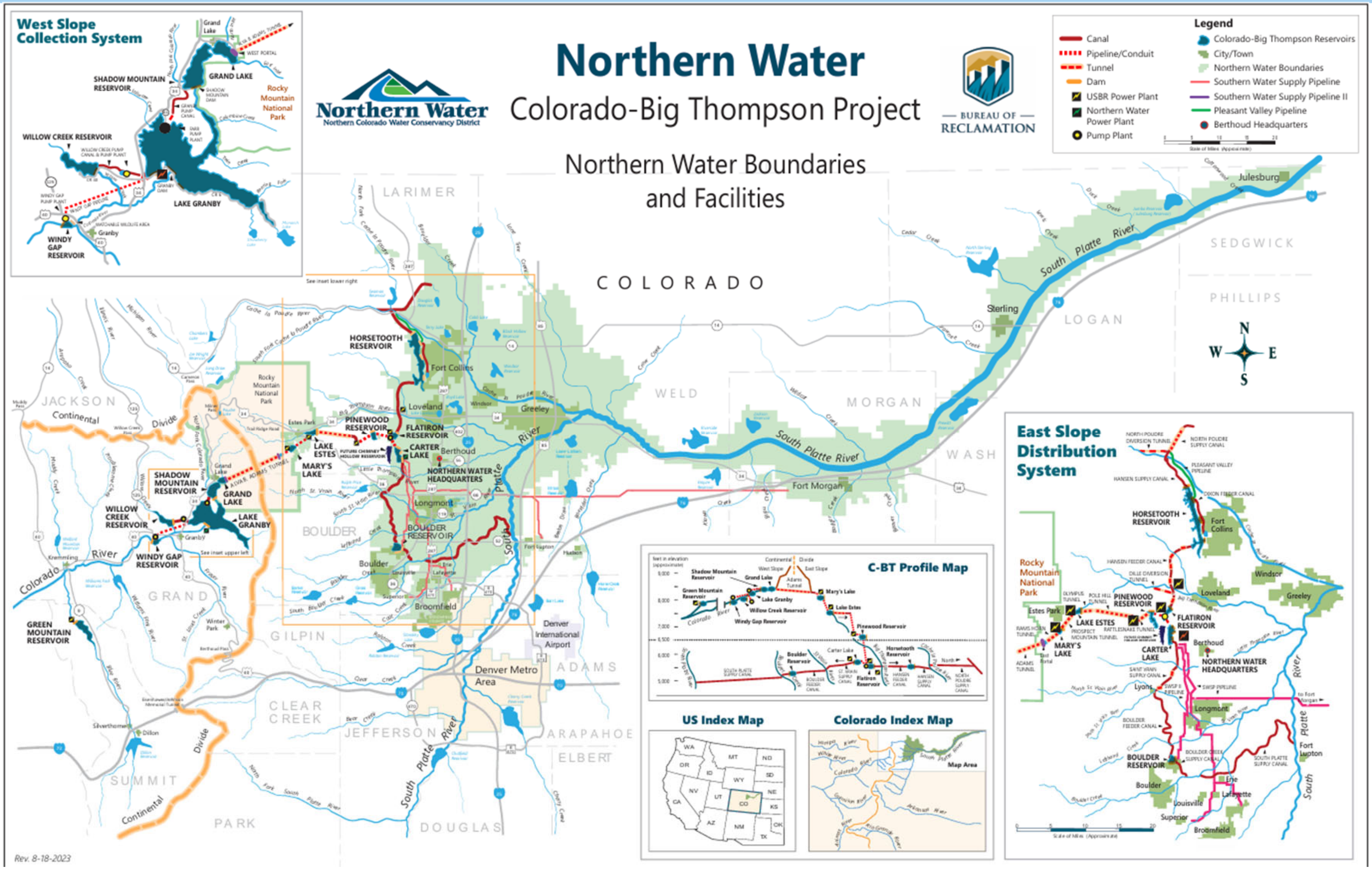

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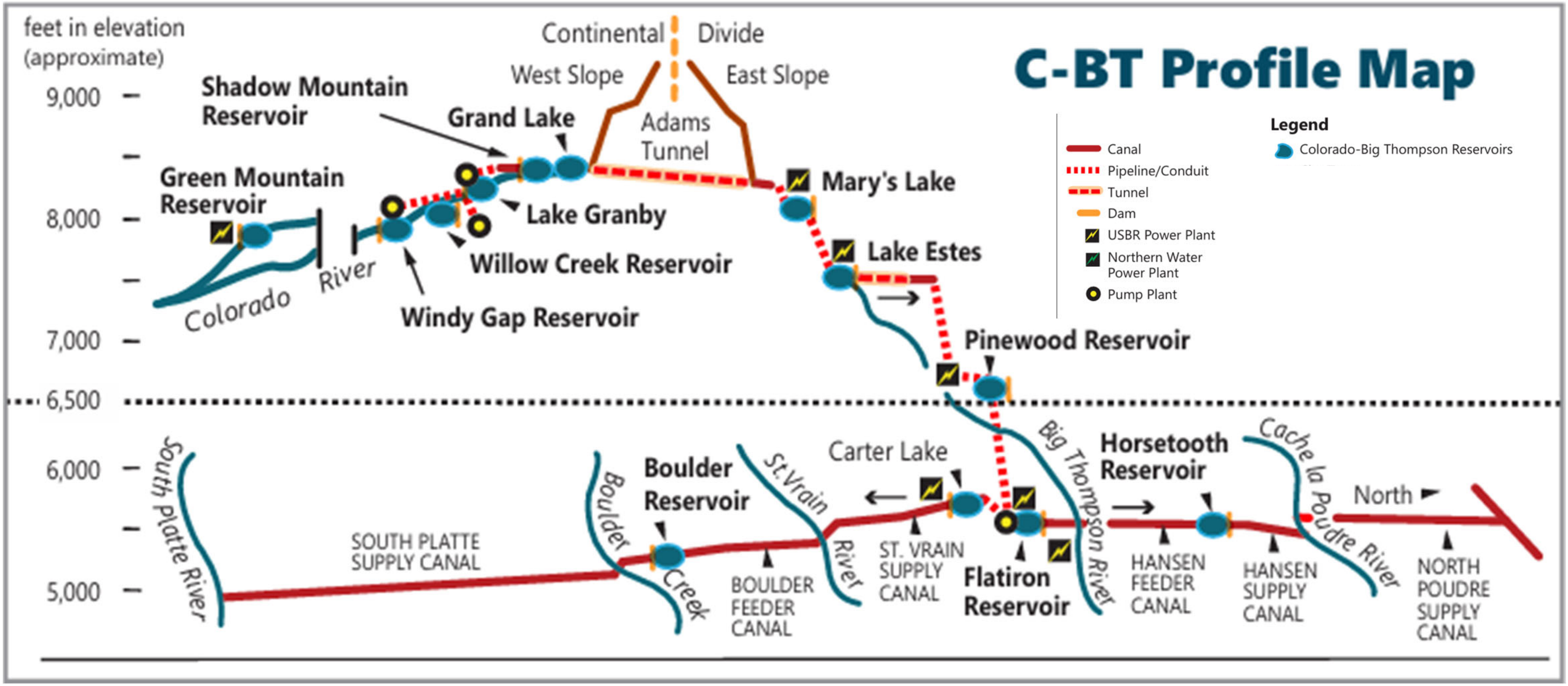
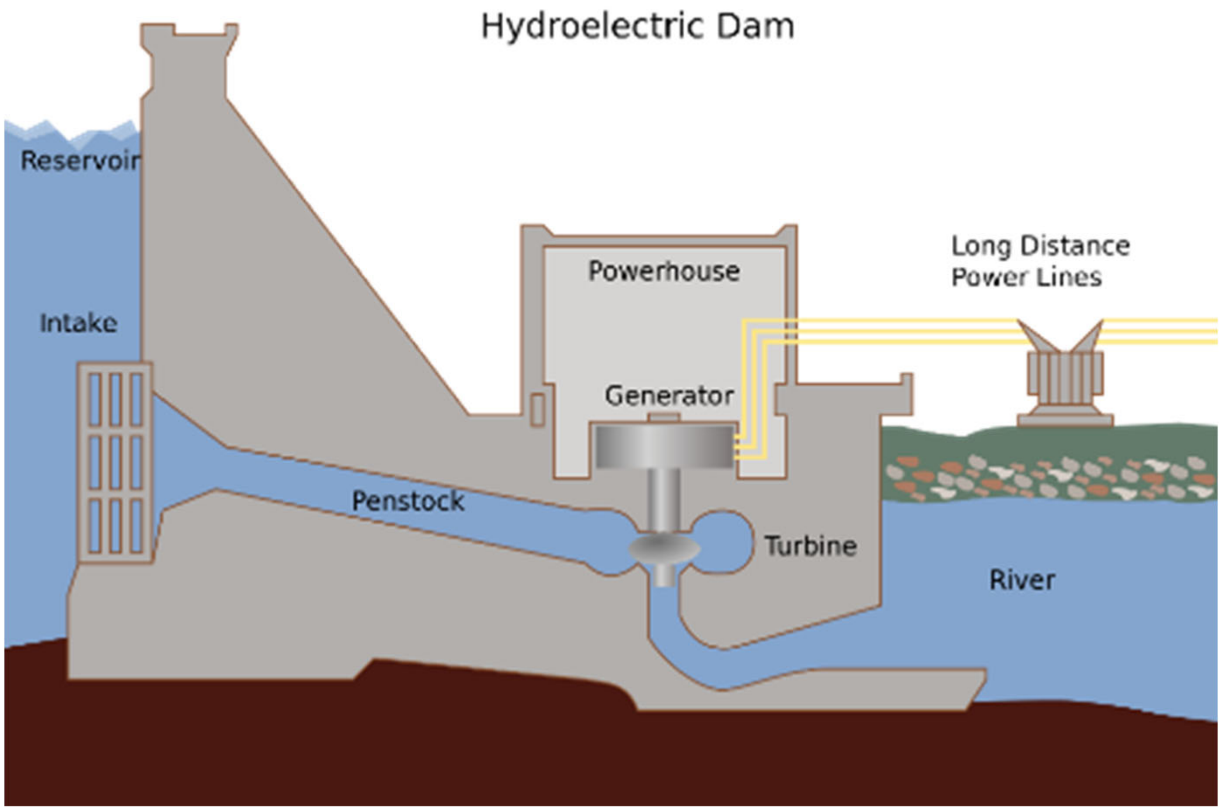


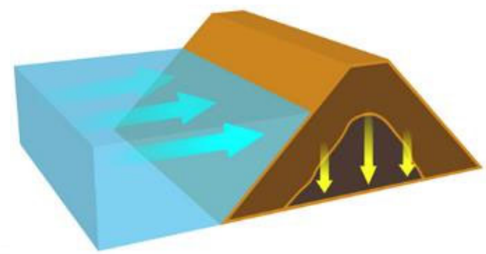
Gravity Structures

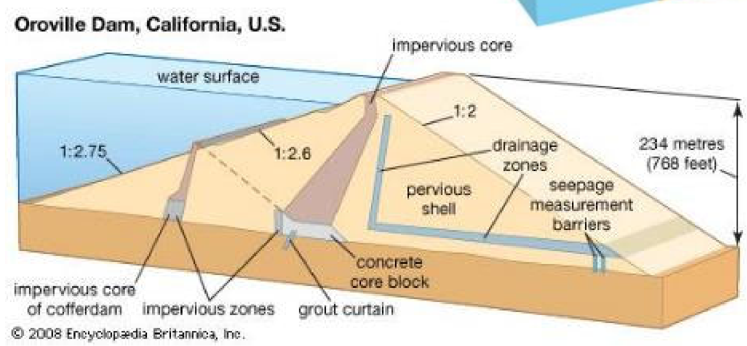


- Cast-in-place, roller compacted, precast, pre-placed aggregate and underwater placed concrete
- Masonry and cyclopean
- Powerhouses, intakes, spillway headworks, etc.
- Greater cross section but needs lower foundation strengths

Earthfill Embankments

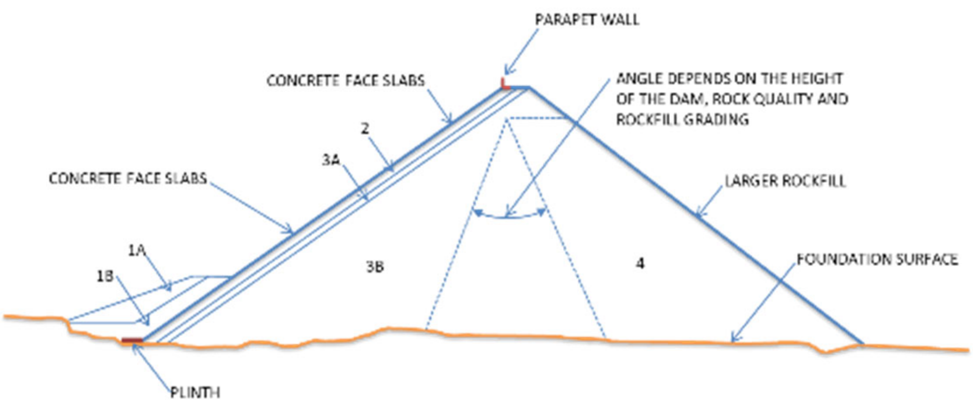
- Variety of material choices
  - Gravels, sands, silts, clay, manufactured products
- Homogeneous
  - 1 impervious material
- Zoned
  - Impervious core protected by filter, drain and shell materials
- Low foundation strength needed





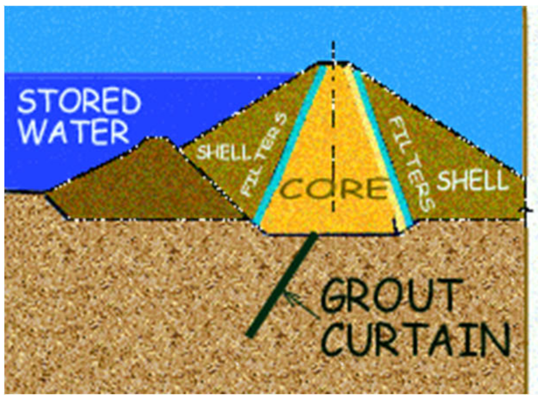
Rockfill Embankments

- Earth core: low permeability core and filter materials within dam body
- Hydraulic Asphalt Concrete core: impervious core and filter materials within dam body
- Upstream lined: concrete, asphalt, or membranes
- Steeper slopes → higher foundation strength required

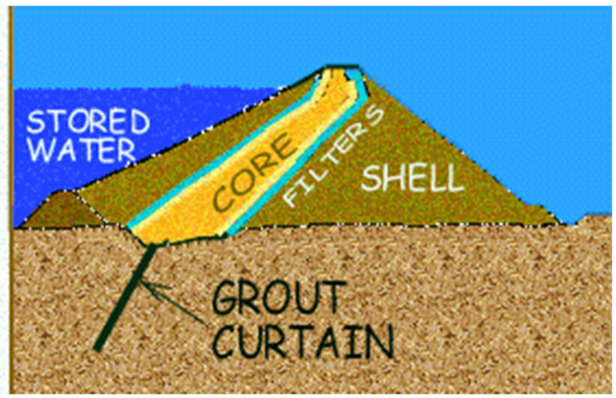


Dam Cross Sections

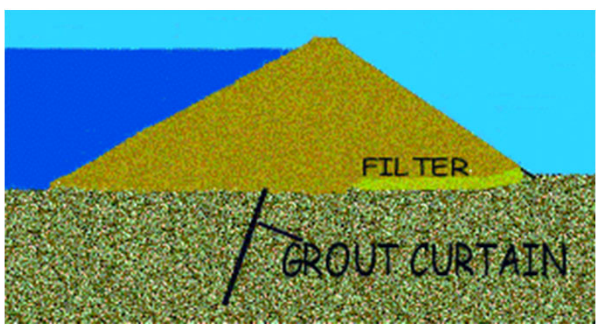
Central Core Embankment Dam



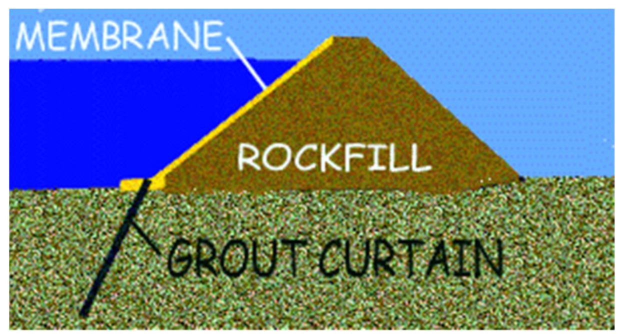
Sloping Core Embankment Dam



Homogeneous Embankment Dam



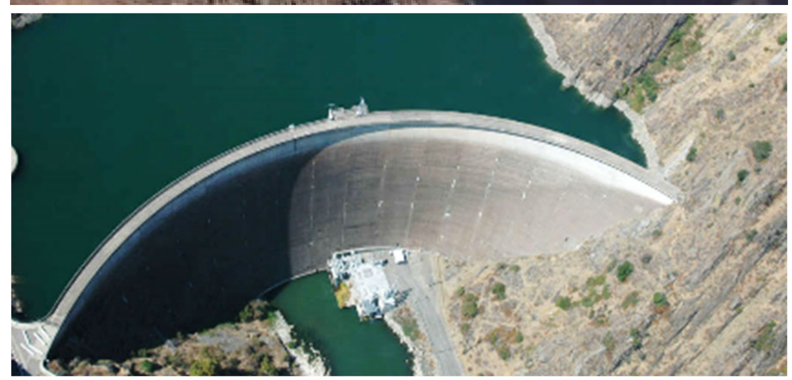
Upstream Lined Embankment Dam



Illustrations from http://www.users.tpg.com.au/houlsby1/Dams%20Usage.htm

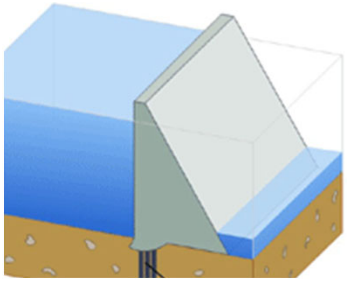
Structural Dams

- Arch Dams
  - Small cross sections
  - Require high foundation and abutment strengths
- Buttress Dams
- Coffer Dams
- Timber Crib
- Flood Walls

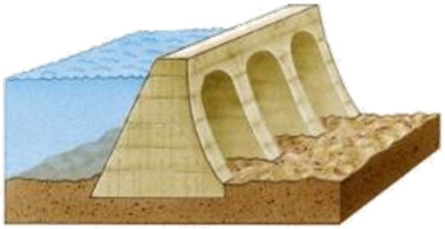


Dam Cross Sections

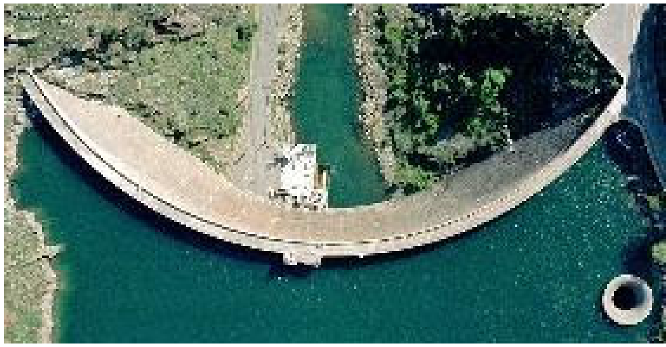
Gravity Dam

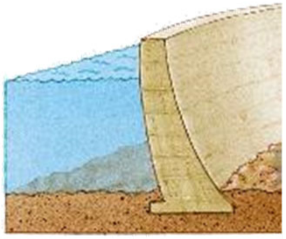


Buttress Dam



Arch Dam





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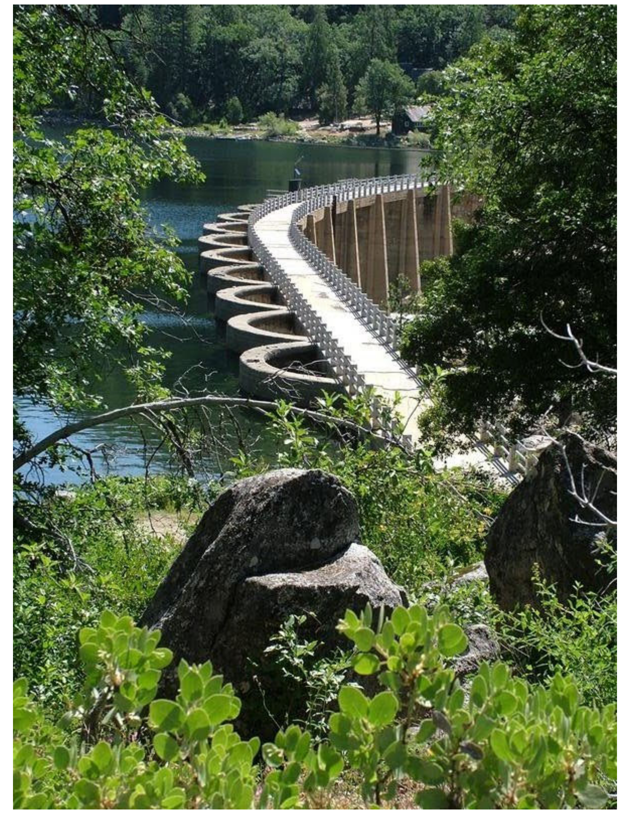
Timber Crib Dam



Multi-Arch Dam

Spillways & Outlet Works

permit passage of excess reservoir water

Energy dissipation is extremely important!

Spillway Types

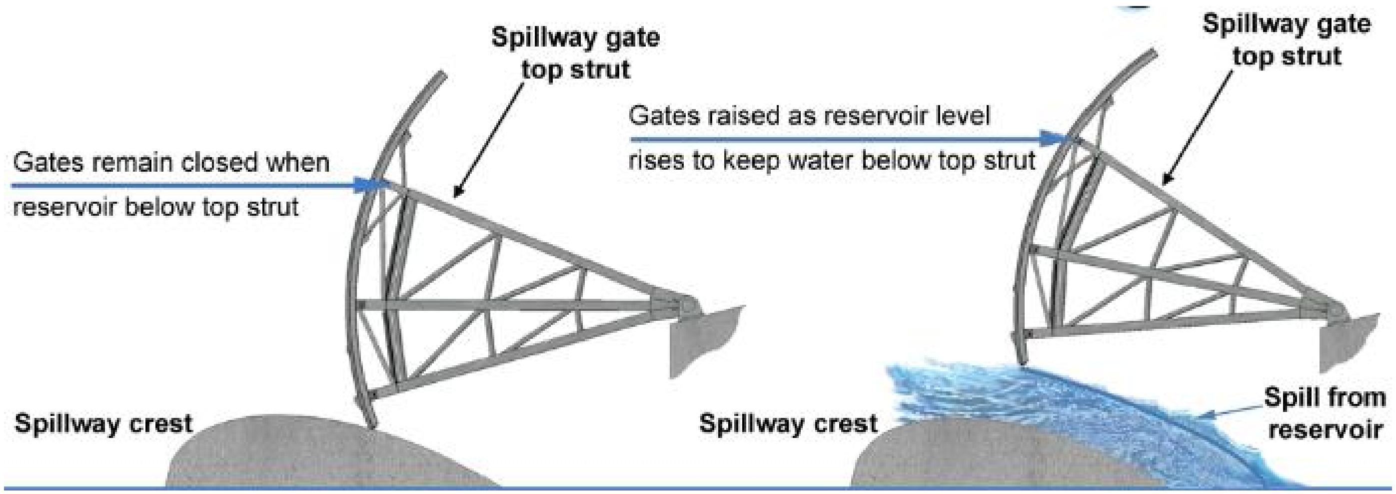
“Uncontrolled” Spillways

- Maintain water levels automatically without reliance on personnel or machines
- Ungated overflow weirs, side channel, labyrinth, drop inlet, fuse plugs

Spillway Types

“Controlled” Spillways

- Provide reservoir drawdown capability during or following a flood event
- Gated spillway, discharge outlet, stoplogs, flashboards, etc.



Design Considerations

Material

- Availability
- Thermal behavior

Foundation

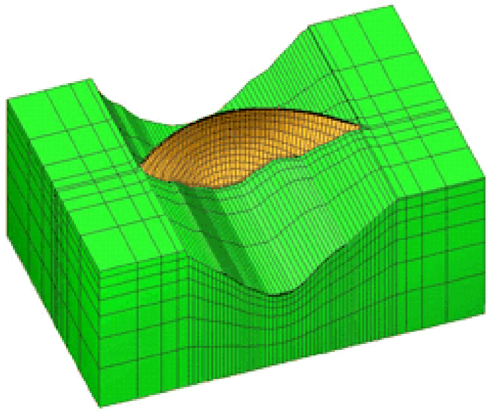
- Bearing, sliding, seepage, liquefaction, and settlement

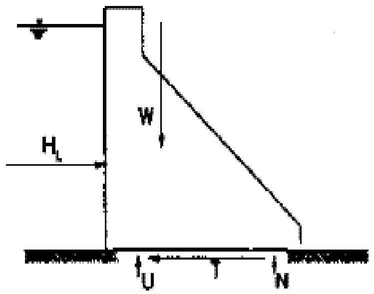
Stability

- Sliding
- Overturning
- Slope stability
- Water barriers and drains

Strength

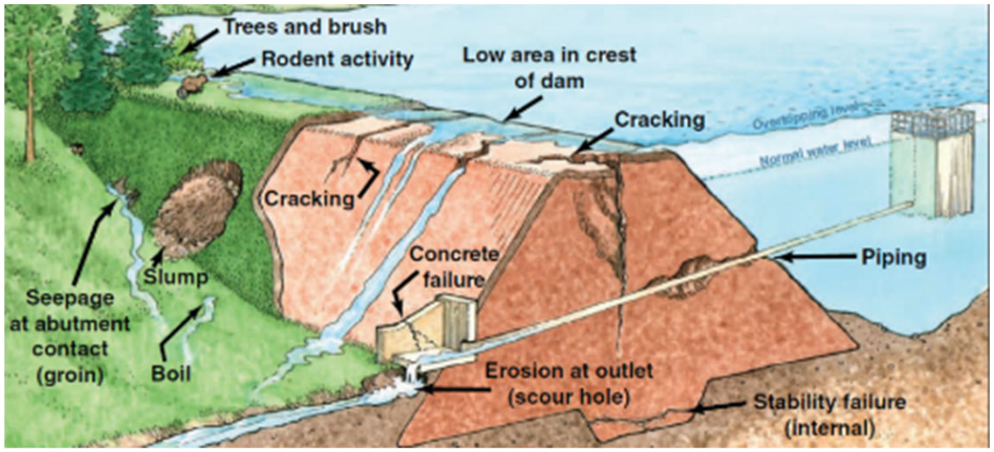
Performance

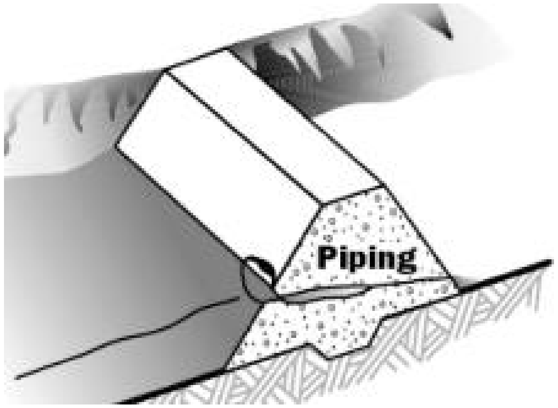




Design Considerations

- Seepage, leakage, and piping
- Settlement
- Material Deterioration
- Overtopping / Surface Erosion
- Seismic Resistance





Design Considerations

- Hazard Potential Classification
  - Categorizes dams based on adverse incremental consequences of a failure or mis-operation
  - Not an indication of the current or expected condition of the dam
  - Classification determines design criteria for the dam such as Inflow Design Flood (IDF), freeboard, spillway and outlet requirements, seismic resistance and analysis requirements, etc.

Dam Downstream Hazard Potential Classifications

CATEGORY[1]	LOW	SIGNIFICANT	HIGH
Direct Loss of Life[2]	None expected (due to rural location with no permanent structures for human habitation)	Uncertain (rural location with few residences and only transient or industrial development)	Certain (one or more extensive residential, commercial or industrial development)
Lifeline Losses[3]	No disruption of services - repairs are cosmetic or rapidly repairable damage	Disruption of essential facilities and access	Disruption of critical facilities and access
Property Losses[4]	Private agricultural lands, equipment and isolated buildings	Major public and private facilities	Extensive public and private facilities
Environmental Losses[5]	Minimal incremental damage	Major mitigation required	Extensive mitigation cost or impossible to mitigate

Water Conveyance Structures

- Conveyance Components
- Design Considerations
  - Channels & Canals
  - Penstocks
  - Tunnels & Shafts
  - Outlet Works

Water Conveyance Structures

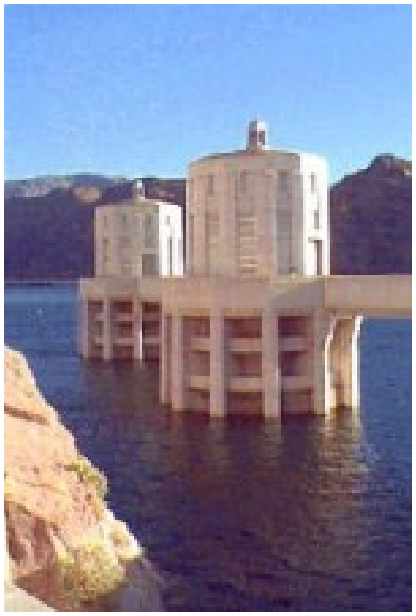
Goals

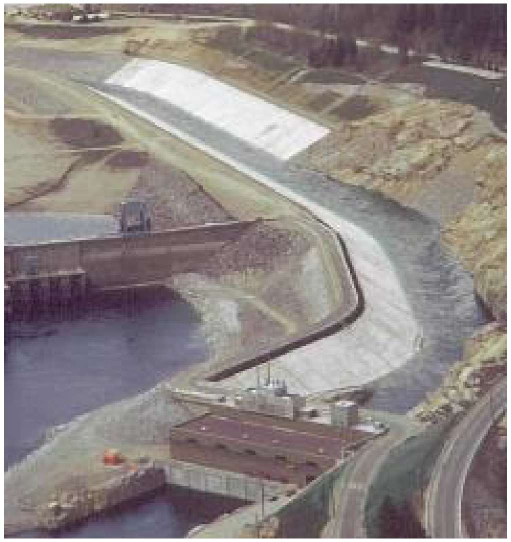
- Deliver the required flow to the turbines
- Minimize head loss
- Maximize power and/or energy output

All for the Least Cost.

Conveyance Components

- **Channels & Canals:** manmade streams or rivers
- **Forebays:** water storage for operation regulation
- **Intakes:** control inflow and block debris, fish, ice, etc. from entry



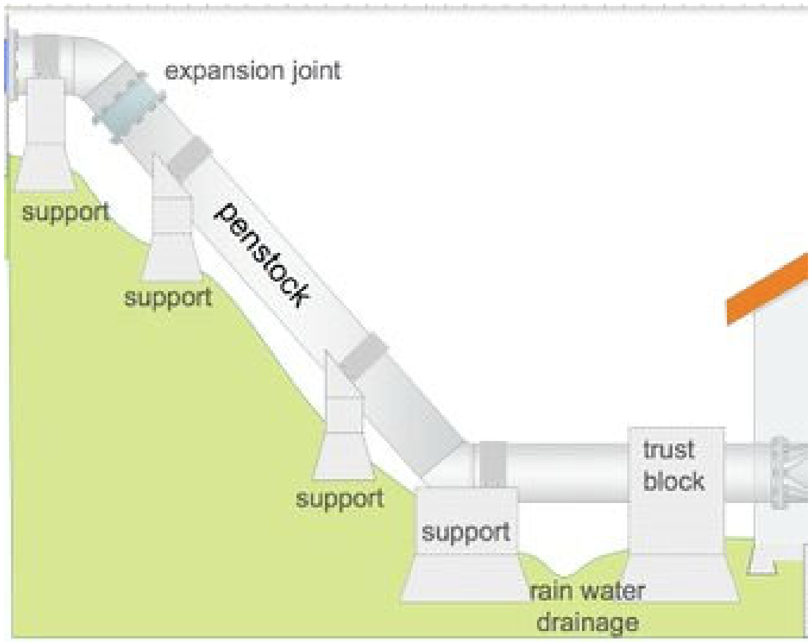


Conveyance Components

- **Flumes:** open conduit, normally elevated, for conveying water
- **Penstocks:** pipe to convey water under pressure
- **Tunnels & Shafts**
- **Surge Chambers:** for pressure fluctuations in water conductors

Conveyance Structure Design Considerations

- Alignment issues
- Hydraulic requirements
  - Flow, Velocity, Head
- Leakage and seepage control
- Dewatering and inspection provisions



Channels & Canals
Design Considerations

- Unlined or lined (clay, concrete, membranes, asphalt, etc.)
- Generally larger volumes of water and slower velocities (losses, erosion, etc.)
  - Unlined: 2 to 6 fps
  - Lined with rock or riprap: up to 10 fps
  - Lined with concrete: up to 20 fps
- Uniformity of cross section and alignment to minimize losses
- Uplift relief and drainage beneath the lining is an important consideration.

Conveyance Structures Design Considerations

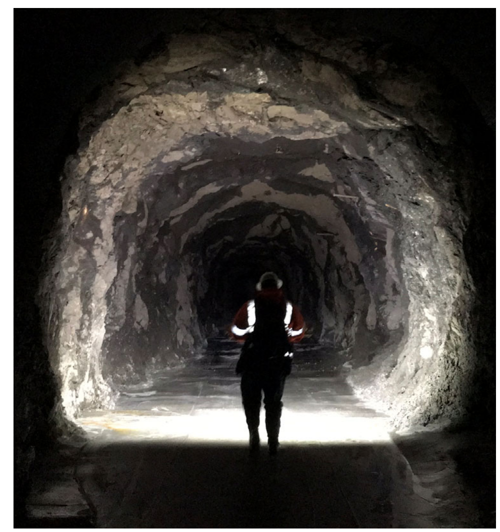
Penstocks & Tunnels

Internal pressure design: *normal operations, transient conditions (surge), negative pressures*

Conveyance Structures Design Considerations

Penstocks & Tunnels

- **External pressure design:** *ground loads, grouting, groundwater*
- **System design:**
  supports, thrust blocks, expansion/contraction, coatings, access



Penstocks

- Supported, buried or encased.
- Materials:
  - Steel, wood stave, concrete, and fiberglass.
  - Steel to be pressure vessel quality steel (refer to ASME guidelines and ASCE 79).
- Design must be done in conjunction with the turbines to ensure water supply is consistent with the machine
  - Water starting time and mechanical starting time
  - Design pressures due to water hammer

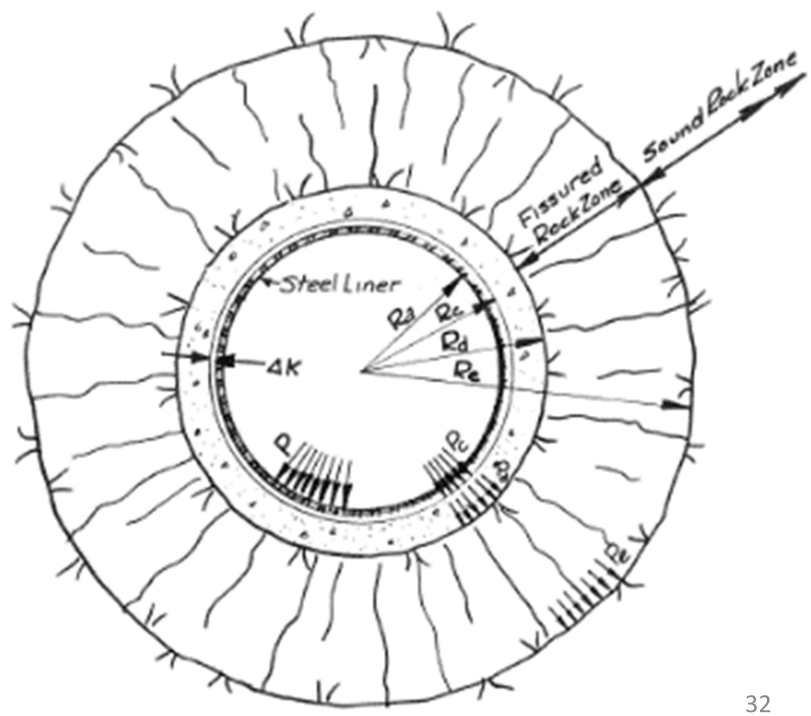
Tunnels and Shafts

Is a lining needed?

- Reduce losses
  - Unlined, velocity ~ 5 to 8 fps
  - Concrete lined, velocity ~ 10 to 20 fps
  - Steel lined, velocity ~ 20 to 30 fps (though upwards of 70 fps near the entrance to the units)
- Leakage / hydraulic jacking
- Support needs, both during construction and long-term operation.

Lining Design

- Optimum design incorporates the steel liner, concrete lining, and rock zones
- Treat air gap between steel and concrete
- Minimum thicknesses
  - Handling for the steel liner
  - Constructability for concrete (min. 12", 18" to 24" for drill and blast)



Outlet Works

- To allow the release of water to satisfy river flow requirements when the power plant is not in operation
- Temporary diversion during initial filling
- To allow for lowering of reservoir for inspection and repairs
- To provide additional spill capacity

Outlet Works

- Basic components include control structures, discharge channels, and terminal structures.
- Discharge channel or conveyance system is often times closed such as a pipe or conduit.
- Releases; i.e., size of outlet dictated by:
  - Flood control regulation / storage regulation
  - Water supply or irrigation demands
  - Navigation
  - Environmental
  - Drawdown

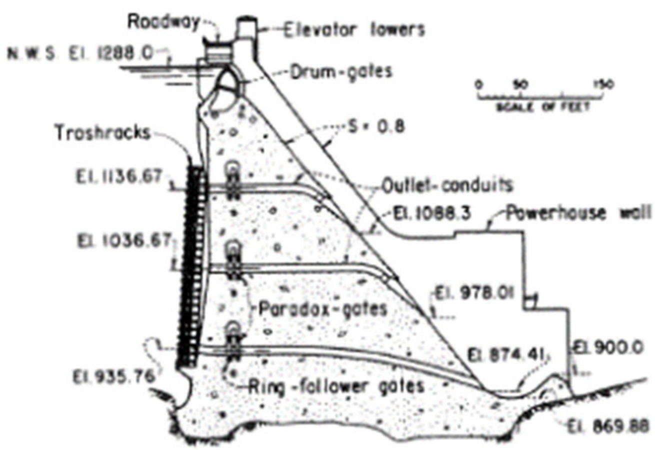
Outlet Works

- Reservoirs are subject to sedimentation
  - Leads to loss of storage volume for water supply, hydropower generation, flood storage, etc.
  - Impacts pool depths that can affect navigation and recreation
  - Restricts flow of sediment downstream sometimes leading to scour downstream and prevents replenishment of downstream bottomlands
- Submergence important
- Trashracks may be needed

Outlet Works

- Water quality related issues may include:
  - Temperature
  - Oxygen concentration
  - Turbidity
  - Minimum flow requirements
- Water below the outlet works is considered “dead storage”

Outlet Works



- Energy dissipation is extremely important
- Common velocities:
  - Concrete lined conduits = 65 fps
  - Steel lined conduits = 160 fps
- Air must be supplied downstream of the gate to prevent cavitation and damage to conduit due to high velocity flow

Water Regulating Structures

Gate vs Valve

Gates

- Low Head
- High Head

Valves

Design Factors & Considerations

Water Regulating Structures

Goals

Regulate the flow

Provide needed flow range and accuracy

Installation, removal, and maintenance ease

All for the Least Cost.

Water Regulating Structures

Gate

Closure device in which a leaf (closure member) is moved across the fluidway from an external position

Valve

Closure device in which the closure member remains fixed axially with respect to the fluidway and is either rotated or moved longitudinally

Questions ??

Thank you all very much !!!

Enjoy the rest of the course

References

- USACE Documents (http://www.usace.army.mil/publications/)
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