INSTITUTE OF AERONAUTICAL ENGINEERING
(Autonomous)
Dundigal, Hyderabad -500 043

WATER RESOURCES ENGINEERING-II

(A70133) JNTUH-R15

B.Tech IV YEAR I SEM

Prepared By:
Ms. B. Navya
Asst. Professor
Department of Civil Engineering

WATER RESOURCES ENGINEERING - II

SYLLABUS (JNTUH R-15)

UNIT-I
Storage works:

Storage works-Reservoirs-Types of reservoirs, selection of site for reservoirs, zones of storage of a reservoir, reservoir yield, estimation of capacity of reservoir using mass curve-Reservoir Sedimentation-Life of Reservoir. Types of dams, factors affecting selection of type of dam, factors governing selection of site for a dam.

UNIT-II

Gravity Dams:

Gravity Dams: Forces acting on a gravity dam, causes of failure of a gravity dam, elementary profile and practical profile of a gravity dam, limiting height of a low gravity dam, Factors of Safety-Stability analysis, Foundation for a Gravity Dam, drainage and inspection galleries.

UNIT-III

Earth dams: types of earth dams, causes of failure of earth dam, criteria for safe design of earth dam, seepage through earth dam-graphical method, measures for control seepage.

Spillways: types of spillways, Design principles of Ogee spillways-Spillway gates. Energy Dissipaters and stilling Basins Significance of jump Height Curve and Tail water Rating Curve-USBR and Indian types of Stilling Basins.

UNIT-IV

Diversion Head works: Types of Diversion head works- weirs and barrages, layout of diversion head work- components. Causes and failure of weirs and Barrages on permeable foundations-Silt ejectors and silt excluders.
Weirs on Permeable foundations-Creep theories-Bligh's, Lane's and Khosla's theories, Determination of uplift pressure-Various Correction Factors-Design principles of weirs on permeable foundations using Creep theories-exit gradient, U/s and D/s sheet piles-Launching Apron.

UNIT-V

Canals Falls-types of falls and their location, Design principles of Notch Fall and sarada type Fall.

Canal regulation works, design principles of distributor and head regulators, Cross regulators-canal outlets, types of canal modules.

Cross Drainage Works: types, selection of site, Design principles of aqueduct, siphon aqueduct and super passage.

Classification of Water Resources Engineering Structures

Water Resources Engg. Structures

- **1. Storage works** — Ex: Reservoirs and Dams
- **2. Overflow structures** — Ex: Spillways
- **3. Diversion Head works** — Ex: Weirs and Barrages
- **4. Canal Regulation works** — Ex: Falls , Head Regulator, Cross Regulator, Outlets
- **5. Cross drainage works** — Ex: Aqueducts, Siphon aqueduct, Super passage, Canal siphon, Level crossing, Inlets and outlets

Water Resources Engineering

The Scope of Water Resources Engineering subject broadly covers three areas

1. Hydrology of the catchment area

   Rainfall, Catchment area characteristics, Abstractions like evaporation, transpiration and infiltration, Runoff into rivers (Empirical and rational formulae, infiltration indices and hydrographs etc.) - Covered in WRE-I

2. Study of Various Water Resources Engineering Structures

   Types and sub-types, Planning, Analyzing, Designing, Checking for Stability, Construction, Operation and Maintenance - Will be covered in WRE-II

3. Command area studies

   Irrigation, Types and Methods of Irrigation, Types of crops, Seasons(Kharif and Rabi), Duty, Delta and Base period of crops, Crop Water Requirements - Covered in WRE-I

STUDY OF VARIOUS WATER RESOURCES ENGINEERING STRUCTURES

Types of Water Resources Structures and sub-types

- Storage works (Reservoirs and Dams
- Overflow structures (Spillways)
- Diversion Head works (Weirs and Barrages),
- Canal Regulation works
- (Falls, Head Regulator, Cross Regulator, Outlets)
- Cross drainage works
- (Aqueduct, Syphon aqueduct, Super passage, Canal syphon, Level crossing, Inlets and outlets)
- Planning, Analysis, Design, Checking for Stability, Construction, Operation and Maintenance of all the above mentioned structures **- All this will be studied in this semester under WRE-II**

UNIT-I
Storage works

Why store?

- Raise head, smooth flow, conflicts and trade offs

Determination of reservoir volume/height

- Mass curve approach, simulation approach

Dam design

- Forces on a dam, Types of dam, Seepage, Spillways

Technical problems with dams

- Silting, failure

Social impact of dams

- Seminars (Monday W6)

Reservoirs
Social impact of dams

- Climate change
- Fertility of downstream banks
- Displacement
- Changes in local economy
- Deforestation
- Possibility of financial collapse
- Possibility of failure
- See; World commission on dams www.dams.org

Reservoirs Summary

- Storage needs may conflict
- Mass balance and the mass curve are useful ways to size reservoirs
- Seepage is an issue with earth dams but can be dealt with by zoning
- There are several varieties of spillway, including side channel, chute, shaft, syphon, and ogee
- Hydraulic jump is a useful technique to reduce spillwater levels
- Dams can fail by silting, overtopping, foundation failure wave action, erosion and lack of maintenance
- Dams can have social and environmental impacts

Bhakra Dam and Reservoir

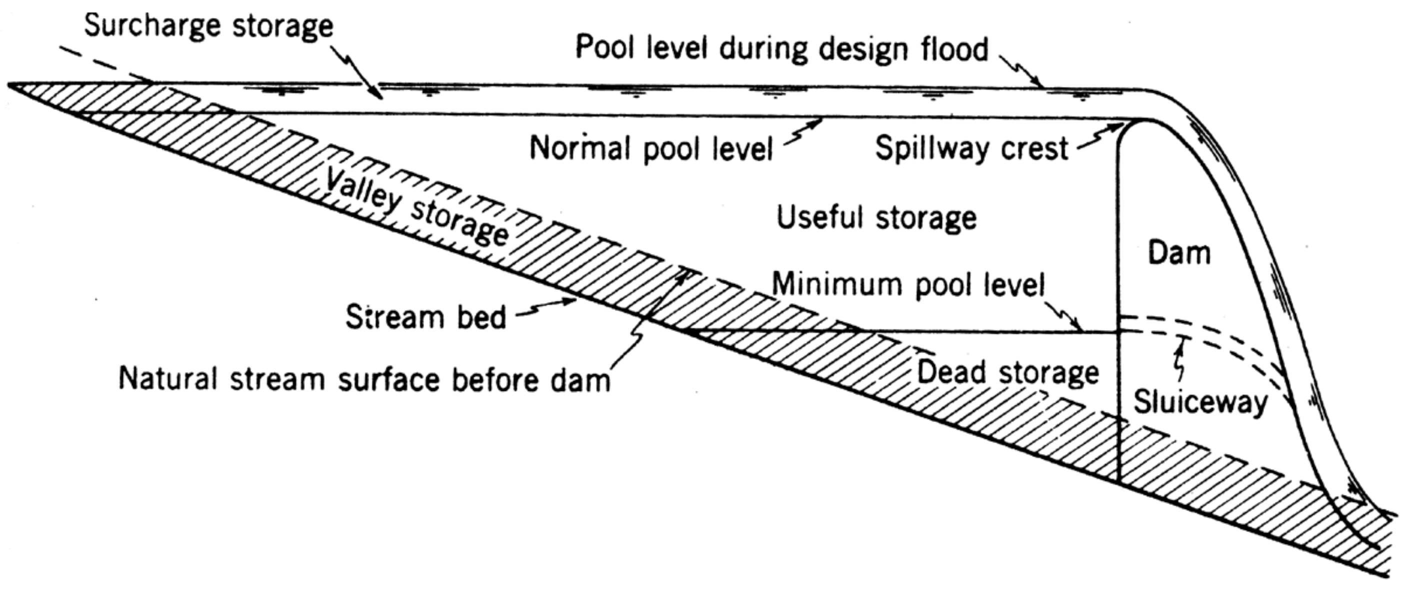
Dam and Reservoir

Reservoirs
Why store: Conflicts

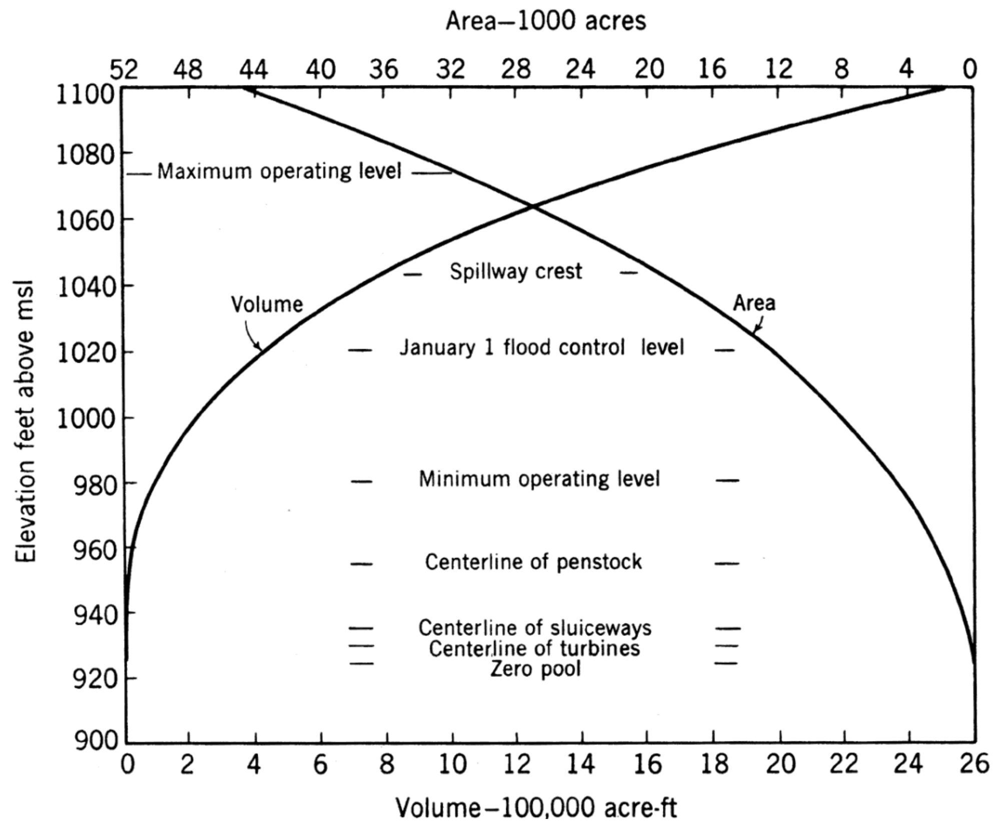
- Maximising head vs. Maximising storage
  - If the storage is used, the head is reduced
- Water use vs. flood control
  - Water use prefers a full reservoir (for use later)
  - Flood control the reservoir should be empty (so floodwater can fill it)

Reservoirs

Why store: The anatomy of a reservoir

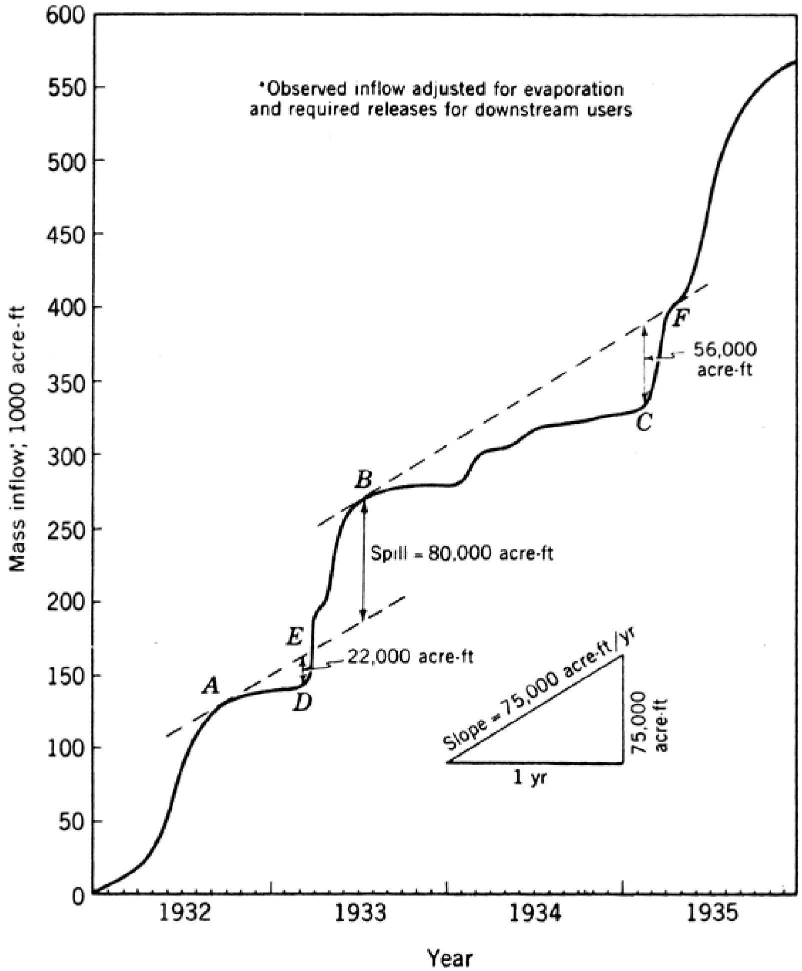


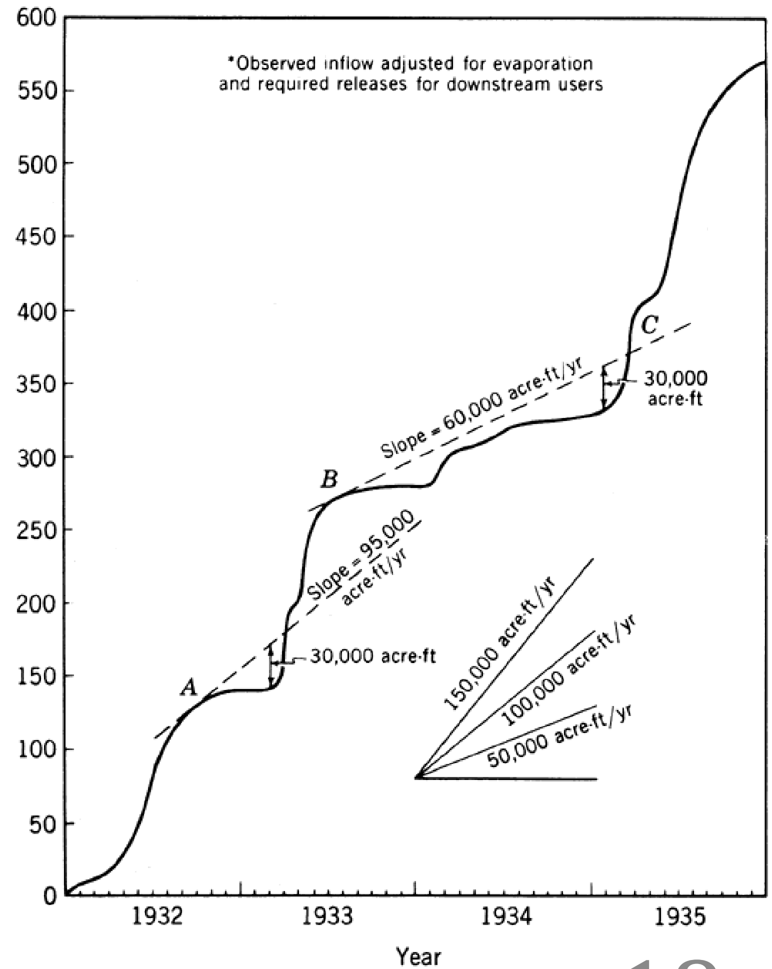
How much to store?



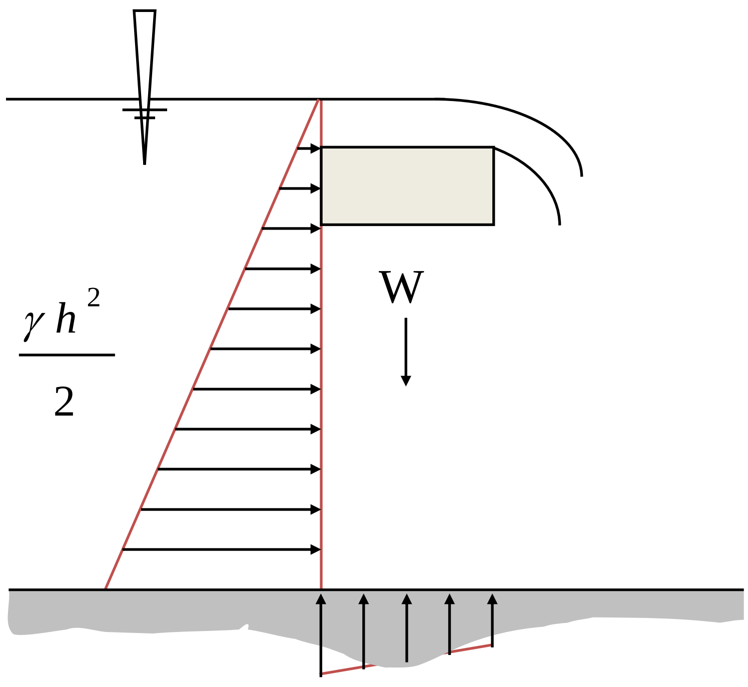
$$h = f(V^3) = f(A^2)$$

How much to store: Mass curve



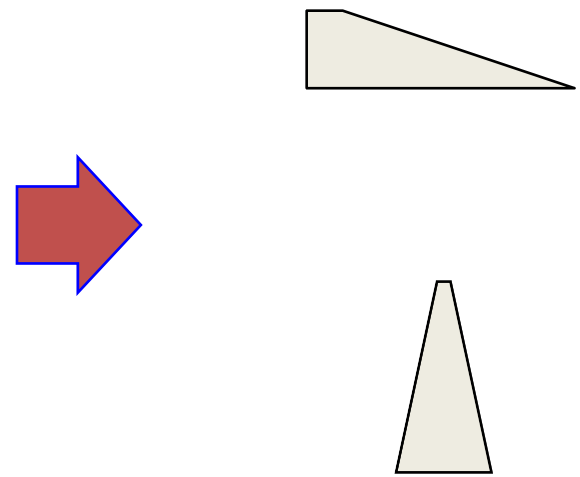


Dam design: Forces on a dam



$$F = \frac{\gamma h^2}{2}$$

$$F = W + \gamma \frac{h}{2} t$$

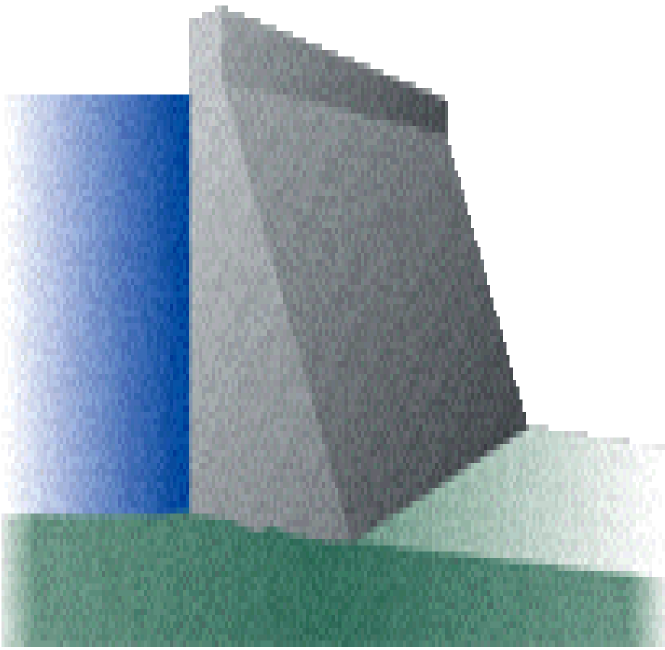


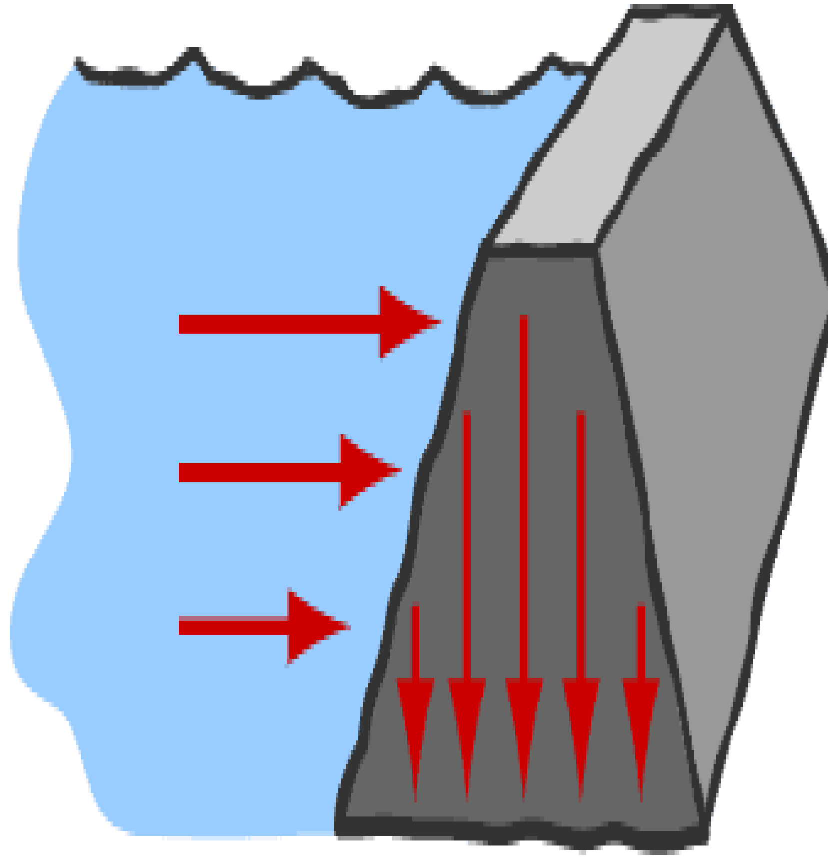
g is the specific weight of water

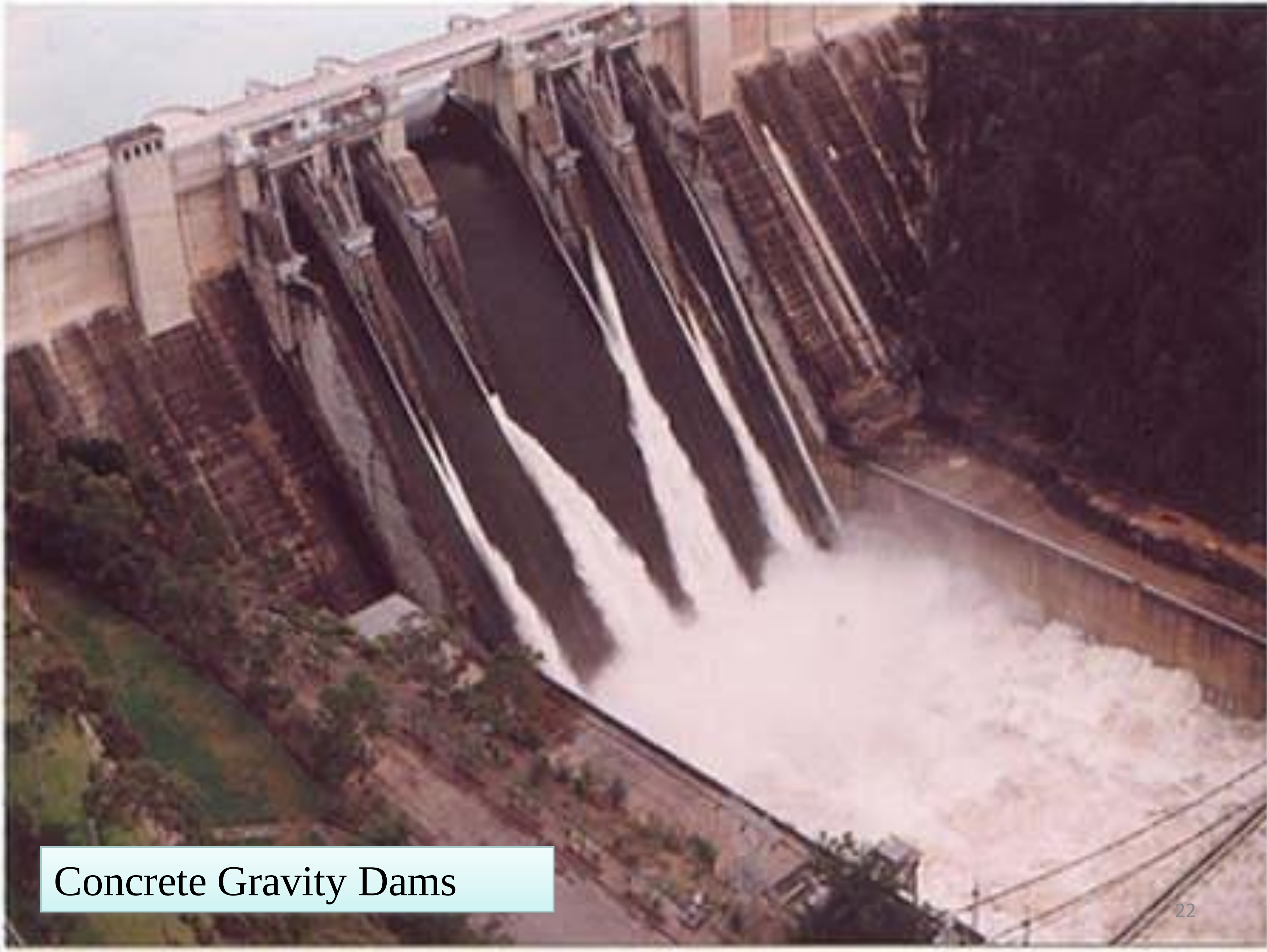
UNIT-II
Gravity Dams

Concrete Gravity Dams

Resist the forces by their own weight

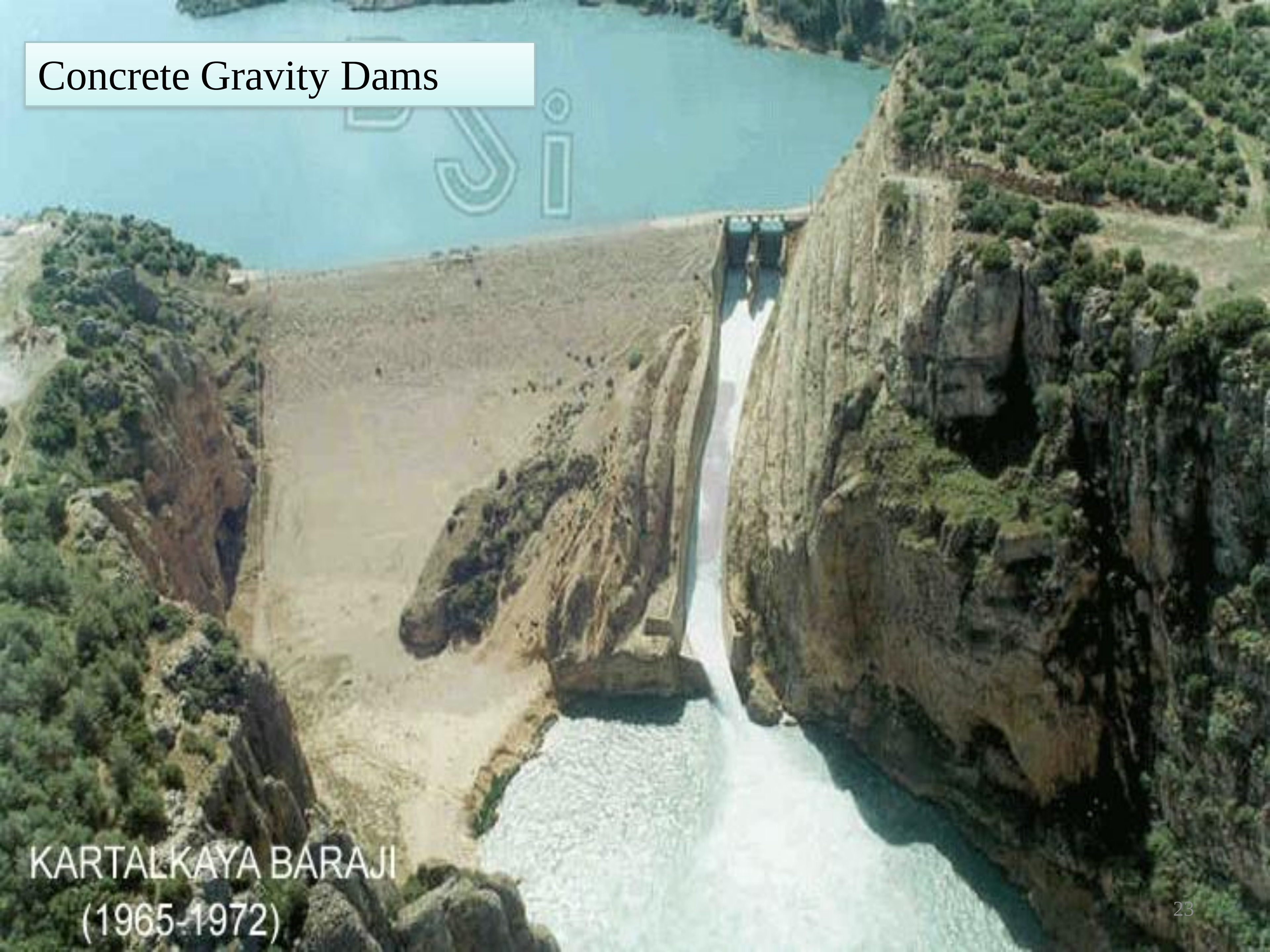




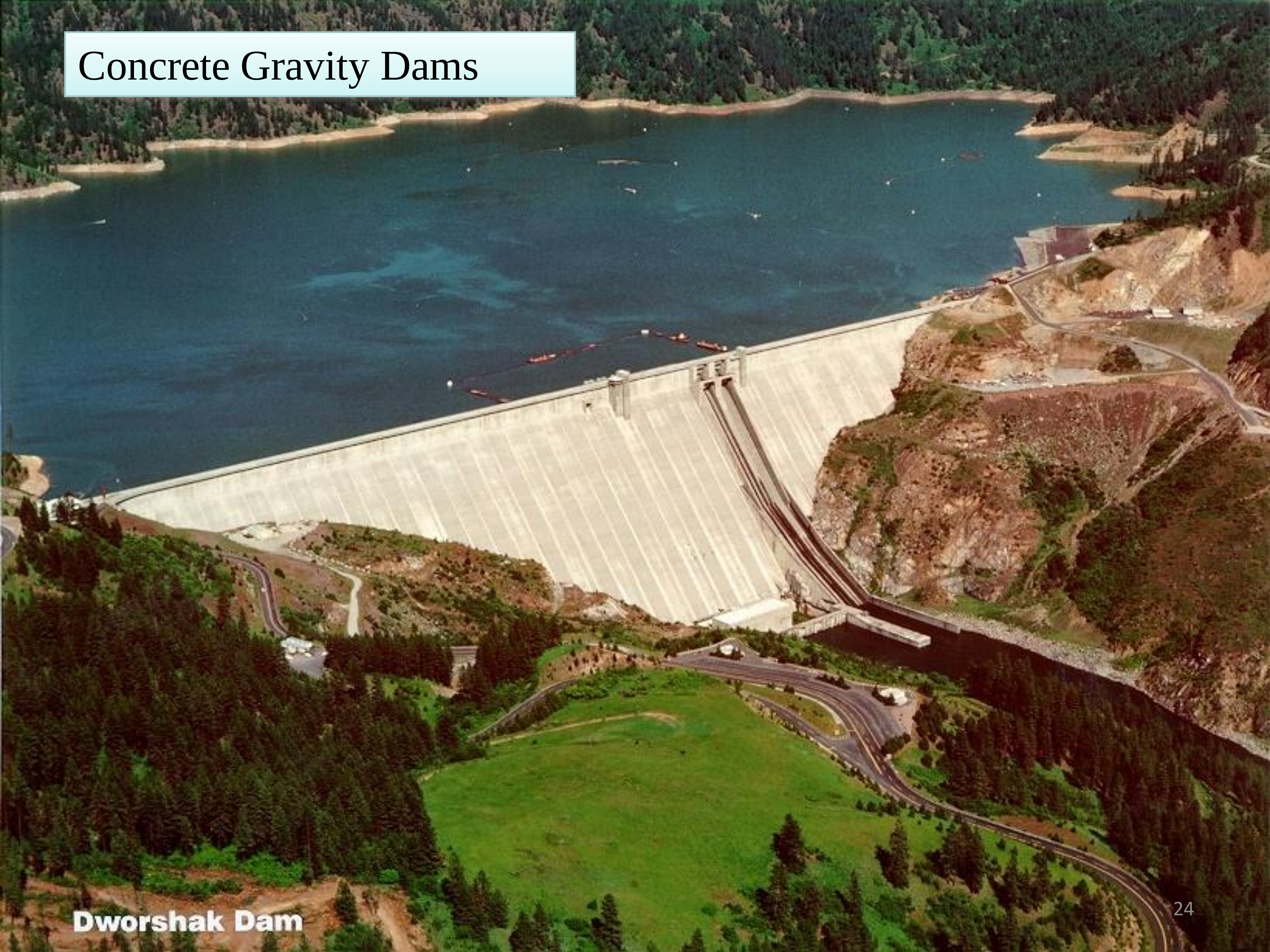


Concrete Gravity Dams

Concrete Gravity Dams



Concrete Gravity Dams

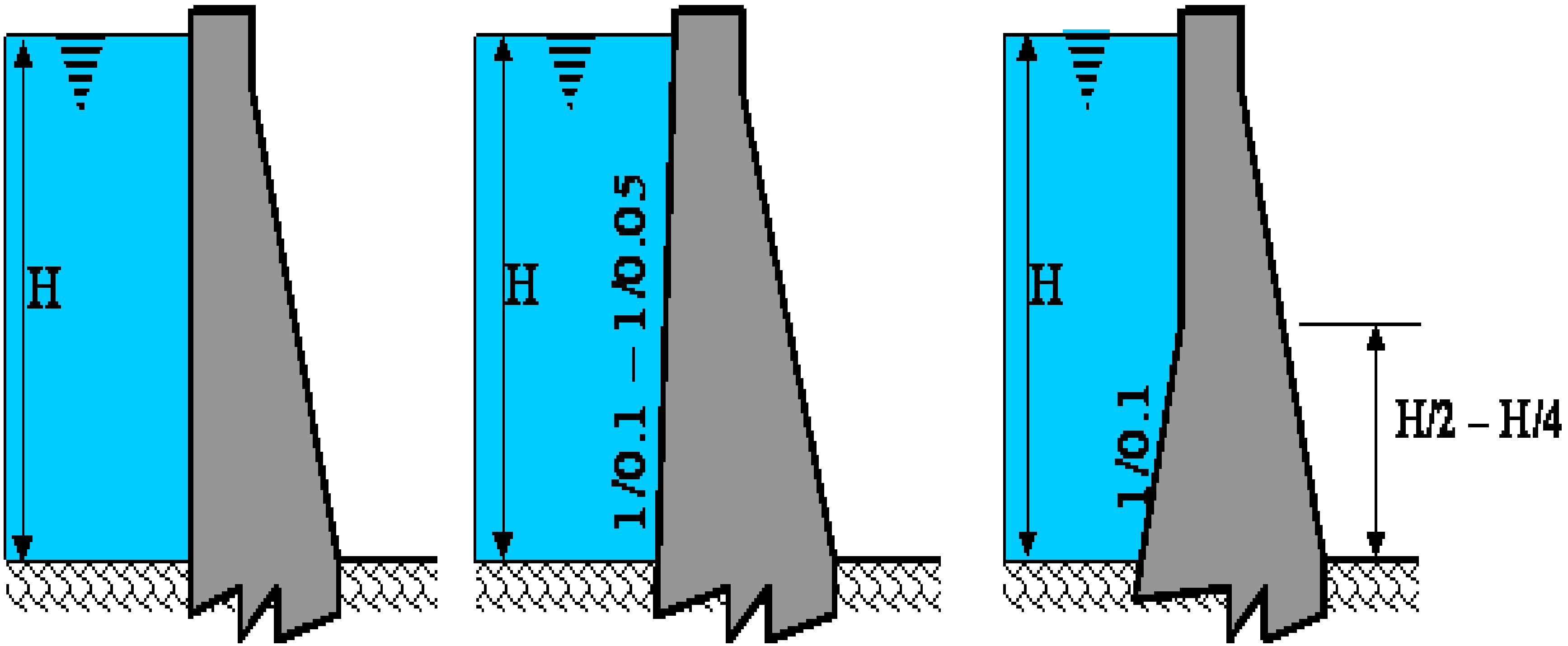


Types:

- Straight Gravity Dams
- Arch Gravity Dams

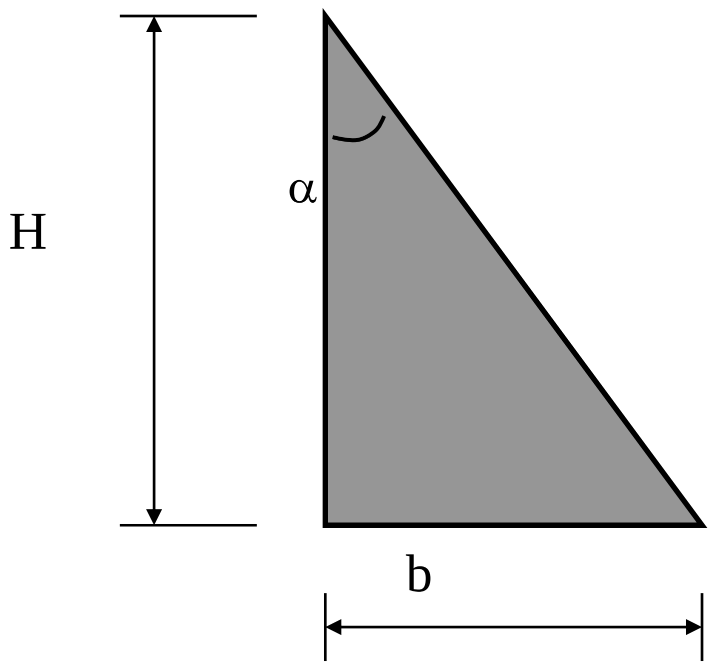
Concrete Gravity Dams

Design Criteria:



Design Principles:

$$tg\ \alpha = \frac{b}{H} \cong \sqrt{\frac{1}{\frac{\gamma_b}{\gamma} - m}}$$

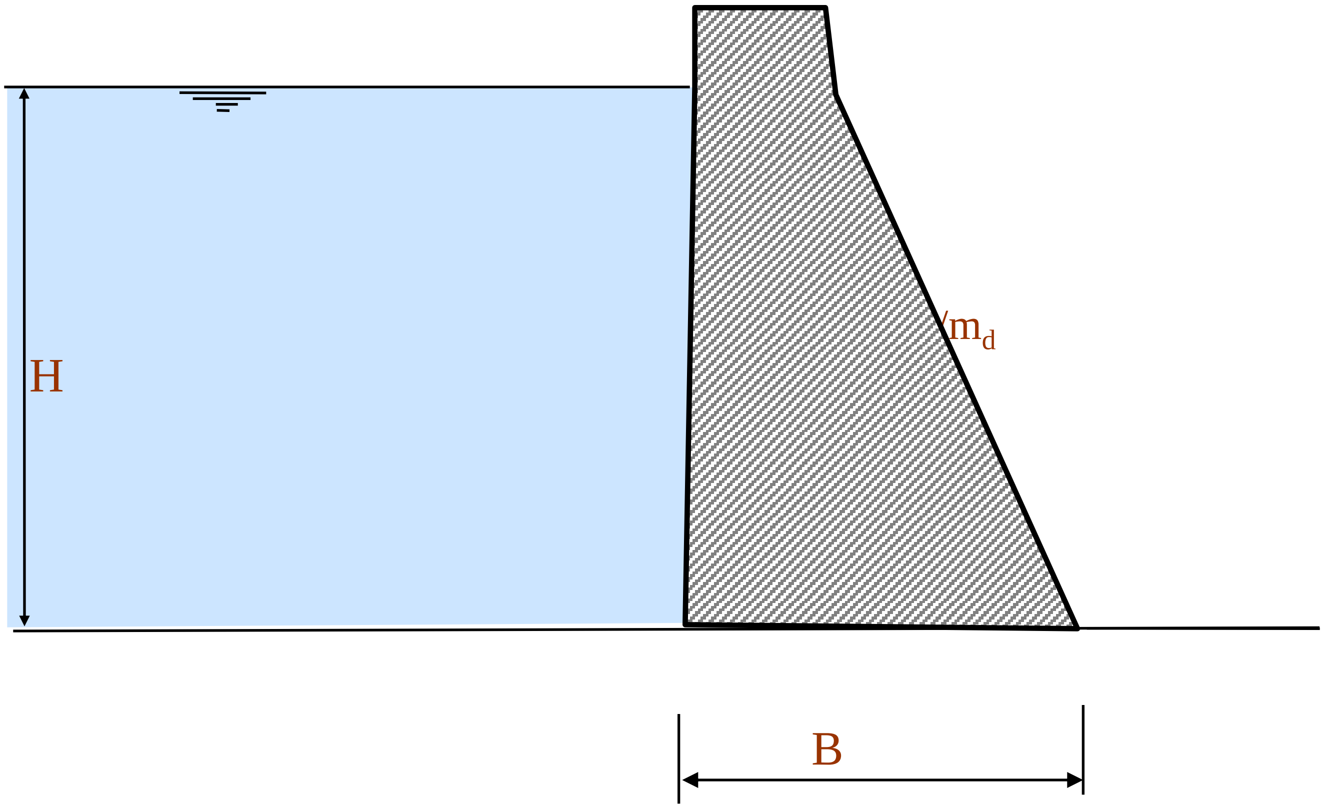


Concrete Gravity Dams

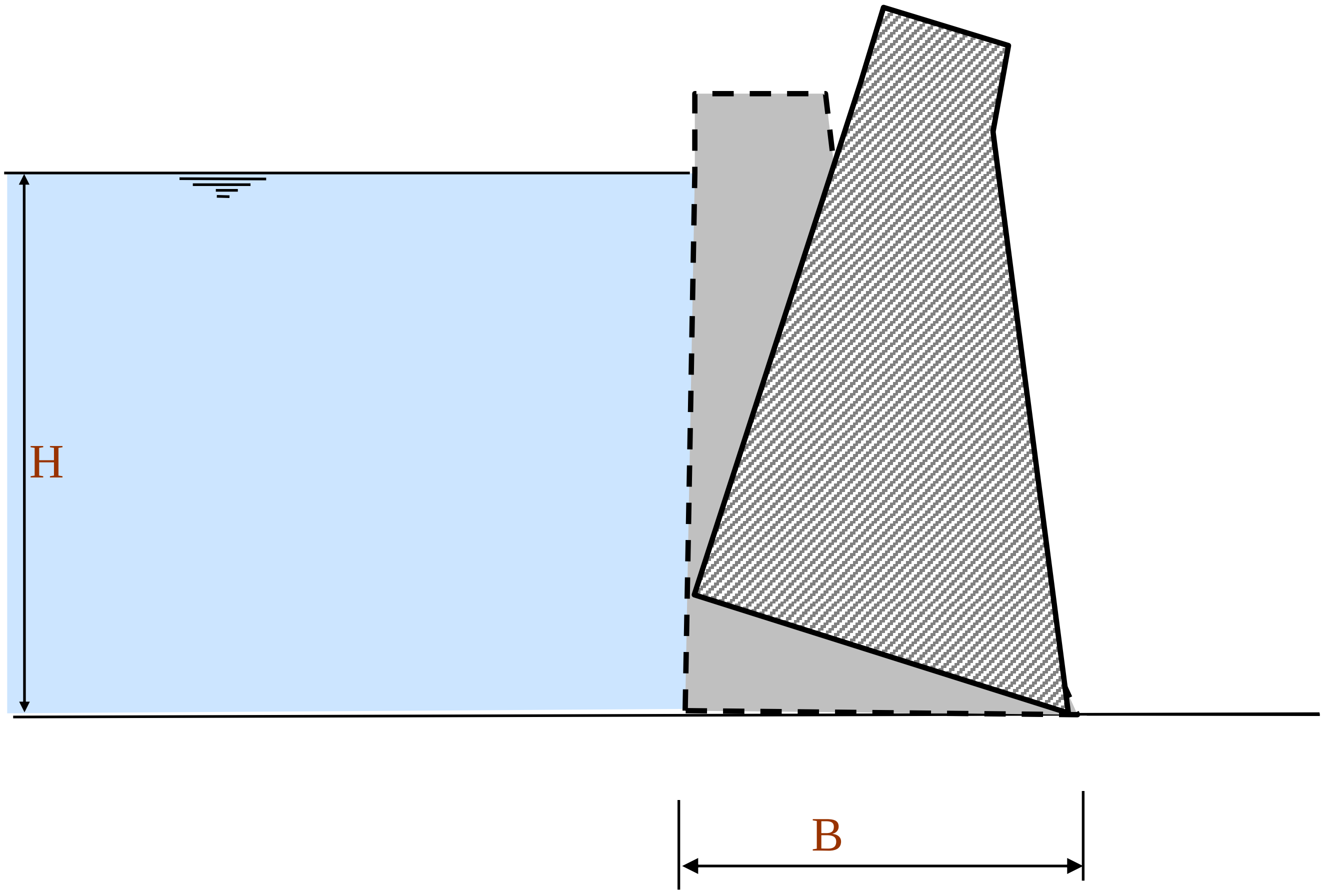
- For the dam dimensions:
- Check out the safety for

- ✓ Overturning
- ✓ Shear & sliding
- ✓ Bearing capacity of foundation
- ✓ No tensile stresses are allowed in the dam body

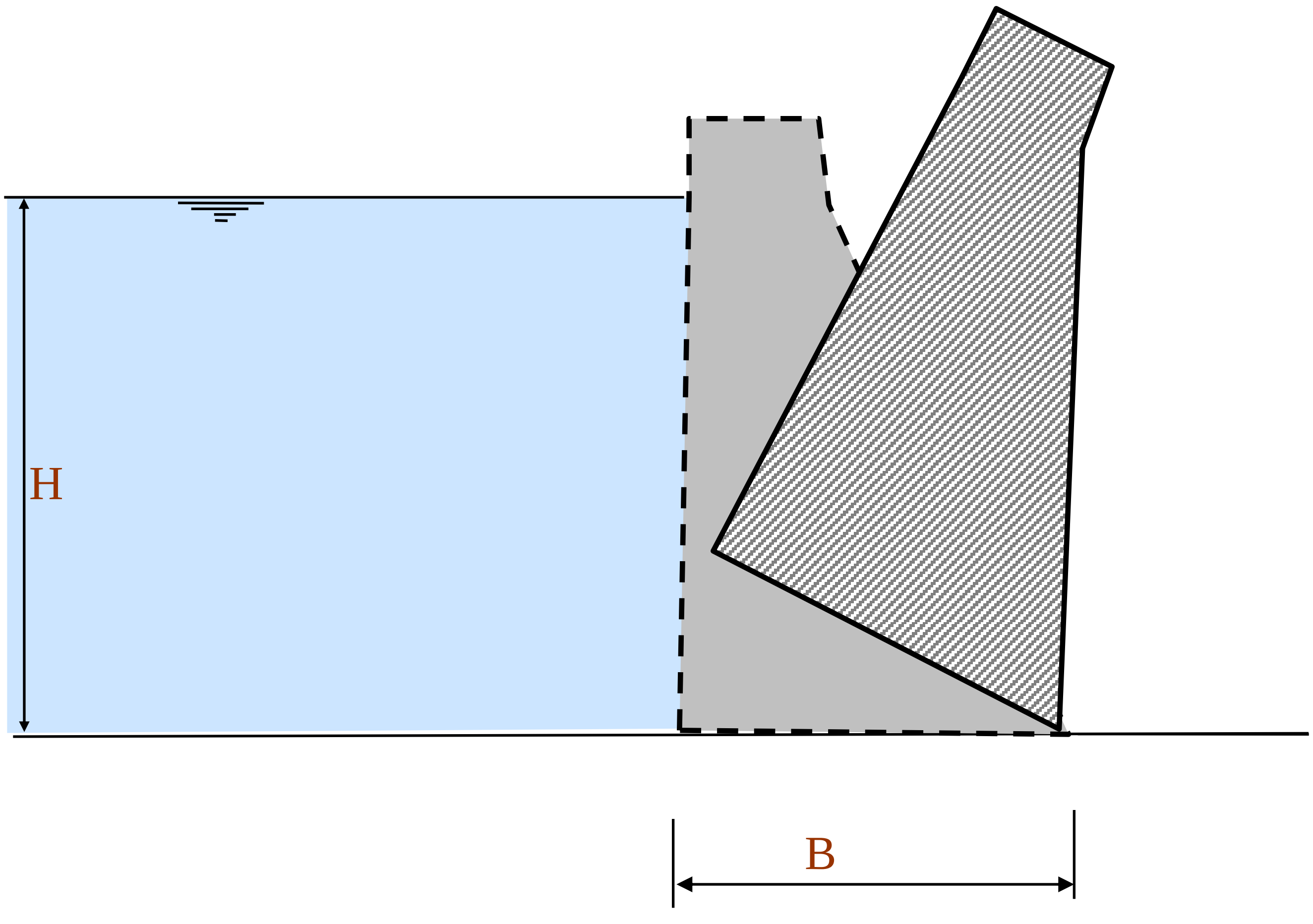
Overturning Check



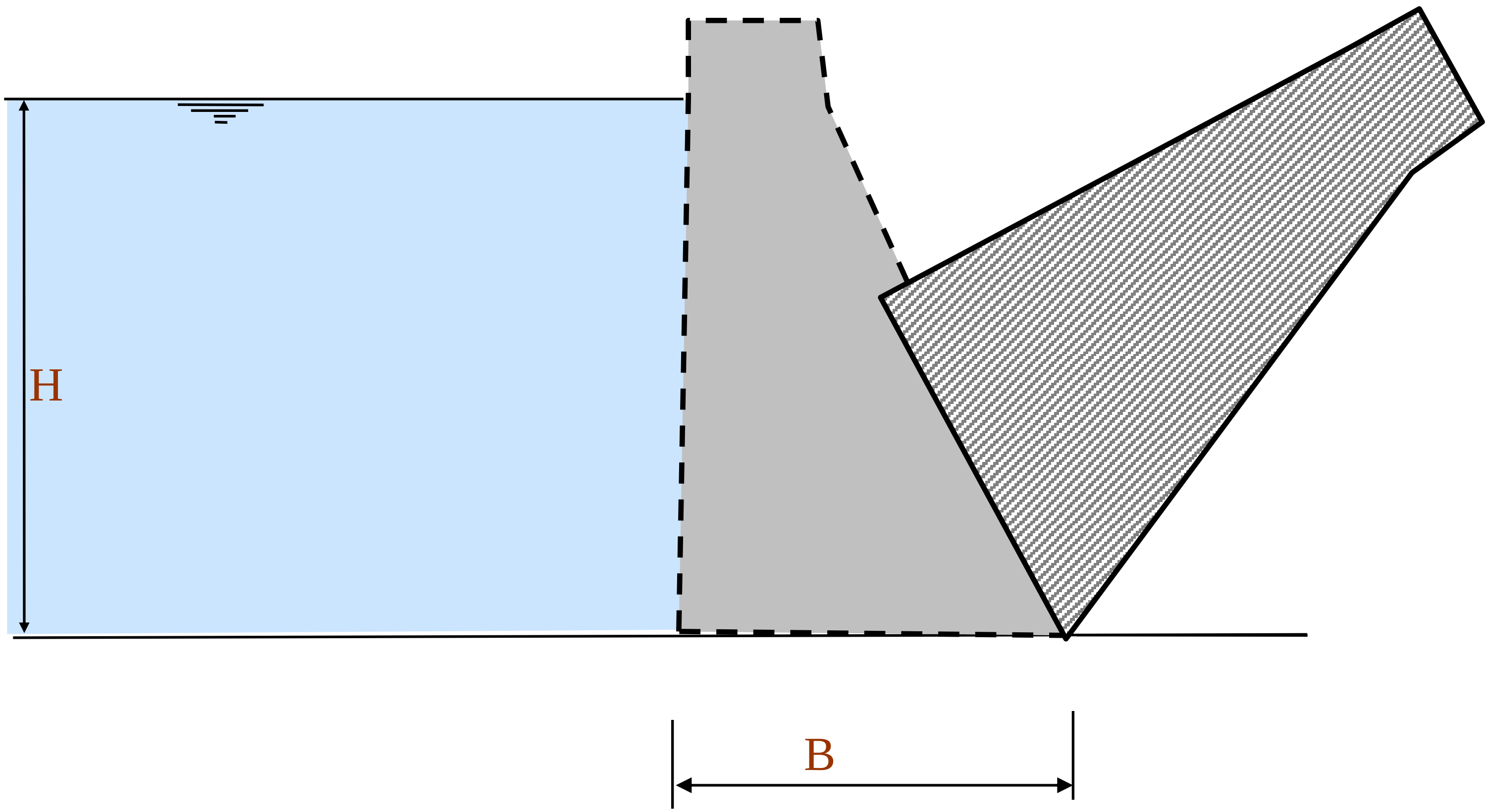
Overturning Check



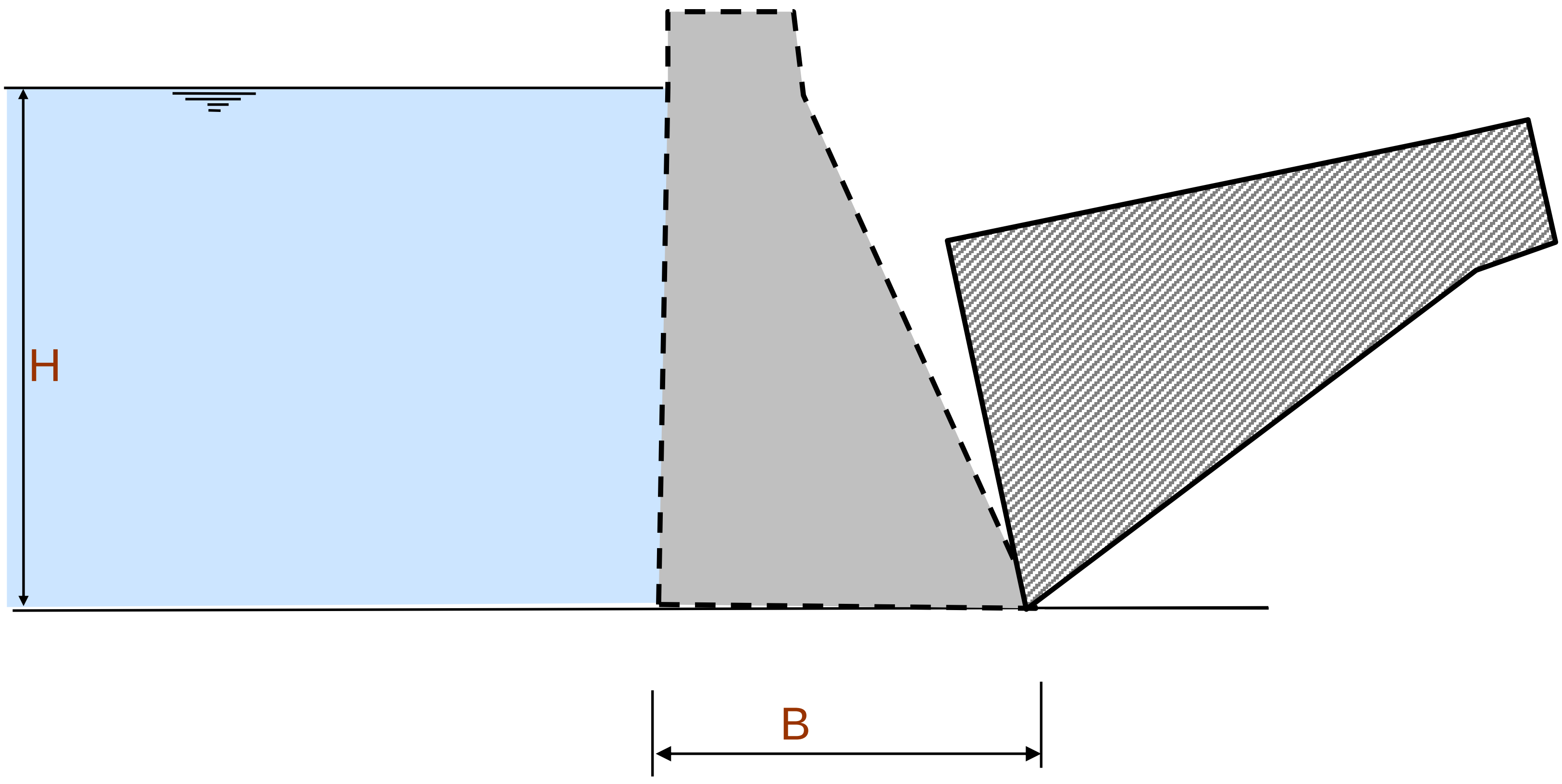
Overturning Check



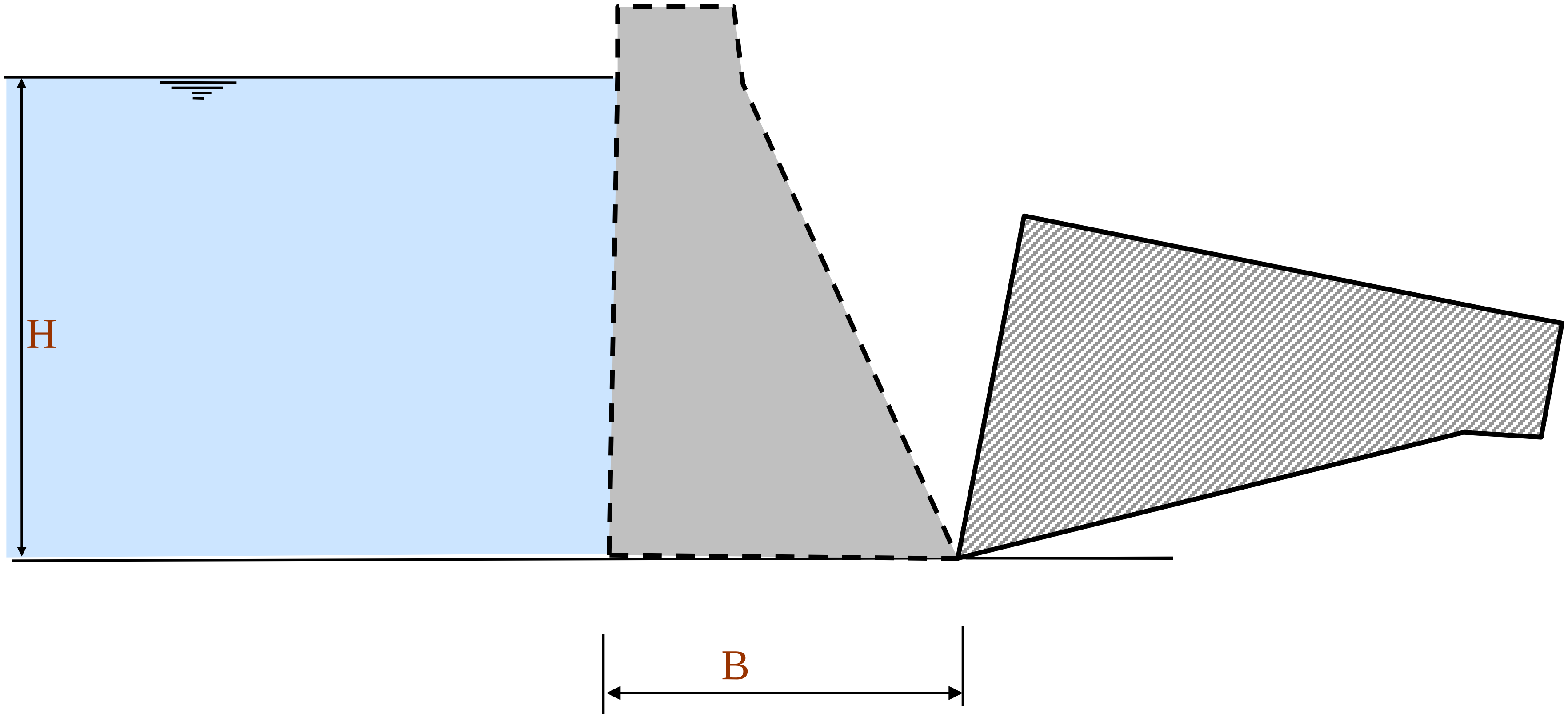
Overturning Check



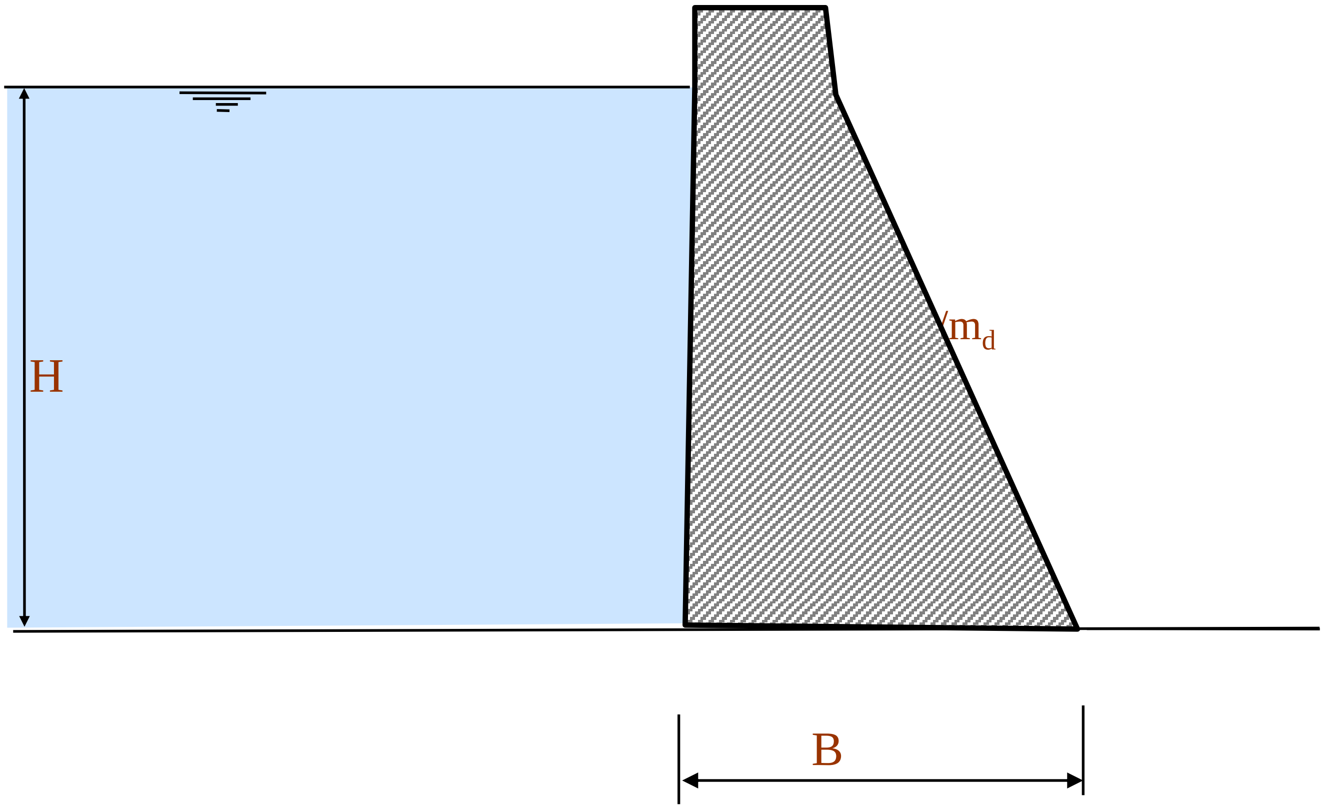
Overturning Check



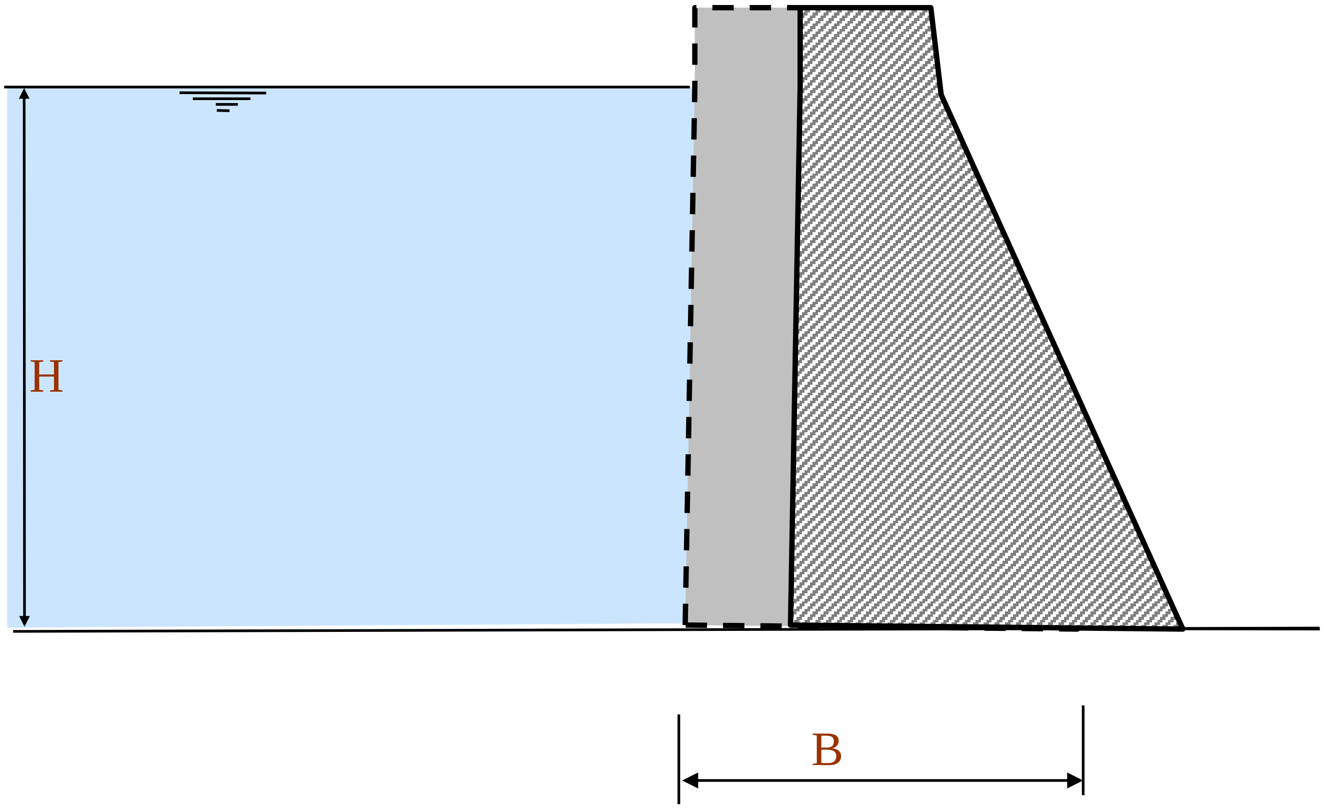
Overturning Check



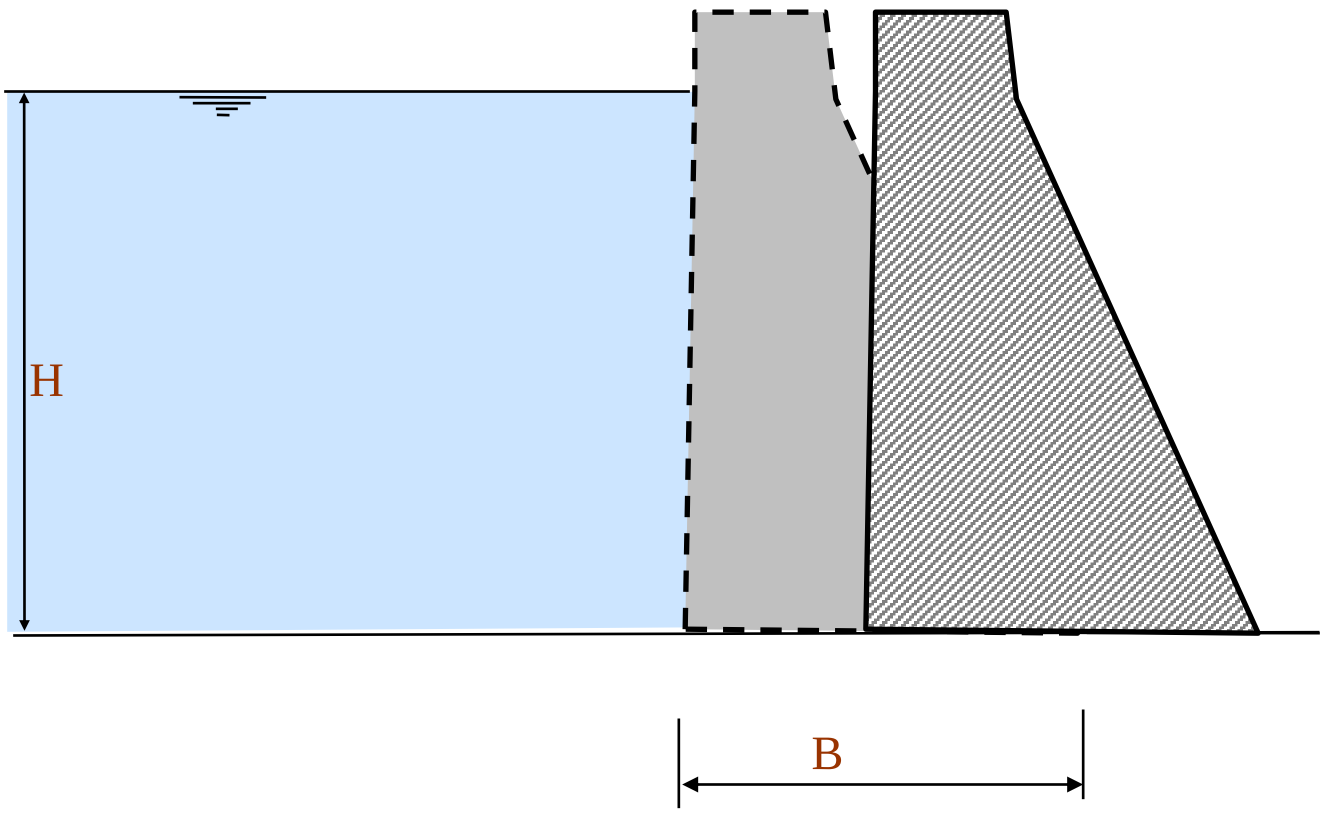
Sliding Check



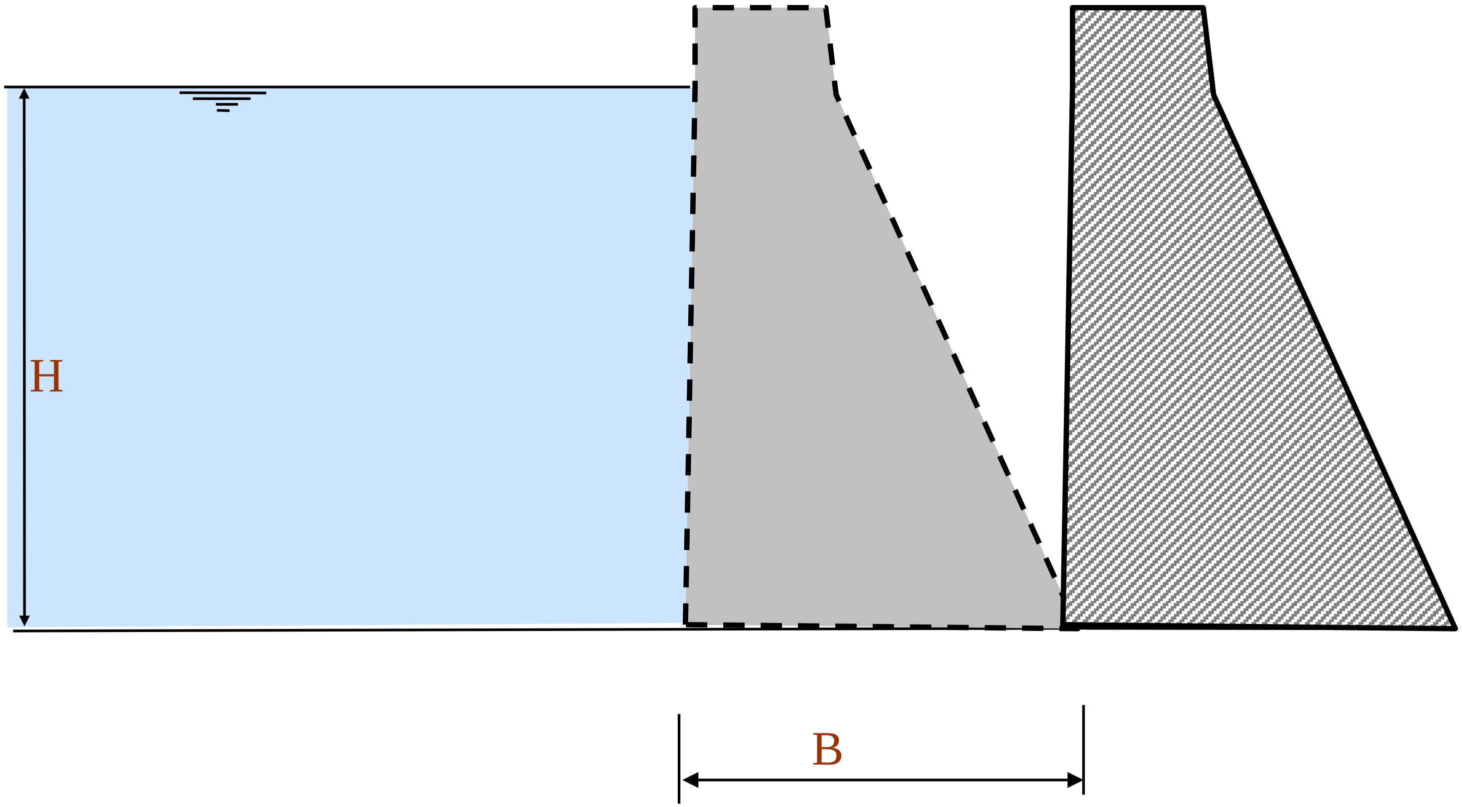
Sliding Check



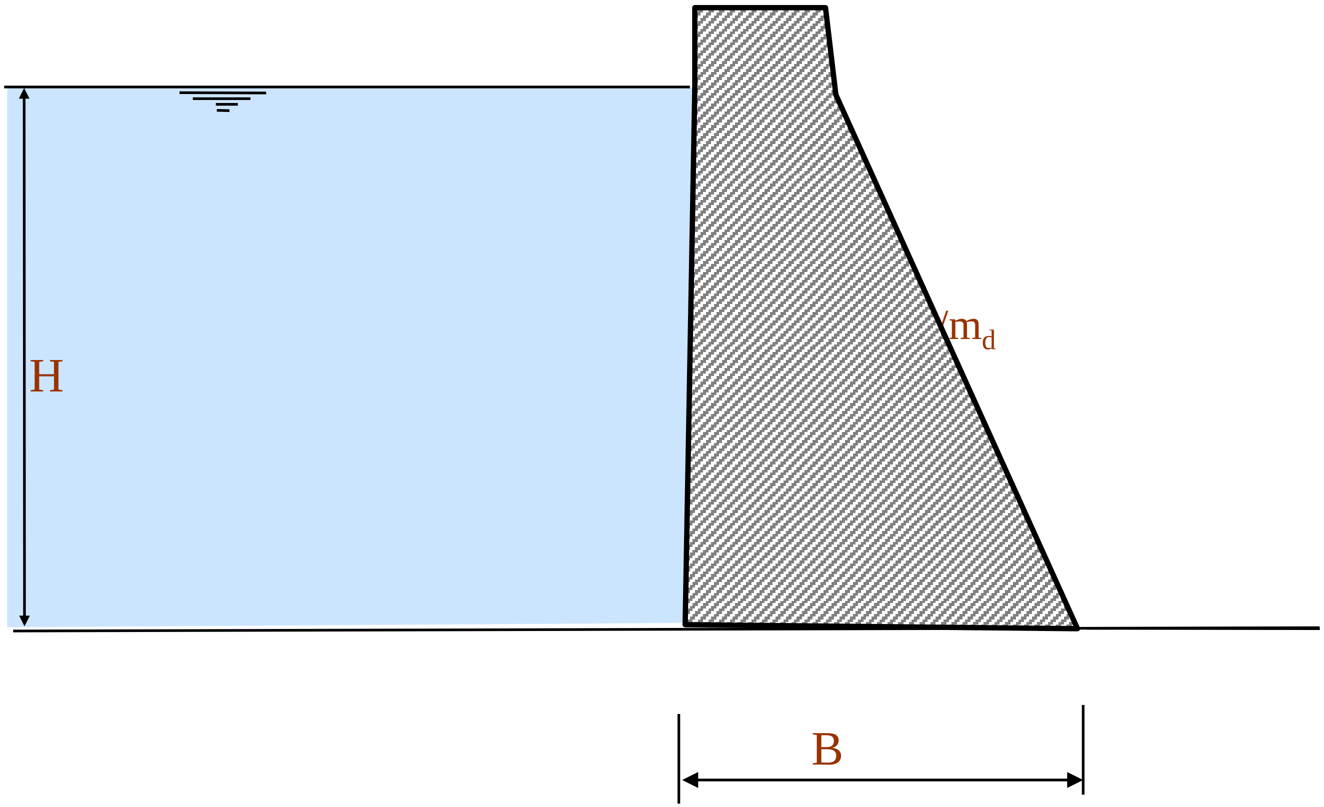
Sliding Check



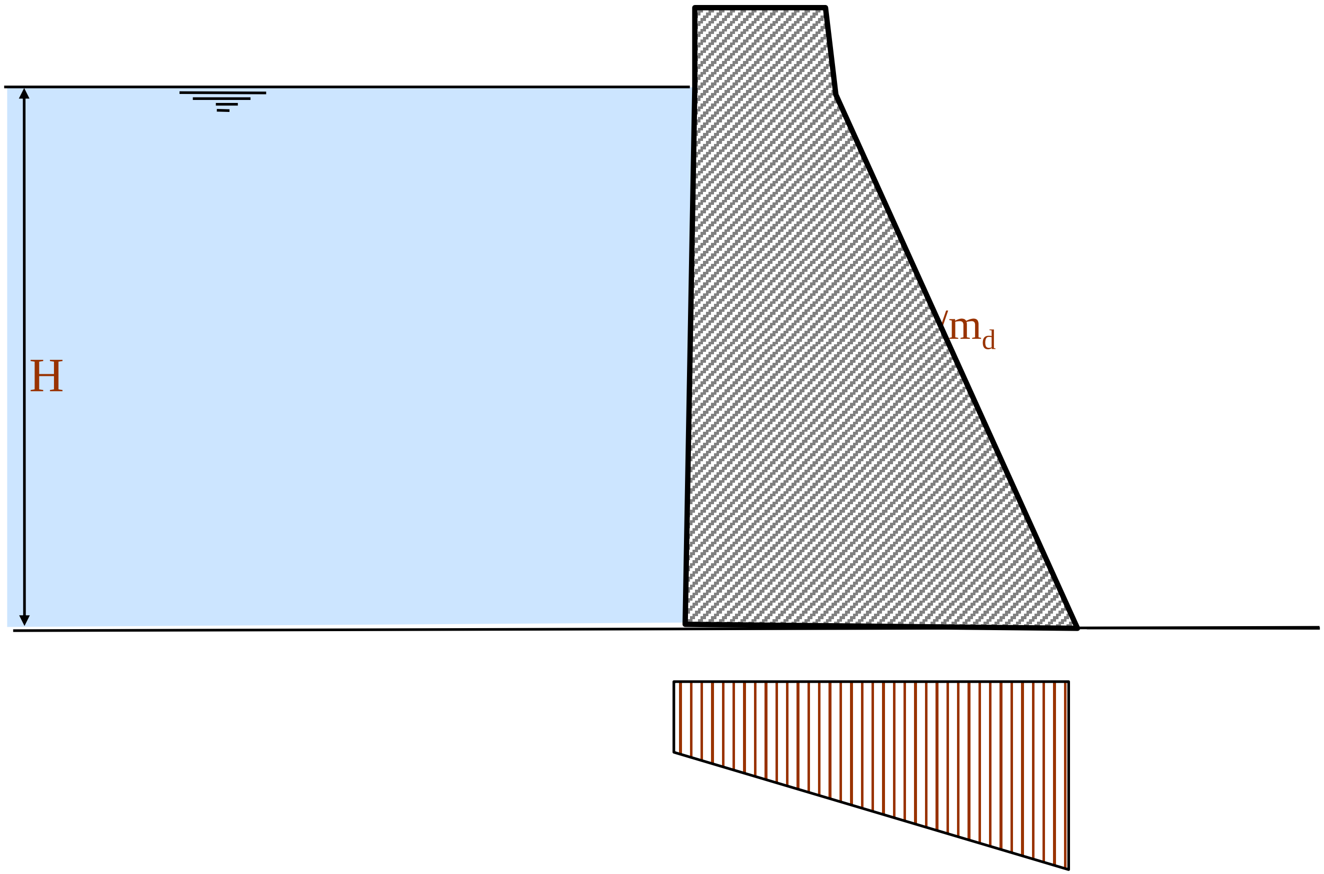
Sliding Check



Sliding Check



Bearing Capacity Check



FORCES ON GRAVITY DAMS

Free body diagram showing forces acting on a gravity dam

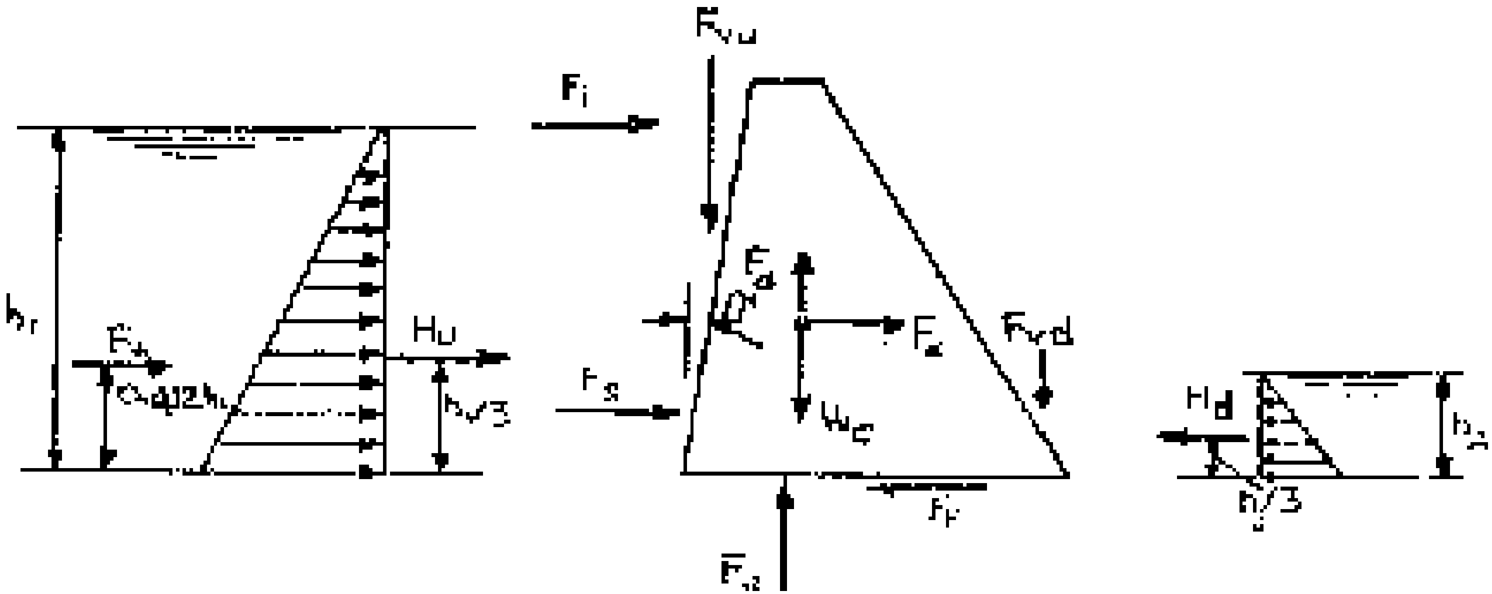


Figure 2.6. Forces acting on a gravity dam.

A) WEIGHT (W_C): Dead load and acts at the centroid of the section

B) HYDROSTATIC FORCES:

Water in the reservoir + tailwater causes Horizontal H_u H_d &

Vertical F_{h1v} F_{h2v}

$$H_u = \frac{1}{2}\gamma\, h_1^2 \qquad H_d = \frac{1}{2}\gamma\, h_2^2$$

C) UPLIFT FORCE (F_u): acts under the base as:

$$F_u = \left[h_2 + \frac{\varnothing}{2}(h_1 - h_2)\right] B\gamma$$

$\phi = 1 \Rightarrow F_u = \left(\frac{h_1 + h_2}{2}\right)\gamma B$

uplift correction factor

D) FORCE OF SEDIMENT ACCUMULATION (F_s):

Determined by the lateral earth pressure expression

$$F_s = \frac{1}{2}\,\gamma_s\,h_B^2\left[\frac{1 - sin\theta}{1 + sin\theta}\right]$$

where

- F_s : the lateral earth force per unit width,
- γ_s : the submerged specific weight of soil,
- h_s : the depth of sediment accumulation relative to reservoir bottom elevation,
- θ : the angle of repose.

⦿ This force acts at h_s /3 above the reservoir bottom.

E) ICE LOADS (F_i): considered in cold climate

Ice force per unit width of dam (kN/m) can be determined from the following table:

Thickness of ice sheet (cm)	Change in temperature (°C/hr)		
	2.5	**5**	**7.5**
25	30	60	95
50	58	90	150
75	75	115	160
100	100	140	180

F) EARTHQUAKE FORCE (F_d):

Acting horizontally and vertically at the center of gravity

$$F_s = k\ W_c$$

k (earthquake coefficient): Ratio of earthquake acceleration to gravitational acceleration.

G) DYNAMIC FORCE (F_w) :

In the reservoir, induced by earthquake as below

$$F_w = 0.726\, C\, k\, \gamma\, h_1^2$$

- Acts at a distance 0.412 h_1 from the bottom

- F_w : the force per unit width of dam
- C : constant given by

$$C = 0.7\left(1 - \frac{\theta'}{90}\right)$$

- θ' : angle of upstream face of the dam from vertical (°C)
  - For vertical upstream face ➔ C = 0.7

H) FORCES ON SPILLWAYS ($\sum F$):

Determined by using momentum equation btw two successive sections:

$$\sum F = \rho \, Q \Delta V$$

- ρ : the density of water
- Q : the outflow rate over the spillway crest
- ΔV: the change in velocity between sections 1 and 2 ($v_2 - v_1$)

⊙ Momentum correction coefficients can be assumed as unity.

I) WAVE FORCES :

Considered when a long fetch exists

LOADING CONDITIONS:

- **Usual loading**

B &Temperature Stresses at normal conditions + C + A + E + D

- **Unusual loading**

B & Temperature Stresses at min. at full upstream level + C + A +D

- **Severe loading**

Forces in usual loading + earthquake forces

UNIT-III
Earth dams

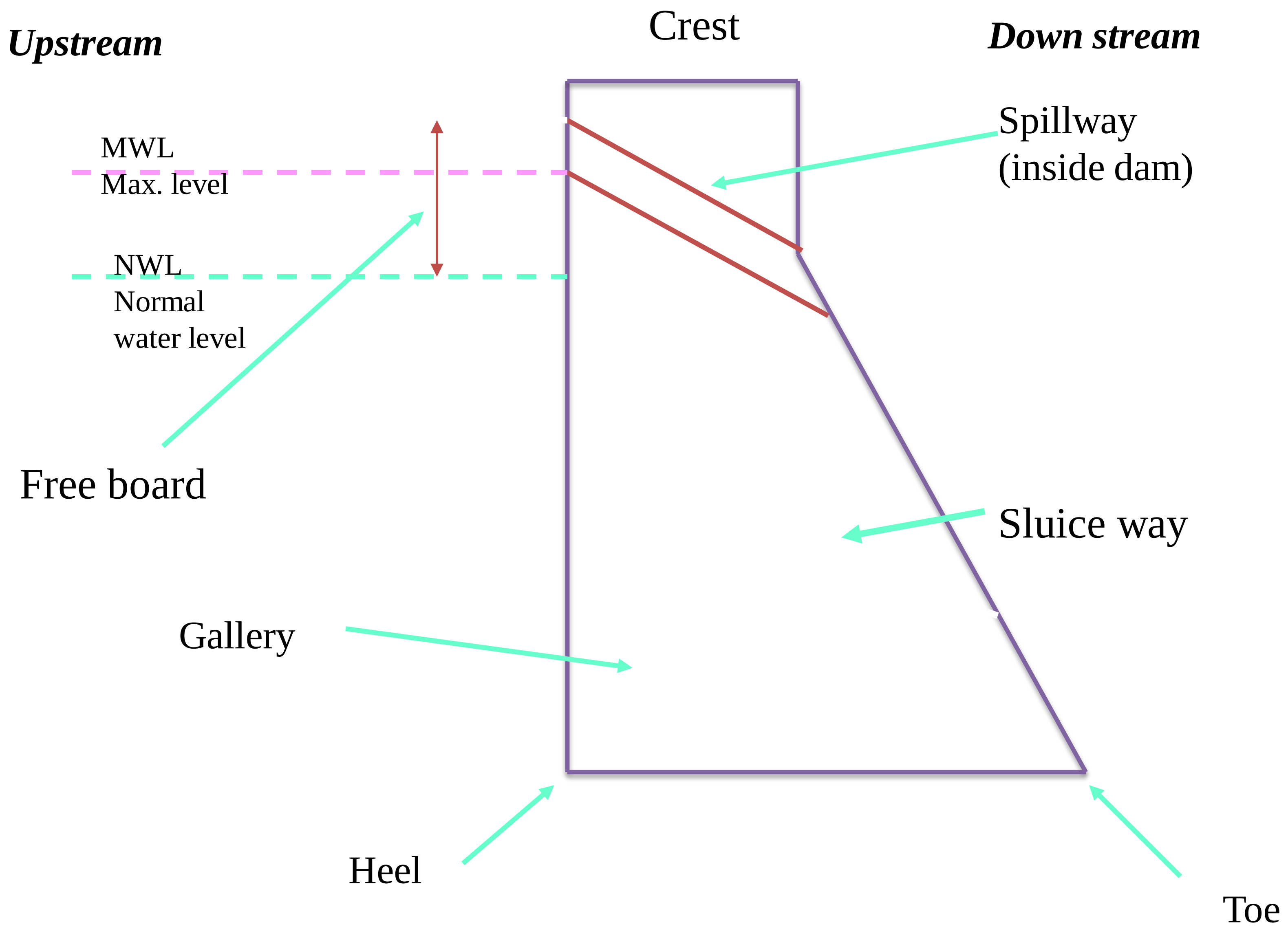
Dams

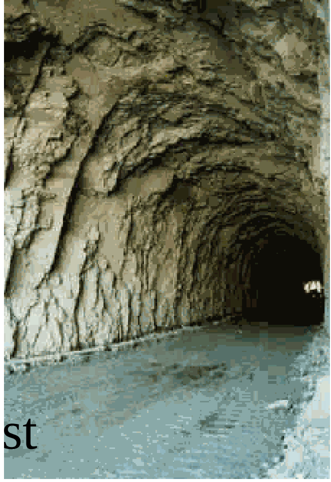
Dam is a solid barrier constructed at a suitable location across a river valley to store flowing water.

Storage of water is utilized for following objectives:

- Hydropower
- Irrigation
- Water for domestic consumption
- Drought and flood control
- For navigational facilities
- Other additional utilization is to develop fisheries

Structure of Dam





- Heel: contact with the ground on the upstream side
- Toe: contact on the downstream side
- Abutment: Sides of the valley on which the structure of the dam rest
- Galleries: small rooms like structure left within the dam for checking operations.
- Diversion tunnel: Tunnels are constructed for diverting water before the construction of dam. This helps in keeping the river bed dry.
- Spillways: It is the arrangement near the top to release the excess water of the reservoir to downstream side
- Sluice way: An opening in the dam near the ground level, which is used to clear the silt accumulation in the reservoir side.

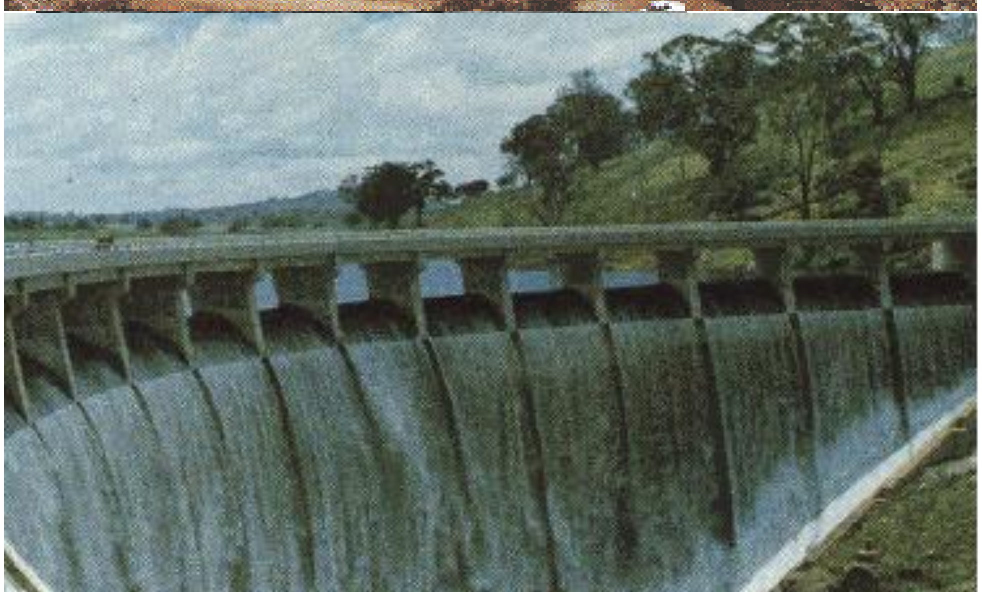
- Bhakra Dam is the highest Concrete Gravity dam in Asia and Second Highest in the world.
- Bhakra Dam is across river Sutlej in Himachal Pradesh
- The construction of this project was started in the year 1948 and was completed in 1963 .

It is 740 ft. high above the deepest foundation as straight concrete dam being more than three times the height of Qutab Minar.

Length at top 518.16 m (1700 feet); Width at base 190.5 m (625 feet), and at the top is 9.14 m (30 feet)

Bhakra Dam is the highest Concrete Gravity dam in Asia and Second Highest in the world.

Arch Dams:



- These type of dams are concrete or masonry dams which are curved or convex upstream in plan

- This shape helps to transmit the major part of the water load to the abutments

- Arch dams are built across narrow, deep river gorges, but now in recent years they have been considered even for little wider valleys.

Types of Earth Dams

Depending upon the method of construction:

1- Rolled fill dam.

2- Hydraulic fill dam.

1- Rolled fill dam

- In the ***rolled fill dam***, the embankment is constructed in successive, mechanically compacted layers by “rollers”.

2- Hydraulic fill dam

- In the case of ***Hydraulic fill dam***, the materials are excavated, transported and placed by hydraulic methods.

Rolled-fill dams

- Rolled-fill earth dams can be sub-divided into:

  1- Homogeneous embankment type.

  2- Zoned embankment type.

  3- Diaphragm embankment type.

1- Homogeneous embankment type

- A purely homogenous type earth dam is composed of a single kind of material, usually impervious or semi-impervious.

- Can be used for low to moderate heights

1- Homogeneous embankment type

- A modified homogeneous section in which internal drainage system (horizontal filter drain or rock toe) is provided

- Advantages:
  - controls the action of seepage, so as to permit much steeper slopes.

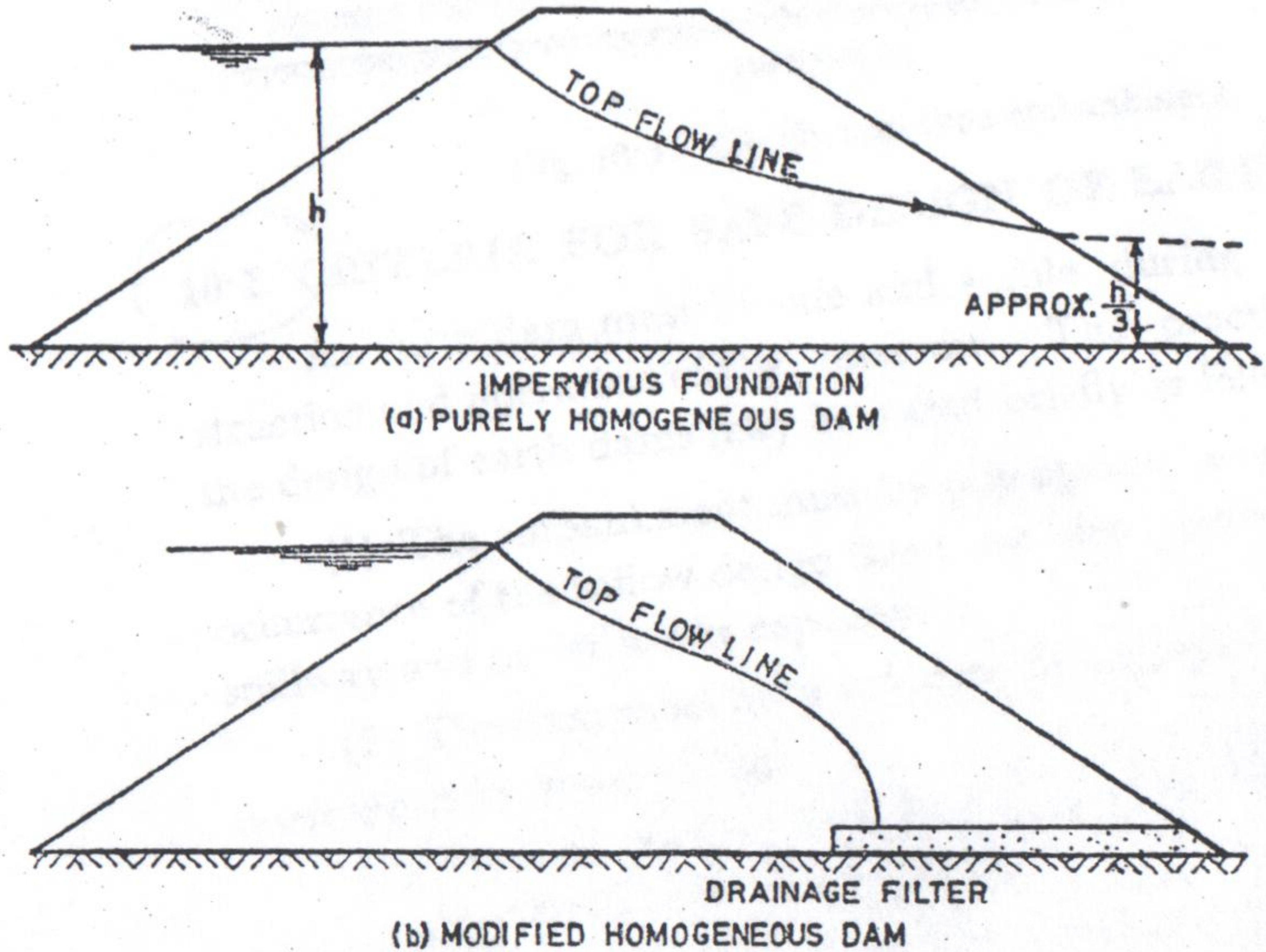


Fig. 10·1. Homogeneous Dam

2- Zoned embankment type

- Zoned embankment type earth dam is the one in which the dam is made up of more than one material.

- Consists of:

Central impervious **core**

Shells: flanking the core and more pervious transition zone (optional)

drainage system

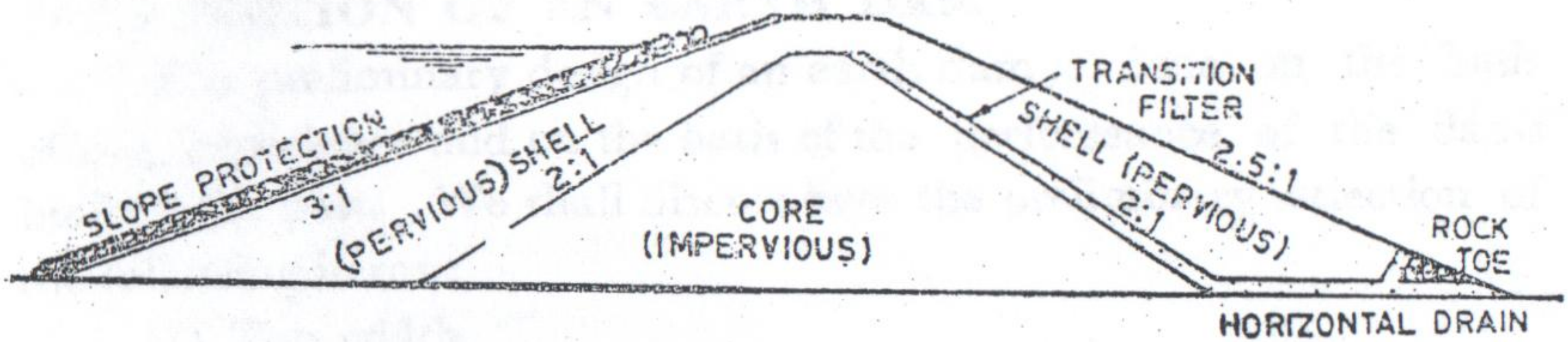


Fig. 10·2. Zoned Embankment.

2- Zoned embankment type

- Function of **shell** layer:

  1- give stability to the central core.

  2- distribute the load over a larger area in the foundation.

  3- The **upstream** pervious zone affords stability against rapid drawdown

  4- the **downstream** pervious zone acts as a drain to control the line of seepage

3- Diaphragm type embankment

- A thin diaphragm of impervious material is provided to check the seepage.

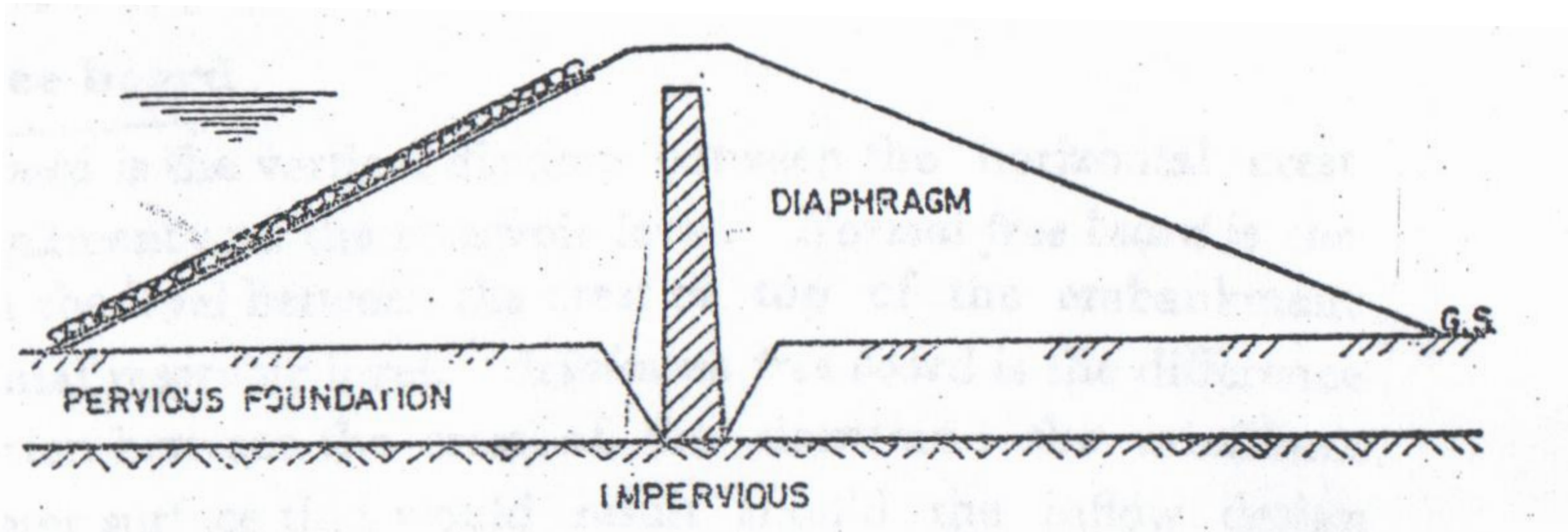


Fig. 10·3. Diaphragm type embankment.

3- Diaphragm type embankment

- Material: impervious soil, cement concrete, bituminous concrete.

- Types: - Central vertical core

  - A blanket at the upstream face

3- Diaphragm type embankment

- Difference between a diaphragm type and zoned type:
  - The thickness of the diaphragm is less than 10 m or the height of embankment.

SECTION OF AN EARTH DAM

- Empirical assumptions shall be made for:

  1- Top width.

  2- Free board.

  3- Upstream and downstream slopes.

  4- Central Impervious core.

  5- Downstream Drainage system.

1- Top width

$$b = \frac{Z}{5} + 3$$

$$b = 0{\cdot}55\, Z^{\frac{1}{2}} + 0{\cdot}2Z$$

$$b = 1{\cdot}65(Z + 1{\cdot}5)^{\frac{1}{3}}$$

2- Free board

- *Free board* is the vertical distance between the crest and the reservoir level.
- Depends on Height and whether there is a sp[illegible] or not.

U.S.B.R. Practice for Free Board

Nature of spillway	*Height of Dam*	*Free board*
Free	any	Minimum 2 m and maximum 3 m over the maximum flood level.
Controll d	Less than 60 m	2·5 m above the top of gates.
Controll d	Over 60 m	3 m above top of gates.

3- Upstream and downstream slopes

- Assume upstream slope 3:1 and downstream slope 2.5:1 or use the table given below:

Side slopes for earth dams according to Terzaghi

	Type of material	*Upstream slope*	*Downstream slope*
(*i*)	Homogeneous well graded material	$2\frac{1}{2}:1$	$2:1$
(*ii*)	Homogeneous coarse silt	$3:1$	$2\frac{1}{2}:1$
(*iii*)	Homogeneous silty clay, or clay		
	Ht. less than 15 m.	$2\frac{1}{2}:1$	$2:1$
	Ht. more than 15 m.	$3:1$	$2\frac{1}{2}:1$
(*iv*)	Sand or sand and gravel with clay core	$3:1$	$2\frac{1}{2}:1$
(*v*)	Sand or sand and gravel with R.C. core wall	$2\frac{1}{2}:1$	$2:1$

4- Central impervious core

1- The **thickness** of the core at any elevation is **not less than** the height of the embankment at that elevation.

2- The **width** of the core at the crest of the dam should be a minimum of **3 m**

5- Downstream drainage system

- Types of drains:
  1- Toe drains
  2- Horizontal blanket drains
  3- chimney drains

UNIT-IV

Diversion Head works:

Diversion Headworks

A diversion head work serves to divert the required supply into the canal from a river.

Weir:

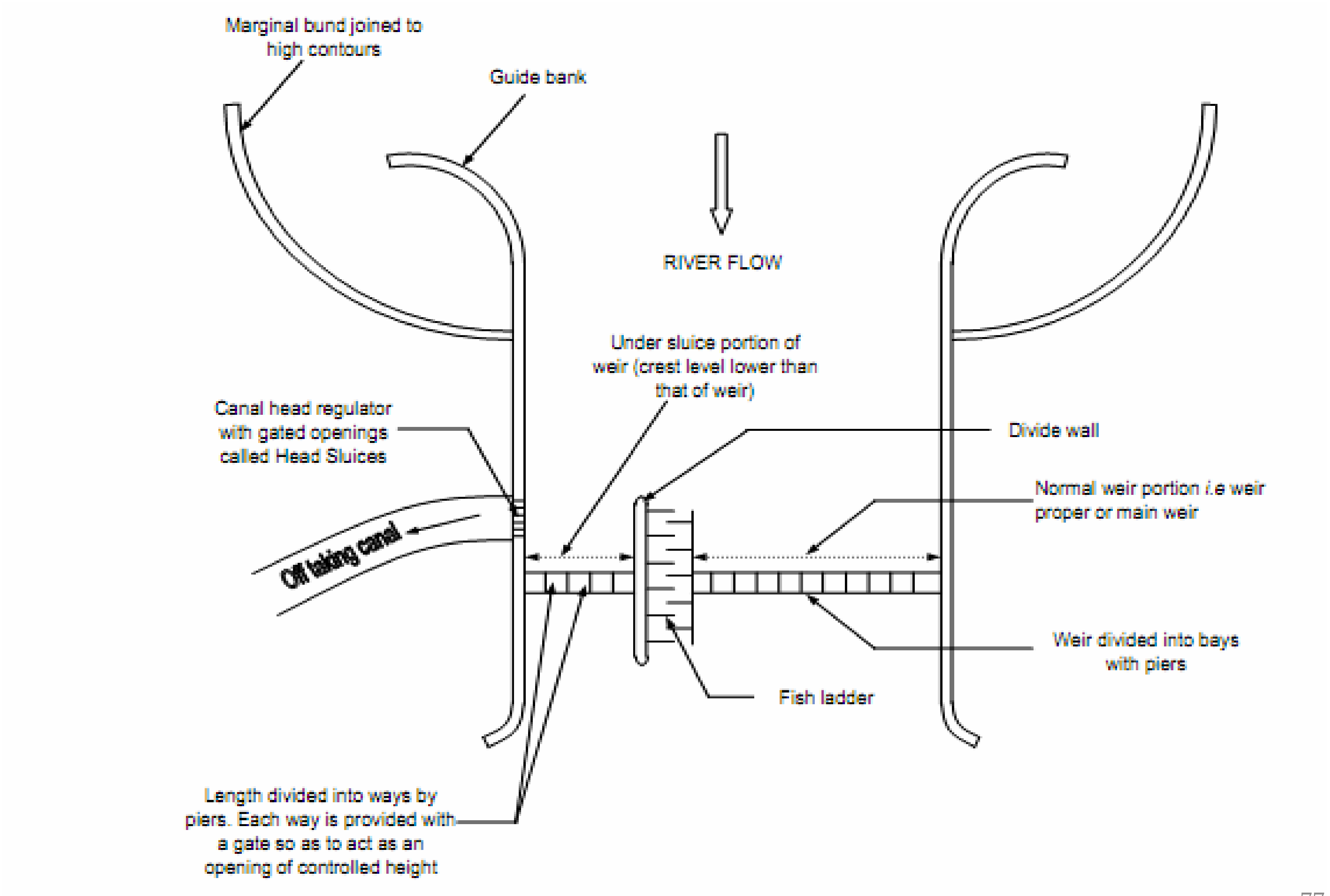
The weir is a solid obstruction put across the river to raise its water level and divert the water into the canal. If the weir also stores for a small period of time then it is called as storage weir.

Barrage:

The function of barrage is similar to that of weir, but the heading up of water is effected by the gates alone. No solid obstruction is put across the river.

Diversion Headworks

Components of Diversion Headworks



Diversion Head Works

Diversion Head works

Diversion Head-Works

Diversion Headworks

Weir

Barrage

UNIT-V
Cross Drainage Works

WHAT IS CROSS DRAINAGE WORK

- when the network of main canals, branch canals, distributaries, etc.. are provided, then these canals may have to cross the natural drainages like rivers, streams, nallahs, etc. at different points.
- The crossing of the canals with such obstacle cannot be avoided.
- So, suitable structures is constructed at the crossing point for the easy flow of water of the canal and drainage in the respective directions.
- These structures are known as **cross-drainage works**.

WHAT IS CROSS DRAINAGE WORK

- Irrigational Canals while carrying water have to cross few natural drainage streams, rivers, etc..
- To cross those drainages safely by the canals, some suitable structures are required to construct. Works required to construct, to cross the drainage are called Cross Drainage Works (CDWs).
- At the meeting point of canals and drainages, bed levels may not be same.
- Depending on their bed levels, different structures are constructed and accordingly they are known by different names.

NECESSITY OF CDW

- The water-shed canals do not cross natural drainages. But in actual orientation of the canal network, this ideal condition may not be available and the obstacles like natural drainages may be present across the canal. So, the cross drainage works must be provided for running the irrigation system.
- At the crossing point, the water of the canal and the drainage get intermixed. So, far the smooth running of the canal with its design discharge the cross drainage works are required.

NECESSITY OF CDWs

- The site condition of the crossing point may be such that without any suitable structure, the water of the canal and drainage can not be diverted to their natural directions. So, the cross drainage works must be provided to maintain their natural direction of flow.

TYEPS OF CDWs

(1) Type I (Irrigation canal passes over the drainage)

(a) Aqueduct,

(b) Siphon aqueduct.

(2) Type II (Drainage passes over the irrigation canal)

(a) Super passage,

(b) Siphon super passage.

(3) Type III (Drainage and canal intersection each other of the same level)

(a) Level Crossing,

(b) Inlet and outlet.

- **Aqueduct**

  The hydraulic structure in which the irrigation canal is taken over the drainage (such as river, stream etc..) is known as aqueduct. This structure is suitable when bed level of canal is above the highest flood level of drainage. In this case, the drainage water passes clearly below the canal.

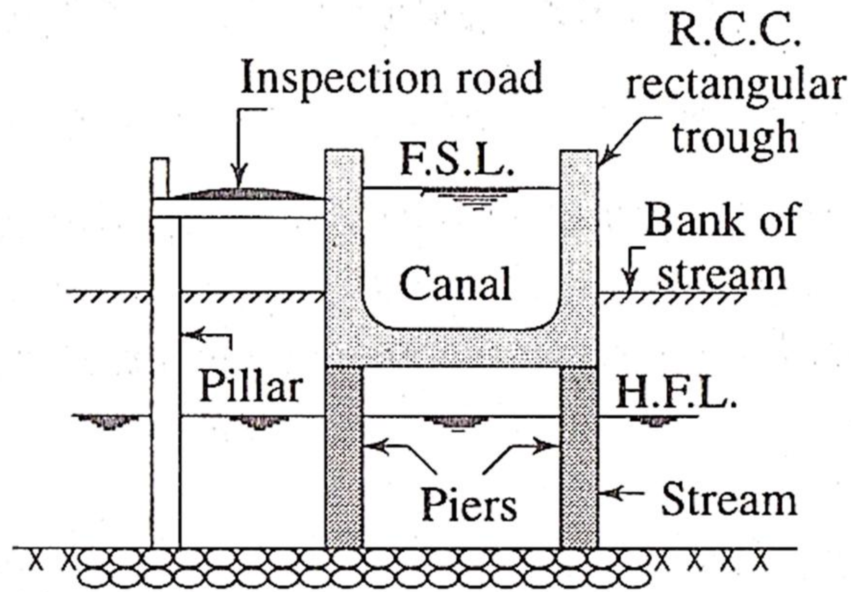
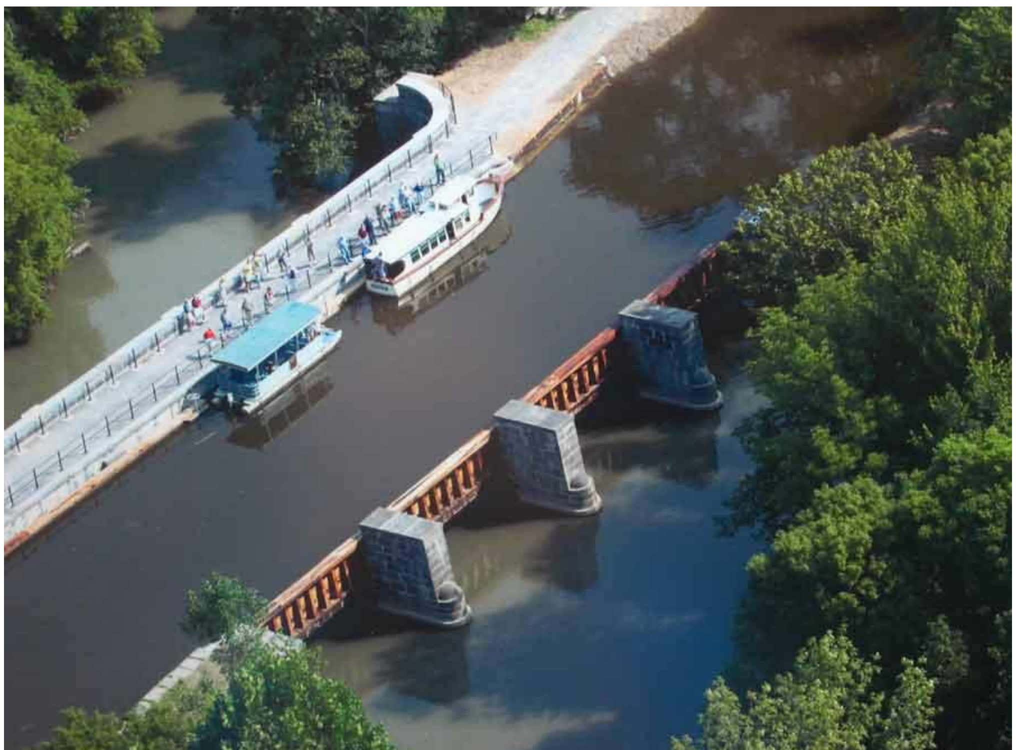


Fig: Aqueduct



Siphon Aqueduct

- In a hydraulic structure where the canal is taken over the drainage, but the drainage water cannot pass clearly below the canal.
- It flows under siphonic action. So, it is known as siphon aqueduct.
- This structure is suitable when the bed level of canal is below the highest flood level.

Siphon Aqueduct

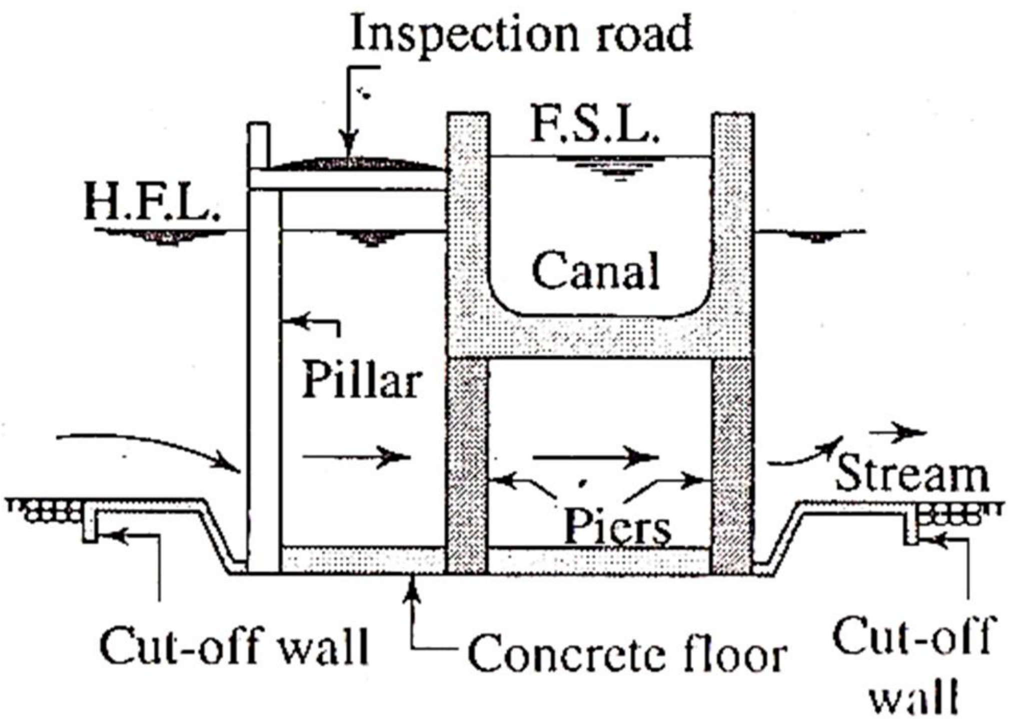


Fig: Siphon Aqueduct

Super Passage

- The hydraulic structure in which the drainage is taken over the irrigation canal is known as super passage.
- The structure is suitable when the bed level of drainage is above the full supply level of the canal.
- The water of the canal passes clearly below the drainage.

Siphon Super Passage

- The hydraulic structure in which the drainage is taken over the irrigation canal, but the canal water passes below the drainage under siphonic action is known as siphon super passage.
- This structure is suitable when the bed level of drainage is below the full supply level of the canal.

Availability of Suitable Foundation

- For the construction of cross drainage works suitable foundation is required. By boring test, if suitable foundation is not available, then the type of cross drainage work should be selected to site Condition.

Economic Consideration

- The cost of construction of cross drainage works should be justified with respect to the project cost and overall benefits of the project.
- So, the type of works should be selected considering the economical point of view.

Discharge of the drainage

- Practically the discharge of the drainage is very uncertain in rainy season.
- So, the structure should be carefully selected so that it may not be destroyed due to unexpected heavy discharge of the river or drainage.

Canal Regulation Works

- Any structure constructed to regulate the discharge, full supply level, and velocity in a canal is known as a Canal Regulation Work. Such structures are necessary for the efficient working and safety of an irrigation channel.
- Fall:

  A fall is an irrigation structure constructed across a canal to lower down its water level and destroy the surplus energy liberated from the falling water which may otherwise scour the bed and banks of the canal.
- Head Regulator and Cross Regulator:

  Head regulator and cross regulator regulate the supplies of the off-taking canal and parent canal respectively.

  Outlets: An outlet is a small structure which admits water from the distributing channel to a field channel or water course.

Cross Regulator

Syphon Aqueduct

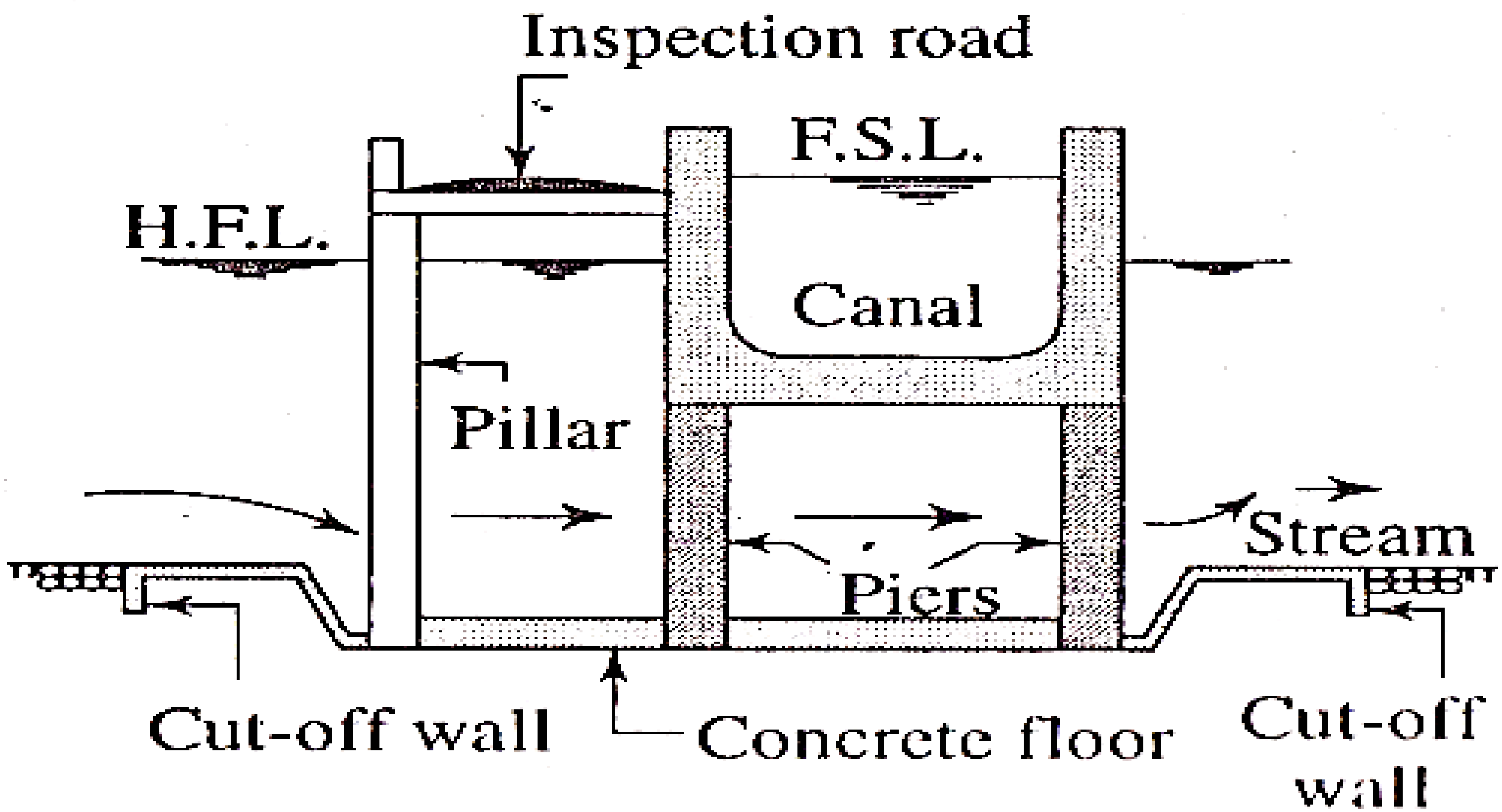


Fig: Siphon Aqueduct

Super Passage

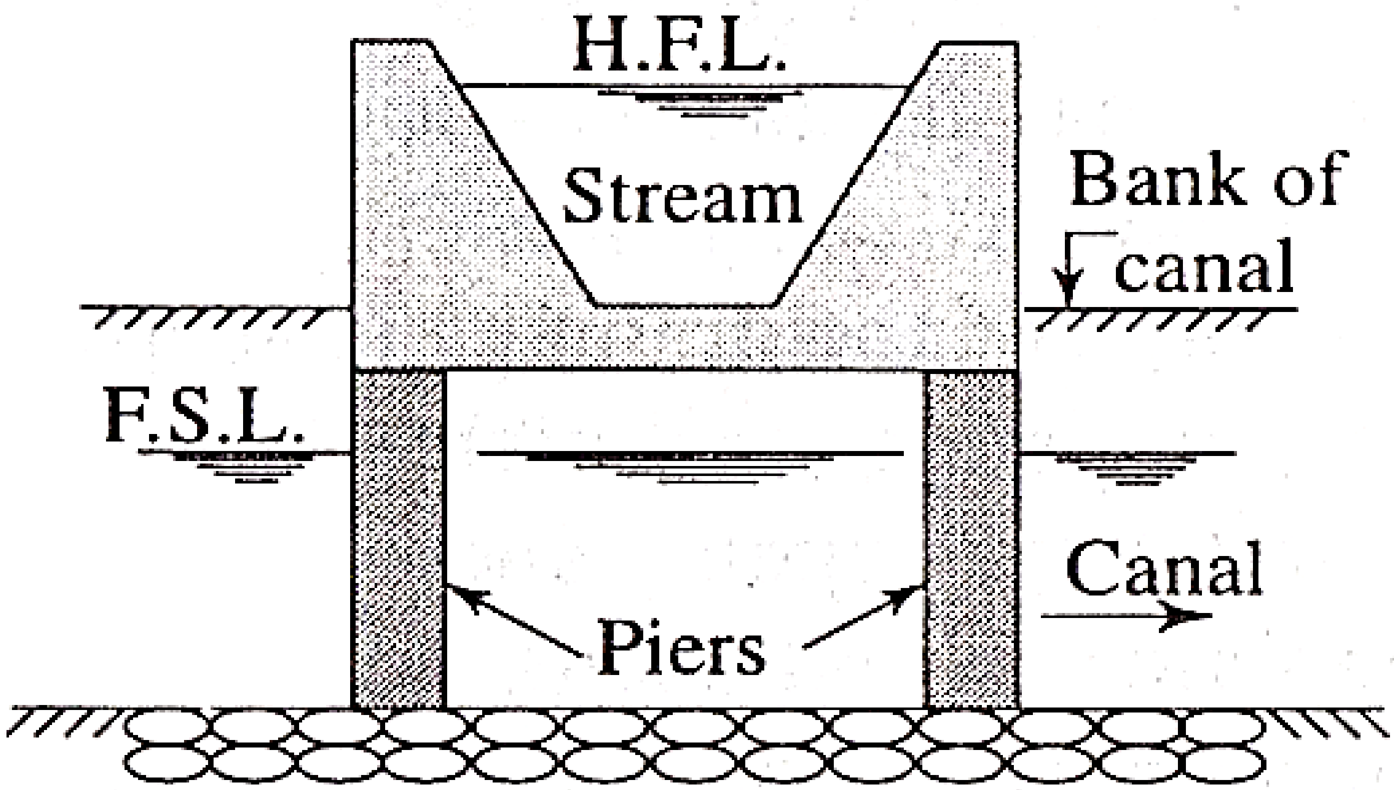


Fig: Super Passage

Super Passage

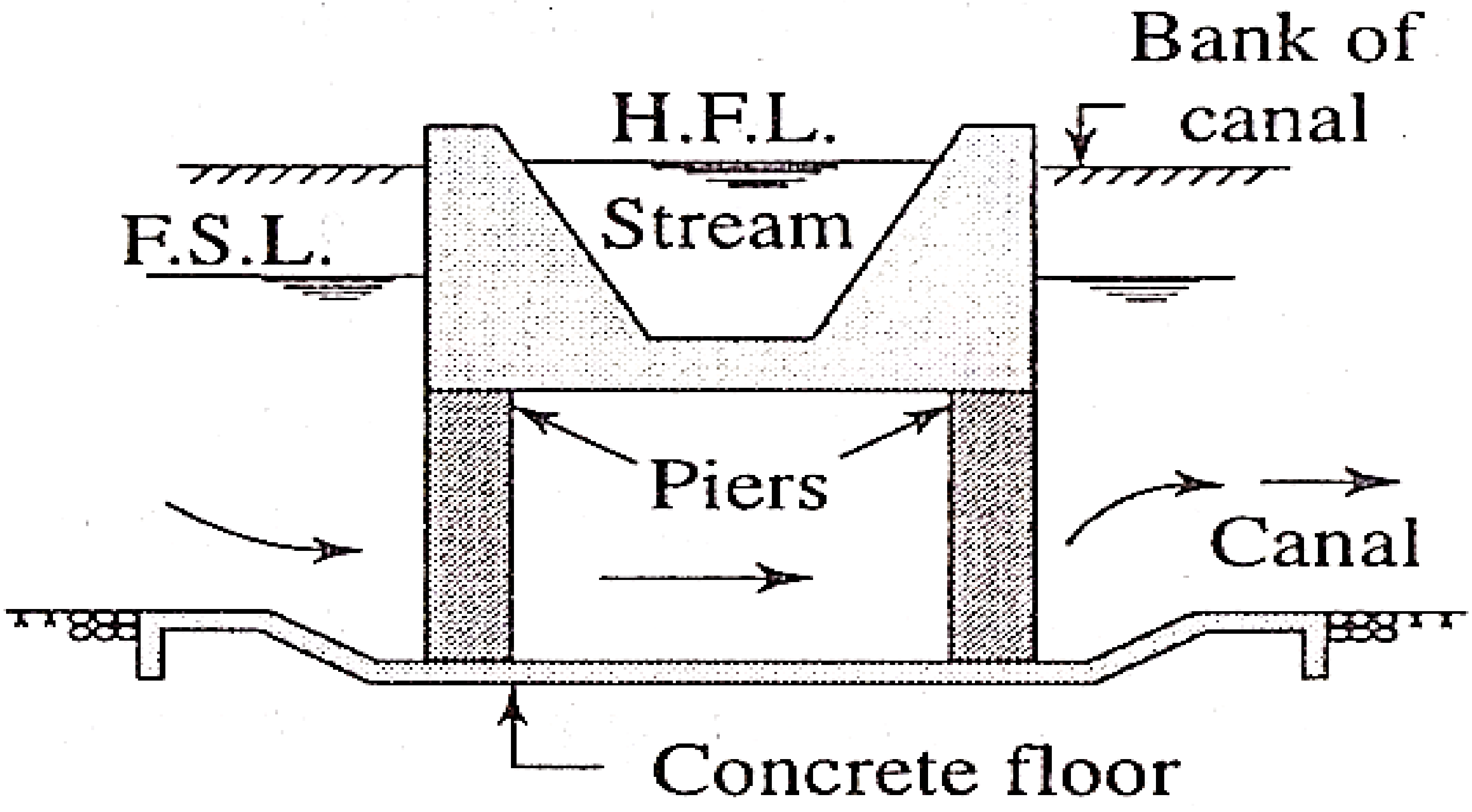


Fig: Siphon Super Passage

Level Crossing

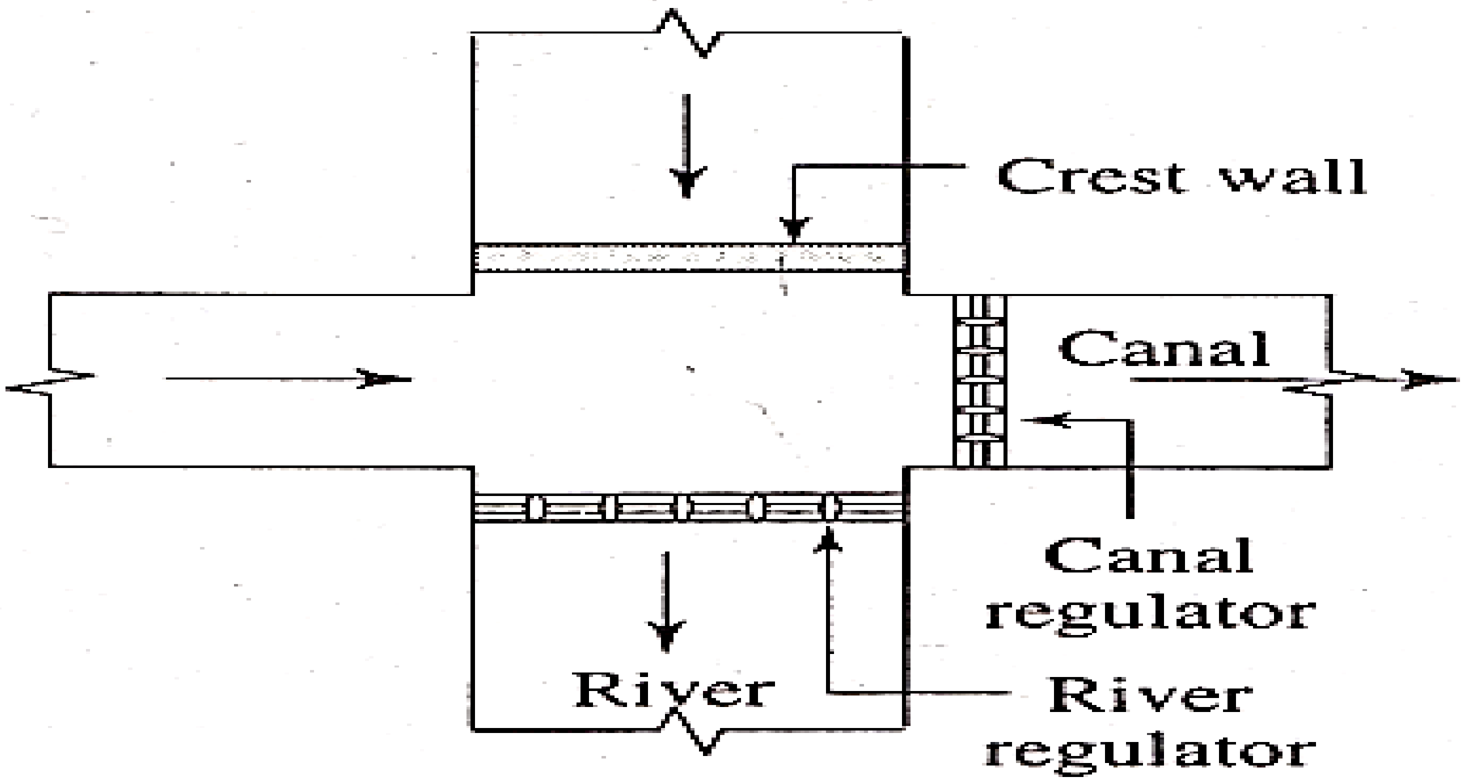


Fig: Level Crossing

Inlets and Outlets

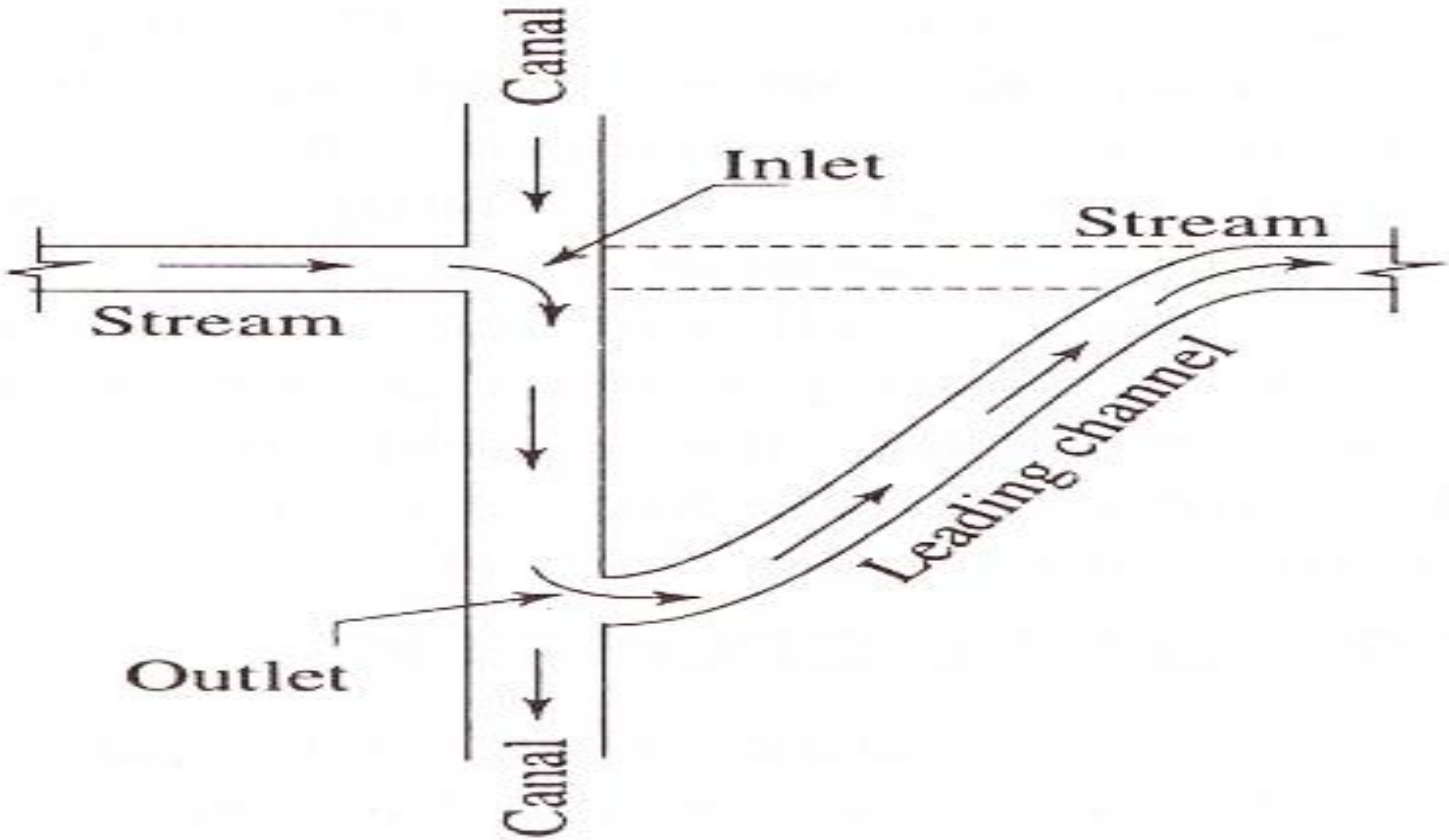


Fig: Inlet and outlet

THANK YOU