N.B.K.R. INSTITUTE OF SCIENCE & TECHNOLOGY:: VIDYANAGAR

(AUTONOMOUS)

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Course Name: Engineering Geology

Unit-VI –GEOLOGICAL INVESTIGATION FOR DAMS, RESERVOIRS AND TUNNELS

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UNIT - VI

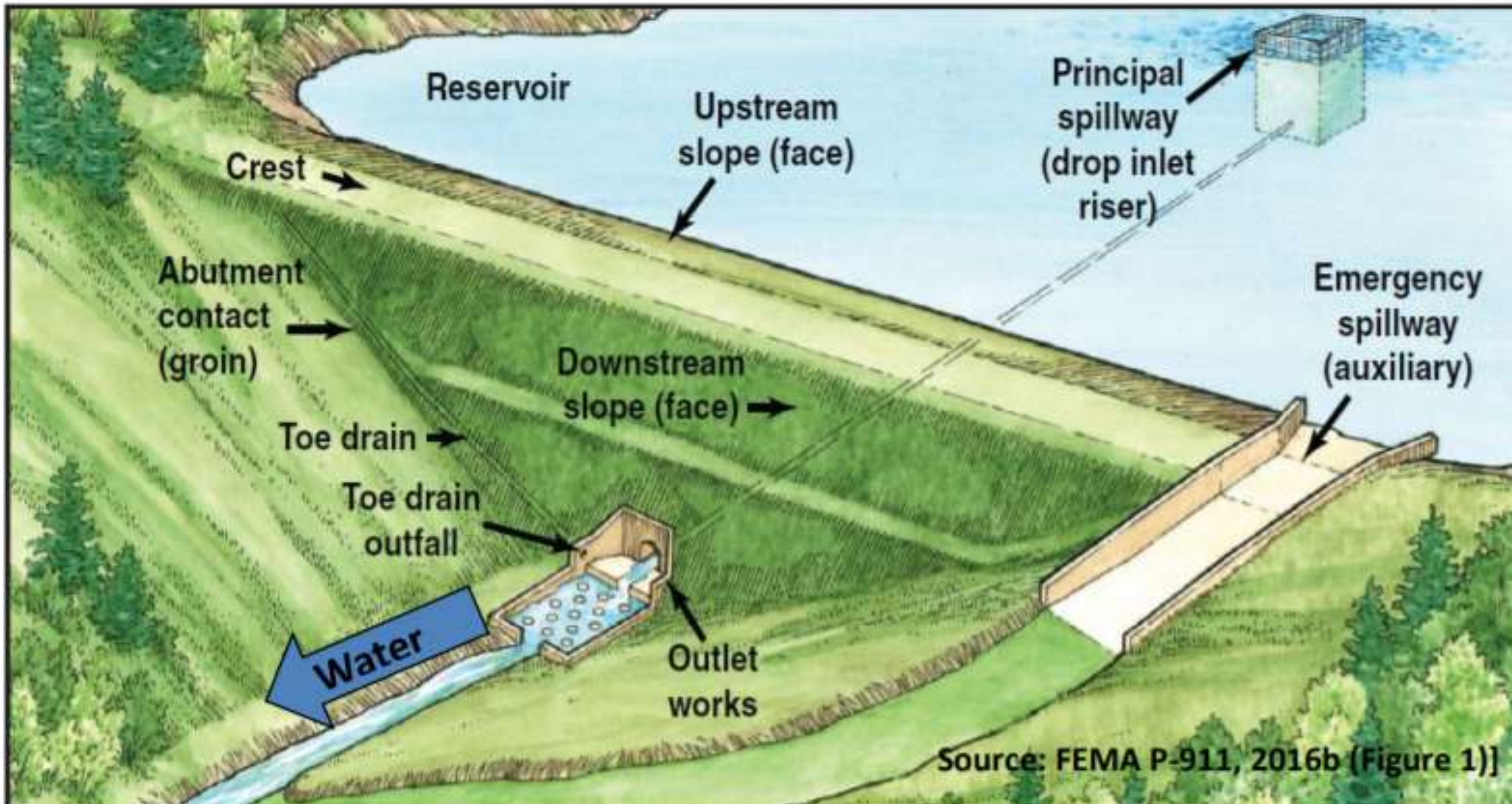
GEOLOGICAL INVESTIGATION FOR DAMS, RESERVOIRS AND TUNNELS:

- Required geological consideration for selecting dam
  - ✓ Geological profile from catchment area to dam site,
  - ✓ Topography, slope, drainage system.
- Reservoir site and geological considerations.
- Failure of Reservoir.
  - ✓ Favorable & unfavorable conditions in different types of rocks in presence of various structural features,
  - ✓ Precautions to be taken to counteract unsuitable conditions for dams, reservoirs
- Tunnel site and geological considerations .
- Two case studies on failure of dams due to ignorance of geological aspects.

Required geological consideration for selecting dam

Dam

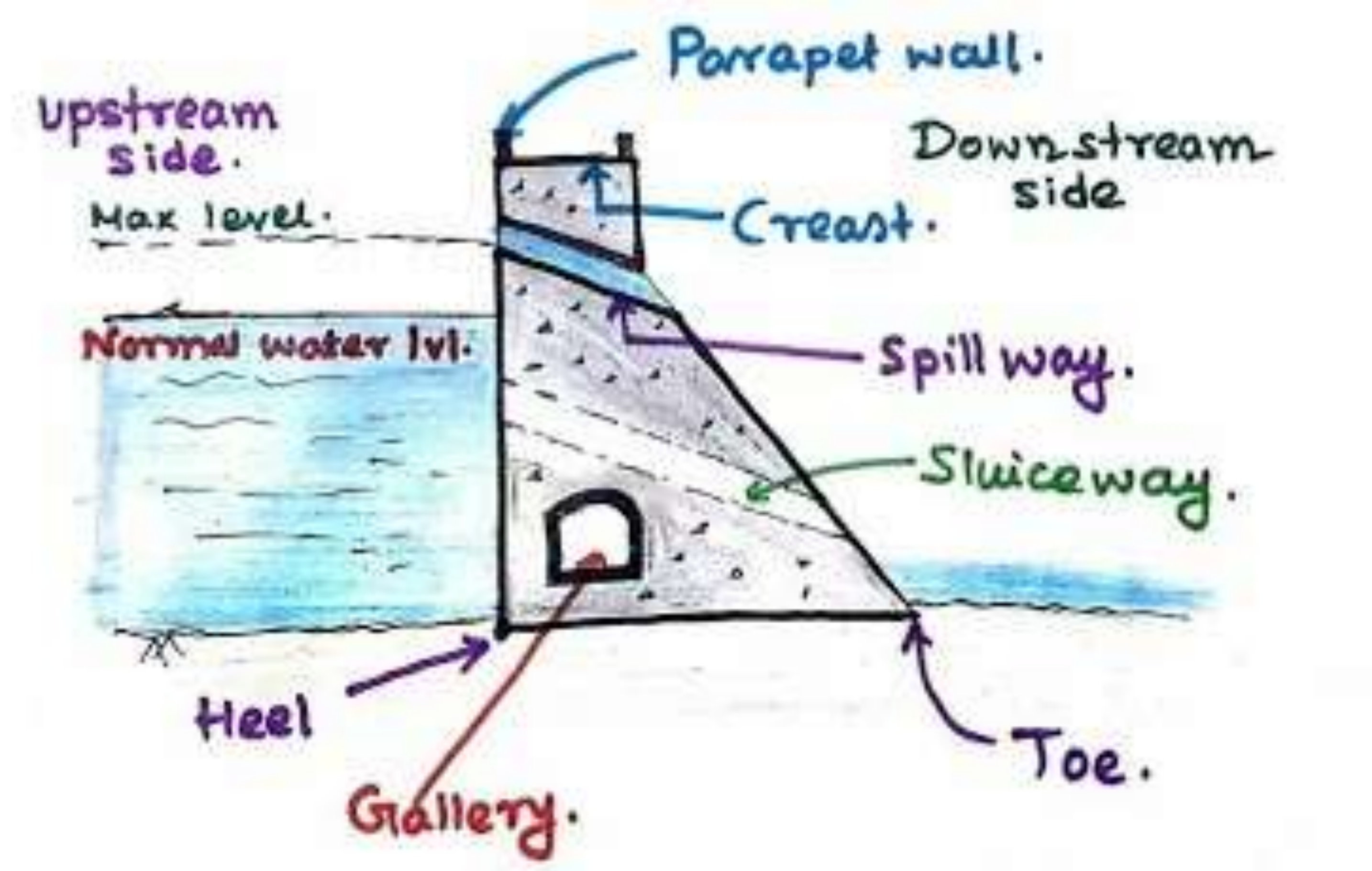
➢A structures constructed across the river to impound or store the water is defined as a dam



https://www.dcr.virginia.gov/dam-safety-and-floodplains/image/parts-of-dam-FEMA.png

Terminology of Dam

- ✓Axis of the dam
- ✓Abutments
- ✓Spill way
- ✓Sluice way
- ✓Crest of the dam
- ✓Toe of the dam
- ✓Free board
- ✓MWL
- ✓DSL
- ✓Upstremside
- ✓Downstream side



Required geological consideration for selecting dam

I. Narrow river valley

II. Occurrence of bed rock at shallow depth

III. Competent rocks suitability for stable foundation

IV. Proper Geological structures

Required geological consideration for selecting dam

I. **Narrow river valley**

A narrow river valley is suitable for dam, when it is free with

- Superficial or residual soil along the slopes or in the valley
- Landslides and rock creep etc.
- Occurrence of buried channel
- Presence of soluble material.

Required geological consideration for selecting dam

II. Occurrence of bed rock at shallow depth

- Strong and stable rocks act as a good foundation for dam.
- These may be found at various depths from place to place.
- Thick overburden on bed rocks is facilitate good strength, so it should be remove and refill with suitable concrete.
- The bed rock at shallow depth can be desirable for dam.

Required geological consideration for selecting dam

III. Competent rocks suitability for stable foundation

- **Suitability of Igneous rocks**
  - Granite,Diorite,rhyolite,gabbro are ideal as strong foundation rocks
  - Strength of basalt is high, but these rocks with vesicles and amygdales are not suitable for foundation of dam, may cause leakage due to vesicles and amygdales.
  - The igneous intrusive rocks like dolerite sills and dykes are not ideal for dam.

- **Suitability of Sedimentary rocks**
  - Shales,siltstones and mudstones are not suitable for dam, because of slippery nature and low cohesion of clay minerals.
  - Sandstone with siliceous and ferruginous cementing material can be ideal for dam. But due to porosity and permeability may effect the suitability of sandstone.
  - Massive limestone are good strength rocks, but the tendency to dissolve in water make these rocks undesirable for dam.
  - Very thin sedimentary rooks are not preferable for dams.

Required geological consideration for selecting dam

III. Competent rocks suitability for stable foundation

- **Suitability of Metamorphic rocks**
  - Gneiss rocks are good in strength, if they are foliated strength will be effect. So unless not having foliated minerals like mica they are suitable for dam.
  - Quartzite are neither porous nor permeable and good in strength, hence these are enough competant and ideal for dam.
  - Marble are also good in strength due to massive and granulose texture, by virtue of dissolved nature marbles are not suitable for dam site.
  - Slates are not suitable for dam, due to slaty cleavage and weak nature.

Note: Weathering and fracturing influences the competency of rock for dams.

Weathered rocks are not ideal because they may create seepage and leakage.

Fractured rooks are also not suitable for dams, due to decrease in strength of rock by shearing and faulting.

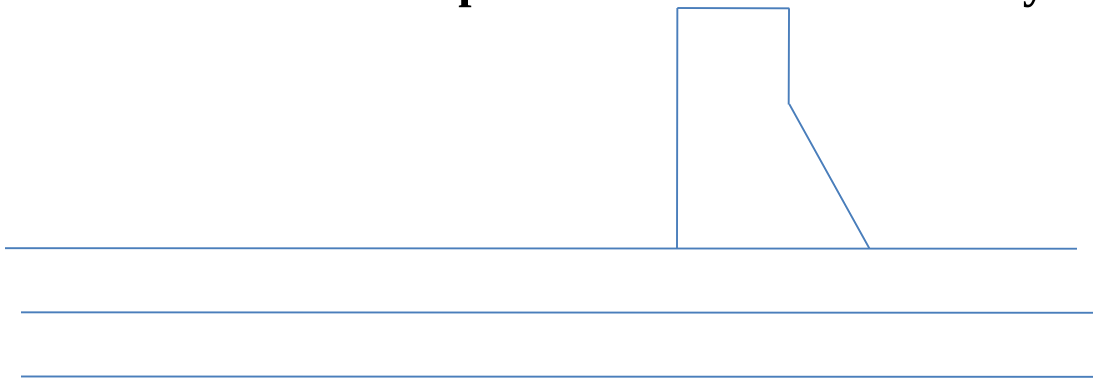
If no alternate, some remedial measures is required to strengthen the rocks.

Required geological consideration for selecting dam

IV. Proper Geological structures

- **Intrusions**
  - Dykes are not suitable for dams, because as they exhibit heterogeneity at the margins with weak rocks.
  - Sills are also not ideal for dams, normally sills are exhibit baked activity, which makes the rocks in to weak.
- **Undisturbed Strata or Horizontal strata**
  - ✓Undisturbed or horizontal rock strata is ideal for dam, because load of the dam is perpedicular to bedding plane is an advantage to bear the load with competent.
  - ✓Uplift pressure also is low, in horizontal beds leakage of water also can be cheked.

Note: These horizontal strata are composed with soft and hard layers shall be undesirable.

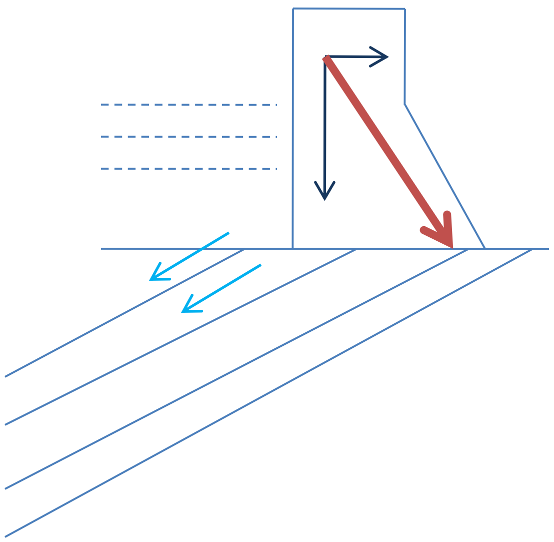


Required geological consideration for selecting dam

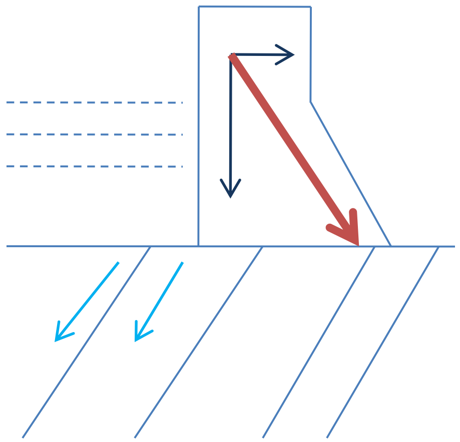
IV. Proper Geological structures

- **Tilted rock strata or beds**
  - **Beds dipping in upstream side**
    - **Dip with 10°-30° is very advantageous and ideal for dam**
      - ✓Because resultant force act perpendicular to the bedding plane, so beds are receive the loads effectively and uplift pressure is also nil on the dam.
      - ✓Percolated water along bedding planes again entered into the reservoir only by that no leakage or loss of water from the reservoir is observed.
    - **Beds with steep upstream side dip**

      ✓This situation is not bad and also not advantageous, because the steep dip cause the rocks are less competent to withstand the loads.



Beds dip in upstream side with gentle slope (10°-30°)

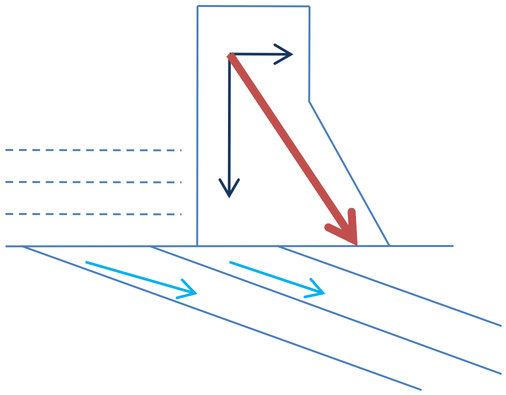


Beds dip in upstream side with steep slope (>30°)

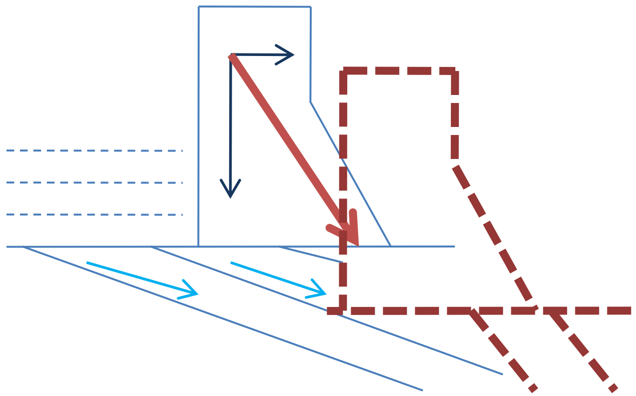
Required geological consideration for selecting dam

IV. Proper Geological structures

- **Beds dipping 10°-30° in downstream side is very dangerous and unsuitable for dam**
  - ✓Because resultant force act parallel to the bedding plane, so beds are less competent and create failure of the dam by displacement.
  - ✓Percolation of water along bedding planes towards downstream side cause leakage or loss of water from the reservoir.



Dam before the effect of resultant force

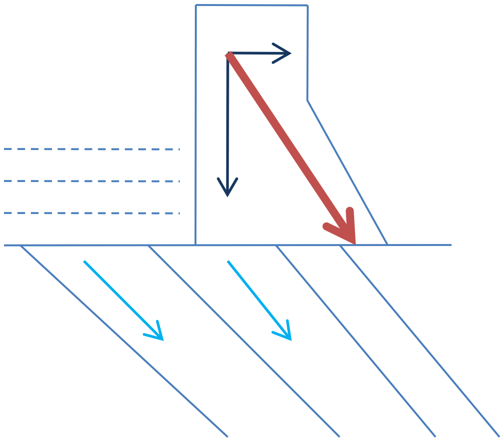


Dam after the effect of resultant force

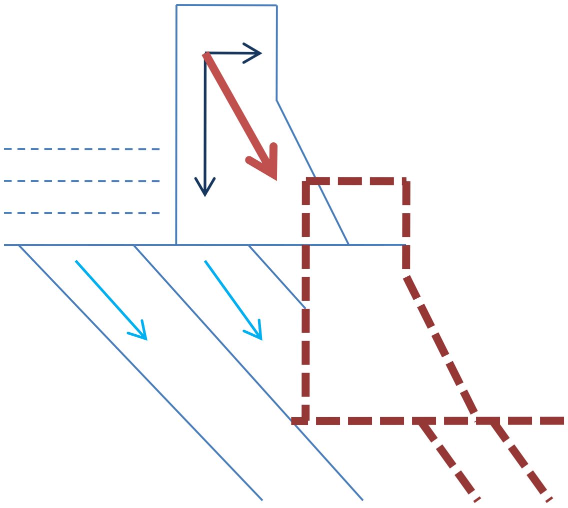
Required geological consideration for selecting dam

IV. Proper Geological structures

- **Steep dipping beds in downstream side is highly dangerous and unsuitable for dam**
  - ✓Because resultant force act parallel to the bedding plane, so beds are less competent and create failure of the dam by more displacement.
  - ✓Percolation of water along bedding planes towards downstream side cause leakage or loss of water from the reservoir.



Dam before the effect of resultant force

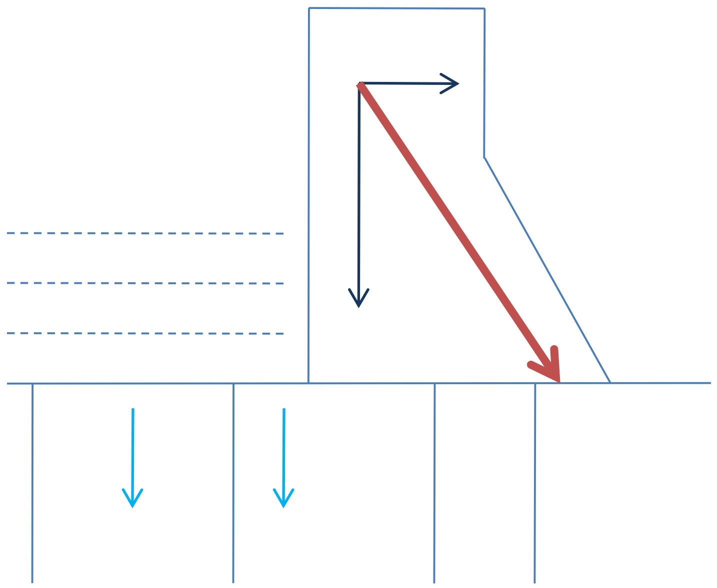


Dam after the effect of resultant force

Required geological consideration for selecting dam

IV. Proper Geological structures

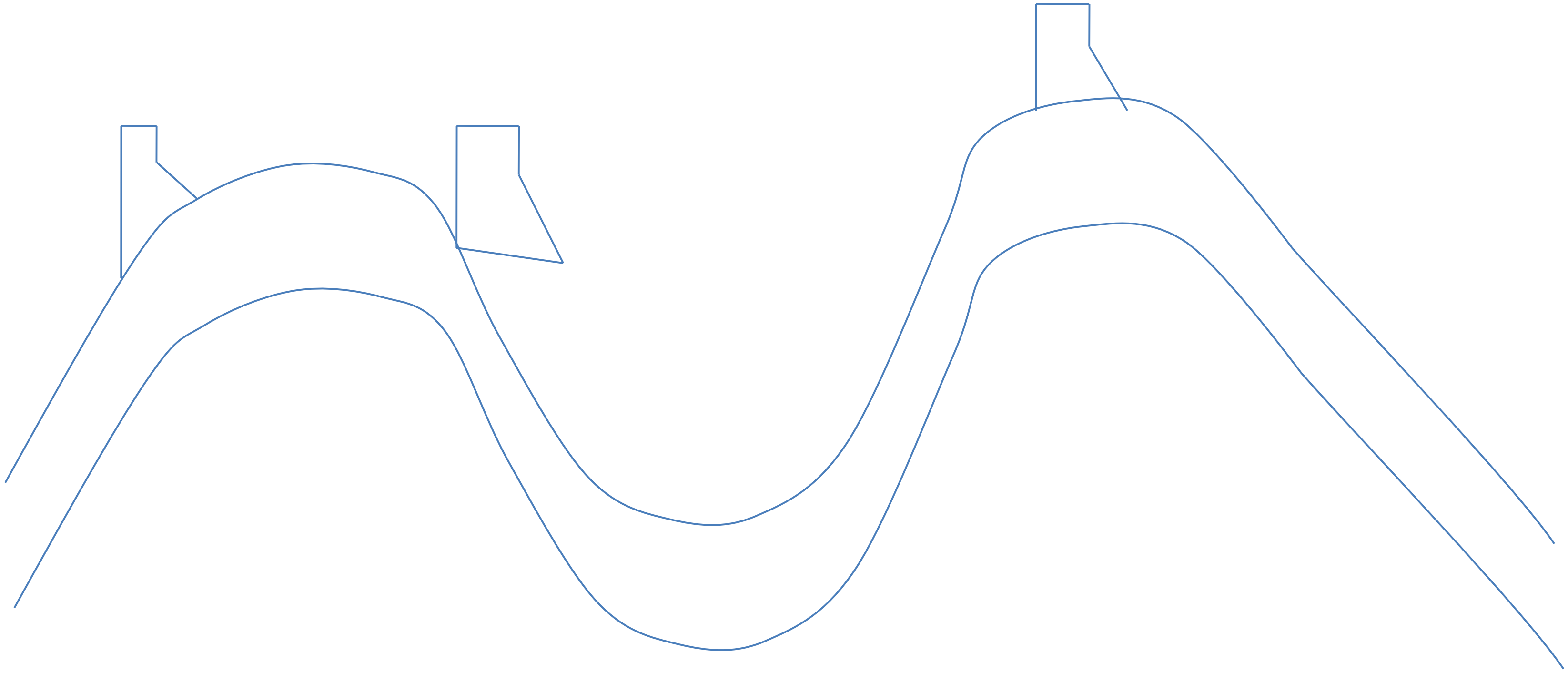
- **Vertical beds**
  - ✓Vertical beds not pose any uplift pressure and also leakage, therefore these are ideal but this scenario is very rare.



Required geological consideration for selecting dam

IV. Proper Geological structures

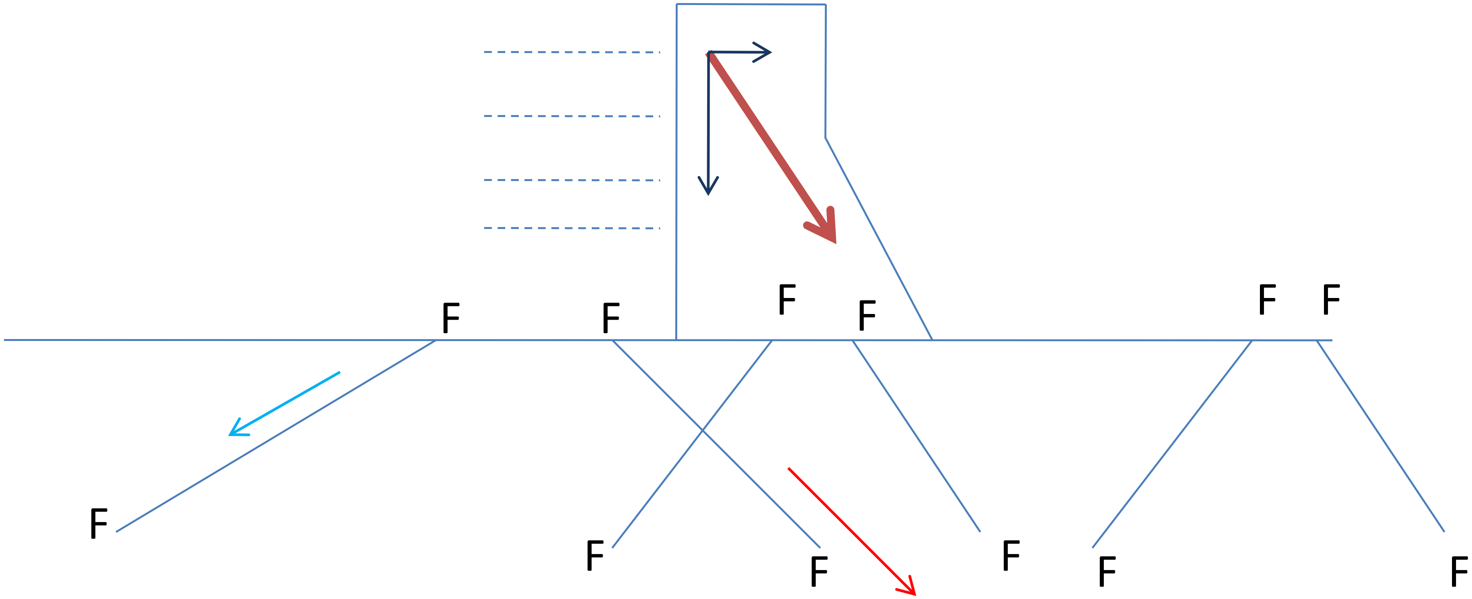
- ➢ **Dams on folded beds**
  - ✓ **Dam on limb which dips in upstream side is favorable**
  - ✓ **If limb of fold dips in downstream side is very dangerous and unsuitable for dam.**
  - ✓ **If the dam founded on crest of the fold is required precautions to treat the fractures.**



Required geological consideration for selecting dam

IV. Proper Geological structures

- **Faults and dams**
  - ✓ Faults dips in upstream side is less harmful.
  - ✓ If faults are dipping in downstream side is very disadvantageous and dangerous to dam.
  - ✓ Faults away from the dam in downstream side may not effect on the dam.



Reservoir

Reservoir

The large area, where the water impounded or stored for future is defined as a reservoir. Various considerations is important for reservoir site selection

Terminology of reservoir

- Rim and abutment of reservoir
- River bed
- Catchment area
- Water line
- Leakage
- Water tightness
- Perennial river
- Water table

.

Required geological consideration for selecting reservoirs

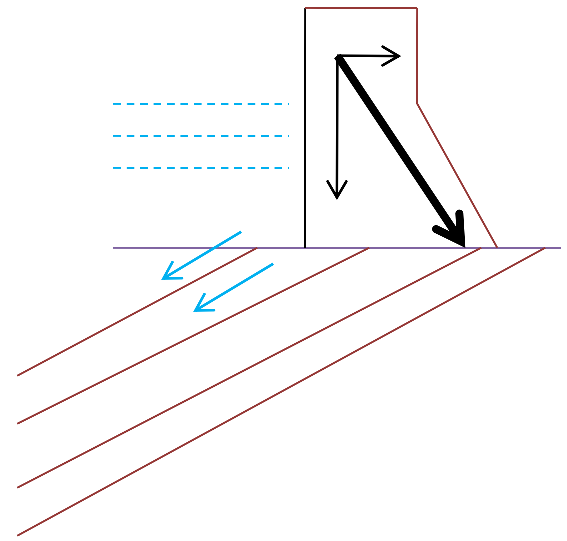
I. Water tightness
II. Buried channels
III. Influence of rock type
  - Igneous rocks
  - Sedimentary rocks
  - Metamorphic rocks
IV. Influence of geological structures
  - Upstream dipping beds
  - Downstream dipping beds
  - Fold
  - Faults
  - Joints
V. Influence of groundwater table
  - Influent condition
  - Effluent condition
VI. Capacity of reservoirs
VII. Effects of evaporation

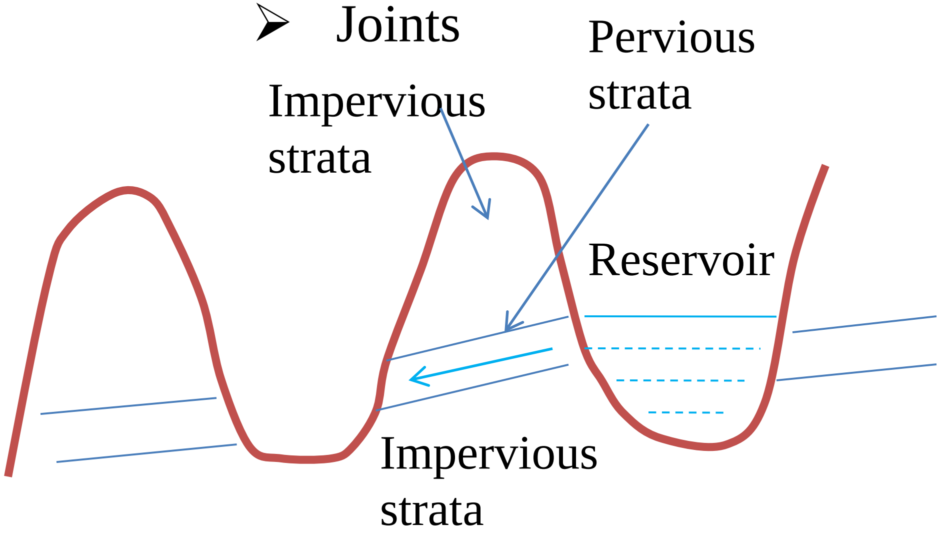
III.Influence of rock type

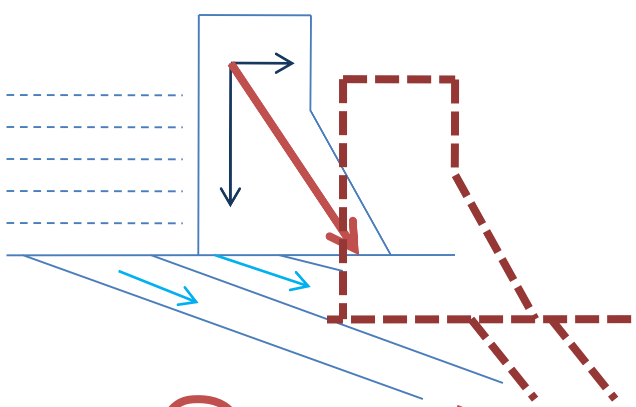
- **Igneous rocks**
  - Intrusive igneous rocks like granite,diorite,gabbro etc. will not cause leakage, hence they are suitable for reservoir unless they not pose any defects like fracture,joint,faults etc.
  - Basalt are not desirable because of their vesicular nature, which create seepage or leakage.
- **Sedimentary rocks**
  - Shale at the reservoir area is desirable due to its high porous nature, therefore leakage from reservoir will not be observed. But they are not ideal in dam site due to incompetent and slippery nature.
  - Sandstone is undesirable for reservoirs, because their porosity and permeability causes leakage of water from the reservoir. But in some cases well cemented sandstone may not cause leakage and hence, they are desirable.
  - Limestone is undesirable, but some cases dolomites or siliceous limestone are desirable for reservoirs with some precautions. In general limestone's are undesirable due to its soluble nature.
- **Metamorphic rocks**
  - Gneiss is desirable
  - Schist is not suitable or undesired
  - Marble is also nor ideal
  - Slates are moderately desirable
  - Quartzites are advantageous due to their water tightness nature.

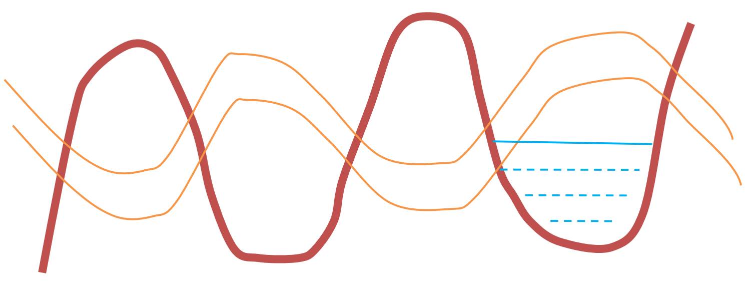
IV. Influence of geological structures

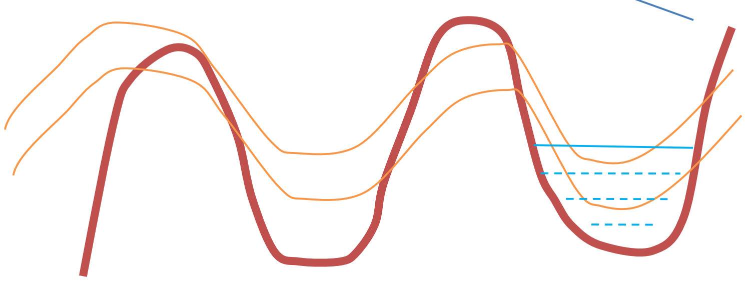
- Upstream dipping beds
- Downstream dipping beds
- Fold
- Faults
- Joints

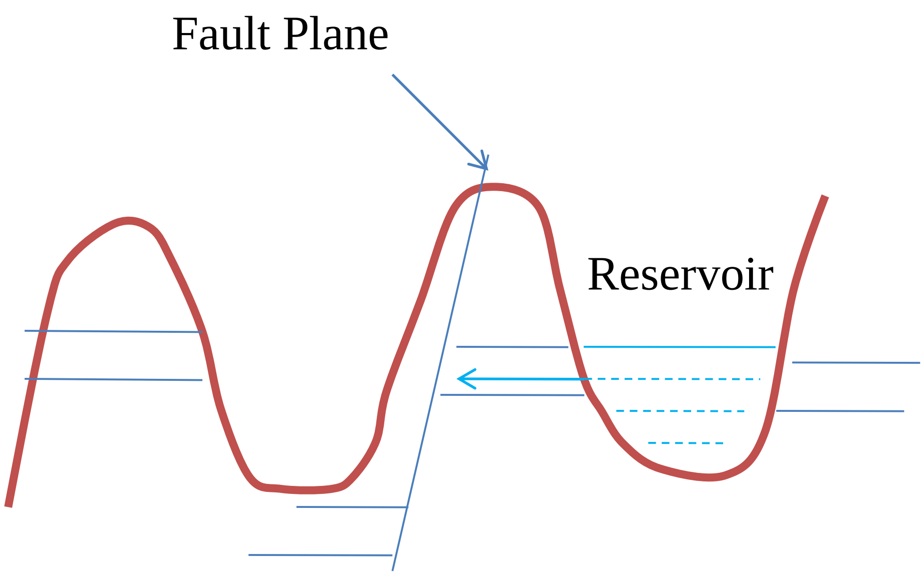


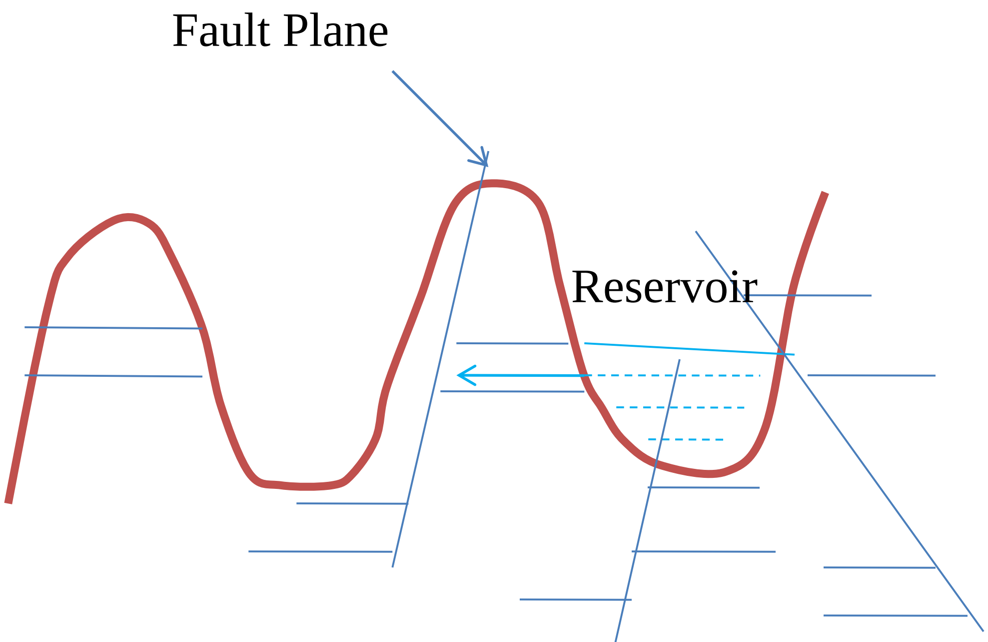




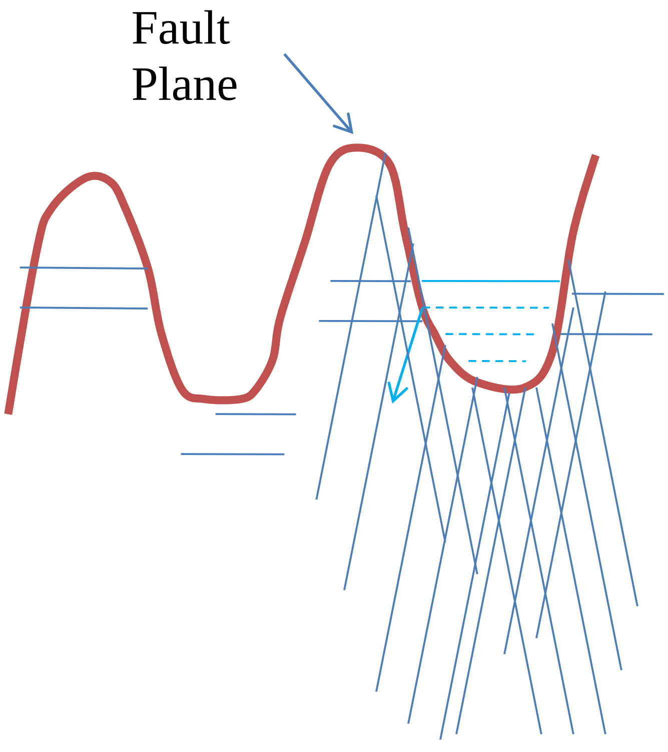








Faults in reservoir area

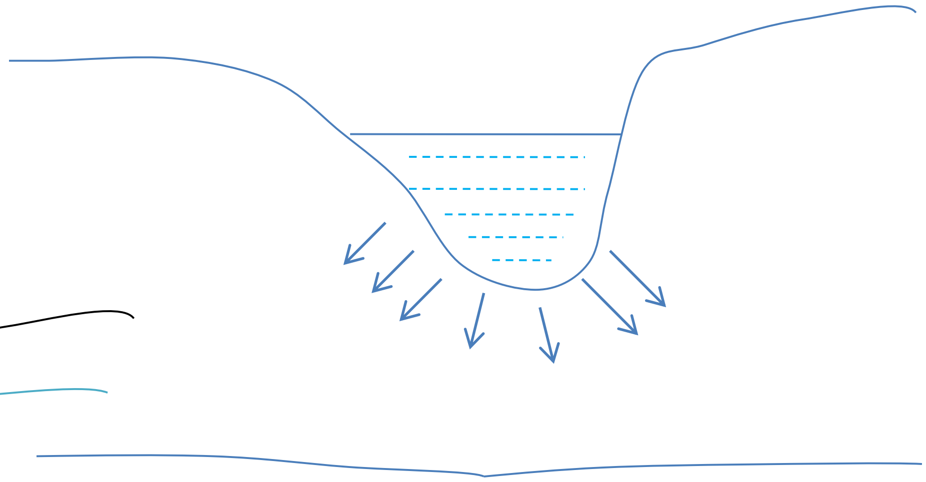


Joints in the reservoir

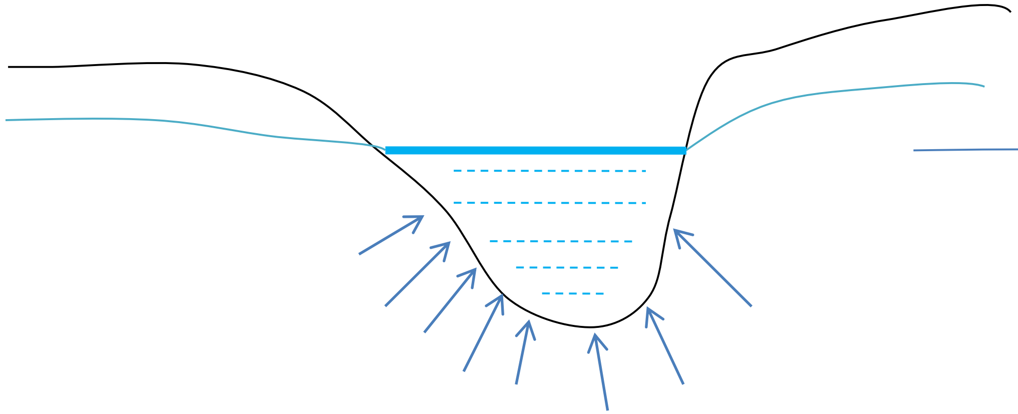
Some water of the reservoir will sink into the ground and the movement of such water depends on the position of the water table and the nature of the rocks.

V. Influence of groundwater table

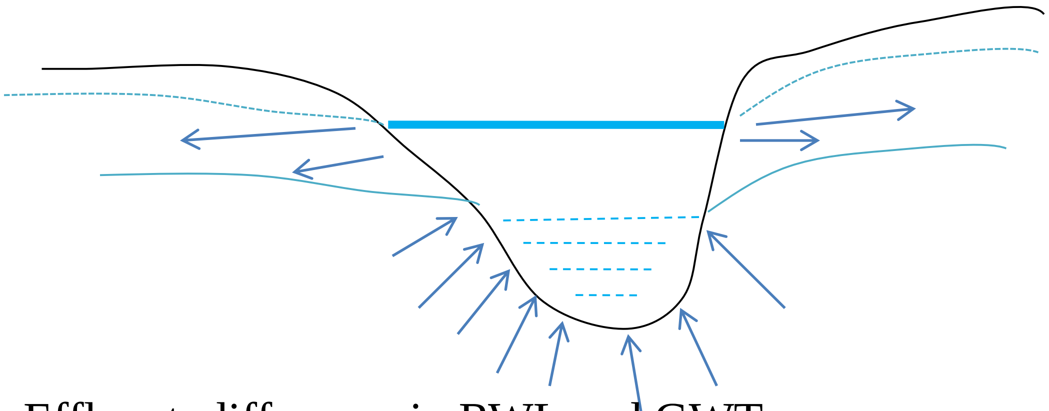
- Influent condition
- Effluent condition



Influent of GWT



Effluent of GWT



Effluent difference in RWL and GWT

V. Influence of groundwater table

- Influent condition
  - When the water level in the reservoir does is aboe the level of the water table of the adjacent ground, there would be serious loss of water by seepage from the reservoir.

- Effluent condition
  - When the water level in the reservoir does not exceed the level of the water table under any adjacent ground (like a local watershed) there would be no serious loss by seepage.
  - But when the reservoir water level is higher at some point.
  - There will be leakage and the amount of such leakage will depend upon the permeability of the rocks.

Failures of reservoir from India as a case study 01-Kopili hydroeletric project

Location

Kopili hydroelectric project-Assam

Kopili project located about 122 km east of shillong.

Lithology or rockt type in project area

Granites,sandstones,limestones and shale of younger age strata's.

Identified problem

Leakage of water from the reservoir area due to lack of water tightness.

Causes or reasons of leakage of water.

This problem caused by limestone, which are present in the reservoir. Limestone in the reservoir area has maximum 90m thickness and in horizontal position. Even though it has great thickness, it cause leakage from the reservoir because of numerous sink holes, caverns and solution channels in it.

Several vertical and horizontal sets of joints also found in the limestone of project area. These joint sets are widen by work of sink holes and solution channels , this process create loss of water from the reservoir area.

Several caves found in the reservoir area, some of which are more than 300 m length and extended from Kopili valley to nearby Umrong valley.

Remedy

Control of leakage along the reservoir rim is only the way to make the reservoir feasible.

A case study 02 on reservoir failure

Annamayya Project

Location

- Medium irrigation project in Kadapa district.
- It is constructed on the Cheyyeru river, near Badanagadda Village of Rajampet Mandal.

Geology

- Dam is constructed on quartzite's, but the reservoir area composed by cavernous dolomite, limestone and shale.

Problem identified

- Leakage through the limestone, which are in reservoir area.
- Due to chemical weathering underground channels were formed to cause leakage of water from the reservoir.

Remedy or repair of leakage

A subsurface dam with diaphragm wall was constructed along the dam axis to control leakage below the dam and its effect.

Tunnel

Tunnels are underground passages or routs used for various purpose.

These horizontal underground passages are made by excavation of rocks below the surface of the earth.

Normally tunnels drive through hills and mountains.

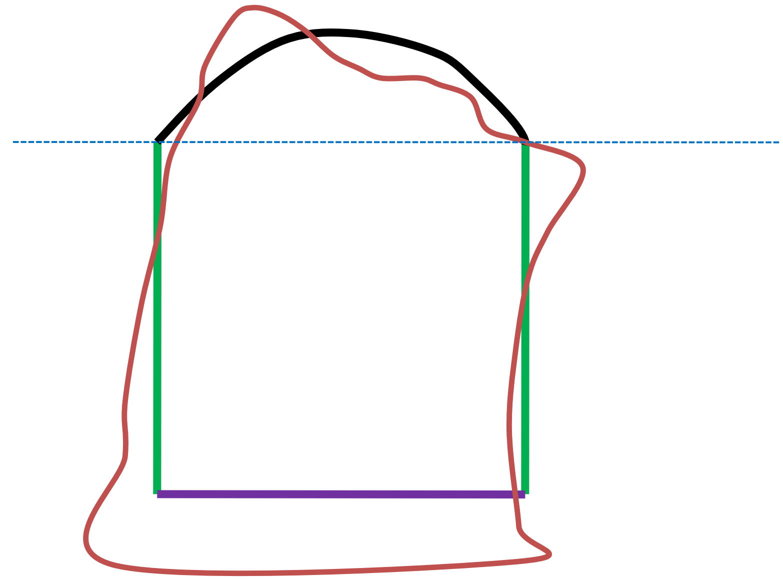
Both ends of the tunnel should be open to access the surface of the earth.

Purpose of tunnels

- To lay road and railway track for transportation to reduce the distance between places,
- To divert the normal flow of river, diversion tunnels are made while dam construction.
- Pressure tunnels is required in hydroelectric power houses for power generation.
- Utility tunnels are used to supply drinking water, laying cables and providing channels for oil supply and sewage disposal.
- In underground mines, especially coal mines tunnels are made to extract coal from coal seams.

Terminology of Tunnel

Floor or invert
Back, crown or roof
Wall of tunnel
Spring line
Shaft
Overburden
Over break
Tunnel support
Lining of tunnel



Geological consideration(study) for Tunnel site.

- Lithology or rock type
  - Igneous rocks
  - Sedimentary rocks
  - Metamorphic rocks

- Geological structure
  - Folds in tunnel
  - Faults in tunnel
- Groundwater conditions.
  - Groundwater table conditions and its problems.

Surface geological study

Sub-surface geological study

Borehole data interpretation through rock core samples

RQD

RMR classification

Geological consideration(study) for Tunnel site.

- **Lithology or rock type**
  - **Igneous rocks**
    - **Intrusive igneous rocks** like granite,diorite,dolerite,gabbro etc. are suitable for tunneling, because of their compactness, hardness and the strength. But the excavation work is more difficult in those rocks.
    - **Extrusive igneous** rocks like vesicular and amygdaloidal basalts are also ideal to drive tunnels. Their vesicular and amygdaloidal texture provides easy workable conditions than intrusive igneous rocks.
    - **Tunnels** in both intrusive and extrusive igneous rocks are not required lining, this is also an advantage for tunnels in igneous rocks.

Geological consideration(study) for Tunnel site.

- **Lithology or rock type**
  - **Sedimentary rocks**
    - Thick bedded **well cemented sandstone** is suitable, because it posses high strength and also easy workability.
    - Thin bedded **poorly cemented sandstone** is not ideal, due to its water saturation condition may use collapse of roof, buckling of sides and swelling of floor of tunnels.
    - Tunnels through the **shale** is required strong lining, because they are weak and incompetent laminated beds. Due to this laminar nature they badly shattered during blasting. Tunnel excavation work is fast through shale due to its softness.
    - **Limestones, dolomitic limestones** are harder and durable, they are not suitable for tunneling because of their tendency to dissolve in water.
    - Conglomerate and breccia are also not suitable for tunneling.

Geological consideration(study) for Tunnel site.

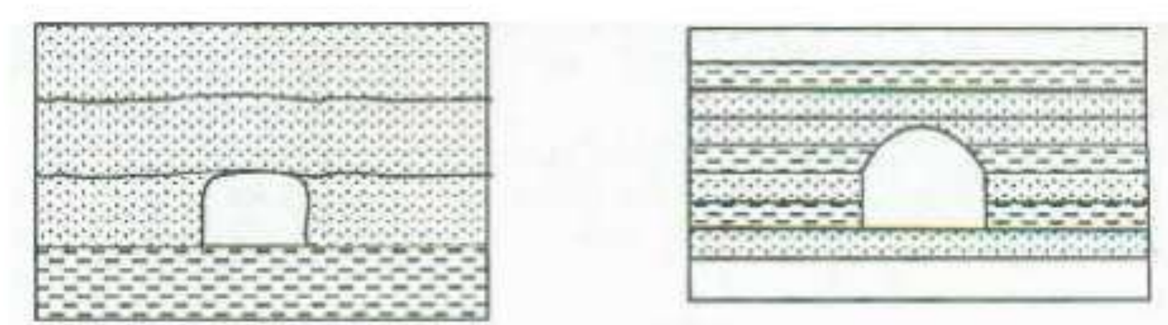
- **Lithology or rock type**
  - **Metamorphic rocks**
    - Gneisses are suitable for tunneling due to its competance,durability and workability.
    - Quartzites are very hard and difficult to make excavation, hence they are also suitable for tunneling.
    - Schisst,slate,phyllite are very soft and have schistosity and foliation, hence workability is easy but good lining is necessary.

Geological consideration for Tunnel site.

Horizontality of rock strata and its consideration for tunnel

Case 01

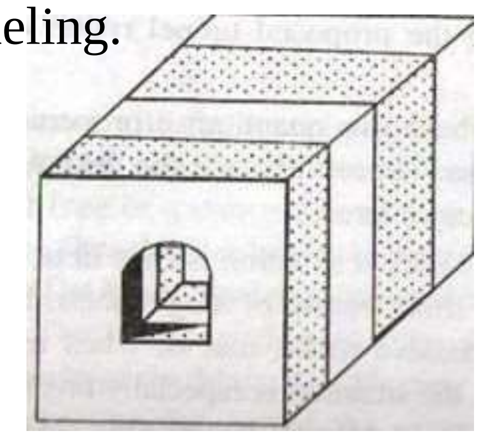
If the rock beds are horizontal in nature, they provide maximum stability to the tunnel, therefore these are most favorable for tunneling. But thin horizontal beds are not ideal for tunnel because they create rock fall at the roof of the tunnel.



A. Safe situation B. Unsafe at top

Case 02

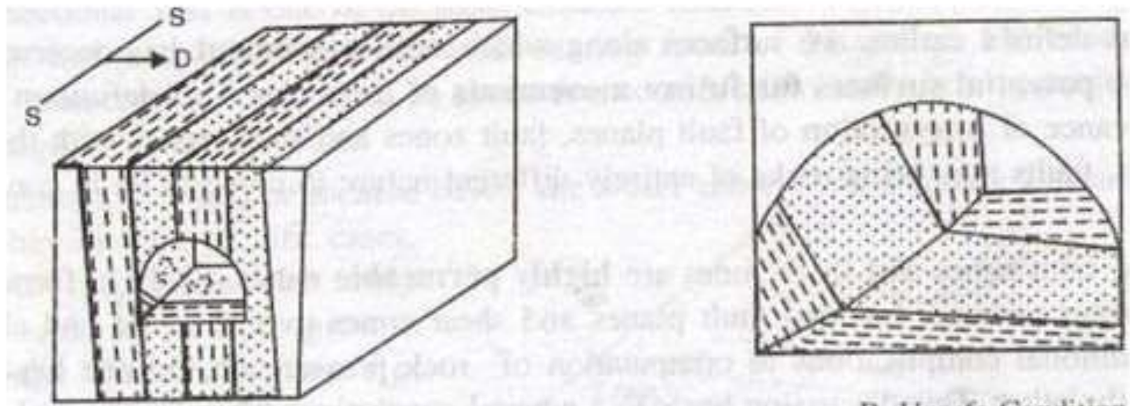
If the vertical beds are found in tunnel site, they also provide maximum stability, hence vertical rock strata are also most favorable for tunneling.



Geological consideration for Tunnel site.

Case 03

Strike of the rock bed is parallel to the axis of the tunnel is not suitable, because more over break is expected from the rocks.



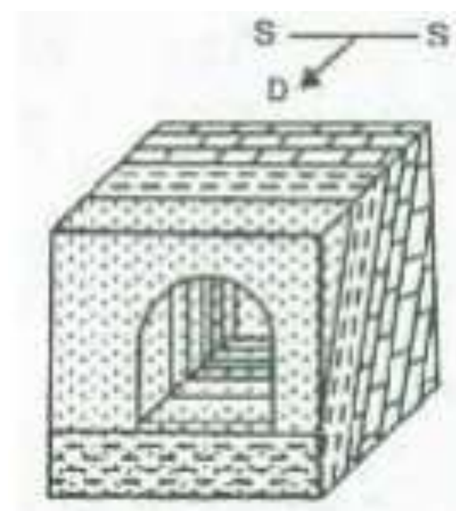
A. General view

B. Unsafe Condition

Case 04

Dip of the rock beds in tunnel site is parallel to the tunnel axis is suitable, because these inclined sequence of rock layers offer a uniform distribution of load on the excavation.

Hence arch action where the rocks at the roof act as natural arch transferring the maximum load on to sides.

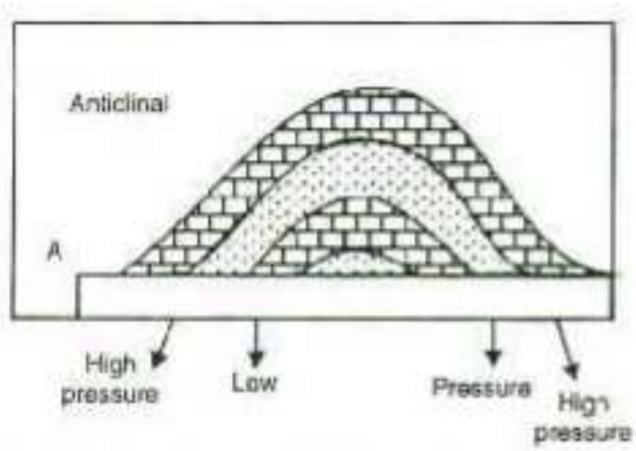


Consideration of geological structures for Tunnel site.

Folds

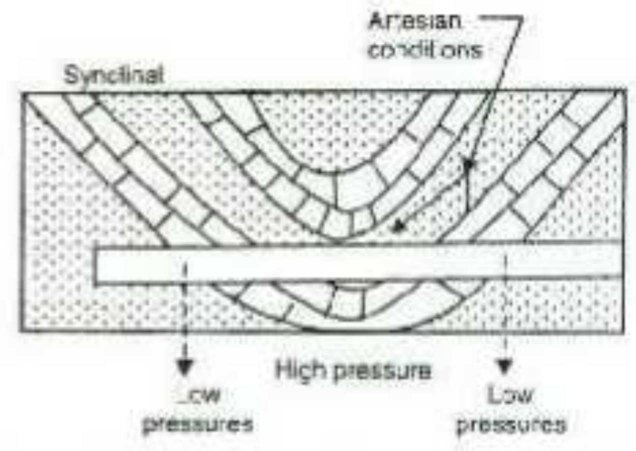
Tunnel in anticline

In anticline fold, loads of rocks at the crest are transferred by arch action to a great extent on to the limbs which may be highly strained.



Tunnel in syncline

In synclinal the folds, loads of rocks are transferred to the trough of syncline. In such cases, rocks of rough regions are greatly strained.

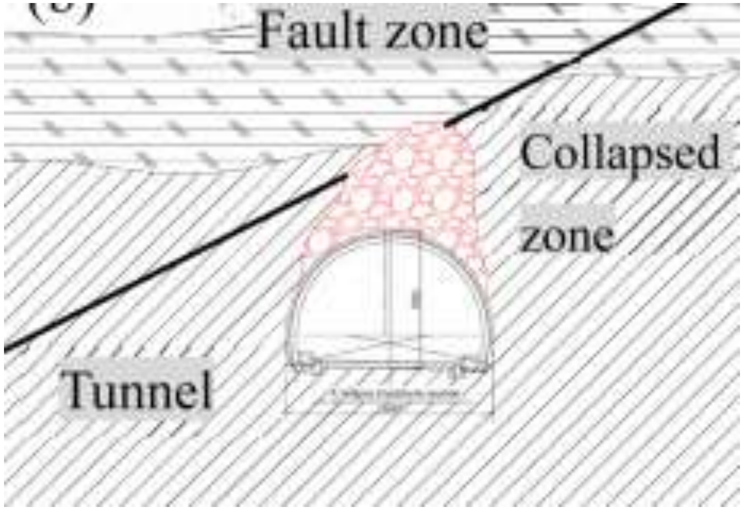


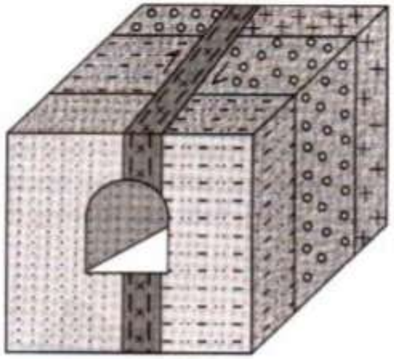
Rocks at axial region of an anticline and syncline are heavily fractured. Therefore tunnels excavation in an anticline and synline pose many problems because of strain energy to be released and cause rock bursts and uncontrolled drainage problems. Therefore tunnels in folded regions required detailed stress strain analysis for better design of tunnel.

Consideration of geological structures for Tunnel site.

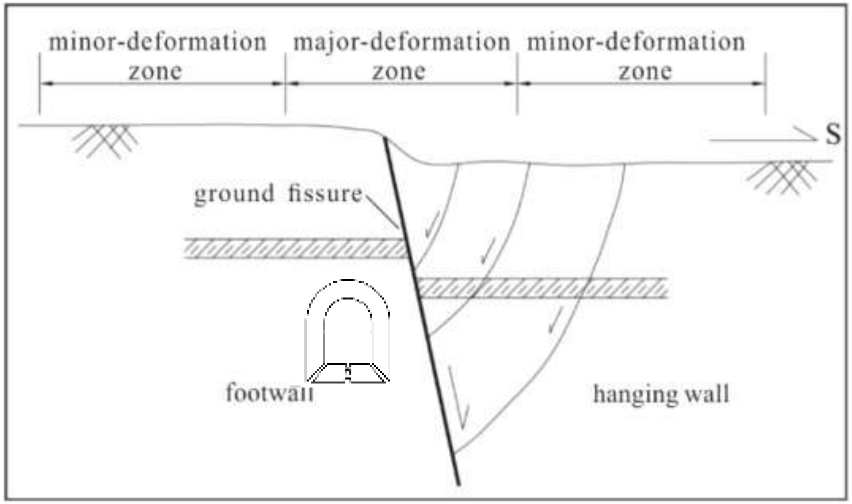
Faults

Tunnel located within the fault zone is highly dangerous.



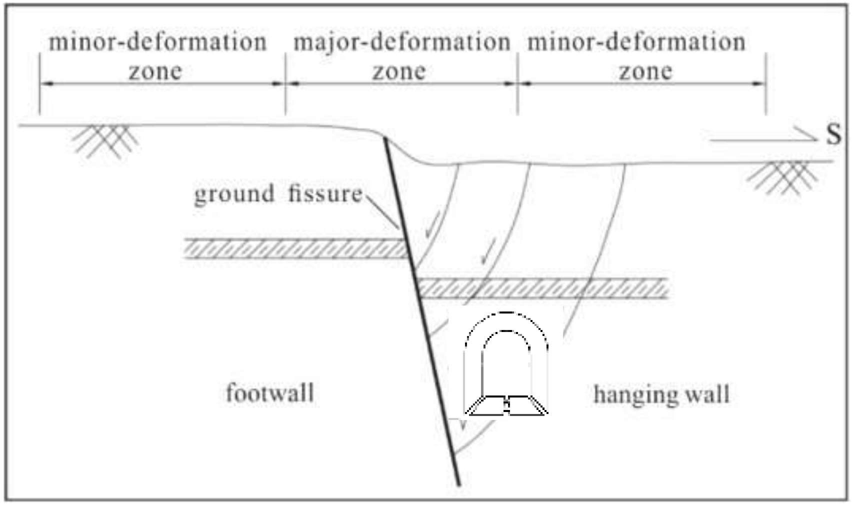


If tunnel located on foot wall of the fault, the crest of the tunnel immediately will be effect.



Consideration of geological structures for Tunnel site.
Faults

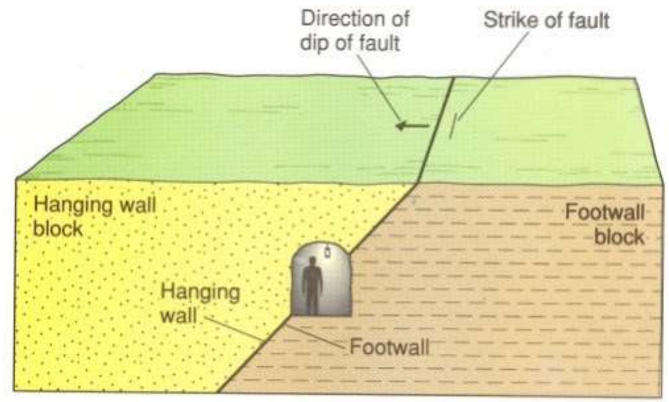
If tunnel located on hanging wall of fault, the floor of the tunnel get effected.



Consideration of geological structures for Tunnel site.

Faults

If tunnel crosses the fault plane, all parts of the like hinge points,crest,walls and floor etc are to be damaged.



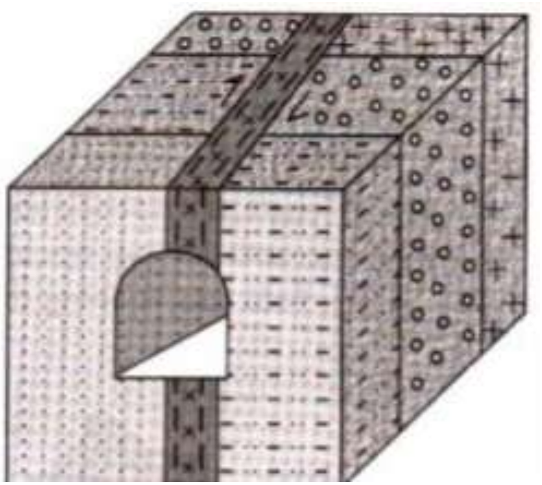
Fault zones and shear zones are highly permeable zones, to form easy ways for ground water passage.

Inclined fault planes and shear zones over the roof and along the sides causes complications on rock strengths on the other.

wherever tunnel is intersected by fault planes or shear zones, it is to be considered as most unsafe situations and hence designed accordingly by providing maximum support and drainage facilities.

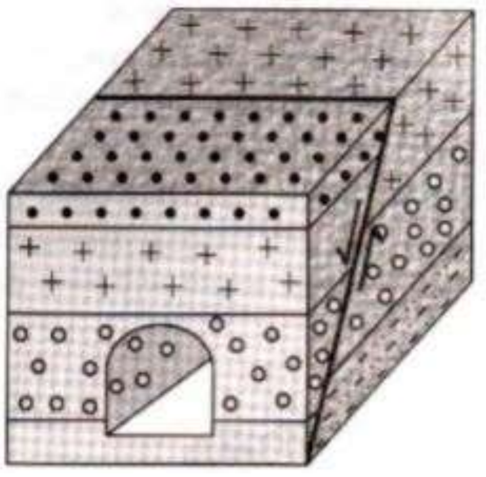
Tunnel located outside the fault means it is away from the deformation zone is safe for tunneling.

Consideration of geological structures for Tunnel site.
Faults
Tunnel along strike of fault plane



Along the strike of the fault plane the rocks are highly shattered and weak, hence they create rock fall, rock burst and drainage problems along the tunnel length. Therefore along the strike of the fault tunnel is very dangerous.

Tunnel perpendicular to strike of fault or parallel to dip direction of fault



If tunnel excavated along the dip of fault, weak zone intersect with tunnel is limited, so the impact of fault on tunnel will be a tolerable.

Consideration of geological structures for Tunnel site.
Joints consideration in tunnel site

The number of joint sets per unit area and their attitude controlling block size and shape, their length and depth persistence, opening and roughness of the joint plane as well as alteration along them etc. are going to be the most important factor which will control the engineering behavior of the rock mass and also approach of tunneling operation as shown in table 1.

The opening of joint plane decrease the strength of the rock, it is considerably high when saturated with water.

Joints are unfavorable for tunneling, because they cause rock fall from the roof of the tunnel , so tunneling in jointed rock is unsafe and need lining.

The joints in rock mass through which tunnel is to be bored are going to play the most important role as their presence is assured.

Suitability of strike and dip of joint plane along tunnel direction shown in table 02.

Table 1: Rock mass behavior and required support for tunnel, based on strength of rocks, joint incidence and their nature of Rock Mass Quality.

ROCK MASS CLASS	**I Very Good**	**Rock II Good Rock**	**III Fair**	**Rock IV Poor Rock**	**V Very Poor Rock**
RMR System	81-100	61-80	41-60	21-40	<20
‘Q’ System	>40	10-40	4-10	1-4	<1
Average Standup Time	20 years for 15m san	01year For 5m span	01week For 5m span	10 hours for 2.5m san	30 minuets for 1m san
Tunnel Support System	None	Spot Bolts	Pattern Bolts	Bolts+Shotcrete	Steel Ribs

Table 2: Suitability of strike and dip of joint to tunnel orientation

Strike perpendicular to tunnel axis				Strike Parallel to tunnel axis		Irrespective of strike
Drive with dip		Drive against dip				
Dip 45°-90°	Dip 20°-45°	Dip 45°-90°	Dip 20°-45°	Dip 45°-90°	Dip 20°-45°	Dip 0°-20°
Very favorable	Favorable	Fair	Unfavorable	Very unfavorable	Fair	Fair

Consideration of geological structures for Tunnel site.

Ground water (table)consideration in tunnel site

Ground water may erodes and corrodes (dissolves) the susceptible constituents from the rocks and thereby rocks alters their original properties constantly with the passage of time.

Heads of static and dynamic water effects the rock strength parameters. In such a situation, tunnel excavation could create worst disaster by sudden release of pressure in the direction of tunnel .

Groundwater seepage conditions along tunnel axis

a) The tunnel axis may be passing entirely through impervious formations in which there is no possibility of water seepage or leakage or movement. It is an ideal condition for tunneling .

b) The tunnel axis might be located mostly above the water table, intercepting the aquifer only in some sections. This situations would require provision for special drainage facilities mainly in water-bearing zones of the section. The lining also necessary at head of the water in the zone of interception to stop leakage of water .

c) The tunnel axis might be located below the water table. Such a situation should be avoided as far as possible. If only the possibility for tunneling, effective drainage systems and support systems have to be planned much in advance and executed with great precision and perfection.

COMMON TUNNEL PROBLEMS AND THEIR CAUSES

A.Different Types of Tunnel Lining Erosion causes

Water erosion

Aggregate swelling

Frost erosion

B. Different Types of Tunnel Bed Problems by water seepage

Tunnel bed cracking

Tunnel bed sinking

C.Different Types of Water Damage by convergence of water fromm all sides of tunnel

Water damage in the course of tunnel construction

Underflow dissolution

Prevention and Control Measures of common tunnel problems

A.Prevention and Control Measures for Lining Erosion

1) Stabilize the rock mass by controlling the groundwater
2) Stabilize the rock mass by injecting cement grout
3) Replace or reinforce the lining
4) Strengthen the lining maintenance

PREVENTION AND CONTROL MEASURES OF COMMON TUNNEL PROBLEMS

A.Prevention and Control Measures for Lining Erosion

1) Stabilize the rock mass by controlling the groundwater
2) Stabilize the rock mass by injecting cement grout
3) Replace or reinforce the lining
4) Strengthen the lining maintenance

Prevention and Control Measures for Tunnel Basement Problems

Prevention and Control Measures for Lining Erosion

1) Stabilize the rock mass by controlling the groundwater
2) Stabilize the rock mass by injecting cement grout
3) Replace or reinforce the lining
4) Strengthen the lining maintenance

Case studies on failure of dams due to geologicical ignorance

St.Fransiso dam

Location:

- The old St. Francis Dam was built in San Francisquito Canyon about 7 miles upstream of its mouth between 1924-26 by the City of Los Angeles Bureau of Waterworks and Supply (referred to herein as BWWS).
- The dam failed catastrophically near midnight on March 12/13, 1928, in its second year of operation.
- It had been brought near its crest elevation of 1835 feet just six days prior to the failure.

Case studies on failure of dams due to geologicical ignorance
St.Fransiso dam

Lithology at St. Fransisco damsite

SESPE formation (sandstone and conglomerate)
Fault----------------
Weathered schist (metamorphic rocks).
PELONA Schist with numerous ancient landslides (metamorphic rocks).

Case studies on failure of dams due to geological ignorance
St.Fransiso dam
Causes of failure:

- Various Engineering geologic studies of the dam site and various potential failure mechanisms of the dam have been carried out over the past years and revealed that.

- The dam was unknowingly situated against and upon a series of Pleistocene-age landslides developed within the Pelona Schist.

- Fluvial gravels and lacustrine silts deposited within the lake and formed the broad upland in Canyon upstream of the old dam site.

- Within this same zone, the southeast side of the canyon is littered with deep-seated rotational slumps developed within the inclined foliation of the Pelona Schist.

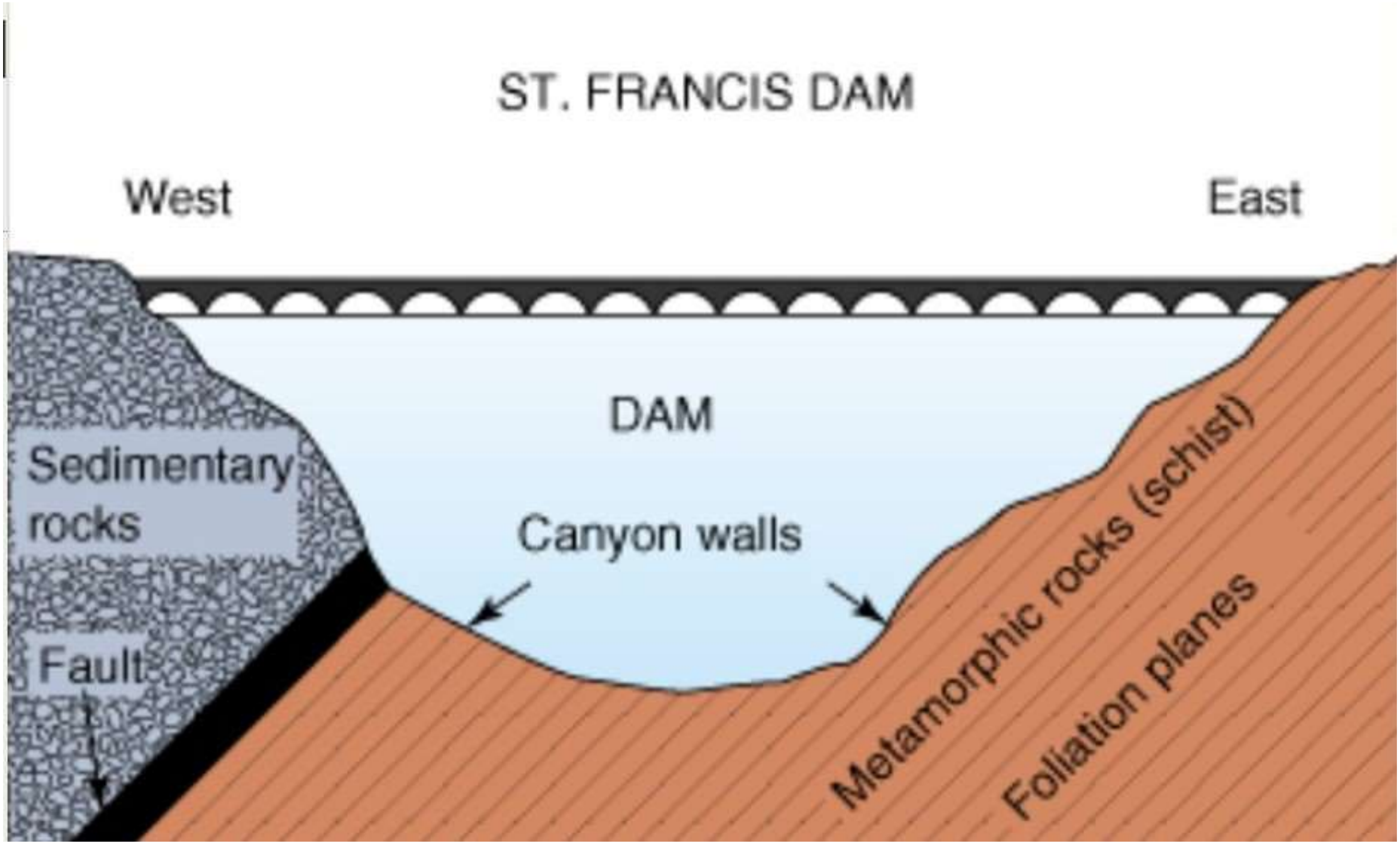
- Presence of the San Francisquito fault beneath the dam’s right abutment comprising gypsum matrix sandstone, which slake under submersion because of gypsum in its matrix.

Case studies on failure of dams due to geological ignorance
St.Fransis dam
Causes of failure:

- Failure as cracks initiated in East abutment and widen by the flood water.

- Later right abutment cracked due to the fault and thrown to downstream side.

- The middle of the dam is stand as remnant.



Geological cross section at St.Francis dam site

Tigra Dam Failure

Location

Tigra Dam constructed between 1913 and 1917 on Sank River, 23 km from Gwalior, Madhya Pradesh. India to provide water for irrigation and drinking purpose.

Causes of failure

The dam was failed on August 4, 1917 shortly after first filling due to a flood event. Some of the reasons on the failure and subsequent damage are

- The dam was founded on stratified sandstone with near horizontal bedding planes with limited excavation for the dam was to about a 2-foot depth
- Weaker zones in the sandstone were reportedly excavated deeper and filled with concrete.
- There were apparently no additional seepage control or cutoff measures installed in the dam foundation.
- On August 4, 1917, reservoir rose to a historic level and overtopped the dam.
- Main cause of failure is generally agreed sliding of sections of the gravity dam along the untreated, stratified foundation.
- The excessive uplift pressures created tension at the heel of the dam and downstream scour due to overtopping, which contributed to the dam slide.

Effect of overtopping on Tigra Dam

https://www.researchgate.net/profile/David-Froehlich-3/publication/321299701/figure/fig8/AS:668598544654352@1536417723628/Displaced-sections-of-Tighra-Dam-in-Madhya-Pradesh-a-masonry-gravity-dam-completed-in.png

https://www.researchgate.net/profile/David-Froehlich-3/publication/321299701/figure/fig3/AS:564804767436801@1511671358977/Large-amount-of-flaking-of-concrete-known-as-spalling-have-developed-in-Rihand-Dam-in_Q320.jpg

Common causes for failure of dams

Sl.No	Cause	Reason
I	Overtopping	1.Insufficient spillway capacity 2. Extreme flood exceeding design criteria
II	Quality problems	1.Piping in dam body 2.Sliding of dam body 3.Piping in foundation 4.4.Piping around spillway 5. Quality issues in spillway 6. Piping around culvert and other embedded structures 7. Quality issues in culvert and others
III	Poor Management	1.Decrease of reservoir capacity for flood control due to over storage prior to flood season 2.Poor management and operation 3. Organization issue: nobody responsible for Management of dam 4.Poor construction planning and scheduling
IV	Disasters	1. Earthquake exceeding design criteria 2. War and Terrorist attack 3. Breaching of upstream dam 4. Rodent den
V	Others	1.Spillway blockage due to bank slide in reservoir 2.Breach due to excavation on dam for discharging 3. Poor Planning of general layout of project

Questions

1. What are the necessary geological considerations in the selection of a dam Site?
2. How would explain the geological causes for failure of dams with a few case studies.
3. Could you Summarize the influencing factors for a successful reservoir?
4. How the faults is considered in the selection of sites for tunnels, dams and reservoirs.
5. Explain the influencing factors for the water - tightness of the reservoir.
6. How the joints are considered in tunnel excavation?
7. Would you illustrate and explain the problems associated with anticline and syncline in tunnel and dam site?
8. What are the precautions to be taken for unsuitable condition for dams, reservoirs and tunnel sites for success of such project?
9. How would you summarize various drainage pattern and their consideration to reservoirs?
10. How can you analyze the impact of strike and dip of fault on tunnel excavation?

ALL THE BEST