**UNIT-V APPLIED GEOLOGY**

Dam Failure: Common causes of dam failure include:

* Geological instability caused by changes to water levels during filling or poor surveying ([Malpasset Dam](https://en.wikipedia.org/wiki/Malpasset_Dam" \o "Malpasset Dam)).
* Sliding of a mountain into the reservoir ([Vajont Dam](https://en.wikipedia.org/wiki/Vajont_Dam" \o "Vajont Dam) – not exactly a dam failure, but caused nearly the entire volume of said reservoir to be displaced and overtop the dam)
* Extreme inflow ([Shakidor Dam](https://en.wikipedia.org/wiki/Shakidor_Dam" \o "Shakidor Dam))
* [Internal erosion](https://en.wikipedia.org/wiki/Internal_erosion) or piping, especially in earthen dams ([Teton Dam](https://en.wikipedia.org/wiki/Teton_Dam))
* [Earthquakes](https://en.wikipedia.org/wiki/Earthquake)

Geology of Dam Sites • The Success of a dam is not only related to its own safety and stability but also to the success of associated reservoirs. In other words, on construction, if a dam stands firmly but if its reservoirs leaks profusely then such a dam is to be treated only as a failure because the purpose for which it was constructed was not served.

Therefore, utmost care is needed in planning for the success of both the dams and the reservoir. • Careful geological studies bring out the inherent advantage or disadvantage of a site and such studies go a long way either in reducing or in increasing the cost of a dam considerably.

The Important Geological requirements which should be considered in the selection of a dam are as follows: •

Narrow River Valleys

• Occurrence of the bedrock at a shallow depth.

• Competent rocks to offer a stable foundation

• Proper Geological Structures

**Narrow River Valley**

* At the proposed dam site, if the river valley is narrow, only a small dam is required, which means the cost of dam construction will be less.
* On the other hand, if the valley is wide, a bigger dam is necessary which means the construction cost will be very high.

Therefore, it is preferable from the economy point of view, to select such a site along the river valley which has the least areal cross-section (i.e.. the narrowest part of the river).

But such sites should not be blindly selected without further investigations, because sometimes they may have severe defects which may lead to serious leakage from the reservoir and may affect the safety of the dam.

Small Dam Big Dam

Narrow River Valley Broad River Valley

**Bedrock at Shallow Depths**

* To ensure its safety and stability a dam has to necessarily rest on (Physically) very strong and (Structurally) very stable (i.e. bedrocks). If such competent bedrocks occur near the surface or at shallow depths, the foundation cost of the dam will naturally be less.
* On the other hand, if competent bedrocks occur at great depths, the cost of the foundation will be very high because it involves extensive work of excavation of loose overburden and concrete refilling.

The Thickness of sediments or loose overburden along the river valley depends on the nature and the stage of development of the river. In other words, strong and fresh bedrocks may occur at or near the surface, therefore only small dams may be suitable theese to serve a limited purpose.

The general occurrence of material like clay, silt, sand and gravel along the river bed, naturally makes it difficult to assess the thickness of loose overburden by mere surfacial studies. Therefore to know the bedrock profile, geophysical investigations such as “Electrical Resistivity studies” or “Seismic refraction Studies” are carried out carefully. The data recorded in the field during investigations are interpreted and the required bedrock profile is visualized.

**Competent Rocks for Safe Foundation:**

If igneous rock occurs at the selected dam site, they will offer a safe base, and weak sedimentary rocks, particularly shale's, poorly cemented sandstones and limestones shall naturally be undesirable to serve as foundation rocks.

The suitability or otherwise of a site to serve as a foundation for major dams depends on factors such as :

• The existing rock type at the dam site.

• The extent of weathering it has undergone

• The occurrence of intrusions

• The extent of fracturing

• The extent of geological structures, the mode and number of rock types concerned.

**Suitability of Igneous Rocks**

* Among the rock types, the occurrence of massive plutonic and (or) hypabyssal igneous rocks is the most desirable at the dam site because they are very strong and durable due to their dense character.
* Interlocking texture, hard silicate mineral composition, occurrence of negligible porosity and permeability, absence of any inherent weak planes, resistance of weathering and their tendency to occur over wide areas.
* Thus all plutonic rocks like Granites, Syenites, diorites and gabbros are very competent and desirable rocks.
* However, volcanic rocks which are vesicular or amygdaloidal, are not equally desirable, obviously because these character contributes to porosity, permeability and hollowness which, in turn, reflect the strength of the rocks.

**Important**: Of Course, it is necessary that such rocks should not have been affected by any intense weathering or fracture or dykes or adverse geological structures like shearing, faulting and jointing.

**Suitability of Sedimentary Rocks**

* In the case of sedimentary rocks, the bedding and its orientation, thickness of beds, nature and extent of compaction and cementation, grain size, leaching of soluble matter, porosity and permeability, associated geological structures and composition of constituents (i.e. Sediments, cementing material, etc.) influence the strength and durability of different sedimentation rocks.

**Based on aforementioned details, it may be stated that**:

* Shales are not inherently incompetent but they also form slippery bases. Therefore they are most undesirable at dam sites.
* Among Sandstone, well-cemented siliceous type are competent and suitable for the dam construction.
* Laterites and conglomerates are undesirable at dam sites
* Limestones are competent if they are massive, i.e.. unaffected by the solution phenomenon, Hence they are undesirable at dam sites.

**Suitability of Metamorphic Rocks**

**Among the metamorphic rocks:**

* “Gneisses” are generally competent like granites, unless they possess a very high degree of foliations and are richly accompanied by mica-like minerals.
* Quartzites are very hard and highly resistant to weathering. They are neither porous nor permeable.
* Marbles, like quartzite, are compact, bear a granulose structure, are not porous, nor permeable and reasonably strong too. But by virtue of their chemical composition and minerals they are unsuitable at dam sites.
* Slates bear a typical slaty cleavage. Hence this rock is soft and weak and undesirable at dam sites.

After learning the suitability of the occurrence of different varieties of common rocks at dam sites, it should be remembered that all types of rocks exhibit within themselves some variations in their chemical and mineral composition.

Finally it may be said that most of the igneous and metamorphic rocks, when fresh and free from structural defects, have enough strength to bear the loads involved in dam of all sizes with surplus safety factor too.

**Effects of Associated Geological Structures**

For the stability of a dam, the occurrence of favorable geological structure is a very important requirement. Under structural geology we have learnt that those rocks bear certain inherent or original physical properties, such characters get modified either advantageously or disadvantageously when geological structure occurs in those rocks.

* **Cases of Undisturbed i.e. Horizontal Strata**
* This geological situation is good at the dam site because the load of the dam acts perpendicular to the bedding planes, which means that the beds are in an advantageous position to bear the loads with full competence.
* Further, the seepage of reservoir water that may take place beneath the dam is effectively prevented by the weight of the dam which acts vertically downwards.
* Thus the possible uplift pressure which is dangerous to the stability of the dam is effectively reduced.

**Cases where Beds lie Perpendicular to the length of the valleys**

**Tilted Beds**

**Dam site with gentle upstream Dip beds**

Beds with 100 to 300 inclination in the upstream directions , Such a situation is ideal because the resultant force acts more or less perpendicular to the bedding plane which are dipping in the upstream side.

**Dam site with Steep upstream Dip beds**

In this case, there shall be no uplift on the dam site and no leakage of water from the reservoir, but due to steep dip the bedding planes are not perpendicular to the resultant force, this means the rock will not be as compatible as in previous case.

**Dam site with Steep or gentle downstream Dip beds**

In this situations dam has all the disadvantages because, here the resultant force and bedding planes are nearly parallel, which means that the beds will be less competent.

**Beds which are Folded**

Folding of beds, which occurs on a relatively large scale, is generally less dangerous than faulting. Unless the folds are of a complex nature.

• However, it should be borne in mind that unlike simply tilted strata, the folded rocks are not only under strain but also physically fractured along the crests. Hence grouting & other precautions may have to be considered, depending on the context, to improve the stability and competence of rocks at the site.

**Beds Which are Faulted**

* Occurrence of faulting irrespective of its attitude (i.e.. Strike and Dip), right at the dam site is most undesirable.
* If the faults are active, under no circumstances, can dam construction be taken up there. This is not only because of the fear of possible relative displacement of the site itself but also due to the possible occurrence of earthquakes.
* Further, if the fault zone is crushed or intensely fractured, it becomes physically incompetent to withstand the forces of the dam.
* **Thus locations of the dam sites on a fault zone is undesirable for different reasons.**

**Beds Which Have Joints**

* Among the different geological structures, joints are the most common and are found to occur in all kinds of rocks, almost everywhere.
* But Since the rocks with these joints are not under any strain, and also because of the scope to overcome their effects easily by simple treatment, they are not considered as serious defects.
* Grouting is generally capable of overcoming the adverse effects of joints because it fill the gaps of joints, increase compactness and competency of the rocks & reduce porosity & permeability.

**RESERVOIRS**

From the Geological point of view, a reservoir can be claimed to be successful if it is watertight (i.e.. if it does not suffer from any serious leakage of water) and if it has a long life due to very slow rate of silting in the reservoir basin. The reservoir, when filled, gives chances for reactivation of underlying inactive faults. This in turn, gives scope for the occurrence of seismicity and landslides in that region.

**Effect of Evaporation**

The natural process of evaporation reduces the quantity of water in the reservoir. Through unwanted, this process is unavoidable. Since reservoirs are open and extended over larger areas. The magnitude of evaporation will be extensive. Of course, such loss shall be less if the topography is such that a reservoir covers a small area but has a great depth to provide adequate capacity.

Reservoir Water- Tightness and Influencing factors

When a river flows over such loose soil or fractured ground, it is natural that some water of the river percolates (or leaks) underground. Before the construction of the dam, this leakage shall be less and limited only to the extent over which the river flow occurs. But when the dam is constructed, the impounding water accumulates in large quantity in a reservoir which covers a very large area.

Further, due to the considerable height of the water in the reservoir, significant hydrostatic pressure develops which will make the leakage more effective on the sides and the floor of the reservoir. Thus, the extent of leakage may become alarmingly great.

**Influence of Rock Types on Reservoir**

* Water-tightness of a reservoir basin is also very much influenced by the kind of rocks that occur at the reservoir site.
* If the rock are porous and permeable, they will cause the leakage of water and hence such rock are undesirable at the reservoir site.

**Reservoir and Igneous Rocks:**

* Intrusive igneous rocks like granite, by virtue of their composition, texture ,their occurance at the reservoir site will not cause leakage of water unless they have other defects like joints, faults, or shear zones.
* But the extrusive (i.e. volcanic) igneous rocks like basalt are not desirable because they are often vesicular.

**Reservoir and Sedimentary Rocks:**

Wide areal extent and frequency of occurrence, sedimentary rocks are the more important in this regard than igneous rocks. Among the different sedimentary rocks shale's are the most abundant followed by sandstone & limestone.

**Shales the extremely fine grained sedimentary rocks.**

* Are highly porous but not permeable. For this reason, the occurrence of shale's at the reservoir site shall not cause any leakage. (of course, at the dam site, its occurrence is considered undesirable because of its incompetency and slippery character).
* Sandstone is an aquifer and hence it has a tendency to cause leakage. However, careful examination is needed to know whether it causes severe leakage or not, if present at the reservoir site. This is so because the porosity and permeability of different sandstone differ depending on a degree of cementation and composition of the cementing materials of sandstones.
* The Occurrence of limestone, the third most common rock of the sedimentary group at the reservoir site is, in general, undesirable. Because they may be internally cavernous and cause profuse leakage.

**Reservoir and Metamorphic Rocks**

* Gneisses, which are one of the most common metamorphic rocks, behave like granite, i.e.. they are neither porous nor permeable.
* The schists, on the other hand, by virtue of their excellent foliation and soft and cleavage-bearing mineral content and a source of weakness and leakage problems.
* The quartzite which are compact, by virtue of their quartz content and granulose structure, are neither porous nor permeable.
* Marbles, through compact, by virtue of their calcium carbonate composition and calcite content are not reliable in terms of their water tightness.
* Slates due to their characteristics slaty due to their characteristic slaty cleavage may tend to cause leakage but their very fine grained nature helps in checking such leakage considerably.

**TUNNELS**

Tunnels are underground passages or routes (or passages through hills or mountains) used for different purposes. They are made by excavation of rocks below the surface or through the hills or mountains.

Like dams, bridges and reservoirs, tunnels are also very important civil engineering projects, but with some differences.

Unlike other civil engineering constructions which lie on the surface, generally, tunnels lie underground (i.e. within the rocks). For this reason, the needs for their safety and stability are more important.

**Effects of Tunneling On the Ground**

The tunneling process deteriorates the physical conditions of the ground. This happens because due to heavy and repeated blasting excavation, the rocks gets shattered to great extent and develop numerous cracks and fractures. This reduces the cohesiveness and compactness of rocks. In other words, rocks become loose and more fractured and porous. This naturally adversely affects the competence of the rocks concerned.

**Geological Considerations for successful Tunneling**

As already stated, the safety success and economy of tunneling depend on the various geological conditions prevailing at the site. As usual, the important geological factors which interfere with this civil engineering project (i.e. tunneling) are

(i) Rock type or Lithological,

(ii) Structural and

(iii) Ground water conditions.

**Importance of Rock Types**

Since tunnels through underground rock masses, obviously the nature of rock types which are encountered along the tunnel alignment is very important for the safety and stability of the tunnel.

* In brief, the competent rocks (i.e. those which are strong, hard and massive) will lead to safe but slow tunneling.
* Incompetent rocks (which are loose or soft or fractured), through amenable for easy tunneling, will be unstable and hence require lining.
* If tunnel extends for considerably long distances, the kind of rocks are may vary from place to place, i.e. Competent at some places and incompetent at some other places.

**Suitability of Igneous Rocks at the Tunnel Site**

* Massive igneous rocks, i.e. the plutonic and hyperbyssal varieties, are very competent but difficult to work. They do not need any lining or any special maintenance.
* This is so because they are very strong, tough, hard, rigid, durable, impervious and tunneling, do not succumb to collapse, floor bumps, side bulges or to any other deformation.
* The volcanic rocks, too in spite of their vesicular or amygdaloidal character are competent and suitable for tunneling.
* Further, by virtue of frequently present vesicular or amygdaloidal structure, they are more easily workable than intrusive rocks.

**Sedimentary Rocks at the tunnel Site**

In general, sedimentary rocks are less competent than igneous rocks. Among the different sedimentary rocks.

* Thick bedded, well-cemented and siliceous or ferruginous sandstones are more competent and better suited for tunneling. They will be strong, easily workable and, moreover, do not require any lining. Thus they possess all the desirable qualities for tunneling, provided they are not affected adversely by any geological structures and ground water conditions.
* Shales, by virtue of their inherent weakness and lamination, may get badly shattered during blasting. But being soft, they can be easily excavated and hence tunneling progresses faster through shale formations. Proper lining is necessary for tunnels built in Shales.
* Among limestones, dolomitic limestone are harder and more durable. They are better than other varieties. On the other hand, calcareous limestones or porous limestones are naturally weaker and softer.
* In a majority of the cases, sedimentary rocks. Being relatively softer, facilitate fast progress of work, but by virtue of their weakness requires suitable lining.

**Metamorphic Rocks at the Tunnel Site**

* Among different metamorphic rocks, gneisses are nearly similar to granites in terms of their competence, durability and workability. Hence, they are capable of withstanding the tunneling process without requiring any lining. The gneissose structure may be advantageous in the excavation process.
* Schists, phyllites, etc, which are highly foliated and generally soft, are easily workable but necessarily require good lining.
* Quartzite are very hard and hence very difficult to work they are more brittle too. They are competent and need no lining.

**Importance of Geological Structures in Tunnels**

**Effects of Joints at the Tunnel Site**

* Most of the rocks in nature possess irregular cracks and regular joints, which are plane of complete separation in rock masses, and clearly represent weakness in them. There will be more qualitively and quantitavely nearer the surface but generally disappear with depth.
* Closely spaced joints in all kind of rocks are harmful. However, in general, in igneous rocks, which are exceptionally strong, the presence may not harm their self- supporting character.
* In Sedimentary rocks, the occurrence of joints is undesirable because these rocks, which are originally weak and incompetent, become still more weak.
* In Metamorphic rocks also, joints are not characteristic, but are frequently present. Granite gneisses and quartzites, being very competent, can remain suitable for tunneling even if some joints occur in them.
* But schists and slates with joints will become very incompetent and necessarily requires lining.
* Marbles, which possess joints, are unsuitable for tunneling because, in them, joints are root causes for the occurrence of sink holes, solution cavities and channels. Further, as common with other types of rocks, the sheet joints occur in this group of rocks too.

**Fault At The Tunnel Site**

As in other civil engineering projects, in tunnels too, faults are harmful and undesirable because they create a variety of problems.

* The active fault are places where there is scope for further recurrence of faulting, which will be accompanied by the physical displacement of litho units. Hence, such faults lead to dislocation and discontinuity in the tunnel alignment. Therefore, irrespective of the relation of the attitude of the fault with the tunnel courses, the occurrence of any active faults in tunnels is very undesirable.
* The fault zones even if inactive, are places of intense fracturing, which means that they are zones of great physical weakness.
* Such a remedial measures of lining (with concrete) also becomes necessary fault zones, being highly porous, permeable and decomposed, are the potential zones to create ground water problems.

**Folds at the Tunnel Site**

Folds represent the deformation of rocks under the influence of tectonic forces. Hence the folded rocks will be under considerable strain. When excavations for tunnels are made in folded rocks, such rocks get the opportunity to release this strain (i.e. stored energy). Such a release may occur in the form of rock bursts or rock falls or bulging of the sides or the floor or the roof. Thus complications of such a kind are likely to occur when tunneling is made in folded regions.

* In folded regions, the tunnel alignment may be parallel or perpendicular or oblique to the axis of folds. Further the tunnel may run along the crests or troughs or limbs.

**Effects of Undisturbed or Tilted Strata at The Tunnel Site**

**Horizontal Beds**

* In cases of horizontal or gently inclined beds, conditions will be favorable for tunneling. But it is desirable that the bed concerned be thick so that the tunnel passes through the same formation. This is preferable because thicker formation are more competent and hence tunnels through them will be safe and stable.

**Inclined Beds**

* The forgoing advantage also occur when the tunnels are made parallel to the strike of massive, thick, inclined beds or when inclined tunnels are made following the directions of the slope.

**Tunnels Parallel to the dip**

* In the latter case, an inclined tunnel driven along the dip of beds must run through the same bed or beds all along its course. The stability of the tunnel in all these cases depends on the nature of the beds which forms the roof. It is relevant to say in this context that the dip and strike galleries in coal mines are driven in this way, i.e. along the true dip and strike, respectively, of the coal seams. These tunnels, therefore, always run along the coal seams and have nearly similar conditions all along their length.
* However, when the tunnel is horizontal and runs parallel to the dip direction, then numerous beds will appear along its course. This is undesirable because in such a case the tunneling conditions differ from place to place and this may lead to problems like stability and over break.

**LANDSLIDES**

* Land slide refers to the downward sliding of huge quantities of land masses. Generally, such slides occurs along steeper slopes of hills or mountains.
* It must be sudden or slow in the occurrence. Also, in magnitude, it may be major or minor. Often, loose and unconsolidated surfacial material undergoes sliding. But sometimes, huge blocks of consolidated rocks may also be involved.
* Landslides are generally, of no concern and can just be ignored if they occur in uninhabited places and places of no human interest.
* But if they occur in places of importance such as highways, railway lines, valleys, reservoirs, inhabited areas and agricultural lands, obviously, such instances lead to blocking of traffic, collapse of buildings, harm to fertile lands and so apart from heavy loss of life and property.

**Causes of Landslides**

* Landslides occur due to various causes, Broadly they may be grouped into two types, i.e. inherent or internal cause and immediate causes.
* Of these, the internal cause are responsible to the extent of creating favorable or suitable conditions for landslide occurrence. The other sets of causes, i.e. immediate cause, play the role of overcoming this frictional resistance or inertia by providing necessary energy in the form of sudden jerk, for the actual occurrence of landslide.

**Internal Causes**

* The causes which are inherent in the land mass concerned are again of various types such as influences of slope, associated water, constituent lithology, associated geological structures, human factors, etc.

**Effects of Slope on Landslides**

* This is very important factor which provides favorable conditions for landslides occurrence. It is both directly and indirectly responsible for land slips. Steeper slopes are prone to land slips of loose overburdens due to great gravity influence, whereas gentle slopes are not prone to such land slips because, in such cases, loose overburden encounters greater frictional resistance; hence any possible slip is stalled.
* It is common observation that any loose material, if piled up, shall have a natural slope of about 350 called the angle of repose.
* However, it should be remembered that hard consolidated and fresh rocks remain stable even against any slope, unless they are adversely affected by other lithological and structural factors.

**Effects of ground or surface water on Landslides**

* This is the most important factor which is mainly responsible for landslide occurrence. This is so because it adversely affects the stability of the loose ground in different ways.
* The presence of water greatly reduces the intergranular cohesion of the particles of loose ground. This weakens the ground inherently and therefore, makes it prone to landslide occurrences.
* On hill slopes, water on percolation through the overlying soil zone may flow down as a film or thin sheet of water above the underlying hard rocks.
* Along hill slopes, rain water, while percolates down, carries with it fine clay and silty material which may form a thin band at the interface of loose overlying material and underlying hard work.
* Water, being the most powerful solvent, not only causes decomposition of minerals but also leaches out the soluble matter of rocks. This reduces the compaction or cohesion of the rock bodies and make it a weak mass.

**Effects of Lithology on Landslides**

* The nature of rock types also influences landslide. For ex. Rocks which are highly fractured, porous and permeable are prone to landslide occurrence because they give scope for the water to play an effective role.
* Rocks which are rich in certain constituents like clay, mica, calcite, gypsum, rock salt and calcareous cementing material are more prone to landslide occurrence because they are easily leached out, causing porosity and permeability.
* Thinner Strata are more susceptible to sliding than thicker strata.

**Effects of Geological Structures on Landslides**

* The geological Structures which increase the chances of landslide occurrence are inclined bedding planes, joints, faults or shear zones. All these are plane of weakness.
* When their dip coincides with that of the surface slope they create conditions of instability.

**Landslides Immediate Causes**

The different causes listed earlier simply create favorable conditions for the occurrence of landslides, but they themselves do not bring about the actual occurrence of landslides. Otherwise, landslides could have occurred anywhere and at any time just if the case were present. But the fact that the landslide occur suddenly at certain times only, indicate that these causes only prepare the ground but because of factors such as frictional resistance the overlying mass will remain in the same place in a critical condition.

Hence such an impulse, which is a sudden jolt or jerk or vibration of the ground, acts as the immediate cause for the occurrence of landslides. This sudden jolting phenomenon of the ground may, in turn, be due to the different natural and artificial reasons like avalanche, volcanic irruptions, falls of meteorite, occurrence of earthquake, blasting of explosives in quarrying, tunneling, road cutting or mining.

**Effects of Landslides**

From the Civil Engineering Point of view, if landslide occurs at vulnerable places, they may cause:

(i) Disruption of transported or blocking of communications by damaging roads and railways and telegraph poles;

(ii) Obstruction to the river flow in valleys, leading to their overflow and floods;

(iii) Damage to sewer and other pipelines

(iv) Burial or destruction of buildings and other construction

**Preventive Measures for Landslides**

To prevent the occurrence of landslides, it would be logical to take such steps which would counter the effects of those factors responsible for landslide occurrence. The main factors which contribute to landslide occurrence are slope, water content, structural defects, unconsolidated or loose character of the overburden, lithology and human interferences.

**Retaining walls To Counter the effect of slope**

Retaining walls may be constructed against the slopes, so that the material which rolls down is not only prevented from further fall but also reduces the slope To Counter the effects of water

A proper drainage system is the suitable measure. This involves the quick removal of percolated moisture by means of surface drainage and subsurface drainage.

The different structural defects such as weak planes and zones may be either covered or grouted suitably so that they are effectively sealed off. These measures not only prevent the avenues for percolation of water but also increase the compaction or cohesion of the material concerned.

**Grouting to Prevent Landslides**

Not to resort to reduce the stability of existing slopes

This is done by not undertaking any undercutting on the surface slope and by not undertaking any construction at the top of the hills.

To Counter the loose nature of the overburden

Growing vegetation, plants and shrubs on loose ground helps in keeping the loose soil to-geather.

Avoiding heavy traffic and blasting operations near the vulnerable places naturally helps in preventing the occurrence of landslides.

**AN earthquake**

An earthquake (also known as a quake, tremor or temblor) is the shaking of the surface of the Earth, resulting from the sudden release of energy in the Earth's lithosphere that creates seismic waves. Earthquakes can range in size from those that are so weak that they cannot be felt to those violent enough to toss people around and destroy whole cities. The seismicity or seismic activity of an area refers to the frequency, type and size of earthquakes experienced over a period of time.

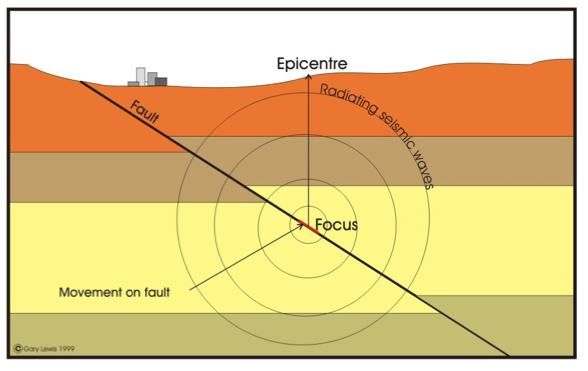
**An earthquake Terminology**

Every tremor produces different types of seismic waves, which travel through rock with different velocities:

Longitudinal p-waves (shock- or pressure waves)

Transverse s-waves (both body waves)

Surface waves — (rayleigh and love waves)

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**Effects of AN earthquakes**

* Landslides and avalanches
* Fires
* Soil liquefaction
* Tsunami
* Floods
* Human impacts

**floods**

A flood is an overflow of water that submerges land that is usually dry. A flood as a covering by water of land by "flowing water",.

Flooding may occur as an overflow of water from water bodies, such as a river, lake, or ocean, in which the water overtops or breaks levees, resulting in some of that water escaping its usual boundaries, or it may occur due to an accumulation of rainwater on saturated ground in an areal flood.

Floods can also occur in rivers when the flow rate exceeds the capacity of the river channel, particularly at bends or meanders in the waterway.

**Principal types**

Areal

Riverine (Channel)

Estuarine and coastal

Urban flooding

Catastrophic

**Causes**

Upslope factors

Downslope factors

Coincidence

**Effects**

*Primary effects*

The primary effects of flooding include loss of life, damage to buildings and other structures, including bridges, sewerage systems, roadways, and canals.

*Secondary and long-term effects*

Economic hardship due to a temporary decline in tourism, rebuilding costs, or food shortages leading to price increases is a common after-effect of severe flooding. The impact on those affected may cause psychological damage to those affected, in particular where deaths, serious injuries and loss of property occur

**Benefits**

Floods (in particular more frequent or smaller floods) can also bring many benefits, such as recharging ground water, making soil more fertile and increasing nutrients in some soils. Flood waters provide much needed water resources in arid and semi-arid regions where precipitation can be very unevenly distributed throughout the year and kills pests in the farming land. Freshwater floods particularly play an important role in maintaining ecosystems in river corridors and are a key factor in maintaining floodplain biodiversity. Flooding can spread nutrients to lakes and rivers, which can lead to increased biomass and improved fisheries for a few years.

For some fish species, an inundated floodplain may form a highly suitable location for spawning with few predators and enhanced levels of nutrients or food. Fish, such as the weather fish, make use of floods in order to reach new habitats. Bird populations may also profit from the boost in food production caused by flooding.

Periodic flooding was essential to the well-being of ancient communities along the Tigris-Euphrates Rivers, the Nile River, the Indus River, the Ganges and the Yellow River among others. The viability of hydropower, a renewable source of energy, is also higher in flood prone regions.

**Flood safety planning**

**Planning for flood safety involves many aspects of analysis and engineering, including:**

* observation of previous and present flood heights and inundated areas,
* statistical, hydrologic, and hydraulic model analyses,
* mapping inundated areas and flood heights for future flood scenarios,
* long-term land use planning and regulation,
* engineering design and construction of structures to control or withstand flooding,
* intermediate-term monitoring, forecasting, and emergency-response planning, and
* short-term monitoring, warning, and response operations.

**Control of floods**

In many countries around the world, waterways prone to floods are often carefully managed. Defenses such as detention basins, levees, bunds, reservoirs, and weirs are used to prevent waterways from overflowing their banks. When these defenses fail, emergency measures such as sandbags or portable inflatable tubes are often used to try to stem flooding. Coastal flooding has been addressed in portions of Europe and the Americas with coastal defenses, such as sea walls, beach nourishment, and barrier islands.

In the riparian zone near rivers and streams, erosion control measures can be taken to try to slow down or reverse the natural forces that cause many waterways to meander over long periods of time. Flood controls, such as dams, can be built and maintained over time to try to reduce the occurrence and severity of floods as well.