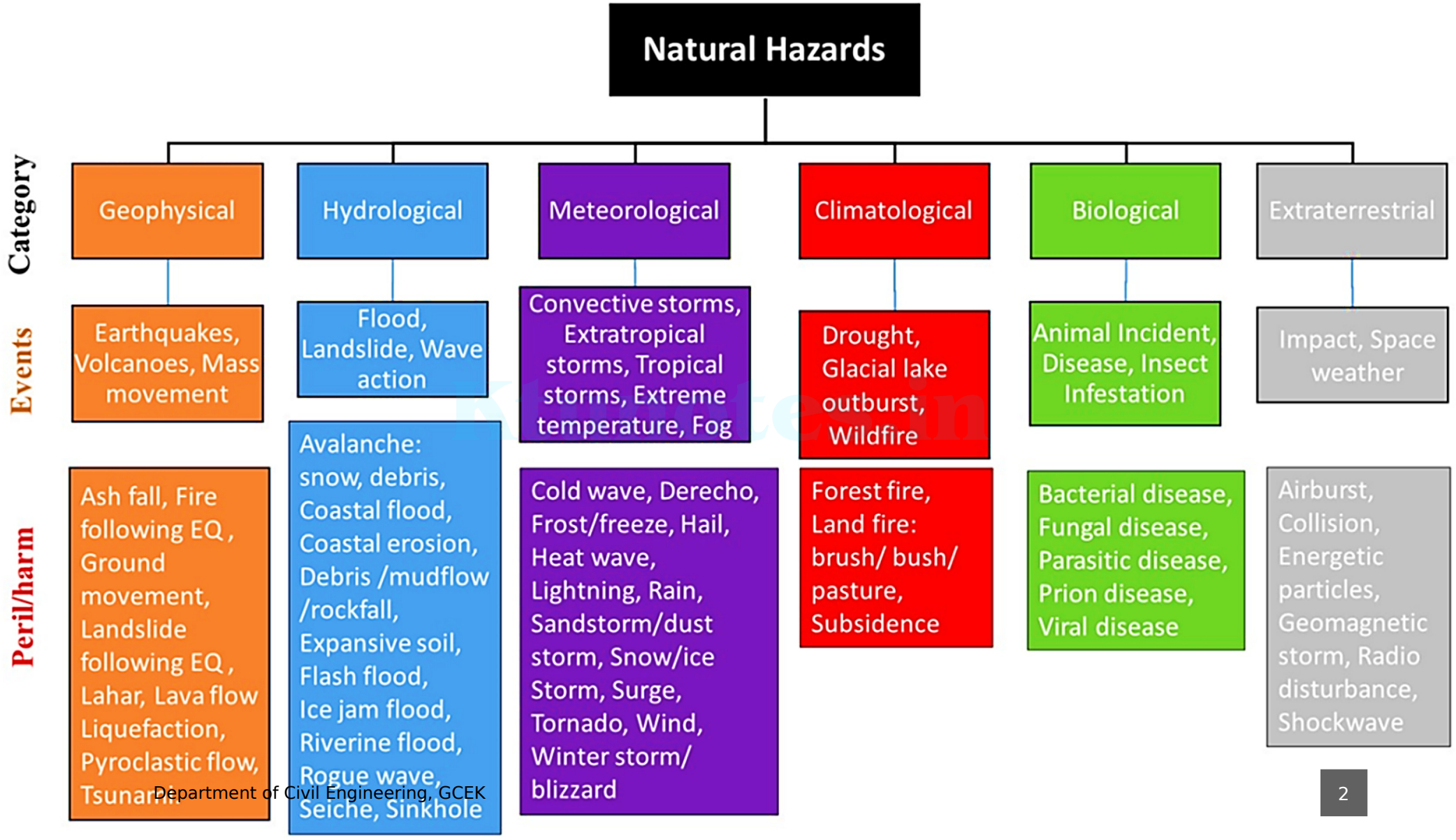
KTU NOTES

The learning companion.

KTU STUDY MATERIALS | SYLLABUS | LIVE NOTIFICATIONS | SOLVED QUESTION PAPERS

MODULE 2


Natural Hazards
Category
Events
Peril/harm
Geophysical
Hydrological
Meteorological
Climatological
Biological
Extraterrestrial
Earthquakes, Volcanoes, Mass movement
Flood, Landslide, Wave action
Convective storms, Extratropical storms, Tropical storms, Extreme temperature, Fog
Drought, Glacial lake outburst, Wildfire
Animal Incident, Disease, Insect Infestation
Impact, Space weather
Ash fall, Fire following EQ , Ground movement, Landslide following EQ , Lahar, Lava flow Liquefaction, Pyroclastic flow, Tsunami
Avalanche: snow, debris, Coastal flood, Coastal erosion, Debris /mudflow /rockfall, Expansive soil, Flash flood, Ice jam flood, Riverine flood, Rogue wave, Seiche, Sinkhole
Cold wave, Derecho, Frost/freeze, Hail, Heat wave, Lightning, Rain, Sandstorm/dust storm, Snow/ice Storm, Surge, Tornado, Wind, Winter storm/ blizzard
Forest fire, Land fire: brush/ bush/ pasture, Subsidence
Bacterial disease, Fungal disease, Parasitic disease, Prion disease, Viral disease
Airburst, Collision, Energetic particles, Geomagnetic storm, Radio disturbance, Shockwave

EARTHQUAKES

- One of the most destructive natural hazard.
- They may occur at any time of the year, day or night, with sudden impact and little warning.
- Earthquakes not only destroys the entire habitat, but also destabilize the government, economy and social structure of the country.

Definition :

It is the sudden shaking of the earth crust.

Seismic Zone Map of India: -2002

About 59 percent of the land area of India is liable to seismic hazard damage

Zone	Intensity
Zone V	Very High Risk Zone Area liable to shaking Intensity IX (and above)
Zone IV	High Risk Zone Intensity VIII
Zone III	Moderate Risk Zone Intensity VII
Zone II	Low Risk Zone VI (and lower)

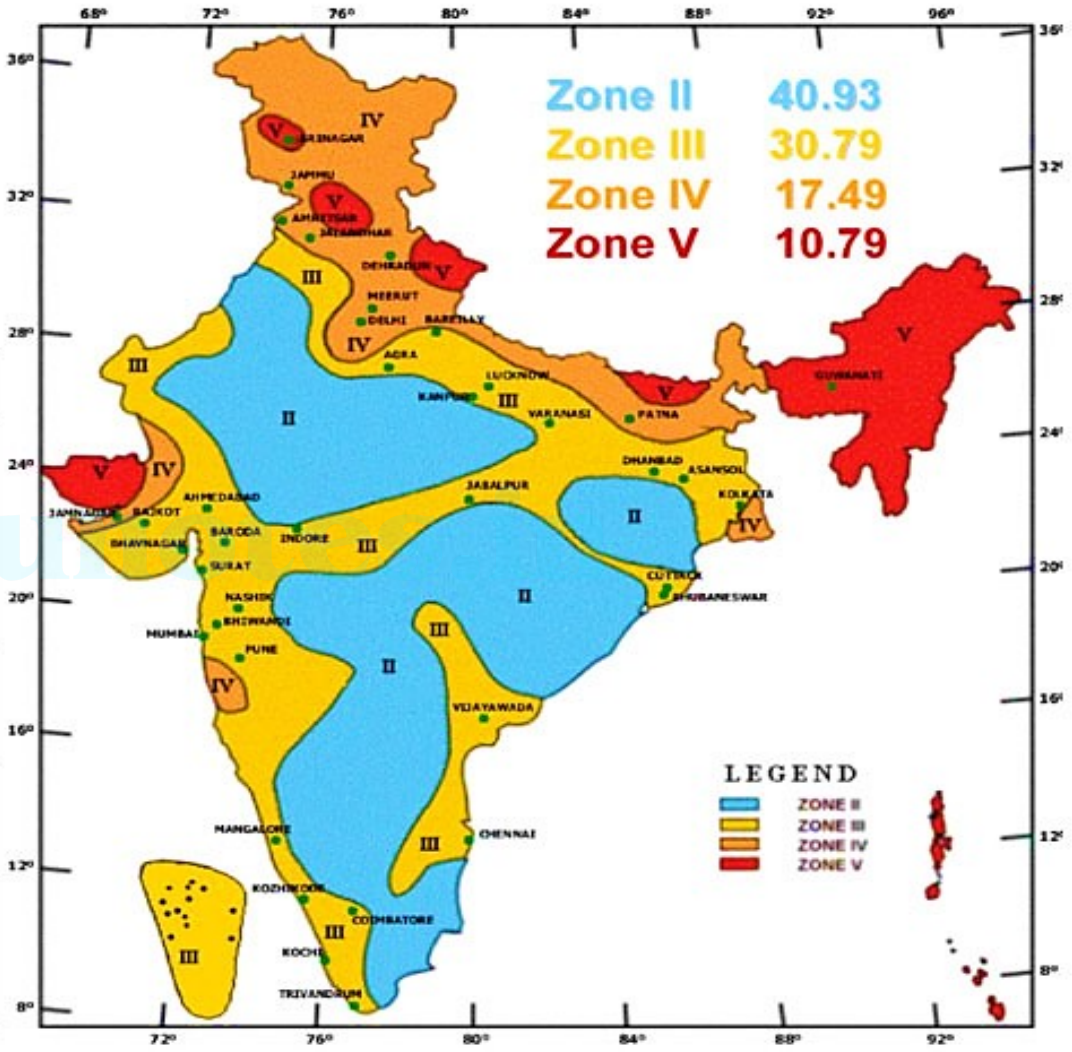


Fig. 1 Seismic zonation and intensity map of India

#	Year of Occurrence	Location/Affected Areas	Magnitude	Deaths
1	2015 (April 25)	Nepal/Bihar, West Bengal, Uttar Pradesh, Delhi	7.9	79 (India)
2	2011 (Sep. 18)	Gangtok, Sikkim	6.9	7,860
3	2005 (October 8)	Kashmir	7.6	1309
4	2004 (Dec. 26)	Sumatara/ Coastal areas of Tamil Nadu, Andhra Pradesh and Kerala	9.3	16,389
5	2001 (January 26)	Kutch, Gujarat	7.7	20,005
6	1999 (March 29)	Chamoli, Uttarakhand	6.8	100
7	1997 (May 22)	Jabalpur, Madhya Pradesh	6.0	56
8	1993 (Sep. 30)	Latur, Maharashtra	6.3	9,748
9	1991(October 20)	Uttarkashi ,Uttarakhand	6.6	2,000
10	1988 (August 21)	Bihar-Nepal Border	6.4	382
11	1975 (January 19)	Himachal Pradesh	6.2	47
12	1950 (August 15)	Arunachal Pradesh	8.5	1500
13	1934 (January, 15)	Bihar	8.3	6000
14	1905 (April 4)	Kangra, Himachal Pradesh	8.0	20,000

Source: Compiled from GoI 2011, EM-DAT (www.emdat.be); IMD (www.imd.gov.in)

PLATE TECTONICS

- German Scientist Alfred Wegener, in 1915, proposed that, 200 million years ago the earth had only one continent called Pangaea.
- Pangaea broken into pieces that slowly drifted into the present configuration of continents.
- The convective flows of Mantle material cause the earth crust and some portion of the mantle to slide on the hot molten outer core.
- This sliding of earth's mass takes place in pieces called **Tectonic Plates.**
- The surface of the earth consists of seven major tectonic plates and many other smaller

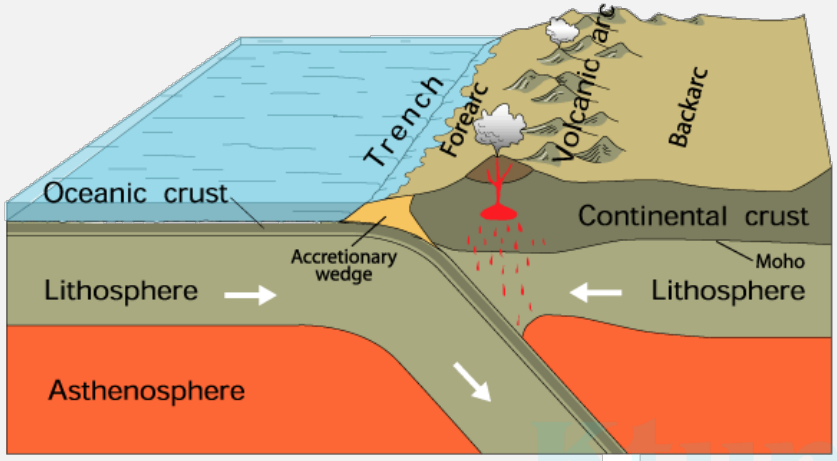
- a) Eurasian Plate
- b) Indo – Australian Plate
- c) Pacific Plate
- d) North American Plate
- e) South American Plate
- f) African Plate
- g) Antarctic Plate

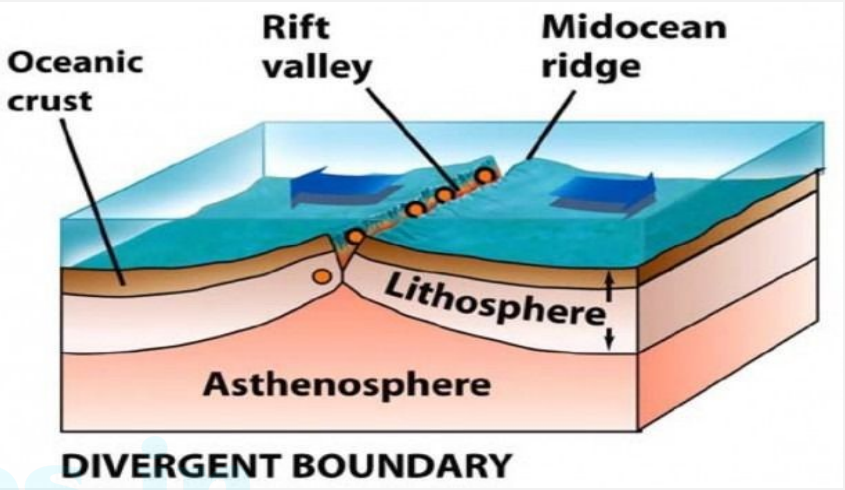
- These plates move in different directions and at different speeds from those of the neighbouring ones.

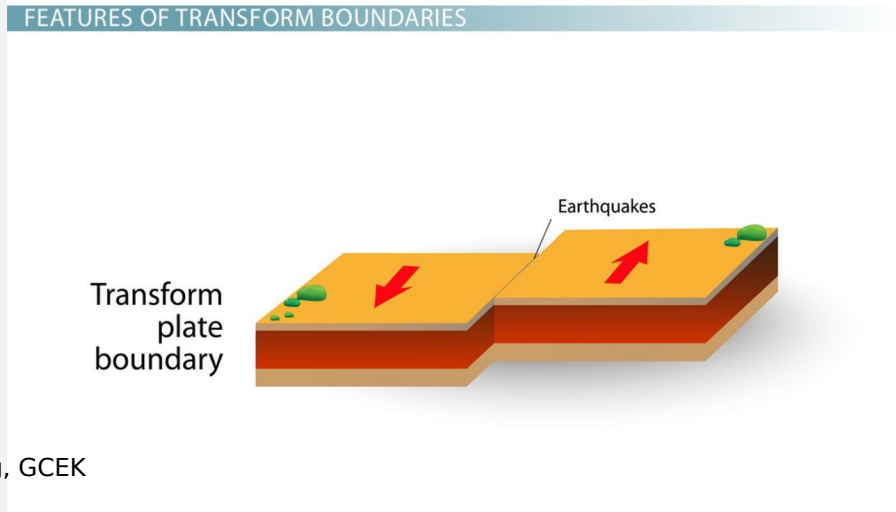
a) **Convergent Boundaries** : Sometimes, the plate in the front is slower; then the plate behind it comes and collides, resulting in the formation of mountains.

b) **Divergent Boundaries** : Sometimes, two plates move away from one another, resulting in the formation of rifts.

c) **Transform Boundaries** : Two plates moves side by side, along the same direction or in opposite directions.


Trench
Forearc
Volcanic arc
Backarc
Oceanic crust
Continental crust
Accretionary wedge
Moho
Lithosphere
Lithosphere
Asthenosphere


Oceanic crust
Rift valley
Midocean ridge
Lithosphere
Asthenosphere
DIVERGENT BOUNDARY


FEATURES OF TRANSFORM BOUNDARIES
Earthquakes
Transform plate boundary

ELASTIC BOUND THEORY

- Tectonic plates are made up of elastic, but brittle rocky material.
- Hence, the elastic energy is stored in them during the relative deformations that occur due to the gigantic tectonic plate actions taking place in the Earth.
- When the rocky material along the interface of the plates in the Earth's crust reaches its strength, it fractures and a sudden movement takes place there.
- The interface between the plates where the movement has

has taken place (called the fault) suddenly slips and releases the large strain energy stored in the rocks at the interface.

- The sudden slip at the fault causes the earthquake – a violent shaking of the earth during which large strain energy released spreads out in the form of seismic waves that travel through the body and along the surface of the Earth.
- After the earthquake is over, the process of strain build up at this modified interface between the tectonic plates starts all over again.
- Scientists called this as the **Elastic Rebound Theory.**

SEISMIC WAVES

- Large strain energy released during an earthquake travels as seismic waves in all directions through the earth's layers, reflecting and refracting at each interface.
- These waves are of two types – **Body Waves and Surface Waves.**
- The surface waves are restricted to near the Earth's surface.
- Body waves consist of **Primary waves (P Waves)** and **Secondary Waves. (S Waves)** and surface waves consist of **Love Waves (L Waves).**

a) **P Waves**

a) Also called as Primary or Push and Pull Waves.

b) Fastest waves in which the particles vibrate in the direction of propogation.

c) Velocity is related to the rigidity of the medium and its density.

b) **S Waves**

a) Wave particles vibrate at right angles in the direction of propogation of the wave.

c) **L Waves**

a) These are sluggish and recorded only after the arrival of body waves. They do not travel through liquids.

RECORDING OF EARTHQUAKES

- The instrument used to record the motion of seismic waves is called seismograph.
- The record produced by the instrument is called as Seismogram.
- A seismograph is designed for recording the horizontal or the vertical component of ground motion.
- A seismograph has three components – **the sensor, the recorder and the timer.**

SEISMOGRAPH

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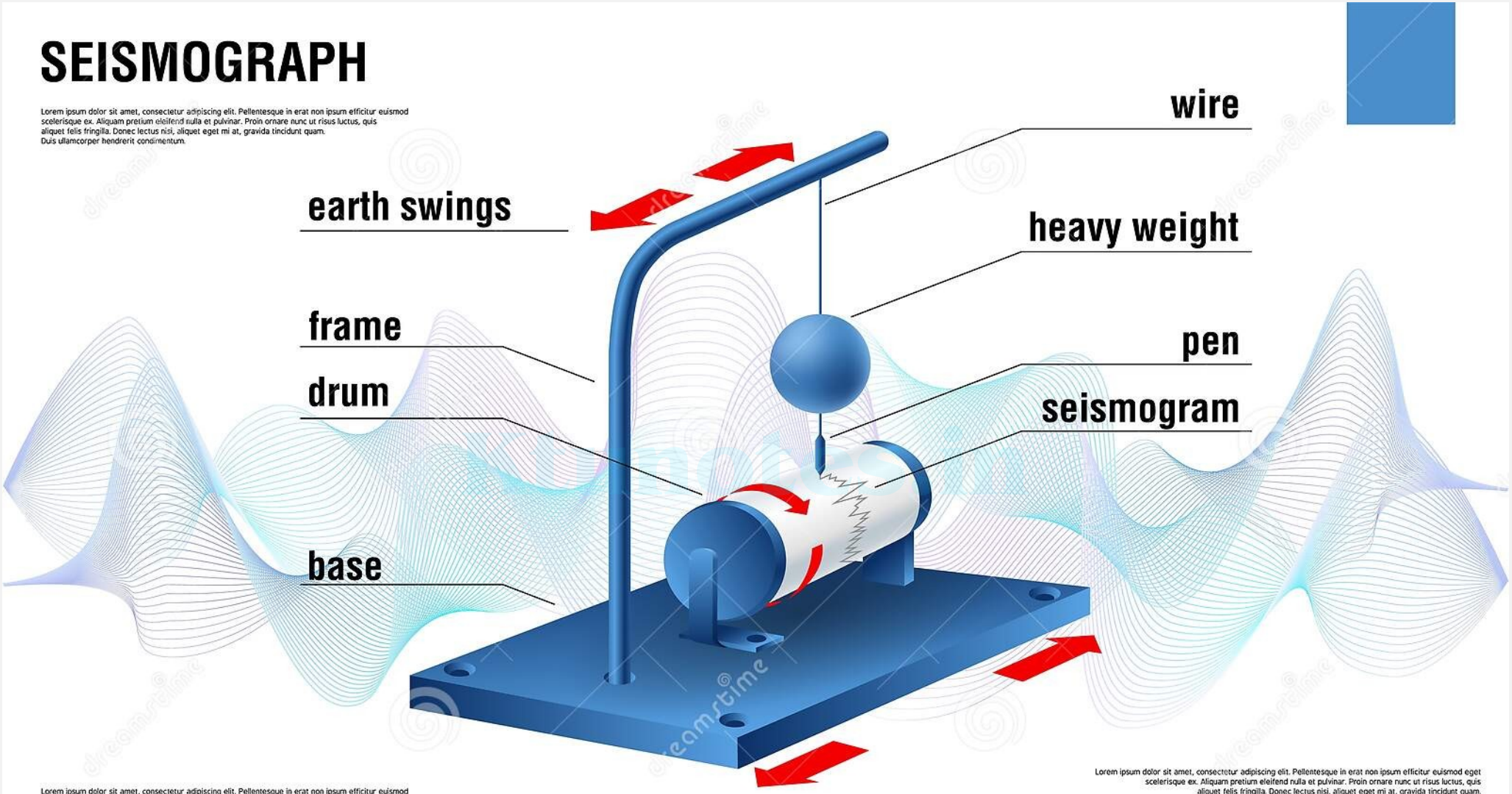

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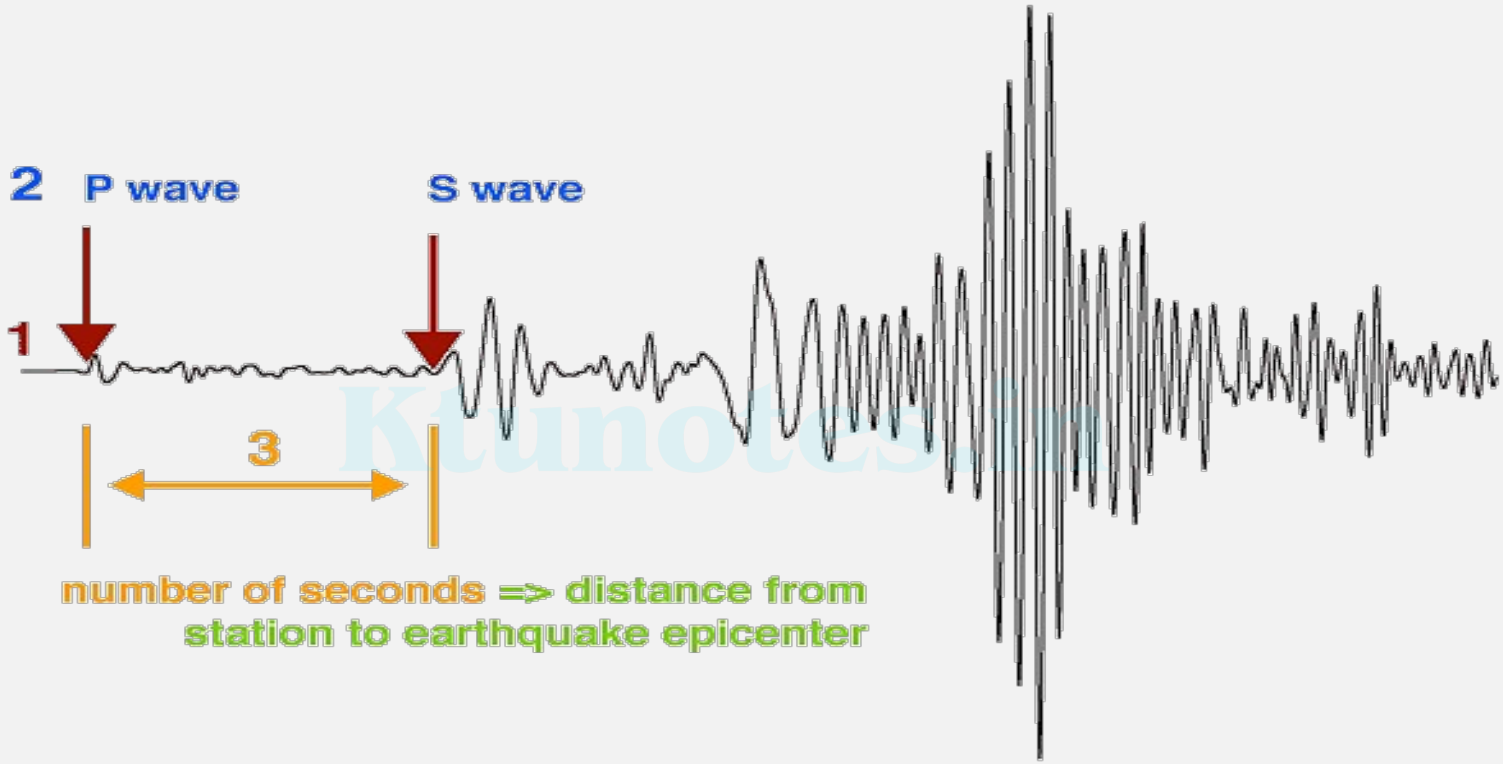
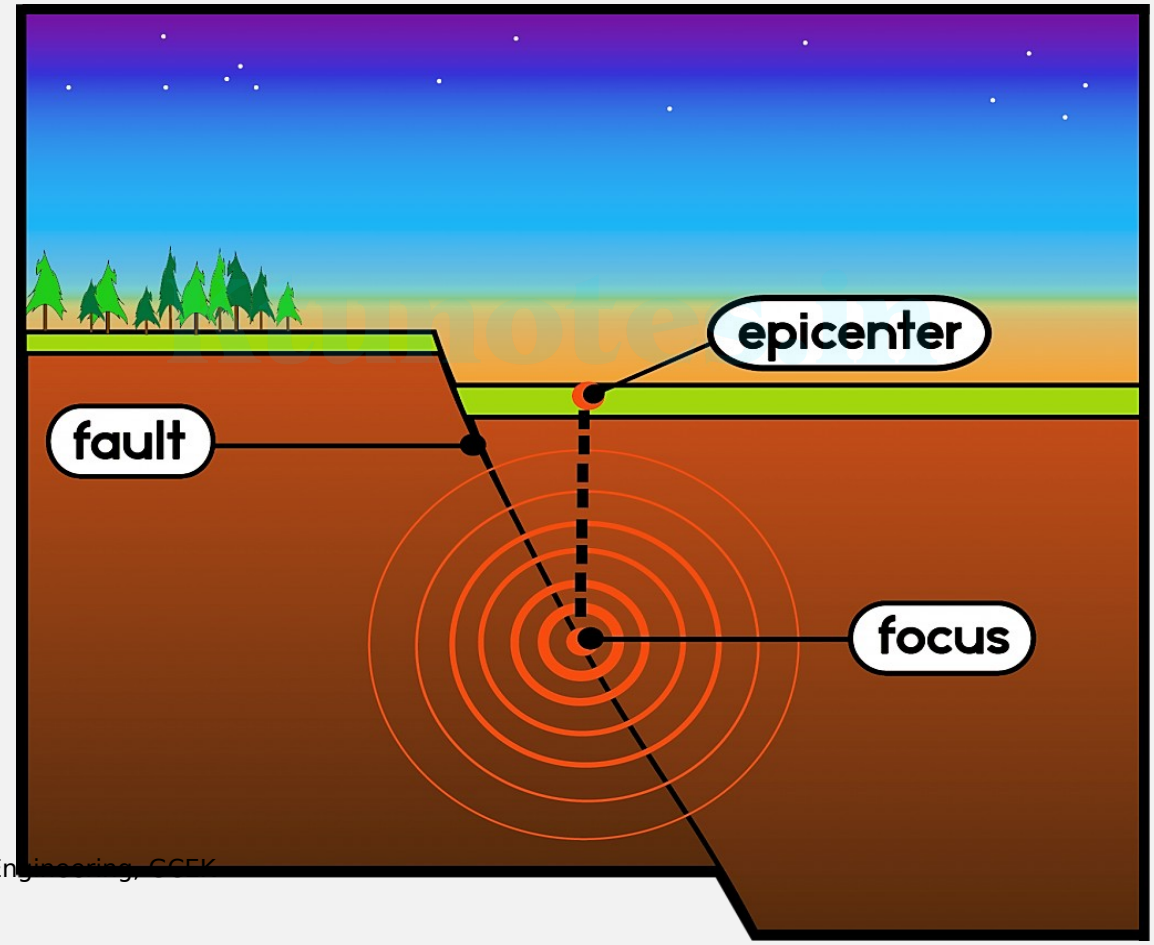

2
P wave
S wave
1
3
number of seconds => distance from
station to earthquake epicenter

TERMINOLOGY



MAGNITUDE OF EARTHQUAKE

- It is a quantitative measure of the actual size of the earthquake.
- Professor Charles Richter noticed that,

At the same distance, seismograms of larger earthquake

have bigger wave amplitude than those of smaller earthquakes.

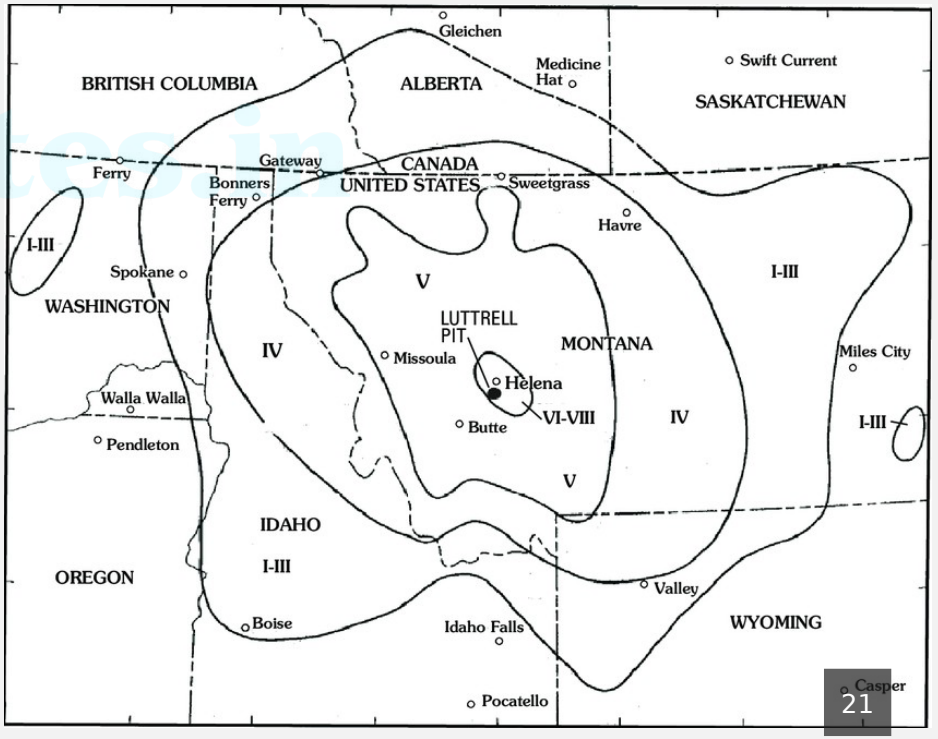
- These prompted him to propose the now commonly used magnitude scale, the **Richter Scale / Local Magnitude Scale.**

Earthquake Magnitude Classes	
Class	**Magnitude**
Great	8 or more
Major	7 - 7.9
Strong	6 - 6.9
Moderate	5 - 5.9
Light	4 - 4.9
Minor	3 -3.9

INTENSITY OF EARTHQUAKES

- It is an indicator of the severity of shaking generated at a given location.
- There are many intensity scales. Two commonly used are the Modified Mercalli Intensity (MMI) Scale and the Medvedev – Sponheur – Karnik (MSK) Scale.
- Both are almost similar and ranges from least perspective to most severe (I –XII).
- The intensity scales are based on the perception by people and animals, performance of buildings and changes to natural surroundings.


X
IX
VIII
VII


Gleichen
BRITISH COLUMBIA
ALBERTA
Medicine Hat
Swift Current
SASKATCHEWAN
Ferry
Gateway
CANADA
UNITED STATES
Sweetgrass
Bonners Ferry
Havre
I-III
Spokane
V
I-III
WASHINGTON
LUTTRELL PIT
MONTANA
IV
Missoula
Miles City
Helena
Walla Walla
VI-VIII
IV
I-III
Butte
Pendleton
V
IDAHO
I-III
OREGON
Valley
WYOMING
Boise
Idaho Falls
Casper
Pocatello

CLASSIFICATION

- Depth of focus
  - Shallow
  - Intermediate
- Magnitude
- Cause of origin
  - Tectonic
  - Non Tectonic

SEISMIC HAZARDS

- Damage occurs to human settlement, buildings, structures and infrastructure, elevated roads, railways, water towers, pipelines, electrical generating facilities.
- Secondary effects include fires, dam failure and landslides which may block water ways and also cause flooding.
- Damage may occur to facilities using or manufacturing dangerous materials resulting in possible chemical spoils.
- Huge loss to the public health system, transport and communication and water supply in the affected areas.

EARTHQUAKES AND PREVENTIVE MEASURES

SAFETY MEASURES (BEFORE)

Check for hazards in the home.

Fasten shelves securely to walls.
Place large or heavy objects on lower shelves.
Store breakable items such as bottled foods, glass, and china in low, closed cabinets with latches.
Hang heavy items such as pictures and mirrors away from beds, couches, and anywhere people sit.
Brace overhead light fixtures.
Repair defective electrical wiring and leaky gas connections. These are potential fire risks.
Secure a water heater by strapping it to the wall studs and bolting it to the floor.
Repair any deep cracks in ceilings or foundations. Get expert advice if there are signs of structural defects.
Store weed killers, pesticides, and flammable products securely in closed cabinets with latches and on bottom shelves.

Identify safe places in each room.

Under sturdy furniture such as a heavy desk or table.
Against an inside wall.
Away from where glass could shatter—around windows, mirrors, pictures, or where book-cases or other heavy furniture could fall over.

Locate safe places outdoors.

In the open, away from buildings, trees, telephone and electrical lines, overpasses, or elevated expressways.

Make sure all family members know how to respond after an earthquake.

Teach all family members how and when to turn off gas, electricity, and water.

Teach children how and when to call 9-1-1, police, or fire department and which radio station to tune to for emergency information.

Contact local emergency management office or Red Cross chapter for information on earthquakes.

Have disaster supplies on hand.

Flashlight and extra batteries

Portable, battery-operated radio and extra batteries

First aid kit and manual

Emergency food and water

Non-electric can opener

Essential medicines

Cash and credit cards

Sturdy shoes

EARTHQUAKES AND PREVENTIVE MEASURES

SAFETY MEASURES (DURING)

Develop an emergency communication plan.

In case family members are separated from one another during an earthquake (a real possibility during the day when adults are at work and children are at school), develop a plan for reuniting after the disaster.

Ask an out-of-state relative or friend to serve as the "family contact." After a disaster, it's often easier to call long distance. Make sure everyone in the family knows the name, address and phone number of the contact person.

If indoors:

Take cover under a piece of heavy furniture or against an inside wall and hold on.

Stay inside.

The most dangerous thing to do during the shaking of an earthquake is to try to leave the building because objects can fall on you.

If outdoors:

Move into the open, away from buildings, street lights, and utility wires.

Once in the open, stay there until the shaking stops.

If in a moving vehicle:

Stop quickly and stay in the vehicle.

Move to a clear area away from buildings, trees, overpasses, or utility wires.

Once the shaking has stopped, proceed with caution. Avoid bridges or ramps that might have been damaged by the quake.

Stay out of damaged buildings. Return home only when authorities say it is safe.

Use the telephone only for emergency calls.

Clean up spilled medicines, bleaches or gasoline or other flammable liquids immediately. Leave the area if you smell gas or fumes from other chemicals.

Open closet and cupboard doors cautiously.

Inspect the entire length of chimneys carefully for damage. Unnoticed damage could lead to a fire.

Be prepared for aftershocks.

Although smaller than the main shock, aftershocks cause additional damage and may bring weakened structures down. Aftershocks can occur in the first hours, days, weeks, or even months after the quake.

Help injured or trapped persons.

Give first aid where appropriate. Do not move seriously injured persons unless they are in immediate danger of further injury. Call for help.

Listen to a battery-operated radio or television for the latest emergency information.

Remember to help your neighbours who may require special assistance — infants, the elderly, and people with disabilities.

EARTHQUAKES AND PREVENTIVE MEASURES

SAFETY MEASURES (AFTER)

Pets after an Earthquake

The behaviour of pets may change dramatically after an earthquake. Normally quiet and friendly cats and dogs may become aggressive or defensive. Watch animals closely. Leash dogs and place them in a fenced yard.

Pets may not be allowed into shelters for health and space reasons. Prepare an emergency pen for pets in the home that includes a 3-day supply of dry food and a large container of water.

Inspection Utilities in a Damaged Home

Check for gas leaks — If you smell gas or hear a blowing or hissing noise, open a window and quickly leave the building. Turn off the gas at the outside main valve if you can and call the gas company from a neighbor's home. If you turn off the gas for any reason, it must be turned back on by a professional.

Look for electrical system damage — If you see sparks or broken or frayed wires, or if you smell hot insulation, turn off the electricity at the main fuse box or circuit breaker. If you have to step in water to get to the fuse box or circuit breaker, call an electrician first for advice.

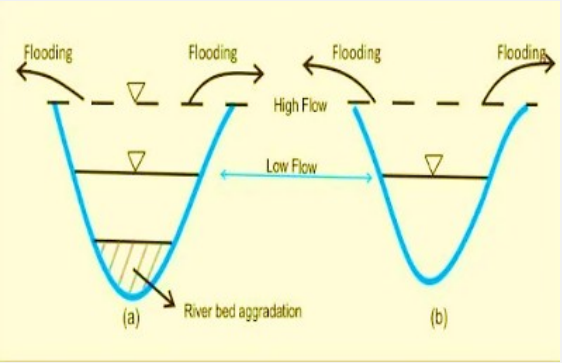
Check for sewage and water lines damage — If you suspect sewage lines are damaged, avoid using the toilets and call a plumber. If water pipes are damaged, contact the water company and avoid using water from the tap. You can obtain safe water by melting ice cubes.

EMERGENCY INFORMATION

- ✓ The best protection during an earthquake is to get under heavy furniture such as a desk, table, or bench.
- ✓ The greatest danger exists directly outside buildings, at exits, and alongside exterior walls. Many injuries and fatalities occur when people run outside of buildings only to be hit by falling debris from collapsing walls.
- ✓ Ground movement during an earthquake is seldom the direct cause of death or injury. Most earthquake-related casualties result from collapsing walls, flying glass, and falling objects.

FLOODS

- A state of high water level along a river channel or on the coast that leads to inundation of land.
- Floods may occur gradually and also may take hours or even happen suddenly without any warning due to breach in the embankment, spill over, heavy rains etc.
- A flood occurs when the volum river becomes greater than bar



TYPES OF FLOODS

- **Slow Onset Floods** : Usually last for a relatively longer period, it may last for one or more weeks or even months.

- **Rapid Onset Floods** : Last for a relatively shorter period, they usually last for one or two days only.

- **Flash Floods** : May occur within minutes or a few hours after heavy rainfall, tropical storm, failure of floods or levees or releases from dams and it causes greater damages to the society.

CAUSES OF FLOODS

- Heavy Rainfall
- Heavy siltation of the river bed reduces the water carrying capacity of the rivers/stream.
- Blockage in the drains lead to flooding of the area.
- Landslides blocking the flow of the stream.
- Construction of dams and reservoirs.
- In areas prone to cyclones, strong winds accompanied by heavy downpour along with storm surge leads to flooding.
- The geological factors are defined by the ***topography, lithology, vegetation of the drainage basin.***

The time from peak rainfall to peak discharge is the **LAG TIME.**

The discharge starts to fall slowly as water is added from through flow and groundwater flows which are much slower.

The soil becomes saturated and overland flow and through flow reach the river and discharge increases. Overland flow arrives first.

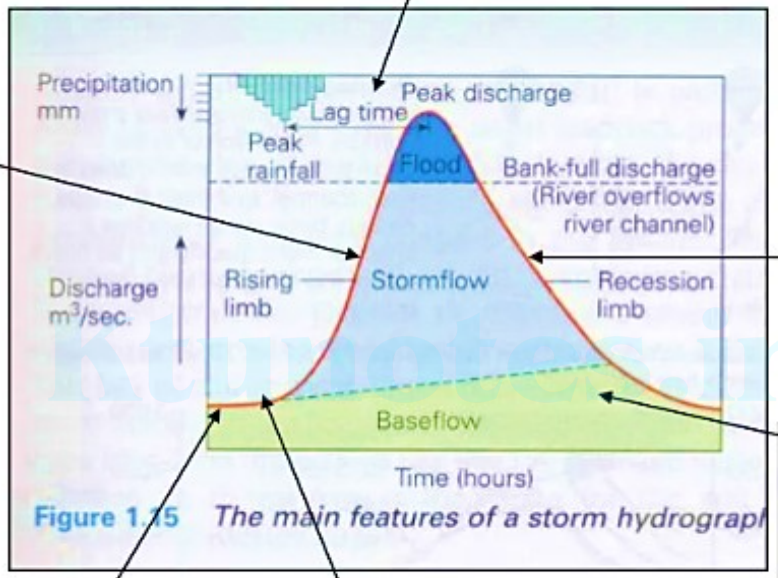


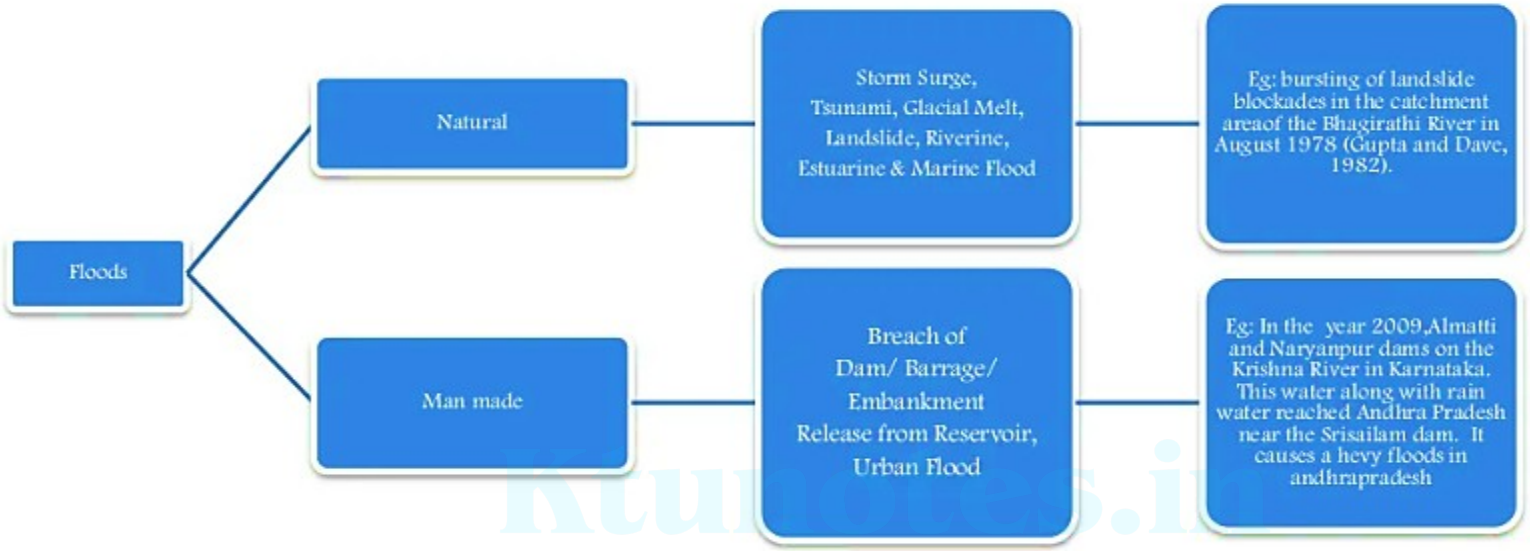
Figure 1.15 *The main features of a storm hydrograph*

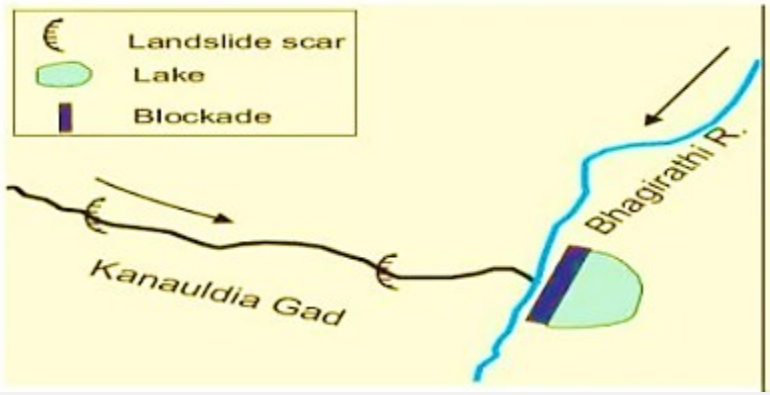
The base flow supplies the river with water between storms and keeps it flowing in summer.

Start of the storm there is a slow rise in discharge, as only a small amount of water falls into the channel

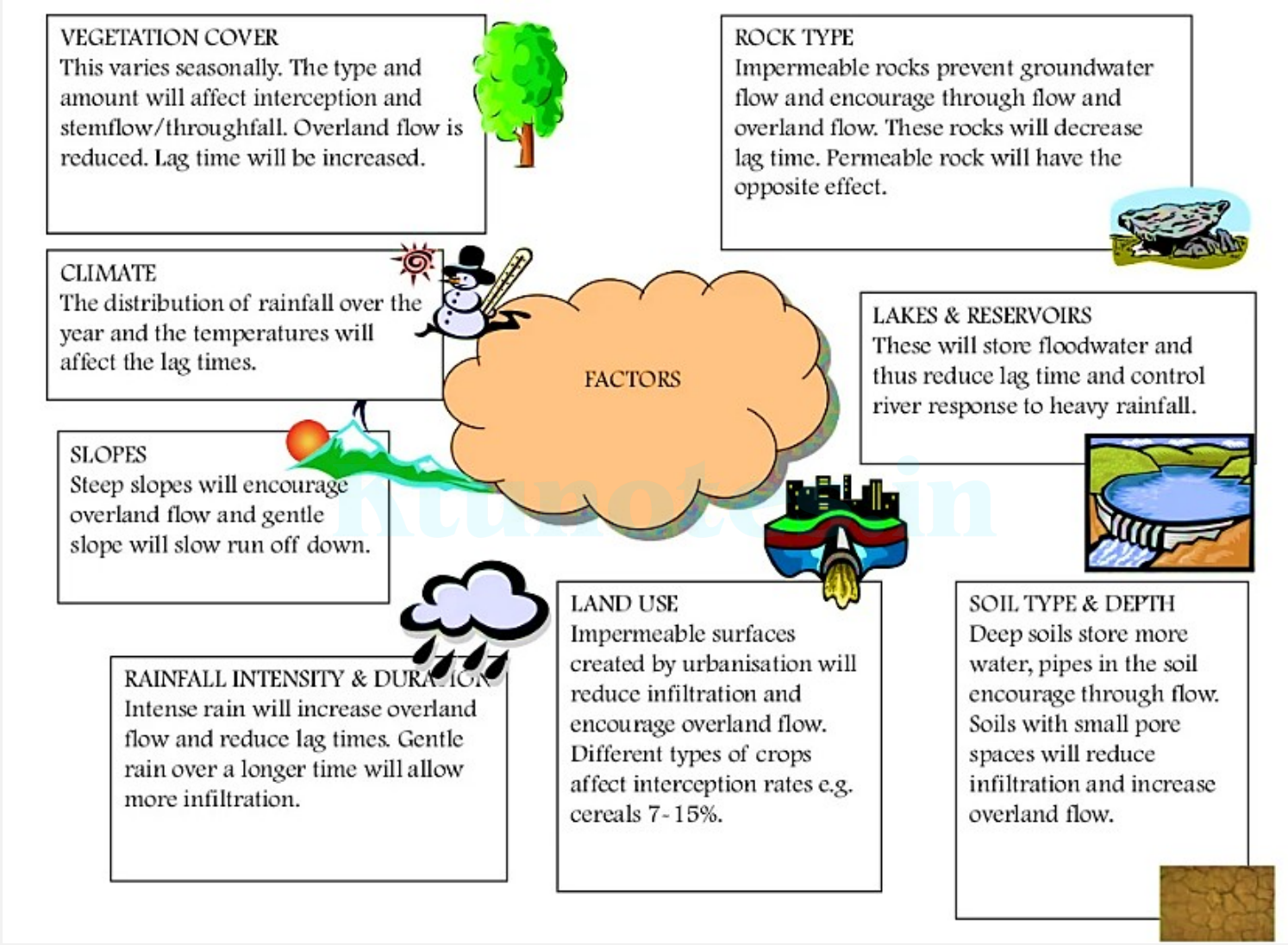
Rainfall is intercepted or infiltrated into the soil moisture store

Contd….


Floods
Natural
Man made
Storm Surge, Tsunami, Glacial Melt, Landslide, Riverine, Estuarine & Marine Flood
Breach of Dam/ Barrage/ Embankment Release from Reservoir, Urban Flood
Eg: bursting of landslide blockades in the catchment areaof the Bhagirathi River in August 1978 (Gupta and Dave, 1982).
Eg: In the year 2009,Almatti and Naryanpur dams on the Krishna River in Karnataka. This water along with rain water reached Andhra Pradesh near the Srisailam dam. It causes a hevy floods in andhrapradesh


Landslide scar
Lake
Blockade
Bhagirathi R.
Kanauldia Gad


MAHARASHTRA
ORISSA
ANDHRA PRADESH
KARNATAKA
TAMIL NADU
KERALA
Flooded area
KRISHNA BASIN
Length: 1300 km
Basin Area: 258,948 sq km
in Karnataka, AP & Maharashtra
Basin population: 74.2 million
(population density 287 per sq km)
Major city: Vijayawada
Last flood: 2009


VEGETATION COVER
This varies seasonally. The type and amount will affect interception and stemflow/throughfall. Overland flow is reduced. Lag time will be increased.
ROCK TYPE
Impermeable rocks prevent groundwater flow and encourage through flow and overland flow. These rocks will decrease lag time. Permeable rock will have the opposite effect.
CLIMATE
The distribution of rainfall over the year and the temperatures will affect the lag times.
FACTORS
LAKES & RESERVOIRS
These will store floodwater and thus reduce lag time and control river response to heavy rainfall.
SLOPES
Steep slopes will encourage overland flow and gentle slope will slow run off down.
RAINFALL INTENSITY & DURATION
Intense rain will increase overland flow and reduce lag times. Gentle rain over a longer time will allow more infiltration.
LAND USE
Impermeable surfaces created by urbanisation will reduce infiltration and encourage overland flow. Different types of crops affect interception rates e.g. cereals 7-15%.
SOIL TYPE & DEPTH
Deep soils store more water, pipes in the soil encourage through flow. Soils with small pore spaces will reduce infiltration and increase overland flow.

FLOODS IMPACTS

- Human Loss
- Property Loss
- Affects the Major Roads
- Disruption of Air / Train / Bus services
- Spread of Water-borne Communicable Diseases
- Communication Breakdown
- Electricity Supply Cut off
- Economic and Social Disruption
- Increase in Air / Water Pollution

Flood forecasting

- Anticipating floods before they occur allows for precautions to be taken and people to be warned so that they can be prepared in advance for flooding conditions.
- For example,
  - Farmers can remove animals from low-lying areas and utility services can put in place emergency provisions to re-route services if needed. Emergency services can also make provisions to have enough resources available ahead of time to respond to emergencies as they occur.
- In order to make the most accurate flood forecasts for waterways, it is best to have a long time-series of historical data that relates stream flows to measured past rainfall events
- Radar estimates of rainfall and general weather forecasting techniques are also important components of good flood forecasting.

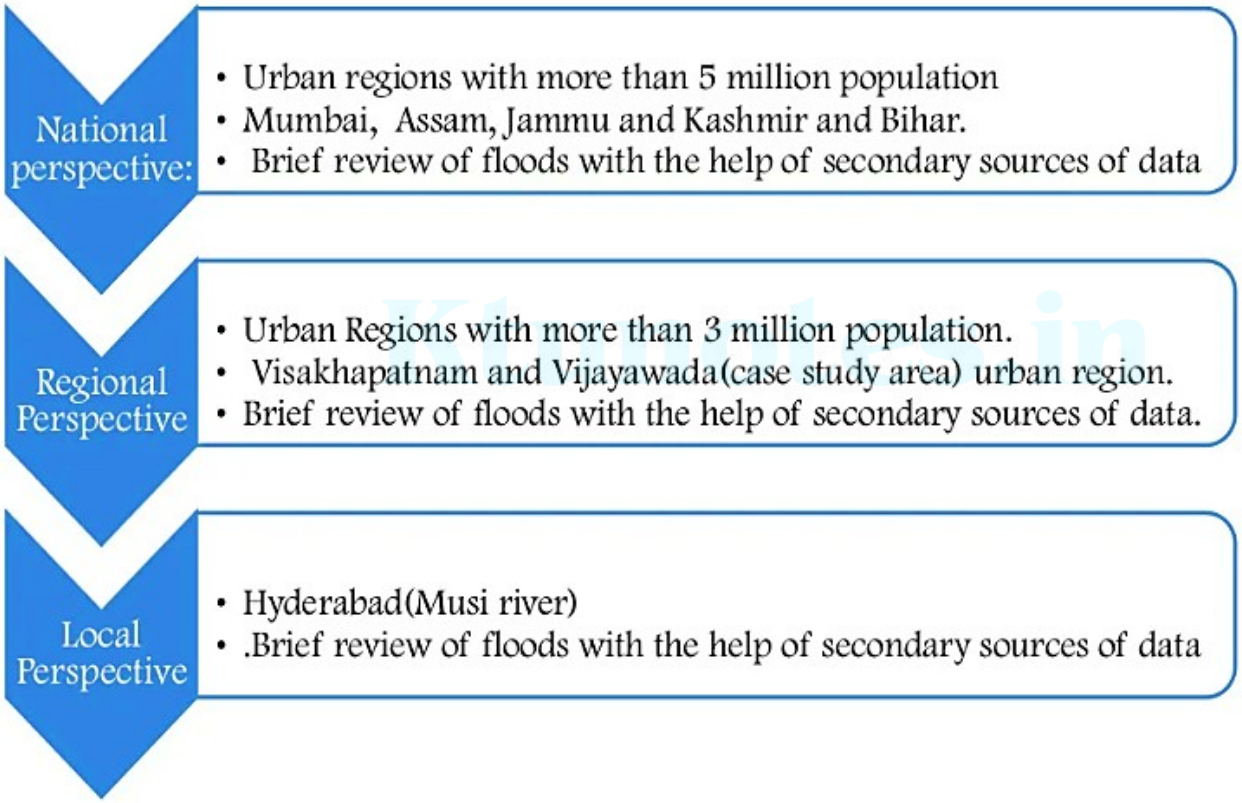
Flood Control

- In many countries around the world, waterways prone to floods are often carefully managed. Defences such as levees, bunds, reservoirs, and weirs are used to prevent waterways from overflowing their banks.
- In the riparian zone near rivers and streams, erosion control measures can be taken to try and 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 and reduce the occurrence and severity of floods as well.

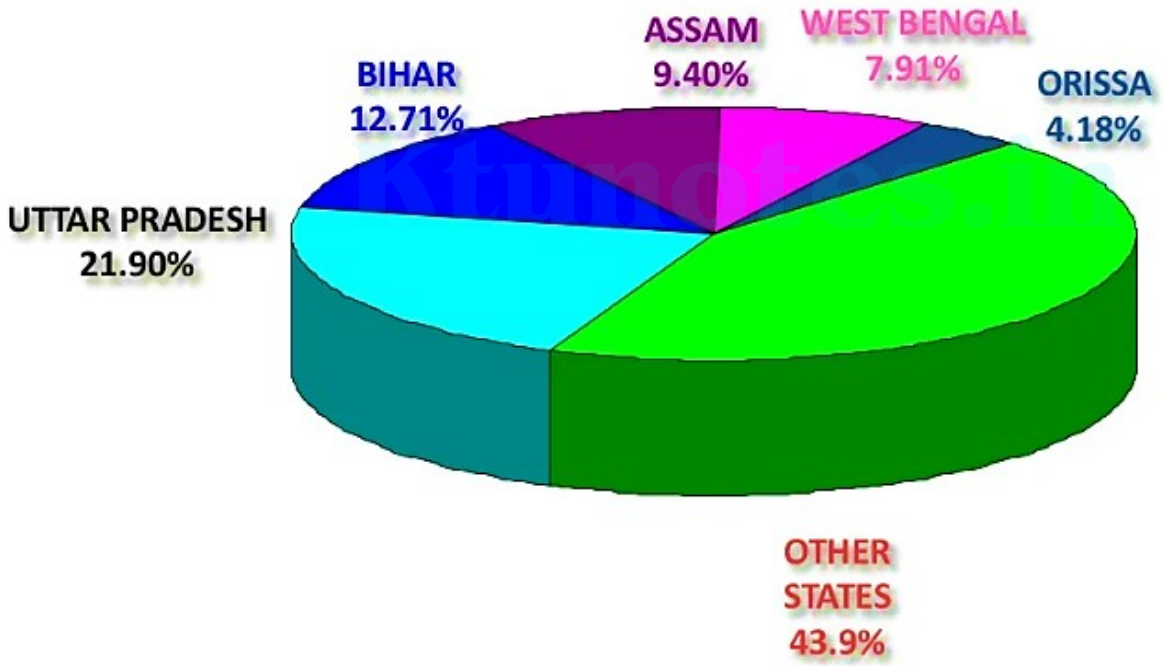
Flood benefits

- 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.
- 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.

METHODOLOGY:



INDIA
FLOOD PRONE AREA

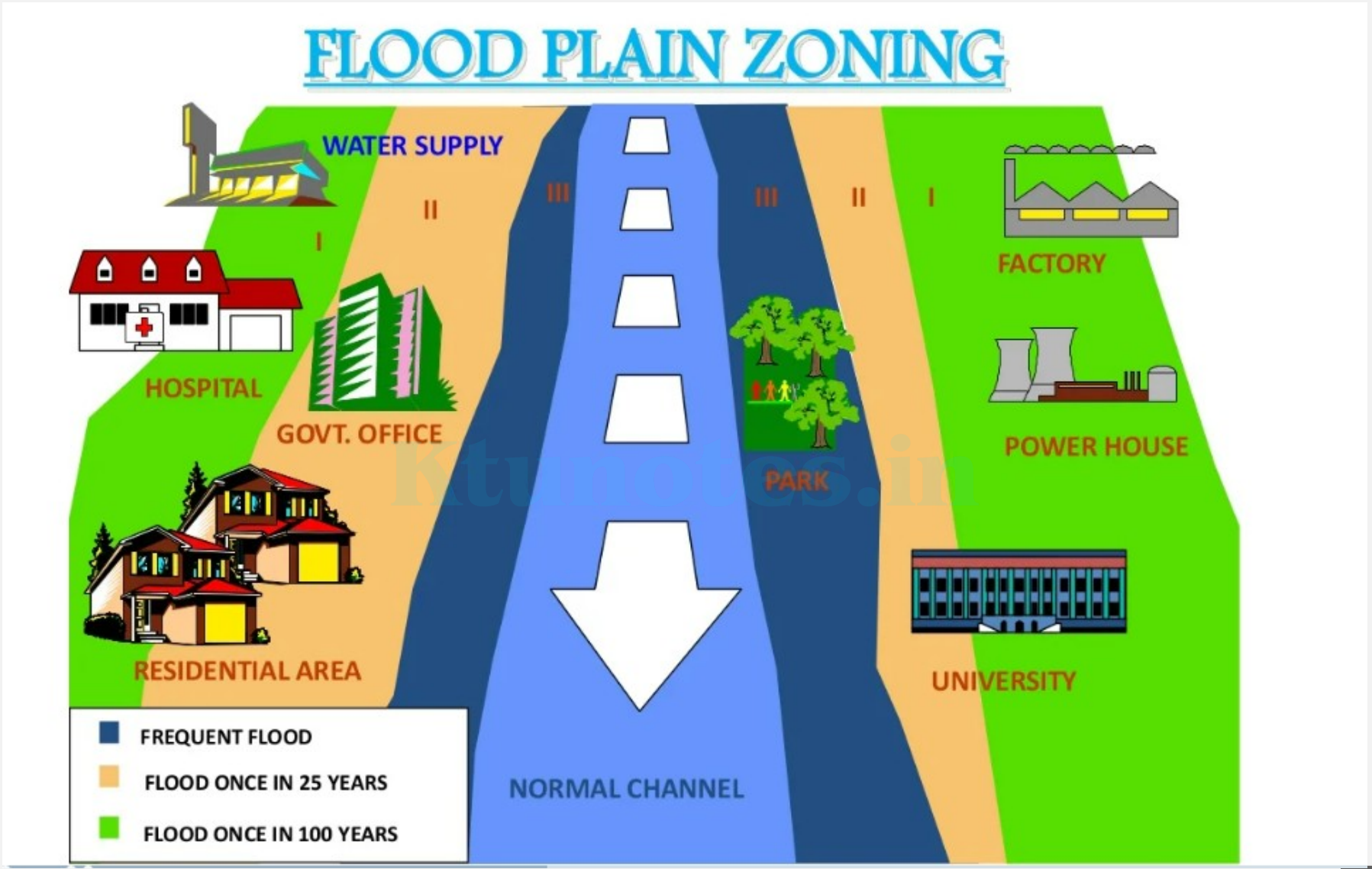


Approaches & measure for long , short term protection from floods in India

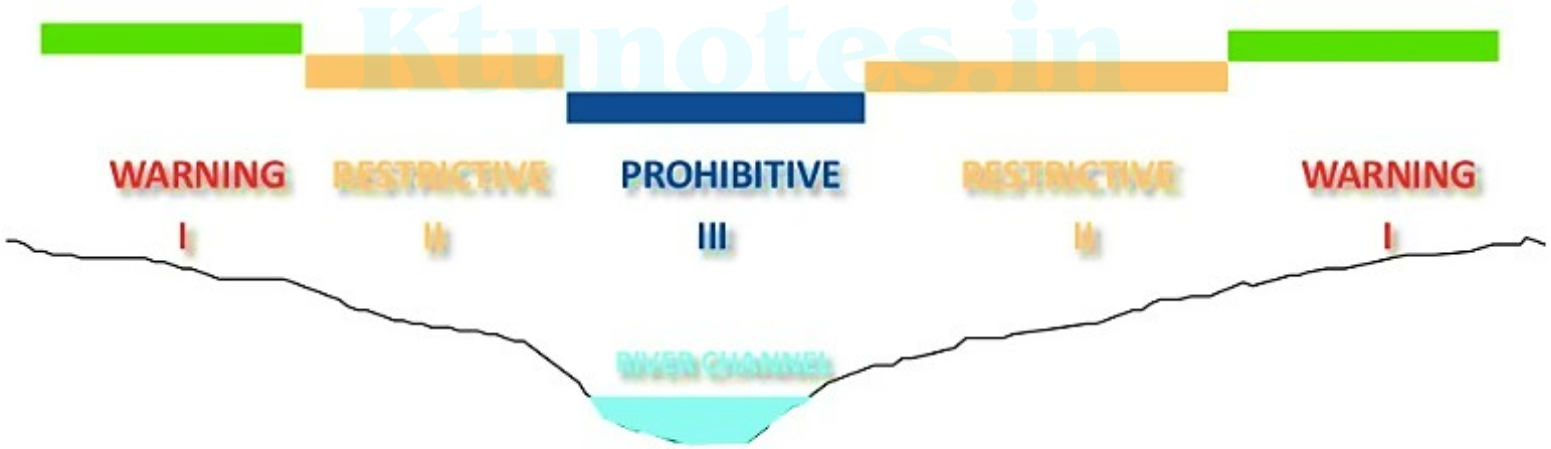
- Attempts to modify the floods: involves flood protection by physical measures such as
  - Construction of embankments
  - Construction of detention reservoirs
  - Channel improvements etc.
- Attempts to modify the susceptibility to flood damage: involves action designed to reduce the vulnerability of property and other developmental activities in the flood plains to the flood hazard
- Attempts to modify the loss burden: Consists of actions to modify the incidence of losses, by spreading them over a large segment of community.
- Bearing the loss: Bearing the loss means living with floods

MEASURES

Structural Measures	Non-Structural Measures
• Embankments • Dams and Reservoirs • Natural Detention basin • Channel improvement • Drainage improvement • Diversion of flood waters	• Flood Plain Zoning and Flood proofing • Flood Preparedness and community level awareness • Flood forecasting and early Warning system • Afforestatation • Public relief • Flood insurance


FLOOD PLAIN ZONING
WATER SUPPLY
I
II
III
III
II
I
FACTORY
HOSPITAL
GOVT. OFFICE
PARK
POWER HOUSE
RESIDENTIAL AREA
UNIVERSITY
FREQUENT FLOOD
FLOOD ONCE IN 25 YEARS
FLOOD ONCE IN 100 YEARS
NORMAL CHANNEL

FLOOD PLAIN ZONING



FLOOD PLAIN ZONING

CONCEPT

- AN IMPORTANT NON-STRUCTURAL MEASURE.
- REGULATES LAND USE IN FLOOD PLAINS TO RESTRICT DAMAGE BY FLOODS.
- INVOLVES DEMARCATION OF ZONES IN FLOOD PLAINS COMPATIBLE WITH FLOOD RISKS INVOLVED.

FLOOD PLAIN ZONING

ZONE REGULATION

PRIORITY - I

ACTIVITY LIMITED TO WATER LEVELS CORRESPONDING TO 100 YEARS FLOOD FREQUENCY AND DRAINAGE CONGESTION FOR 50 YEARS RAINFALL.

FLOOD PLAIN ZONING

ZONE REGULATION

PRIORITY - II

ACTIVITY LIMITED TO LEVELS CORRESPONDING TO 25 YEARS FLOOD FREQUENCY AND DRAINAGE CONGESTION FOR 10 YEARS RAINFALL FREQUENCY.

FLOOD PLAIN ZONING

ZONE REGULATION

PRIORITY - III

LESS ECONOMIC AND COMMUNITY ACTIVITY IN AREAS VULNERABLE TO FREQUENT FLOODS.

FLOOD MANAGEMENT

FUTURE STRATEGIES

- Focused Approach
- Basin Wise Action Plan
- Flood Plain Zoning
- Role of Central Government
- Funding of Planned Flood Management Works
- Adequacy of Flood Cushion in Reservoirs

Before the Disaster	During the Disaster	After the Disaster
• Learn warning signs and community alert system	During a flood watch	• Don't return home until authorities express itis safe to do so
• Stockpile emergency building materials • Install check valves in sewer traps to prevent flood waters from backing up in sewer drains • Plan and practice an evacuation route • Have disaster supplies on hand • Develop an emergency communication plan in case of separation • Ask an out-of-state relative to serve as the "family contact" • Teach family members how and when to turn off the gas, electricity, and water and teach children how and when to call 9-1-1 • Ask your insurance agent about flood insurance	If indoors: • Turn on battery operated radio to get latest emergency information • Get pre-assembled emergency supplies • If told to leave, do so immediately. If outdoors: • Climb to high ground and stay there • Avoid walking through any floodwaters. • If in a car, turn around and go another way; if your car stalls, abandon it immediately and climb to higher ground. During an evacuation: • If advised to evacuate, do so immediately to avoid flooded roads, being sure to follow recommended evacuation routes and listen to radio for evacuation instructions	• Help neighbors whom may need assistance • Use extreme caution when entering buildings • Inspect foundations for cracks or other damage and examine walls, floors, doors, and windows to make sure that the building is not in danger of collapsing • Watch out for animals, especially poisonous snakes, that may have come into your home with flood waters • Watch for loose plaster and ceilings that could fall • Take pictures of damage for insurance claims • Look for fire hazards • Throw away all food (including canned) that has come in contact with flood waters • Pump out flooded basements gradually (~ 1/3 amount of water per day) to avoid structural damage

TSUNAMI

TSUNAMI

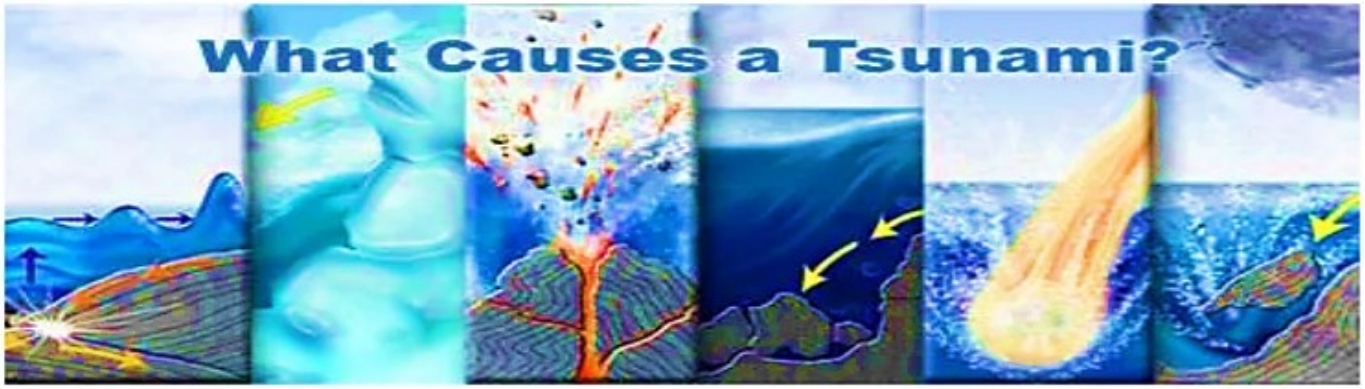
- Tsunami is a Japanese word Tsu means ‘harbour’ and nami means ‘wave’.
- They are called tidal waves but they have actually nothing to do with the tides. However their appearance from shore is similar to rapidly rising or falling tides.
- Tsunami is a series of wave created when water is moved very quickly.
- Tsunami is gravity wave system, triggered by vertical disturbances in ocean. They are long waves sometime with hundreds of miles b/w their crests, just like the concentric waves generated by an object dropped into a pool.

GENERAL CHARACTERISTICS

- Tsunami differs from ordinary ocean waves, which are produced by wind blowing over water.
- The tsunamis travel much faster than ordinary waves.
- Compared to normal wave speed of 100 kilometers per hour, tsunami in the deep water of the ocean may travel the speed of a jet airplane - 800 kilometers per hour! And yet, in spite of their speed, tsunami increases the water height only 30-45cm and often passes unnoticed by ships at sea.
- Contrary to the popular belief, the tsunami is not a single giant wave.
- It is possible for a tsunami to consist of ten or more waves which is then termed as 'tsunami wave train'.
- The waves follow each other 5 to 90 minutes apart.
- Tsunami normally causes flooding as a huge wall of water enters the main land.

CAUSES OF TSUNAMI

1. Earthquake
2. Icefall
3. Volcanic eruptions
4. Heavy rainfall
5. Cosmic impacts
6. Landslide



PREDICTABILITY OF TSUNAMIS

There are two distinct types of tsunami warning:

- International tsunami warning systems and
- Regional warning systems
- Tsunamis have occurred in all the oceans and in the Mediterranean Sea, but the great majority of them have occurred in the Pacific Ocean.
- Since scientists cannot exactly predict earthquakes, they also cannot exactly predict when a tsunami will be generated.

International Tsunami Warning Systems:

- Shortly after the Hilo Tsunami (1946), the Pacific Tsunami Warning System (PTWS) was developed with its operational center at the Pacific Tsunami Warning Center (PTWC) near Honolulu, Hawaii.
- The PTWC is able to alert countries several hours before the tsunami strikes.
- The warning includes predicted arrival time at selected coastal communities where the tsunami could travel in few hours.
- A tsunami watch is issued with subsequent arrival time to other geographic areas.

Regional Warning Systems usually use seismic data about nearby earthquakes to determine if there is a possible local threat of a tsunami.

- Such systems are capable enough to provide warnings to the general public in less than 15 minutes.
- In India, the ***Survey of India*** maintains a tide gauge network along the coast of India. The gauges are located in major ports.

- In 1995 the US National Oceanic and Atmospheric Administration (NOAA) began developing the Deep Ocean Assessment and Reporting of Tsunami (DART) system.
- By 2001 six stations had been deployed in the Pacific Ocean.
- Each station consists of a sea bed bottom pressure recorder (at a depth of about 6000 m) which detects the passage of a tsunami and transmits the data to a surface buoy. The surface buoy then radios the information to the PTWC.(Pacific Tsunami Warning Center)
- Apart from the tide gauge, tsunami can be detected with the help of radars.
- The 2004 Indian Ocean tsunami, recorded data from four radars and recorded the height of tsunami waves two hours after the earthquake.
- It should be noted that the satellites observations of the Indian Ocean tsunami would not have been of any use in delivering warnings, as the data took five hours to process and it was pure chance that the satellites were overhead at that time. However, in future it is possible that the space-based observation might play a direct role in tsunami warning.

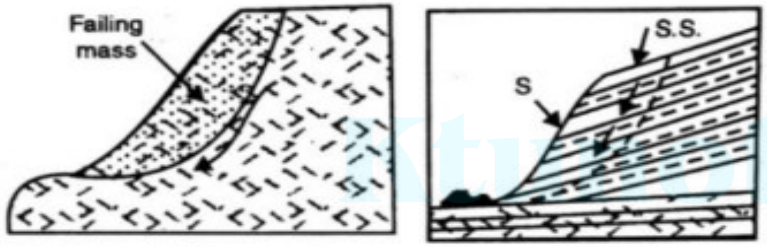
EFFECTS OF TSUNAMIS

- Local tsunami events or those less than 30 minutes from the source cause the majority of damage.
- The force of the water can raze everything in its path.
- It is normally the flooding affect of the tsunami that causes major destruction to the human settlements, roads and infrastructure thereby disrupting the normal functioning of the society.
- Withdrawal of the tsunami causes major damage. As the waves withdraw towards the ocean they sweep out the foundations of the buildings, the beaches get destroyed and the houses carried out to sea.

LANDSLIDES

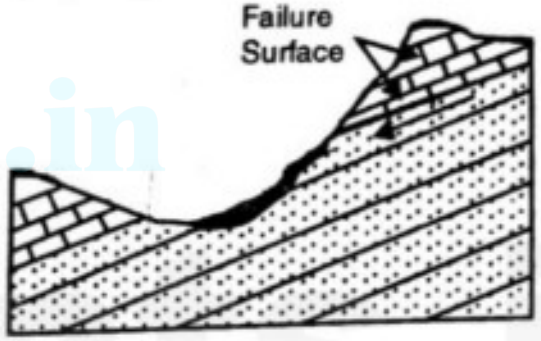
- Movement of superficial mass of soil and rock.
- A temporary instability can cause mass of soil and rock leave their original position **abruptly** or **extremely slow** and lead to downgrade movement.
- This movement of ground may entrail to loss of property and life, especially when they happen to occur in or near populated areas, along highways, railway lines, dams, tunnels etc.
- Such movement of the superficial masses is called landslide or landslip.

- True landslide is a type of mass failure in which a superficial mass fails by moving as a whole along a definite surface of failure.
- The surface of failure may be planar or semicircular in outline.
- It is often characteristic of a landslide that the mass above the failure surface is unstable whereas the material lying below this surface is generally stable.
- In unconsolidated deposits, loose inherently weak rock masses, sliding commonly takes place along curved shear surfaces.



(A & B) Sliding in a Mass Along a Circular Failure Surface; S = Slope, SS = Sliding surface.

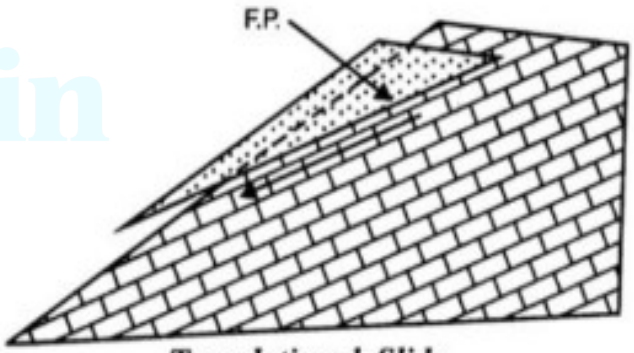
- But when the mass involved is hard, brittle and coherent, such as massive rocks, shear surfaces are broadly planar in nature. In such cases, a set of joint planes or bedding planes or fault planes may be the most convenient natural planes of failure.



Slide Along a Planar Surface (A Bedding Plane

TYPES OF LANDSLIDES

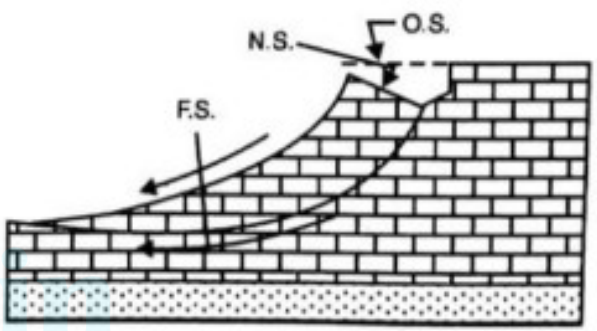
- **Transitional slides**:
  - The **surface of failure is generally planar in character, speed of failure is quite rapid**
  - The nature of mass involved in failing may be rock blocks, rock slabs, debris and soil cover or even a mixture of all of them.
  - These slides are quite frequent in slopes made up of rocks and cohesive soil.



Translational Slide
F.P. = Plane of failure

- **Rotational slides**:

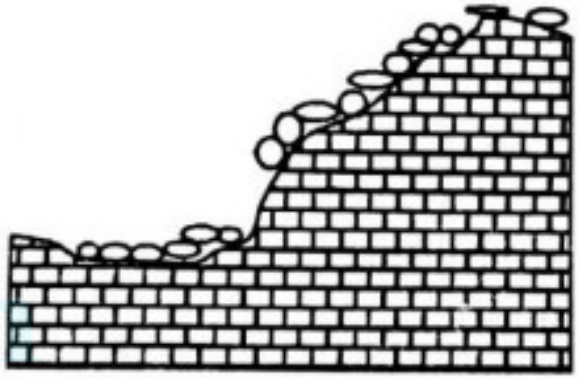
  - In such slides, the **failing surface is generally curved in character and the speed of failure is also quite rapid**
  - Because of the nature of the failing surface, the movement of the mass takes the form of a sort of **rotation, rather than translation**.
  - The material involved in failure tilts downwards at the rear end and heaves up at the front or toe.



Rotational Slide
Note tilting back at the top of sliding block
O.S. = Original Surface N.S. = New Surface
F.S. = Failure Surface.

- **Rock toppling and falls**:

  - These are grouped along with slides although there may be little or no sliding involved in their failure (since they are commonly associated or accompanied with landslides)
  - They are essentially a slope-failure phenomenon.
  - In the falls, there is almost a free, sudden and fast decent from a steep slope.
  - These conditions are favored for this type of failure is weathering of rocks on the slopes due to climatic changes e.g. frost action, expansion and contraction, leaching of natural binders etc.

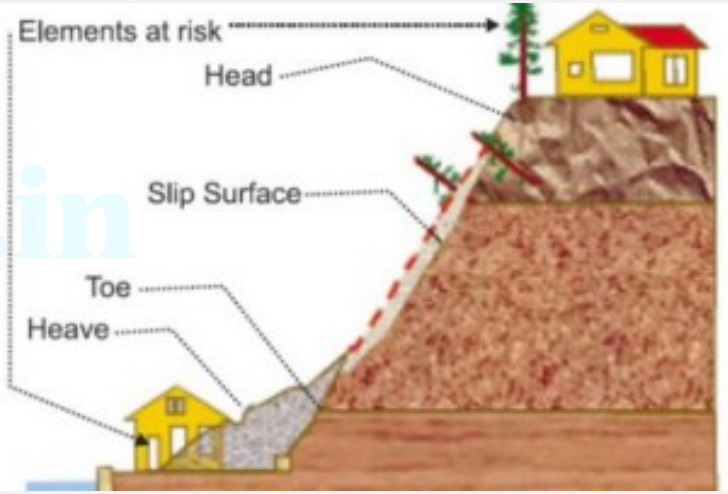


CAUSES OF LANDSLIDES

- Internal factors:
- Nature of slope
- Role of water
- Composition of mass
- Geological structures
- External factors:
- Vibrations due to artificial causes - Heavy blasting and heavy traffic on hill roads
- Vibrations due to natural causes – Earthquakes
- Removal of the support at the foot of the slope, during excavation for road widening.
- Removal of trees

EFFECTS OF LANDSLIDES

The most common elements at risk are the settlements built on the steep slopes, built at the toe and those built at the mouth of the streams emerging from the mountain valley. All those buildings constructed without appropriate foundation for a given soil and in sloppy areas are also at risk. Roads, communication lines are vulnerable.



CONTROL MEASURES OF LANDSLIDES

1. **Drainage**
   - Water presence is the one of the factor that leads to the mass movement.
   - Avoid water content either by surface or sub-surface methods.
     - Construct series of ditches
     - Backfill the pits on the soil surface with concrete or asphalt to prevent the water impounding.
     - Cover the slope surface with granular material to remove excess rainfall.
     - Remove the cracks and fissures in the surface by filling with cement, bitumen or clay mixture.
     - Construct interception drains (To reduce pore water pressure)
     - Oiling of slope surfaces
     - Electro- osmosis
     - Heating the slope surface to avoid water content

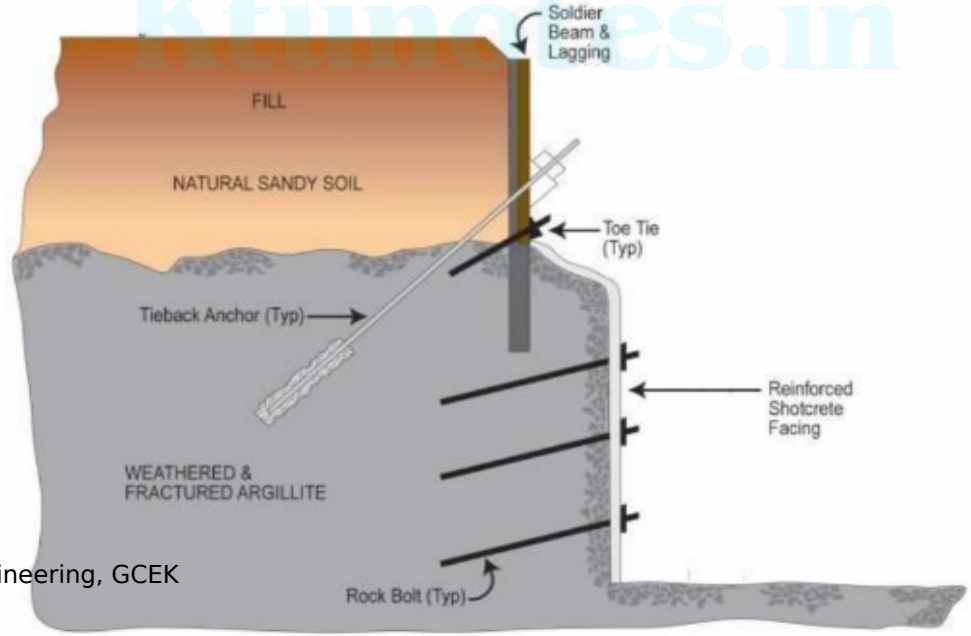
2. Retaining structures

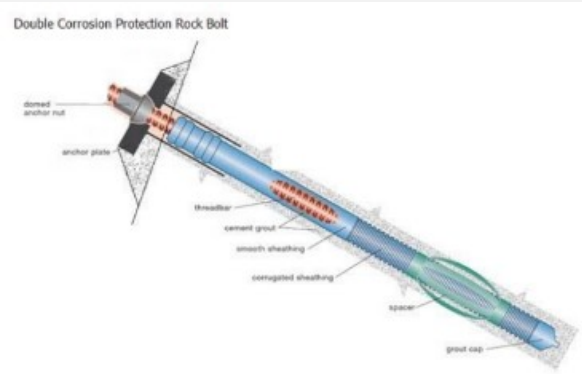
- **Construct Retaining walls and buttresses**
- These are suitable where:
  (a) The ground is neither too fine nor too plastic.
  (b) The sliding mass is likely to remain dry
  (c) The movement is of a shallow nature and limited extent

3. Slope reinforcement by rock bolting

Rock Bolts

- Rock bolts are used to tie up different rock blocks together thereby improving the stability of rock mass.
- A rock bolt is a steel bar of suitable dia (2-25mm) and length (60cm- 5m) one end of which is designed for expanding and other end is threaded to take a nut and washer.
- Such a bolt is inserted into a hole drilled in the rock at a proper angle with the plane of weakness and its end within the rock is made to expand whereby it fits tightly into the rock.
- The other end is tied on a plate with the help of a nut and washer. The rod is generally pre-stressed and is always placed in tension.
- When placed in the above fashion, the rock bolt held up within the two ends of the bolt gets compressed and hence stabilized against falling.





Rock Anchors

- Rock anchors are structural elements made up of cables, bars. Like bolts, it is also placed in previously drilled holes and then whole or part of them is bonded to the rock using a proper technique.
- They may be tensioned after placing in the hole before or after grouting which is an integral part of anchorage system.
- Anchor system may exceed 20-30m in length and once installed they modify the original stress field of the rock to a considerable extent.
- Use corrosion resistant materials for rock anchors

4. Slope treatment

- Treat the top layers of formation
- Apply concrete or mortar on the top surface.
- The mixture of cement and sand (1:3) with little water is applied on the face under pressure and thus the slopes gains sufficient strength on hardening.
- Flatten the slope to ensure stability.
- Decreasing the load on slopes (For example on hill roads, reduce the traffic)
- Provide benches at the foot of the slope
- Promote afforestation (Vegetation cover reduces the infiltration of water)

MODULE 2 & 5

EARTHQUAKES

- It is the sudden shaking of the earth crust.
- The impact of an earthquake is sudden and there is hardly any warning, making it impossible to predict.
- Massive earthquakes generally occur near the junction of two tectonic plates, e.g., along the Himalayan range, where the Indian plate goes below Eurasian plate.
- The Indian sub- continent situated on the boundaries of two continental plates is very prone to earthquakes.
- Earthquakes not only destroy the entire habitation but may de-stabilize the government, economy and social structure of the country.

Seismic Zone Map of India: -2002

About 59 percent of the land area of India is liable to seismic hazard damage

Zone	Intensity
Zone V	Very High Risk Zone Area liable to shaking Intensity IX (and above)
Zone IV	High Risk Zone Intensity VIII
Zone III	Moderate Risk Zone Intensity VII
Zone II	Low Risk Zone VI (and lower)

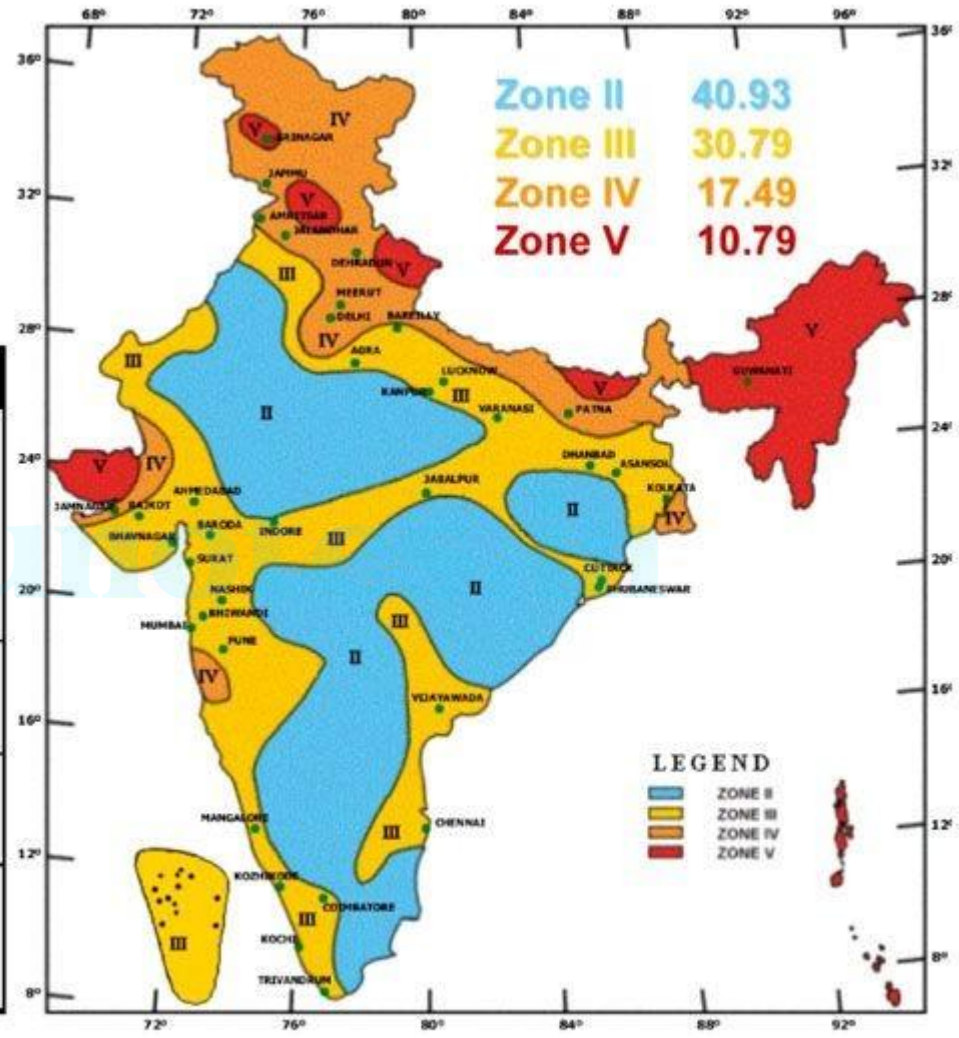
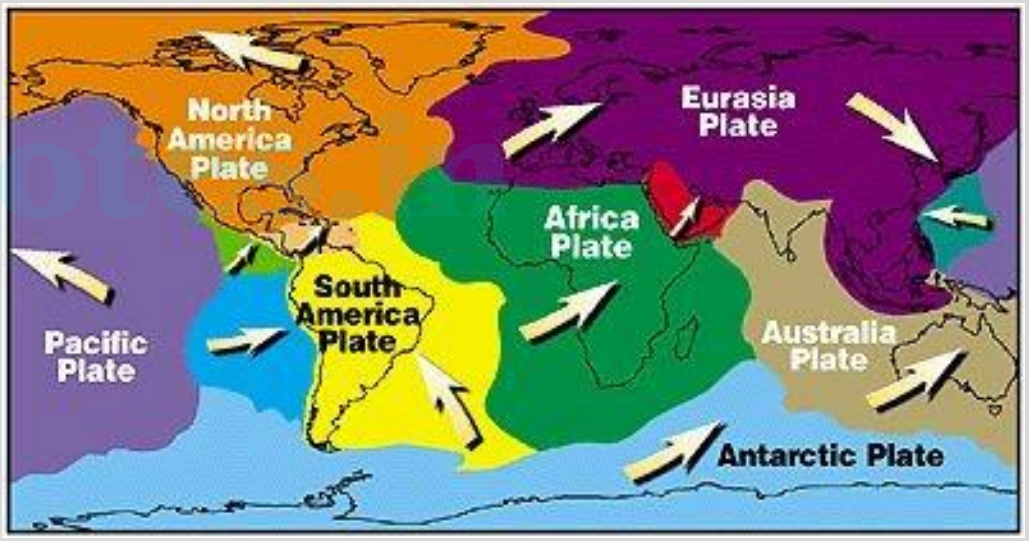


Fig. 1 Seismic zonation and intensity map of India

PLATE TECTONICS

- German scientist Alfred Wegener, in 1915 proposed that, 200 million years ago the earth had only one continent called Pangaea.
- Pangaea broke into pieces that slowly drifted into the present configuration of continents.
- The convective flows of Mantle material cause the Crust and some portion of the Mantle, to slide on the hot molten outer core.
- This sliding of Earth's mass takes place in pieces called Tectonic Plates.
- The surface of the Earth consists of seven major tectonic plates and many smaller ones

- (a)Eurasian Plate
- (b)Indo – Australian plate
- (c) Pacific plate
- (d)North – American Plate
- (e) South – American Plate
- (f) African Plate
- (g) Antarctic Plate



- These plates move in different directions and at different speeds from those of the neighboring ones.
- (a) **Convergent Boundaries**: Sometimes, the plate in the front is slower; then, the plate behind it comes and collides (and mountains are formed).
- (b) **Divergent Boundaries**: sometimes two plates move away from one another (and rifts are created).
- (c) **Transform Boundaries**: Two plates move side- by-side, along the same direction or in opposite directions.
- The convergent boundary has a peculiarity (like at the Himalayas) that sometimes neither of the colliding plates wants to sink.

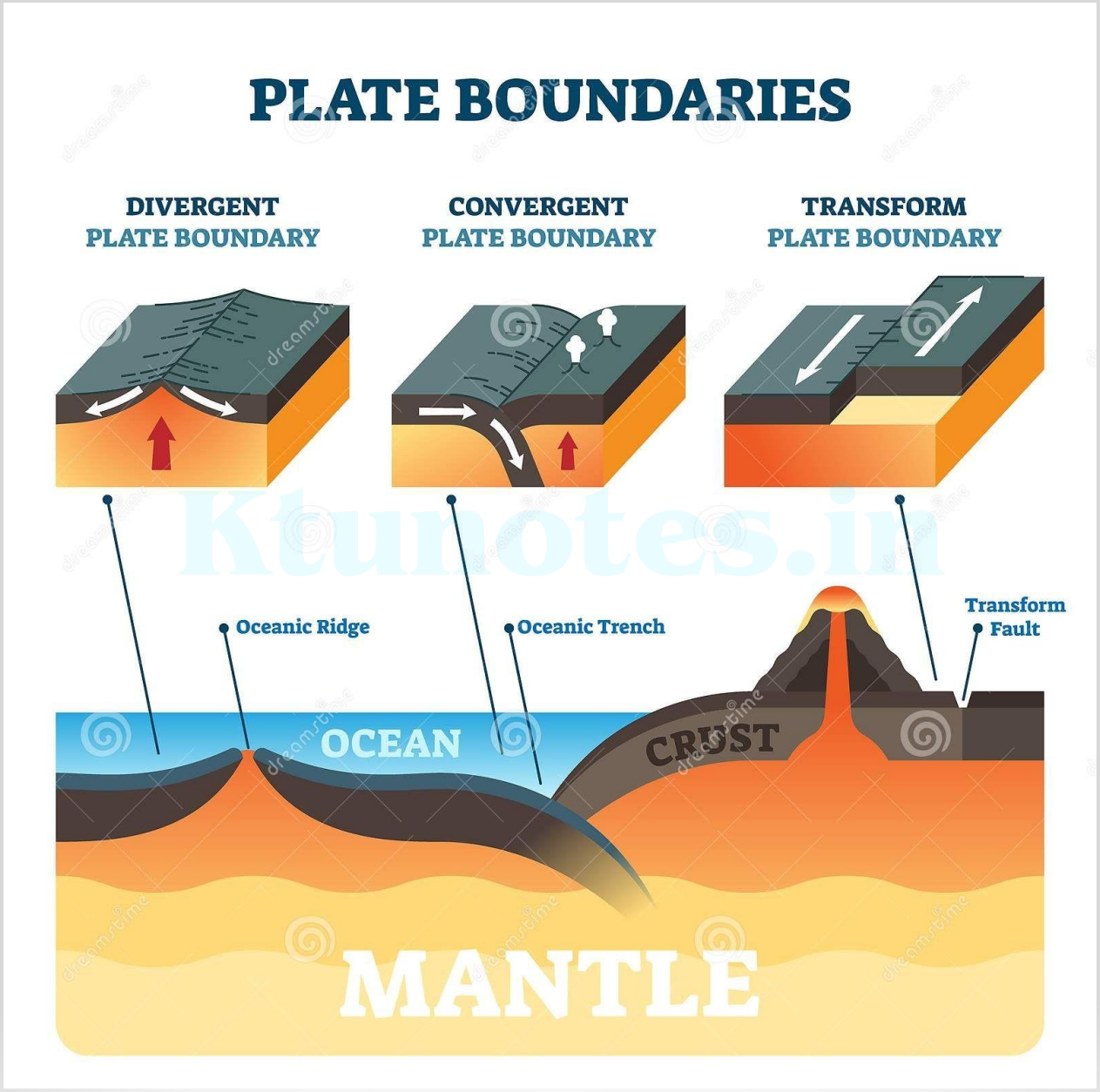


PLATE BOUNDARIES
DIVERGENT
PLATE BOUNDARY
CONVERGENT
PLATE BOUNDARY
TRANSFORM
PLATE BOUNDARY
Oceanic Ridge
Oceanic Trench
Transform
Fault
OCEAN
CRUST
MANTLE

- https://www.earthquakeauthority.com/Blog/2020/Understanding-Plate-Tectonic-Theory
- https://www.youtube.com/watch?v=3ZpDjdFzQUM

ELASTIC REBOUND THEORY

- Tectonic plates are made of elastic but brittle rocky material.
- Hence, elastic strain energy is stored in them during the relative deformations that occur due to the gigantic tectonic plate actions taking place in the Earth.
- When the rocky material along the interface of the plates in the Earth's Crust reaches its strength, it fractures and a sudden movement takes place there
- The interface between the plates where the movement has taken place (called the fault) suddenly slips and releases the large elastic strain energy stored in the rocks at the interface.

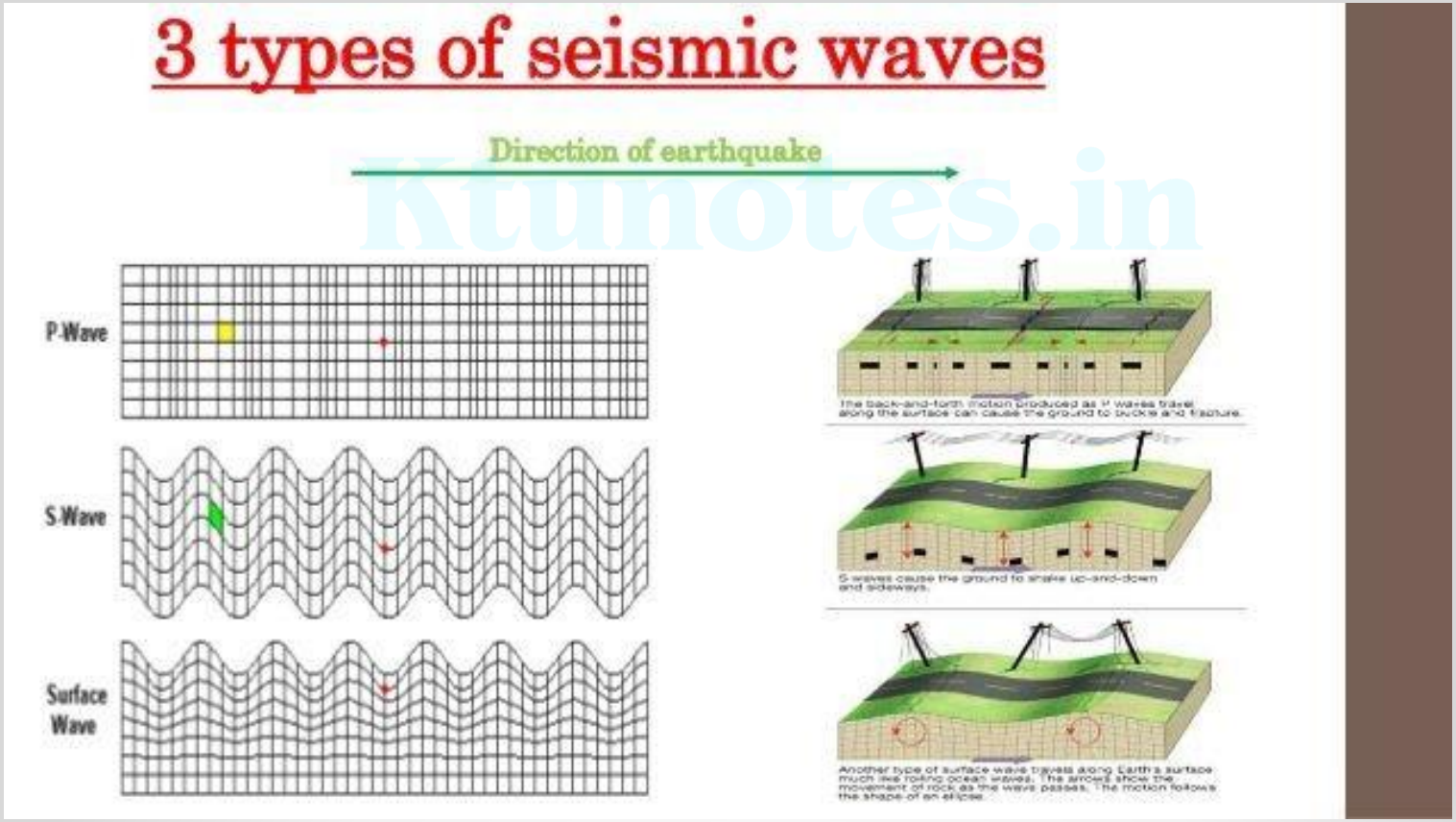
- The sudden slip at the fault causes the earthquake - a violent shaking of the Earth during which large elastic strain energy released spreads out in the form of seismic waves that travel through the body and along the surface of the Earth.
- After the earthquake is over, the process of strain build-up at this modified interface between the tectonic plates starts all over again.
- Earth scientists know this as the Elastic Rebound Theory.
- https://www.youtube.com/watch?v=nFv2eaZiR40

SEISMIC WAVES

- Large strain energy released during an earthquake travels as seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface.
- These waves are of two types - body waves and surface waves
- The surface waves are restricted to near the Earth's surface Body waves consist of Primary Waves (P-waves) and Secondary Waves (S-waves), and surface waves consist of Love waves (L-waves).
- (a) The P-waves
  - These are also called primary waves, push and pull waves.
  - These are the fastest waves in which the particles vibrate in the direction of propagation.
  - The velocity of P - wave is related to the rigidity of the medium and its density

- (b) The S- waves
  - These are also called secondary waves.
  - In these waves particles vibrate right angles to the direction of propagation of the wave.
- (c) The L-waves
  - These waves also called Long waves or surface waves.
  - These waves are sluggish and recorded only after the arrival of the P and S waves.
- S-waves do not travel through liquids.
- S-waves in association with effects of Love waves cause maximum damage to structures

- https://www.youtube.com/watch?v=uA_OLKfQpYA

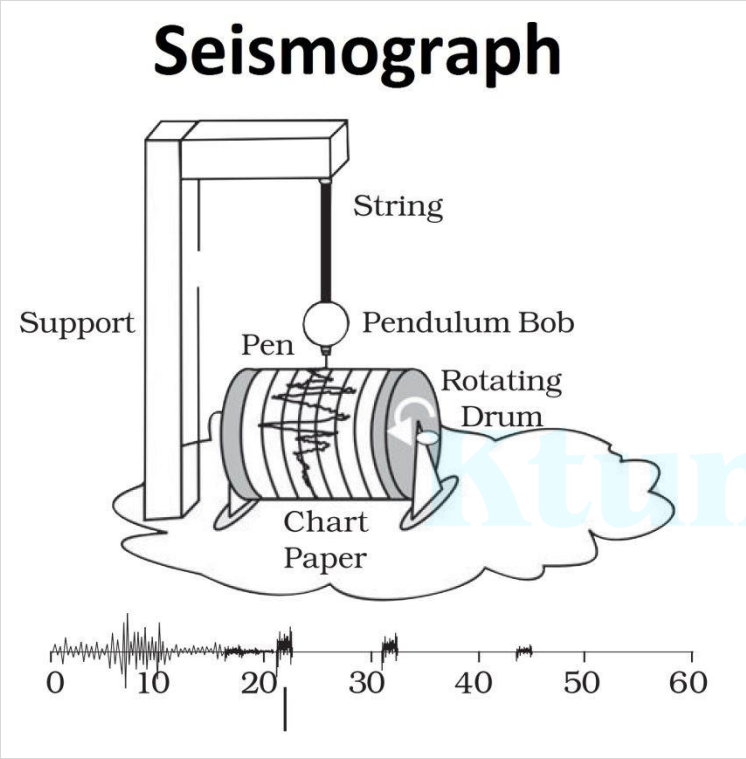


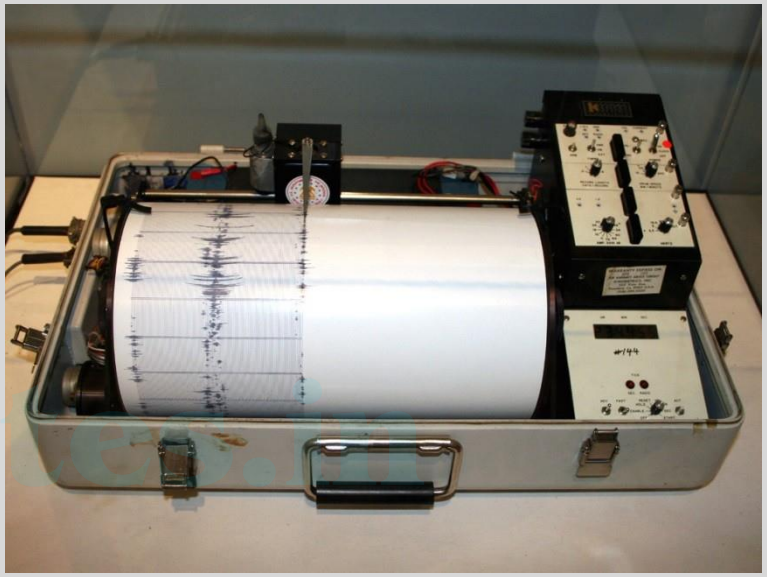
RECORDING OF EARTHQUAKES

- The instrument used to record the motion of seismic waves is called seismograph
- The record produced by the instrument is called Seismogram
- A seismograph is designed for recording either the horizontal or the vertical component of ground motion
- A seismograph, has three components – the sensor, the recorder and the timer.
- (a) The Sensor: The pendulum mass, string, magnet and support
- (b) The Recorder: The drum, pen and chart paper constitute the recorder; and
- (c) The Timer: the motor that rotates the drum at constant speed forms the timer.
- Pendulum type seismographs are generally used.

Principle of Seismograph

- A pen attached at the tip of an oscillating simple pendulum (a mass hung by a string from a support) marks on a chart paper that is held on a drum rotating at a constant speed.
- A magnet around the string provides required damping to control the amplitude of oscillations.
- One such instrument is required in each of the two orthogonal horizontal directions.
- For measuring vertical oscillations, the string pendulum is replaced with a spring pendulum oscillating about a fulcrum.



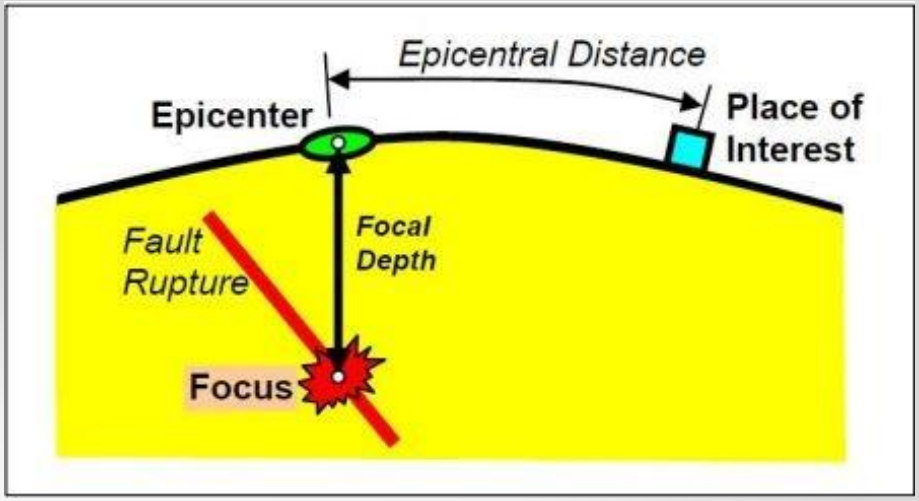


–Today, digital instruments using modern computer technology are more commonly used.

–The digital instrument records the ground motion on the memory of the microprocessor that is in- built in the instrument.

TERMINOLOGY

- The point on the fault where slip starts is the Focus or Hypocenter, and the point vertically above this on the surface of the Earth is the Epicenter.
- The depth of focus from the epicenter, called as Focal Depth.
- Most of the damaging earthquakes have shallow focus with focal depths less than about 70km.
- Distance from epicenter to any point of interest is called epicentral distance.



MAGNITUDE OF EARTHQUAKE

- Magnitude is a quantitative measure of the actual Size of the earthquake.
- Magnitude of an earthquake is a measure of its size
- Professor Charles Richter noticed that,
- (a) At the same distance, seismograms of larger earthquakes have bigger wave amplitude than those of smaller earthquakes; and
- (b) For a given earthquake, seismograms at farther distances have smaller wave amplitude than those at close distances.
- These prompted him to propose the now commonly used magnitude scale, the Richter scale.
- It is obtained from the seismograms and accounts for the dependence of waveform amplitude on epicentral distance.
- This scale is also called Local Magnitude scale.

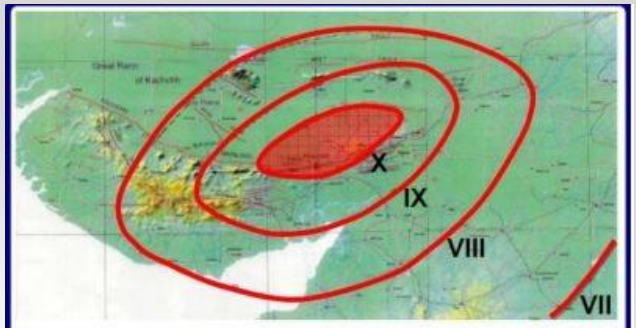
Earthquakes are classified based on magnitude as

Group	Magnitude
Great	8 and higher
Major	7 – 7.9
Strong	6 – 6.6
Moderate	5 – 5.9
Light	4 – 4.9
Minor	3 – 3.9
Very Minor	< 3.0

INTENSITY OF EARTHQUAKE

- Intensity is an indicator of the severity of shaking generated at a given location
- Intensity is a qualitative measure of the actual shaking at a location during an earthquake, and is assigned as Roman Capital Numerals.
- There are many intensity scales.
- Two commonly used ones are the Modified Mercalli Intensity (MMI) Scale and the Medvedev–Sponheuer–Karnik (MSK) Scale.
- Both scales are quite similar and range from I (least perceptive) to XII (most severe).

- The intensity scales are based on three features of shaking,
- (a) Perception by people and animals,
- (b) performance of buildings, and
- (c) Changes to natural surroundings.
- The distribution of intensity at different places during an earthquake is shown graphically using isoseismals, lines joining places with equal seismic intensity.



Isoseismal Map of the 2001 Bhuj (India) Earthquake (MSK Intensity)

CLASSIFICATION OF EARTHQUAKES

- (a) Depth of focus as basis:
  - i. Shallow : Depth of focus lies up to 60km below the surface
  - ii. Intermediate : Depth of focus lies between 60-300km below the surface
  - iii. Deep seated : Depth of focus lies between 300-700km below the surface
- (b) Magnitude as basis
- (c) Cause of origin as basis:
  - i. Tectonic earthquakes: Caused due to relative displacements of blocks of the crust of the earth along the rupture planes
  - ii. Non-tectonic earthquake: Caused due to volcanic eruptions, atomic explosions landslides and subsidence.

SEISMIC HAZARDS

- Damage occurs to human settlement, buildings, structures and infrastructure, especially bridges, elevated roads, railways, water towers, pipelines, electrical generating facilities.
- The hazards associated with earthquakes are
- Ground Shaking
- Structural Hazards
- Liquefaction
- Landslides
- Lifeline Hazards
- Tsunami

- https://www.youtube.com/watch?v=_r_nFT2m-Vg

POSSIBLE RISK REDUCTION MEASURES:

- **Community preparedness**: Community preparedness is vital for mitigating earthquake impact. The most effective way to save you even in a slightest shaking is 'DROP, COVER and HOLD'.

- **Planning:** The Bureau of Indian Standards has published building codes and guidelines for safe construction of buildings against earthquakes. Before the buildings are constructed the building plans have to be checked by the Municipality, according to the laid down bylaws.

POSSIBLE RISK REDUCTION MEASURES:

- **Public education** is educating the public on causes and characteristics of an earthquake and preparedness measures. It can be created through sensitization and training programme for community, architects, engineers, builders, masons, teachers, government functionaries teachers and students.
- **Engineered structures**: Buildings need to be designed and constructed as per the building by laws to withstand ground shaking. Architectural and engineering inputs need to be put together to improve building design and construction practices.

QUAKE RESISTANT BUILDINGS

- **The foundations**
- Structure on Loose sediments weak rocks is subjected to greater risk as compared to structures on hard rocks
- Soil particles undergo settlement during earthquake
- Foundations should be excavated to the same level
- The superstructure should be thoroughly tied with the foundations by introducing reinforcements to prevent sliding

QUAKE RESISTANT BUILDINGS

- **The body**
- Walls should be properly designed for resisting lateral forces
- Walls should be light in weight and made up of wood or light weight as possible
- Use reinforcements in the wall
- **The roof**
- Flat roofs gives better resistance as compared to sloping roofs
- Care should be taken to minimize the lateral stresses when tiles and corrugated sheets are used in flat roofs
- Projections beyond roof like chimneys should be avoided

- https://www.youtube.com/watch?v=c4fKBGsllZI

EARTHQUAKE HAZARD MITIGATION

- Establishing earthquake monitoring centres (seismological centres) for regular monitoring and fast dissemination of information among the people in the vulnerable areas. Use of Geographical Positioning System (GPS) can be of great help in monitoring the movement of tectonic plates.
- Preparing a vulnerability map of the country and dissemination of vulnerability risk information among the people and educating them about the ways and means minimizing the adverse impacts of disasters.
- Modifying the house types and building designs in the vulnerable areas and discouraging construction of high-rise buildings, large industrial establishments and big urban centres in such areas.
- Finally, making it mandatory to adopt earthquake-resistant designs and use light materials in major construction activities in the vulnerable areas.

- https://www.youtube.com/watch?v=oFtmILpR7LE

MASS MOVEMENT

- Movement of the ground may entail loss to property and life, especially when they happen to occur in or near the populated areas, along highways, railway lines, dams and reservoirs, tunnels or under heavy structures.
- Such movements of the superficial masses have been termed in common language as landslides or landslips, technically termed as Mass Movement.

CLASSIFICATION

- On the basis of type of failure, mass movements are divided into 3 types

- 1. Flowage
- 2. Sliding
- 3. Subsidence

Flowage

- By flowage is understood a downgrade movement of mass along no definite surface of failure.
- Mass involved in this type of failure is primarily unconsolidated or loosely packed or rendered so by natural processes of decay and disintegration.
- The result is that the movement is distributed throughout the mass and in a highly irregular manner.
- Flowage is further distinguished into slow and rapid flowage.
- In the slow flowage, failure is not easily perceptible. The ground may be moving downslope at as such low rates as few centimeters a year or even less.
- In rapid flowage, however, the movement of failing mass may be easily visible and the mass may travel a few meters or more a day.

Sliding

- True landslide is a type of mass failure in which a superficial mass fails by moving as a whole along a definite surface of failure.
- The surface of failure may be planar or semicircular in outline.
- It is often characteristic of a landslide that the mass above the failure surface is unstable whereas the material lying below this surface is generally stable.
- In unconsolidated deposits, loose inherently weak rock masses, sliding commonly takes place along curved shear surfaces.
- But when the mass involved is hard, brittle and coherent, such as massive rocks, shear surfaces are broadly planar in nature.
- In such cases, a set of joint planes or bedding planes or fault planes may be the most convenient natural planes of failure.

Translational slides

- The surface of failure is generally planar in character, speed of failure is quite rapid
- The nature of mass involved in failing may be rock blocks, rock slabs, debris and soil cover or even a mixture of all of them.
- These slides are quite frequent in slopes made up of rocks and cohesive soil.

Rotational slides

- In such slides, the failing surface is generally curved in character and the speed of failure is also quite rapid
- Because of the nature of the failing surface, the movement of the mass takes the form of a sort of rotation, rather than translation.
- The material involved in failure tilts downwards at the rear end and heaves up at the front or toe.

Rock toppling and falls

- These are grouped along with slides although there may be little or no sliding involved in their failure (since they are commonly associated or accompanied with landslides)
- They are essentially a slope-failure phenomenon.
- In the falls, there is almost a free, sudden and fast decent from a steep slope.
- These conditions are favored for this type of failure is weathering of rocks on the slopes due to climatic changes e.g. frost action, expansion and contraction, leaching of natural binders etc..

- https://www.youtube.com/watch?v=x4SraQEdywE

Subsidence

- It is defined as sinking or settling of the ground in almost vertically downward direction which may occur because of removal of natural support from the underground or due to compaction of the weaker rocks under the load from overlying mass.
- https://www.youtube.com/watch?v=eqCfIVJfGlk

- **Landslide Hazard** refers to the potential of occurrence of a damaging landslide within a given area; such damage could include loss of life or injury, property damage, social and economic disruption, or environmental degradation.
- **Landslide Vulnerability** reflects the extent of potential loss to given elements (or set of elements) within the area affected by the hazard, expressed on a scale of 0 (no loss) to 1 (total loss); vulnerability is shaped by physical, social, economic and environmental conditions.
- **Landslide Risk** refers to the probability of harmful consequences-the expected number of lives lost, persons injured, extent of damage to property or ecological systems, or disruption of economic activity –within a landslide prone area. The risk may be individual or societal in scope, resulting from an interaction between the hazard and individual or societal vulnerability.
- **Landslide Risk Evaluation** is the application of analyses and judgments (encompassing physical, social, and economic dimensions of landslide vulnerability) to determine risk management alternatives, which may include determination that the landslide risk is acceptable or tolerable.

- https://study.com/academy/lesson/mass-wasting-definition-types-causes-processes.html

CAUSES OF MASS MOVEMENT

- There are many factors involved in causing mass movement. Some of them have direct role and some are indirectly responsible for the instability of land mass.
- All such factors can be grouped into two, Internal factors & External factors.
- **Internal factors**
  - These include such causes, which tend to reduce the shearing strength of soil or rock mass.
  - Nature of Slope
  - Role of Water
  - Composition of Mass
  - Geological Structures
- **External factors**

- https://www.youtube.com/watch?v=YW8BKbpaXPI

Nature of Slope

- A great majority of mass failures are confined to slopes only, it is reasonable to conclude that nature of a slope may be a deciding factor in defining the stability of a land mass.
- By nature of slope it is meant here, the type of material of which the land mass is made up (soil or rock) and the angle at which this particular mass is inclined with the horizontal (the slope angle).
- Any mass forming a slope is subject to two types of forces:
- First, those forces or strength by virtue of which it can retain the soil mass in stable position (i.e. shear strength of soil) and second, those forces which tend to induce failure into it.

Role of Water

- Both surface and subsurface water have important role in causing mass movement.
- Water may to reduce the shearing strength of a rock or soil mass in a number of ways.
- Water that penetrates the soil and rocks through seepage and moves into the pores of the mass may be the cause of development of an uplift or pore-pressure within the mass under consideration.
- Water accumulates at the back of a mass may exert a pressure
- Repeated change of state with climate changes.
- Water also facilitates mass failure through its lubricating action.

Composition of Mass

- Materials are stable in a given set of conditions of slope and water content
- rock formation is stable as compared to soil formation
- Cohesive soil is stable compared to non- cohesive soil
- Igneous rock is stronger rock

Geological Structures

- Geological structures are of great significance in defining the stability of mass, especially in rocks.
- Relationship of geological structures with the stability of mass has been depends upon
- (a) Bedding planes
- (b) The Metamorphic Structures
- (c) The Jointing Structures

Bedding planes

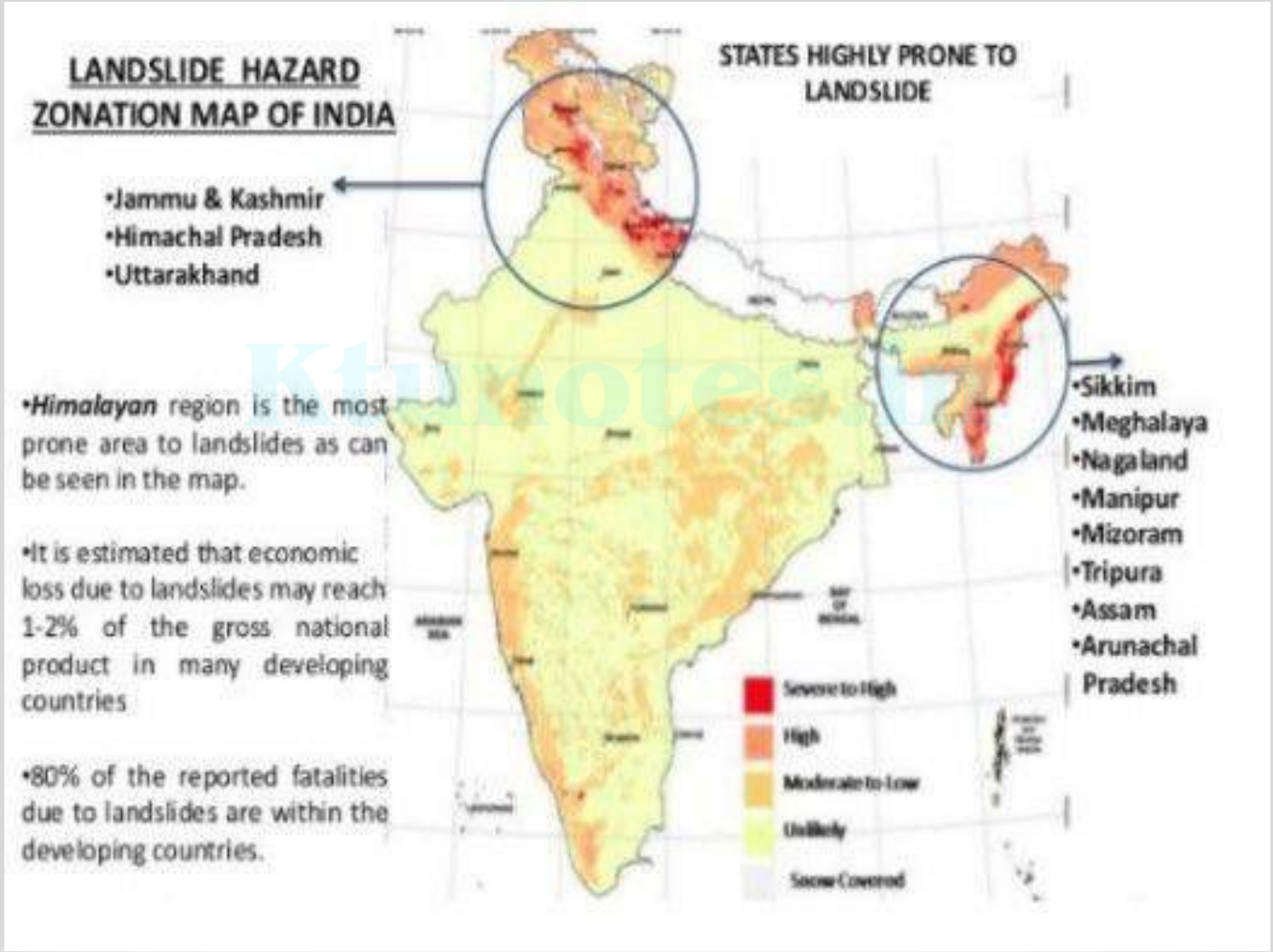
- Many sedimentary rocks are layered or stratified and thickness of layers may range from few centimeters to many meters.
- The bedding plane (the surface between any two adjacent layers) is a plane, with least cohesion in a layered mass.
- These layers may be horizontal, inclined at various angles with the horizontal (dipping) or even vertical.
- The dip or inclination of the stratified rocks exerts very important influence on the stability of slopes.
- **CASE I**: The layers are horizontal (Dip = 0°). Such rocks forming the slopes of the natural valleys and artificial cuts are stable at all the angles up to 90°. When they fail, it may be due to presence of secondary jointing or related fractures.
- **CASE II:** The layers are Inclined. In such a situation, assuming that the rock is free from any other types of discontinuities (joints, shear and fault zones), the stability of a slope (natural the artificial) will depend primarily on the condition whether the layers are dipping backwards into the mountain or forward into the valley or the cut.

- **The Metamorphic Structures**
- Schistosity, foliation and cleavage structures as found in metamorphic rocks like schists, gneisses and slates respectively and thus all behave as surfaces of weakness and promote the failure.
- **The Jointing Structures**
- Joints reduce the shear strength of soil and rock formations

External factors

- An analysis of many slope failure makes it clear that in some cases an external factor might have triggered the slide
- External factors include vibrations from artificial and natural phenomenon.
- Vibrations due to artificial causes - Heavy blasting and heavy traffic on hill roads
- Vibrations due to natural causes – Earthquakes
- Another important external factor is the removal of the support at the foot of the slope, during excavation for road widening.
- Removal of trees is another is another external cause for mass movement

Distributional Pattern:



MONITORING OF MASS MOVEMENTS

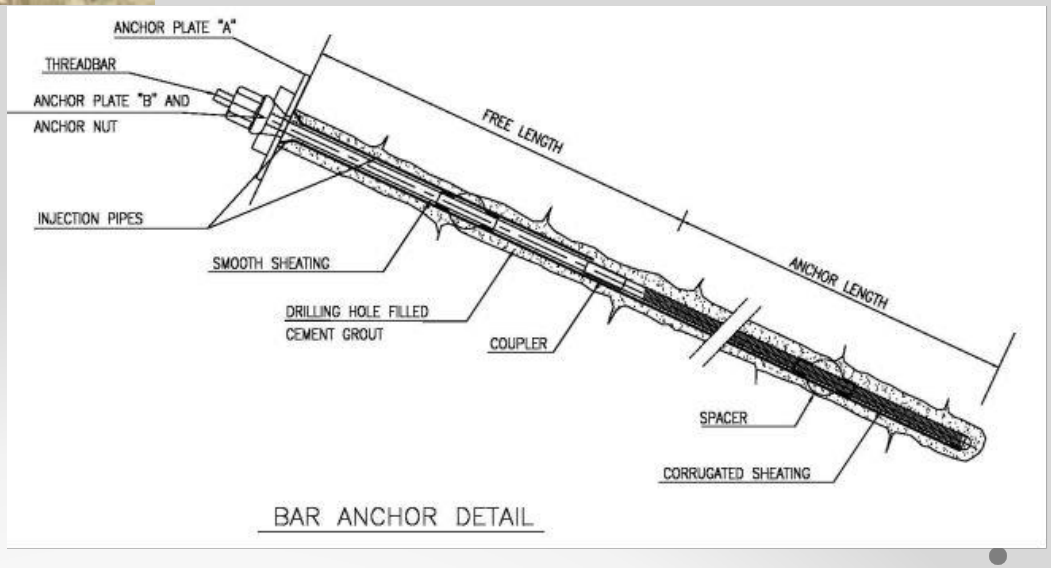
- Detection of possibility of failure before its occurrence by noting the present conditions is called Monitoring.
- Monitoring of slopes may be achieved by using conventional surveying techniques.
- Land or mass movement can be ascertained using electronic equipment, laser equipment, settlement gauges and extensometers.
- Pore water pressure can be measured using the Piezometers and thus possibility of failure by pore water pressure can be understood.

Rock Bolts

- Rock bolts are used to tie up different rock blocks together thereby improving the stability of rock mass.
- A rock bolt is a steel bar of suitable dia (2-25mm) and length (60cm- 5m) one end of which is designed for expanding and other end is threaded to take a nut and washer.
- Such a bolt is inserted into a hole drilled in the rock at a proper angle with the plane of weakness and its end within the rock is made to expand whereby it fits tightly into the rock.
- The other end is tied on a plate with the help of a nut and washer. The rod is generally pre- stressed and is always placed in tension.
- When placed in the above fashion, the rock bolt held up within the two ends of the bolt gets compressed and hence stabilized against falling.

Rock Anchors

- Rock anchors are structural elements made up of cables, bars. Like bolts, it is also placed in previously drilled holes and then whole or part of them is bonded to the rock using a proper technique.
- They may be tensioned after placing in the hole before or after grouting which is an integral part of anchorage system.
- Anchor system may exceed 20-30m in length and once installed they modify the original stress field of the rock to a considerable extent.
- Use corrosion resistant materials for rock anchors
- https://www.youtube.com/watch?v=x9TTi8N8Afg



BAR ANCHOR DETAIL

Slope treatment

- Treat the top layers of formation
- Apply concrete or mortar on the top surface.
- The mixture of cement and sand (1:3) with little water is applied on the face under pressure and thus the slopes gains sufficient strength on hardening.
- Flatten the slope to ensure stability.
- Decreasing the load on slopes (For example on hill roads, reduce the traffic)
- Provide benches at the foot of the slope
- Promote afforestation (Vegetation cover reduces the infiltration of water)

- https://www.youtube.com/watch?v=At0G2HEgVDo
- https://www.youtube.com/watch?v=QnyufKaokak
- https://www.youtube.com/watch?v=44waiItHM1w
- https://www.youtube.com/watch?v=B1FXMlzdJEA&t=7s

CONTROL OF MASS MOVEMENTS

- Drainage
- Retaining structures
- Slope reinforcement by rock bolting
- Slope treatment

Drainage

- Water presence is the one of the factor that leads to the mass movement.
- Avoid water content either by surface or sub-surface methods.
  - Construct series of ditches
  - Backfill the pits on the soil surface with concrete or asphalt to prevent the water impounding.
  - Cover the slope surface with granular material to remove excess rainfall.
  - Remove the cracks and fissures in the surface by filling with cement, bitumen or clay mixture.
  - Construct interception drains (To reduce pore water pressure)
  - Oiling of slope surfaces
  - Electro- osmosis
  - Heating the slope surface to avoid water content

Retaining structures

- Construct Retaining walls and buttresses
- These are suitable where:
- (a) The ground is neither too fine nor too plastic.
- (b) The sliding mass is likely to remain dry
- (c) The movement is of a shallow nature and limited extent

MODULE 2 & 5

Types of Natural Disasters II- Floods, Coastal disasters- Cyclones, Tsunamis. Nature of impacts.

FLOODS

- Flood is a state of high water level along a river channel or on the coast that leads to inundation of land, which is not usually submerged.
- Floods are relatively slow in occurrences and often, occur in well-identified regions and within expected time in a year.
- Floods occur commonly when water in the form of surface run-off exceeds the carrying capacity of the river channels and streams and flows into the neighboring low-lying flood plains.
- Floods can also be caused due to a storm surge (in the coastal areas), high intensity rainfall for a considerably longer time period, melting of ice and snow, reduction in the infiltration rate and presence of eroded material in the water due to higher rate of soil erosion.
- Every stream flows in a particular stage at a particular place during different intervals of time in a year such as a dry stage, half-full stage and bank full stage.
- This depends upon climate and precipitation in the catchment area.
- A flood occurs when the volume of water in the river becomes greater than bank-full stage:

TYPES OF FLOODS

- According to their duration flood can be divided into different categories:
- (a) Slow-Onset Floods: Slow Onset Floods usually last for a relatively longer period, it may last for one or more weeks, or even months.
- (b) Rapid-Onset Floods: Rapid Onset Floods last for a relatively shorter period, they usually last for one or two days only.
- (c) Flash Floods: Flash Floods may occur within minutes or a few hours after heavy rainfall, tropical storm, failure of dams or levees or releases from dams, and it causes the greatest damages to society.

Flash floods

- Flash floods are local floods of great volume and short duration.
- A flash flood generally results from a torrential rain or “cloudburst” on relatively small and widely dispersed streams.
- Runoff from the intense rainfall results in high flood waves.
- Discharges, quickly reach a maximum and diminish almost as rapidly.
- Flood flows frequently contain large concentrations of sediment and debris.
- Flash floods also result from the failure of a dam.
- Flash floods are particularly common in mountainous areas and desert regions but are a potential threat in any area, where the terrain is steep, surface runoff rates are high, streams flow in narrow canyons, and severe thunderstorms prevail.

River floods

- River floods are caused by precipitation over large areas or by melting of the winter's accumulation of snow, or by both.
- These floods differ from flash floods in their extent and duration. Whereas flash floods are of short duration in small streams, riverine floods take place in river systems whose tributaries may drain large geographic areas and encompass many independent river basins
- Floods on large river systems may continue for periods ranging from a few hours to many days.

Coastal floods/Storm surge

- Storm surge or tidal surge is an offshore rise of water associated with a low pressure weather system, typically a tropical cyclone.
- Storm surge is caused primarily by high winds pushing on the ocean's surface.
- The wind causes the water to pile up higher than the ordinary sea level
- Low pressure at the center of a weather system also has a small secondary effect,
- It is this combined effect of low pressure and persistent wind over a shallow water body which is the most common cause of storm surge flooding problems.
- The term "storm surge" in casual (non-scientific) use is storm tide; that is, it refers to the rise of water associated with the storm, plus tide, wave run-up, and freshwater flooding.

CAUSES OF FLOODS

- a. Heavy rainfall
- b. Heavy siltation of the river bed reduces the water carrying capacity of the rivers/stream.
- c. Blockage in the drains lead to flooding of the area.
- d. Landslides blocking the flow of the stream.
- e. Construction of dams and reservoirs
- f. In areas prone to cyclone, strong winds accompanied by heavy down pour along with storm surge leads to flooding.

The geological factors

- a. Topography: The steeply sloping land conveys the run-off after heavy rains directly to the stream within a short time from both the sides thereby reaching the bank full stage.
- b. Lithology (i.e. type of soil or rock): impervious, compacted, solid and massive rocks or soils, greater volumes of run-off reach the streams contributing towards the flood-stage situation.
- c. Vegetation: Vegetation in the form of grasses, bushes or even forests with well- developed root network system act as effective barriers and retarders against run-off.

TYPICAL ADVERSE EFFECTS:

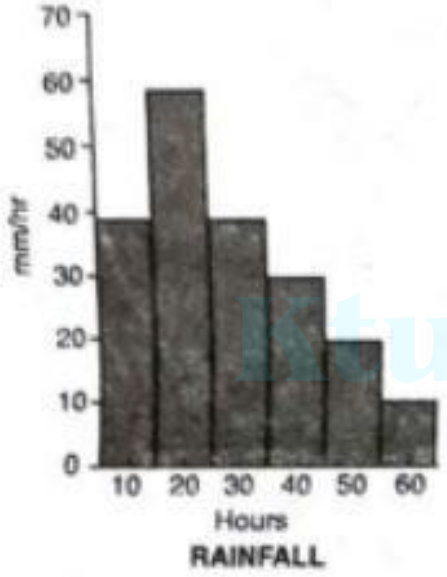
- loss of life and property.
- Structures like houses, bridges; roads etc. get damaged by the gushing water, landslides triggered on account of water getting saturated, boats and fishing nets get damaged.
- There is huge loss to life and livestock caused by drowning.
- Lack of proper drinking water facilities, contamination of water (well, ground water, piped water supply) leads to outbreak of epidemics, diarrhea, viral infection, malaria etc.
- Flooding also leads to a large area of agricultural land getting inundated as a result there is a huge crop loss. This results in shortage of food, and animal fodder.
- Floods may also affect the soil characteristics.
- The land may be rendered infertile due to erosion of top layer or may turn saline if sea water floods the area

MONITORING OF FLOODS

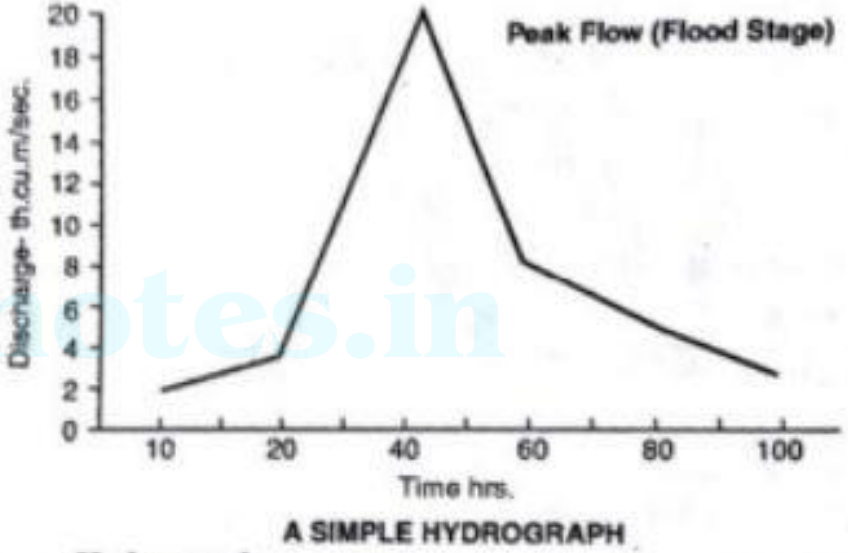
- Anticipating floods before they occur allows for precautions to be taken and people to be warned so that they can be prepared in advance for flooding conditions.
- In order to make the most accurate flood forecasts for waterways, it is best to have a long time-series of historical data that relates stream flows to measure past rainfall events.
- Radar estimates of rainfall and general weather forecasting techniques are also important components of good flood forecasting.

Magnitude and Frequency of flood

- The magnitude of a flood is generally indicated by the discharge of water from a channel at a particular point.
- The discharge of flow is commonly indicated by means of a hydrograph.
- As the name indicates, a hydrograph is a plot between discharge of a stream at a particular place in cubic meters/sec or cubic feet/sec over a period of time (day/week/month/year).
- A flood is often indicated by the Peak in a hydrograph
- If we have hydrographs of a river for longer periods (or years) then it can be used for flood prediction studies
- If we have longer periods of hydrographs, the frequency of flood i.e. its recurrence or periodicity can be predicted.
- If a flood has return period of 10 years it means it occurs once in 10 years.



RAINFALL



A SIMPLE HYDROGRAPH

Hydrograph

POSSIBLE RISK REDUCTION MEASURES:

- **Mapping of the flood prone areas** is a primary step involved in reducing the risk of the region. Historical records give the indication of the flood inundation areas and the period of occurrence and the extent of the coverage. Warning can be issued looking into the earlier marked heights of the water levels in case of potential threat. In the coastal areas the tide levels and the land characteristics will determine the submergence areas. Flood hazard mapping will give the proper indication of water flow during floods.

- **Land use control** will reduce danger of life and property when waters inundate the floodplains and the coastal areas. The number of casualties is related to the population in the area at risk. In areas where people already have built their settlements, measures should be taken to relocate to better sites so as to reduce vulnerability. No major development should be permitted in the areas which are subjected to high flooding. Important facilities like hospitals, schools should be built in safe areas. In urban areas, water holding areas can be created like ponds, lakes or low-lying areas.

- **Construction of engineered structures** in the flood plains and strengthening of structures to withstand flood forces and seepage. The buildings should be constructed on an elevated area. If necessary build on stilts or platform. Flood Control aims to reduce flood damage. This can be done by decreasing the amount of runoff with the help of reforestation (to increase absorption could be a mitigation strategy in certain areas), protection of vegetation, clearing of debris from streams and other water holding areas, conservation of ponds and lakes etc. Flood Diversion include levees, embankments, dams and channel improvement.

Flood Management.

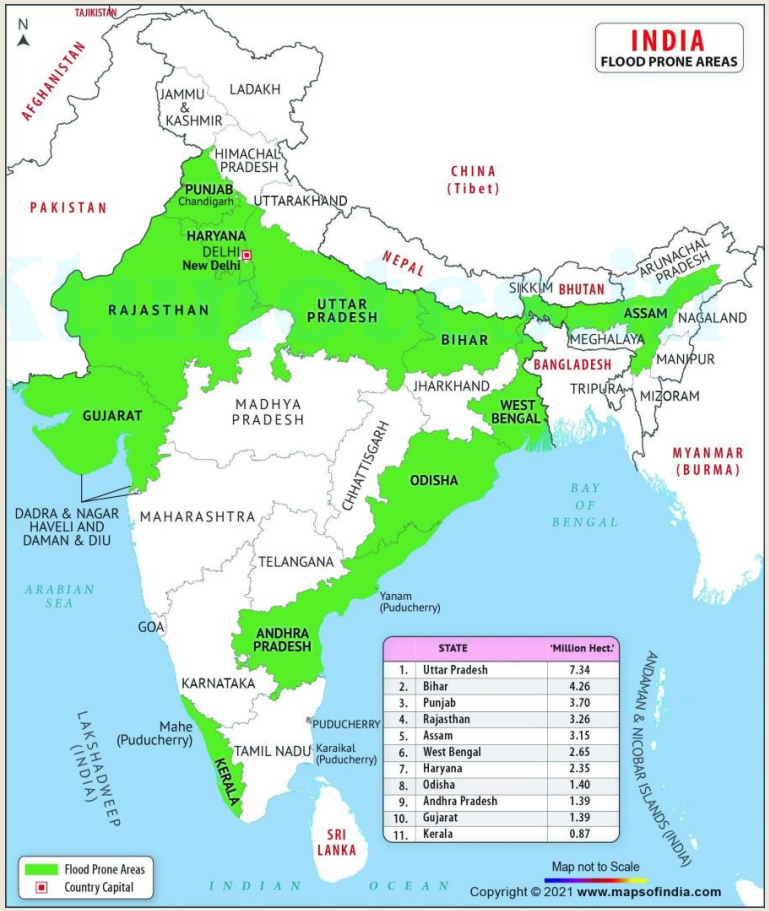
- In India, systematic planning for flood management commenced with the Five Year Plans, particularly with the launching of National Programme of Flood Management in 1954.
- During the last 48 years, different methods of flood protection structural as well as nonstructural have been adopted in different states depending upon the nature of the problem and local conditions.
- Structural measures include storage reservoirs, flood embankments, drainage channels, anti-erosion works, channel improvement works, detention basins etc. and non-structural measures include flood forecasting, flood plain zoning, flood proofing, disaster preparedness etc.
- The flood management measures undertaken so far have provided reasonable degree of protection to an area of 15.81 million hectares throughout the country.

Flood plain zoning

- **Flood hazard zone I** (Active flood plain area): Prohibit development (business and residential) within flood plain Maintain area in a natural state as an open area or for recreational uses only.
- **Flood hazard zone II** (Alluvial fans and plains with channels less than a metre deep, bifurcating, and intricately interconnected systems subject to inundation from overbank flooding):
  - *Flood-proofing to reduce or prevent loss to structures is highly recommended.*
  - *Residential development densities should be relatively low; development in obvious drainage channels should be prohibited.*
  - *Dry stream channels should be maintained in a natural state and/or the density of native vegetation should be increased to facilitate superior water drainage retention and infiltration capabilities.*
  - *Installation of upstream storm water retention basins to reduce peak water discharges.*
  - *Construction should be at the highest local elevation site where possible.*
- **Flood hazard zone III** (Dissected upland and lowland slopes; drainage channels where both erosional and depositional processes are operative along gradients generally less than 5%):
  - *Similar to flood hazard zone II*
  - *Roadways that traverse channels should be reinforced to withstand the erosive power of a channeled stream flow.*


FLOOD PLAIN ZONING
WATER SUPPLY
HOSPITAL
GOVT. OFFICE
PARK
FACTORY
POWER HOUSE
RESIDENTIAL AREA
UNIVERSITY
NORMAL CHANNEL
FREQUENT FLOOD
FLOOD ONCE IN 25 YEARS
FLOOD ONCE IN 100 YEARS

DISTRIBUTIONAL PATTERN OF FLOODS IN INDIA



Warning

- Flood forecasting and warning has been highly developed in the past two decades.
- With the advancement of technology such as satellite and remote-sensing equipment flood waves can be tracked as the water level rises.
- Except for flash floods there is usually a reasonable warning period. Heavy precipitation will give sufficient warning of the coming river flood.
- High tides with high winds may indicate flooding in the coastal areas.
- Evacuation is possible with suitable monitoring and warning.
- Warning is issued by the Central Water Commission (CWC), Irrigation & Flood Control Department, and Water Resources Department.
- CWC maintains close liaison with the administrative and state engineering agencies, local civil authorities to communicate advance warning for appropriate mitigation and preparedness measures.

FLOOD BENEFITS

- 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.
- 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.
- 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.

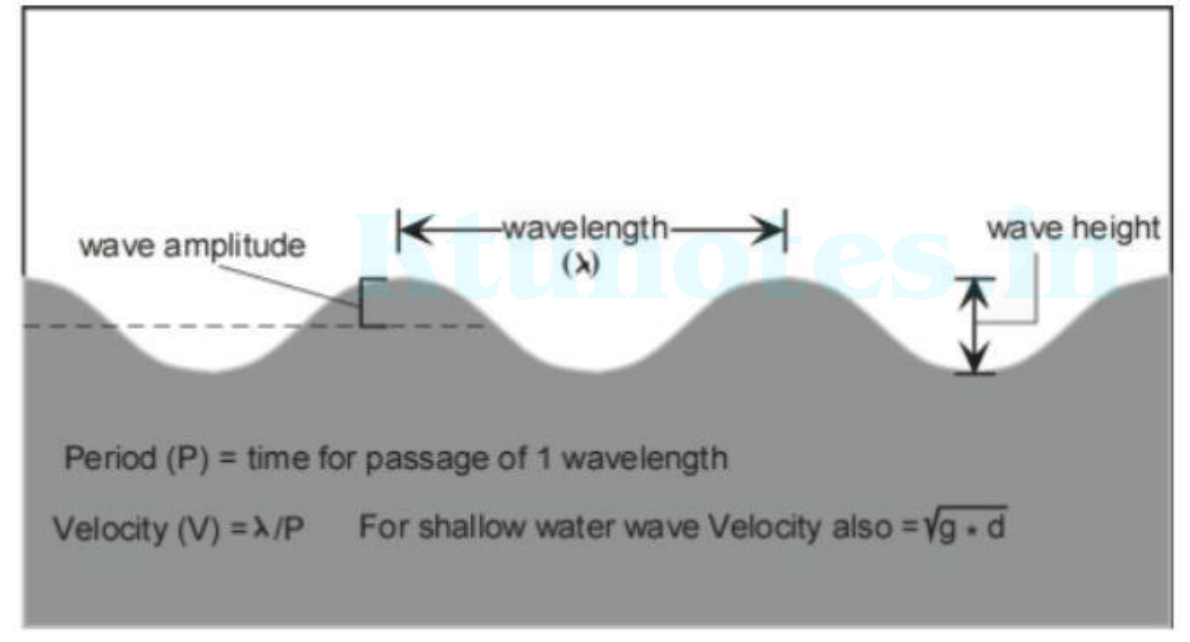
TSUNAMI

- The term Tsunami has been derived from a Japanese term Tsu meaning 'harbor' and nami meaning 'waves'.
- These waves which often affect distant shores, originate by rapid displacement of water from the lake or the sea either by seismic activity, landslides, volcanic eruptions or large meteoroid impacts.
- sea water is displaced with a violent motion and swells up, ultimately surging over land with great destructive power.
- The effects of a tsunami can be unnoticeable or even destructive.

What is a Tsunami?

- A tsunami is a very long-wavelength wave of water that is generated by sudden displacement of the seafloor or disruption of any body of standing water.
- Tsunami are sometimes called "seismic sea waves", although they can be generated by mechanisms other than earthquakes.
- Tsunami have also been called "tidal waves", but this term should not be used because they are not in any way related to the tides of the Earth.
- Because tsunami occur suddenly, often without warning, they are extremely dangerous to coastal communities.

Physical Characteristics of Tsunami



How Tsunami are Generated

- Earthquakes
- Volcanic Eruptions
- Landslides
- Underwater Explosions
- Meteorite Impacts

Predictability:

- There are two distinct types of tsunami warning:
  - *a) International tsunami warning systems*
  - *b) Regional warning systems.*
- a) International Tsunami Warning Systems:
  - *Shortly after the Hilo Tsunami (1946), the Pacific Tsunami Warning System (PTWS) was developed with its operational center at the Pacific Tsunami Warning Center (PTWC) near Honolulu, Hawaii.*
  - *The PTWC is able to alert countries several hours before the tsunami strikes.*
  - *The warning includes predicted arrival time at selected coastal communities where the tsunami could travel in few hours.*
  - *A tsunami watch is issued with subsequent arrival time to other geographic areas.*

  b) Regional Warning Systems
  - *It use seismic data about nearby earthquakes to determine if there is a possible local threat of a*
  - *tsunami. Such systems are capable enough to provide warnings to the general public in less than 15*
  - *minutes.*

Typical adverse effects

- Local tsunami events or those less than 30 minutes from the source cause the majority of damage.
- The force of the water can raze everything in its path.
- It is normally the flooding affect of the tsunami that causes major destruction to the human settlements, roads and infrastructure thereby disrupting the normal functioning of the society.
- Withdrawal of the tsunami causes major damage.
- As the waves withdraw towards the ocean they sweep out the foundations of the buildings, the beaches get destroyed and the houses carried out to sea.
- Damage to ports and airports may prevent importation of needed food and medical supplies.
- Apart from the physical damage, there is a huge impact on the public health system.
- Deaths mainly occur because of drowning as water inundates homes.

Risk reduction measures:

- **Site Planning and Land Management-**
- The designation and zoning of tsunami hazard areas for such open-space uses as agriculture, parks and recreation, or natural hazard areas is recommended as the first land use planning strategy. This strategy is designed to keep development at a minimum in hazard areas.
- In areas where it is not feasible to restrict land to open-space uses, other land use planning measures can be used. These include strategically controlling the type of development and uses allowed in hazard areas, and avoiding high-value and high occupancy uses to the greatest degree possible.
- **Flood management**
- Flooding will result from a tsunami. Tsunami waves will flood the coastal areas. Flood mitigation measures could be incorporated.

- **Engineering structures**
- Most of the habitation of the fishing community is seen in the coastal areas. The houses constructed by them are mainly of lightweight materials without any engineering inputs. Therefore there is an urgent need to educate the community about the good construction practices that they should adopt such as:
- Site selection – Avoid building or living in buildings within several hundred feet of the coastline as these areas are more likely to experience damage from tsunamis.
- Construct the structure on a higher ground level with respect to mean sea level.
- Elevate coastal homes: Most tsunami waves are less than 3 meters in height. Elevating house will help reduce damage to property from most tsunamis.
- Construction of water breakers to reduce the velocity of waves.
- Use of water and corrosion resistant materials for construction.
- Construction of community halls at higher locations, which can act as shelters at the time of a disaster.

How to Protect Your Property

- Avoid building or living in buildings within several hundred feet of the coastline.
- Make a list of items to bring inside in the event of a tsunami.
- Elevate coastal homes.
- Follow flood preparedness precautions.
- Have an engineer check your home and advise about ways to make it more resistant to tsunami water.

What to Do After a Tsunami

- Continue listening to the radio, Coast Guard emergency frequency station, or other reliable source for emergency information.
- Help injured or trapped persons. Give first aid where appropriate.
- Use the telephone only for emergency calls.
- Stay out of the building if waters remain around it.
- When re-entering buildings or homes, use extreme caution.
- Open the windows and doors to help dry the building.
- Shovel mud while it is still moist to give walls and floors an opportunity to dry.
- Check food supplies.

CYCLONE

- Cyclone is a region of low atmospheric pressure surrounded by high atmospheric pressure resulting in swirling atmospheric disturbance accompanied by powerful winds blowing in anticlockwise direction in the Northern Hemisphere and in the clockwise direction in the Southern Hemisphere.
- They occur mainly in the tropical and temperate regions of the world.
- Cyclones are known by different names in different parts of the world:
- Typhoons in the Northwest Pacific Ocean west of the dateline
- Hurricanes in the North Atlantic Ocean, the Northeast Pacific Ocean east of the dateline, or the South Pacific Ocean.
- Tropical cyclones - the Southwest Pacific Ocean and Southeast Indian Ocean.
- Severe cyclonic storm
- Tornado in South America

Types of Cyclones

- **Tropical cyclones**: are what most people are familiar with because these are cyclones that occur over tropical ocean regions. Hurricanes and typhoons are actually types of tropical cyclones, but they have different names so that it's clear where that storm is occurring. Hurricanes are found in the Atlantic and Northeast Pacific, typhoons are found in the Northwest Pacific.
- **Polar cyclones**: are cyclones that occur in Polar Regions like Greenland, Siberia and Antarctica. Unlike tropical cyclones, polar cyclones are usually stronger in winter months.
- **Mesocyclone**: is when part of a thunderstorm cloud starts to spin, which may eventually lead to a tornado.

General Characteristics:

- 1. Strong winds
- 2. Exceptional rain
- 3. Storm surge
- Cyclones are generally accompanied by strong winds which cause a lot of destruction.
- In some cases it is accompanied by heavy downpour and also the rise in the sea which intrudes inland there by causing floods.

The development of a cyclone

- a) Formation and initial development state:
  - *Four atmospheric/ oceanic conditions are necessary for the formation of a cyclone namely:*
  - *A warm sea temperature in excess of 26 degree centigrade, to a depth of 60 meters, which provides abundant watervapour in the air by evaporation.*
  - *High relative humidity (degree to which the air is saturated by to a height of about 7000 meters, facilitates condensation of water vapor into droplets and clouds, releases heat energy and induces drop in pressure.*
  - *Atmospheric instability (an above average decrease of temperature with altitude) encourages considerable vertical cumulus cloud convection when condensation of rising air occurs.*
  - *A location of at least 4-5 latitude the Equator allow the influence of the force due to the earth's rotation (Coriolis force)to take effect in inducing cyclonic wind circulation around low pressure centers.*

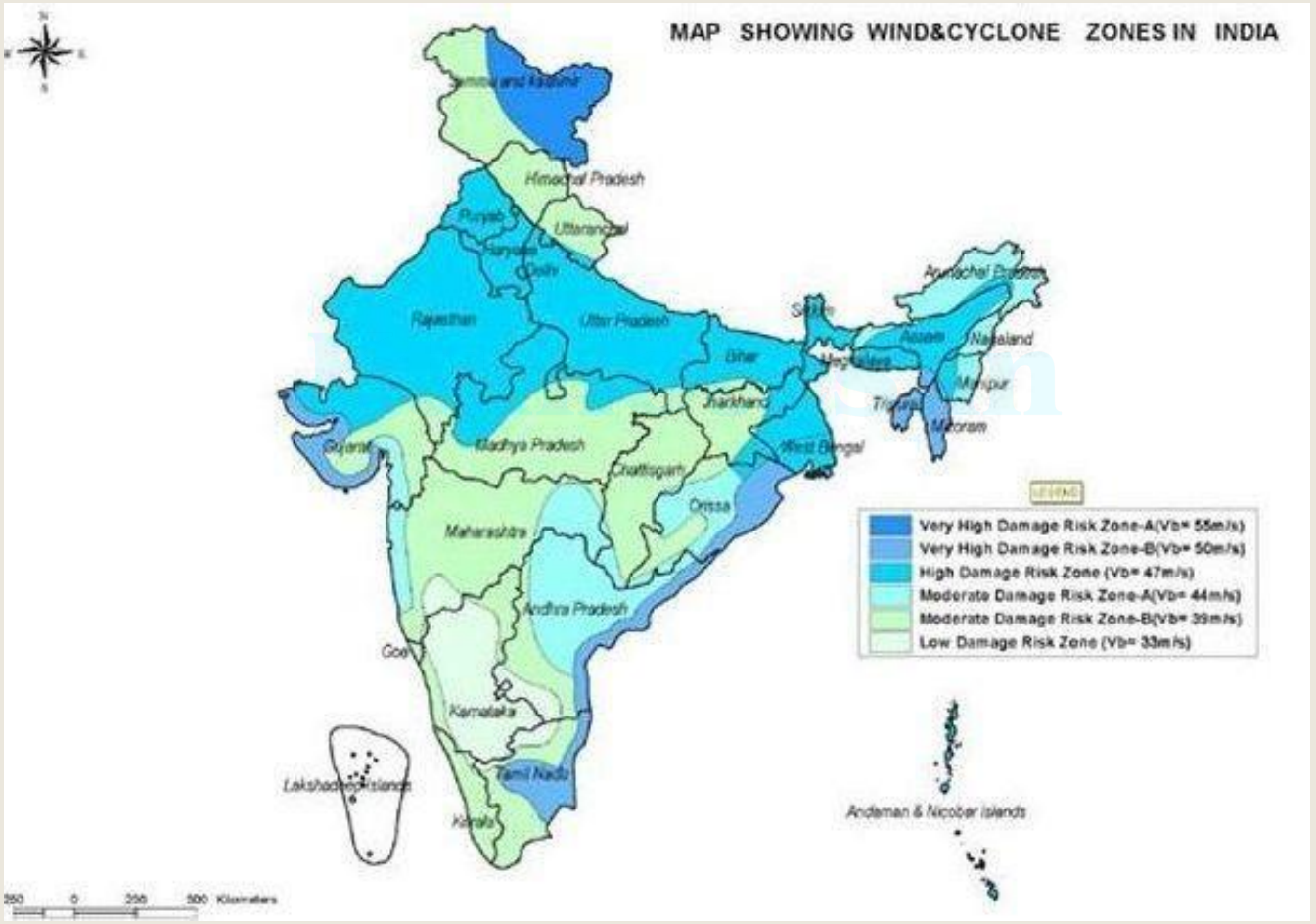
- b) Fully matured:
  - *The main feature of a fully mature tropical cyclone is a spiral pattern of highly turbulent giant cumulus thundercloud bands.*
  - *These bands spiral inwards and form a dense highly active central cloud core which raps around a relatively calm zone. This is called the "eye" of a cyclone.*
  - *The eye looks like a black hole or a dot surrounded by thick clouds. The outer circumference of the thick cloud is called the 'eye wall'.*

- c) Weakening or decay
  - *A tropical cyclone begins to weaken as soon as its source of warm moist air is abruptly cut off.*
  - *This is possible when the cyclone hits the land, on the cyclone moves to a higher altitude or when there is the interference of another low pressure.*

Indian Cyclones

- The 7516.6 kilometers long Indian coastline is the earth's most cyclone battered stretch of the world.
- Around 8 per cent of the total land area in India is prone to cyclones.
- About two-third of the cyclones that occur in the Indian coastline occur in the Bay of Bengal.
- The states which are generally affected in the east coast are West-Bengal, Orissa, Andhra Pradesh; Tamil Nadu and on the west coast Gujarat, Maharashtra, Goa, Karnataka and Kerala.

Distributional Pattern:



Effects of Cyclones and Hurricanes:

- Tropical cyclones cause heavy rainfall and landslides.
- They cause a lot of harm to towns and villages, causing severe damage to kuccha houses. Coastal businesses like shipyards and oil wells are destroyed.
- They harm the ecosystem of the surrounding region. iv. Civic facilities are disturbed.
- Agricultural land is severely affected, especially in terms of water supply and soil erosion.
- It causes harm to human, plant and animal life.
- Communication systems are badly affected due to cyclones.

Management and Mitigation of Cyclones and Hurricanes:

- Coastal areas should be well prepared to meet eventualities that arise from cyclones.
- Houses should be constructed such that they can withstand the heavy rainfall and forceful winds.
- Shelter beds should be created to check soil erosion and speed of winds.
- Remote sensing techniques should be used to forecast cyclones appropriately.
- Possible Risk Reduction Measures:

Coastal belt plantation

- green belt plantation along the coastal line in a scientific interweaving pattern can reduce the effect of the hazard.
- Providing a cover through green belt sustains less damage.
- Forests act as a wide buffer zone against strong winds and flash floods.
- Without the forest the cyclone travel freely inland.
- The lack of protective forest cover allows water to inundate large areas and cause destruction.
- With the loss of the forest cover each consecutive cyclone can penetrate further inland.

Hazard mapping

- Meteorological records of the wind speed and the directions give the probability of the winds in the region.
- Cyclones can be predicted several days in advance.
- The onset is extensive and often very destructive. Past records and paths can give the pattern of occurrence for particular wind speeds.
- A hazard map will illustrate the areas vulnerable to cyclone in any given year. It will be useful to estimate the severity of the cyclone and various damage intensities in the region.
- The map is prepared with data inputs of past climatological records, history of wind speed, frequency of flooding etc.

Engineered structures

- Good construction practice should be adopted such as:
  - *Cyclonic wind storms inundate the coastal areas. It is advised to construct on stilts or on earth mound.*
  - *Houses can be strengthened to resist wind and flood damage. All elements holding the structures need to be properly anchored to resist the uplift or flying off of the objects. For example, avoid large overhangs of roofs, and the projections should be tied down.*
  - *A row of planted trees will act as a shield. It reduces the energy.*
  - *Buildings should be wind and water resistant.*
  - *Buildings storing food supplies must be protected against the winds and water.*
  - *Protect river embankments.*
  - *Communication lines should be installed underground.*
  - *Provide strong halls for community shelter in vulnerable locations.*

Improving vegetation cover

- The roots of the plants and trees keep the soil intact and prevent erosion and slow runoff to prevent or lessen flooding.
- The use of tree planted in rows will act as a windbreak.
- Coastal shelter belt plantations can be developed to break severe wind speeds.
- It minimizes devastating effects.
- The Orissa calamity has also highlighted the need for urgent measures like shelterbelt plantation along cyclone-prone coastal areas.
- Species chosen for this purpose should not only be able to withstand the impact of strong cyclonic winds, but also check soil erosion.