Unit -2 (DM)

Earthquake

Earthquake is the result of a sudden release of energy (seismic waves) in the Earth's crust, caused by sudden breaking and movement of large sections (tectonic plates) of the earth's crust. Most earthquakes occur along the fault lines when the plates slide past each other or collide against each other.

The seismicity of an area refers to the frequency, type and size of earthquakes experienced over a period of time.

This movement of masses generate shock waves that may be powerful enough to

- alter the surface of the Earth, thrusting up cliffs and opening great cracks in the ground and
- cause great damage - collapse of buildings, man-made structures, broken power and gas lines and the consequent fire, landslides, snow avalanches, tsunamis and volcanic eruptions.

SEISMOLOGY AND ITS IMPORTANCE

Seismology and its importance –

- Earthquake is defined as the shaking of earth's surface due to any reason which results in release of large amount of energy.
- The energy released during an earthquake is enormous.
- For example – the energy released during Bhuj earthquake (India 2001) was about 400 times more than the energy released by the 1945 atom bomb dropped in Hiroshima.
- The word seism means earthquake. Hence seismology or earthquake engineering is defined as the branch of science which deals with the study of earthquake.
- It includes study of origin, propagation, recoding and analyzing seismic waves.

Importance –

1. It helps us in understanding the earthquake their nature and effect on our life.
2. It helps us in designing the building earthquake resistant structures to minimize the loss of lives and property.
3. It also helps us in planning effective disaster management programme during earthquake by preparing ourselves in a better way to reduce the effect of

Structure of Earth

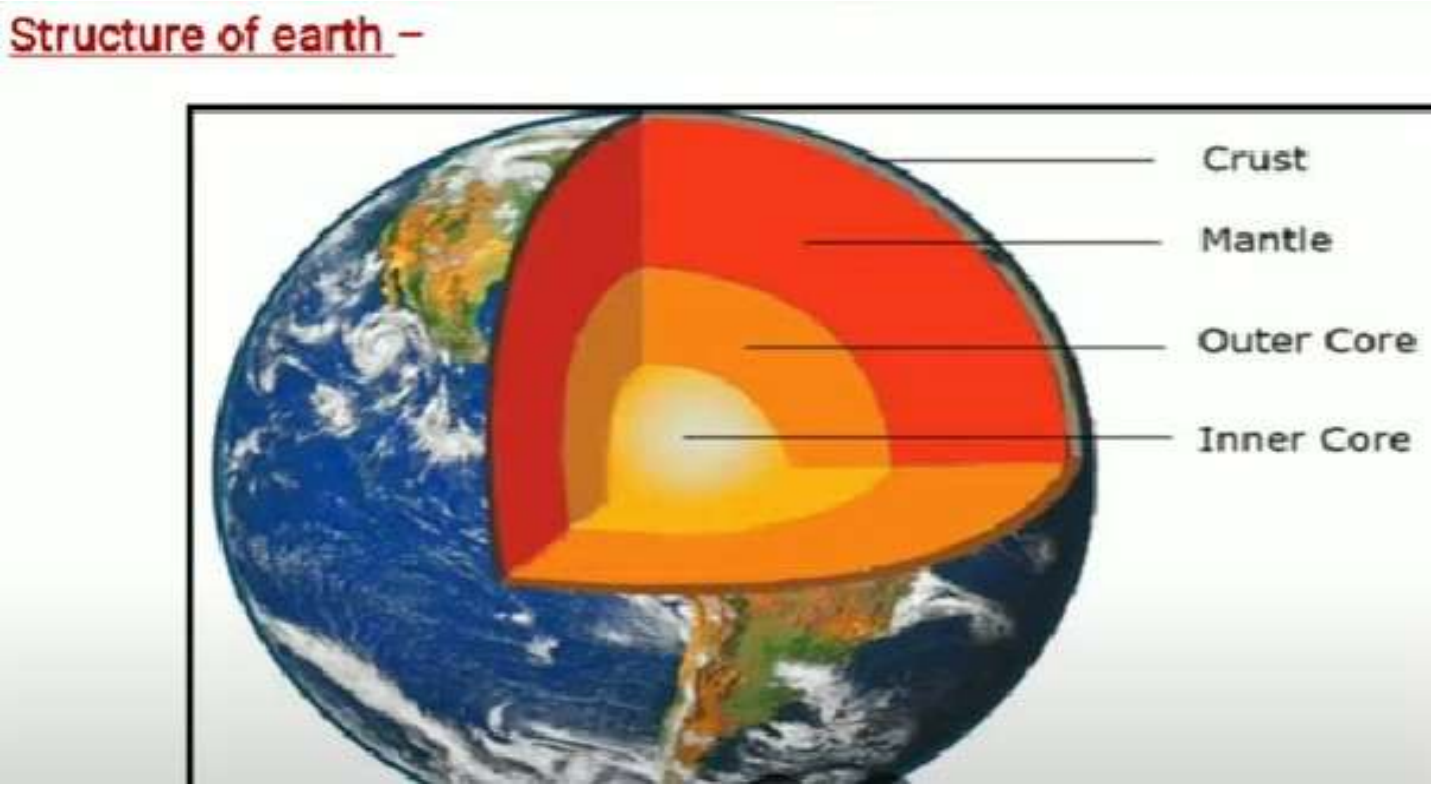
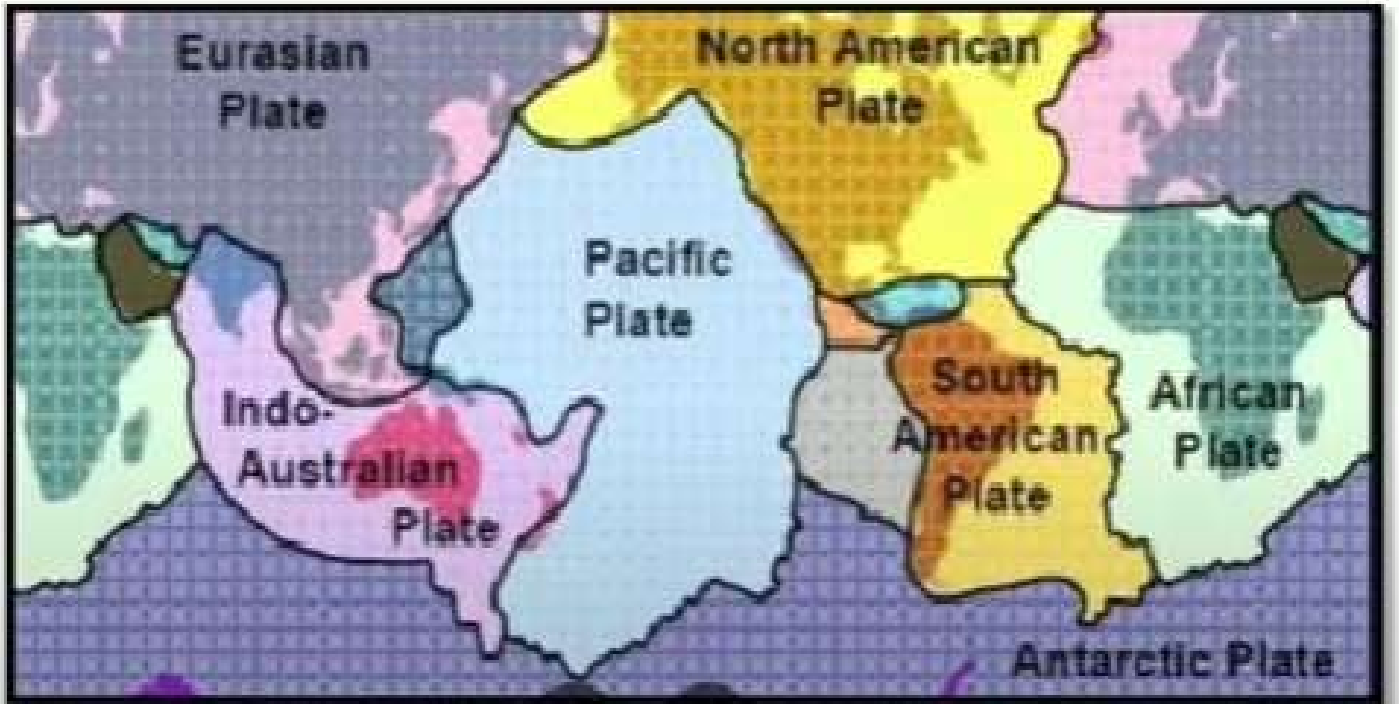


Plate Tectonics

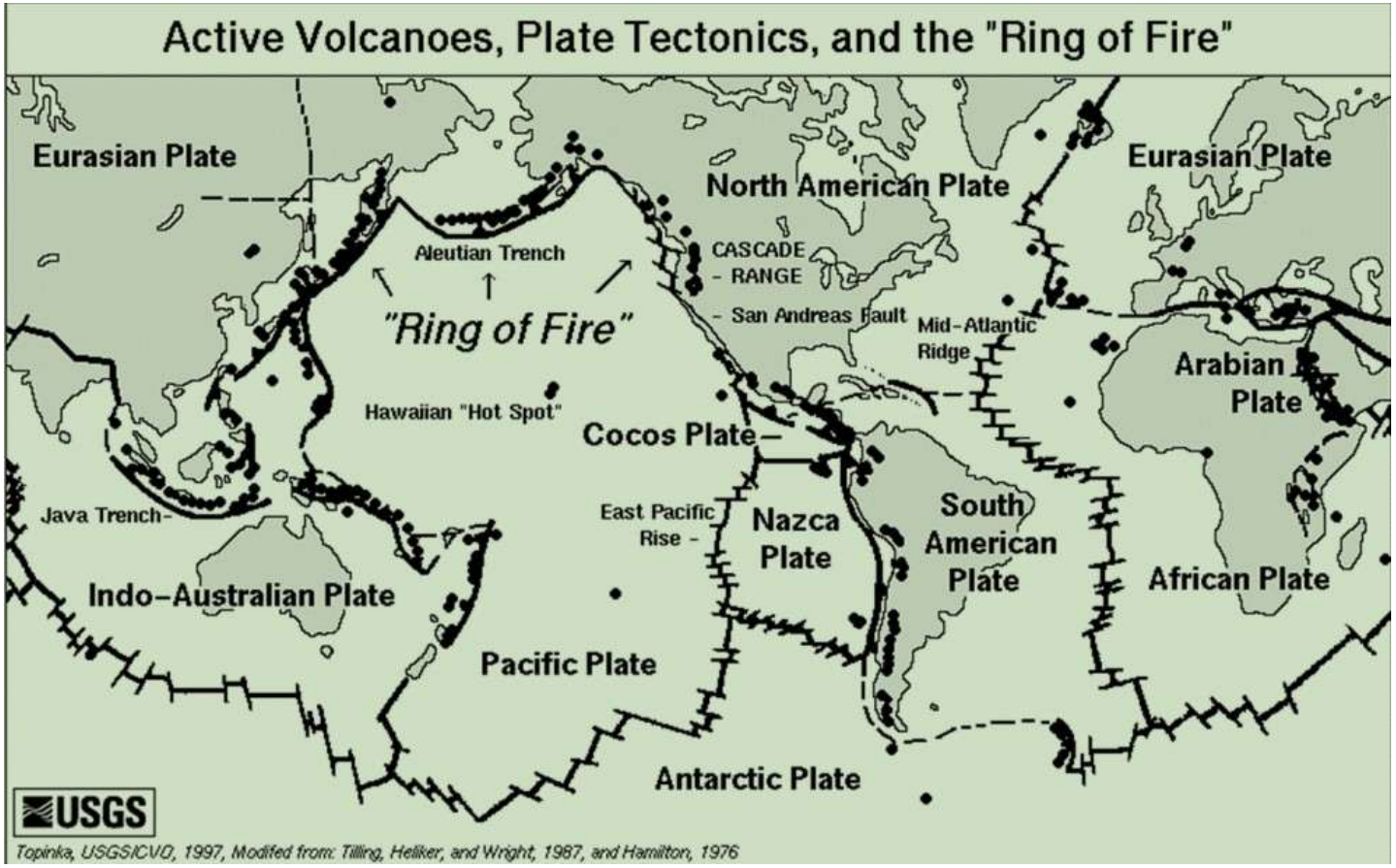
Plate tectonics –

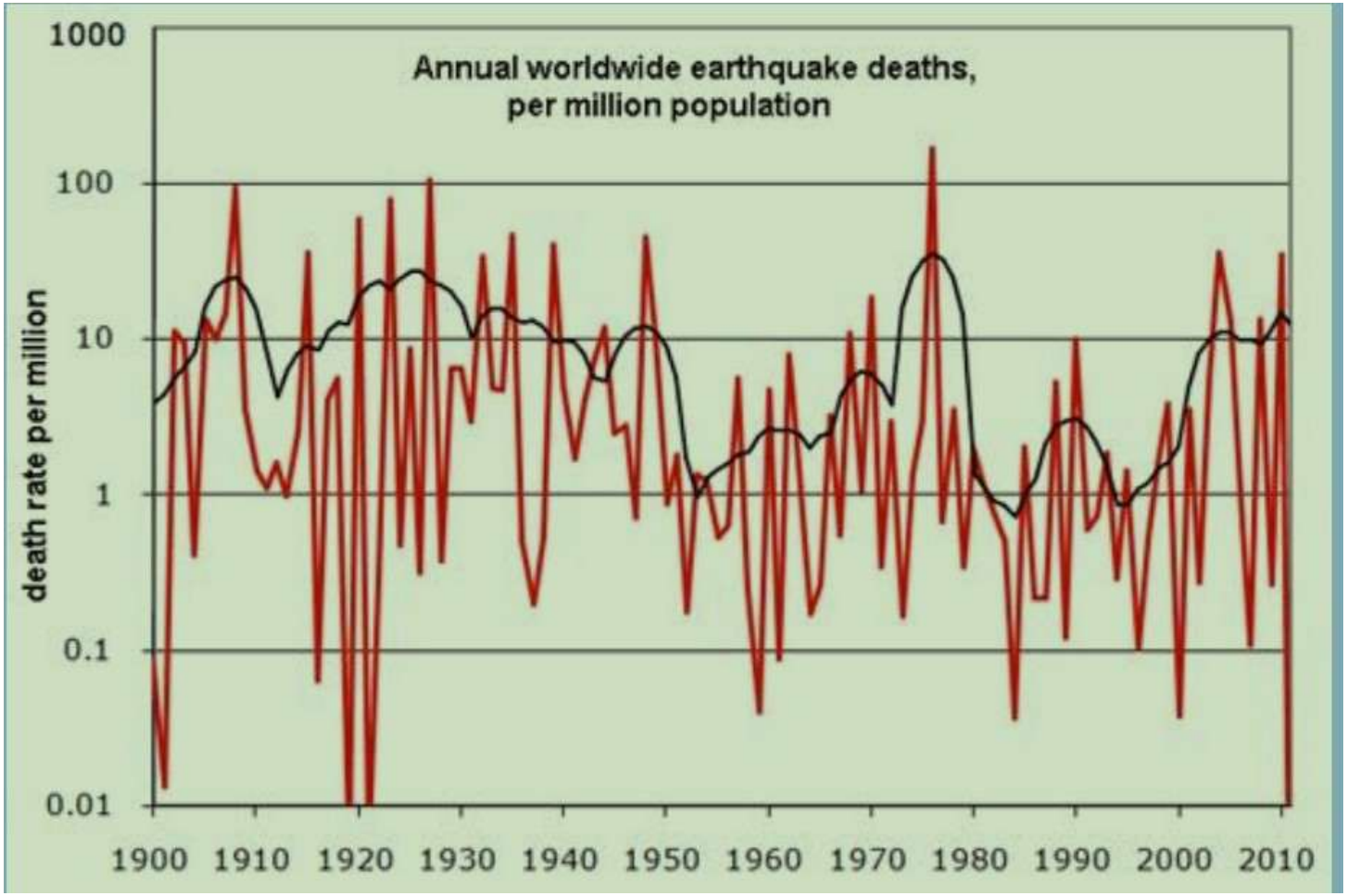
- Theory of plate tectonics is based on the theory of continental drift which explains the origin of continents and oceans.
- According to this theory a long time ago, large amount of material masses joined together to form the earth.
- Large amount of heat was generated during this fusion. As the earth cooled down the heavier material sank to the center and the lighter ones towards the top.
- The upper part formed is called as crust and the inner part is called as core
- The high temperature and pressure difference between the crust and core results in convection currents (like flow of water molecules when heated up).
- These currents result in circulation of the earth's mass form the crust to core and vice versa.
- The hot molten lava comes out and cold rock mass goes into the earth. This flow of material causes the crust and some part of mantle to slide on the outer core.
- This sliding of earth's mass takes place in different part of the earth. Called as Tectonic plates.

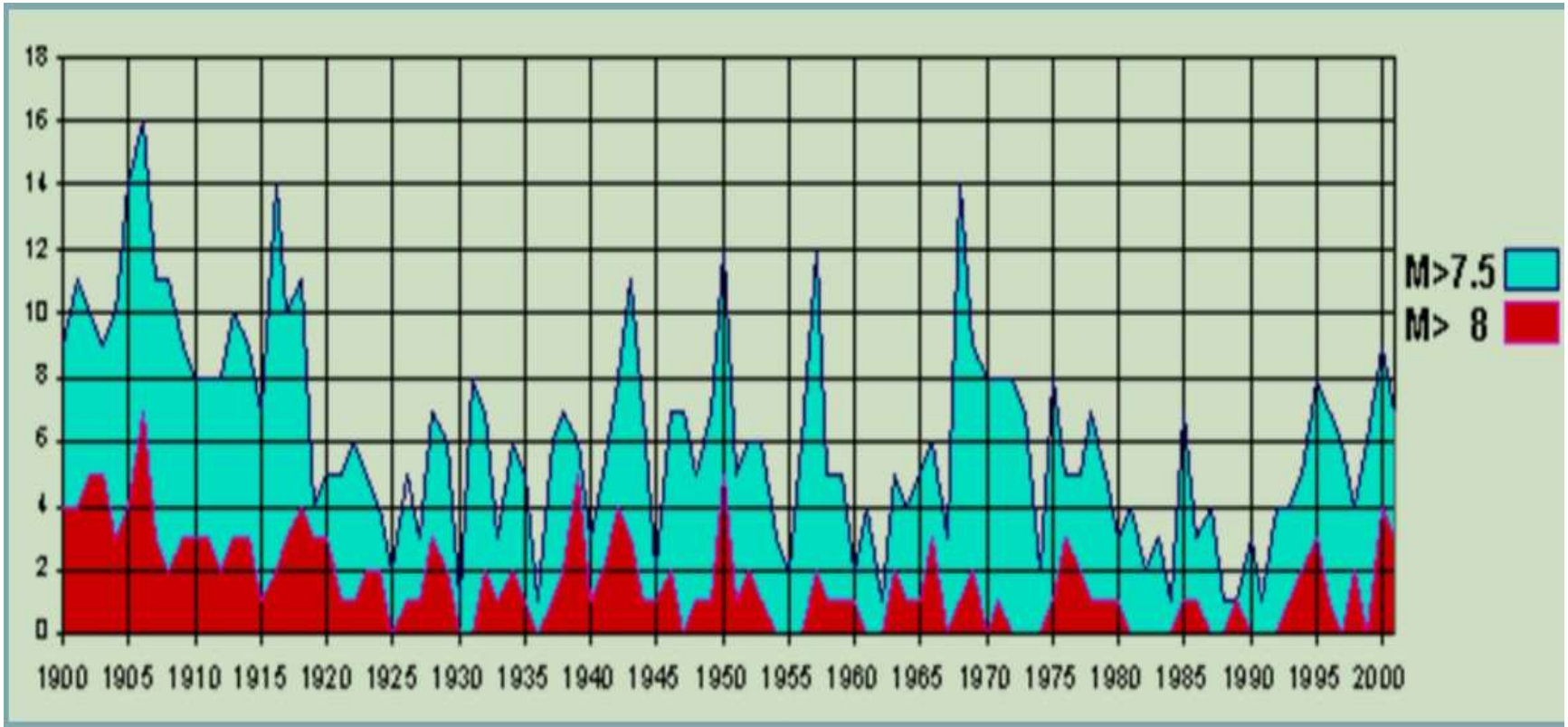
- The surface of earth consist of seven major tectonic plates and many small plates. These plates moves in different direction and at different speeds.
- Thus resulting in rising and sinking of the continents.(formation of mountains and valleys)
- These movements result in the formation of mountains (Like Alps and Himalayas)



	Boundary Types		What can happen
1.	**Convergent Boundary**		1. Earthquakes 2. Mountain Building 3. Volcanoes erupt
2.	**Divergent Boundary**		1. Earthquakes 2. Sea floor spreading 3. Volcanos erupt
3.	**Transform Boundary**		1. Earthquakes


Active Volcanoes, Plate Tectonics, and the "Ring of Fire"
Eurasian Plate
North American Plate
Eurasian Plate
Aleutian Trench
CASCADE
- RANGE
- San Andreas Fault
"Ring of Fire"
Mid-Atlantic
Ridge
Arabian
Plate
Hawaiian "Hot Spot"
Cocos Plate
Java Trench
East Pacific
Rise
Nazca
Plate
South
American
Plate
African Plate
Indo-Australian Plate
Pacific Plate
Antarctic Plate
USGS
Topinka, USGS/CVO, 1997, Modified from: Tilling, Heliker, and Wright, 1987, and Hamilton, 1976


Annual worldwide earthquake deaths,
per million population
death rate per million
1000
100
10
1
0.1
0.01
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2010



Earthquake frequency - High Magnitudes

Causes of earthquake

Causes of Earthquake –

- Earthquake are primarily caused due to two reason

1. Natural disturbances

a. Volcanic cause

b. Tectonic cause

2. Artificial disturbance

Natural disturbance –

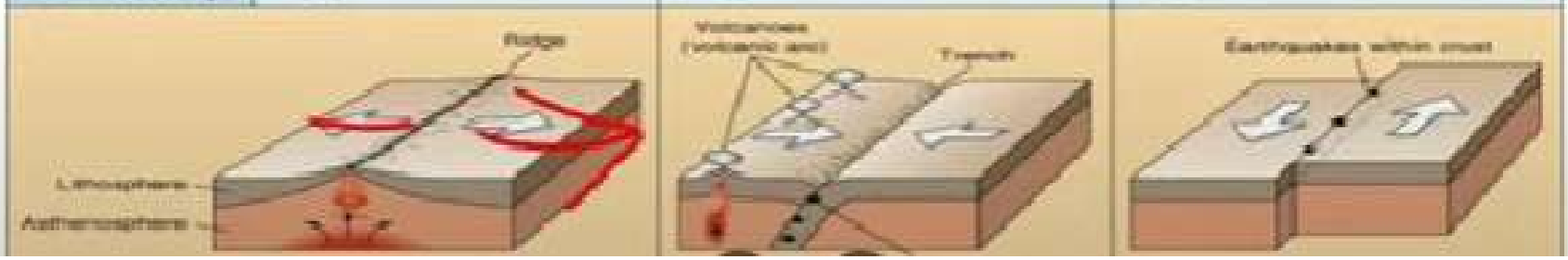
a. Volcanic causes –

- Volcanic activity keeps on taking place in several parts of the world. Very often, it produces sudden out burst or explosions .
- This impact is sometimes strong enough to produce vibration in the nearby area. People living in Japan and Italy, have experience this type of earthquake frequently.
- The damage caused due to this type of earthquake is confined within a few kilometers. All volcanic eruption don't produce earthquake.

b. Tectonic causes –

- Tectonic cause are those which occur inside earth. According to the theory of plate tectonic, the curst layer is made up of rocks and is divided into many plates.
- These plates are constantly in motion in different direction and with different speeds. These plates have strain energy stored in them.
- The earthquake which occur due to sudden release of strain energy as a result of sudden slip of fault is called as tectonic earthquake.

Type of Margin	Divergent	Convergent	Transform
Motion	Spreading	Subduction	Lateral sliding
Effect	Constructive (oceanic lithosphere created)	Destructive (oceanic lithosphere destroyed)	Conservative (lithosphere neither created or destroyed)
Topography	Ridge/Rift	Trench	No major effect
Volcanic activity?	Yes	Yes	No



Artificial disturbance –

- Sometime the surface of the earth vibrates due to man made or artificial disturbance.

1. Nuclear test and explosions
2. Mining blasts in the mining area
3. A massive landslides along hill slops caused because of deforestation.
4. Large and deep excavations
5. Vibration induced due to heavy machinery used in industries or movement of heavy vehicles.

- All these causes occur over the earth's surface so these are also called as surface causes.

More Causes :

Reservoir-induced seismic activity appears to occur on dams with heights more than 100 m. The extra water pressure created by large reservoirs is the most accepted explanation for the seismic activity.

World Commission on Dams, Reservoir-Induced Seismicity (RIS) is related to the extra water pressure created in the micro-cracks and fissures in the ground .

Hydraulic fracturing has a low risk for inducing earthquakes that can be felt by people. Underground injection of wastewater produced by hydraulic fracturing and other energy technologies has a higher risk of causing such earthquakes

Artificial lakes

Creation of deep artificial lake (high Water column) alters in-situ stress along an existing fault . Weight of the water column significantly change the stress on the underlying fault and increase the effective stress through the increased pore water pressure. This stress change can lead to sudden movement resulting in an earthquake

Mining

Large scale Voids alter the balance of forces in the rock, causing rock bursts. These voids may collapse producing seismic waves and also reactivate existing faults causing minor earthquakes. Collapse of Natural cavern sinkholes/ natural cavern produce an identical local *seismic event.*

Waste disposal wells

Injection of liquids (high-saline water) into waste disposal (salt water disposal (SWD) wells, is practiced in disposing of produced water from oil and natural gas wells. This activity result in increasing the subsurface pore pressure, trigger movement along faults.

Extraction of fossil fuels / groundwater

The changes in crustal stress patterns caused by the large scale extraction of groundwater as well fossil fuels has been shown to trigger earthquakes.

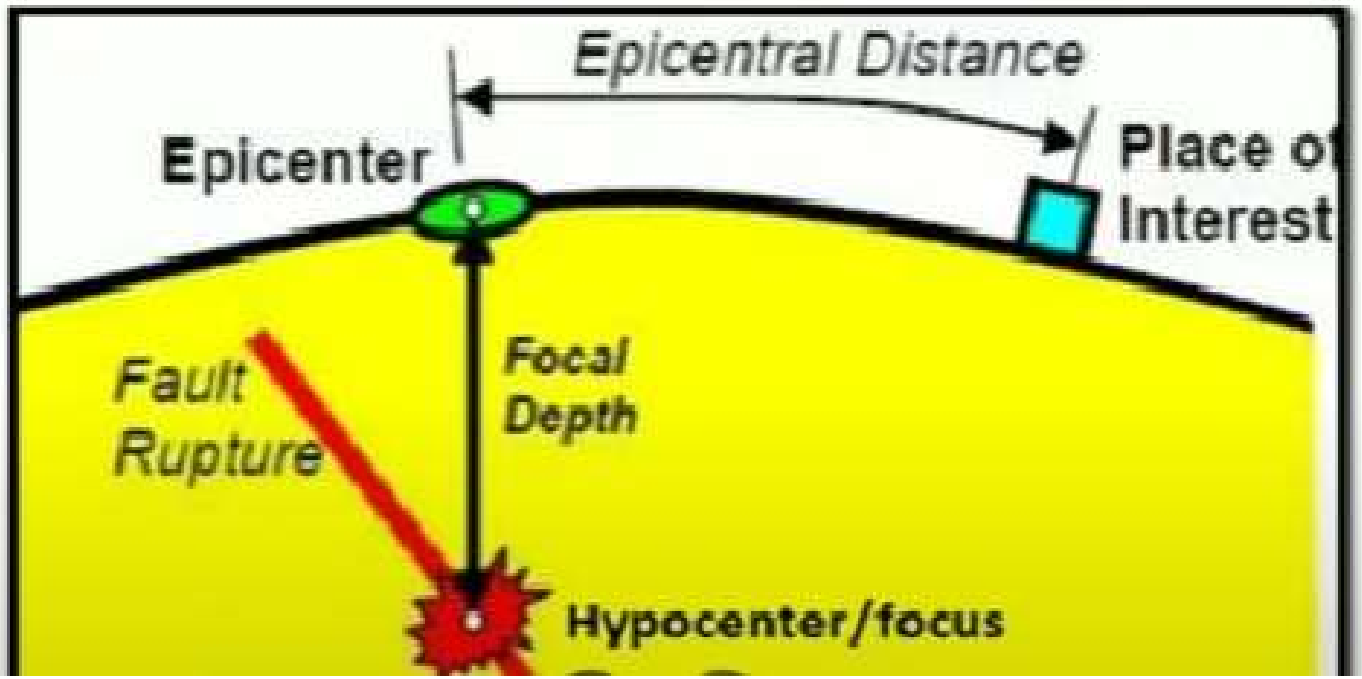
Geothermal energy

Enhanced geothermal systems (EGS), involves pumping fluids at pressure to enhance or create permeability through the use of hydraulic fracturing techniques. Hot dry rock (HDR) actively creates geothermal resources through hydraulic stimulation. Induced seismicity events are reported from the Geysers geothermal field has been strongly correlated with injection data

Terminology –

1. **Hypocenter –**

- The point inside the surface of the earth from where the earthquake originate is termed as hypocenter. This is also known as **focus.** It is the point on the fault where the slip or the movement starts.



2. **Epicenter –**

- The point on the earth's surface vertically above the hypocenter is called as epicenter.

3. **Focal depth –**

- The depth of focus from the epicenter is called as focal depth. It is an important parameter in determining the extent of damage of an earthquake.
- The focal depth of most of the major earthquake causing lot of damage in shallow depth.

4. **Epicenter distance –**

- Distance from epicenter to point of any interest is called as epicentral distance.
- As the epicentral distance is increased the effect of earthquake become less. The damage is maximum at the epicenter and surrounding area.

5. **Fore shocks and after shocks –**

- A fault rupture is not a simple one time movement that produce the earthquake. In fact we never have just one earthquake.
- The fault movement generates a series of earthquake. Out of these the biggest one is called as earthquake (Main shock).

- The smaller size earthquakes that takes place before a big earthquake are foreshocks and those after the big earthquake are called after shocks

Seismic waves –

- When the earth shakes, it releases energy in the form of seismic waves which travel inside the earth and also on the surface of the earth.
- The study of seismic waves and their records is very important in seismology. They not only help us in assessing the magnitude, intensity and location of the earthquake nut also give us information about the interior of earth.

Types of seismic waves

1. Body waves
2. Surface waves

Body waves –

- The seismic waves which originate inside the earth and travel through the various layers of the earth in all directions are called as body waves. Body waves are of following two types.

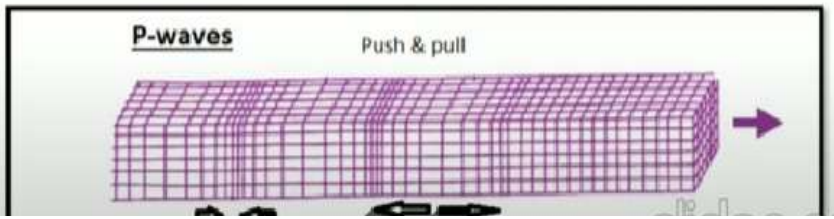
1. Primary waves (P - wave)
2. Secondary waves (S – wave)

Primary waves (P waves) –

- P - waves moves in a push and pull fashion like sound waves. Thus the material particles undergoes compression (Push) and extension (Pull) as shown in fig. below.

Properties of P-waves –

1. These are the fastest seismic wave and thus first to reach at the recording station.
2. P – wave can travel through any material be it solid, liquid or gas.
3. Their speed depends upon the density and compressibility of the material through which they are passing.
4. These are longitudinal waves like sound waves which moves in push and pull fashion.
5. P wave make loud thunderous noise near the epicenter.

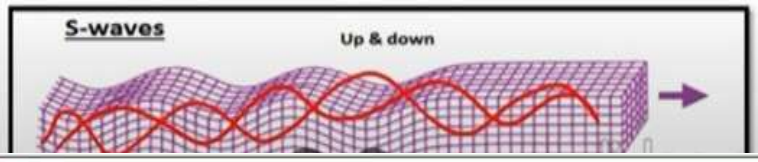


Secondary waves (S waves) –

- S – wave are those body waves which propagate by vibrating the material particles at right angles to the direction of propagation.
- These waves are transverse in nature like light waves. These are also called as shear waves.

Properties of secondary wave –

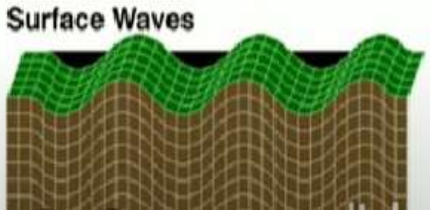
1. S – wave are slower than P-wave and hence second to reach at the recording station.
2. S wave can travel through solids only because liquids and gases do not have shear strength.
3. S wave are transverse in nature like light wave.
4. The velocity of S wave depends upon the density and shear strength of the materaial through which they pass.



Surface waves –

- The seismic waves which travel along the surface are called as surface waves.
- These waves do not propagate deep inside the surface of the earth. These are also called as long wave.
- These waves can be visualized as the ripples caused by throwing a rock into water.
- These waves are the slowest, thus last to reach the recording station.
- Surface waves shakes the ground surface and are responsible for all the damage occurring on the earth's surface.
- These are most destructive in nature.
- It is also of two type.

1. **Love waves**
2. **Rayleigh waves**

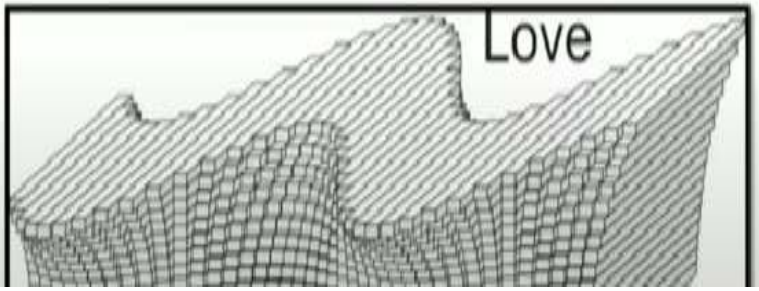


Love waves (L-wave) –

- These waves were detected by seismologist A.E.H Love in 1911 and thus are named as love wave.

Properties of love wave

1. Love waves cause surface motion similar to S- waves. But with no vertical component, thus the motion is from side to side in a horizontal plane roughly parallel to the earth's surface
2. Love wave travel faster than Rayleigh waves and like S – wave they do not move though liquid or air.
3. Love waves along with S – waves cause maximum damage to the structure.

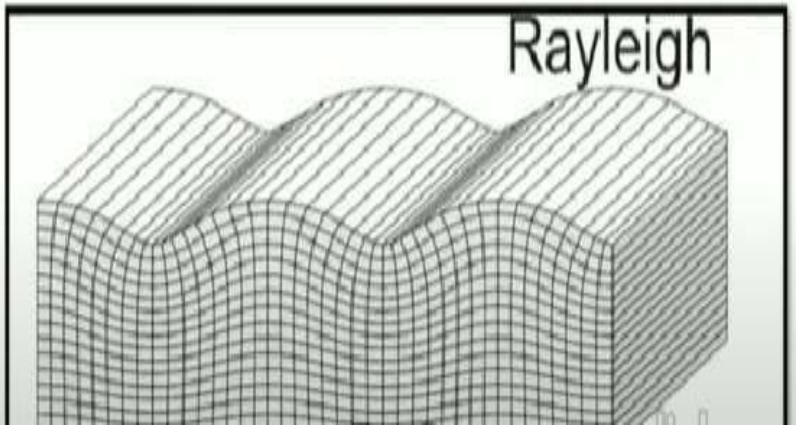


Rayleigh wave –

- These waves are first discovered by Rayleigh in 1885. In these waves material particles vibrate in a backward elliptical path in the vertical plane

Properties of love wave

1. The shaking produced by Rayleigh waves causes both vertical and horizontal movement.
2. They advance in a backward rotation elliptical motion as shown in fig. given below.

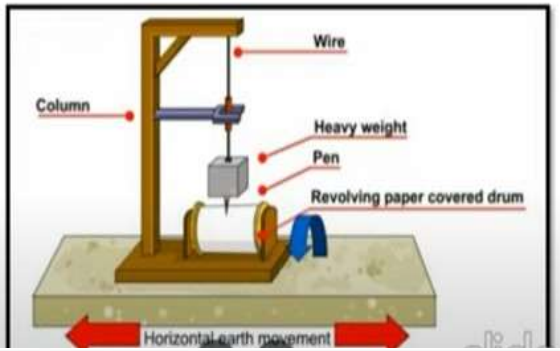


Seismograph –

- Shaking of ground on the earth's surface is caused by seismic waves. The instrument which measure earthquake shaking and record them is called as seismograph.

Parts of a seismograph -

1. Sensor
2. Recorder
3. Timer



Sensor –

- The sensor is used to sense or detect vibrations. It consists of a pendulum mass, string, magnet and support.

Recorder –

- The recorder is used to record the seismic vibrations on a paper. It consists of a drum, pen and chart paper. The chart paper is wrapped on the drum.

Timer –

- The timer is the motor that rotates the drum having chart paper at constant speed.

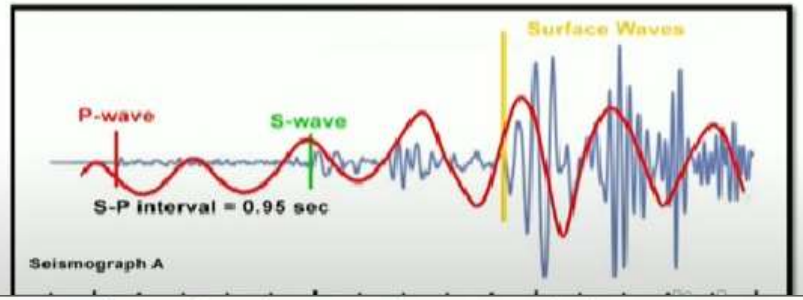
Working of a Seismograph –

- The construction of typical seismograph consists a simple pendulum (a string and mass) is suspended freely but a magnet is tied around the string to dampen the oscillation .
- A pen is attached at the tip of the pendulum which marks the movement or oscillations of the pendulum on the chart paper wrapped the rotation drum.
- Whenever there is earthquake the vibrations are produced and the pendulum vibrates simultaneously thus recording these vibrations on the paper with the pen.

Since the earthquake motion is 2-D one such instrument is required in earth perpendicular direction to recorded both the components of motions

Seismogram –

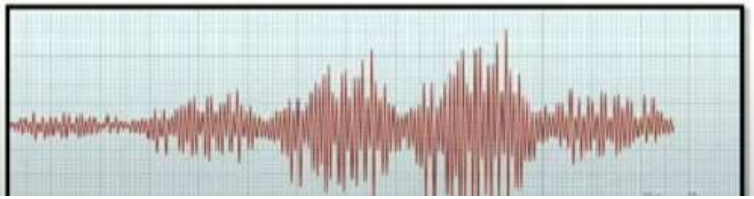
- The record of an earthquake is called as seismogram. In a seismogram the earthquake waves are recorded in the order, they arrive at the recording station. P-waves being the fastest, recorded first, followed by S-waves and then slowest L-wave.
- Using the time the various waves takes to reach the station, the location of the epicenter and hypocenter, focal depth etc. can be determined.



- The variation of ground acceleration with time, recorded at a point on ground during earthquake is called an **accelerogram.**

Uses of Seismogram –

1. It is used for determining the epicenter of the earthquake.
2. These are the records of the earthquakes, thus they are used for obtaining the seismic parameters which are used in design of structure and also for identifying the seismic zones
3. Seismogram also help us in studying the seismic waves their nature and propagation which helps in assessing the time and severity of the earthquake.



Earthquake size –

- Earthquake size is measured of the qualitative and quantitative effects of the vibrations produced by the earthquake.

Earthquake size is defined in terms of two things.

1. Magnitude
2. Intensity

Magnitude –

- It is a quantitative estimate of the earthquake size. It is a measure of amount of energy released during the earthquake.
- The magnitude of an earthquake is generally measured on Richter Scales.

Intensity –

- It is a qualitative measure of the earthquake. It is a way of measuring or rating the effect of an earthquake at different sites.
- Intensity data are very much useful for the development of seismic risk map of an area or country.
- These map have got various uses like planning safe site for important structure like large dams and nuclear power plants and determination of historic seismicity of an area etc.
- Two scales are commonly used – **(Modified Mercalli Intensity - MMI)** & **MKS** scale. Both are similar and range from (**I – least severity**) to (**XII – most sever**)

It depends upon

1. **Earthquake magnitude**
2. **Distance from hypocenter or epicenter**
3. **Type of foundation material**
4. **Building style**
5. **Duration of shaking**

Earthquake classification based on their magnitude

Group	Magnitude
Great	8 and higher
Major	7 – 7.9
Strong	6 – 6.9
Moderate	5 – 5.9
Light	4 – 4.9
Minor	3 – 3.9
Very minor	< 3.0

Comparison of Magnitude, intensity and Acceleration

Richter magnitude	Mercalli Intensity	Acceleration (% age)
2 and less	I – II	Usually not felt by people < 0.1 – 0.19
3	III	Felt indoor by some people, 0.2 – 0.49
4	IV – V	Felt by most people, 0.5 – 1.9
5	VI – VII	Felt by all, building damage, 2 – 9.9
6	VII – VIII	People scared, moderate damage , 10 – 19.9
7	IX – X	Major damage , 20 – 99.9
8 and up	XI - XII	Damage nearly total over 100

Isoseismal –

- An imaginary contour line joining place of equal earthquake intensity is called as isoseismal and a map showing different isoseismal for a particular earthquake is called as and isoseismal map.

Based on location –

- On the basis of location of occurrence of earthquake they are classified as

a. Interplate earthquake
b. Intraplate earthquake

Interplate earthquake –

- Most earthquakes in the world occur along the boundaries of the tectonic plates and are called interplate earthquake.
- It is seen that epicenter of about 99% of earthquakes are in the narrow zones of interplate boundaries.

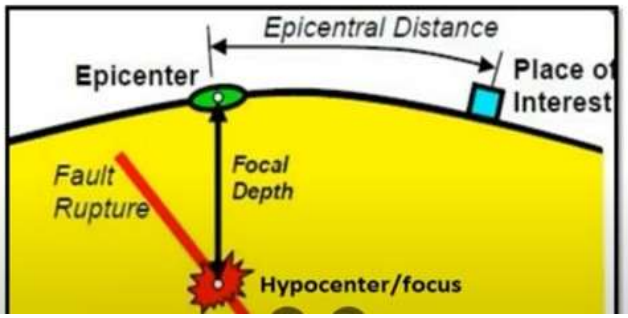
Intraplate earthquake –

- The earthquakes occurring within a plate itself away form the plate boundaries are called as intraplate earthquake

Based on focal depth –

- The earthquake are classified into following three types based on focal depth

1. Shallow earthquake
2. Intermediate earthquake
3. Deep earthquake



Shallow earthquake –

- The earthquake whose focal depth is less than 70 km and called as shallow depth earthquake.
- Nearly 80 % of earthquake are shallow, and are of great concern of civil engineers.

Intermediate earthquake –

- Those earthquake in which focal depth is form 70 to 300 km are called as intermediate earthquake.

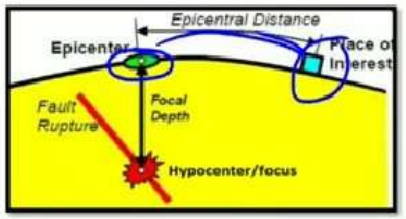
Deep earthquake –

- The earthquake whose focal depth is greater than 300 km is called as deep earthquake.

Based on epicentral distance –

- On the basis of epicentral distance (affected area) the earthquake are classified into following three types

1. Local earthquake
2. Regional earthquake
3. Teleseismic earthquake



Local earthquake –

- The affected area is very less within 500 km of the epicenter of the earthquake

Regional earthquake –

- The affected area due to the earthquake is with in 500 km to 1000 km of the epicenter of earthquake

Teleseismic earthquake –

- The affected area is greater than 1000 km of the epicenter of the earthquake

Seismic zoning –

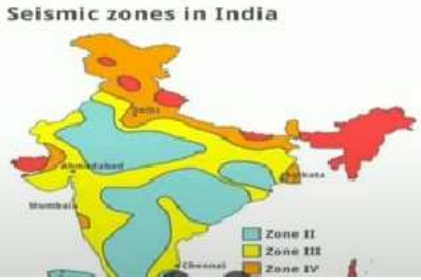
- The seismicity or earthquake activity at a place is assessed by its distance form the fault rocks, and from the past records.
- It varies in different parts of a country or region. It is seen from the past records that earthquake activity are more or less same in a particular are or zone.
- Therefore a country can be divided into zones of similar seismic activity.
- Seismic zoning can be defined as dividing a country or region into smaller zones on the basis of their seismicity or earthquake activity.

It depends upon the following

- The seismic history of a region. It means the detail study of the earthquake that have occurred in past, their characteristics like magnitude, intensity and extent of damage etc.
- The tectonic features of the plate which could cause an earthquake in future.

Seismic zones of India –

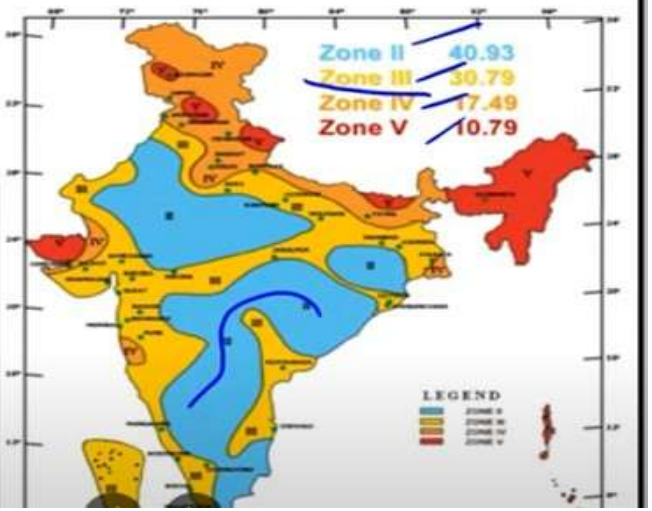
- The different geology at different location in the country implies that the possibility of damaging earthquakes takes place at different locations is different.
- Thus a seismic zone map is required to identify these region.
- Based on the levels of intensity during past earthquakes the 1970 zone map divided India into five zones (I, II, III, IV & V)
- The map has been revised lastly in 2002 and it has holy for seismic zone – (II, III, IV & V)



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)



Effects of Earthquakes

Physical Damage

- Landslides
- Mudslides
- Tsunamis
- Liquefaction
- Fires

Structural Damage

- Buildings Collapse
- Roadways Collapse

Structural damage depends on:

- Strength of the earthquake waves that reach the surface
- Duration of the motion
- Proximity
- Geologic foundation
- Structural design and construction quality

Emotional Damage

- Deaths

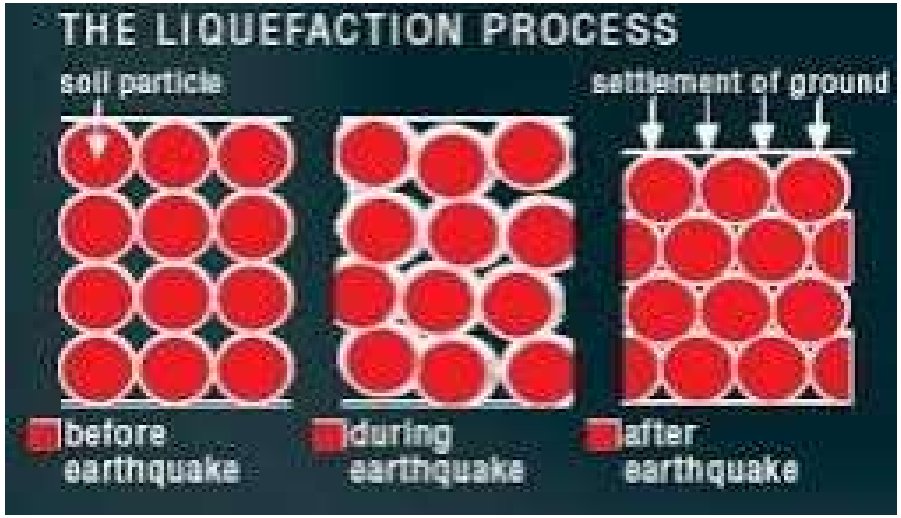
people trapped under the rubble and debris. Falling structures and flying glass and other objects striking

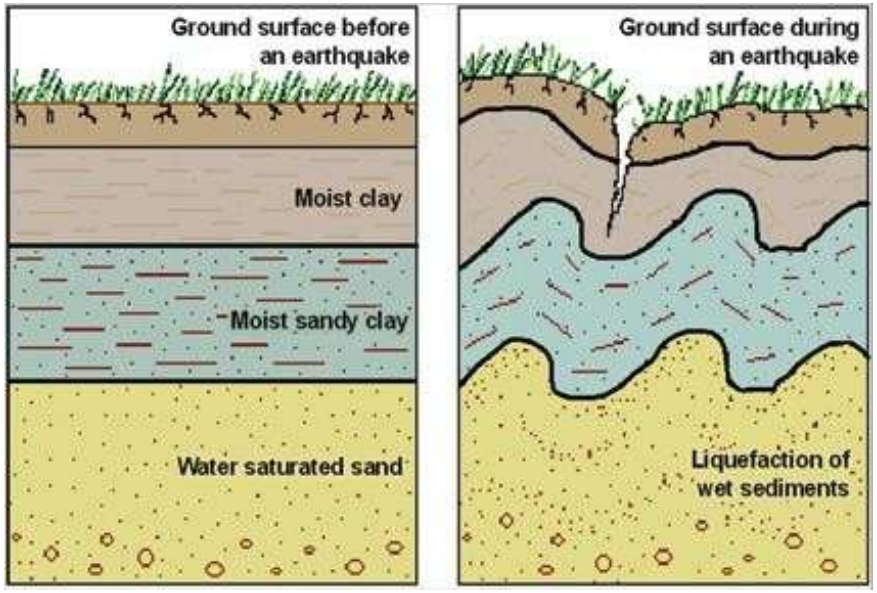
Effects of Earthquakes

- Ground Motion: Shaking of structures results in damage or total collapse structures
- Liquefaction: Happens in loose saturated cohesion-less soils in which the firm soil is converted into a fluid state which has no shear strength and thus structures found on these soils fail due to loss of bearing capacity of the ground
- Landslides/avalanches: Vibrations during earthquake trigger large slope failures
- Fire, Dust and Pollution : Indirect effect of earthquakes (large scale damage triggered by EQ to gas pipe line and power lines)
- Tsunamis: large waves created by the instantaneous displacement of the sea floor during submarine earthquakes

Soil liquefaction

Soil liquefaction is a phenomenon whereby a saturated or partially saturated soil substantially loses strength and stiffness in response to an applied stress, usually earthquake shaking or other sudden change in stress condition, causing it to behave like a liquid





Landslide and avalanches – trigger the slope instability leading to landslide. Landslide danger persist even during emergency operations.

Fire is caused by damaging of electrical power or gas lines. In the event of water mains rupturing and a loss of pressure, It may also difficult to stop a fire once it started.

Human impacts

Injury and loss of life, dust, road and bridge damage, general property damage, and collapse or destabilization of buildings.

The aftermath may bring disease, lack of basic necessities, mental consequences such as panic attacks, depression to survivors,[56] and higher insurance premiums

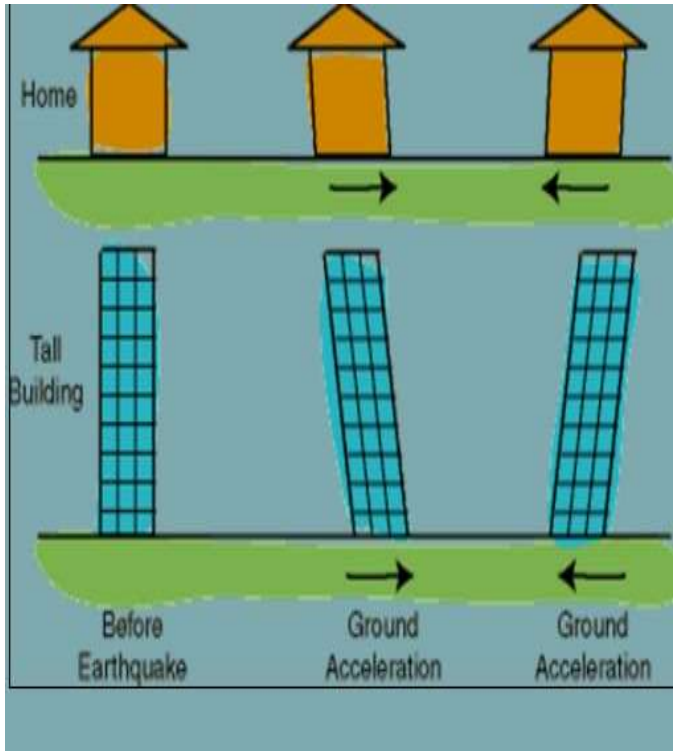
Effects of earthquake (Contd.....)

Shaking and ground rupture resulting in more or less severe damage to buildings and other rigid structures. The severity of the local effects depends on the complex combination of the earthquake magnitude, the distance from the epicenter, and the local geological and geomorphological conditions, which may amplify or reduce wave propagation. The ground-shaking is measured by ground acceleration.

Ground rupture is a visible breaking and displacement of the Earth's surface along the trace of the fault, which may be of the order of several metres in the case of major earthquakes. Ground rupture is a major risk for large engineering structures such as dams, bridges and nuclear power stations and requires careful mapping of existing faults to identify any which are likely to break the ground surface within the life of the structure.

Tsunamis are long-wavelength, long-period sea waves produced by the sudden or abrupt movement of large volumes of water. In the open ocean the distance between wave crests can surpass 100 km, and the wave periods can vary from five minutes to one hour. Such tsunamis travel 600-800 km/hour, depending on water depth. Large waves produced by an earthquake or a submarine landslide can overrun nearby coastal areas in a matter of minutes. Tsunamis can also travel thousands of kilometers across open ocean and wreak destruction on far shores hours after the earthquake that generated them.

Ordinarily, subduction earthquakes under magnitude 7.5 on the Richter scale do not cause tsunamis, although some instances of this have been recorded. Most destructive tsunamis are caused by earthquakes of magnitude 7.5 or more



Factors affecting the Impact of Earthquakes:

- Depth: If the hypocentre of an earthquake is close to the surface then it is more likely to cause greater damage than a deep earthquake.
- Duration: A longer earthquake is likely to cause greater damage than an earthquake that lasts only a few seconds.
- Magnitude: Obviously a stronger earthquake is going to have a greater impact than a weaker one.
- Time of Day: Time of day can be important. If people are sleeping and get trapped in their beds more people can be killed. In Japan an earthquake that struck while people were cooking their evening dinner caused widespread secondary hazards (fire) that caused more deaths.

Earthquake prediction depending on time scale

Long term prediction estimates the statistical probability of earthquakes occurring in a 10 to 100years time scale.

Intermediate term prediction also estimates the statistical probability of earthquakes occurring, but in a 1 to 10 years time scale.

Short term prediction is up to a few weeks, and is focused on finding precursors.

Intermediate-term and long-term predictions are typically based on trend methods such as elastic rebound, characteristic earthquakes, seismic gaps, or seismicity patterns.

Earthquake precursor is an anomalous phenomenon for effective warning of an impending earthquake. None have been found to be reliable for the purposes of earthquake prediction

Earthquake Pre-cursor

Unusual Animal behaviour

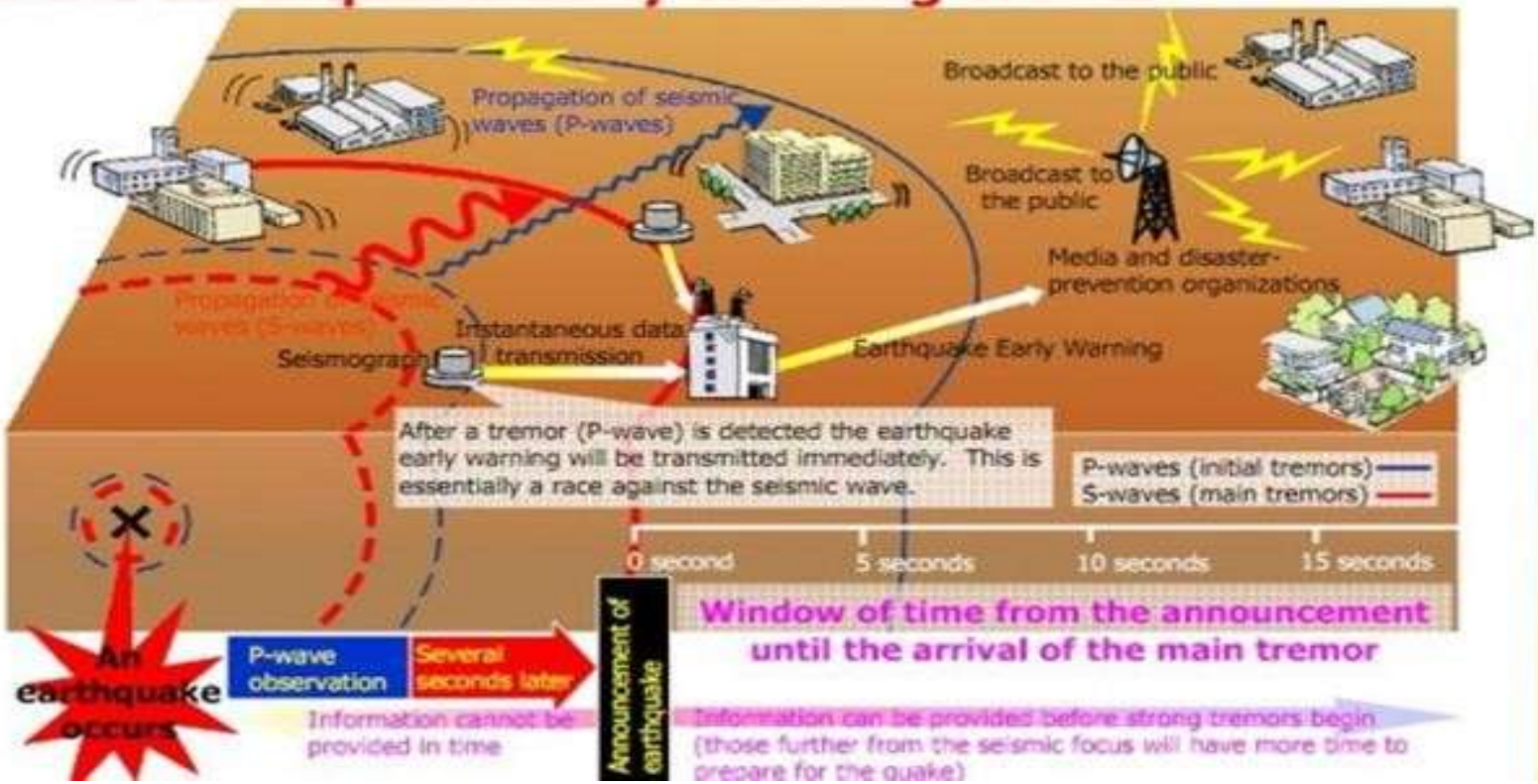
- Thousands of frogs crossed the road near earthquake area in China Hibernating animals leaving their underground nests
- Animals becomes restless, refuse to go into dens and move up to higher elevations
- Birds vacate their nest
- Deep water fish come closer to the surface and shore
- May be due to foreshock activity at magnitudes that most people do not notice. Change in the well water level
- Sudden changes in water levels. Large surface waves force particles of rock near to the surface to rise or deplete
- Water levels can be affected by any fault creeps, crust tilts, or other seismic activity

Earthquakes are predicted where they are likely to happen, but not, when they will happen and how strong they will be. The following aspects are considered:

- Micro earthquakes
- Changes in rock stress
- Ground subsidence, uplift or tilt
- Changes in magnetic field and electrical resistivity of rocks
- Animal behaviour
- Seismic history

Earthquake Early Warning: How can an earthquake alert be announced before tremors are felt?

How the Earthquake Early Warning Works



Stages of Earthquake alert information and observation (Wyss 1981)

Earthquake alert	Conditions and observations necessary
Stage 1	An approximately defined area is estimated to be more likely than surrounding seismic areas to experience a future earthquake (eg. Seismic gap or occurrence of at least one geophysical, geological or geodetic anomalous observation).
Stage 2	One or several crustal parameters show the beginning of a long to medium-term pattern of change known to have occurred before some other earthquakes. At least one of the prediction elements (location, size or time)is still poorly defined (eg. Occurrence time uncertainty is approximately equal to 50 percent of precursor time)
Stage 3	Changes in crustal parameters are observed which can be interpreted as indicating that the end of the long-term preparatory process is near (eg the anomalies return to normal). The three prediction elements are fairly well defined (eg. occurrence time uncertainty is less than about 20 percent of precursor time)
Stage 4	In addition to the conditions of stage 3,an anomaly is measured which can be interpreted as a short-term precursor. Occurrence time uncertainty may range from hours to weeks.

Safety measures based on earthquake predictions

(Savarenskij and Neresov 1978)

Period of prediction	Buildings	Material assets	Safeguards for human life	Special measures
Operative (a few hours to one or two days)	Evacuate dangerous buildings; cease activities in places of public assembly	Evacuate the most important material assets	Allocate emergency equipment in the danger area; prepare medical establishments	Cut off electricity and gas mains; shut down nuclear reactors and dangerous chemical plants
In the short term(from 2 to 4 months)	Estimate probable damages; prepare public evacuation plans	Preserve major assets	Prepare emergency measures and medical establishments	Remove or safeguard hazardous substances; lower reservoir levels, etc
In the long term (12 months)	Strengthen buildings of particular vulnerability to earthquakes		Plan emergency food stores; plan the use to be made of medical establishments	Transfer of hazardous substances to other places of storage.

Structural and Non-structural Earthquake Mitigation Measures

Mitigation would remain the key and the most effective strategy to reduce the risks of earthquake. Broadly mitigation strategies are twofold: structural and non-structural. Structural mitigation measures generally refer to capital investment on physical constructions or other development works, which include engineering measures and construction of hazard resistant and protective structures and other protective infrastructure. Non-structural measures refer to awareness and education, policies techno-legal systems and practices, training, capacity development etc. The structural and non-structural prevention/mitigation measures for the earthquake hazard are mentioned below:

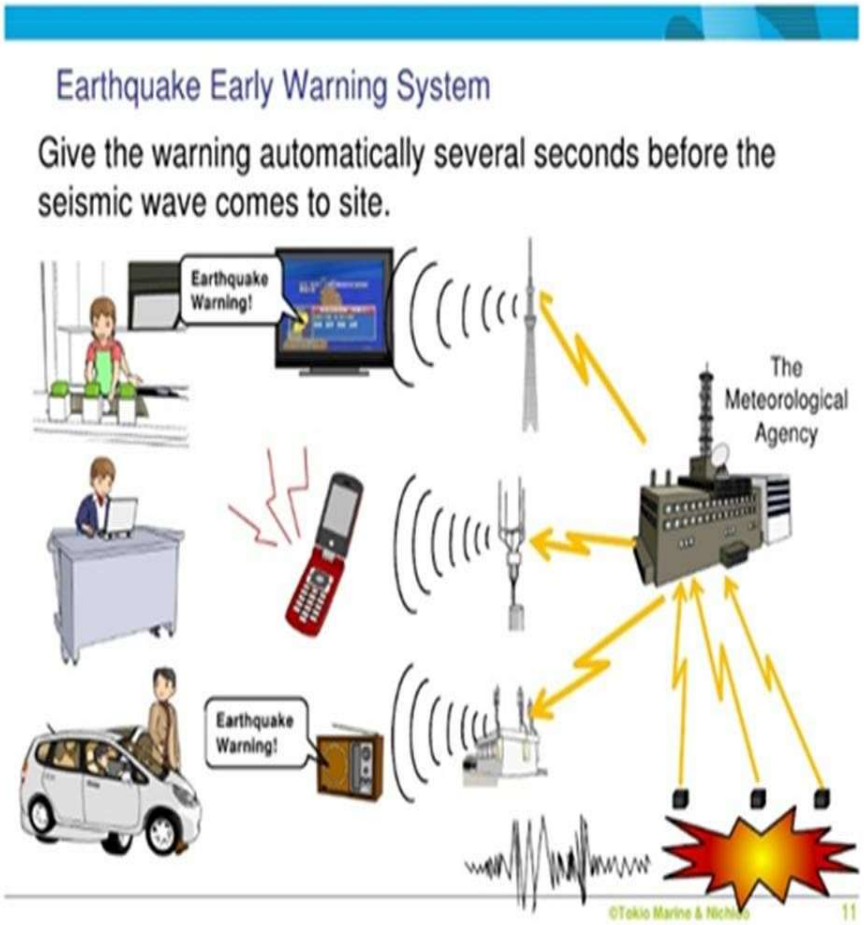
Task	Activities	Responsibility
Land Use Planning	To undertake micro-zonation study according to priority area • To provide or make available seismic micro-zonation map • Provide vulnerability and risk assessment map	• Revenue Dept. • COR • Science & Technology Dept. • ISR • SDMA
Development and Enactment of Building Codes and Standards	Enactment of building codes and construction standards • Enforcement of codes / Land use regulations o Restricting development activity in highly seismic risk zone o Shifting of economic activities to less risk areas o Compliance with land use ordinances • Amendment of Town Planning Act and development of regulations to include seismic building codes and standards • Amendment in Panchayats Act, Rules and bye-laws • Revision of General Development Control Regulations	UD & UHD Dept. • Panchayat & Rural Housing Dept • R & B Dept. • Municipal Commissioners • All line Dept.
Earthquake Resistance Design for Different Seismic Zones	To develop earthquake resistant design features for the construction of public utility structures • To develop earthquake resistant design features for the construction of residential structures • To develop and promote earthquake resistant construction in rural and semi-urban areas • To provide earthquake resistant design for incorporating in different types of structures to the line departments • To develop earthquake resistant design features for the	Revenue Dept., • COR • R & B Dept. • Panchayat & Rural Housing Dept

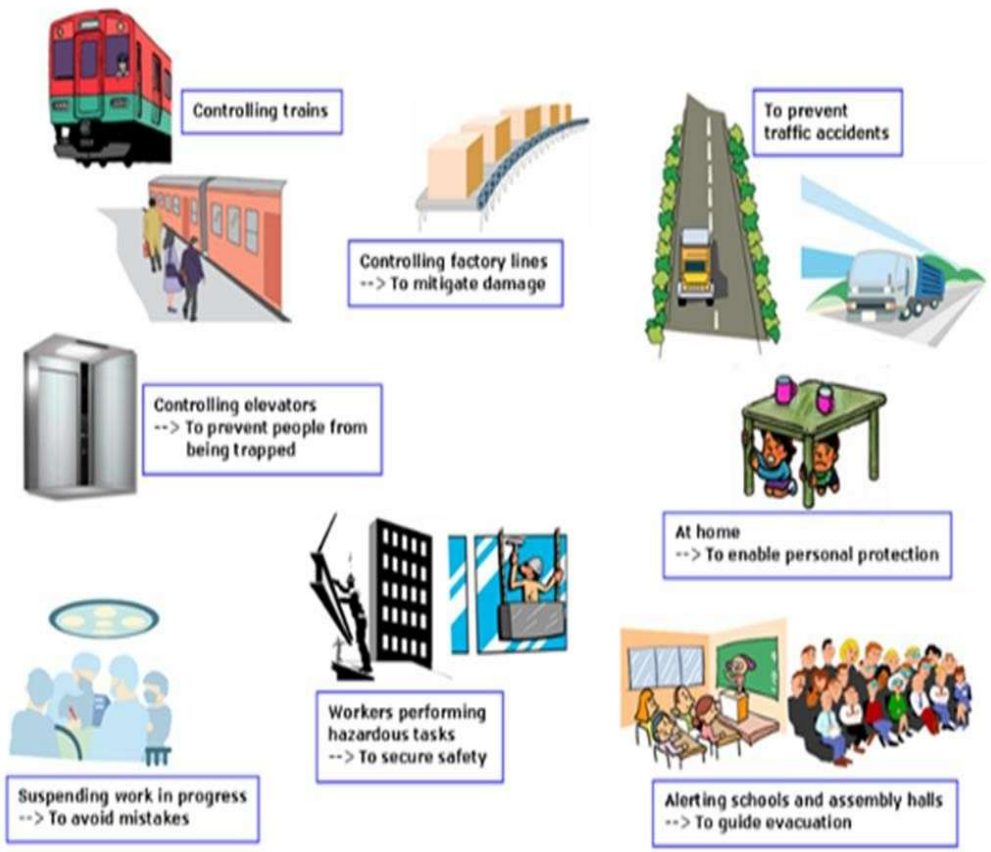
Retrofitting of Existing Structure	• Create a database of existing structure in the State o Public o Private • Identify the available resources • Identify structures that require retrofitting • Prepare a scheme/programme for retrofitting • Prioritising structures especially, critical/lifeline structures	• Revenue Dept. • R & B Dept. • UD & UHD Dept. • Panchayat & Rural Housing Dept
Removal of Unsafe Buildings	• Inventory of unsafe buildings • Identify the potential loss due to removal of building • Formulate suitable financial/assistance packages • Empowering the implementing agencies to execute the task.	• Revenue Dept • UD & UHD • Panchayats, RD & RHD Dept • Finance Dept • RD Dept • R & B Dept • Local Self Govt.
Monitoring of Seismic Activities	• Establish seismological network and round the clock monitoring • Dissemination of information and reporting • Conduct seismological research	• Science & Technology Dept. • ISR • IMD • CWC

Non-Structural Measures		
Planning	• Establish Techno-legal regime for ensuring compliance of earthquake resistant design and construction practices in all new constructions • Prepare earthquake management plan o Prepare departmental action plan and SOP for earthquake hazard o Conduct mock drills at regular intervals o Update the plan as per the requirement o Monitor similar activities at district & taluka level	• Revenue Dept. • COR • All line depts. • Dist. Collectors • Municipal Commissioners • Disaster Mamlatdar
Capacity Building	• Develop earthquake hazard IEC materials for Publication & Distribution • Organize training programmes, seminars and workshops • Include disaster related topics in School and college curriculum • Encourage favourable taxation/ incentive • Development of Rapid Visual Screening procedures and Detailed Vulnerability Assessment	• Revenue Dept. • COR • GSDMA/GIDM • Information Dept. • Education Dept. • Finance Dept./ UD & UHD Dept./Panchayat & Rural Housing Dept.
Awareness	• To disseminate earthquake risk to general public residing in earthquake prone zones • Media campaign for awareness generation in general public	• SDMA • Information Dept.
Community Based Disaster Management	• Strengthening capacity of local self government entities to understand local vulnerability and risk, earthquake prevention needs, preparedness and response capabilities through participatory approach	• Revenue Dept. • COR • GSDMA • UD & UHD Dept./Panchayat & Rural Housing Dept.
Encourage Earthquake Engineering	• Include earthquake engineering topics in curriculum • Provide professional training about earthquake resistance construction to engineers and architects • Provide training to masons • Encourage soil and material testing in laboratories	• Education Dept. • GIDM • R & B Dept. • GSDMA • UD & UHD Dept. Science & Tech. Dept.
Safety Audits	Carrying out structural safety audit of all critical lifeline structures • Regular conduction of Fire Safety Audits and Electrical Safety Audits • Licensing and certification of professionals	• Revenue Dept., • R & B Dept. • UD & UHD Dept • Panchayat & Rural Housing Dept. • Other line Dept.

Earthquake early warning systems

- use developments in science and technology in monitoring earthquake and alert people when shaking waves generated by an earthquake are expected to arrive at a location.
- seconds to minutes of advance warning information allow people and systems to protective actions in protecting life and property from destructive shaking




Controlling trains
Controlling factory lines
--> To mitigate damage
To prevent
traffic accidents
Controlling elevators
--> To prevent people from
being trapped
At home
--> To enable personal protection
Workers performing
hazardous tasks
--> To secure safety
Suspending work in progress
--> To avoid mistakes
Alerting schools and assembly halls
--> To guide evacuation

Steps For Earthquake Preparedness
1
Identifiy potential hazards in your home and begin to fix them!
2
Create a disaster preparedness plan.
3
Prepare disaster supply kits.
4
Identify your building's potential weaknesses and begin to fix them.
5
Protecing yourself during earthquake shaking—DROP, COVER AND HOLD ON
6
After the earthquake, check for for injuries and damage.
7
When safe, continue to follow your disaster preparedness plan.

What to do during an earthquake
DROP!
COVER!
HOLD ON!
CALM DOWN
Try to stay as calm as possible
INSIDE
Stay away from furniture, windows and lamps
OUTSIDE
Stay away from buildings, walls and power poles
STOP
If you are driving stop in a safe place, turn on the hazard lights and stay inside the vehicle
If you use a wheelchair, put the brakes on in a safe place and protect your head with your arms
If you are in a crowded place protect your head with your arms or take cover under seats and tables

CALM DOWN
Try to stay as calm as possible
INSIDE
Stay away from furniture, windows and lamps
OUTSIDE
Stay away from buildings, walls and power poles

What to do after an earthquake
TURN OFF
water, electricity and gas
USE
the stairs
DO NOT USE
elevators
PUT OUT
any fire
LIGHT
with flashlights, not fire
DO NOT ENTER
damaged buildings
If you are trapped
Cover your mouth and nose; don't shout because you can suffocate in the dust. Hit with an object to show your position
Injured people
Do not move seriously injured people unless they are in imminent danger of being harmed
Be alert to the possible aftershocks that might occur
Do not use the phone unless absolutely necessary
Pay attention only to information from the authorities

Tsunami

- A tsunami is a series of great sea waves caused by an underwater earthquake, landslide, or volcanic eruption. More rarely, a tsunami can be generated by a giant meteor impact with the ocean.

• Tsunami (pronounced soo-NAH-mee) is a Japanese word. Tsunamis are fairly common in Japan, and many thousands of Japanese have been killed by them in recent centuries.

• An earthquake generates a tsunami if it is of sufficient force and there is violent movement of the earth to cause substantial and sudden displacement of a massive amount of water.

• A tsunami is not a single wave but a series of waves, also known as a wave train. The first wave in a tsunami is not necessarily the most destructive. Tsunamis are not tidal waves.

•

- Tsunami waves can be very long (as much as 60 miles, or 100 kilometers) and be as far as one hour apart.
- They are able to cross entire oceans without great loss of energy. The Indian Ocean tsunami traveled as much as 3,000 miles (nearly 5,000 kilometers) to Africa, arriving with sufficient force to kill people and destroy property.

• Where the ocean is deep, tsunamis can travel unnoticed on the surface at speeds up to 500 miles an hour (800 kilometers an hour), crossing an ocean in a day or less. Scientists are able to calculate arrival times of tsunamis in different parts of the world based on their knowledge of water depths, distances, and when the event that generated them occurred

Tsunami

Volcanic eruptions and earthquakes disrupt the land and water surfaces. The short duration impacts over the water column along with on-going wind induced events result in major disaster.

- A series of large waves of extremely long wavelength and period is usually generated by a violent, impulsive undersea disturbance or activity near the coast or in the ocean is termed as Tsunami.
- Generated by non seismic disturbances such as volcanic eruptions or underwater landslides
- Tsunamis waves have a small amplitude (wave height) at offshore and a very long wavelength (hundreds of (km.). Normal ocean waves have a wavelength of 30 or 40 meter

Definition (Tsunami)

- A tsunami is a chain of long waves caused by a sudden displacement of the ocean's surface, usually caused by an earthquake, large volcanic eruptions, meteorite impact and more. Tsunami usually causes extensive damage to the natural environment as well as to human life.

- Perhaps the most recent and the most destructive example of a Tsunami in India was the Indian Ocean Tsunami of 2004. It caused major destruction and loss of life in the southern parts of India. It is still remembered as one of the biggest natural disasters that have ever occurred in our country.

Causes of tsunami

i) high magnitude (Richter scale) earthquakes of submarine origin

ii) landslides entering into seas

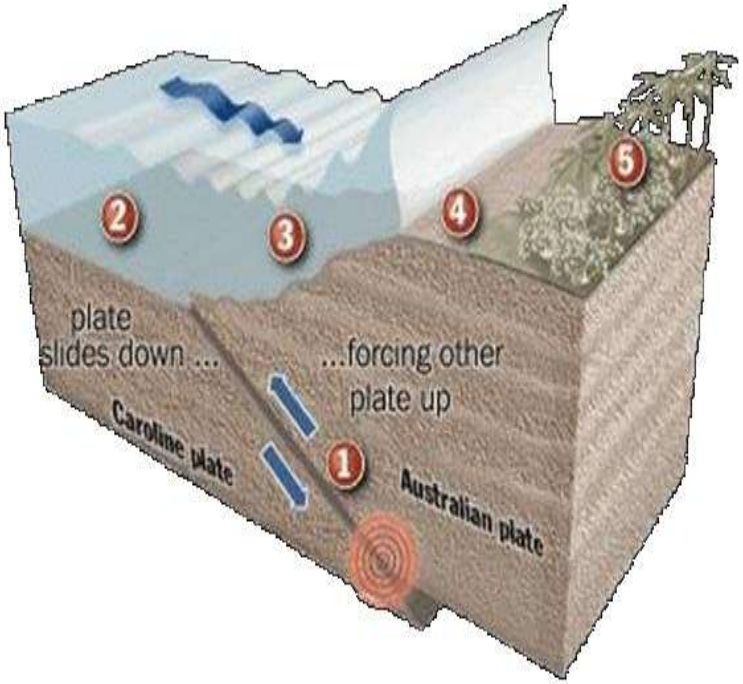
iii) After effects of volcanic eruption and its debris

iv) impact of meteorites/asteroids in oceanic areas

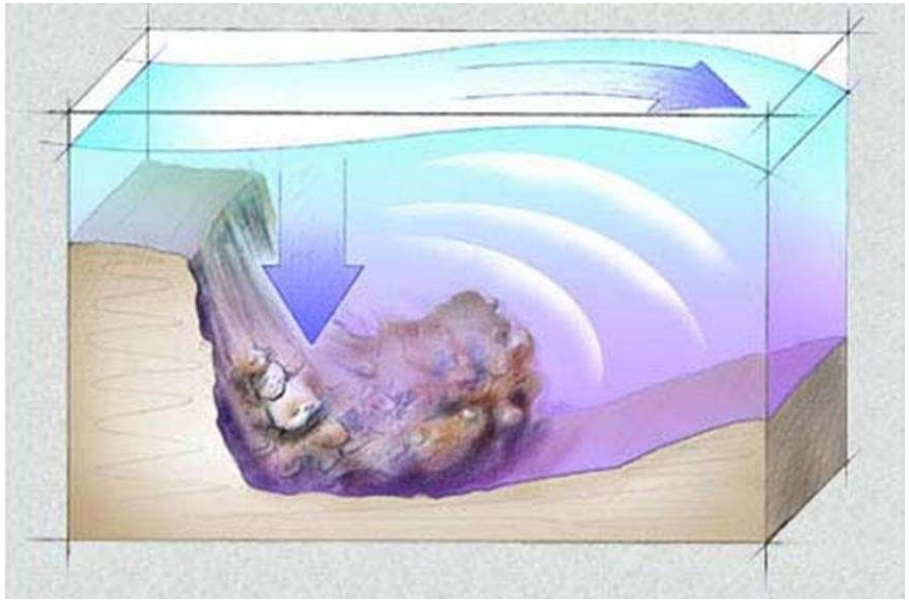
v) atmospheric/weather factors leading to severe cyclones.

- Undersea earthquakes occur at boundaries between Earth's tectonic plates, cause the water above to be moved up or down. The displaced wateracts under the influence of gravity, attemptsto find a stable position again.
- Undersea landslides is triggered by large earthquakes can also cause tsunami waves.
- Undersea volcano eruptions create enough force to uplift the water column and generate a tsunami.
- Asteroid impacts disturb the water from above, as momentum from falling debris is transferred to the water into which the debris falls.

Tsunami wave generated from the plate movement



Underwater landslide



Characteristics of tsunami

i) Tsunami wave heights range from 1 to 524m

ii) wave length 500 to 800 km

iii) wave periods 1.6 to 3.3 meter with values ranging from 40-80 m

iv) Tsunamis with long periods of 15 to 100m and with travel speed of

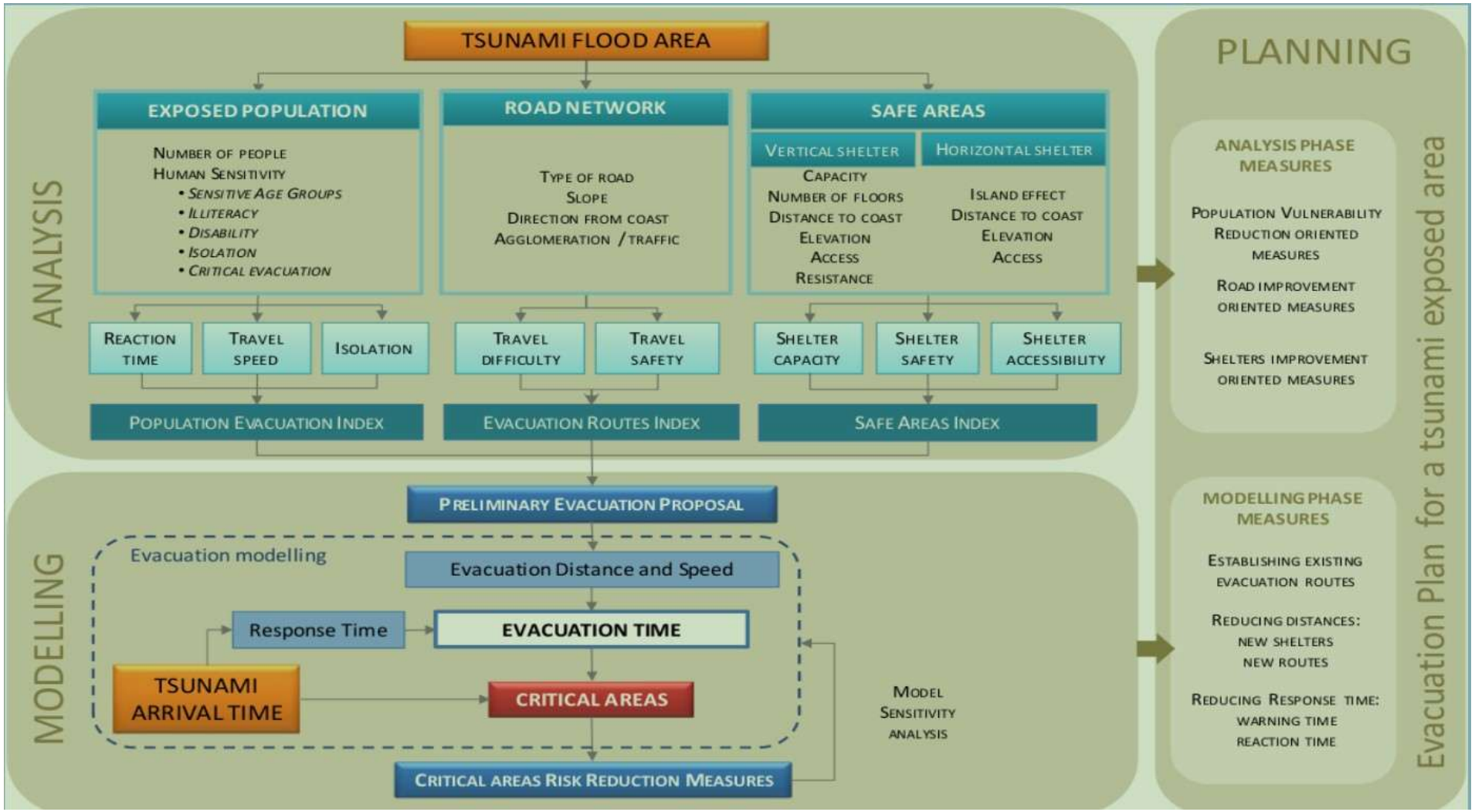
828 km^{-1} in Pacific ocean (1987)

v) Indian ocean tsunami (2004) waves traveled upto 800 km^{-1} in open ocean (Shanmugam 2008).

Location	Percentage
Atlantic east coast	1.60%
Mediterranean	10.10%
Bay of Bengal	0.80%
East Indies	20.30%
Pacific ocean	25.40%
Japan and Russia	18.60%
Pacific east coast	8.90%
Caribbean	13.80%
Atlantic west coast	0.40%

Intensity scale for Tsunami damage assessment (Soloviev (1978)

Intensity	Run-up height (m)	Description	Frequency in Pacific
I	0.5	**Very slight** –Weak waves to be detected by tide gauges only	
II	1	**Slight** – Wave noticed only by people living along on the flat shore.	One / 4 months
III	1	**Rather Large** – Generally noticed. Generally noticed. Flooding of gently sloping coastal areas. Light sailing vessels are carried onto the shore. Slight damage to light structures located nearer to the coast. Reversal of river flow in estuaries.	
IV	4	**Large** – Flooding of the shore to some depth. Light scouring on made grounds. Embankments and dykes damaged. Slight damage to solid structures. Large sailing vessels and ships swept inland or carried onto the sea. Floating debris on the coast.	One / year
V	8	**Very large** General flooding of shore to some depth. Damage to Quays and heavy structures near the sea. Destruction of light structures. Severe scouring of shore and extensive littering of debris and sea living animals. All sea-going vessels are carried onto the shore except large vessels. Large bores in estuaries. Damaged harbor and people and animal are dragged onto the sea by strong roaring waves.	One / 3 yrs.
> VI	16	**Disastrous** – Significant destruction of manmade structures upto considerable distance. Flooding of coast to great depths. Severe damage to large ship, up-rooted or broken trees and major causalities..	One /10 yrs


TSUNAMI FLOOD AREA
ANALYSIS
EXPOSED POPULATION
Number of people
Human Sensitivity
• Sensitive Age Groups
• Illiteracy
• Disability
• Isolation
• Critical evacuation
ROAD NETWORK
Type of road
Slope
Direction from coast
Agglomeration / traffic
SAFE AREAS
Vertical shelter
Capacity
Number of floors
Distance to coast
Elevation
Access
Resistance
Horizontal shelter
Island effect
Distance to coast
Elevation
Access
Reaction time
Travel speed
Isolation
Travel difficulty
Travel safety
Shelter capacity
Shelter safety
Shelter accessibility
Population Evacuation Index
Evacuation Routes Index
Safe Areas Index
MODELLING
Preliminary Evacuation Proposal
Evacuation modelling
Evacuation Distance and Speed
Response Time
EVACUATION TIME
TSUNAMI ARRIVAL TIME
CRITICAL AREAS
Model Sensitivity analysis
Critical areas Risk Reduction Measures
PLANNING
Analysis phase measures
Population Vulnerability Reduction oriented measures
Road improvement oriented measures
Shelters improvement oriented measures
Modelling phase measures
Establishing existing evacuation routes
Reducing distances: new shelters new routes
Reducing Response time: warning time reaction time
Evacuation Plan for a tsunami exposed area

Questions based on Tsunami

- Q1What is the biggest tsunami ever recorded?

Ans: World's Biggest Tsunami: The largest recorded tsunami with a wave 1720 feet tall in Lituya Bay, Alaska

- Q2: How tsunamis are caused?

Ans: A tsunami is a series of large waves generated by an abrupt movement on the ocean floor that can result from an earthquake, an underwater landslide, a volcanic eruption or - very rarely - a large meteorite strike. However, powerful undersea earthquakes are responsible for most tsunamis

- Q3 What are the 4 main causes of tsunamis?

Ans: Some of the major reasons for formation of tsunamis are as follows:

• (i)Undersea earthquakes •(ii) Landslides •(iii) Volcanic Eruptions •(iv) Meteorites and Asteroids

- Q4: Why are tsunamis so dangerous?

Ans: Very large tsunamis can cause damage to coastal regions thousands of miles away from the earthquake that caused them. Beaches, lagoons, bays, estuaries, tidal flats and river mouths are the most dangerous places to be. It is rare for a tsunami to penetrate more than a mile inland.

- Q5: How bad are tsunamis?

Ans: A tsunami is a series of ocean waves caused by an underwater earthquake, landslide, or volcanic eruption. More rarely, a tsunami can be generated by a giant meteor impact with the ocean. These waves can reach heights of over 100 ft. About 80% of tsunamis happen within the Pacific Ocean's “Ring of Fire”

- Q6: How can tsunami be controlled?

Ans: 1. Avoid building or living in buildings within several hundred feet of the coastline. ...

- 2. If you do live in a coastal area, elevate your home to help reduce damage. ...
- 3. Take precautions to prevent flooding.
- 4. Have an engineer check your home and advise about ways to make it more resistant to tsunami water.

Q7: Write some steps for Tsunami Preparedness

- Ans: Tsunamis are large ocean waves generated by major earthquakes beneath the ocean floor or major landslides into the ocean. Rising to several feet or higher, they can strike the coast with devastating force. People on beaches or in low coastal areas, such as estuaries and rivers, need to be aware that a tsunami could arrive within minutes of a severe earthquake –and the danger period can continue for many hours. Tsunamis can occur any time of year, day or night.
- To escape a tsunami, go as high and as far as you can – ideally to a spot 100 feet above sea level or 2 miles away.
- Every foot inland or upward may make a difference!
- If you can see the wave, you are too close for safety

CYCLONES

- Why in news
- In the year 2020, Cyclone Amphan (pronounced as UM-PUN) formed over Bay of Bengal intensified and turned into a “super cyclonic storm” , the second super cyclone since 1999.
- In another incident Mumbai has been hit by a cyclone (Cyclone Nisarga) after a gap of 129 years.

Introduction

- Cyclones are rapid inward air circulation around a low-pressure area. The air circulates in an anticlockwise direction in the Northern hemisphere and clockwise in the Southern hemisphere.
- Cyclones are usually accompanied by violent storms and bad weather.
- The word Cyclone is derived from the Greek word Cyclos meaning the coils of a snake. It was coined by Henry Peddington because the tropical storms in the Bay of Bengal and the Arabian Sea appear like coiled serpents of the sea.

- **Classification**

There are two types of cyclones:

- Tropical cyclones; and
- Extra Tropical cyclones (also called Temperate cyclones or middle latitude cyclones or Frontal cyclones or Wave Cyclones).
- The World Meteorological Organisation uses the term 'Tropical Cyclone’ to cover weather systems in which winds exceed ‘Gale Force’ (minimum of 63 km per hour).
- Tropical cyclones develop in the region between the Tropics of Capricorn and Cancer. They are large-scale weather systems developing over tropical or subtropical waters, where they get organized into surface wind circulation.
- Extra tropical cyclones occur in temperate zones and high latitude regions, though they are known to originate in the Polar Regions

Table: Pattern of Wind Direction in Cyclones and Anticyclones

Pressure system	Pressure condition at the center	Pattern of Wind Direction	
		Northern Hemisphere	
Cyclone	**Low**	Anticlockwise	clockwise
Anticyclone	High	clockwise	Anticlockwise

- Anticyclones
- An anticyclone is the opposite of a cyclone i.e. i.e., it has an outward-spiralling air circulation around a high pressure centre.
- An anticyclone's winds rotate clockwise in the Northern Hemisphere around a center of high pressure.
- In anticyclones, air comes in from above and sinks to the ground. High pressure centers generally have fair weather.

Tropical Cyclones

- Tropical cyclones are violent storms that originate over oceans in tropical areas and move over to the coastal areas bringing about large scale destruction caused by violent winds, very heavy rainfall and storm surges.
- Tropical Cyclones are one of the most devastating natural calamities in the world.
- Tropical cyclones originate and intensify over warm tropical oceans. The conditions favourable for the formation and intensification of tropical storms are:
- Large sea surface with temperature higher than 27° C.
- Presence of the Coriolis force.
- Small variations in the vertical wind speed.
- A pre-existing weak low- pressure area or low-level-cyclonic circulation.
- Upper divergence above the sea level system

Stages of Formation: Tropical Cyclones

The development cycle of tropical cyclones may be divided into three stages:

- Formation and Initial Development Stage
- The formation and initial development of a cyclonic storm depends upon the transfer of water vapour and heat from the warm ocean to the overlying air, primarily by evaporation from the sea surface.
- It encourages formation of massive vertical cumulus clouds due to convection with condensation of rising air above the ocean surface.

Mature Stage

- When a tropical storm intensifies, the air rises in vigorous thunderstorms and tends to spread out horizontally at the tropopause level. Once air spreads out, a positive pressure at high levels is produced, which accelerates the downward motion of air due to convection.
- With the inducement of subsidence, air warms up by compression and a warm 'Eye' (Low pressure centre) is generated. The main physical feature of a mature tropical cyclone in the Indian Ocean is a concentric pattern of highly turbulent giant cumulus thundercloud bands.

Modification and Decay

- A tropical cyclone begins to weaken in terms of its central low pressure, internal warmth and extremely high speeds, as soon as its source of warm moist air begins to ebb or is abruptly cut off.
- This happens after its landfall or when it passes over cold waters.

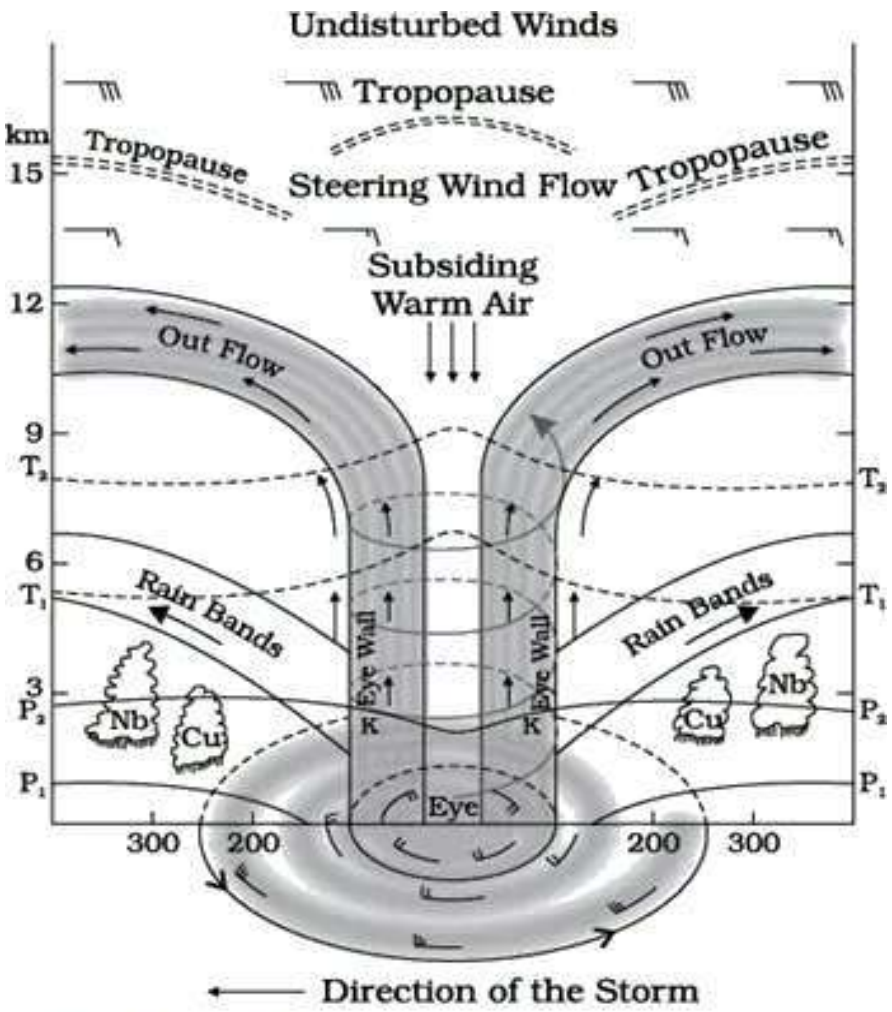


Fig: Vertical section of the tropical cyclone

- Nomenclature of Tropical Cyclones
- The naming of tropical cyclones is a recent phenomenon. The process of naming cyclones involves several countries in the region and is done under the aegis of the World

Meteorological Organization (WMO).

- For the Indian Ocean region, a formula for naming cyclones was agreed upon in 2004. Eight countries in the region - Bangladesh, India, Maldives, Myanmar, Oman, Pakistan, Sri Lanka and Thailand - all contributed a set of names which are assigned sequentially whenever a cyclonic storm develops.
- Hudhud, Titli, Phethai, Fani, Vayu and Amphan are among the names of cyclones in the Indian Ocean region.

Worldwide Terminology of Tropical Cyclones

- They are given many names in different regions of the world – eg.they are known as Typhoons in the China Sea and Pacific Ocean; Hurricanes in the West Indian islands in the Caribbean Sea and Atlantic Ocean; Tornados in the Guinea lands of West Africa and southern USA.; Willywillies in north-western Australia and Tropical Cyclones in the Indian Ocean.

- **Extratropical Cyclone**
- Extratropical cyclones are referred to as mid-latitude depressions, temperate cyclones, frontal depressions and wave cyclones.
- These are active above the mid-latitudinal region between 35° and 65° latitude in both the hemispheres. The direction of movement is from west to east and more pronounced in the winter seasons. It is in these latitude zones the polar and tropical air masses meet and form fronts
- **Formation of Extratropical Cyclones**
- The origin and development of temperate cyclones is best explained by the Polar Front theory.
- According to this theory, the warm-humid air masses from the tropics meet the dry-cold air masses from the poles and thus a polar front is formed.
- The cold air mass is denser and heavier and due to this reason, warm air mass is pushed up.
- This interaction of cold and warm air masses creates instability and a low pressure is created at the junction particularly in the center of interactions.
- Thus, a void is created because of lessening of pressure. The surrounding air rushed in to occupy this void and coupled with the earth's rotation a cyclone is formed.
- Extratropical cyclones present a contrast to the more violent cyclones or hurricanes of the tropics, which form in regions of relatively uniform temperatures.

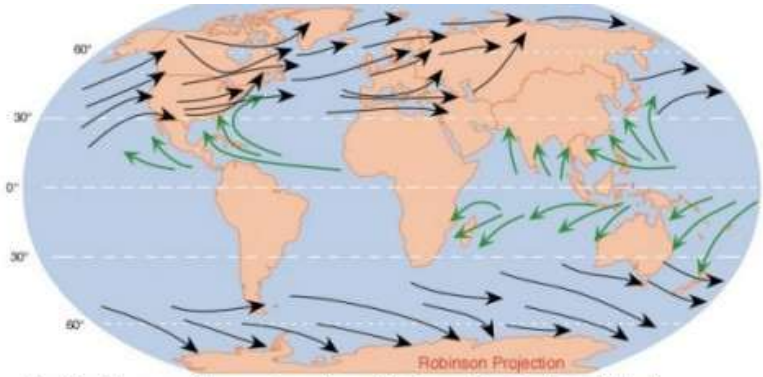


Fig: Principle areas of Temperate cyclones (Black arrow lines) and Tropical cyclones (Green arrow lines)

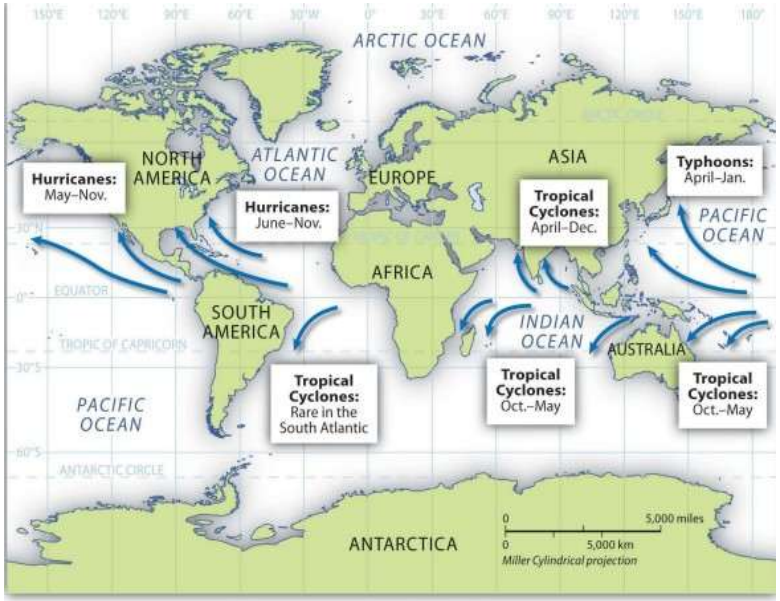


Fig: Distribution of cyclones in tropical regions.

- **Air Mass**
- Air Mass is an extremely large body of air whose properties of temperature and moisture content (humidity), at any given altitude, are fairly similar.
- It can cover hundreds of thousands of square miles of area.
- It may have only a little horizontal variation in temperature and moisture throughout the air mass.
- When an air mass remains over a homogenous area for a sufficiently longer time, it acquires the characteristics of the area. The homogenous regions can be the vast ocean surface or vast plains.
- **Fronts**
- When two different air masses (having distinctly different properties) meet, the boundary zone between them is called a front.
- There are four types of fronts:
- Stationary front: When the front remains stationary, it is called a stationary front.
- Cold front: When the cold air moves towards the warm air mass, its contact zone is called the cold front,
- Warm front: If the warm air mass moves towards the cold air mass, the contact zone is a warm front.
- Occluded front: If an air mass is fully lifted above the land surface, it is called the occluded front.
- The fronts occur in middle latitudes and are characterised by steep gradient in temperature and pressure. They bring abrupt changes in temperature and cause the air to rise to form clouds and cause precipitation

- **Cyclones in India**
- Tropical Cyclones
- Tropical cyclones originate over the Bay of Bengal, Arabian Sea and the Indian ocean. These tropical cyclones have very high wind velocity and heavy rainfall and hit the Indian Coastal states of Tamil Nadu, Andhra Pradesh, West Bengal,Odisha and Gujarat (These five states are more vulnerable to cyclone disasters than others in India).
- Most of these cyclones are very destructive due to high wind velocity and torrential rain that accompanies it.
- There are three elements associated with cyclones which cause destruction during its occurrence.
- These are
- Strong Winds/Squall: It damages installations, dwellings, communications systems, trees etc., resulting in loss of life and property.
- Torrential rains and inland flooding: Rain is a serious problem for the people who become shelter less due to the cyclone. Heavy rainfall is usually spread over a wide area and causes large scale soil erosion and weakening of embankments.
- Storm Surge: It is an abnormal rise of sea level near the coast caused by a severe tropical cyclone. Due to storm surge sea water inundates low lying areas of coastal regions drowning human beings and livestock, causes eroding beaches and embankments, destroys vegetation and leads to reduction of soil fertility.

Management of Cyclones

- There are many structural and non-structural measures for effective disaster management of cyclones.
- The structural measures include construction of cyclone shelters, construction of cyclone resistant buildings, road links, culverts, bridges, canals, drains, saline embankments, surface water tanks, communication and power transmission networks etc.
- Non-structural measures like early warning dissemination systems, management of coastal zones, awareness generation and disaster risk management and capacity building of all the stakeholders involved.
- These measures are being adopted and tackled on a State to State basis under the National Cyclone Risk Mitigation Project (NCRMP) being implemented through World Bank Assistance.

Landslide

- Definition: landslide may be defined as a process involving the downward and outward movement of a part of the slope forming material due to the action of gravity, other forms of mass movements like falls, flows, topples and creeps are generally included in the term landslides. This document also considers snow avalanches as within the ambit of landslide management.

- **Historical background:**

- Landslides form a significant component of the natural disasters that affect most of the hilly regions round the globe.
- Recent studies on global landslide disasters indicate that some of the highest risk landslide disaster zones are located in Colombia, Tajikistan, India, China, and Nepal where the estimated number of people killed per year per 100 sq. km area was found to be more than one.
- Historical records indicate that the highest number of lives lost to a single landslide event were in the earthquake-triggered landslide disaster in Kansu Province of China in1920.
- Landslide event of the last century was an earthquake-triggered debris avalanche in 1970 on the slopes of Mt. Huascaran, Peru, which advanced with an average speed of 320 km/hr, burying the towns of Yungay and Ranrahirca, killing more than 18,000 people. Similarly, in Europe, the 1963 Vaiont reservoir slide in North-Eastern Italy, resulted in the death of 2,000 people.

Landslide

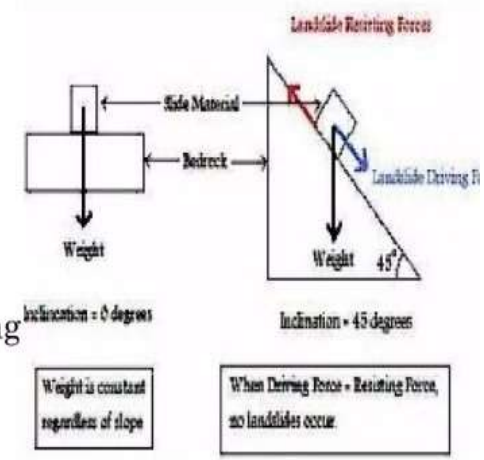
INTRODUCTION

- A landslide is a downward or outward movement of soil, rock or vegetation, under the influence of gravity.

- Factor of Safety(F):

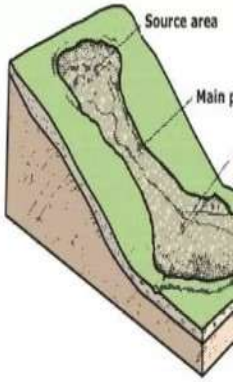
$$F = \frac{\text{Resisting Force(R)}}{\text{Driving Force(D)}}$$

When, F< 1 = landslide occur



- Resisting forces(R) preventing the mass from sliding down the slope are inversely proportional to the same hill slope angle and directly proportional to the friction angle of the material.

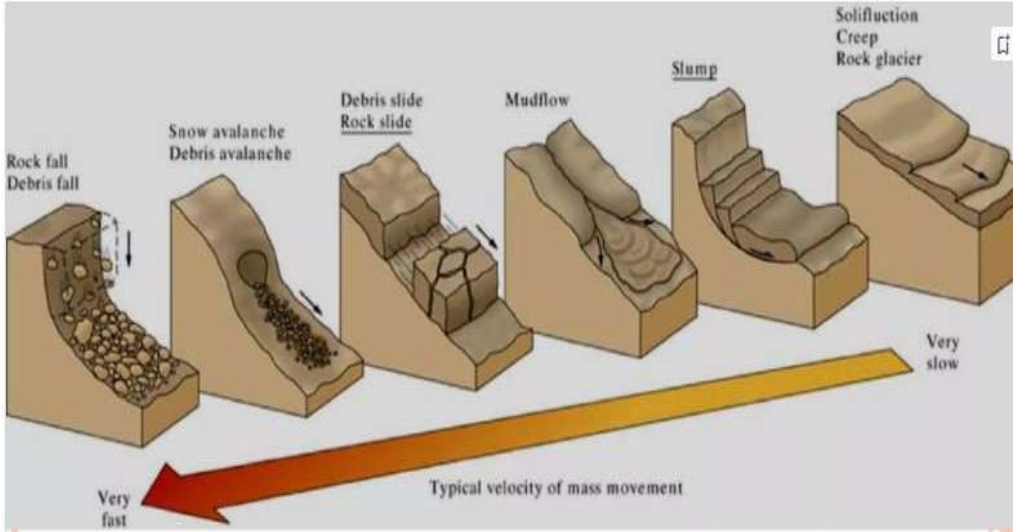
- In addition, the resisting forces can be significantly reduced in case of rain or earthquake vibrations.



- Three distinct physical events occur during a landslide: the initial slope failure, the subsequent transport, and the final deposition of the slide materials.

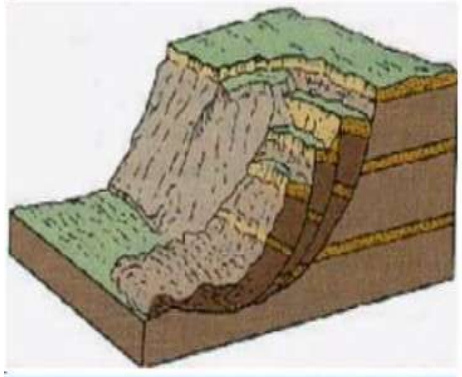
- **Types of landslide**:

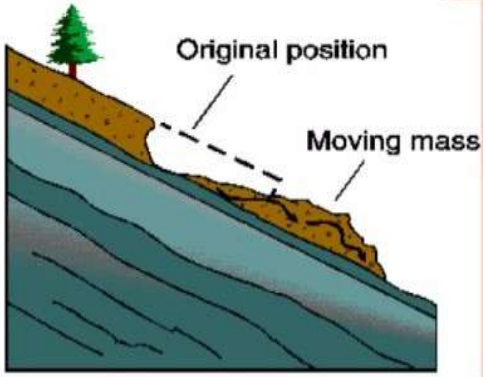
TYPES OF MOVEMENT		TYPES OF MATERIAL		
		Bedrock	Soils	
			Coarse Grained Soil	Fine Grained Soil
Falls		Rock fall	Debris fall	Earth fall
Topples		Rock topple	Debris topple	Earth topple
Slides	Rotational	Rock slide	Debris slide	Earth slide
	Translational			
Lateral spreads		Rock spread	Debris spread	Earth spread
Flows		Rock flow	Debris flow	Earth flow
Complex: Combination of two or more types of movement				



- The speed of the movement may range from very slow to rapid.
- The speed of the landslide will make an even more or less avoidable and therefore, more or less risky.
- It is important to distinguish the different types of landslides to be able to understand how to deal with each of them.

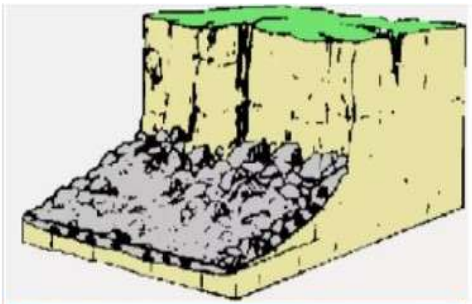
COMMON TYPES OF LANDSLIDES



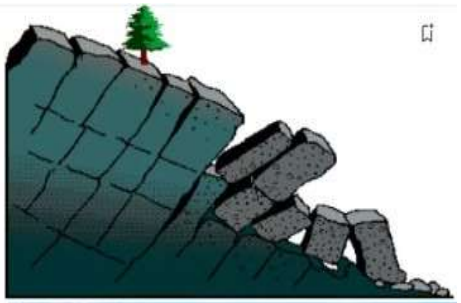


a) Rotational slides move along a surface of rupture that is curved and concave.

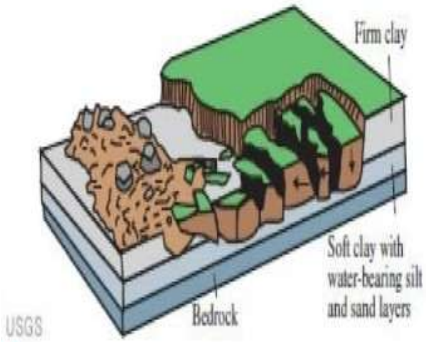
b) Translational slides occurs when the failure surface is approximately flat or slightly undulated



c) Rock Fall:
Free falling of detached bodies of bedrock (boulders) from a cliff or steep slope



d) **Rock toppling** occurs when one or more rock units rotate about their base and Collapse.



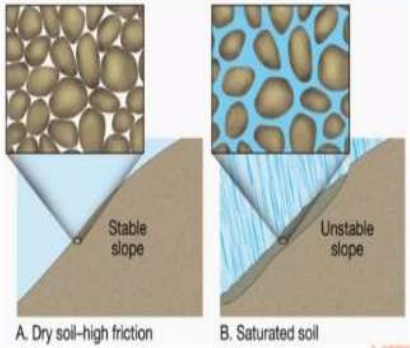
e) **Lateral spreading** occurs when the soil mass spreads laterally and this spreading comes with tensional cracks in the soil mass.

f) **Debris Flow:**
Down slope movement of collapsed, unconsolidated material typically along a stream channel.

CAUSES OF LANDSLIDES

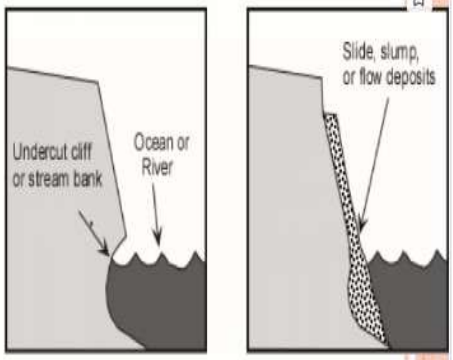
A) **Natural Factors:**

- **Gravity:** Gravity works more effectively on steeper slopes.
- **Geological factors:** Geology setting that places permeable sands and gravels above impermeable layers of silt and clay or bedrock.

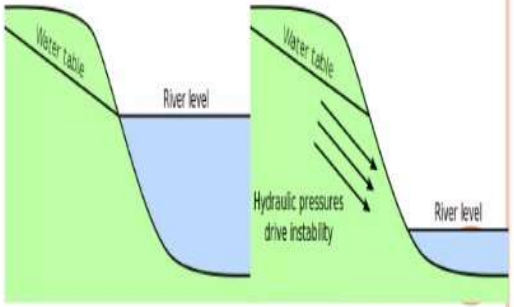


- **Heavy and prolonged rainfall:** slides occur often with intense rain by creating zone of weakness, also water tables rise with heavy rain makes some slopes unstable.
- **Earthquakes:** Ground vibrations created during Earthquakes.

- **Waves:** Wave action can erode the beach or the toe of a bluff, cutting into the slope, and setting the stage for future slides.



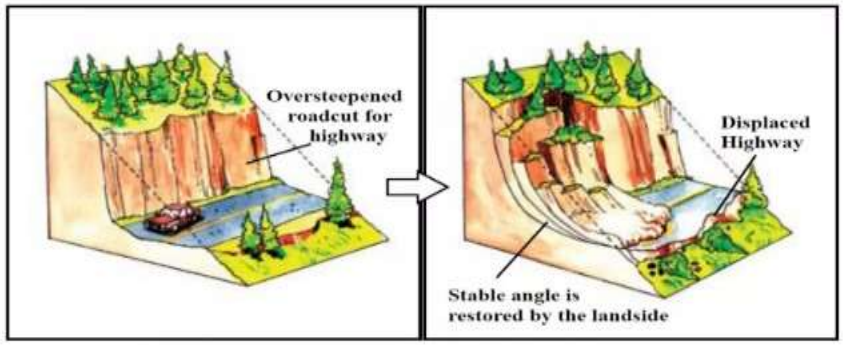
- **Volcanoes:** volcanic ash deposits (sometimes called as lahars deposits) are prone to erosion and subjected to mud flows due to intense rainfall.
- Fluctuation of water levels due to the tidal action.
- Deposition of loose sediments in delta areas.



B) **Anthropogenic Factors:**

- **Inappropriate drainage system:** Surface runoff of irrigated water on slopes exposes soil under cultivation to erosion. Part of this water is absorbed by soil increasing its weight, which can put an additional load on the slope.
- **Cutting & deep excavations on slopes for buildings, roads, canals & mining:**

causes modification of natural slopes, blocking of surface drainage, loading of critical slopes and withdrawal to toe support promoting vulnerability of



- **Change in slope/land use pattern, deforestation, agricultural practices on steep slopes:** contributed to creep and withdrawal of toe support in many cases.

C) **Combination of factors:**

- For example, an earthquake may trigger a landslide, which in turn may dam a valley causing upstream flooding and subsequent dam burst. This will lead to flooding in lower catchments areas.

EFFECTS AND LOSSES DUE TO LANDSLIDES

A) **Direct Effects:**

- Physical Damage-Debris may block roads, supply lines (telecommunication, electricity, water, etc.) and waterways.
- Causalities- deaths and injuries to people and animals.

B) **Indirect Effects:**

- **Influence of landslides in dam safety-** failure of the slopes bordering the reservoir, Flooding caused by movements of large masses of soil into the reservoir.
- **Landslides and flooding-** Debris flow can cause flooding by blocking valleys and stream channels, forcing large amounts of water to backup causing backup/ flash flood.

C) **Direct losses:**

- Loss of life, property, infrastructure and lifeline facilities, Resources, farmland and places of cultural importance.

D) **Indirect losses:**

- Loss in productivity of agricultural or forest lands, Reduced property values, Loss of revenue, Increased cost, Adverse effect on water quality and Loss of human productivity,

INDICATORS OF LANDSLIDES PHENOMENON

A) **Terrain/Morphologic Features Indicating Risk of a Landslide-**

- **Steep slopes:** slope with angles over 30 degrees should be avoided if possible.
- **Old landslides sites:** the old landslide can be reactivated, for example, by heavy rainfall or an earthquake.
- **New cracks** or unusual bulges in the ground or street pavements.

B) **Landslide Risk Indicators:**

- Tilting or cracking of concrete floors and foundations.
- Soil moving away from foundations.
- Broken water lines and other underground utilities.
- Leaning telephone poles, trees, retaining walls, or fences.
- Rapid increase in ground water levels, possibly accompanied by increased turbidity (soil content).
- Sticking doors and windows, and visible open spaces indicating jambs.
- Sudden decrease in ground water levels though rain is still falling or just recently stopped.

How to minimize the landslide hazard

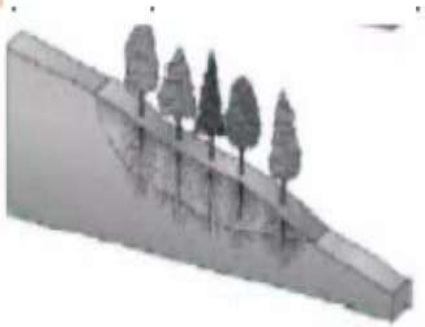
A) Passive Intervention

- Choose a safe location to build your home, away from steep slopes and places where landslides have occurred in the past.
- Prevent deforestation and vegetation removal.
- Avoid weakening the slope.

B) **Active Preventive Intervention**

- **Reforestation:** Root systems bind materials together and plants do both prevent water percolation and take water up out of the slope.
- **Proper water** runoff must be ensured by providing a proper canalization network.
- **Drainage:** good ground drainage is essential to prevent saturation and consequent weakening. Drainage is also needed in civil work, like retaining walls.

- **Proper land use measures:** Adopt effective land-use regulations and building codes based on scientific research.
- **Structural measures:** Nets, Retaining walls and major civil works to mitigate landslides. (Bioengineering).



C) **Non- Structural measures:**

- **Awareness generation:** Educate the public about signs that a landslide is imminent so that personal safety measures may be taken.
- **Financial Mechanisms:** Support the establishment of landslide insurance.
- **Legal and Policy:** legislation to direct a governmental or private program to reduce landslide losses should be strengthened.

D) **Landslide Hazard Mapping and Use of GIS:**

- Landslide Hazard Zonation of the Vulnerable Areas.
- Use of remote sensing and ground truth data for making landslide hazard zone map.
- Here, such maps are used to develop mitigation plans in consultation with experts.

LANDSLIDE PREPAREDNESS AND SAFETY MEASURES

A) **Before a landslide:**

- Find out if landslides have happened in your area in the past.
- Look out for landslide warning signs like doors or windows jammed for the first time, new cracks appea in walls, bricks, foundations, retaining walls, tilt of utility poles or trees.
- Consider relocation in case your house is located in ar area particularly vulnerable to landslides. While doin so, **remember:**

i) Do not build on or at the base of unstable slopes, on or at the base of minor drainage hollows, at the base or on top of an old fill slope, at the base or top of a steep cut slope.

ii) Do not cut down trees or remove vegetation or avoid slope weakening.

iii) If the house cannot be relocated, then ensure proper drainage and proper retaining walls.

- **Always stay alert and awake!!!** Listen to radio/television for warnings of intense rainfall, storm and damp weather. These usually trigger landslides/debris or mudflow.
- Make an evacuation plan in case of a landslide with all the emergency items.

B) **During a landslide:**

- Listen to any unusual sounds that might indicate moving debris, such as trees cracking or boulders knocking together. A trickle of flowing or falling mud or debris may precede larger flows.

❖ While you are outdoors during a landslide

- Try to get out of the path of the landslide or mudflow by running to the nearest high ground or away from the path.
- If you are near a river, be alert for any sudden increase or decrease in water flow or for a change from clear to muddy water. Such changes may indicate landslide upstream. So move quickly to safer areas.

- If the rocks and other debris are approaching, run to the nearest shelter such as group of trees or a building.

- While you are indoors during a landslide

- Stay inside and remain alert. Listen to radio/ television for any update. i.e. if landslide occurs outside.
- If your house falls apart due to landslide and if there is no escape, hold on to something strong and protect your head.

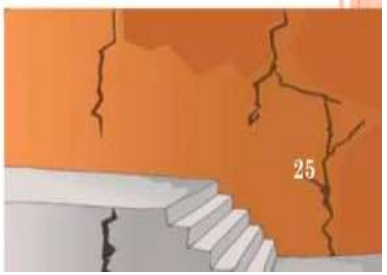
C) **After a landslide:**

- Stay away from the landslide area as there may be danger of additional slides. Do not drive through.
- Watch for flooding which may occur after a landslide.
- Check for injured or trapped persons near the slide, without entering the slide area. Direct rescuers to their locations.

- Help neighbours who may require special assistance– infants, elderly people and disabled people.

- Listen to local radio/television stations for the latest emergency information.
- Look for and report broken utility lines to appropriate authorities.

- Check the building foundation, walls and surrounding land for damage. The safety of the areas needs to be assured before reoccupation.



Flood

- Flood is the most frequent type of natural calamity that may be caused by heavy rainfall or some other factors. It can have various disastrous impacts. The flood may lead to a scarcity of clean drinking water. Drought is the opposite of flood; it is also a natural calamity.

A flood is usually an excess of water that drowns usually dry land. Usually, there are five types of floods.

- River flood occurs when the water level of the sea rises above the top of the banks of the river.
- A coastal flood is an inundation of dry land areas along the coast of seawater.
- Strome surge is an abnormal increase in the water level in coastal areas.
- Inland flooding is flooding that does not occur in coastal areas or occurs inland.
- A Flash flood is a flood that begins after 3-6 hours of heavy rain.

- Causes of Flood

There may be many causes of floods. The main causes are given below.

- **Ice and Snow Melt** - Some mountains have ice caps on them. When this icecap melts in the summer season, it results in huge releases of water into the places that are usually dry.
- **Lack of Vegetation** - vegetation can interrupt the flow of water. If there will be no vegetation, there will be nothing to slow down the flow of water.
- **Broken Dams** - When heavy rain comes, the water level increases in the dams and ageing dams can break and can unleash overflows of water in the household.
- **Heavy Rains** - Whenever there is heavy rain and the drainage system is not proper, it may result in a flood or flood-like conditions.
- **Climate Change** - Climate changes occur mainly due to human practices. Due to deforestation, there will be more carbon dioxide in the atmosphere, which may lead to the melting of glaciers.
- **Emission of Greenhouse Gases** - The burning of fossil fuels can lead to the emission of greenhouse gases which increase the atmospheric temperature and hence there will be melting of the glaciers.

- Effects of Flood
- A flood can harm wildlife.
- Flood carries contamination and can cause disease.
- A flood can trigger breeding events and migration.
- There may be a loss of goods and life in the flood.
- A flood can cause soil erosion.

Causes of flooding

PHYSICAL

- Climatological
- Nature of drainage basin
- Coastal influences

HUMAN

- Urbanisation
- Deforestation

Physical Causes:

- **Climatological factors:**

1. Intense rainfall (rainfall intensity > infiltration capacity) – common in semi-arid areas
2. Prolonged period of rainfall produces saturation of the soil and overland flow (widespread flooding in UK during summer 2007 was the result of the wettest summer since 1766)
3. A sudden increase in temperature producing rapid snowmelt, which can be made worse by frozen ground limiting infiltration
4. (1995 Rhine flood in Germany & Netherlands)

Physical Causes:

- **Nature of drainage basin:**

1. Infiltration rate depends on rock and soil
2. Shape of the river basin, gradient and vegetation covers affect how quickly run-off reaches the channel

Physical Causes:

- **Coastal influences:**
- High seasonal tides, sto surges, tropical cyclones can result in higher wate levels in rivers and low-lying coastal areas
  - E.g. Bangladesh

Human causes of flooding

1. Deforestation

- Reduces interception and evapotranspiration
- Increase run-off
- Decrease in channel capacity due to amt of sediment being carried into river channel
- E.g. Maraca rainforest in the Amazon Basin

2. Urbanisation increases the magnitude and frequency of floods by:

- The creation of highly impermeable surfaces such as roads, roofs and pavements
- Smooth surfaces served by a dense network of drains, gutters and underground sewers, effectively increasing drainage density

Urbanisation

- Natural river channels are often constricted by bridge supports or riverside facilities, reducing their carrying capacity

- Straightening river channels and lining them with concrete as part of building projects lead to faster delivery of water downstream

Urbanisation

- Failure of hard engineering such as a dam burst can produce catastrophic flooding
  - Dam burst in an iron ore mine near Seville, Spain 1999

- Land management techniques such as:
  - drainage systems,
  - digging ditches or
  - ploughing up and down a slope

  → will decrease lagtime for water to reach the river channel

Risk assessment

The process of finding the probability (how likely it is to happen) that a hazardous event of particular size occur within a given period of the time and estimating its impact

Impacts of flooding

- Building and property washed away by water and mud
- Crops ruined and farmlands saturated for months
- People and animals can drown in fast flowing water
- Transport can be interrupted; airport can be closed, roads and railways submerged under water
- Sewage contaminate drinking water and causes diseases like cholera & typhoid

Agencies in India related to Flood Management:

1)The Central Flood Control Board

• to lay down general principles and policies in connection with flood control measures;

• to consider and approve master plans for flood control submitted by the states/river commission; and

• to arrange for necessary assistance in connection with planning and execution of flood control works. As a follow_x0002_up to a decision of the CFCB in 1954, a Flood Wing was added to the then Central Water and Power Commission;

- the Flood Wing served as the Secretariat of the CFCB.

2) The Central Water Commission: This wing is also responsible for flood

forecasting and the hydrological observations' network in the country.

3)The Ganga Flood Control Commission:

4) The Brahmaputra Board:The Board, with the approval of the central government, is also to take up the

construction of multipurpose dams and works connected therewith proposed in the Master Plan and operate such dams

and works.

5)The Indian Meteorological Department:

- To take meteorological observations and to provide current and forecast meteorological information for optimum operation of weather-sensitive activities like agriculture, irrigation, shipping, aviation, offshore oil explorations, etc.

• To warn against severe weather phenomena like tropical cyclones, northwesterly dust storms, heavy rains and snow, cold and heat waves, etc., which cause destruction of life and property.

• To provide meteorological statistics required for agriculture, water resource management, industries, oil exploration and other nation building activities.

• To conduct and promote research in meteorology and allied disciplines.

• To detect and locate earthquakes and to evaluate seismicity in different parts of the country for development projects.

6. National Centre for Medium Range Weather Forecasting

7. National Remote Sensing Agency

8. National Flood Management Institute

9. State & District Level Organizations

National Flood Mitigation Project:

The NDMA has proposed to take up a National Flood Mitigation Project in the Eleventh Five Year plan whose aims and objectives will be evolved in due course. Broadly, it will address the following issues:

- assessment of the risk and vulnerabilities associated with various flood disasters;
- mitigation and reduction of the risk, severity or consequences of floods;
- capacity development including enhancing the capabilities of communities and training functionaries.
- effective preparedness to deal with floods;
- improving the promptness and efficacy of response to impending threats of floods or actual occurrence;
- ensuring that arrangements are in place to organise rescue, relief and rehabilitation;
- improving the quality and increasing the speed of rehabilitation and reconstruction processes;
- creating awareness and preparedness and providing advice and training to the agencies involved in flood DM and the community.

Tentatively the component-wise activities including structural and non-structural measures (e.g. infrastructural, equipment, stores, capacity–building, etc.) that will be funded under the project include:

• Carrying out special studies on threat perception/vulnerability analysis/flood disaster risk assessment of the flood

prone areas.

• Facilitating the establishment of state-level training institutions for imparting training for flood disaster

preparedness/mitigation etc creating awareness of flood disaster, and training and educating people to cope up

with floods at district/block levels.

• Securing prompt and people-friendly dissemination of information to the public.

• Establishing a dedicated communication network that can remain functional during floods.

• Setting up of Flood shelters.

• Suitably locating flood disaster relief centres/basic infrastructure like hospitals, stores, etc., on high ground, so

that they remain functional during floods.

• Creating and maintaining an adequately trained disaster response force.

• Identifying road transport/rail/ communication networks that connect flood disaster relief/supply centres to flood

prone areas and including construction of new rail/road infrastructure that may be reliably used during floods.

Bengal Famine (1943)

- Background
- Abrupt Policies
- Impact of Famine
- Role of Winston Churchill

Background

- From the late nineteenth century through the Great Depression, social and economic forces exerted a harmful effect on the structure of Bengal's income distribution and the ability of its agricultural sector to sustain the populace.

- These included a rapidly growing population, increasing household debt, stagnant agricultural productivity, increased social stratification, and alienation of the peasant class from their landholdings.

- ***These processes left social and economic groups mired in poverty and indebtedness, unable to cope with the economic shocks they faced in 1942 and 1943, in the context of the Second World War.***

- According to a 1941 census.Its population had increased by 43% between 1901 and 1941—from 42.1 million to 60.3 million. Over the same period India's population as a whole increased by 37%

Background

- Bengal's economy was almost solely agrarian, but agricultural productivity was among the lowest in the world.Land quality and fertility had been deteriorating in Bengal and other regions of India, but the loss was especially severe.

- It was estimated in 1930 that the Bengali diet was the least nutritious in the world. Structural changes in the credit market and the rights of land transfer in rural Bengal not only helped push it into recurring danger of famine, but also dictated which economic groups would suffer the greatest hardship.

- ***The Indian system of land tenure, particularly in Bengal, was very complex, with rights unequally divided among three diverse economic and social groups: traditional absentee large landowners or zamindars; the upper-tier "wealthy peasant" jotedars; and, at the lower socioeconomic level, the ryot (peasant) smallholders and dwarfholders, bargadars (sharecroppers), and agricultural***

- Agricultural labourers.*Zamindar* and *jotedar* landowners were protected by law and custom,but those who actually cultivated the soil, with small or no landholdings, suffered persistent and increasing losses of land rights and welfare.

- ***The jotedars effectively dominated and impoverished the lowest tier of economic classes in several districts of Bengal.***

- At the time of the famine, millions of Bengali agriculturalists held little or no land. In absolute terms, the social group which suffered by far the most of every form of impoverishment and death during the Bengal famine of 1943 were the landless agricultural labourers.

Japanese Invasion to Burma

- The Japanese campaign for Burma began in late December 1941, and set off an immediate exodus for India of more than half of the one million Indians then living in Burma.

- On April 26, 1942, all Allied forces were ordered to retreat from Burma into India. Immediately, the demands of the military became the focus of official attention;

- ***By April 1942, Japanese warships and aircraft had sunk approximately 100,000 tons of merchant shipping in the Bay of Bengal.The Japanese raids put additional strain on the railways, which also endured flooding in the Brahmaputra, a malaria epidemic.***

- Throughout the period, the rail transportation of relief and civil supplies was compromised by the railways' increased military obligations, and by dismantling of the rail tracks also

- The fall of Rangoon in March 1942 cut off the import of Burmese rice into India and Ceylon. Due in part to rises in local populations, prices for rice were already 69% higher in September 1941 than in August 1939.

- The Japanese attack had not only provoked a scramble for rice across India, but had also sparked a dramatic and unprecedented price inflation in Bengal, and in other rice producing regions of India.

- Across India and particularly in Bengal, this caused a "derangement" of the rice markets. Despite this, Bengal continued to export rice to Ceylon for months afterward, even as the beginning of a food crisis began to become apparent.

- *The influx of refugees created more demand for food, clothing and medical aid, further straining the resources of the province.All this, together with transport problems were the direct causes of inter-provincial trade barriers on the movement of foodgrains, and contributed to a series of failed government policies that further exacerbated the food crisis*

Abrupt Policies

- Nearly the full output of India's cloth, wool, leather and silk industries were sold to the military. British military authorities feared that the Japanese would proceed through Burma and invade British India via the eastern border of Bengal.

- As a preemptive measure, they launched a two-pronged scorched-earth initiative in eastern and coastal Bengal to prevent or impede the invasion by denying access to food supplies, transport and other resources.

- ***First, a "denial of rice" policy was carried out . As a second prong, a "boat denial" policy was designed to deny Bengali transport to any invading Japanese army. It applied to districts readily accessible via the Bay of Bengal.***

- *The policy authorised the Army to confiscate, relocate or destroy any boats large enough to carry more than ten persons, and allowed them to requisition other means of transport such as bicycles, bullock carts, and elephants*

- ***Many Indian provinces and princely states imposed inter-provincial trade barriers beginning in mid-1942. preventing other provinces from buying domestic rice. One underlying cause was the anxiety and soaring prices that followed the fall of Burma.***

- As food prices rose and the signs of famine became apparent from July 1942, he Government of Bengal and the Chamber of Commerce devised a Foodstuffs Scheme to provide preferential distribution of goods and services to workers in essential war industries, to prevent them from leaving their positions.

- Rice was directed away from the starving rural districts to workers in industries. Essential workers received subsidised food.

At last

- *The unfavorable military situation of the Allies after the fall of Burma led the US and China to urge the UK to enlist India's full cooperation in the war by negotiating a peaceful transfer of political power to an elected Indian body; this goal was also supported by the Labour Party in Britain.*

- British prime minister Winston Churchill responded to the new pressure through the Cripps' mission, broaching the post-war possibility of an autonomous political status for India in exchange for its full military support, but negotiations collapsed in early April 1942.

- On 8 August 1942 the Indian National Congress launched the Quit India movement, intended as a nationwide display of nonviolent resistance. The British authorities reacted by imprisoning the Congress leaders. Without its leadership, the movement changed its character and took to sabotaging factories, bridges, telegraph and railway lines, and other governmen property.

Role of Churchill oin Bengal famine

NATURAL DISASTERS

- In late 1942 Bengal was affected by a series of natural disasters. First, the winter rice crop was afflicted by a severe outbreak of fungal brown spot disease.

- *Then, on 16–17 October a cyclone and three storm surges in October ravaged croplands, destroyed houses and killed thousands, at the same time dispersing high levels of fungal spores across the region and increasing the spread of the crop disease.*

- Following these events, official forecasts of crop yields predicted a significant shortfall. Traders warned of an impending famine, but the Bengal Government did not act on these predictions.

- *Beginning around December 1942–January 1943, high-ranking government officials and military officers began requesting food imports for India through government and military channels, but for months these requests were either rejected or reduced to a fraction of the original amount by Churchill's War Cabinet.*

- ***The Secretary of State for India, Leo Amery,*** was on one side of a cycle of requests for food aid and subsequent refusals from the British War Cabinet that continued through 1943 and into 1944

- Rather than meeting this request, the UK promised a relatively small amount of wheat that was specifically intended for western India (that is, not for Bengal) in exchange for an increase in rice exports from Bengal to Ceylon

Famine

- on 4 August 1943 less than three weeks before *The Statesman's* graphic photographs of starving famine victims in Calcutta would focus the world's attention on the severity of the

- The cabinet again offered only a relatively small amount, explicitly referring to it as a token shipment. The explanation generally offered for the refusals included insufficient shipping.

- The Cabinet also refused offers of food shipments from several different nations. Churchill's animosity and even racism toward Indians decided the exact location where famine would

FAMINE

- The acceleration to full-scale famine by May 1943 being a consequence of price decontrol. However, in some districts the food crisis had begun as early as mid-1942.

- ***In May 1943, six districts Rangpur, Mymensingh, Bakarganj, Chittagong, Noakhali and Tipperah were the first to report deaths by starvation***.

- Deaths by starvation had peaked by November 1943;by December, disease had become the most common cause of death. Disease-related mortality then continued to take its toll through early-to-mid 1944.

- ***Among diseases, malaria was the biggest killer. From July 1943 through June 1944, the monthly death toll from malaria averaged 125% above rates from the previous five years, reaching 203% over average in December 1943***

Cloth famine

- The famine fell hardest on the rural poor. As the distress continued, families adopted increasingly desperate means for survival. First, they reduced their food intake and began to sell jewelry, ornaments, and smaller items of personal property.
- Eventually, families disintegrated; men sold their small farms and left home to look for work or to join the army, and women and children became homeless migrants, often travelling to Calcutta or another large city in search of organised relief.
- Corpses were disposed of in rivers and water supplies, contaminated drinking water. Many people drank contaminated rainwater from streets and open spaces where others had urinated or defecated. Disposal of corpses soon became a problem for the government and the public
- As a further consequence of the crisis, a "cloth famine" left the poorest in Bengal clothed in scraps or naked through the winter.
- The British military consumed nearly all the textiles produced in India by purchasing Indian-made boots, parachutes, uniforms, blankets, and other goods at heavily discounted rates.
- It exported 177 million yards of cotton in 1938–1939 and 819 million in 1942–1943. The country's production of silk, wool and leather was also used up by the military.
- In May 1943 prices were 425 percent higher than in August 1939. Many women "took to staying inside a room all day long, emerging only when it was their turn to wear the single fragment of cloth shared with female relatives

Exploitation

- One of the classic effects of famine is that it intensifies the exploitation of women; the sale of women and girls, for example, tends to increase. The sexual exploitation of poor, rural, lower-caste and tribal women by the *jotedars* had been difficult to escape even before the crisis.

- hose who migrated to Calcutta frequently had only begging or prostitution available as strategies for survival; often regular meals were the only payment.

- In late 1943, entire boatloads of girls for sale were reported in ports of East Bengal. Families sent their young girls to wealthy landowners overnight in exchange for very small amounts of money or rice.

- Brothels were their sole means of survival. Women who had been sexually exploited could not later expect any social acceptance or a return to their home or family.

Bhopla Gas Tragedy

- The Bhopla Gas Tragedy (commonly referred to as Bhoapl disaster) was a gas leak incident in India, considered one of the world's worst industrial catastrophes
- It occured on the night of 3rd Dec 1984 at the Union carbide of India Limited (UCIL) pesticide plant in Bhopal, Madhya Pradesh
- A leak of methyl isocyanate (MIC) gas and other chemicals from the plant resulted in the exposure of hundreds or thosuands of people

Background

- UCIL was a pesticide plant which manufactured the pesticide carbaryl (chemical name -1naphthyl methylcarbamate) under the brand name Sevin.
- Carbaryl was discovered by an American company Union Carbide Corporation (UCC) which was UCIL's parent company holding a majority stake.
- Minority stakes were held by Indian banks and the public
- UCIL manufactured carbaryl using MIC as an intermediate
- Although there are other methods to produce the end product, they cost more
- MIC is a highly toxic chemical and extremely dangerous to human health

Reasons for the Bhopal Gas Tragedy

- Storing MIC in large tanks and filling beyond recommended levels
- Poor maintenance
- Failure of several safety systems
- Safety systems being switched off to save money including the MIC tank refrigeration system which could have mitigated the disaster severity
- Plant location area

Consequences of Bhopal Gas Tragedy

- Initial effect of exposure
- Coughing
- Felling of suffocation
- Severe eye irritation
- Burning in the respiratory tract
- Breathlessness Stomach pain and vomiting
- Blepharospasm (abnormal contraction or twitching of the eyelid)

Disaster was not an accident

- UC has deliberately ignored the essential safety
- Despite all this, it refused to accept responsiblity
- A $3billion compensation case was filed in 1985 but accepted lowly $470 million in 1989.

Tsunami: The Earth’s Pandemonium

- Tsunami of 2004 in Indian Ocean
- The waves originated due to the earthquake with epicenter close to the western boundary of sumatra
- Tsunami from Earthquake?????
- Indian Plate went under the Burma plate
- Earthquake of 9.0 richter scale was originated
- After thrusting of the Indian Plate below the Burma plate, the water mass rushed back towards the coastline (800km/hr)
- Indira point (Southernmost point of India) got submerged
- More than 10,000people and affected more than lakh
- Worst affected were the coastal areas of Andhra Pradesh, Tamilnadu, Kerala, Puducherry and the Andaman and Nicobar Islands.

Tsunami: The Earth’s Pandemonium

- Is Tsunami Predictable?
- It is possible to give a three hour of a potential tsunami
- Indian Ocean vs Pacific Ocean
- tsunami of Dec 2004, is the most devastating tsunami in the last several hundred years
- Reasons: Lack of monitoring, the early warning systems, and knowledge among the coast dwelleres of Indian Ocean.
- The First indication of Tsunami: rapid withdrawal of the water from the coastal region

Bhuj Earthquake

- Bhuj Gujrat suffered a masive earthquake on 26th January 2001
- Earthquake measuring 6.9 on Richter scale
- An earthquake is measured with a machine called sismograph (magnitude of earthquake is measured on teh Richter Scale

- Magnitude on Richter Scale
- 2.0 on less = felt only a little
- Over 5.0= Can cause damage thing falling
- Over 6.0= Very strong
- Over 7.0= Major earthquake

- School worst affected
- At least 97 students and 31 teachers are feared to have lost their lives following the collapse of science buildings
- Bhuj releif effort
- Three days after the quake, concern rose about flood, blankets and medical supplies not reaching everyone.
- Destruction of Bhuj
- Phone lines, water pipelines and power stations transmission lines were knocked out
- Fire in the city
- Hundreds of fires started as charcoal, cookers overturned.
- Emergency declared in quake zone
- The president declares a state of emergency
- CM's appeal to teh center
- Gujrat appeals for finanical help. the chief minister of Gujrat has launched an appeal for the center of deal with disaster

Vulnerability

- Vulnerability describes the characteristics and circumstances of a community, system or asset that make it susceptible to the damaging effects of a hazard. There are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors. Examples may include:
- poor design and construction of buildings,
- inadequate protection of assets,
- lack of public information and awareness,
- limited official recognition of risks and preparedness measures, and
- disregard for wise environmental management.

Factor Affecting Vulnerability

- Physical factors
- Social factors
- Economic factors
- Environmental factors

Vulnerability varies significantly within a community and over time

1. Physical Vulnerability may be determined by aspects such as population density levels, remoteness of a settlement, the site, design and materials used for critical infrastructure and for housing (UNISDR).

- Example: Wooden homes are less likely to collapse in an earthquake, but are more vulnerable to fire.

2. Social Vulnerability refers to the inability of people, organizations and societies to withstand adverse impacts to hazards due to characteristics inherent in social interactions, institutions and systems of cultural values. It is linked to the level of well being of individuals, communities and society. It includes aspects related to levels of literacy and education, the existence of peace and security, access to basic human rights, systems of good governance, social equity, positive traditional values, customs and ideological beliefs and overall collective organizational systems (UNISDR).

- Example*:* When flooding occurs some citizens, such as children, elderly and differently-able, may be unable to protect themselves or evacuate if necessary.

- **3.Economic Vulnerability:**The level of vulnerability is highly dependent upon the economic status of individuals, communities and nations The poor are usually more vulnerable to disasters because they lack the resources to build sturdy structures and put other engineering measures in place to protect themselves from being negatively impacted by disasters.
- Example: Poorer families may live in squatter settlements because they cannot afford to live in safer (more expensive) areas.
- **4. Environmental Vulnerability:** Natural resource depletion and resource degradation are key aspects of environmental vulnerability.