Geological Disasters

Earthquake[1]

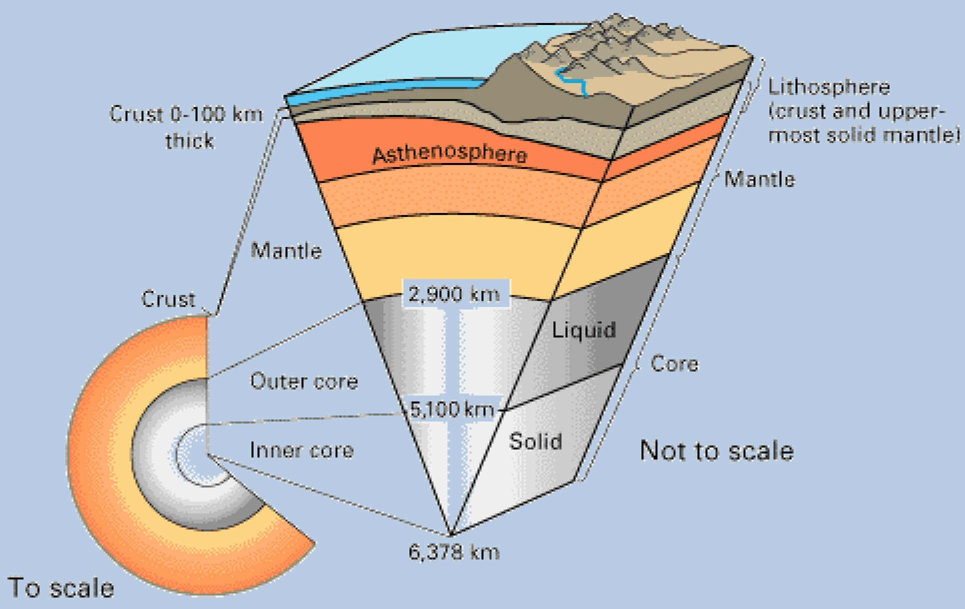
Earthquakes are one of the most destructive of natural hazards. An earthquake occurs due to sudden transient motion of the ground as a result of release of elastic energy in a matter of few seconds. The impact of the event is most traumatic because it affects large areas, occurs all of a sudden and is unpredictable. They can cause large scale loss of life and property and disrupts essential services such as water supply, sewerage systems, communication and power, transport, etc. They not only destroy villages, towns and cities but the aftermath leads to destabilize the economy and social structure of the nation.

What is an Earthquake[2]

An earthquake is the movement or trembling of the ground produced by the sudden displacement of rock in the Earth's crust. Earthquakes result from crustal strain, volcanism, landslides, and collapse of caverns. Stress accumulates in response to tectonic forces until it exceeds the strength of the rock. The rock then breaks along a preexisting or new fracture called a fault. The rupture extends outward in all directions along the fault plane from its point of origin (focus). The rupture travels in an irregular manner until the stress is relatively equalized. If the rupture disturbs the surface, it produces a visible fault **on the surface**. Earthquakes are recorded by seismograph consisted of a seismometer, a shaking detector and a data recorder. The moment magnitude of an earthquake is conventionally reported, or the related and mostly obsolete Richter magnitude, with magnitude 3 or lower earthquakes being mostly imperceptible and magnitude 7 causing serious damage over large areas. Intensity of shaking is measured on the modified Mercalli scale. In India Medvedev-Sponheuer-Karnik scale, also known as the MSK or MSK-64, which is a macroseismic intensity scale, is used to evaluate the severity of ground shaking on the basis of observed effects in an area of the earthquake occurrence. Due to earthquake seismic waves are generated and measurements of their speed of travel are recorded by seismographs located around the planet.

Causes of Earthquakes

An Earthquake is a series of underground shock waves and movements on the earth's surface caused by natural processes within the earth's crust. To learn more about the occurrence of this event lets know more about the interior of the earth.



(Source: http://pubs.usgs.gov/publications/text/inside.html)

Internal structure of Earth

Earthquakes are caused by natural tectonic interactions within the earth's crust and it is a global phenomena. They may arise either due to the release of energy from the strained rock inside the

Earth or tectonic movements or volcanic activity. The sudden release of accumulated energy or stresses in the earth or sudden movement of massive land areas on the earth's surface cause tremors, commonly called earthquakes.

Seismic Waves

Large strain energy released during an earthquake travel as seismic waves in all directions through the Earth's layers, reflecting and refracting at each interface. These waves are of two types - body waves and surface waves; the latter is restricted to near the Earth's surface. Body waves consist of Primary Waves (P-waves) and Secondary Waves (S-waves), and surface waves consist of Love waves and Rayleigh waves. Under P-waves, material particles undergo extensional and compressional strains along the direction of energy transmission, but under S-waves, oscillate at right angles to it. Love waves cause surface motions similar to that by S-waves, but with no vertical component. Rayleigh wave makes a material particles oscillate in an elliptic path in the vertical plane (with horizontal motion along direction of energy transmission).

Magnitude

Magnitude is a quantitative measure of the actual size of the earthquake. Professor Charles Richter noticed that (a) at the same distance, seismograms (records of earthquake ground vibration) of larger earthquakes have a bigger wave amplitude than those of smaller earthquakes; and (b) for a given earthquake, seismograms at farther distances have a smaller wave amplitude than those at close distances. This prompted him to propose the now commonly used magnitude scale, the Richter Scale. It is obtained from the seismograms and accounts for the dependence of waveform amplitude on epicentral distance. This scale is also called Local Magnitude scale. There are other magnitude scales, like the Body Wave Magnitude, Surface Wave Magnitude and Wave Energy Magnitude. These numerical magnitude scales have no upper and lower limits; the magnitude of a very small earthquake can be zero or even negative.

Intensity

Intensity is a qualitative measure of the actual shaking at a location during an earthquake, and is assigned as Roman Capital Numerals. There are many intensity scales. Two commonly used ones are the Modified Mercalli Intensity (MM!) Scale and the MSK Scale. Both scales are quite similar and range from I (least perceptive) to XII (most severe). The intensity scales are based on three features of shaking -perception of people and animals, performance of buildings, and changes in natural surroundings. The distribution of intensity at different places during an earthquake is shown graphically using isoseismals, lines joining places with equal seismic intensity.

What are the various types of earthquake?

Classification of earthquake is based on several parameters. Based on scale of magnitude (M), earthquake may be of the Micro ($M < 3.5$) or macro ($M > 3.5$) type.

- **Depending upon the extent of energy released and strength of the ground shaking it may be of several types, like moderate, strong, very strong, great and very great earthquake.**
- **Depending up on the scale of damage, the earthquake may be of various types, such as Less damaging earthquake, Moderate damaging earthquake, and catastrophic earthquake.**
- **Depending upon the focal depth (h) of the event, it could be a shallow earthquake ($d < 70$ km); intermediate depth earthquake ($70 < h < 300$ km); the deep earthquake ($300 < h < 700$ km).**
- **Depending upon the location of events in different tectonic settings, earthquake may be of intra-plate, inter-plate, and sub-oceanic earthquake.**
- **Depending upon involvement of other agencies / phenomena with earthquake genesis, it may be of several types, such as Reservoir induced; Fluid-driven earthquake; Tsunamigenic earthquake, and volcanic earthquake.**
- **Depending upon the type of faulting involved during earthquake genesis, earthquake may be categorized into several categories, such as normal faulting, reverse faulting, thrust faulting, and mega-thrust earthquake.**
- **Depending upon the frequency content, the earthquake may be of Low-Frequency tremors or high – Frequency tremors.**
- **Depending upon the epicenter distance (distance between earthquake main shock and the recording stations), the earthquake may be classified into Local, Regional and Global earthquake.**

Intensity scale

It manifests the degree of damage, which gets diminished as we go away from the main shock source zone and the reverse is also true.

Mercalli intensity scale

The **Mercalli intensity scale** is a seismic scale used for measuring the intensity of an earthquake. It measures the effects of an earthquake, and is distinct from the moment magnitude usually reported for an earthquake (sometimes described as the obsolete Richter magnitude), which is a measure of the energy released. The intensity of an earthquake is not totally determined by its magnitude.

The scale quantifies the effects of an earthquake on the Earth's surface, humans, objects of nature, and man-made structures on a scale from I (not felt) to XII (total destruction). Values depend upon the distance to the earthquake, with the highest intensities being around the epicentral area. Data gathered from people who have experienced the quake are used to determine an intensity value for their location. The Mercalli (Intensity) scale originated with the widely-used simple ten-degree Rossi-Forel scale which was revised by Italian vulcanologist, Giuseppe Mercalli in 1884 and 1906.

In 1902 the ten-degree Mercalli scale was expanded to twelve degrees by Italian physicist Adolfo Cancani. It was later completely re-written by the German geophysicist August Heinrich Sieberg and became known as the Mercalli-Cancani-Sieberg (MCS) scale.

The Mercalli-Cancani-Sieberg scale was later modified and published in English by Harry O. Wood and Frank Neumann in 1931 as the Mercalli-Wood-Neumann (MWN) scale. It was later improved by Charles Richter, the father of the Richter magnitude scale.

The scale is known today as the **Modified Mercalli scale** (MM) or **Modified Mercalli Intensity scale** (MMI).

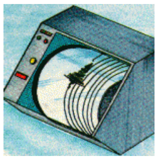
Modified Mercalli Intensity Scale

The lower degrees of the Modified Mercalli Intensity scale generally deal with the manner in which the earthquake is felt by people. The higher numbers of the scale are based on observed structural damage.

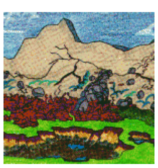
The small table is a rough guide to the degrees of the Modified Mercalli Intensity scale [6,7]. The colors and descriptive names shown below differ from those used on certain shake maps in other articles.

Magnitude	Typical Maximum Modified Mercalli Intensity[6]
1.0 - 3.0	I
3.0 - 3.9	II - III
4.0 - 4.9	IV - V
5.0 - 5.9	VI - VII
6.0 - 6.9	VII - IX
7.0 and higher	VIII or higher

The large table[7] gives Modified Mercalli scale intensities that are typically observed at locations near the epicenter of the earthquake. The correlation between magnitude and intensity is far from total, depending upon several factors, including the depth of the earthquake, terrain, population density, and damage. For example, on May 19, 2011 an earthquake of magnitude 0.7 in Central California, United States 4 km deep was classified as of intensity III by the United States Geological Survey (USGS) over 100 miles (160 km) away from the epicenter (and II intensity almost 300 miles (480 km) from the epicenter), while a 4.5 magnitude quake in Salta, Argentina 164 km deep was of intensity I.

	MMI Value	Summary Damage Description Used on Maps	Description of Shaking Severity	Full description shortened fromElementary Seismology[7]
	I	Not mapped	Not mapped	Not felt.
	II	Not mapped	Not mapped	Felt by people sitting or on upper floors of buildings.

	**III**	Not mapped	Not mapped	Felt by almost all indoors. Hanging objects swing. Vibration like passing of light trucks. May not be recognized as an earthquake..
	**IV**	Not mapped	Not mapped	Vibration felt like passing of heavy trucks. Stopped cars rock. Hanging objects swing. Windows, dishes, doors rattle. Glasses clink. In the upper range of IV, wooden walls and frames creak.
	**V**	Light	Pictures Move	Felt outdoors. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing. Pictures move. Pendulum clocks stop.
	**VI**	Moderate	Objects Fall	Felt by all. People walk unsteadily. Many frightened. Windows crack. Dishes, glassware, knickknacks, and books fall off shelves. Pictures off walls. Furniture moved or overturned. Weak plaster, adobe buildings, and some poorly built masonry buildings cracked. Trees and bushes shake visibly.
	**VII**	Strong	Nonstructural Damage	Difficult to stand or walk. Noticed by drivers of cars. Furniture broken. Damage to poorly built masonry buildings. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, unbraced parapets and porches. Some cracks in better masonry buildings. Waves on ponds.

	**VIII**	Very Strong	Moderate Damage	Steering of cars affected. Extensive damage to unreinforced masonry buildings, including partial collapse. Fall of some masonry walls. Twisting, falling of chimneys and monuments. Wood-frame houses moved on foundations if not bolted; loose partition walls thrown out. Tree branches broken.
	**IX**	Violent	Heavy Damage	General panic. Damage to masonry buildings ranges from collapse to serious damage unless modern design. Wood-frame structures rack, and, if not bolted, shifted off foundations. Underground pipes broken.
	**X**	Very Violent	Extreme Damage	Poorly built structures destroyed with their foundations. Even some well-built wooden structures and bridges heavily damaged and needing replacement. Water thrown on banks of canals, rivers, lakes, etc.
	**XI**	Not mapped because these intensities are typically limited to areas with ground failure.		Rails bent greatly. Underground pipelines completely out of service.
	**XII**	Not mapped because these intensities are typically limited to areas with ground failure.		Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown into the air.

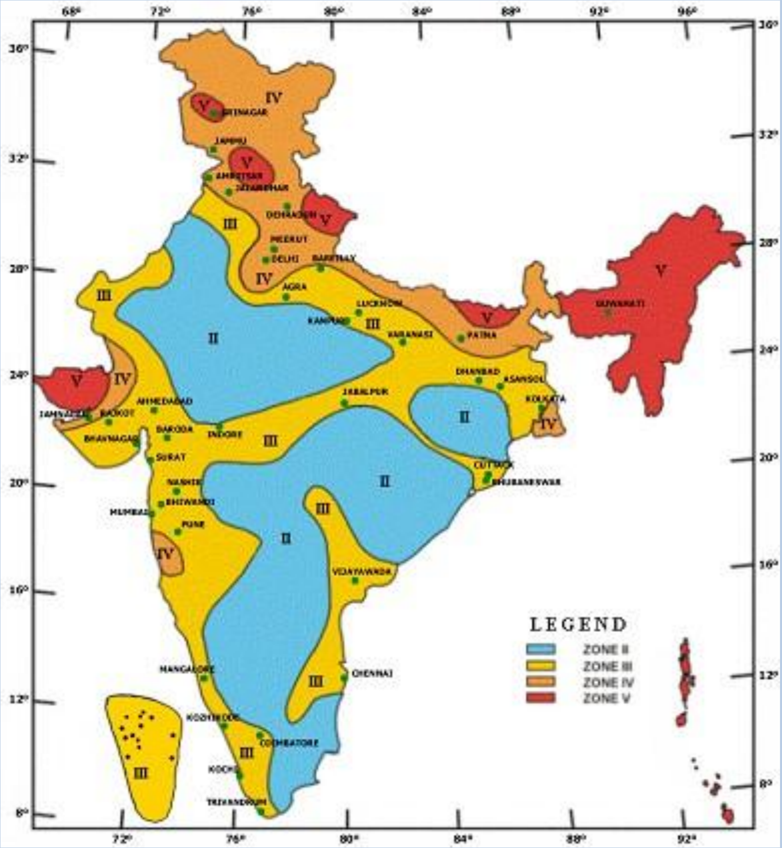
INDIA - Basic Geography and Tectonic Features[1]

India lies at the northwestern end of the **Indo-Australian Plate,** which encompasses India, Australia, a major portion of the Indian Ocean and other smaller countries. This plate is colliding against the huge **Eurasian Plate** and going under the Eurasian Plate; this process of one tectonic plate getting under another is called **subduction.** A sea, **Tethys,** separated these plates before they collided. Part of the lithosphere, the Earth's Crust, is covered by oceans and the rest of the continents. The former can undergo subduction at great depths when it converges against another plate, but the latter is buoyant and so tends to remain close to the surface. When continents converge, large amounts of shortening and thickening takes place, like in the Himalayas and the Tibetan.

Three chief tectonic sub-regions of India are the mighty Himalayas along the north, the plains of the Ganges and other rivers, and the peninsula. The Himalayas consist primarily of sediments accumulated over long geological time in the Tethys. The Indo-Gangetic basin with deep alluvium is a great depression caused by the load of the Himalayas on the continent. The peninsular part of the country consists of ancient rocks deformed in the past Himalayan-like collisions. Erosion has exposed the roots of the old mountains and removed most of the topography. The rocks are very hard, but are softened by weathering near the surface. Before the Himalayan collision, several tens of millions of years ago, lava flowed across the central part of peninsular India, leaving layers of basalt rock. Coastal areas like Kachchh show marine deposits testifying to submergence under the sea millions of years ago.

Seismic Zones of India[1]

The varying geology at different locations in the country implies that the likelihood of damaging Earthquakes taking place in different locations are different. Thus, a seismic zone map is required to identify these regions. Based on the levels of intensities sustained during damaging past earthquakes, the 1970 version of the zone map subdivided India into five zones - I, II, III, IV and V. The maximum Modified Mercalli (MM) intensity of seismic shaking expected in these zones was V **or less, VI, VII, VIII,** and **IX and higher,** respectively. Parts of Himalayan boundary in the north and northeast, and the Kachchh area in the west were classified as zone V. The seismic zone maps are revised from time to time as more understanding is gained on the geology, the seismotectonics and the seismic activity in the country. The Indian Standards provided the first seismic zone map in 1962, which was later revised in 1967 and again in 1970. The map has been revised again in 2002, and it now has only four seismic zones - II, III, IV and V. The areas falling in seismic zone I in the 1970 version of the map merge with those of seismic zone II. Also, the seismic zone map in the peninsular region has been modified. Chennai city, now comes in seismic zone III as against in zone II in the 1970 version of the map. This 2002 seismic zone map is not the final word on the seismic hazard of the country, and hence there can be no sense of complacency in this regard.



(Source: Bureau of Indian Standards)

Seismic zoning map of India

Can we predict Earthquakes[2,3]

With the present state of knowledge of science, it is not possible to predict earthquakes. It is so because the physics involved in earthquake genesis is very complex. The mechanism of earthquake generating processes is still not adequately understood us because of involvement of multi-component parameters in earthquake genesis.

Earthquake forecasting and prediction is an active topic of geological research. Geoscientists are able to identify particular areas of risk and, if there is sufficient information, to make probabilistic forecasts about the likelihood of earthquakes happening in a specified area over a specified period. These forecasts are based on data gathered through global seismic monitoring networks, high-density local monitoring in knowing risk areas, and geological field work, as well as from historical records. Forecasts are improved as our theoretical understanding of earthquakes grows, and geological models are tested against observation. Long-term forecasts (years to decades) are currently much more reliable than short to medium-term forecasts (days to months).

It is not currently possible to make deterministic predictions of when and where earthquakes will happen. For this to be possible, it would be necessary to identify a ‘diagnostic precursor’ – a characteristic pattern of seismic activity or some other physical, chemical or biological change, which would indicate a high probability of an earthquake happening in a small window of space and time. So far, the search for diagnostic precursors has been unsuccessful. Most Geoscientists do not believe that there is a realistic prospect of accurate prediction in the foreseeable future, and the principal focus of research is on improving the forecasting of earthquakes.

Important organizations in India

- Ministry of Home Affairs
  http://www.ndmindia.nic.in/
- CESS, (Centre for Earth Science Studies)
  http://www.cessind.org/
- GSI, (Geological Society of India)
  http://www.geosocindia.org/
- GSI, (Geological Survey of India)
  http://www.gsi.gov.in/
- IMD, (India Meteorological Department)
  http://www.imd.gov.in/
- NDMA, (National Disaster Management Authority) (India)
  http://ndma.gov.in/ndma/index.htm
- NGRI, (National Geophysical Research Institute)
  http://www.ngri.org.in/
- NICEE,(National Information Centre of Earthquake Engineering)
  http://www.nicee.org/
- www.seedsindia.org

- WIHG, (Wadia Institute of Himalayan Geology)
  http://www.wihg.res.in/
- Map of earthquakes in India
  http://www.mapsofindia.com/maps/india/majorearthquake.htm
- Indian standards on earthquake engineering
  http://www.bis.org.in/other/quake.htm
- Seismic codes in India
  http://www.nicee.org/IITK-GSDMA_Codes.php
- Reading materials on EE in India
  http://www.nicee.org/readingview.php?PHPSESSID=d4243d3b2c2ae22c408267348995dbaa
- Indian and global information
  http://www.nicee.org/links.php?id=1

Earthquake Early Warning[2]

Earthquake early warning (EEW) can provide a few seconds to tens of seconds warning prior to ground shaking during an earthquake. Several countries, such as Japan, Taiwan, Mexico have adopted this methodology based on the fact that such warning can (1) rapidly detect the initiation of an earthquake, (2) determine the size (magnitude) and location of the event, (3) predict the peak ground motion expected in the region around the event, and (4) issued a warning to people in locations that may expect significant ground motion.

Prediction of an earthquake is still a subject of speculations yet several schools of thoughts are available. In the effort to predict earthquakes, people have tried to associate an impending earthquake with such varied phenomena as seismicity patterns, electromagnetic fields, weather conditions and unusual clouds, radon or hydrogen gas content of soil or ground water, water level in wells, animal behavior, and the phases of the moon.

Mitigation measures

When an earthquake strikes a building is thrown mostly from side to side, and also up and down along with the building foundation the building structure tends to stay at rest, similar to a passenger standing on a bus that accelerates quickly. Building damage is related to the characteristics of the building, and the duration and severity of the ground shaking. Larger earthquakes tend to shake longer and harder and therefore cause more damage to structures.

Structural

No buildings can be made 100% safe against earthquake forces. Instead buildings and infrastructures can be made earthquake resistant to a certain extent depending upon serviceability requirements. Earthquake resistant design of buildings depends upon providing the building with strength, stiffness and inelastic deformation capacity, which are great enough to withstand a given level of earthquake-generated force. This is generally accomplished through the selection of an appropriate structural configuration and the careful detailing of structural members, such as beams and columns, and the connections between them.

There are several different experimental techniques that can be used to test the response of structures to verify their seismic performance, one of which is the use of an **earthquake shaking table** (a **shaking table**, or simply **shake table**). This is a device for shaking structural models or building components with a wide range of simulated ground motions, including reproductions of recorded earthquakes time-histories.

Nonstructural

The non-engineered traditional construction commonly practiced in different areas of the country depends greatly on the respective local context of the area. In other words the technologies vary significantly from area to area. These technologies have evolved and as a result have got optimized. In India an overwhelming majority of houses, are of non-engineered load bearing type. These structures, especially houses, have been traditionally built over the past century or longer, using the locally available materials and the locally practiced technologies that have been most common in the area, including stone, bricks, earth, lime and timber for walls, and clay tiles, stone or mud for roofing supported on under-structure made of local timber such as Teak, Acacia, Neem, Deodar, Pine and also Bamboo. In the recently built structures one also finds a mix of the traditional and new materials/technology such as cement, concrete and steel. The structures have a pitched roof or flat roof, and are single story or double story.

After Bhuj earthquake, significant effort was taken to repair and strengthening of damaged buildings. A guideline for Repair and strengthening guide for earthquake damaged low rise domestic buildings in Gujarat is made.

Seismic retrofitting

Seismic retrofitting is the modification of existing structures to make them more resistant to seismic activity, ground motion, or soil failure due to earthquakes. With better understanding of seismic demand on the structures and with our recent experiences with large earthquakes near urban centers, the need of seismic retrofitting is well acknowledged.

The Framework for Earthquake Management[4]

Disaster Management plans in the past were primarily based on intuitive considerations and past lessons. While past experience provides valuable inputs for the development of risk reduction strategies, the absence of a rigorous Risk Management framework has resulted in weak sustainability and inadequate extension of post-earthquake efforts in other earthquake-prone areas in India. The Disaster Management systems in several developed countries have evolved on the basis of a rigorous Risk Management framework as practiced in Australia, New Zealand and Canada. The Risk Management framework, which provides the logic for these Guidelines, places, local communities at the center, helps to interface them with decision makers and provides the opportunity for continuous and effective feedback between the community at risk and other stakeholders. The essential feature of this Risk Management framework is to view earthquake management issues in a holistic and integrated manner by identifying, analyzing, evaluating and finally, effectively treating the risks. These steps will be implemented through a consultative and participatory process by involving the key stakeholders and will be monitored and reviewed concurrently at various stages of implementation.

Disaster Management Plans[4]

Central ministries, departments and state governments are required to prepare DM plans to improve earthquake preparedness, mitigation and emergency response in accordance with these guidelines. A typical DM plan will, inter alia, include aspects of earthquake management, like identification of all tasks to be undertaken before, during and after an earthquake; outline the response mechanism with clearly defined roles and responsibilities of various stakeholders; and identify the available resources to ensure their effective utilization in the event of an earthquake. The plans will spell out the strategies for addressing the various tasks relating to earthquake preparedness and awareness creation, capacity development, monitoring and enforcement of earthquake-resistant codes and building byelaws. They will also include emergency response, earthquake-resistant design and construction of new structures, and selective seismic strengthening and retrofitting of priority and lifeline structures in earthquake-prone areas. The

India Disaster Resource Network (IDRN) database of resource inventories in the districts will be strengthened by the states through regular updating. States will also integrate this database with their Disaster Management plans.

Institutional Mechanisms for Implementation[4]

The Disaster Management Act, 2005 has mandated the formation of apex bodies in each of the states and Union Territories (UTs), called the State Disaster Management Authority (SDMA) at the state level and the District Disaster Management Authority (DDMA) at the district level for effective Disaster Management. While the National Disaster Management Authority (NDMA) is responsible for developing national policy and guidelines, the National Executive Committees (NEC) will prepare the National Disaster Management Plan which will be approved by the NDMA. The State Executive Committees (SECs) of the SDMAs are responsible for developing their DM plans as per the national policy and guidelines, and for implementing the Guidelines with the help of the DDMAs. The state governments/State Disaster Management Authority will set up State Earthquake Management Committees (SEMCs) and designate a nodal officer responsible for seismic safety. The SEMCs will consist of specialists with field experience in earthquake management, as well as representatives of the various stakeholders. These committees will assist the SDMAs in preparing their DM plans and in developing appropriate implementation and monitoring mechanisms.

Guidelines for Earthquake Management[4]

Central ministries and departments and the state governments will prepare DM plans, which will have specific components of earthquake management, based on these Guidelines. These plans will cover all aspects of the entire DM cycle, be reviewed and updated at periodic intervals and implemented through appropriate, well coordinated and time bound actions as laid down in these Guidelines. As most development activities, especially in high seismic risk areas, can enhance earthquake risk unless special efforts are made to address these concerns, all these agencies will make special efforts to ensure the incorporation of earthquake-resistant features in the design and construction of all new buildings and structures.

Earthquake Safety Tips[5]

Before & during

- Make your house earthquake resistant and secure heavy furniture and objects.

- Choose a couple of family meeting places; pick easy to identify, open and accessible places that you can easily reach. Prepare to be self-sufficient for a minimum of three days.
- If inside, stay inside."DROP, COVER and HOLD! Drop under firm furniture. Cover as much of your head and upper body as you can. Hold onto the furniture. Move to an inside wall and sit with your back to the wall, bring your knees to your chest and cover your head. Stay away from mirror and window. Do not exit the building during the shaking.
- If outdoors, move to an open area away from all structures, especially buildings, bridges, and overhead power lines.

After

- Move cautiously, and check for unstable objects and other hazards above and around you. Check yourself for injuries.
- Anticipate aftershocks, especially if the shaking lasted longer than two minutes.
- Stay out of damaged buildings. Listen to the radio or watch local TV for emergency information and additional safety instructions.

References:

[1]http://www.nicee.org/EQTips.php

[2]http://www.saarc-sadkn.org/about_earthquake.aspx

[3]http://www.geolsoc.org.uk/Education-and-Careers/Resources/Field-Work-Resources/Gower-Field-Guide/The-structure-of-Gower-five-guided-tours/~/~/link.aspx?_id=01717E64-6124-4AFE-B50E-B131712902E8&_z=z

[4]National Disaster Management Authority, Govt. of India, (2007): National Disaster Management Guidelines, Management of Earthquakes.

[5]National Institute of Disaster Management, Ministry of Home Affairs, Govt. of India, Do’s & Don’ts for Common Disasters

[6]USGS website. Magnitude / Intensity comparision. http://earthquake.usgs.gov/learn/topics/mag_vs_int.php

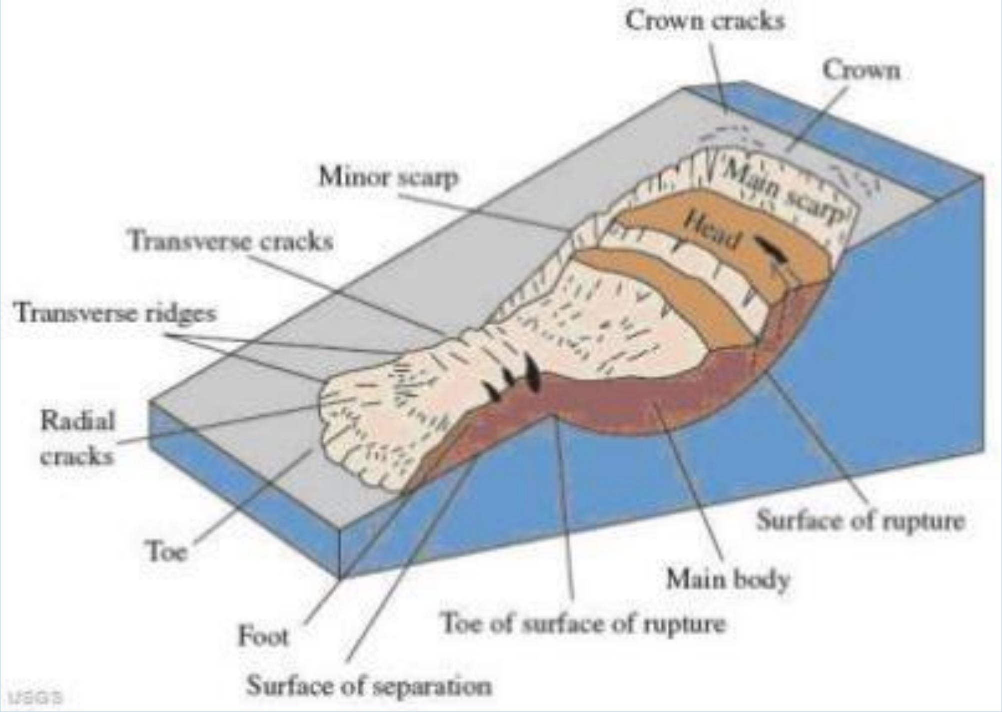
[7]Eathquake and hazards program website. Modified Mercalli Intensity Scale (MMI). http://quake.abag.ca.gov/shaking/mmi/

Landslide[1]

Landslides are simply defined as down slope movement of rock, debris and/or earth under the influence of gravity. This sudden movement of material causes extensive damage to life, economy and environment. It is the most common and universally accepted collective term for most slope movements of the massive nature. The term has sometimes been considered unsuitable as the active part of the word denotes sliding, whereas it connotes even movements without sliding like fall, topple, flow etc.

Morphology of Landslides

Before we discuss about different types of landslides, it would be good to learn about the morphology of landslides and its various features/parts as given below.



Source: USGS

Components of landslides

Parts of Landslides – Description of Features

Accumulation - The volume of the displaced material, which lies above the original ground surface

Crown – The practically undisplaced material still in place and adjacent to the highest parts of the main scarp

Depletion – The volume bounded by the main scarp, the depleted mass and the original ground surface

Depleted mass – The volume of the displaced material, which overlies the rupture surface but underlies the original ground surface

Displaced material – Material displaced from its original position on the slope by movement in the landslide. It forms both the depleted mass and the accumulation.

Flank – The undisplaced material adjacent to the sides of the rupture surface. Compass directions are preferable in describing the flanks, but if left and right are used, they refer to the flanks as viewed from the crown.

Foot – The portion of the landslide that has moved beyond the toe of the surface of rupture and overlies the original ground surface.

Head – The upper parts of the landslide along the contact between the displaced material and the main scarp.

Main body – The part of the displaced material of the landslide that overlies the surface of rupture between the main scarp and toe of the surface of rupture.

Main scarp – A steep surface on the undisturbed ground at the upper edge of the landslide, caused by movement of the displaced material away from undisturbed ground. It is the visible part of the surface of rupture.

Minor scarp – A steep surface on the displaced material of the landslide produced by the differential movement within the displaced material.

Original ground surface – the surface of the slope that existed before the landslide took place.

Surface of separation – The part of the original ground surface overlain by the foot of the landslide

Surface of rupture – The surface that forms the lower boundary of the displaced material below the original ground surface.

Tip – The point of toe farthest from the top of the landslide.

Toe – The lower, usually curved margin of the displaced material of a landslide, it is the most distant part from the main scarp.

Top – The highest point of contact between the displaced material and the main scarp.

Toe of surface of rupture – The intersection (usually buried) between the lower part of the surface of rupture of a landslide and the original ground surface.

Zone of accumulation – The area of landslide within which the displaced material lies above the original ground surface.

Zone of depletion – The area of the landslide within which the displaced material lies below the original ground surface.

Classification[2]

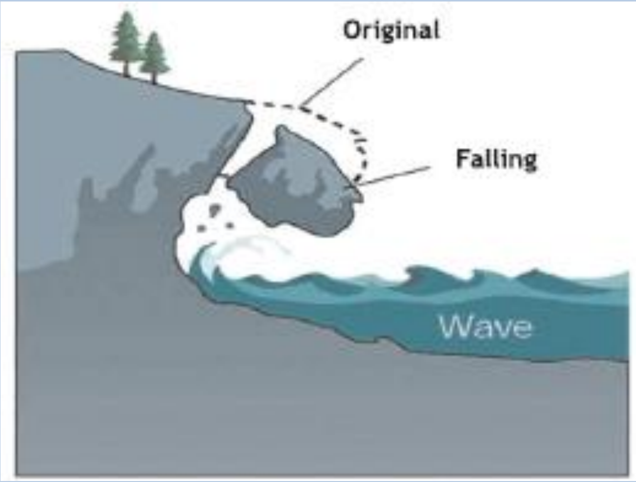
<table>
<tr><th colspan="3" rowspan="3">Type of movement</th><th colspan="3">Type of material</th></tr>
<tr><th>Rock</th><th>Soils</th><th>Debris</th></tr>
<tr><td></td><td>Predominantly fine</td><td>Predominantly coarse</td></tr>
<tr><td colspan="3">Falls</td><td>Rockfall</td><td>Earth fall</td><td>Debris fall</td></tr>
<tr><td colspan="3">Topples</td><td>Rock topples</td><td>Earth topples</td><td>Debris topples</td></tr>
<tr><td rowspan="3">Slides</td><td>Rotational</td><td></td><td>Rock slump</td><td>Earth slumps</td><td>Debris slump</td></tr>
<tr><td rowspan="2">Translational</td><td>Few units</td><td>Rock block slide</td><td>Earth block slide</td><td>Debris block slide</td></tr>
<tr><td>Many units</td><td>Rock slide</td><td>Earth slide</td><td>Debris slide</td></tr>
<tr><td colspan="3">Lateral spreads</td><td>Rock spread</td><td>Earth spread</td><td>Debris spread</td></tr>
<tr><td colspan="3" rowspan="3">Flows</td><td>Rock flow</td><td>Earth flow</td><td>Debris flow</td></tr>
<tr><td>Rock avalanche</td><td></td><td>Debris avalanche</td></tr>
<tr><td>(Deep creep)</td><td colspan="2">(Soil creep)</td></tr>
<tr><td colspan="3">Complex</td><td colspan="3">Nature of movement varies with time</td></tr>
<tr><td colspan="3">Compound</td><td colspan="3">Nature of movement varies in different parts of the failed slopes</td></tr>
</table>

Landslide types based on process of failure

Based on process types, there are five types of landslides i.e. Fall, Topple, Slide, Spread, Flow and Subsidence.

Fall: is a very rapid to an extremely rapid movement which starts with a detachment of material from steep slopes such as cliffs, along a surface on which little or no shear displacement takes place. The material then descends through the air by free falling, bouncing or rolling onto the slopes below.

- The detachment of soil or rock from a steep slope along a surface on which little or no shear displacement takes place.
- Movement very rapid to extremely rapid.
- Free fall if slope angle exceeds 76 degrees and rolling at or below 45 degrees.



A sketch showing mode of failure in the fall

***Topple*:** involves overturning of material. It is the forward rotation of the slope mass about a point or axis below the centre of gravity of the displaced mass. Topples range from extremely slow to extremely rapid movements.

- The forward rotation out of the slope of a mass or a rock about a point or axis below the centre of gravity of the displaced mass.
- Movement varies from extremely slow to extremely rapid.
- Driven by gravity and sometimes by water or ice in cracks in mass.

Sketch showing the end-over-end motion of rock down a slope during toppling

Slide: movement of material along a recognizable shear surface e.g. translational and rotational slides.

- Downslope movement of a soil or mass occurring dominantly on surfaces of or on relatively thin zones of intense shear strain.
- The sign of ground movement are cracks of the original ground.

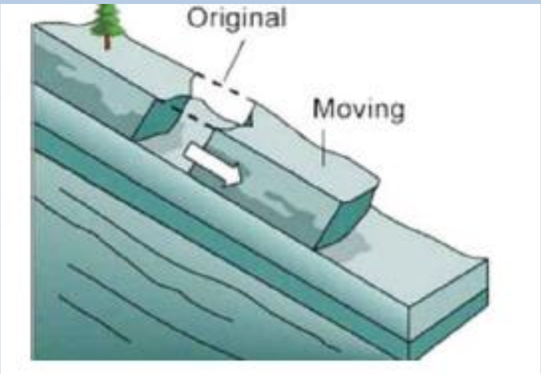


Fig. Sketch showing movement parallel to planes of weakness and occasionally parallel to slope

Modes of Sliding:

- Translational / planar slides
- Wedge slides
- Rotational slide

Flow: is a landslide in which the individual particles travel separately within a moving mass. Spatially continuous movement, in which surfaces of shear are shortlived, closely spaced and usually not preserved.

Flows are differentiated from slides, on the basis of water content, mobility and evolution of the movement.

Features for recognition of flows are

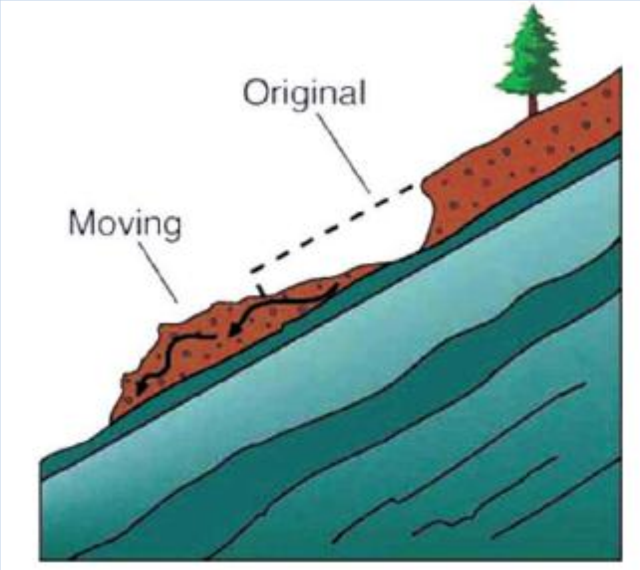
i. Crown may have few cracks.

ii. The main scarp typically has serrated or funnel shaped upper part; is long and narrow, bare and commonly striated.

iii. Flanks are steep and irregular in the upper part; may have levees built up in the middle and lower parts.

iv. The body has flowlines, follow drainage ways, is sinuous, and is very long compared to width.

v. The toe spreads laterally in lobes; if dry, may have steep front.

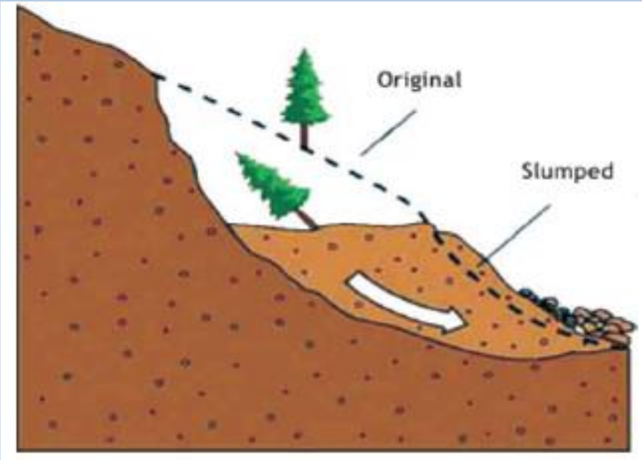


Sketch showing viscous to fluid like motion of debris, often channeled

Spread

- Sudden movement on water- bearing seams of sand or silt overlain by homogeneous clays or loaded by fills.
- May result from liquefaction or flow of softer material.

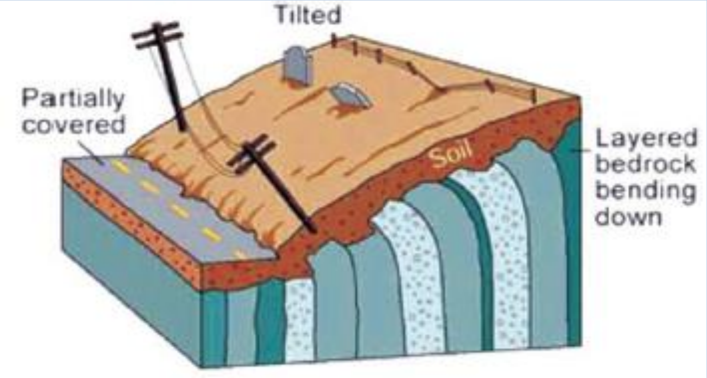
***Slump*:** It is a type of rotational failure on the slopes. The trees bend or fall backwards on towards the slope.



Sketch showing slump type failure

Creep:Very slow rates of slope movements, usually a few millimeter per year, that is imperceptible in nature) is covered under this category.

However, one may find landslides that do not fall directly under any of these typical singular types of slope failures. Such landslides may be composite, complex or multi-tier.



Gradual movement of slope material during creep

Multi-tier / Multi-rotational landslides: When more than one main scars appears in a landslide site and slope mass has more than one slip surface along which movement takes place.

Complex Landslides: Those landslides where the nature of failure process is not consistent but changes with time. For example, a landslide that begins with rock sliding changes its nature to a rockfall due to a steepening of slopes during a failure, may again result into a debris flow due to the formation of a channel during the process of past failures. Thus, it becomes, often very difficult to prevent and control such complex landslides. It requires a persistent study to understand the causes of such landslides properly. These landslides are also found to be chronic and recurring in nature. For example, Kaliasaur landslide in Alaknanda valley, Uttarakhand has displayed complex failure.

Composite Landslides: The slopes which fail in different manners simultaneously at the same site are termed as composite landslides. These landslides display a composite nature as different parts of the landslide indicate a different process type. The types of failure vary due to changes in slope aspect, gradient, heterogeneity in slope mass, landcover, structural / tectonic controls etc. For example, Matli landslide in Bhagirathi valley, Uttarakhand is an example of composite landslide.

Causal Factors for Landslides

There can be several different causative factors for the occurrence of landslides which may work individually or collectively to cause a landslide. Broadly these factors can categorize into ground conditions, geomorphological processes, physical processes and man-made processes. A brief list of these causal factors is given in the table below.

a. Ground Conditions

- Plastic weak material
- Sensitive material
- Collapsible material
- Weathered material
- Sheared material
- Jointed or fissured material
- Adversely oriented structural discontinuities including faults, unconformities, flexural shears, sedimentary contacts
- Adversely oriented mass discontinuities (including bedding, schistosity, cleavage)
- Contrasts in permeability and its effects on ground water
- Contrasts in stiffness (stiff, dense material over plastic material)

b. Geomorphological Processes

- Tectonic uplift
- Volcanic uplift
- Glacial Rebound
- Fluvial erosion of the slope toe
- Wave erosion of the slope toe

- Glacial erosion of the slope toe
- Erosion of the lateral margin
- Subterranean erosion (solution, piping)
- Deposition loading of slope at its crest
- Vegetation removal (by erosion, forest fire, drought)
- Ground Cracks
- Subsidence

c. Physical Processes

- Intense rainfall over a short period
- Rapid melt of deep snow
- Prolonged heavy precipitation
- Rapid drawdown following floods, high tides or breaching of natural dam
- Earthquake
- Volcanic eruption
- Breaching of crater lake
- Thawing of permafrost
- Freeze and thaw weathering
- Shrink and swell weathering of expansive soils

d. Man-Made Processes

- Excavation of the slope or its toe
- Loading of the slope or its crest
- Drawdown of reservoir
- Irrigation
- Defective maintenance of drainage system
- Water leakage from services like water supplies, sewage, storm water drains
- Vegetation removal (deforestation)
- Mining and quarrying in open pits or underground galleries
- Creation of dumps of very loose waste
- Artificial vibration including traffic, pile driving, heavy machinery,blasting and explosion
- Poor maintenance of remedial measures

Classification of Conditions/Factors responsible for Landslides

Some slopes are susceptible to landslides whereas others are not so. Many factors contribute to the instability of the slopes, but the main factors indicating stability conditions are relief, drainage, bedrock, regolith, vegetation, climate, earthquake, paleo-features and man-made conditions. The conditions/factors governing landslides can be classified as inherent (terrain) and external factors as given below.

a. **Inherent or basic conditions**

Geology

- Lithology
- Structure

Hydrologic conditions and climate

- Vegetation

b. External Factors/conditions include precipitation, vibrations induced by earthquake / blasting / explosion, loading or unloading of slopes etc. These factors may actually produce two different types of changes, i.e. changes in stress conditions and changes in strength of materials. The different factors producing different changes are given below for illustration.

c. Factors producing unfavorable changes in conditions

Those that change stress conditions

- Erosion or deposition
- Fluctuation in water level
- Seismic vibrations
- Construction activity
- Cuttings
- Reservoir fluctuations
- Landuse practices

Those that change strength of materials

- Progressive softening of fissured clays
- Disintegration of granular rocks (freeze & thaw)
- Hydration of clay minerals
- Drying and cracking of clays

- Loss of cementitious material from coherent material by solution

d. Landslide's Driving Force

The principal driving force for any landslide is the gravitational force which tends to move out the mass due to the hill slope angle and its weight. The resisting forces preventing the mass from sliding down the slope are inversely proportional to the same hill slope angle and proportional to the friction angle of the material. Stability of the material resting on a slope will be reduced with an increased slope angle. In addition, the resisting forces can be significantly reduced in case of rain or earthquake vibrations.

Potential landslide risk indicators: The following simple observations and inspection by community, municipal officials and property owners, may assist in assessing potential landslide hazards. It is important to note that some of these features can also be due to causes other than landslides, such as swelling clays.

- Saturated ground or seeps in areas that are not typically wet
- New cracks and scarps or unusual bulges in the ground, roads or pavements
- Movement of ancillary structures such as decks and patios in relation to a house
- Sticking doors and windows, and visible open spaces, indicating jambs and frames out of plumb
- Soil moving away from foundations
- Tilting or cracking of concrete floors and foundations
- Broken water lines and other underground utilities
- Leaning telephone poles, trees, retaining walls or fences
- Offset fence lines or retaining walls
- Sunken or displaced road surfaces
- Rapid increase in creek water levels, possibly accompanied by an increase in turbidity (soil content)
- Sudden decrease in creek water levels, though rain is still pouring or just recently stopped
- Springs, seeps or saturated ground in areas that are not typically wet
- Thorough cracks in walls, gaps between roof and wall etc.
- Damage to building elements

Landslides Risk Reduction Measures[3,4]

Drainage Corrections: The most important triggering mechanism for mass movements is the water infiltrating into the overburden during heavy rains and consequent increase in pore pressure within the overburden**.** Hence the natural way of preventing this situation is by reducing infiltration and allowing excess water to move down without hindrance. As such, the first and foremost mitigation measure is drainage correction. This involves maintenance of natural drainage channels, both micro and macro in vulnerable slopes.

Proper land use measures: Adopt effective land-use regulations and building codes based on scientific research. Through land-use planning, discourage new construction or development in identifying hazard areas without first implementing appropriate remedial measures.

Structural measures: Adopt remedial techniques (i.e., buttresses, shear keys, sub-drains, soil reinforcement, retaining walls, etc.) of existing landslides that are in close proximity to public structures.

Afforestation: The afforestation program should be properly planned so the little slope modification is done in the process. Bounding of any sort using boulders, etc. has to be avoided. The selection of suitable plant species should be such that can with stand the existing stress conditions of the terrain.

Awareness generation: Educate the public about signs that a landslide is imminent so that personal safety measures may be taken.

Some of these signs include:

(i) Springs, seeps, or saturated ground in areas that have not typically been wet before.

(ii) New cracks or unusual bulges in the ground, street pavements or sidewalks.

(iii) Soil moving away from foundations, and ancillary structures such as decks and patios tilting and/or moving relative to the house.

(iv) Sticking doors and windows, and visible open spaces.

(v) Broken water lines and other underground utilities.

(vi) Leaning telephone poles, trees, retaining walls or fences.

(vii) Sunken or dropped-down road beds.

(viii) Rapid increase in a stream or creek water levels, possibly accompanied by increased turbidity (soil content).

(ix) Sudden decrease in creek water levels even though rain is still falling or just recently stopped.

Landslides Safety Tips:

Before and during:

- Avoid building houses near steep slopes, close to mountain edges, near drainage ways or along natural erosion valleys.
- Avoid going to places affected by debris flow. In mud flow areas, build channels to direct the flow around buildings.
- Stay alert and awake. Many deaths from landslides occur while people are sleeping.
- Listen for unusual sounds that might indicate moving debris, such as trees cracking or boulders knocking together.
- Move away from the landslide path or debris flow as quickly as possible.
- Avoid river valleys and low-lying areas. If you are near a stream or channel, be alert for any sudden increase or decrease in water flow and notice whether the water changes from clear to muddy.

After:

- Go to a designated public shelter if you have been told to evacuate.
- Stay away from the slide area as there may be danger of additional slides.
- Check for injured and trapped persons near the slide, without entering the direct slide area.

References:

[1]National Institute of Disaster Management, Ministry of Home Affairs, Govt. of India, (2012):Training Module on Comprehensive Landslides Risk Management.

[2]http://www.saarc-sadkn.org/landslide.aspx

[3]http://pubs.usgs.gov/fs/2004/3072/fs-2004-3072.html

[4]http://geology.isu.edu/wapi/envgeo/EG4_mass_wasting/EG_module_4.htm

[5]National Institute of Disaster Management, Ministry of Home Affairs, Govt. of India, Do’s & Don’ts for Common Disasters

Tsunami[1]

Tsunamis and earthquakes happen after centuries of energy build up within the earth. A tsunami (in Japanese ‘tsu’ means harbor and ‘nami’ means wave) is a series of water waves caused by the displacement of a large volume of a body of water, usually an ocean. In the Tamil language it is known as “Aazhi Peralai”. Seismicity generated tsunamis are the result of abrupt deformation of sea floor, resulting vertical displacement of the overlying water. Earthquakes occurring beneath the sea level, the water above the reformed area is displaced from its equilibrium position. The release of energy produces tsunami waves which have small amplitude but a very long wavelength (often hundreds of kilometer long). It may be caused by non-seismic event also such as a landslide or the impact of a meteor.

Characteristics: Tsunami in the deep ocean may have very long wave length of hundred of kilometer and travels at about 800 km per hour, but an amplitude of only about 1 km. It remains undetected by ships in the deep sea. However, when it approaches the coast its wavelength diminishes, but amplitude grows enormously, and it takes very little time to reach its full height. The Computer model can provide tsunami arrival, usually within minutes of the arrival time. Tsunamis have great erosion potential, stripping beaches of sand, coastal vegetation and dissipating its energy through the destruction of houses and coastal structure.

How do landslides, volcanic eruptions, and cosmic collisions generate tsunamis?[2]

A tsunami can be generated by any disturbance that displaces a large water mass from its equilibrium position. In the case of earthquake-generated tsunamis, the water column is disturbed by the uplift or subsidence of the sea floor. Submarine landslides, which often accompany large earthquakes, as well as collapses of volcanic edifices, can also disturb the overlying water column as sediment and rock slump downslope and are redistributed across the sea floor. Similarly, a violent submarine volcanic eruption can create an impulsive force that uplifts the water column and generates a tsunami. Conversely, supermarine landslides and cosmic-body impacts disturb the water from above, as momentum from falling debris is transferred to the water into which the debris falls. Generally speaking, tsunamis generated from these mechanisms, unlike the Pacific-wide tsunamis caused by some earthquakes, dissipate quickly and rarely affect coastlines distant from the source area. What happens to a tsunami as it approaches land?

As a tsunami leaves the deep water of the open ocean and travels into the shallower water near the coast, it transforms. The tsunami's energy flux, which is dependent on both its wave speed and wave height, remains nearly constant. Consequently, as the tsunami's speed diminishes as it travels into shallower water, its height grows. Because of this shoaling effect, a tsunami, imperceptible at sea, may grow to be several meters or more in height near the coast. When it finally reaches the coast, a tsunami may appear as a rapidly rising or falling tide, a series of breaking waves, or even a bore.

Tsunami Warning System[3,4]

A state-of-the-art early warning centre is established at Indian National Centre for Ocean Information Services (INCOIS) with all the necessary computational and communication infrastructure that enables reception of real-time data from all the sensors, analysis of the data, generation and dissemination of tsunami advisories following a standard operating procedure. Seismic and sea-level data are continuously monitored in the Early Warning Centre using a custom-built software application that generates alarms/alerts in the warning centre whenever a pre-set threshold is crossed. Tsunami warnings/watches are then generated based on pre-set decision support rules and disseminated to the concerned authorities for action, following a Standard Operating Procedure. The efficiency of the end-to-end system was proved during the large under-sea earthquake of 8.4 M that occurred on September 12, 2007 in the Indian Ocean.

In the aftermath of the 2004 Indian Ocean tsunami, Pacific Tsunami Warning Centre PTWC has taken on additional areas of responsibility, including the Indian Ocean, South China Sea, Caribbean Sea, and Puerto Rico & U.S. Virgin Islands (until June 2007). In order to know the occurrence of tsunamigenic earthquakes in the past 60 days in and around the Indian ocean sea.

The Indian Tsunami Early Warning System has the responsibility to provide tsunami advisories to Indian Mainland and the Island regions. Acting as one of the Regional Tsunami Advisory service Providers (RTSPs) for the Indian Ocean Region, ITEWS also provide tsunami advisories to the Indian Ocean rim countries along with Australia & Indonesia.

Establishment of India Tsunami Early Warning System (ITEWS)[4]

The December 26, 2004 earthquake and the subsequent tsunami exposed the vulnerability of the Indian coastline to Oceanic hazards. Following the event, India started its own interim tsunami warning center in the first quarter of 2005 to issue tsunami bulletins generated from seismic information. The interim services were succeeded by setting up of a state-of-the-art Indian Tsunami Early Warning System (ITEWS) at the Indian National Centre for Ocean Information Services (INCOIS), Hyderabad, under the Earth System Sciences Organization (ESSO), Govt. of India. The system implemented in phases became full-fledged 24X7 operational early warning system in October 2007.

Components of ITEWS[4]

The Tsunami Early Warning System comprises a real-time network of seismic stations, Bottom Pressure Recorders (BPR), tide gauges and 24 X 7 operational warning centre to detect tsunamigenic earthquakes, to monitor tsunamis and to provide timely advisories following the Standard Operating Procedure (SOP), to vulnerable community by means of latest communication methods with back-end support of a pre-run model scenario database and Decision Support System (DSS).

Currently Warning Centre disseminates tsunami bulletins to various stakeholders through multiple dissemination modes simultaneously (Fax, Phone, Emails, GTS and SMS etc.). Users can also register on the website for receiving earthquake alerts and tsunami bulletins through emails and SMS.

Tsunami Information[5]

Tsunamis are formed by a displacement of water - a landslide, volcanic eruption, or, as in this case, slippage of the boundary between two of the earth's tectonic plates -slabs of rock 50 to 650 feet (15 to 200 m) thick that carry the Earth's continents and seas on an underground ocean of much hotter, semi-solid material.

The December 26 2004 mega tsunami was caused by slippage of about 600 miles (1,000 km) of the boundary between the India and Burma plates off the west coast of northern Sumatra. The convergence of other plates strains the area, and at the quake's epicenter, the India plate is moving to the northeast at 2 inches (5 cm) per year relative to the Burma plate. The aftershocks were distributed along the plate boundary from the epicenter to near Andaman Island.

Tsunamis can travel up to 600 mph (965 km per hour), 521 knots) at the deepest point of the water, but slow as they near the shore, eventually hitting the shore at 30 to 40 mph (48 to 64 kph or 26 to 35 knots). The energy of the wave's speed is transferred to height and sheer force as it nears shore.

The 7.3 magnitude aftershock might have been powerful enough to create further tsunamis, but did not.

Historical information[4]

The Indian coastal belt has not recorded many Tsunamis in the past. Waves accompanying earthquake activity has been reported over the North, Bay of Bengal. During an earthquake in 1881 which had its epicenter near the center of the Bay of Bengal, Tsunamis were reported. The earthquake of 1941 in the Bay of Bengal caused some damage in Andaman region. This was unusual because most Tsunamis are generated by shocks which occur at or near the flanks of continental slopes. During the earthquakes of 1819 and 1845 near the Rann of Kutch, there were rapid movements of water into the sea. There is no mention of waves resulting from these earthquakes along the coast, adjacent to the Arabian sea, and it is unlikely that Tsunamis were generated. Further west, in the Persian Gulf, the 1945 Makran earthquake (magnitude 8.1) generated Tsunami of 12 to 15 meters height. This caused a huge deluge, with considerable loss of life and property at Ormara and Pasi. The estimated height of the Tsunami at Gulf of Cambay was 15m but no report of damage is available. The estimated height of the waves was about 2 meters at Mumbai, where boats were taken away from their moorings and casualties occurred.

A list showing the Tsunami that affected Indian coast prior to Sumatra Earthquake of December 26, 2004, is given in the below table.

Date	Cause	Impact
12th April, 1762	Earthquake in Bay of Bengal.	Tsunami wave of 1.8m at Bangladesh coast
31st December, 1881	Magnitude 7.8 earthquake beneath the Car Nicobar	Entire East coast of India including Andaman & Nicobar coast was affected by tsunami
27th August, 1883	Eruption of krakatoa volcano (Sunda Strait) Indonesia	East coast of India was affected and 2 m Tsunami was reported at Chennai.
26th June, 1941	A 8.1 Magnitude earthquake in Andaman	East Coast of India was affected by tsunami.
27th November, 1945	27th November, 1945 (21 Hour 56 Min. 50 Sec. UTC) in the Makran subduction zone (Baluchistan, Pakistan) (24.5N & 63.0E) with Mw of 8.1	West coast of India was affected by Tsunami

Tsunami Risk and Vulnerability in India[6]

The Indian Ocean Tsunami on 26th December, 2004 which devastated the coastal communities in 14 countries, caused enormous loss of life and damage to property, assets and infrastructure in the coastal villages of Kerala, Tamil Nadu, Andhra Pradesh, Puducherry and the Andaman & Nicobar Islands. The tsunami risk and vulnerability which the coastal communities in India are exposed to, even by a distant high intensity earthquake in Indonesia, came as a shock and surprise to the unsuspecting public. The absence of an effective Tsunami Early Warning System (TEWS) and the last mile connectivity to disseminate alert and early warning messages to the coastal communities as well as the lack of public awareness and emergency response preparedness among the various stakeholder groups made the tsunami response more difficult and challenging. Most Tsunamis are caused by earthquakes (of magnitude more than 6.5 on the Richter Scale), with a vertical disruption of the water column generally caused by a vertical tectonic displacement of the sea bottom along a zone of fracture in the earth's crust which underlies or borders the ocean floor. Tsunamis are also generated by volcanic eruptions and submarine landslides, nuclear explosions, and even due to impact or fall of large size meteorites, asteroids, and comets from outerspace. Tsunamigenic zones that threaten the Indian Coast have been identified by considering the historical tsunamis, earthquakes, their magnitudes, location of the area relative to a fault, and also by tsunami modelling. Both the east and west coasts of India and the island regions are likely to be affected by tsunamis from the five potential source regions, viz., the Andaman-Nicobar- Sumatra island arc, Indo-Burmese zone, Nascent Boundary (in the central Indian Ocean), Chagos archipelago and the Makran subduction zone.

Even though most people were not aware of the tsunami risk in India's coastal states, the Indian Ocean Tsunami of 26th December 2004 exposed the inherent vulnerabilities of the coastal communities in our 7516 km long coastline. The coastal population has been increasing steadily, mostly due to the expanding scope for exploitation of sea resources and economic activities propelled by increasing urbanization and industrialization in the coastal districts as well as increasing employment opportunities due to the unprecedented expansion in tourism-related activities. However, so far the efforts to strengthen the preparedness of the coastal communities to face the increasing threats of storm surges, sea level rise, coastal erosion, etc. have been often restricted to localized campaigns with very limited impact, in spite of the increasing disaster risk and vulnerability of the coastal communities.

Tsunami in the Indian Sub-continent[6]

In the past, a few devastating tsunamis have occurred in the Indian Ocean and in the Mediterranean Sea. The most significant tsunami in the region of the Indian Ocean was the one associated with the violent explosion of the volcanic island of Krakatoa in August 1883 which reportedly triggered a thirty metre high tsunami wave and killed 36,500 people in Java and Sumatra in Indonesia.

Although not as frequent as in the Pacific Ocean, tsunamis generated in the Indian Ocean pose a great threat to all the countries of the region. Countries most vulnerable to tsunamis in the Indian Ocean region are: Indonesia, Thailand, India, Sri Lanka, Pakistan, Iran, Malaysia, Myanmar, Maldives, Somalia, Bangladesh, Kenya, Madagascar, Mauritius, Oman, Reunion Island (France), Seychelles, South Africa and Australia. Even though tsunamis occur very rarely in the Indian Ocean region, in the last 300 years, this region recorded 13 tsunamis and 3 of them occurred in the Andaman and Nicobar region for which the details of location of epicenter, death/damage caused etc. are not known. The three tsunamis which affected Andaman and Nicobar islands occurred on 19th August 1868, 31st December 1881 and 26th June 1941. The 1945 tsunami following an earthquake of magnitude 8.2 Ms in the Arabian Sea had a maximum run up of 13 metres in Pakistan and resulted in the death of 4,000 people. Overall, the run-up levels in the Indian Ocean tsunamis varied from 1 to 13 metres. In 1977, a strong earthquake of magnitude Ms 8.1 struck west of Sumba Island in Indonesia, but there were no reports of casualties in India due to this tsunami.

Indian Ocean Tsunami of 26th December 2004[6]

The Indian Ocean Tsunami of 26th December 2004 is one of the most destructive Tsunamis known to have hit India and 13 other countries in the Indian Ocean region. With a combined toll of 238,000 casualties (including 51,500 people missing), and roughly more than 1.5 million people displaced in fourteen countries, this tsunami resulted in damage and destruction of property, assets and infrastructure in the coastal areas. In India 10,749 people lost their lives due to the tsunami and 5,640 people were missing in the Tsunami affected areas.

Tsunami Risk Assessment and Vulnerability Analysis[6]

It is important to collect historical tsunami data and on run-ups for better future estimate of tsunami hazard. The Indian National Centre for Ocean Information Services (INCOIS), Hyderabad has compiled databases of tsunamigenic earthquakes and carries out posttsunami studies. It is important to collect historical tsunami data and on run-ups for better future estimate of tsunami hazard. The Indian National Centre for Ocean Information Services (INCOIS), Hyderabad has compiled databases of tsunamigenic earthquakes and carries out post tsunami studies.

Prior to the Tsunami of 26 December 2004, the most destructive Pacific-wide Tsunami of recent history occurred along the coast of Chile on 22nd May 1960. All coastal towns between the 36th and 44th S (latitude) parallels either were destroyed or heavily damaged by the action of the waves and the quake. The combined Tsunami and earthquake toll included an estimated 2,000 people killed, 3,000 people injured, 2 million people rendered homeless and caused damages estimated at $550 million. Off Corral, the waves were estimated to be 20.4 meters (67 feet) high. The Tsunami caused 61 deaths in Hawaii, 20 in the Philippines, and 100 or more in Japan. Wave heights varied from slight oscillations in some areas to range of 12.2 meters (40 feet) at Pitcairn Islands, 10.7 meters (35 feet) at Hilo, Hawaii and 6.1 meters (20 feet) at several locations in Japan. Tsunamis are very common in the Pacific Ocean because it is surrounded on all sides by a seismically active belt. In the Hawaiian Islands, tsunamis approach from all directions, namely, from Japan, the Aleutian Islands and from South America.

The Tsunami Hazard and Its Assessment[6]

Tsunamis are generated by large and rapid displacements of water, mainly from sudden and large scale changes in the configuration of the sea floor associated with fault displacement or gigantic underwater landslides, which could be mainly due to earthquakes.

Till the Indian Ocean tsunami hit the Indian shores on 26th December 2004, people were not aware about the possible tsunami threat in India. Only a few tsunami events in the past have occurred in the Indian Ocean and some of them were highly destructive, causing inundation and flooding wiping out fishery business, disrupting tourism, polluting drinking water, damaging vegetation and crops, destroying shelters and damaging coastal navigation system making huge impact on the economy. It also caused widespread damage to jetties, harbours and coastal structures. Both East and West Indian shorelines are vulnerable to tsunami wave action. It has more than 2200 km shoreline which is heavily populated. For a tsunami to hit Indian coastline, it is necessary that a tsunamigenic earthquake of magnitude greater than 6.5 should occur. Actual tsunami hazard of a coastline depends on its bathymetry and coastal topography.

Earthquakes generate tsunamis by vertical movement of the sea floor as in normal faulting or thrust faulting. If the sea floor movement is horizontal, tsunamis are not generated as in strike slip earthquake. However, it is equally possible that tsunamis are triggered also by marine landslides into or under the water surface. They can also be generated by volcanic activity and meteorite impacts, but such events are extremely rare. Tsunami hazard along a coastline is therefore a combination of all the potential sources of tsunamis that lie in the neighbouring sea or ocean. Tsunami velocity is dependent on the depth of water through which it travels, and is equal to the square root of depth times the gravitational acceleration. Tsunami waves travel at a speed of approximately 700 km/ hr in 4000 m of water. In 10 m of water the velocity drops to about 36 km/hr.

The Tsunami Hazard Area may be empirically defined using a deterministic approach, based upon the observed run-up and inundations during the Tsunami and the potential maximum wave heights for the scenario tsunamis. As found applicable, remote sensing and geographic information system (GIS) of the coastal areas may be used. For the terrestrial environment, the hazards may be presented as inundation levels, in terms of run-up heights at specified land contours. The definition of the tsunami hazard zones, as preliminary estimates, is given below. For Tsunami mitigation as well as development strategies in rural and urban areas, the coastal areas can be divided into four hazard zones, with zone 1 as the less dangerous zone and the zone 4 as the most dangerous zone.

The zones are defined as:

- Zone-1 maximum water depth 0-3 m
- Zone-2 maximum water depth 3-6 m
- Zone-3 maximum water depth 6-9 m
- Zone-4 maximum water depth > 9 m

Multi-Hazard Situation in Coastal Areas of States/UTs[6]

The tsunami affected coast will have a small width of 500 m to about 1.5 km forming part of the coastal management zone. The areas in most cases will be subjected to severe cyclonic wind storms and storm surges which may even be higher than the tsunami run-up levels. Many of the areas in the deltaic plains of the rivers will be subjected to flooding under heavy rains. The Andaman & Nicobar Islands and the Kutch district of Gujarat are in the most severe Seismic Zone V and some coastal areas of Saurashtra and Maharashtra are in seismic zone IV. Besides, many coastal areas are in seismic zone III. This fact will have an important bearing while preparing the DM plans for the tsunami hazard zones on the coasts. The National Disaster Management Guidelines prepared by NDMA for the Management of Cyclones, Medical Preparedness and Mass Casualty Management and Psycho Social Health and Mental Health Services also provide inputs for the preparation of Disaster Management Plans in the coastal areas which are prone to tsunamis.

The assessment of vulnerability and risk and mapping thereof in the tsunami hazard area must be carried out taking the various other hazards as applicable. Many of the areas prone to tsunamis are also prone to storm surges caused by tropical cyclones. Hence, a multihazard approach will have to be followed for addressing the preparedness, mitigation and emergency response requirements in the coastal areas.

Tsunami Vulnerability Assessment[6]

The vulnerability assessment of both built and natural environment due to tsunami impact will be developed for shores and harbours by MoES. Potential damage from any Tsunami prevails because of hydrological effects to structures by pressure and suction, scouring and liquefaction, cracking and slumping. These result in structural damage to buildings, contents in the house, as well as damage to infrastructure (roads, bridges, water supply, sewerage, wharves, seawalls), and navigational aids. There is the potential for "seiching" in the shallow harbour areas where alternately (from the tsunami waves), water is drained from the harbour and then flooded to depths greater than high tide levels. The above damages also pose a threat to human life by causing death and injury.

Vulnerability can be defined as the predisposition of something to be affected because of inherent properties of a system, process and community. The vulnerability assessment is expressed as details of elements of the built, natural and human environments vulnerable to potential tsunami-related damage. The Tsunami Hazard Zones (THZs) consisting of terrestrial environments around the shores and the marine environments need to be included in the vulnerability assessment.

The generic lists of ecologically sensitive areas and areas of particular concern are stated below:

a) The ecologically sensitive areas include mangroves; coral reefs; sand beaches; sand dunes; inland tidal water bodies, i.e. estuaries, lakes, lagoons, creeks; mudflats; marine wildlife protected areas under the Wildlife (Conservation) Act; coastal fresh water lakes; salt marshes ; turtle nesting grounds; horse shoe crab habitats; sea grass beds; sea weed beds and nesting grounds of migratory birds.

b) The areas of particular concern include: coastal municipalities/corporations (the entire notified area); coastal panchayats with population density more than 400 persons (entire notified area) as per the latest Census of India; ports and harbours; notified tourism areas; mining sites; notified industrial estates; Special Economic Zones; cultural heritage areas; notified archaeological sites under the Protected Monuments Act; Critical Defence areas/installations; power plants; and other strategic installations.

Tsunami Preparedness[6]

Warning System Components and Instruments

- A Network of Land-based Seismic Stations for earthquake detection and estimation of source parameters in the two known tsunamigenic zones (viz. Java-Sumatra-Andaman-Myanmar belt and the North Arabian Sea) that would affect the Indian Ocean region and communicating the same to Early Warning Centre in near-real time.

- Detection of Tsunami generation through a network of 10-12 bottom pressure recorders (that could detect and measure a change in water level of 1 cm at water depths of up to 6 km of water) around these two tsunamigenic zones,
- Monitoring the progress of Tsunami and Storm Surges through a network of 50 real time tide gauges,
- Tsunami Modelling (addressing the inundation and amplification all along the coast and islands for different tsunami originating from different sources),
- Generating and updating a high resolution data base on bathymetry, coastal topography, coastal land use, coastal vulnerability as well as historic data base on Tsunami and Storm Surge to prepare and update Storm Surge/Tsunami hazard maps in 1:5,000 scale (for coastal areas within 1-3 km in general and for 10-25 km at selected areas near coastal water bodies),
- Setting up a dedicated National Early Warning Centre (NEWC) for monitoring tsunamis and storm surges in India for operation on 24x7 basis and for generation of timely advisories, and
- Capacity building, training and education of all stakeholders on utilisation of the maps, warning and watch advisories.

Tsunami Terminology

Arrival Time: Time of arrival of the first wave of a tsunami at a particular location.

Coastal Area: The area of land behind the sea coast up to the zero inundation line during the estimated future tsunamis and beyond the coast in the sea requiring tsunami management; the area on the landward side of the mean water line and the area up to 5m. water depth on the seaward side of the mean water line.

Estimated Time of Arrival: Computed arrival time of the first wave of a tsunami at the coast after the occurrence of specific major disturbance in the ocean like earthquakes, landslides, volcanic activity in the ocean, meteorite impact on the ocean surface, etc.

Far field Tsunami: A tsunami capable of widespread destruction, not only in the immediate region of its generation, but across the entire ocean basin.

Green's Function: A type of function used to solve inhomogeneous differential equations subject to boundary conditions.

Inundation Distance: The distance that a tsunami wave penetrates onto the shore, measured horizontally from the mean water line.

Intensity: Intensity is the degree of damage caused by a tsunami.

Local Tsunami or Near- field Tsunami: A tsunami which has destructive effects (confined to coasts within 200 Kms of the Source with arrival time less than 30 minutes).

Near-Field Tsunami: A tsunami from a nearby source, generally less than 200 km or associated with a short travel time of less than 30 minutes.

Regional Tsunami: A tsunami capable of destruction in a particular geographic region, generally within about1000 km of its source. Regional tsunamis also occasionally have very limited and localized effects outside the region.

Tsunami: A Japanese term meaning "harbour wave", derived from the characters "tsu" meaning harbour and "nami" meaning wave, to describe a system of ocean gravity waves having a long wave length and period (time between crests), formed as a result of large-scale disturbance of the sea caused by an earthquake.

Vulnerability Line: Vulnerability line is a setback line to be demarcated on the coastal stretches, taking into account the vulnerability of the coast to natural and man-made hazards.

Do's & Dont's[6]

Before & During

- Find out if your home is in the danger zone.
- Know the height of your street/house above sea level and the distance from the coast.
- People living along the coast should consider an earthquake or strong ground rumbling as a warning signal.
- Try and climb a raised platform or climb the highest floor of any house or building which you might see.
- Make evacuation plans and a safe route for evacuation. Stay away from the beach.
- Never go down near the beach to watch the Tsunami.
- Listen to a radio or television to get the latest information and be ready to evacuate if asked to do so.
- If you hear an official warning, evacuate at once. Return home only after authorities advice it is safe to do so.

After

- Stay tuned to the battery-operated radio for the latest emergency information. Help injured and trapped persons.
- Stay away from flooded and damaged areas until officials say it is safe to return.
- Enter your home with caution.
- Use flashlight when entering damaged houses. Check for electrical short circuit and live wires.
- Check food supplies and test drinking water.

References:

[1]Ministry of Home Affairs, Government of India (2011): Disaster Management in India

[2]http://www.sristi.org/dmis/landslides

[3]http://www.saarc-sadkn.org/tws.aspx

[4]http://www.tsunami.incois.gov.in/ITEWS/earlywarningsystemcomponents.jsp

[5]National Disaster Management Authority, Govt. of India, (2010): National Disaster Management Guidenilne, Management of Tsunamis.

[6]National Institute of Disaster Management, Ministry of Home Affairs, Govt. of India, Do’s & Don’ts for Common Disasters.

Volcanoes

What is a Volcano?[1]

A volcano is a vent or chimney which transfers molten rock known as magma from depth to the Earth's surface. Magma erupting from a volcano is called lava and is the material which builds up the cone surrounding the vent.

(Source: http://globalbhasin.blogspot.in/p/glimpses-of.html)

A volcano is active if it is erupting lava, releasing gas or generates seismic activity. A volcano is dormant if it has not erupted for a long time, but could erupt again in the future. Once a volcano has been dormant for more than 10 000 years, it is termed extinct.

The explosiveness of a volcanic eruption depends on how easily magma can flow and the amount of gas trapped within the magma. Large amounts of water and carbon dioxide are dissolved in magma causing it to behave in a similar way to gas expanding in fizzy drinks, which forms bubbles and escapes after opening.

As magma rises quickly through the Earth's crust, gas bubbles form and expand up to 1000 times their original size.

Volcanoes can be different in appearance with some featuring perfect cone shapes while others are deep depressions filled with water. The form of a volcano provides a clue to the type and size of its eruption which is controlled by the characteristics and composition of magma. The size, style and frequency of eruptions can differ greatly, but all these elements correlated to the shape of a volcano. Three common volcanoes are:

Shield volcano

When magma is very hot and runny, gases can escape and eruptions are gentle with considerable amounts of magma reaching the surface to form lava flows. Shield volcanoes have a broad, flattened dome-like shape created by layers of runny lava flowing over its surface and cooling. Because the lava flows easily, it can move down gradual slopes over great distances from the volcanic vents. The lava flows are sufficiently slow for humans to outrun or outwalk them. This type of magma has a temperature between 800°C and 1200°C and is called basaltic magma.

Composite volcano (Strato)

Also known as strato-volcanoes, these volcanoes are characterised by an explosive eruption style. When magma is slightly cooler it is thick and sticky, or viscous, which makes it harder for gas bubbles to expand and escape. The resulting pressure causes the magma to foam and explode violently, blasting it into tiny pieces known as volcanic ash. These eruptions create steep sided cones. They can also create lava flows, hot ash clouds called pyroclastic flows and dangerous mudflows called lahars. This type of magma has a temperature between 800°C and 1000°C and is called andesitic magma.

Caldera volcano

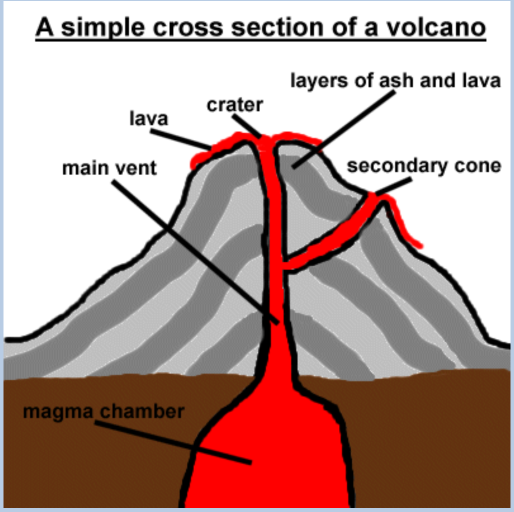
These erupt so explosively that little material builds up near the vent. Eruptions partly or entirely empty the underlying magma chamber which leaves the region around the vent unsupported, causing it to sink or collapse under its own weight. The resulting basin-shaped depression is roughly circular and is usually several kilometres or more in diameter. The lava erupted from caldera volcanoes is very viscous and generally the coolest with temperatures ranging from 650°C to 800°C and is called rhyolitic magma. Although caldera volcanoes are rare, they are the most dangerous. Volcanic hazards from this type of eruption include widespread ash fall, large pyroclastic surges and tsunami from caldera collapse into oceans.

Volcanic hazards

Volcanic hazards include explosions, lava flows, bombs or ballistics, ash or tephra, pyroclastic flows, pyroclastic surges, mudflows or lahars, landslides, earthquakes, ground deformation, tsunami, air shocks, lightning, poisonous gas and glacial outburst flooding known as jökulhlaups. Each hazard has a different consequence, although not all occur in all eruptions or in association with all volcanoes.

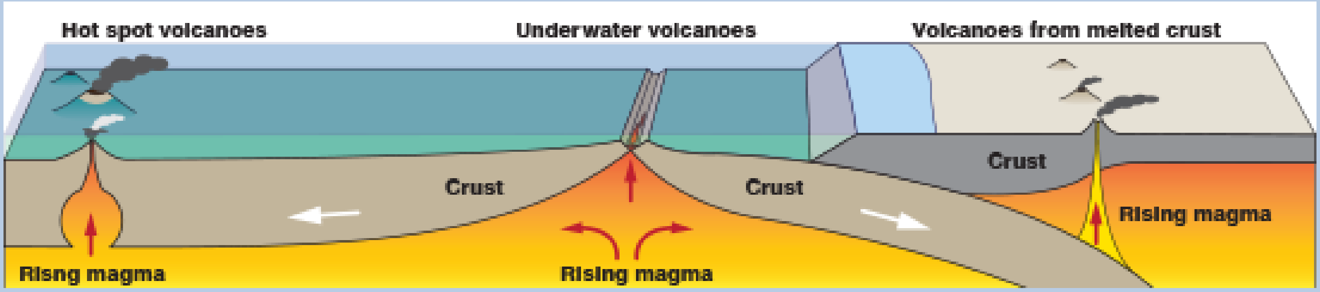
Volcanic eruptions are measured using a simple descriptive index known as the Volcano Explosivity Index, which ranges from zero to eight. The index combines the volume of material ejected with the height of an eruption column and the duration of the eruption.

What are the main features of a volcano?[2]



What Causes Volcanoes?[3]

Volcanoes occur when material significantly warmer than its surroundings is erupted onto the surface of a planet or moon from its interior. On Earth, the erupted material can be liquid rock ("lava" when it's on the surface, "magma" when it's underground), ash, cinders, and/or gas. There are three reasons why magma might rise and cause eruptions onto Earth's surface.



Volcanoes on Earth form from rising magma. Magma rises in three different ways.

Magma can rise when pieces of Earth's crust called tectonic plates slowly move away from each other. The magma rises up to fill in the space. When this happens underwater volcanoes can form. Magma also rises when these tectonic plates move toward each other. When this happens, part of Earth's crust can be forced deep into its interior. The high heat and pressure cause the crust to melt and rise as magma. A final way that magma rises is over hot spots. Hot spots are exactly what they sound like-hot areas inside of Earth. These areas heat up magma. The magma becomes less dense. When it is less dense it rises. Each of the reasons for rising magma are a bit different, but each can form volcanoes.

Types of Volcano[4]

If asked to draw a volcano, most people will sketch a steep, cone-shaped mountain, usually with clouds billowing from the summit. This is one type, but some of the most explosive volcanoes are less obvious, and represented by large depressions that may be filled with water.

Although New Zealand's active volcanoes look quite different from one another, they can be grouped into three main landform types:

- Classic cones or stratovolcanoes
- Volcanic fields
- Calderas and collapse craters.

Each of these has distinct landforms, and the violence and styles of eruptions are unique to each. These differences reflect the main type of magma erupted:

- Andesite at the cone volcanoes
- Basalt at the volcanic fields
- Rhyolite at the calderas.

How is the Volcano Formed?[5]

The glowing magma of Earth's mantle pushes up towards the surface, searching for ways to escape through cracks in the Earth's crust. It does not always get through. If the crust is too dense, the magma stops and flows back,until, with the gasses of the magma, it stays trapped. In time it succeeds in escaping- then, it explodes like a cork from a bottle. A volcano is 'born'. This erupts magma into the air in the form of molten lava, gas, ash and solid fragments.

How safe are Volcanoes? [5]

Volcanoes are much safer than other natural events such as earthquakes, floods, and hurricanes. However, volcanic eruptions can hurl hot rocks for at least 30 km. Floods, airborne ash, or noxious fumes can spread 160 km or more. If you live or work near a known volcano, active or dormant, be ready to evacuate at a moment's notice. Stay out of the area. A lateral blast of a volcano can travel many km from the mountain. Trying to watch an erupting volcano is a deadly idea.

- Be prepared for these disasters that can be spawned by volcanoes: earthquakes, flash floods, landslides and mudflows, thunderstorms, tsunamis.
- Evacuation: Although it may seem safe to stay at home or in the office and wait out and eruption, doing so could be very dangerous. The rock debris from a volcano can break windows and set buildings on fire. Leave the area before the disaster begins.

Safety recommendations when visiting an active Volcano[5]

Pre-Planning

Read about past eruptions: Volcanic eruptions can repeat themselves. What the volcano has done in the past is what it is capable of doing in the future. While volcanoes are inherently unpredictable, studies of past eruptions at a particular volcano will give anindication of what is possible.

Read about past accidents: Analyze what went wrong in past accidents. The Bulletin of the Global Volcanism Network (Smithsonian Institute) has the best monthly volcanic activity reports including accident reports. Two accidents have happened on field trips associated with

International Volcanology Conferences (Galeras in 1993 and Semeru 2000). Many scientists are inexperienced when it comes to climbing volcanoes. Theoretical knowledge is no replacement for field experience.

Observe the volcano for at least 24 hours before getting close to the danger zone: Record the number of explosions per hour and know what the volcano is doing. Sometimes a two to three day observation period is required before approaching the summit area. Simply arriving at the volcano and climbing straight to the summit is asking for trouble!

Know the current volcano warning level: How does this compare to the "normal" state of volcanic activity. Volcano warning levels may be expressed in different forms. Warning levels may mean different things on different volcanoes. Learn what the current activity level means for the particular volcano you are visiting. Remember, most volcanoes are not monitored by scientists so don't rely on the authorities knowing the danger level. Absence of evidence is not evidence of absence. If there is no current eruption warning, it does not necessarily mean the volcano is safe.

Be self sufficient: Do not expect other people to come into the danger zone and rescue you. Don't expect people to risk their life to get you out of danger.

Take all precautions in Preventing an accident: Be very conservative in your actions. Don't assume the volcano is safe if everything looks quiet. It may be the "calm before the storm". A blocked vent can be quiet but the pressure can be building to a large eruption.

Obey local Authorities: Don't enter any area on the volcano if the local authorities prohibit it.

Precautions in the Danger Zone

Wear the correct equipment at all times: Wear a helmet and take a gas mask. If your helmet is not strapped on at all times it is useless. Even effusive volcanoes like Kilauea may send dangerous projectiles into the air from lava sea-water interactions and methane explosions. Unstable ground can result in falls and head injuries.

Beware of many sources of danger on a volcano: Extreme heat, cold, windstorms, heavy rain/ acid rainfall, lightning, altitude sickness, blizzards, getting lost, volcanic activity, unstable terrain, dangerous plants, animals, and insects. Volcanoes generate their own weather which can be severe and different from that only a few km away. Localized wind storms may reach 150 km/hr without warning. Cooling lava flows may still be deadly, when rain falling on the hot surface may displace breathable air after it flashes to steam (people died from the effect at Nyiragongo eruption in 2002).

Survey the ground on approach to the crater: Look for evidence of recent ejecta. If you can see recent bombs on the ground then you can be hit. Limit your time in that area. It is preferable you relocate to a safer zone. Some vents eject projectiles in a particular direction. Don't stay in the firing line. Recent bombs are black and stand out from the brown colour of older lava.

Watch out for rock falls and avalanches when climbing the crater: Falling rocks and unstable ground pose one of the most immediate hazards when climbing a volcano. Don't kick rocks down the slope and try to limit your impact on the unstable terrain. Watch out for other climbers above and below you. The crater edge may be overhanging. Know where you are walking at all times. Be careful of new ground slumping or cracking.

Beware of Hazardous Gases: Hazardous gases emitted by volcanoes include carbon dioxide, sulfur dioxide, hydrogen sulfide, radon, hydrogen chloride, hydrofluoric acid, and sulfuric acid. Gases can be toxic directly or displace oxygen from the environment leading to anoxia. Never enter a depression near active fumaroles, especially on a day without wind. Toxic gases can pool in the depression leading to a dangerous situation.

Can you directly see the vent: If you can directly see the vent then the projectiles have a direct line of sight to you. Rocks and lava can be ejected at 200 m per second, sometimes even supersonic. You might be hit before you even hear the explosion. Lateral projectiles are some of the most dangerous and can be lethal in even a minor eruption.

Beware of periods of low activity: Quiet periods at a volcano may lure you into a false sense of security, and make you go closer than you would otherwise. Beware of a quiet volcano.

Limit your time in the danger zone: The closer you go to the vent, the greater the risks. In zone 1 (see above) even a minor eruption can be fatal. The risks multiply exponentially in this zone. Spend only minutes in this zone, if you need to be there at all. There is really no reason to be in zone 1 of a volcano. The scientists at Galeras made the fatal error of staying 4 hours in this area! Remember you will be killed here if you stay long enough. It is like sleeping on a freeway. Eventually something will hit you if you stay long enough. Some scientists enter the danger zone immediately after a large eruption because they believe the magma column may be lowered for a while.

Exit the danger zone well before sunset: Start the climb early and exit by midday. If something goes wrong, then rescue will be almost impossible at night. If you survive the accident, then you may die of exposure during the cold night at altitude.

Observe from a safe location: Stay up wind and away from the direction of travel of projectiles. Have an evacuation plan with 2 exits. Mentally rehearse your escape plan continuously while in the danger zone. Vent migration may make a previously safe area off limits. Take time to study the volcano topography before going too close.

If caught in an eruption near the crater take cover: You have a 50% chance of survival if you are caught in an eruption. Hiding behind boulders or in a depression will shield you from lateral projectiles. Watch for vertical projectiles.

Visibility may suddenly reduce to almost zero without warning: This can be due to fog, cloud, rain, volcanic fumes or nightfall. Be sure you can deal with these situations. Most people would have severe problems walking out of an area under these conditions. A familiar location will become a nightmare under limited visibility. If you find yourself in very low visibility then you may just have to sit and wait until conditions improve.

Leave the area if it becomes dangerous: There is no point having a safety plan if it is ignored. Two scientists were killed on Guagua Pichincha Volcano in 1993 when they remained in the crater despite getting a radio warning of possible eruption 85 minutes earlier.

Do not approach lava flowing through vegetation: Underground explosions occur in front of lava flowing over burning vegetation. Plants burn without oxygen as they are covered by lava, creating methane gas. The gas fills underground lava tubes. When the methane ignites, the ground explodes up to 100 meters in front of the advancing lava flow. Rocks and debris blast in all directions.

Look for warning signs of an eruption: Explosive activity may be preceded by earthquakes or rock falls. You may only have 30 seconds warning but this may give you time to take cover or evasive action.

Watch out for Heavy Rain: Heavy rain can cause flash flooding and lahars. A decision to climb an erupting volcano should be based on a risk-benefit analysis. To see an eruption is one of the greatest sights in nature but thechallenge must be accepted with common sense and knowledge of the risks.

Do’s & Dont’s[6]

Before a Volcano

There is usually plenty of warning that a volcano is preparing to erupt. Scientists monitor the Cascade range volcanoes as well as those in Hawaii and Alaska for information to help predict volcanic events. Many communities close to volcanoes now have volcano warning systems to alert citizens. But, if you live anywhere in Washington, Oregon, California, Idaho, Utah, and possibly Wyoming and Nevada you may be affected by an eruption in the Cascade range. Taking a few precautions now won't cost much and are a good idea to do anyway:

- Keep 3 extra air filters and oil filters on hand for your vehicle.
- Keep 3 extra filters for your home heating/cooling system.
- Keep a roll of plastic wrap and packing tape so you can wrap and protect computers, electronics, and appliances from ash.
- Store emergency food and water in your home.
- Find out if your community has a warning system and know the warning signs.
- Create an evacuation plan. It is best to head for high ground away from the eruption to protect against flood danger.
- Define an out-of-town contact for all family members to reach to check in.
- Besides your family emergency kit, have disposable breathing masks and goggles for each family member.

During an Eruption

Much like a tsunami, a volcano is usually a sudden, explosive disaster requiring immediate evacuation to a safer location. The rock debris, pyroclastic flows, and floods will make the area around the volcano dangerous to anyone that stays. The lower valleys will be most dangerous.

- Follow the directions of authorities.
- Take your family emergency kit and evacuate.
- Evacuate to an area upwind rather than downwind if possible.
- When evacuating, if you are in a valley, or close to a stream, or crossing a bridge, check upstream for mudflows. A mud flow is extremely heavy and can destroy a bridge quickly. Take a different route or get to high ground quickly - mudflows can be extremely fast too.

If you are unable to evacuate,

- Seek shelter indoors if possible.

- Close all windows and doors to keep ash out. Seal up drafts. Do what you can to keep ash out.
- Seek higher ground - flash floods, mud, and poisonous gasses will accumulate in low-lying areas.
- Put on long pants, long-sleeved shirt, and hat.
- Wear a dust mask or wetted handkerchief to help filter ash.
- Leave your vehicles turned off until the eruption has ended and the dust can settle. Ash destroyed many vehicle engines during the Mount St. Helens eruption.

After an Eruption

There is still danger after an eruption even if there is no flowing lava. The fact is, it may take years for the environment to recover from the changes caused by the volcano. And, ongoing tremors and further eruptions may make the area uninhabitable for a long time. In the short-term, recovery and clean-up includes:

- Stay inside and listen for volcano information on your radio or tv.
- Minimize your movements and keep all windows and doors closed.
- Keep your skin covered with long pants, long-sleeved shirt and hat to avoid irritation from ash.
- If you have to go outside, where a dust mask and eye goggles.
- Drive slowly and carefully with your lights on - the ash is slippery and stirring it up will clog your enginge. If you do any driving in the ash, there is a good chance you will destroy your engine. Change your oil and air filters after 100 miles at the most when driving through heavy dust.
- Remove ash from your roof if you are concerned about its weight. More than 3 or 4 inches may be too much.
- Spray your yard with your water hose to dampen the ash. This helps keep it from blowing around more. Use as little water as possible.
- Check with your neighbors to see what help they need.
- Shake off and remove your outdoor clothes in your garage before going inside.
- Use your vacuum to dust - dustrags will act like sandpaper rubbing the ash around.
- Check in with your emergency contact to let them know your status and plan.
- Check with authorities on guidelines for ash removal and disposal.

References:

[1] http://www.ga.gov.au/hazards/volcano/volcano-basics/what.html

[2]http://www.geography.learnontheinternet.co.uk/topics/whatvolcano.html#features

[3]http://spaceplace.nasa.gov/volcanoes2/en/

[4] http://www.teara.govt.nz/en/volcanoes/page-1

[5]Canadian Red Cross, Indonesia Mission, Tsunami Recovery Operations, Banda Aceh, Indonesia (2009): Disaster Preparedness Tips (A guide book for personal safety in the field with special reference to Indonesia)

[6]http://www.emergencydude.com/volcano.shtml