

## Natural Hazards Lecture Notes:

### **Slide 1.**

Title Slide

### **Slide 2.**

Firstly, we need to know what a “Geohazard” is:

- It is an Earth process that upon interaction with human activity causes loss of life and (or) property.
- By “Earth process” we mean a natural event that occurs within the lithosphere/crust, hydrosphere (e.g. weather system) or atmosphere.

Why is it important that we study Geohazards?

- Because they are a hazard to the human population and (or) infrastructure
- If human lives were not threatened or endangered then the process would not be classed as a “hazard” and it would not be so vital that we understand the processes involved.

The hazard assessment branch of science, that provides a wide range of jobs, has become very popular over the last few years. With wild weather seemingly becoming more common globally the race is on to find ways to reduce the impact of hazardous events on the human population.

### **Slide 3.**

Why is the human element so critical, or, why is it becoming more important to understand these events?

- The Earth’s population is increasing and therefore, as existing cities etc become full and people search for new space to live in, more and more enter into areas that are prone to hazards.
- For example, today around 50% of the 6 billion inhabitants on Earth live in cities. Current trends suggest that by 2025 there will be 8 billion people on Earth and 66% of them will be living in cities.
- Of all the cities, 40% of them lie on the coast and therefore are prone to severe storm and tsunami damage.

There are many other examples:

- The sides of volcanoes have very fertile soils, so farmers plant their crops or graze their livestock closer and closer to the volcanic vent in order to increase their revenue
- People build houses further up into mountains in areas where landslides occur.

### **Slide 4.**

“Before and After” photographs from Phuket, Thailand, of the 2004 Boxing Day (26th of December) tsunami.

### **Slide 5.**

- We need to remember that we can not stop the geologic process (you can’t stop a volcano from erupting, or a cyclone from forming), we also can not stop the population from growing.

- We can only attempt to reduce the hazard to life and property.

To combat the increasing risk we need more studies to attempt to understand and help forecast future events. We need to be able to monitor the hazardous systems (e.g. volcano monitoring, meteorological/weather monitoring) and to be able to quickly communicate the information from the scientists to the general population.

All of this helps with the aim to MITIGATE (reduce) the effect of the natural hazards.

### **Slide 6.**

There are many types of natural events that can impact human processes:

- Volcanoes, floods, earthquakes, tornadoes, tsunamis, (*Presenter: Can the students think of any more examples?*)... landslides, avalanches, forest fires.....?

- These events can occur either without warning, for example an earthquake.

- Or they may occur with warning, for example you can monitor with satellites when and where a cyclone will hit the coastline. Also, some volcanoes change their behaviour before an eruption, the sides of the volcano may swell and crack as hot molten rock is pushed up towards the surface.

These warnings are called “precursors”. Precursors are what scientists look out for when trying to forecast a future event.

### **Slide 7.**

To help forecast an event and mitigate (reduce) the hazards involved scientists need to know three things:

- 1.The Frequency of the event, i.e. how often the event occurs (on a scale of every month, year, 10 years, 1000 years etc.)

- 2.The Magnitude of the event, i.e. how powerful the event is. This often relates to how destructive the event is.

- There is an important link between frequency and magnitude: for example, an event with a high F and low M may not be as devastating and a hazard with low F but high M.

3. The Scope of an event describes the area the hazard effects. Will the hazard or damage be contained only locally (e.g. landslides, fires, floods and earthquakes), or on a larger regional scale (e.g. tsunami's, explosive volcanoes, large-scale earthquakes, cyclones). The largest, most catastrophic events may even effect the entire globe (e.g. large volcanoes, global warming, meteorite impacts)...

Knowing these three factors for each natural hazard event will help the population to plan for future events.

### **Slide 8.**

See Natural Hazards exercise 1.

### **Slide 9.**

The next parts of the lecture will provide details and give examples of a number of specific natural hazards.

We will first look at earthquakes and tsunamis generated by earthquakes.

### **Slide 10.**

- An earthquake is a sudden release of stored energy in the Earth's crust. For example, this can be caused by sudden movement/slipping along a fault plane or the cracking of rock stressed by tectonic forces.
- This movement sends out seismic waves that travel through the crust potentially causing damage at the surface by a shaking or displacement of the ground.

Terminology:

- The **focus** of an earthquake is the actual location of the energy released inside the Earth's crust.
- The **epicentre** is the point on the Earth's surface directly above the focus.

### **Slide 11.**

The conditions required to put rocks under the amount of stress needed to fracture them mainly occurs around the boundaries of tectonic plates. As plates push together or slide past each other they stick due to friction and then suddenly break and earthquakes are produced.

This figure shows the distribution of earthquakes around the globe. You will notice that they are not randomly distributed, but form lines that snake around the globe. These lines follow the known boundaries of tectonic plates. (*For an overview of plate tectonics see the Plate Tectonics lecture in this series*)

### **Slide 12.**

- The Magnitude of an earthquake is conventionally reported using the Richter Scale. You may have noticed on the news the reporter saying "This earthquake was measured at 6.2" - they are referring to the Richter Scale.
- Magnitude 3 or lower earthquakes will be difficult to notice at the surface, whereas Magnitude 7 and above earthquakes will cause serious damage over a wide area.

*Presenter: Quickly go through an overview of the scale. Note the Frequency (Approx. number each year), small magnitude earthquakes are a lot more common than the devastating high magnitude earthquakes. However there are still 20 > Magnitude 7 earthquakes every year!!*

### **Slide 13.**

- The San Francisco earthquake of 1906 was a major earthquake that hit San Francisco and the coast of northern California on Wednesday, April 18, 1906. The most widely accepted estimate for the magnitude of the earthquake is 7.8; however, other values have been proposed from 7.7 to as high as 8.3.

- The epicenter occurred offshore, about 2 miles (3 km) from the city. It ruptured along the San Andreas Fault for a total length of 296 miles (477 km).
- The earthquake and resulting fire is remembered as one of the worst natural disasters in the history of the USA. The death toll from the earthquake and resulting fire represents the greatest loss of life from a natural disaster in California's history.
- The economic impact has been compared with the more recent Hurricane Katrina disaster.

*Presenter: Refer to the photos to show the large scale of the damage.*

#### **Slide 14.**

- Earthquakes are important hazards to understand as they are responsible for the deaths of the highest number of people per event for any natural hazard.
- They commonly strike without warning, therefore people can not evacuate to safer areas.
- Also there is not a predictable trend to the number of earthquakes per year, when and where they occur (within earthquake prone regions around tectonic plate boundaries) is randomly distributed.

For example there are 1000's of earthquakes every year, but only around 20 of them are magnitude 7 or higher. These 20 events account for 90% of the energy released from all of the earthquakes put together and result in 80% of all the earthquake fatalities.

#### **Slide 15.**

Photographs showing examples of the destruction caused by earthquakes.

#### **Slide 16.**

We can not stop earthquakes from happening and we get no warning as to when they will occur....so how do we lessen the risk of earthquake activity?

- The simple answer is to be prepared:
- In earthquake prone regions the buildings can be reinforced and designed to prevent the likelihood of collapse during an earthquake.
- The population can be educated about what to do in the event of an earthquake and evacuation and rescue plans can be drawn up in advance to minimise chaos and panic if/when an earthquake occurs.
- For example, earthquake education is now part of the curriculum in schools in some states of the USA and in Japan.

#### **Slide 17.**

- An earthquake that occurs under the ocean has the potential to form a tsunami.
  - Tsunami is a Japanese word with "tsu" meaning harbor and "nami" meaning wave.
- Not every earthquake will form a tsunami, the movement must result in the VERTICAL DISPLACEMENT of water.
- That is: if a piece of the ocean floor moves either up or down (see the Extension and Compression fault examples) the ocean water will be rapidly displaced and this will form waves at the surface.

- If two pieces of crust slide past each other (see Transform fault example) there is no vertical movement of the crust or the overlying water and a tsunami will not form.

### **Slide 18.**

This cartoon diagram summarises how an earthquake may form a tsunami.

1. Shows normal conditions. Note the presence of a pre-existing crack or fault in the seafloor
2. The earthquake! An earthquake causes a piece of the seafloor to be pushed up into the overlying ocean. This causes the water to also be displaced/pushed up.
3. The displaced water forms tsunami wave that can travel thousands of kilometres before it reaches land. The wave will break when it does eventually reach the shore potentially causing flooding as the water level rises well above normal sea level.
4. Mud, sand and a trail of debris (trees, building material etc) is left deposited on the sea shore after the wave has subsided.

### **Slide 19.**

You most probably remember the 2004 South Asian Boxing Day tsunami event. This tsunami was caused by an earthquake off the coast of Sumatra that measured a magnitude of 9.2!! The biggest earthquake recorded in 40 years!

*Presenter: Can ask the students if they saw the aftermath of the tsunami on the television and what they remember of the images.*

### **Slide 20.**

- The earthquake off the Sumatran coast was originally recorded as 9.0 but has been increased to 9.2. At this magnitude it is the second largest earthquake ever recorded.
- This earthquake was also reported to have the longest duration of faulting, lasting between 500 and 600 seconds (8.3 to 10 minutes).
- The earthquake was so large that it caused the entire planet to vibrate as much as half an inch, or over a centimetre!!
- It occurred at a convergent (*Presenter: remember the diagram of the convergent fault*) tectonic plate boundary, where an estimated 1,600 km of faultline slipped about 15 m (a LOT of rock moved!).
- The earthquake released  $20 \times 10^{17}$  Joules of energy, which is like setting off 475 million kilograms of TNT or 23,000 atomic bombs!!

NOTE: The largest earthquake ever recorded, which measured 9.5, was in Chile on May 22, 1960.

### **Slide 21.**

- The sudden vertical rise of the seabed during the earthquake displaced massive volumes of water, resulting in a tsunami that struck the coasts of 12 countries around the Indian Ocean.
- Because of the distances involved, the tsunami took anywhere from fifteen minutes to seven hours (for Somalia) to reach the various coastlines. The northern regions of the Indonesian

island of Sumatra were hit very quickly, while Sri Lanka and the east coast of India were hit roughly 90 minutes to two hours later.

These animations show how the tsunami wave radiated out from the 1,600 km rupture in the seafloor.

- The red and yellow areas are those of higher than usual water levels and blue are the areas of lower than normal water levels. Note how the wave dissipates with distance, therefore the countries close to the epicentre are hit by a significantly bigger wave than those further away.

### **Slide 22.**

The tsunami caused widespread flooding and fatalities. Thousands of people died and many more were displaced from their homes. This photo shows an example of the devastation caused by the waves.

### **Slide 23.**

So, we have seen that tsunami's can be extremely devastating - but the question is, what can we do about them?

Firstly, we can monitor for them:

- If there is an earthquake in the ocean, specialist monitoring stations like the Pacific Tsunami Warning Centre (PTWC - pictured top right) can monitor the ocean surface using satellites, radar and buoys in the water that measure current speed and waves. These systems will pick up the presence of a tsunami.
- If a tsunami does occur the PTWC can warn local authorities in the areas where the tsunami is likely to hit.
- Computer simulations, using the speed of the tsunami wave, can estimate the time of arrival for the tsunami.
- This technology is very expensive to run and maintain however, and many poorer countries have to rely on stations from other countries that are far away. For example a tsunami that hit Papua New Guinea in 1998 was undetected as it originated close to the island and was undetected by the PTWC which is located in Hawaii.

### **Slide 24.**

Some areas, such as Hawaii, have building restrictions in hazard prone regions. For example, tsunamis hit the town of Hilo in 1946 and 1960 destroying the harbour and a large part of the town (top photo). Now this region of the city has a ban on the construction of new buildings there and the majority of the land has been turned into a park (bottom photo).

### **Slide 25.**

Seawalls have been constructed on many beaches not only for protection against tsunami's but also the hazards of large storm waves.

- Seawalls are designed to make waves break early (before the shoreline), therefore dissipating their energy before they reach the shore.

Some walls are designed to build up the shoreline to prevent waves from over topping the shore and flowing into residential areas.

### Slide 26.

Finally, to protect the population against tsunamis they need to be educated about the hazards involved and warning systems (sirens, emergency service teams) and evacuation plans (escape to higher ground) need to be established.

### Slide 27.

See Natural Hazards Exercise 2.

### Slide 28.

### Slide 29.

Same Storm - Different Names...depending on where you are in the world tropical storms have different names:

- In the Atlantic and Pacific Oceans (eastern) they are called **hurricanes**.
  - average of 10 named storms per season
  - ~6 becoming hurricanes
  - Over the western Pacific Ocean they are called **typhoons**.
  - average of 16 named storms per season
  - ~9 becoming typhoons
  - The western Pacific ocean is a major source of tropical storms as the water is warmest and there are large distances between landmasses.
  - Over the Indian Ocean the storms are called **cyclones**. “Cyclone” is the best overall phrase to use for high intensity rotating storms.
- Storms that form north of the equator spin counterclockwise. Storms south of the equator spin clockwise. This difference is because of Earth's rotation on its axis.

### Slide 30.

- Tropical cyclones are a MAJOR natural hazard that can cause large numbers of fatalities and extensive damage.

For example the 1991 Bangladesh cyclone, “Cyclone Gorky”, was among the deadliest tropical cyclones on record. On the night of the 29th of August the cyclone struck the southeastern coast of Bangladesh with winds of around 250 km/h (155 mph). The storm forced a 6 metre (20 foot) storm surge wave inland over a wide area, killing at least 138,000 people and leaving as many as 10 million homeless.

### Slide 31.

- Cyclones can devastate large areas, for example Hurricane Katrina (August 2005, USA) had gale force winds extending 120 miles (190 km) from the storm centre (“eye of the storm”) - remember cyclones are radial (circular) so that makes it approximately 240 miles (380 km) from one side to the other!
- In 1999 Hurricane Floyd caused 2.6-million coastal residents across the entire US state of Florida to evacuate their homes.

- The hurricane produced torrential rainfall that caused widespread flooding over a period of several weeks; nearly every river basin in the eastern part of the state exceeded 500-year flood levels.

Hurricane Floyd was responsible for 57 fatalities and US\$5.6 billion of damage.

### **Slide 32.**

- Tropical cyclones form only over warm ocean waters near the equator.
- To form a cyclone, warm, moist air over the ocean rises upward from near the surface. As this air moves up and away from the ocean surface, it leaves less air near the surface. So basically as the warm air rises, it causes an area of lower air pressure below.
- Air from surrounding areas with higher air pressure pushes in to the low pressure area. Then this new “cool” air becomes warm and moist and rises, too. And the cycle continues...
- As the warmed, moist air rises and cools the water in the air forms clouds. The whole system of clouds and wind spins and grows, fed by the ocean’s heat and water evaporating from the ocean surface.
- As the storm system rotates faster and faster, an eye forms in the centre. It is very calm and clear in the eye, with very low air pressure. Higher pressure air from above flows down into the eye.

When the winds in the rotating storm reach 39 mph (63 kmph), the storm is called a “tropical storm”. And when the wind speeds reach 74 mph (119 kmph), the storm is officially a “tropical cyclone” or hurricane. Tropical cyclones usually weaken when they hit land, because they are no longer being “fed” by the energy from the warm ocean waters. However, they often move far inland, dumping many centimetres of rain and causing lots of wind damage before they die out completely.

### **Slide 33.**

- Cyclones are divided into categories depending on the strength of the winds produced. There are many different classification scales but one you may be familiar with is the Saffir-Simpson Hurricane Scale. This scale is used to describe storms in Hollywood movies, e.g. “Twister” and “The Day After Tomorrow”.

The classifications (1-5) are intended primarily for use in measuring the potential damage and flooding (storm surge) a cyclone will cause upon landfall.

### **Slide 34.**

- The students probably would have seen on the news in 2005 the devastating effect that Hurricane Katrina had on the area of New Orleans and surrounds....

- Hurricane Katrina was the costliest and one of the deadliest hurricanes in the history of the USA.

- It was the sixth-strongest Atlantic hurricane ever recorded and the third-strongest hurricane on record that made landfall in the United States.

- Katrina formed on the 23rd of August 2005 and caused devastation along much of the north-central Gulf Coast of the United States.

- The most severe loss of life and property damage occurred in New Orleans, which flooded as the previously emplaced flood defenses failed. The hurricane caused severe destruction across the entire coast of Mississippi and Alabama, as far as 100 miles (160 km) from the storm's centre.

- There were at least 1,836 fatalities recorded and damage estimates are over 81 billion US dollars!

Top Image: A radar image of Hurricane Katrina making its landfall in Louisiana.

Bottom Image: The storm track Hurricane Katrina followed. The colors indicate the category of the hurricane with light yellow as a category 1 storm (lowest) and red as category 5 (highest).

### **Slide 35.**

Damage from Hurricane Katrina in Louisiana.

Left photo: Flooded motorway and surrounding suburbs in New Orleans.

Top right: Bridge damage caused by Katrina - each section of the road has collapsed.

Bottom right: 16 foot (5 m) and higher waves pushed over 23 shrimp boats and the cargo ship named "Caribbean Clipper" (pictured with all of the cars on it) onto shore, along with over 6 fishing boats aground (4 shown). The captain of the 179 foot (55 m) cargo ship M/V *Caribbean Clipper* rode out Katrina on board the ship! The ship was returned to sea, six months later, using a large crane to unload the cargo and re-float the hull.

### **Slide 36.**

We have seen that tropical storms can and do produce a lot of damage, but how is this damage produced? What are the dangers involved?

Firstly, there is the "Storm Surge":

- A storm surge is caused by strong winds pushing on the ocean's surface. The wind causes the water to pile up higher than the ordinary sea level. Storm surges are particularly damaging when they occur at the time of a high tide, which increases the risk of flooding.

- Storm surges are extremely destructive to property, can cause flooding and large amounts of erosion.

- Storm Surges account for 90% of all fatalities associated with cyclones.

- Presenter: When finished explaining click for photograph of flooding caused by Hurricane Wilma's (USA) storm surge in October 2005.*

### **Slide 37.**

Destruction from strong winds will effect a wider region than that damaged by the storm surge. The wind can uproot trees, bring down powerlines, and damage properties.

NOTE: The sheet of corrugated iron wrapped around the tree in the bottom photograph.

### **Slide 38.**

Flying debris - enough said? Imagine being out in winds carrying building material fast enough to split a tree truck in two.....

### **Slide 39.**

How to do mitigate the risk from a cyclone?

- Early warning systems are needed to give people time to make their home safe (e.g. board up windows and doors), or to evacuate to a designated shelter. This may come in the forms of alarms or sirens sounded throughout a town, or notification by radio, television and local enforcement services (police, fire brigade etc.).

- Meteorological stations around the globe can trace the track of a cyclone and predict when and where the storm will make landfall. So in many cases warnings can be made in advance of the disaster.

- In cyclone-prone regions infrastructure can be emplaced to decrease the damage caused by the cyclone

- For example, “cyclone walls” (top photograph) have been built along coastal areas to stop or lessen the impact of a storm surge. These can also be used as roads along which residents can evacuate.

- In low-lying coastal regions communal storm shelters can be built. These act as an evacuation point for people living in the surrounding areas.

- For all of these measures to work the population need to be educated about the threat of the storms and what to do in case of an emergency.

#### **Slide 40.**

Natural Hazards such as earthquakes, tsunamis, cyclones, volcanic eruption, avalanches and landslides, and more are a major cause of fatalities.

- This graph shows the the number of deaths per year due to natural hazards. Remember this is in addition to normal global fatalities due to age, famine, disease etc.

- Every year there are close to 10,000 fatalities caused by natural hazards. In the event of large-scale events (seen by the peaks on the graph) this number rises to ten's of thousands! (Note the logarithmic scale used for the graph)

Natural Hazards cannot be stopped, however measures can be taken to lessen the impact they have on the population. To do this we need to understand the processes involved for each type of event and work out individual emergency plans of action.

Personal Student Stories/Discussion:

- Has anyone in the class experienced a natural hazard event? Earthquake? Tsunami? Tornado? Flood? Seen a volcano erupt? Or a landslide?

- What was it like? Were there plans emplaced? Was it calm or were people panicked?

- If the students were managing the disaster plan would they have done anything differently?