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**Marine Geology**

**By**

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**On**

# Indian Ocean Tsunami and early Warning system in East Africa & the Republic of Mauritius.

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## 1.0 Introduction

Tsunami, or harbor (tsun-) wave (-ami) in Japanese, are caused by geological processes, such as earthquakes, landslides or volcanic eruptions, which displace large volumes of ocean water. The displaced sea surface propagates outward from the source as a series of ocean waves with extremely long wavelengths and periods. Wind-generated waves cause water motion to depths of 150 m; a tsunami involves water movement to the sea floor bottom. The Earth-moving event is most typically an earthquake but tsunamis are also generated from submarine or terrestrial landslides and volcanoes.

## 2.0 The 2004 Indian Ocean (Sumatra Andaman) Earthquake and (Boxing Day) Tsunamis

### 2.1 Generation

The 2004 event in the Indian Ocean occurred at 00:58 UTC (08:58 local time) on 26 December, 2004. The earthquake-generating tsunami had a moment magnitude between 9.1 and 9.3. The event affected the orbit of the Earth and triggered other earthquakes approximately 11,000 km away in Alaska (West et al., 2005).

The epicenter of the Sumatra- Andaman mega thrust event was 30 km undersea around 250 km NW of Sumatra along the Indo-Australian plate boundary. It is estimated that this section of the plate had not moved for >200 years, which during that time, accumulated a lot of energy (McKee, 2005). At the time of impact, the earthquake set a new record for the longest duration at between 8 and 10 min (Walton, 2005). The earthquake ruptured the Sumatra and Sunda subduction zones over a length of 1,300 km (Sibuet et al., 2007), which generated a massive tsunami consisting of two or three main waves and numerous smaller ones. Based upon seabed surveys, it is estimated that there was at least 10 and 45 m of lateral and vertical movement, respectively, along the fault line (Bagla, 2005).

The main earthquake was followed by a series of aftershocks that were recorded in the Andaman Islands archipelago in the Bay of Bengal between India and Myanmar. The largest aftershock registered a magnitude of 8.7 off the coast of Sumatra, because it generated a tsunami that resulted in substantial loss of life.

## 2.2 Size and Extent

The tsunami took between 15 min (Sumatra) and 7 h (Somalia) to reach various locations along the Indian Ocean coastline. Locations closest to the epicenter in the northern regions of the Indonesian island of Sumatra were hit very quickly, whereas Sri Lanka and the east coast of India were hit roughly 2 h later, for example. Thailand was also struck about 2 h later, despite being closer to the epicenter, because the tsunami traveled more slowly in the shallow Andaman Sea (see figure 1-6).

The height ranged from 2 to 3 m at the African coast (Kenya) and up to 10-15 m at Sumatra, the region closest to the earthquake epicenter. The maximum height of the main tsunami wave was between 24 and 30 m and the second main wave was between 10 and 15 m high.

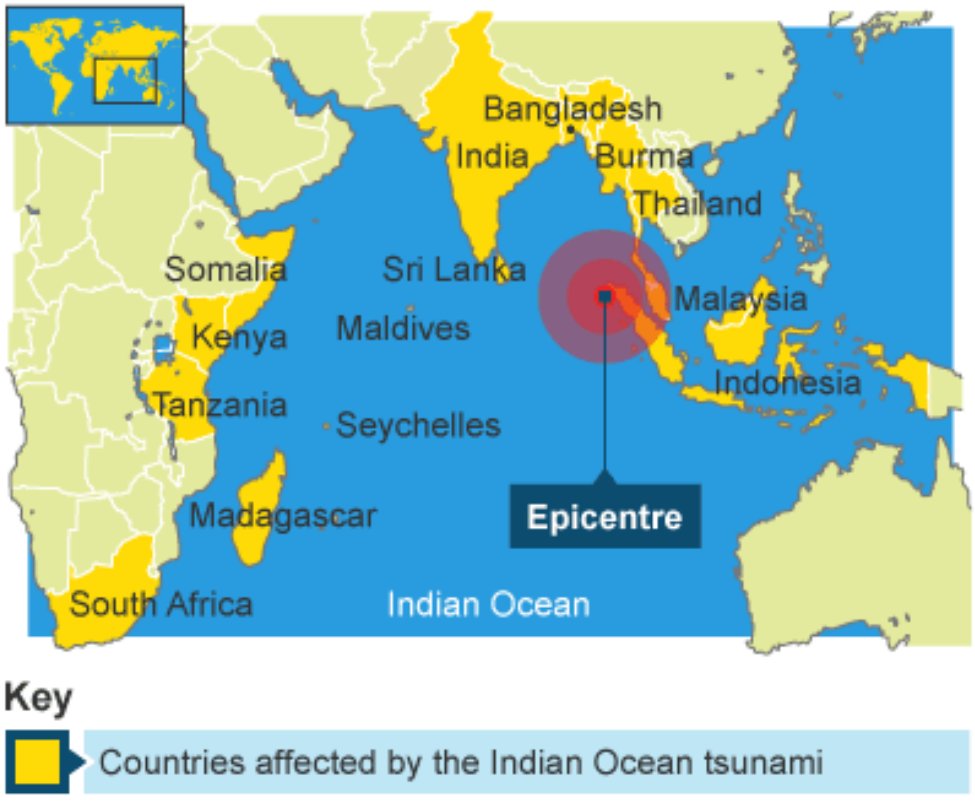


**Figure 1: Countries affected by the Indian Ocean tsunami**

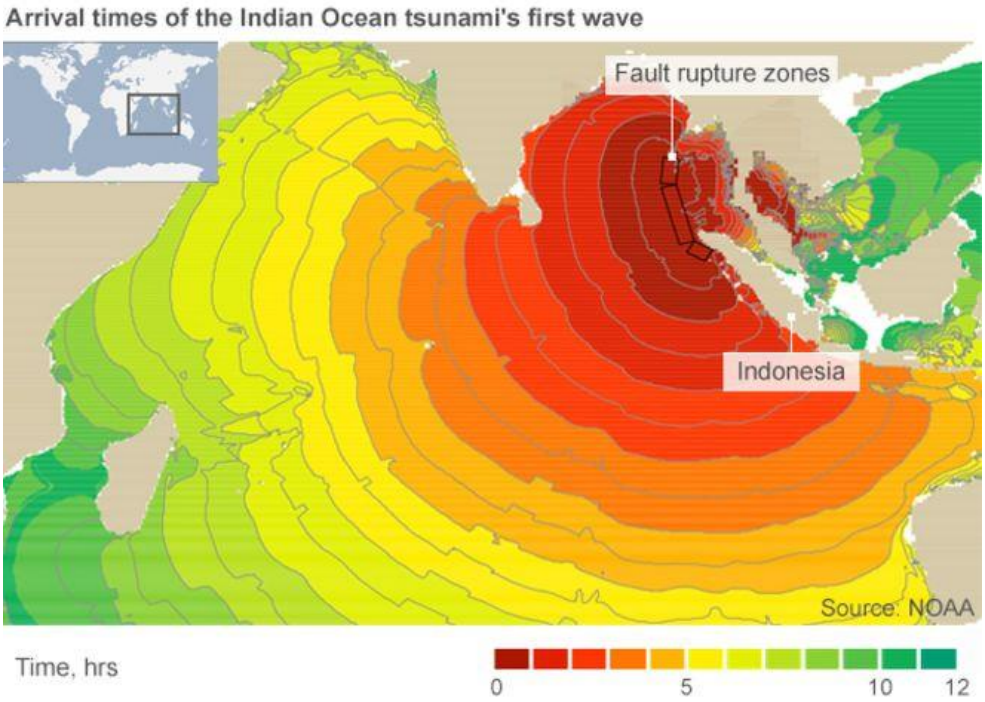


**Figure 2: Arrival times of the Indian Ocean tsunami first wave**

**Figure 3: Seawater splashes in the air as the first tsunami waves hit Ao Nang, Krabi Province, Thailand**


**Figure 4: People flee as a tsunami wave comes crashing ashore at Koh Raya, part of Thailand's territory in the Andaman Islands, 23 kilometers from Phuket island, southern Thailand.**

**Figure 5: Waves wash through houses at Maddampegama, about 60 kilometers (38 miles) south of Colombo, Sri Lanka**

**Figure 6: A general view of the scene at the Marina beach in Madras**

## 2.3 Impacts

This event caused the largest loss of life of any known tsunami with 230, 000-280,000 estimated fatalities (Diacu, 2009). The impact of the Boxing Day tsunami was exacerbated by the scale of seabed displacement, its proximity to the coastline of Banda Aceh Province in Indonesia where most fatalities and damage occurred, and the lack of an Indian Ocean Tsunami Detection and Warning System. Even with a functioning warning system in place, the people of Banda Aceh would have had less than 15 min to evacuate. Ultimately approximately 170,000 of the fatalities occurred in this area. One of the great tragedies of this event is that with a warning system in place, it is believed that all 60,000þ lives lost in Sri Lanka, Thailand, India, Maldives, Bangladesh, Malaysia, Myanmar, and in several countries in East Africa could have been avoided (Table1 & Figure 7-10). This estimate includes around 9,000 tourists, mainly from Europe, vacationing in Thailand; for example, Sweden lost >500 citizens. The scale of destruction and damage was enormous, but in most places, it was limited to within 1 or 2 km of the coastline.

**Table 1: Estimated arrival time of the first tsunami wave**

| Country | Distance from Epicenter (km) | Elapsed Time to Reach Coast |
|---|---|---|
| Sumatra | 100 | <15 min |
| Thailand | 550–600 | 1 h |
| Malaysia | 550–600 | 1 h |
| Myanmar (Burma) | 750 | 1 h 15 min |
| Andaman Islands | 750–800 | 1 h 20 min |
| Sri Lanka | 1,500 | 2 h 30 min |
| India | 1,850 | 2 h 45 min |
| Maldives | 2,350 | 3 h 30 min |
| Somalia | 4,750 | 7 h 30 min |

**Source:** After Kowalik et al. (2005)

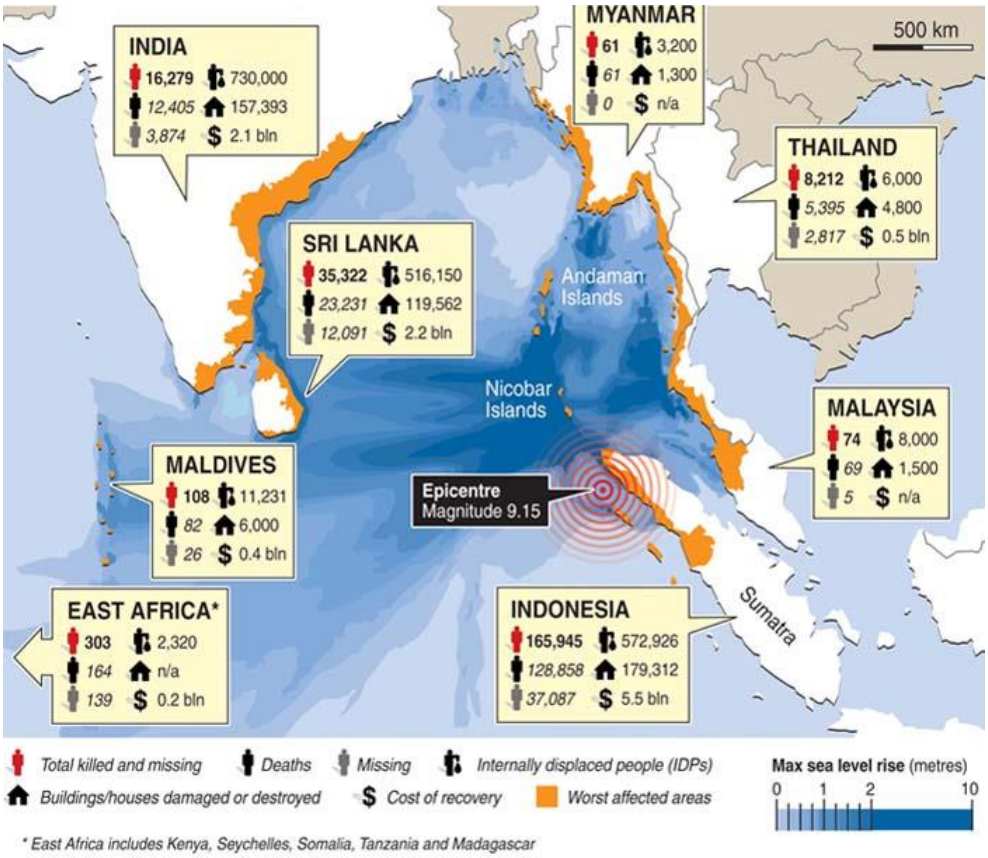


**Figure 7: Countries affected by tsunami**

**Figure 8: rescue and clean-up crew survey a flooded lobby at the Seapearl Beach Hotel along Patong Beach on Phuket Island, Thailand, after massive tsunami waves smashed coastlines.**

**Figure 9: the devastated district of Banda Aceh in Aceh province located on Indonesia's Sumatra Island in the aftermath of the massive December 26, 2004 tsunami.**

**Figure 10: Indonesian military personnel unload corpses from a truck on January 9, 2005 in Banda Aceh, Indonesia**

## 2.4 Aftermath

In the aftermath of the tsunami, the UN Intergovernmental Oceanographic Commission (IOC), comprising UN Educational, Scientific and other partners, began coordinating efforts to create an Indian Ocean early warning system and administering evacuation plans. At a 2005 UN Meeting in Kobe, Japan, it was agreed to establish a warning system that would become operational in June, 2006. The warning system consists of 25 seismographic stations reporting to 26 national tsunami information centers and six DART_ (Deep-Ocean Assessment and Reporting of Tsunami) buoys. In 2012, Thailand successfully launched their national warning system, The Thai National Disaster Warning Center established 136 warning towers and three tsunami-detection buoys in the Andaman Sea that are connected to the United States Geological Survey, the World Meteorological Organization.

## 3.0 Disaster Risk Reduction Strategic Framework and Action Plan

In line with the *Hyogo Framework for Action* (HFA) 2005-2015 and the *Sendai Framework for Disaster Risk Reduction (2015 – 2030),* a Strategy and Action Plan for Disaster Risk Reduction, mainstreaming the likely effects of climate change was prepared under the African Adaptation Program (AAP). The Government has enacted a National Disaster Risk Reduction and Management Act in July 2016. The new Act provides for a legal framework to the National Disaster Risk Reduction and Management Centre (NDRRMC) for the prevention and reduction of the risk of disasters; mitigation of the adverse impacts of disasters; disaster preparedness; effective response to disasters; and, management of post-disaster activities. The Act also provides for the setting up of a National Disaster Risk Reduction and Management Council, which will lay down national guidelines and oversee the implementation of the Management Policy, Management Plan and Strategic Framework related to National Disaster Risk Reduction.

## 3.1The National Disaster Risk Reduction and Management Centre (NDRRMC)

The NDRRMC has the mandate to plan, organise, coordinate and monitor all disaster risk reduction and management activities at all levels. It ensures that Disaster Risk Reduction & Management is in line with international best-practice models, identifies and addresses specific needs of vulnerable groups, and protects against the creation of future risks as a consequence of the possible effects of climate change. In the event of a major disaster, natural or man-made, the National Emergency Operations Command (NEOC) coordinates with all ministries and agencies that respond to disaster and provides guidance according to existing contingency plans and standard operating procedures.

## 3.2 Occurrence and Potential Threat of a Destructive Tsunami: The Tsunami Warning System (South West Indian Ocean)

Following the Indian Ocean-wide disaster caused by the December 26, 2004 Tsunami, it became evident that any country in the Indian Ocean could be under the potential threat of such a natural hazard at any time.

A tsunami wave generated in the Indian Ocean may affect the Mauritius, Rodrigues, Agalega and St Brandon. In addition, there is a hypothesis that volcanic activity in Reunion Island represents a potential hazard which can generate a tsunami. The Government of the ROM has established a Tsunami Emergency Scheme to:

a) Ensure co-ordination of the standing procedures of concerned stakeholders in the event of an emergency situation.

b) Save life and protect property in coastal regions and other vulnerable areas of Mauritius, Rodrigues, Agalega and St. Brandon.

c) Provide recovery assistance to the affected local communities.

The Regional Tsunami Service Providers (RTSP) from India, Indonesia and Australia will provide tsunami bulletins to the National Tsunami Warning Centres (NTWC) of the Indian Ocean countries, including Mauritius.

**Bulletin Type 1 – Earthquake Bulletin:** providing details on earthquakes of magnitude 6.5 or greater (Mwp), which have the potential to generate tsunamis.

**Bulletin Type 2 – Tsunami Forecast:** providing an initial forecast of tsunami threat, including details such as Estimated Time of Arrival (ETA) and Estimated Tsunami Height (ETH) for each coastal zone under threat.

**Bulletins Type 3 – Tsunami Forecast and Observations:** providing the same information as the Tsunami Forecast Bulletins, with the following additional information on observed sea-level anomalies.

**Bulletins Type 4 –Tsunami Service Finalization:** providing information on the finalization of advice or termination of the tsunami threat.

This Scheme assumes that each stakeholder identified herein has its own Tsunami Emergency Operational Plan.

Subsequently, roles, responsibilities and actions of each stakeholder are laid down during the following conditions:

(a) General preparedness

(b) Tsunami Watch

(c) Tsunami Warning

(d) Aftermath

### 3.3 Tsunami Warning System (Mauritius)

The Tsunami Warning System has taken into consideration the degree of risk as well as the time factor. In virtue of its geographical location, Mauritius, Rodrigues and the Outer Islands have a lead-time of 5-7 hours before tsunami waves are likely to reach their coasts generated from either the Sumatra or the Makran source.

The Tsunami Warning System consists of the following stages:

(a) **Tsunami Watch**

This bulletin implies that a strong earthquake, generally of the magnitude greater than or equal to 7.0 on the Richter scale, has occurred in a region adjacent to the Indian Ocean and there is a likelihood of a tsunami being generated is evoked. This bulletin is issued as a means of providing an advance alert to areas that could be impacted by destructive tsunami waves. At this stage, the Chairperson of the Crisis Committee and the NDRRMC will be informed.

(b) **Tsunami Warning**

This bulletin confirms that a destructive tsunami will affect Mauritius/ Rodrigues / Outer Islands (Agalega and St. Brandon) within the next 5-7 hours. In case the incident point is closer to Mauritius/ Rodrigues/ Outer Islands (Agalega and St. Brandon, the lead-time will be correspondingly lesser.

(c) **Termination**

### 3.4 Warning/ Alerting Agency: Mauritius Meteorological Services (MMS)

The MMS is the main warning /alerting agency in the event of a Tsunami for the Republic of Mauritius. As soon as a Tsunami Bulletin is received from the RTSPs informing of the occurrence of a strong earthquake giving rise to ocean-wide tsunami which is moving towards the South West Indian Ocean, the MMS will put into effect its Tsunami Emergency Plan.

### 3.5 Coordinating Bodies: National level

National Disaster Risk Reduction and Management Council/Crisis Committee

Once a Tsunami Watch bulletin is issued by the MMS, the Minister of Environment, Sustainable Development, and Disaster and Beach Management will convene the Crisis Committee and all the different stakeholders to take actions.

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