InaTEWS

Indonesia Tsunami Early Warning System

Concept and Implementation

AGENCY FOR METEOROLOGY CLIMATOLOGY AND GEOPHYSICS

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JAKARTA

BMKG

TSUNAMI EARLY WARNING SYSTEM
InaTEWS
INDONESIA

INDONESIA

KEMKOKESRA RISTEK BMKG BPPT LIPI BAKOSURTANAL

ESDM BNPB BAPPENAS KEMKOMINFO TNI POLRI

KEMDAGRI KEMLU DKP KLH LAPAN ITB

GERMANY CHINA JAPAN FRANCE USA

UNESCO UNDP

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Version 1

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National Coordinating Agency for Surveys and Mapping Agency - BAKOSURTANAL
Agency for the Assessment and Application of Technology - BPPT
State Ministry of Research and Technology - RISTEK
Indonesian Institute of Sciences - LIPI
National Disaster Relief Agency - BNPB
German Indonesia Tsunami Early Warning System - GITEWS

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PREFACE

End of 2004 was marked by a very large earthquake in Aceh which generated a gigantic tsunami, causing the deaths of more than a quarter million people around Indian region. This human tragedy received a great number of responses from Indonesian community and also the world, on both, providing help and assistance to the people of Aceh and North Sumatra which were affected by the disaster, and reducing the impact of tsunami disasters in the future, not only for Aceh region but the entire region of Indonesia. This is achieved by developing a system, namely: The Indonesia Tsunami Early Warning System, abbreviated InaTEWS.

InaTEWS is a national project that involves a number of institutions under the coordination of the State Ministry of Research and Technology. The institutions are: the State Ministry of Research and Technology (RISTEK), Agency of Meteorology Climatology and Geophysics (BMKG), Coordinating Agency for Surveys and Mapping Agency (Bakosurtanal), Agency for the Assessment and Application of Technology (BPPT), the Indonesian Institute of Sciences (LIPI), The Ministry of Home Affairs and the National Disaster Relief Agency (BNPB), and also supported by experts from Bandung Institute of Technology (ITB). BMKG, Bakosurtanal and BPPT are technical institutions which carry out operational observation of earthquake parameters, plate movement and sea level monitoring while Ristek, LIPI, Depdagri and BNPB have takeb responsibility to increase public awareness and preparedness. Local Government has an important role in developing the operational system, especially by the increasing public awareness and preparedness.

InaTEWS development is carried out by the Indonesian Government through the institutions mentioned above, with support from donor countries and organizations, which include: Germany, China, Japan, the United States of America, France, UNESCO, UNDP, UNOCHA, ISDR, etc. The German Government gives significant contributions in the development of end-to-end InaTEWS, which includes: monitoring system, data processing and analysis, dissemination, capacity building, and increasing public awareness and preparedness.

Currently InaTEWS is operational although not all the system has been installed completely, as for example the sea level monitoring system, from totally 23 that are planned to be installed, only 3 have already been installed. The Decision Support System also needs fine-tuning as well as human resources capacity building. Preliminary operation started in mid-2005, finally InaTEWS will be launched in November 2008 by the President of the Republic of Indonesia.

We all know for sure that someday tsunami will occur again in our country even though we still can't figure out when, where and how big it will. It is my expectation that InaTEWS can be effectively used to provide a tsunami early warning therefore the number of casualties can be reduced in case of tsunami occurrence in the future.

Furthermore the benefit of InaTEWS is not only for the Indonesian community, but also for the international community mainly for countries around the Indian Ocean and Southwest Pacific also South China Sea.

This booklet contains a brief description about seismo-tectonic regime in Indonesia, the concept and implementation of InaTEWS as well as increasing public awareness and preparedness. Hopefully, this booklet can contribute to increase the readers' knowledge that can be applied in emergency situations.

Jakarta, March 25, 2010
Agency of Meteorology Climatology and Geophysics

Dr. Ir. Sri Woro B. Harijono, M.Sc.

1. Earthquake and Tsunami Desember 26, 2004

At the end of 2004, on Sunday, December 26 2004, Indonesia and eight other countries in the Indian Ocean region were stricken by a gigantic tsunami disasters generated by a very large erthquake. This earthquake and the resulting tsunami claimed a quarter million lives in several countries of Asia and Africa, which included: Indonesia, India, Bangladesh, Myanmar, Maladewa, Srilangka, Malaysia, Thailand, Somalia dan Kenya.

Figure 1 : a. Baiturahman Mosque at Banda Aceh after earthquake and tsunami
b. Height of the wave at Thailand coast
c. Train that collapse after hit by tsunami in Sri Lanka

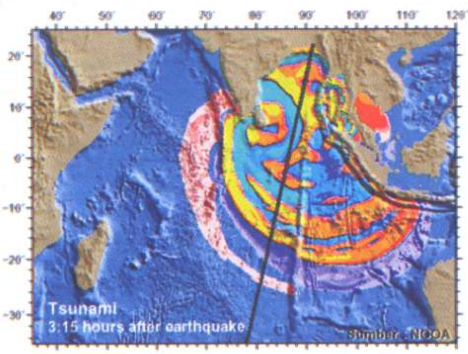


Figure 2. Wave propagation model of Tsunami Aceh December 2004

The deadly tsunami was generated by a magnitude 9,3 SR earthquake which located at 3,3 degrees South, 95,98 degrees East, off the west coast of Northern Sumatra. The earthquake caused strong ground motion and fractures along 1200 km that extends from Aceh to Andaman.

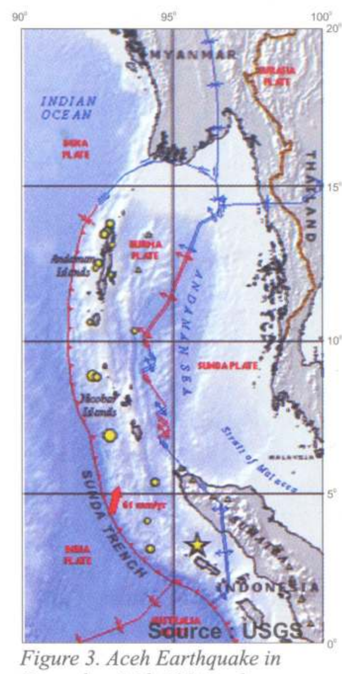


Figure 3. Aceh Earthquake in December 26th 2004 and resulted fault zones

The tsunami tragedy late 2004 has left sadness and extraordinary suffering specially for people of Aceh and North Sumatra Provinces, in particular the Indonesian nation in general. According to BNPB data, 173.741 people died and 116.368 people remained missing, while in North Sumatra 240 people were killed. The estimated loss is around one million houses and buildings that were destroyed, and half million people becoming refugees. The land that used to be green, the housing that used to be in good order, all destroyed only within minutes leaving behind debris and dead bodies.

Aceh was in tears, Indonesia was sorrowful and the world gave a hand as a humanitarian gesture and in solidarity with the survivers.

Figure 4. Satelite images Before and After the Aceh Tsunami December 2004.

As a forum of International solidarity, on January 2005, a meeting was convened that was also attended by UN Secretary General Kofi Annan. In the meeting, it was agreed that many countries would give help and assistance including efforts to reduce the impact of such a disaster in the future.

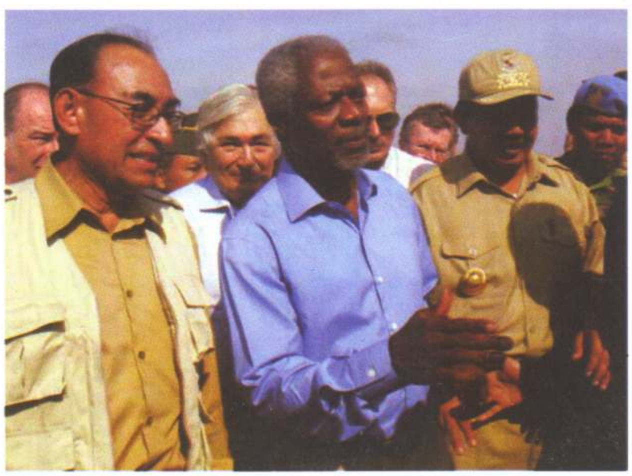


Figure 5. Kofi Annan, UN Secretary General , arrived in Banda Aceh to see directly the impact of the tsunami.

2. Indonesia Vulnerable to Earthquake and Tsunami

Indonesia is located in a zone of high seismic activities due to the triple junction of three mega tectonic plates, namely: Indo-Australian Plate to the south, the Pacific Plate to the east and Eurasian Plate, where most Indonesian territory is located. The relative movement of the three tectonic plates and also in relation to two other plates, the Philipine- and Caroline Plates, is causing the occurrence of earthquakes at the convergent plate boundaries associated with regional faults which are further earthquake source areas.

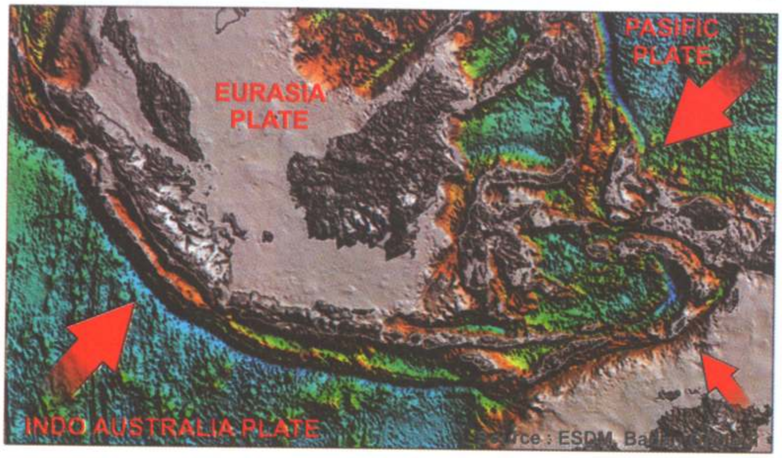


Figure 6. Tectonic Setting In Indonesia

Due to relative movement between plates and activities of both local and regional faults, thousands of earthquakes occur every year, but most of these earthquake can only be detected by an instruments called seismographs, while earthquake with magnitude more than 5.5 SR or can be felt. They occur about 70-100 times, while the destructive earthquakes occur between 1-2 times per year.

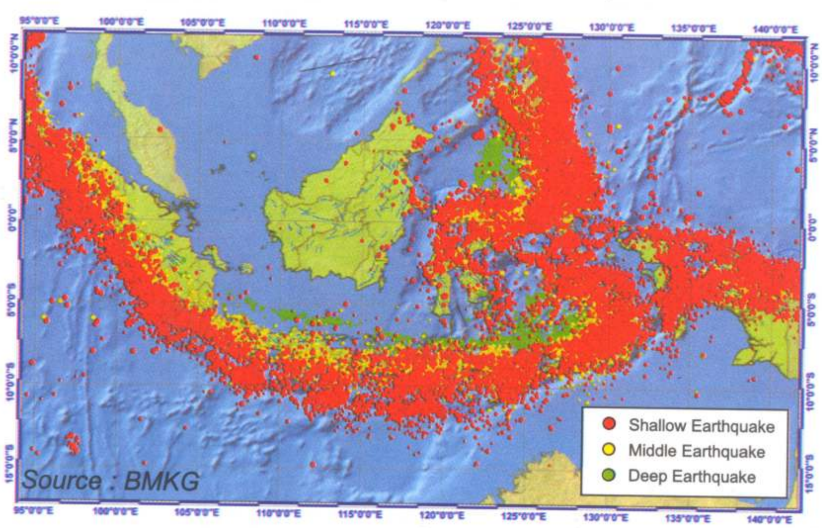


Figure 7. Seismicity Map of Indonesia 1973-2009

From 1991 until 2009 30 destructive earthquake have been recorded and a total of 14 destructive tsunamis. On 12 December 1991, the tsunami that occurred close to Flores Island killed more than 2000 people. This was followed by the East Java Tsunami 1994, Biak Tsunami 1996, Sulawesi Tsunami 1998, North Maluccan tsunami 2000 and the Giant Aceh tsunami on 26 December 2004, Nias Tsunami 2005, West Java Tsunami 2006 and Bengkulu Tsunami 2007. Based on this data it can be said that a tsunami hits Indonesian coasts on an average of once every two years.

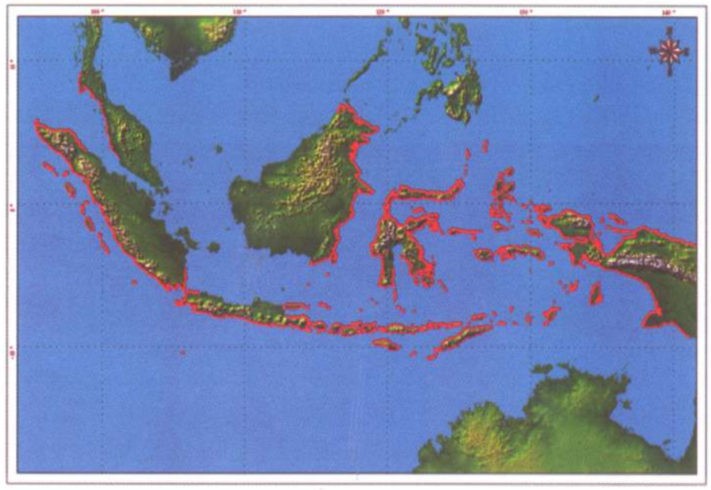


Figure 8. Areas vulnerable to Tsunami In Indonesia

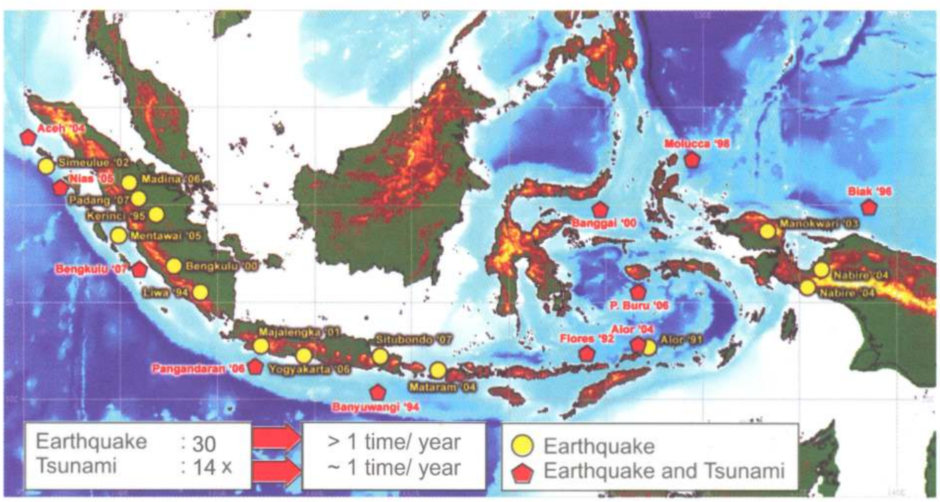


Figure 9. Destructived earthquakes and Tsunamis, period : 1991 - 2009

3. Concept and Design of InaTEWS

Source : Int'l Tsunami Information Center (ITIC)

Figure 10. The Three Integral Components Tsunami Warning and Mitigation System

3.1. Triangle Concept

Basic concept of InaTEWS development is based on the model proposed by International Tsunami Information Center (ITIC): to build an end to end Tsunami Early Warning System using triangle pattern where the angle points are the components of the system. The components are:

1. Operational Component.
Handling the activities of monitoring, processing, analyzing, preparing warning, issuing and dissemination.

2. Mitigation and Emergency Responses Components.
Emergency response to disasters, public education, improving community preparedness and awareness, shelter and logistic preparation, evacuation map, field training etc.

3. Capacity Building Component.
Giving support through research and development, validating against component 1 and 2 and also increasing the capacity of human resource.

3.2. InaTEWS Design

A cross section of Java island to the south up to Indian Ocean is taken as an illustration. The big earthquake sources generally located at subduction area, which is a convergence zone between Indo-Australian tectonic plate and Eurasian plate. To detect an earthquake seismic monitoring network is required; to measure deformation a GPS network is deployed; to detect a tsunami buoys and a tide gauge network is needed. The recorded data of land and sea monitoring equipment is sent to National Monitoring Center through satellite communications.

When an earthquake occurs, the resulting waves propagate through the crust and mantle of the earth and are recorded by seismographs. The recorded seismic waves are then used to determine location and magnitude of the earthquake. If the resulting analysis shows that the earthquake parameters fulfill the criteria to potentially generate tsunami (location at the sea, magnitude > 7.0 SR, depth < 70 km) then National/Regional Tsunami Warning Center (NTWC/RTWC) will issue and distribute potential tsunami warning mainly to several interface institutions that have authority to take further action for spreading the information through various media including siren activation. A potential tsunami warning is followed by confirmation of tsunami occurrence based on the result of the data from tsunami detection sensor buoys or tide gauges.

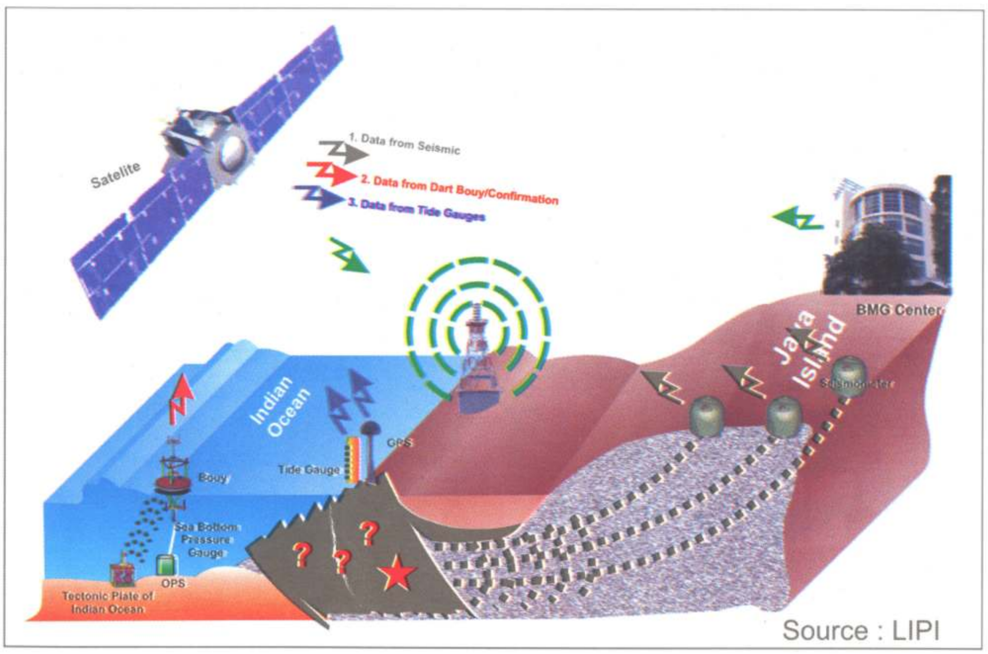
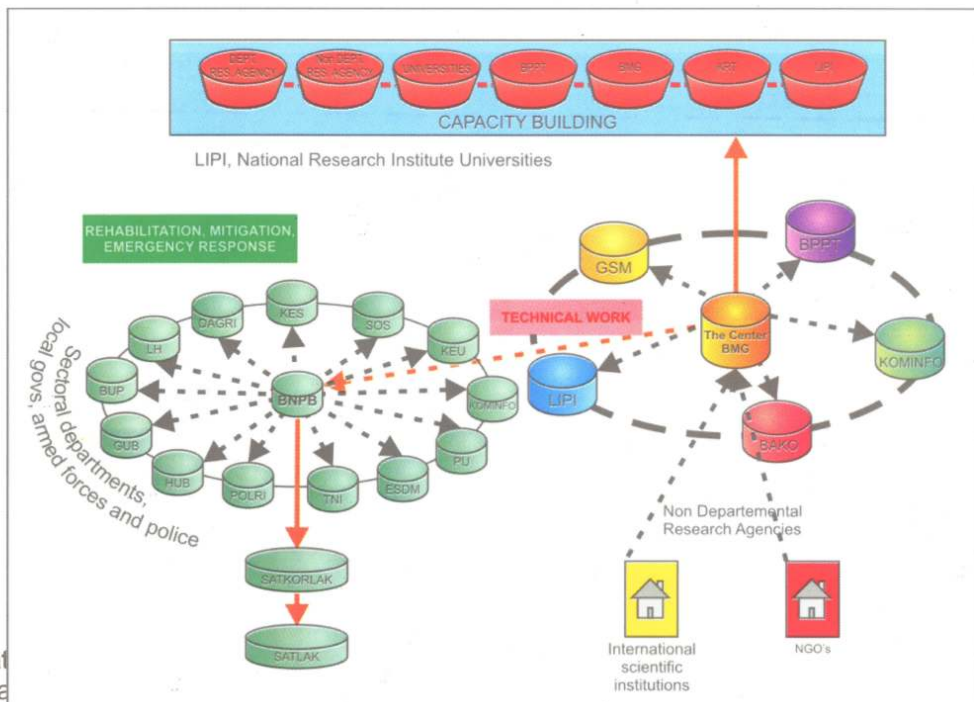


Figure 11. InaTEWS Grand Design

4. Multi Institution and Multi National Involvement

The establishment of InaTEWS is a national program and implemented under the coordination of the State Ministry of Research and Technology and involves 16 national institutions, namely : State Ministry of Research and Technology (Ristek), Ministry of National Development Planning (Bappenas), Ministry of Energy and Mineral Resoueces (ESDM), Ministry of Marine and Fishery Affairs (DKP), Ministry of Environment (LH), National Police (Polri), Agency of Meteorology Climatology and Geophysic (BMKG), National Coordinating Agency for Survey and Mapping (Bakosurtanal), Agency for Assessment and Application of Technology (BPPT), Indonesia Institute for Sciences (LIPI), National Institute for Space Aviation (LAPAN), Bandung Institute of Technology(ITB), Ministry of Communications and Information Technology (Kominfo), Ministry of Home Affairs (Depdagri), Ministry of Foreign Affairs (Deplu), National Disaster Relief Agency (BNPB) and under supervision of Coordinating Ministry for People's Welfare (Menkokesra)

The key ministries/institutions are:



Coordinat

The legal a ... The ministry is also responsible to coordinate with all related institutions in the development of InaTEWS.

Figure 12. Institutions Involved in The Tsunami Warning and Mitigation System

Ministry of Research and Technology (Ristek):
InaTEWS is state-of-the-art technology, starting from high sensitive and reliable sensors up to the needs of ICT for data and information, processing system, human resources development and transfer of technology. It is one of the roles of Ristek to adopt the sophisticated technology from InaTEWS to Indonesian culture.

Agency of Meteorology Climatology and Geophysics (BMKG):
BMKG is responsible for the Seismic monitoring system and before the December 2004 event, BMKG had already been operating 30 geophysical stations sand 5 regional centers equipped with 27 remote seismic sensors.

To accelerate the installations of broadband seismic sensors BMKG set up most of the seismic sensors in BMKG stations facilities, with basic consideration that tsunami will only be generated by large earthquakes. For the first step most of seismic sensors are located in the BMKG stations, sites which are usually not quiet enough for seismic sensors deployment. To improve data quality and analysis when the station quality is under minimum requirement, then the seismometer will be relocated accordingly. BMKG is the agency responsible for hosting the Operational Center, which collects and processes all seismic data, calculates earthquake locations, analyzes whether the earthquake is tsunamigenic, issues the earthquake information and tsunami warning, integrates other observation data for confirmation or cancellation of the warning.

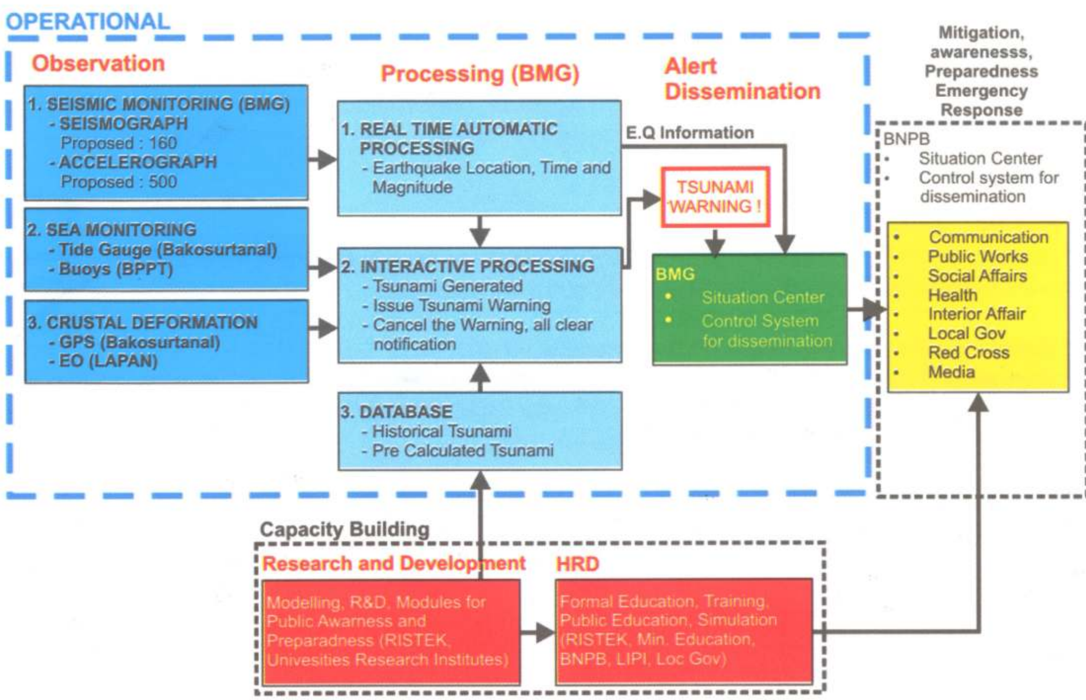


Figure 13. Multi Institutional Tasks Arrangement of The InaTEWS

Agency for the Assessment and Application of Technology (BPPT):
BPPT is responsible for the deployment and operation of buoys from which the data is transmitted to BMKG and to BPPT. This Agency operates the research vessels Baruna Jaya needed for installation, maintenance, relocating the buoys. BPPT is also responsible for tsunami run-up modelling.

National Coordinating Agency for Survey and Mapping (Bakosurtanal):
Bakosurtanal is responsible for installing and operating tide gauges and GPS networks. Before the earthquake and tsunami of December 2004 Bakosurtanal has already been operating 60 tide gauges stations consist of 35 analogue and 25 digital instruments. The stations are still not yet operating in real-time data transmission, neither to Bakosurtanal nor to BMKG. Similarly, the GPS network consist of 9 stations which are also still stand alone units. Both, tide gauges and GPS data will be sent to BMKG in near-real-time to enhance the accuracy of the warning.

Indonesian Institute of Sciences (LIPI):
LIPI is responsible for preparing modules for public awareness and preparedness. LIPI has conducted several field surveys to socialize and inform the local government and community of the dangers of earthquake generated tsunamis. This institute will also be responsible to conduct research in geo-science as well as tsunami research.

Ministry of Communication and Information Technology:
All mass media and telecommunications providers are under the authority of this ministry, so its role is very important for the warning dissemination process.

National Disaster Relief Agency (BNPB)
Activities related to emergency response, mitigation, rehabilitation and reconstruction become responsibility of this institution. BNPB is also one of the insititution that has an obligation to disseminate an early warning.

Ministry of Home Affairs:
The local governments are under the coordination of this ministry, so program for public education, public awareness and preparedness are coordinated through this ministry.

Police of the Republic of Indonesia (Police Headquarter)
Police Headquarter has a very good network communication from the headquarters to the Regional Police (POLDA) as well as the resort police. These facilities are then used to send a tsunami early warning to areas that have possibility to be hit by a tsunami.

Bandung Institute of Technology (ITB):
ITB is responsible to prepare the tsunami database that will be installed at the Situation Center in BMKG. As a university institution, ITB will also be responsible for the preparation and development of the human resources needed to sustain InaTEWS in the future.

Multi National Involvement

The establishment of InaTEWS is carried out by the government of Indonesia and is supported strongly by donor countries, international organizations, NGOs etc. Assistance is coming from:

- Germany, through the GITEWS project, comprising the development of monitoring systems, situation centers, telecommunications, capacity building (human resources, research, local and institutional).
- China through ICDN, is contributing seismic monitoring stations, to BMKG Operational Center, telecommunications and capacity building.
- Japan, through real-time JISNET, is involved in part of seismic monitoring system. Through JICA, a contribution is made to BMKG Operational Center and capacity building.
- France is involved in upgrading the existing seismic network and Tremors.
- USA, USAID through multi institutions involves in sea level monitoring, capacity building, conducting local, national and international workshops and visits. USTDA in the form of Technical Assistance.
- UNESCO, IOC, ITIC supports infrastructure development, Capacity Building, Technical Assistance.
- CTBTO support seismic data
- IFRC supports capacity building.

5. Operational Component of InaTEWS

A. Monitoring System

- Land Monitoring
  - Seismic (160 broadband seismometer, 500 accelerometer)
  - GPS (40)
- Sea Level Monitoring
  - Buoys (22)
  - Tide Gauges (80)
  - CCTV

B. Processing System

- Seismic : 10 Regional Center (RC), 1 National Center (NC)
- Other : 1 Tide Gauges Center, 1 Buoys Center, 1 GPS Center

C. Telecommunication

- Upstream (Data Collection)
- Down stream (Dissemination)

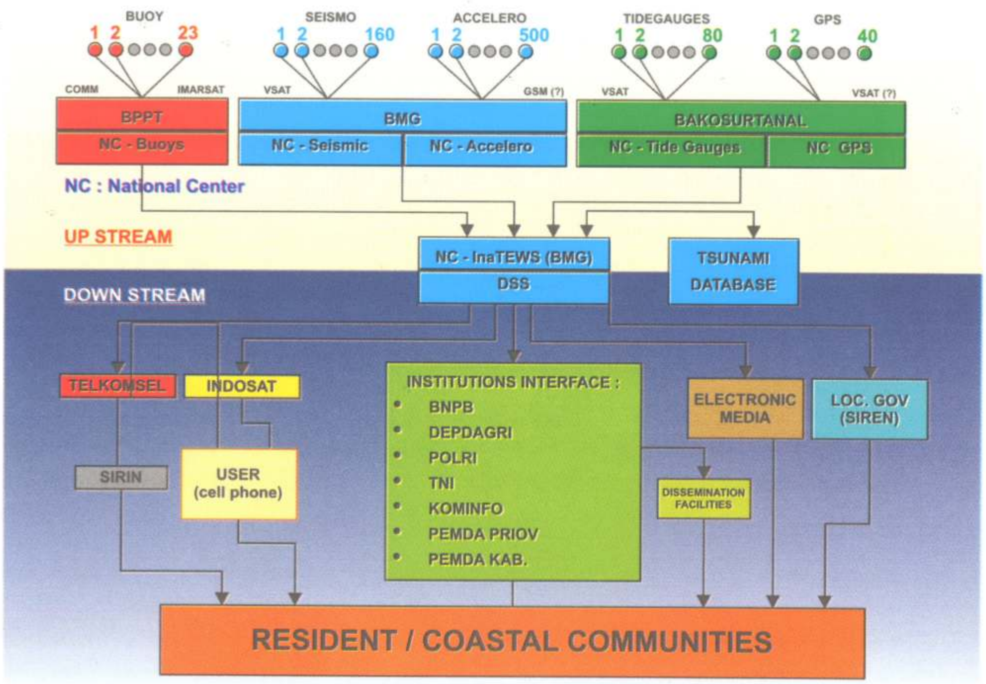


Figure 14. Data Flow of InaTEWS

5.1 Seismic Network (BMKG)

When an earthquake occurs, the seismic wave is propagating almost omni-directional from the hypocenter. The signal is recorded by network of seismometers and then sent via VSAT to the Centers where it is processed and analyzed by seismologist on duty to produce earthquake parameter information. When the earthquake parameter fulfils the criteria of generating a tsunami then a tsunami warning will be issued. In case a tsunami has been generated the signal detected by buoys is expected to arrive soon after the seismic signal which can be used to confirm or cancel the warning.

Figure 15. Seismic Station

The Seismic Network has been designed consisting of 160 broadband seismometer, 500 accelerometers and will be group into 10 Regional Centers. With this number of sensors and the distance between those sensors which is in the order of 100 km it is intended that within first 3 minutes after the the earthquake has occurred in Indonesian territory the hypocenter can be located.

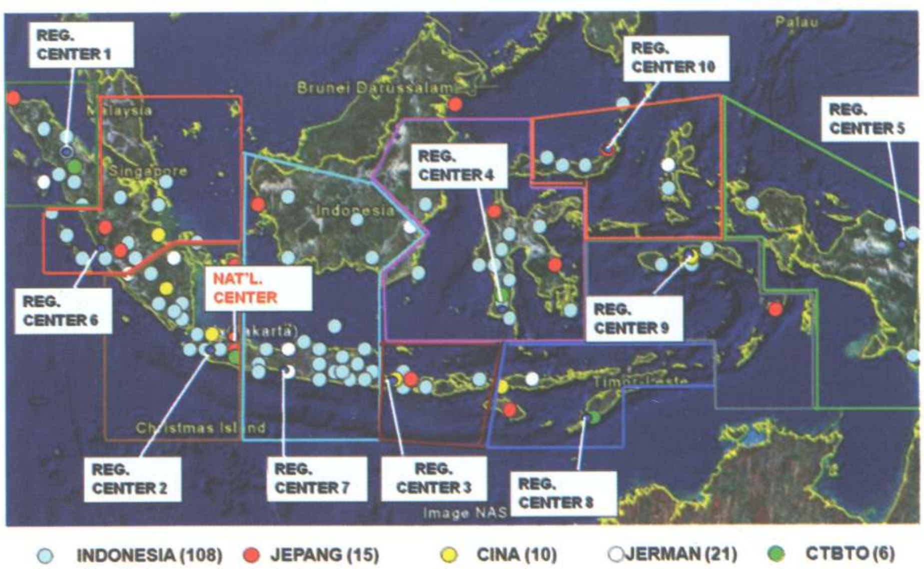


Figure 16. Broadband Seismic Network and Accelerometer

5.2. GPS and Tide Gauge (Bakosurtanal)

Bakosurtanal operates GPS and Tide Gauges monitoring networks. The GPS network as part of the Land Monitoring System is installed in several locations together with a seismometer or tide gauge or installed individually in accordance with the needs of the network. Bakosurtanal plans to install 40 GPS sensors.

Figure 17. GPS Station

Bakosurtanal plans to install 80 Tide Gauges for InaTEWS; up to present 39 tide gauges are already operational and the data transmitted in near real-time via VSAT IP and GTS. The data of 4 (out of 39) tide gauges is received at BMKG Operational Center via GTS with a delay of 15 minutes.

Figure 18. GPS Network

Figure 19. Tide Gauge Station Sadeng

The 30 stations supported by the Government of Indonesia have been installed in 2007 and are using VSAT IP communications, that means the data will be available in real time to Bakosurtanal. The data will be sent to InaTEWS Centre in BMKG using VPN and will be backed up via VSAT.

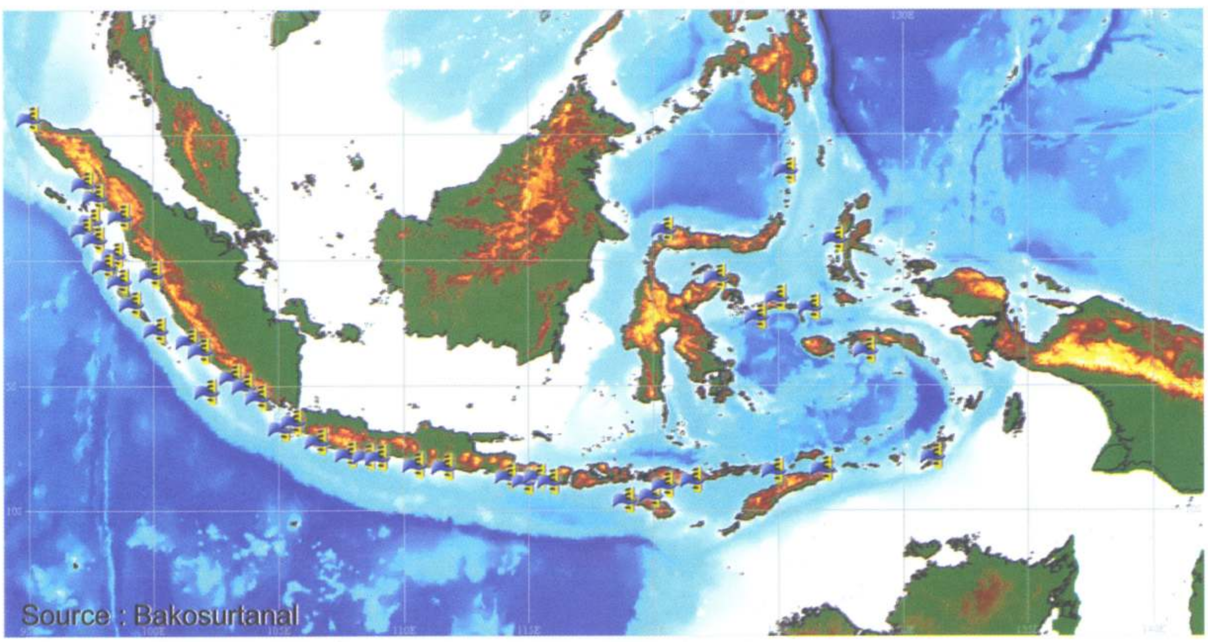


Figure 20. Indonesia Sea level Network

5.3. Buoys (BPPT)

Figure 21. Buoy at Merak

At the end of 2005 BPPT and GEOMAR German Marine Institut through GITEWS project have deployed 2 buoys in Indian Ocean offshore South-West Sumatra. Unfortunately, after about two months of operation both buoys moorings were severed and they started drifting away from their original locations. But equipped with GPS equipment the buoys location could be monitored which led to their recovery. Similar incidents repeatedly occurred also to both system developed by BPPT and the donated buoy of NOAA-USA.

Figure 22. Buoy G2 "Said Jenie"

In early 2006 BPPT had already reengineered their buoys instruments. The buoys were tested as a dummy system and deployed in December at Sunda Strait. The data is send to BPPT Center via Imarsat communications and then directly passed on to BMKG using VPN and backup via VSAT IP.

The activities carried out in 2007 included the design, construction and installation of 3 Indonesian buoys, deployment of Dart buoys assisted by NOAA, re-deployment of 2 German buoys and new deployment of 2 German buoys.

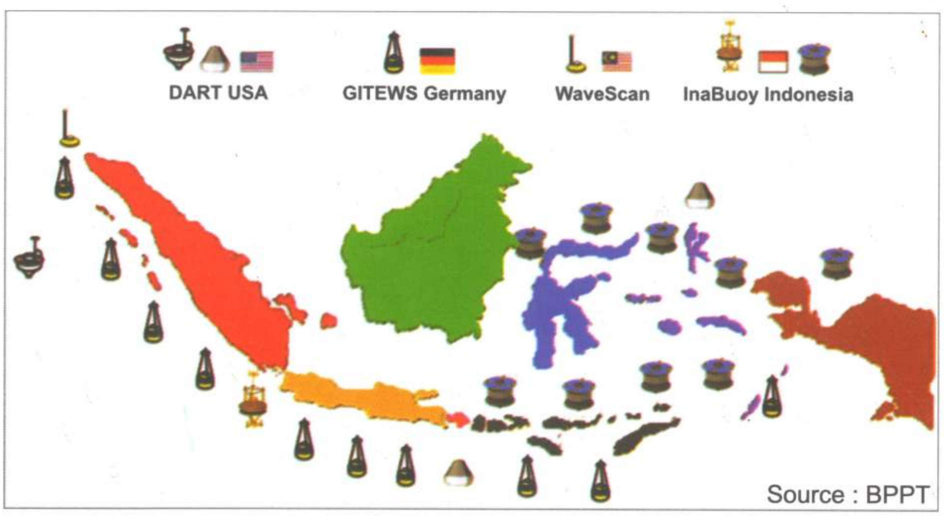


Figure 23. Indonesia Buoys Network

5.4. Communication System

The basic communication system for data collection is satellite based using VSAT system. For seismic data the communication system uses 3 type of VSAT, namely:

1. System LIBRA, Canada Technology : 105
2. System Reftec, American Technology : 40
3. System CSM, BMKG rents from CSM Provider : 16

Some of the tide gauges and GPS stations will use VSAT communication as well, but for buoys will use different types of satellite based communication.

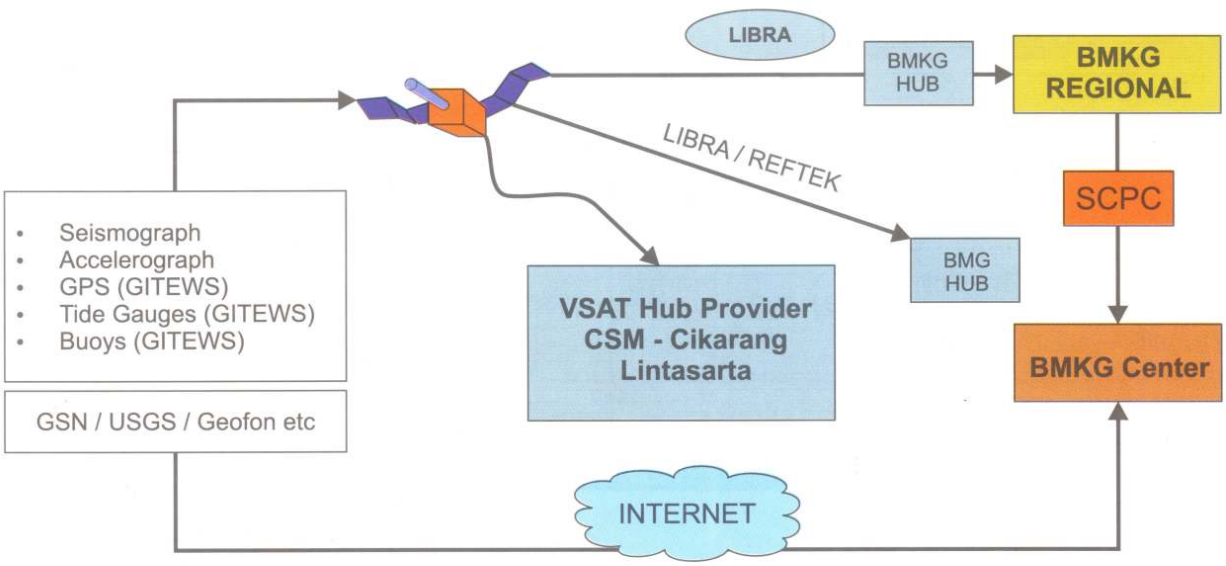


Figure 24. Communication System For Data Collection

6. National Tsunami Warning Center

Figure 25. InaTEWS Operational Center Building

The Tsunami Warning Center (InaTWC) hosted by BMKG will occupy a new building that is still on the progress of finishing. It is expected end of 2007 the building will be ready to host the InaTWC, which is actually located just besides the existing operational building.

Equipment installed at the BMKG Operational Center are seismic processing facilities coming from Germany, China, Japan (NIED), France. The system in operation for InaTEWS is the German System SeiscomP, as its real-time automatic processing has shown us already good and satisfactorily results even though still needs development. The system has recently been updated now calculating earthquake magnitude comparable to moment magnitude which is appropriate for tsunami warning. This system upgrade has been tested during the last Earthquake that generated a tsunami southwest of Southern Sumatra, close to Bengkulu city. The magnitude issued for the tsunami warning was 7.9 and equal to the magnitude issued by PTWC and JMA a few minutes later.

At the National Center, a Decision Support System (DSS) will integrate all monitoring information coming from seismic, GPS, buoys and tide gauges as well as tsunami simulations generated from the tsunami data base and geospatial data. The system will give recommendations to the manager on duty on the level of warning and the time the warning should be issued. The DSS will be ready by end of 2008.

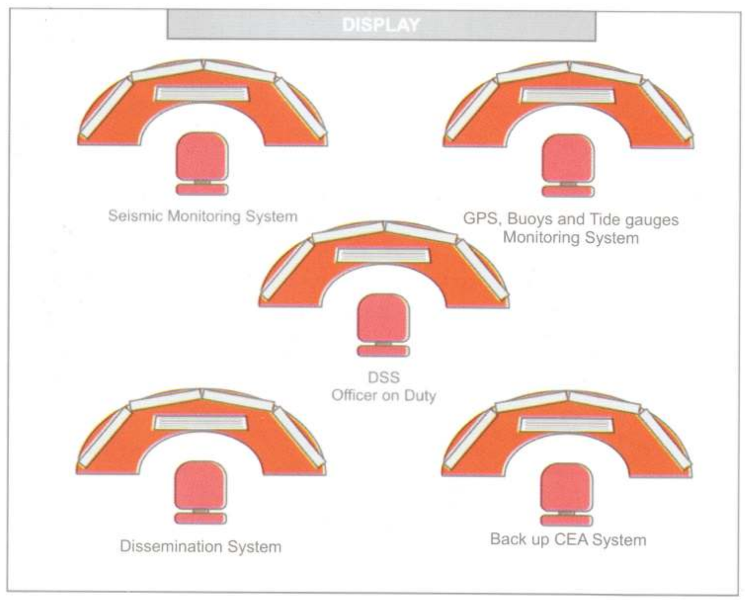


Figure 26. Layout of Control Room

The Decision Support System is a tool for the manager on duty in preparing the Tsunami Warning. The DSS puts together earthquake information, observations recorded by buoys, tide gauge and GPS. If signals indicate that a tsunami has been generated simulations will be used to estimate geographical location and possible impact to issue a timely warning to the people in danger.

Logical Overview of DSS

- Currently, a decision whether or not a tsunami could be generated s based on earthquake magnitude, location and depth.
- When the DSS is completely installed and operational the decision is based on detailed information delivered by the sensor systems and tsunami simulation system.
- DSS consists of information gathering system, information processing and information dissemination system.
- DSS provides an overview of acqurired information and map projections that assist the operator in the dissemination process.

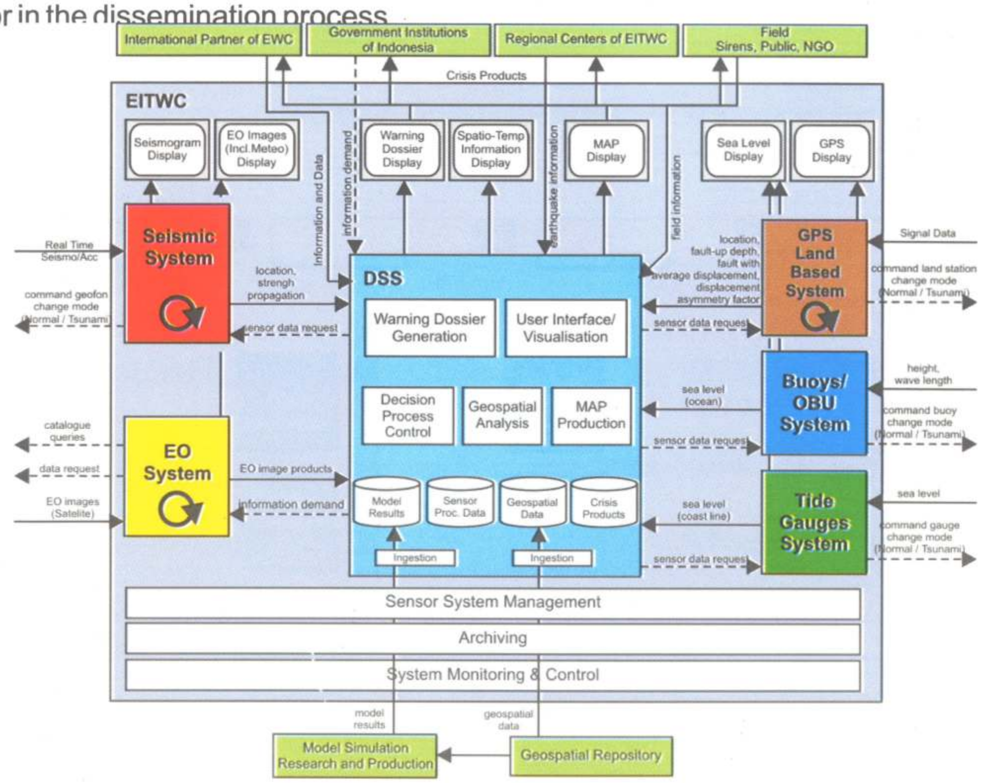


Figure 27. Logical Overview of Decision Support System

DSS-GUI (Graphic User Interface) with 4 screens

1. Perspective Situation;
   - Earthquake Parameter
   - Advising on the situation in disaster area before delivering warning to the area
   - Overview on modeling tsunami.
   - Visualization of data from ocean monitoring.

2. Perspective Observation;
   - Real-time data from GPS, tide gauges, buoys and seismic network
   - Information of deformation crustal, and tsunameter

3. Perspective Decision;
   Offering quality of warning as a system product to be evaluated by duty officer before dissemination.

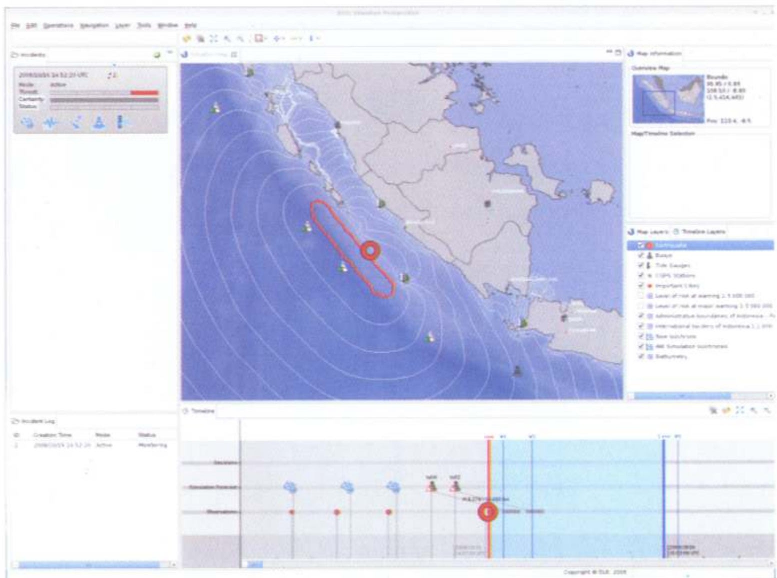
4. Perspective Product;
   - Sound text warning of message and clarification
   - Confirmation and dissemination

1. Situation	: Three minutes after the earthquake
2. Observation	: Real time observation from all monitoring system
3. Decision	: Proposed type of warning systems
4. Product	: Information sent to a local

Figure 28. DSS GUI (Graphical User Interface)

Situation Perspective

- Less than 5 minutes after earthquake, DSS map earthquake location along with tsunami simulation
- Dynamic timeline moves according to time below the panel. Current time marked with red line and dynamic red contour also. Deadline 5 minutes after earthquake marked with special signs.



Gambar 29. Perspective Situation afteran earthquake that generated tsunami

Observation Perspective

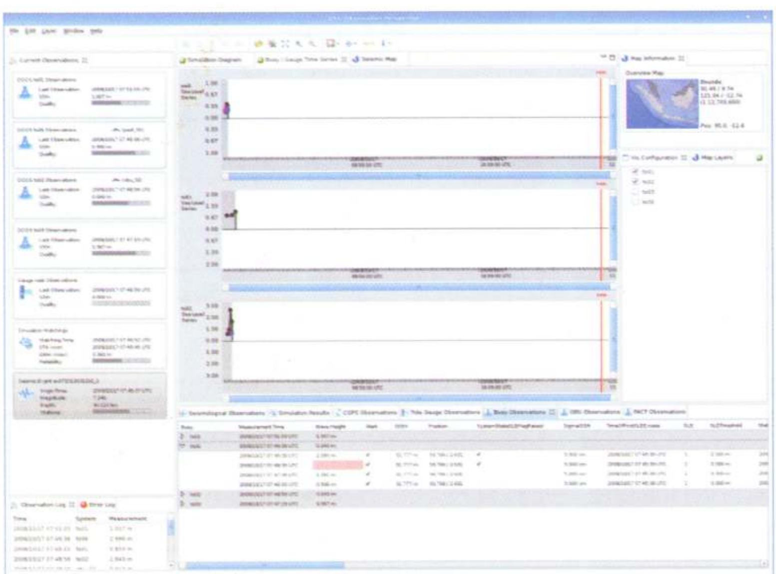


Figure 30. Observations Perspective from equipments used in DSS

- Using the GUI, the operator can see the real-time GPS, tide gauge, buoy or seismic data.
- As according to situation there, hence displayed the condition of observation to determine action hereinafter, start from warning up to end of warning.

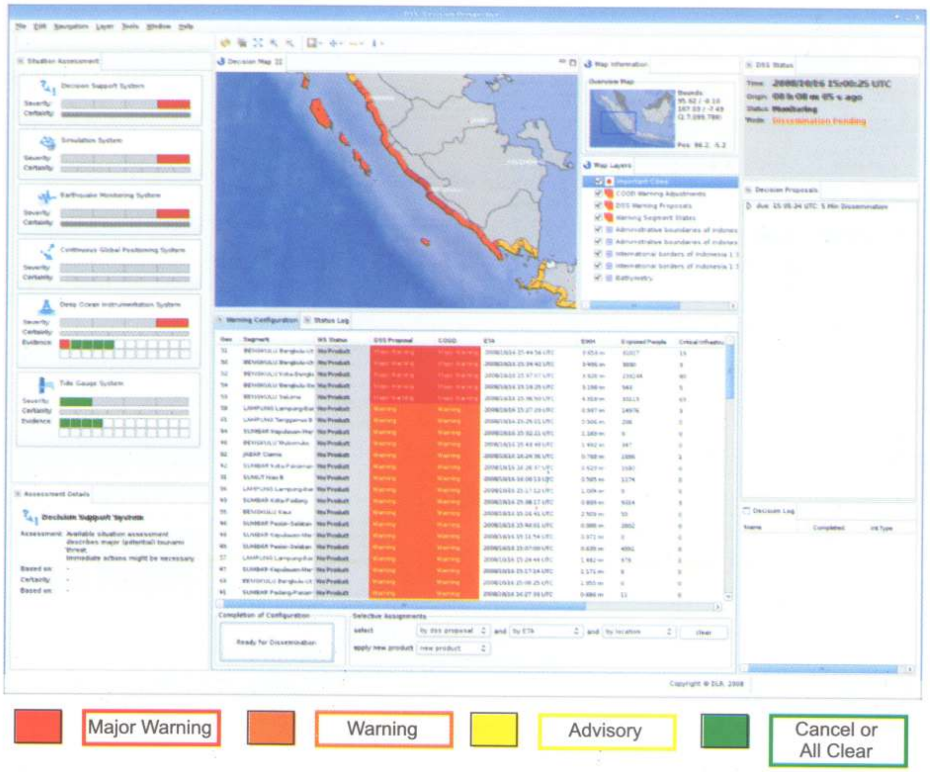


Figure 31. Decision Perspective

Decision Perspective

- Product from tsunami modeling is a tsunami height map according to the impact which possibly will be experienced.
- Standard criteria to determine warning type:

  Tsunami height > 3 meter represent major tsunami

  Tsunami height 0.5 - 3 meter represent warning

  Tsunami height < 0.5 meter represent advisory
- Each monitoring parameter (GPS, tide gauge, buoy) gives a situation information at left LCD panel coded with color symbol.

7. Dissemination System

Basically, the dissemination system becomes the responsibility of several relevant institutions: BMKG has an obligation to prepare and disseminate the "warning" to be to public.

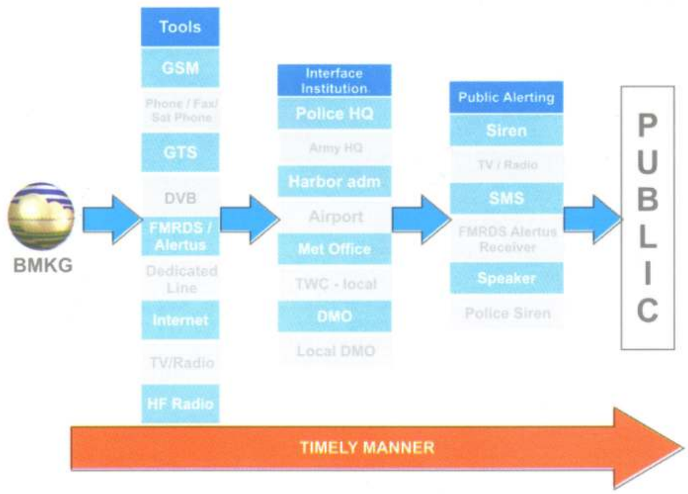


Figure 32. Dissemination Overview of Tsunami Warning Information

Based on the instruction of President of the Republic of Indonesia in a press conference at Anyer Marbella Hotel, Banten on July 20, 2006, that the first 5 minutes after an earthquake becomes BMKG responsibility to prepare and issue the “tsunami warning”.

The following step is in the responsibility of a number of institutions which are in charge of providing the information to the communities under threat.

The Tsunami warning is sent to interface institutions through various of communication of channels, namely: Rent Line (LC) VSAT,VPN-MPLS, GSM, internet, telephon, fax, digital video broadcasting (DVB), radio wave communication. Interface institutions primarily are: local government of the Province, Ministry of Home Affairs, POLRI, TNI, TV, Radio, GSM Operators, BNPB, etc.
It is expected that interface institutions will continue the dissemination through other institutions linked to them or directly to the public.

The application system that is used is called: five in one application, which means delivery of a warning message using 5 different modes but sent from 1 dissemination server. The five modes are: alarm activation, fax server, SMS server, web and text to voice systems.

Beside automatic delivery simultaneously through five modes, Five in One Application which is designed by BMKG staff has another advantage: tsunami warning receiver server can act as a dissemination server to send the tsunami warning to recipients. Therefore the warning delivery process can be carried out directly and systematically.

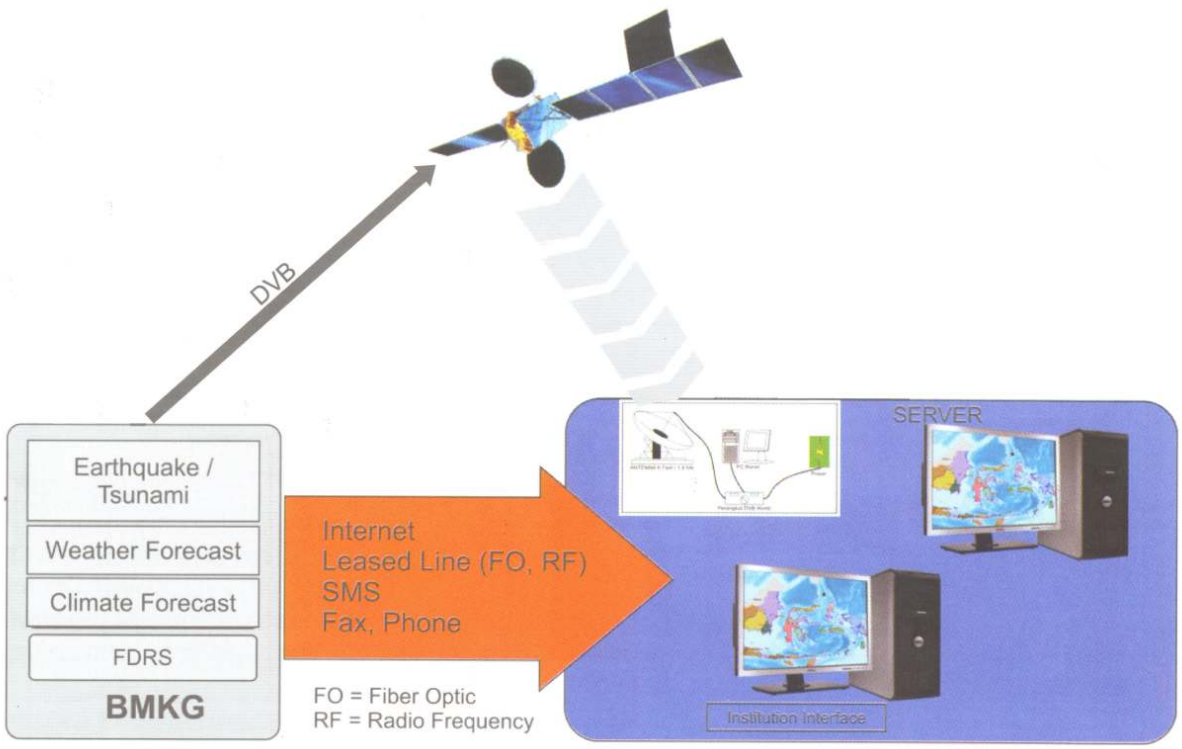


Figure 33. Tsunami Warning Dissemination System through various of Telecommunication modes: Leased Line, Fax, telephone, Internet and Digital Video Broadcasting.

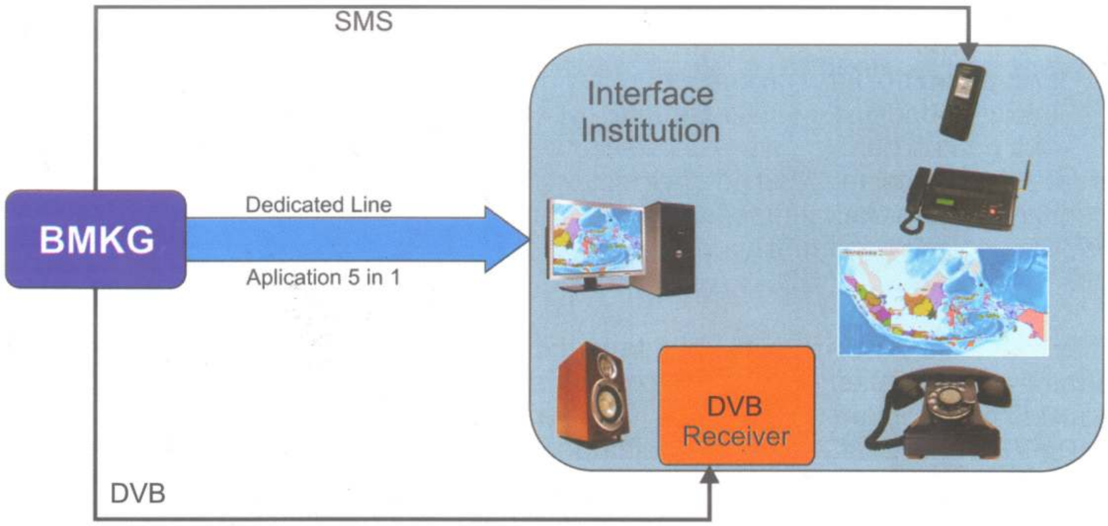


Figure 34. Five in One Information Dissemination System

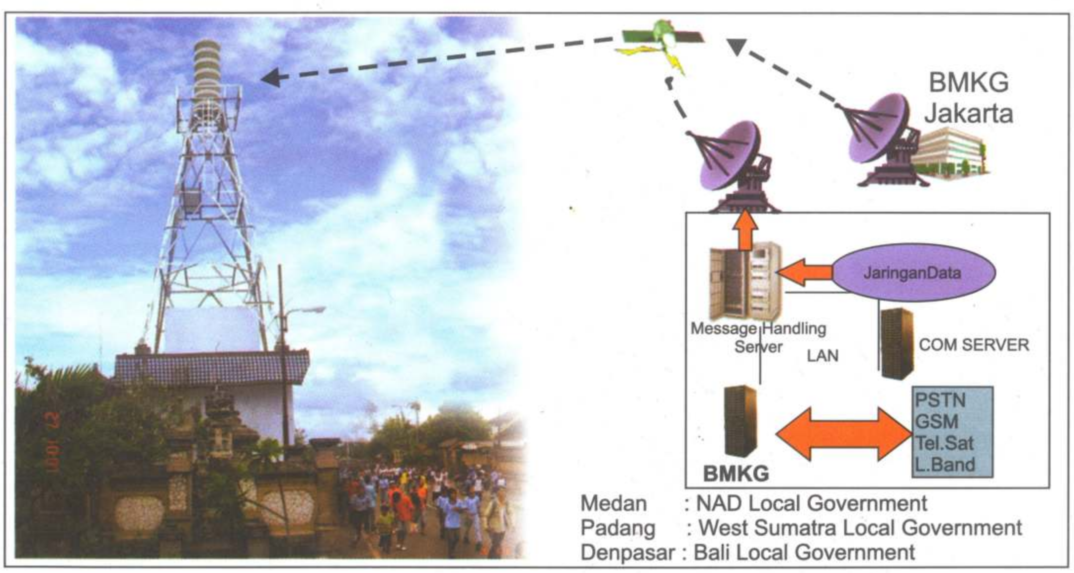


Figure 35. Siren System

Figure 36. Siren location in Aceh

So far, the most efficient dissemination system is via SMS to both individual (officials) and institutions. A warning information through SMS is forwarded to public through various facilities such as television, radio, chain of command from officials and siren phonation.

Dissemination of warning through electronic media such as radio and television is also effective. However, the most effective system is the siren because it is widely heared from locations in areas that are potentially hit by tsunami. So this system is one of the best choices.

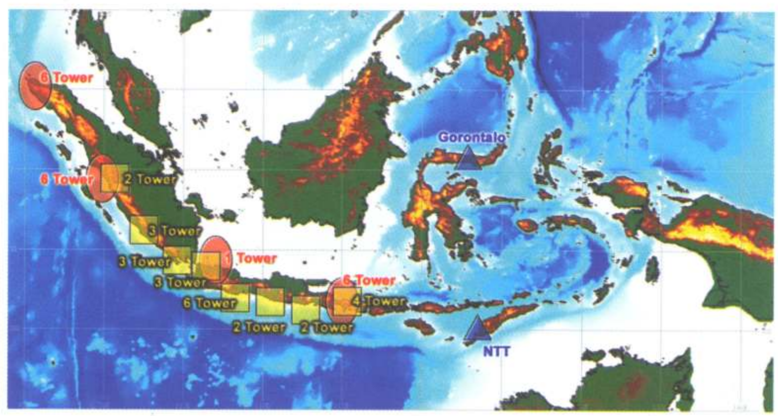


Figure 37. Tsunami Siren network in Indonesia

So far 24 siren units have been inastalled in Indonesia and are integrated into the Control central system. Units exist in 6 provinces: Aceh, Sumatera Barat, Bengkulu, Bali, Gorontalo, and Manado.

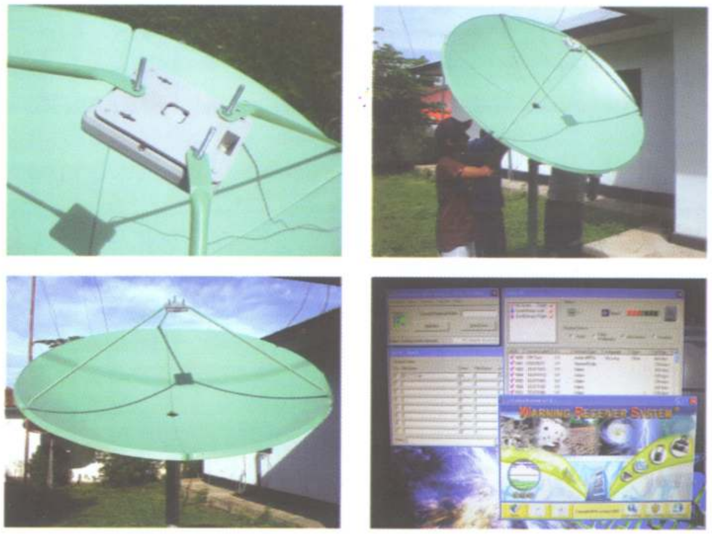


Figure 38. Moluccas and Papua DVB need disc antenna

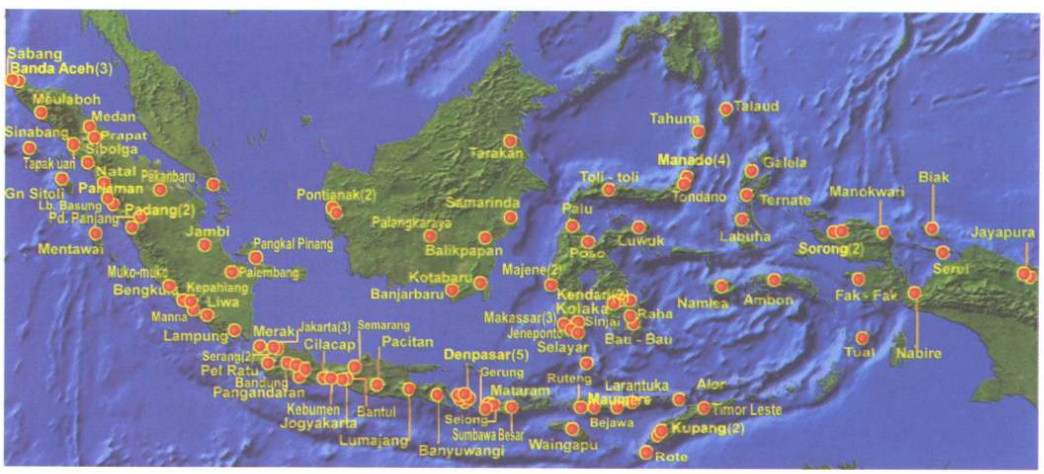


Figure 39. DVB Distribution Map

8. Tsunami Database

Tsunami modeling database is a collection of scenarios which contains parameters of tsunami such as: tsunami wave arrival time and tsunami height on a coast. Those scenarios are based on historical earthquakes and tsunamis that have occurred in Indonesia and also earthquake risk assessment on an area that may have the potential to generate tsunami. When an earthquake that generates a tsunami occurs, the simulation database will provide information about arrival time and tsunami height in areas that will be hit by tsunami. The information is integrated into InaTEWS system as an input for tsunami warning information.

The database of tsunami modeling is grouped into 14 regions including all regions of Indonesia,: South Sea of Java, southern Sumatera Sea, Makassar Strait, Flores Sea, the Sea of Sulawesi, Aceh-Andaman Sea, Halmahera Sea, southern Sea of Java, Molluca Sea, northern Sea of Papua, Timor Sea, Seram Sea, Banda Sea and Arafuru Sea, where generally tsunami types in Indonesia are local (tsunami wave arrival time is more than 30 minutes) and very local tsunami (tsunami wave arrival time is less than 30 minutes), with a total of 220,000 simulation.

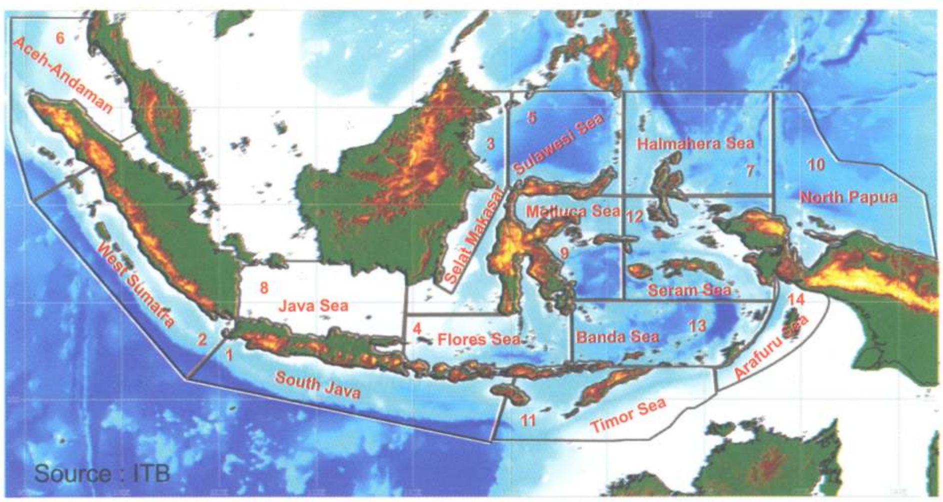
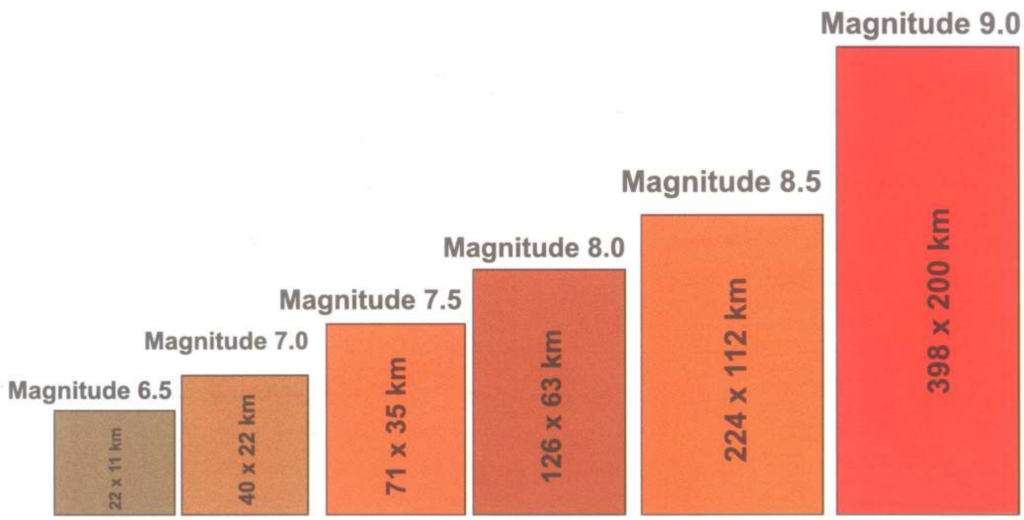


Figure 40. Hypothesis of Earthquake sources Distribution in Indonesia

Magnitude of the Earthquake and Fault Areas of Tsunami Sources

Tsunami scenarios are based on the earthquake parameters information which are: magnitude, fault orientation, fault area, etc.

Based on empirical calculations, the stronger the earthquake the larger the fault area, hence the tsunami source is larger too, as shown in figure below:



$$\text{Log}(L) = 0.5\,Mw - 1.9$$
$$\text{Log}(W) = 0.5\,Mw - 2.2$$

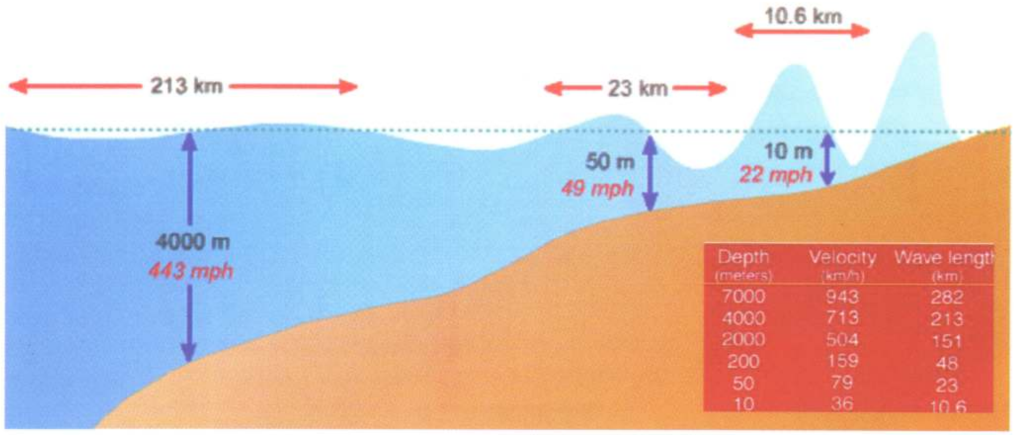
Where :
L = Fault Length W = Fault Width (Km) Mw = Moment Magnitude

Figure 41. The Comparison between Magnitude Scale of an earthquake and Tsunami Source Rupture Area

Characteristics of Tsunami

The velocity of tsunami and its wavelength depend on the depth of the sea. The deeper the sea, the longer the wavelength, the higher the speed. On the other hand, the amplitude of tsunami in deep water is smaller than in the shallow water.

The Tsunami velocity is equal to the square root of the product of the earth's gravitational constant (9.8 m/sec2), times to the depth of the water.



Default Paragraph Font;Figure 42. Tsunami speed and height depend on the depth of the sea

The Tsunami velocity is equal to the square root of the product of the earth's gravitational constant (9.8 m/sec2), times to the depth of the water

$$v = \sqrt{g(m/s^2) \times d(m)}$$

v = velocity
g = gravitasi (9,8 m/s^2)
d = depth

Tsunami Modeling

The step by step approach to create a tsunami database is as follows:

- The study about earthquake and tsunami as well as preparing bathymetry data
- Tsunami source model
  - Calculating tsunami sources based on their tectonic setting
- Tsunami wave Propagation
  - Calculating tsunami height and the arrival time along the coast
- Developing a software to call and interpolate tsunami data base for tsunami height and the arrival time along the coast.
  - This software is useful in selecting 16 files that will be interpolated henceforth to provide information for a tsunami early warning.
- Integrating of the tsunami database software with the Geographic Information System (GIS)

9. Education and Community Preparedness

Things that also important are education and community preparedness in facing tsunami hazards, as one component of the three integral components of InaTEWS.

Tsunami warning information received by the intermediate institutions such as Local Government and other related institutions should be sent to the community afterwards they can respond the warning preparing for evacuation. Therefore it is required that educational efforts are made to improve preparedness of communities that live in areas vulnerable to tsunami hazard. Institutions that are involved in educating the community from either domestic or international are: RISTEK, LIPI, BMG, Universities, PMI, Local Government, NGOs, UNESCO, GTZ and others. All these institutions have actively participated in various educational activities and community preparedness through socialization, workshops, tsunami simulation, table top simulation, and they work together with various parties, especially with the local governments.

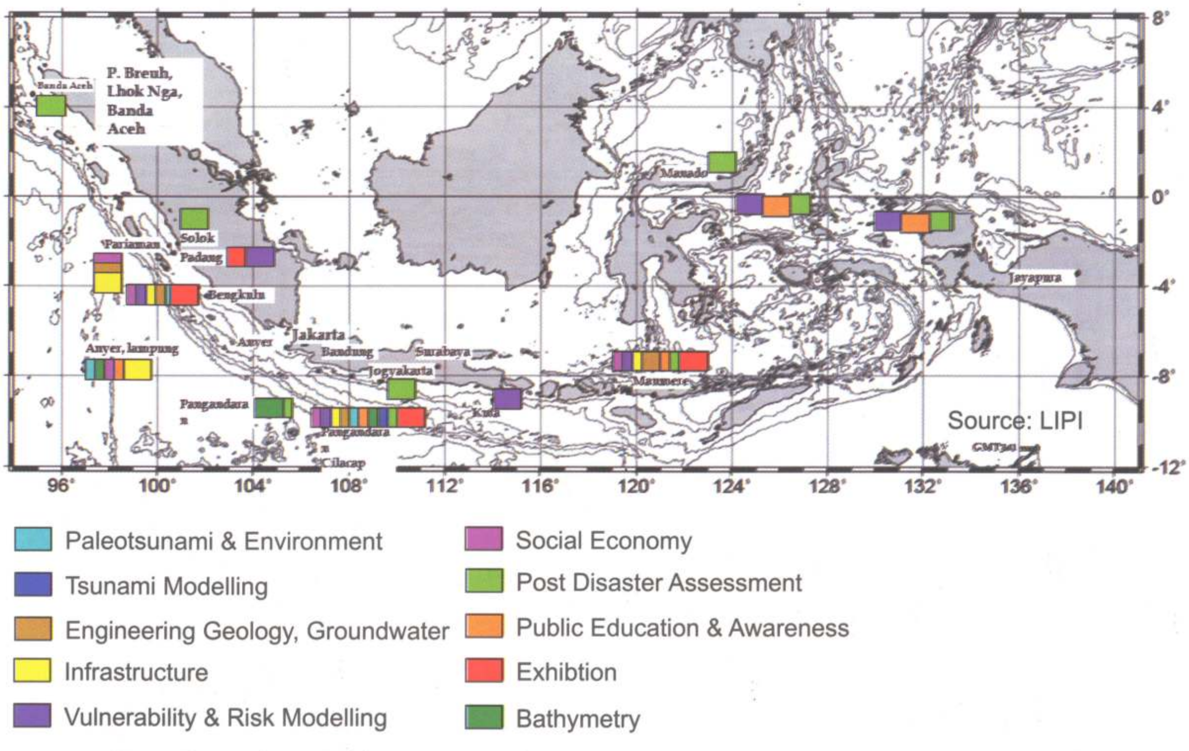


Figure 43. Some locations where community educations and preparadness about tsunami has been carried out

It is expected that following the activities mentioned above, the local government and the community will have preparedness in facing tsunami hazards. To support the success of these activities, it is hoped that community and Local Government can participate actively in the following matters by: taking part to secure the disaster detection equipment that is installed in their region, preparing tsunami risk map along with the rescue scenarios, preparing an evacuation area along with the map, installing guidance signs/direction of evacuation, building a crisis center/command center, conducting tsunami-Drill periodically, constructing sirens, constructing the escape building/tsunami shelter, put disaster consideration in the spatial arrangement and put disaster educational into local content of school curriculum.

One of the implementations to validate Ina-TEWS readiness is by carrying out a tsunami drill every 26 December. The first tsunami drill was carried out in Padang on December 26, 2005, in Bali on December 26, 2006, Banten on December 26, 26 Desember 2007 Nation Wide, and 26 December 2008 in Yogyakarta, Manado, Gorontalo. In October 14, 2009 IO-WAVE as regional level tsunami drill carried out. Tsunami Drills run well and get positive responses from both community and local government.

Figure 44. Tsunami Drill

The stages for increasing public awareness and preparedness compiled by LIPI team into 8 stages, including:

1. Training of officials / officers in local government environment.
2. Training for community representatives
3. Preparation of modules for public education

Figure 45. Trainings for the Community

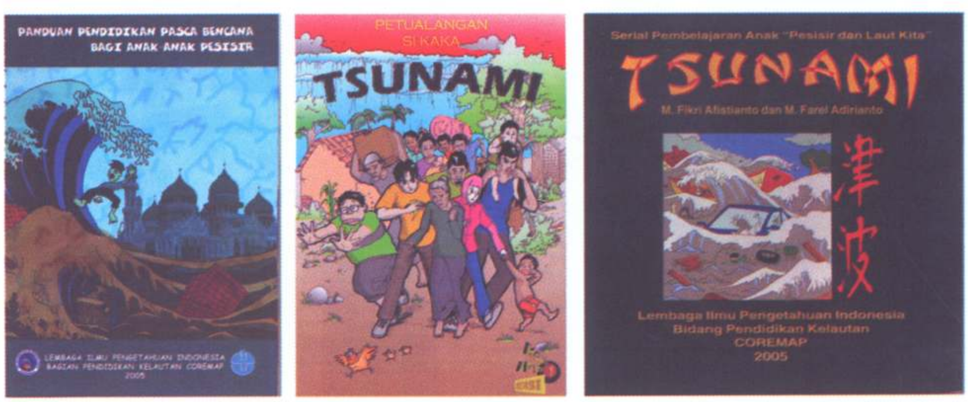


Figure 46. Modules for Public Education

4. Preparing maps and evacuation route
5. Preparaing and installating road signs for tsunami evacuation
6. Simulation of tsunami early warning systems and evacuation process (Tsunami Drill)
7. Public sosialization through through electronic and print media
8. Trainings for school children.

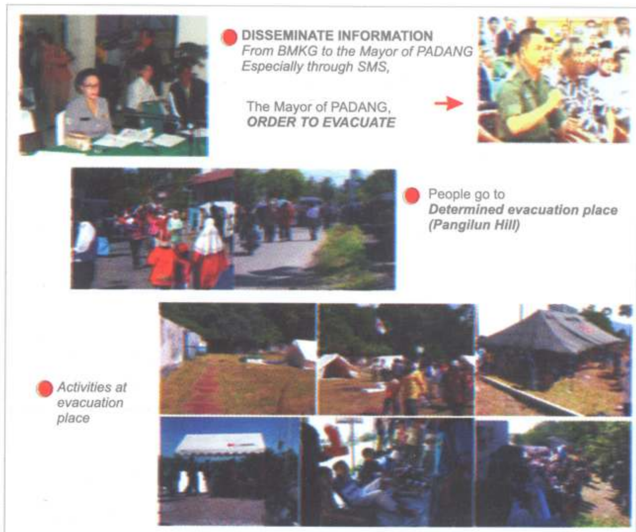


Figure 47 Tsunami Drill Simulation

Figure 48. Tsunami Socialization through Electronic Media

10. Bengkulu Earthquake and Tsunami, September 12, 2007

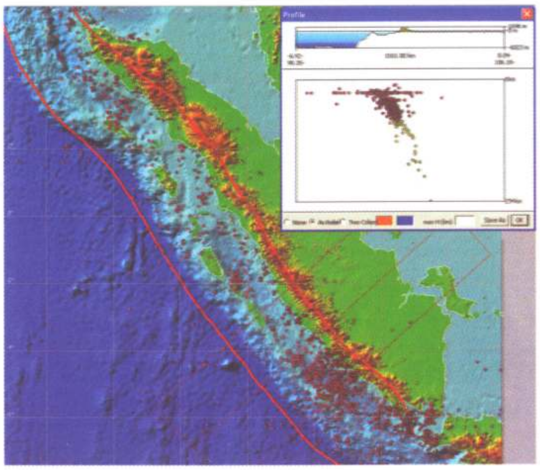


Figure 49. Subduction Area and Strike-slip Fault in Sumatra

On September 12, 2007, at 18:10:23 local time, an earthquake occurred in the Indian Ocean with a magnitude of 7.9 Mw, location: 4.67 S, 101.30 E, at a depth of 10 km. The earthquake had a high tsunami potential along west coast of Bengkulu and Padang provinces. In less than 5 minutes Ina-TEWS successfully transmitted the earthquake information of possibility tsunami warning to community and interface institutions, therefore the information could be used immediately.

In general, earthquake characteristics in Sumatra region are affected by a subduction of Indo-Australian Plate beneath the Eurasian Plate and Sumatra fault system which extends from Aceh to Lampung (Figure 1). The Bengkulu earthquake occurred at subduction zone of Indo-Australian plates beneath Eurasian plates in the Indian Ocean which is known as megathrust zone with small angle of subduction (10-20 degrees) to a depth about 30 km. This can be seen from the cross section of distribution of Bengkulu earthquake (Figure 2). From the distribution of the aftershocks it is seen that the rupture zone due to this earthquake reaches about 400 km (Figure 3).

Earthquakes that generally occur in Sumatra megathrust zone have large magnitude and potentially can generate a tsunami, threatening Sumatra fore-arc and the west coast of Sumatra. During the period 2000 to 2007 , 5 earthquakes with a magnitude 7 - 9 Richter scale have been recorded including the Aceh Earthquake and Tsunami that had caused the loss of a quarter million lives and inflicted severe damages to infrastructures and properties. (Figure 4). Results from tsunami modeling show that the average travel time of tsunami waves to reach the west coast of Sumatra is about 20 minutes. The Bengkulu earthquake in 2007 generated a small tsunami in some places along the west coast of Bengkulu and West Sumatra provinces.

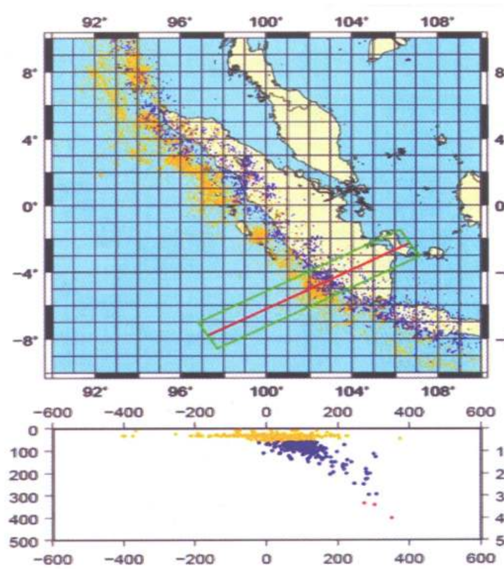


Figure 51. A Cross section of Earthquakes distribution in Bengkulu

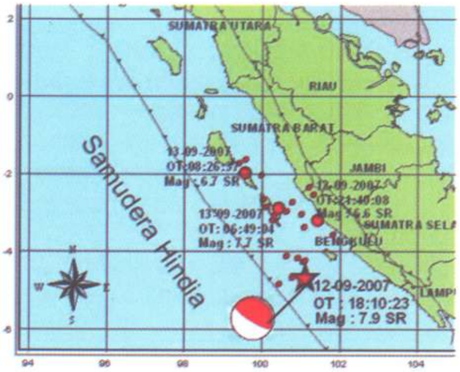


Figure 51. Rupture Zone of Bengkulu Earthquake, September 12, 2007

This is shown by the tsunami traces obtained during a field survey in North Bengkulu and Muko-Muko. From the observation of sea level in Padang, it is shown that there is a significant changing in daily tidal patterns. At the origin time of the earthquake, at first the sea level fell about 0.5 m then rose up to 1 m. This gives us information that there was a rising of the sea level caused by the earthquake. Tsunami modeling of the earthquake resulted in initial information on tsunami parameters such as: tsunami wave arrival time and tsunami height in some high areas in Bengkulu and West Sumatra as well as visualization of tsunami wave propagation. The results of field measurement in 3 locations near west coast of Muko-Muko shows that the tsunami height is between 2.15 m - 3.6 m, while the result obtained from tsunami modeling in the same locations is 2.8 meters. We can see that both of the results are quite consistent, as well as tsunami height, (tsunami height from sea level observation is more than 1 m, while from modeling is 1.15 m). It can be concluded that the tsunami modeling especially for Sumatra regions is good enough to be used as a basic consideration of tsunami warning

Location	Coordinates		The Time of Tsunami Arrived	High Tsunami
	Longitude	Latitude		
Bengkulu City	102.233	-3.800	13 minutes	5.10 m
North Bengkulu	101.616	-3.250	16 minutes	6.40 m
Muko Muko	101.133	-2.633		2.80 m
Seluma	102.516	-4.166	6 minutes	7.85 m
South Bengkulu	102.883	-4.466	18 minutes	4.75 m
Coastal South of West Sumatera	100.848	-1.935	57 minutes	1.90 m
Padang City	100.336	-0,953	74 minutes	1.15 m

Tabel 1. Information of tsunami height and arrival time in several places in Bengkulu and Padang provinces.

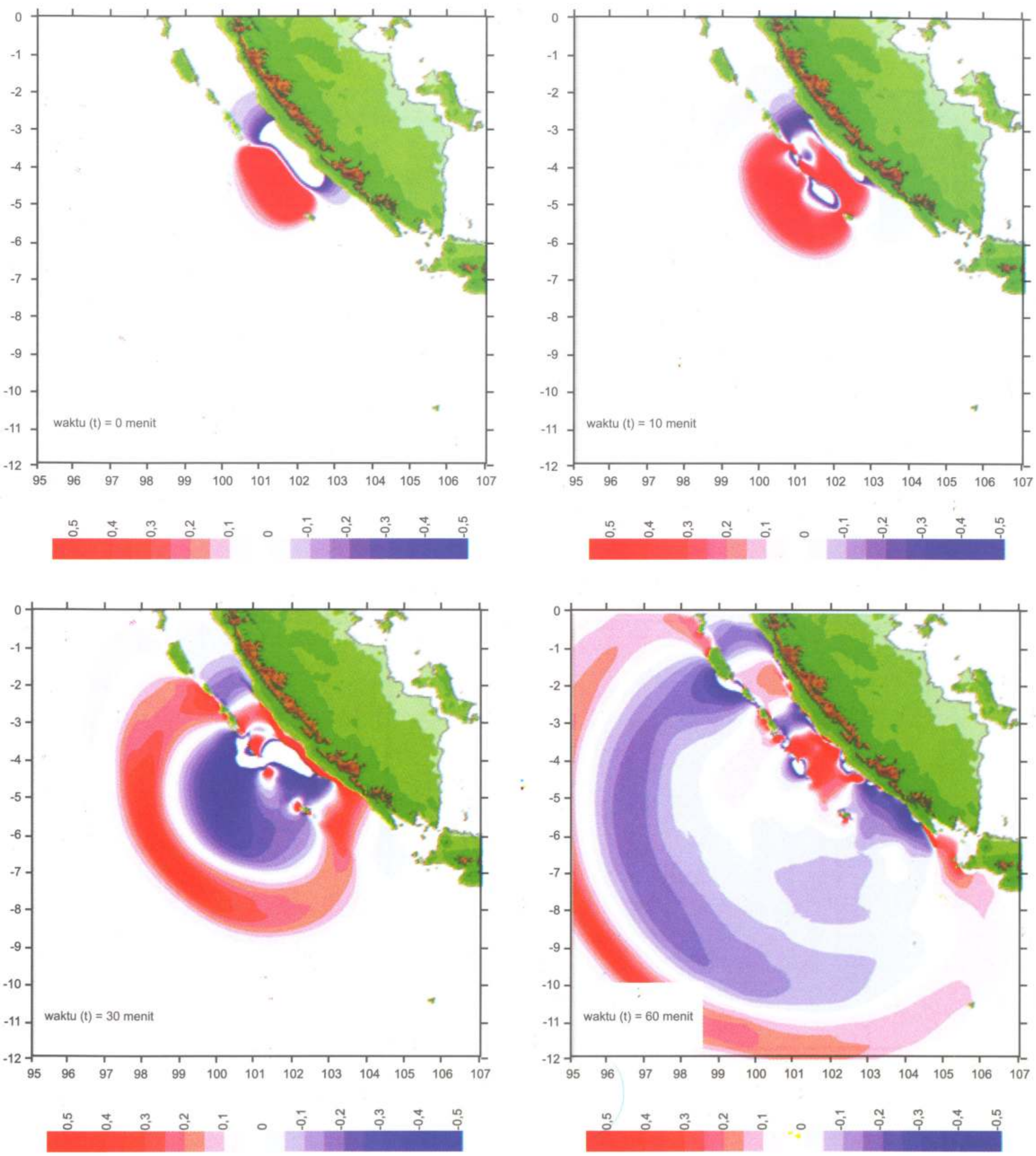
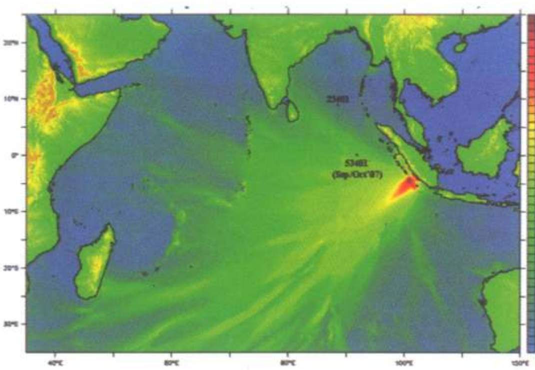
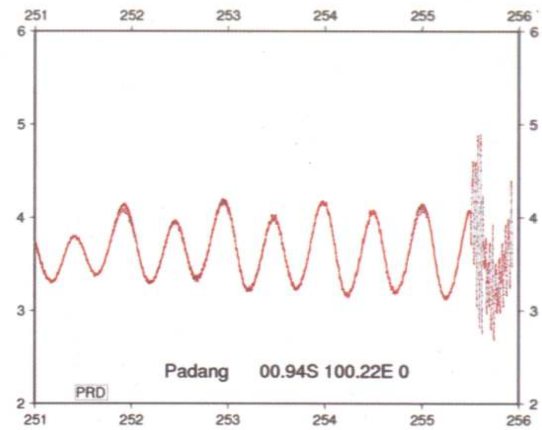


Figure 52. Wave Propagation Modeling of Bengkulu Tsunami, September 12, 2007





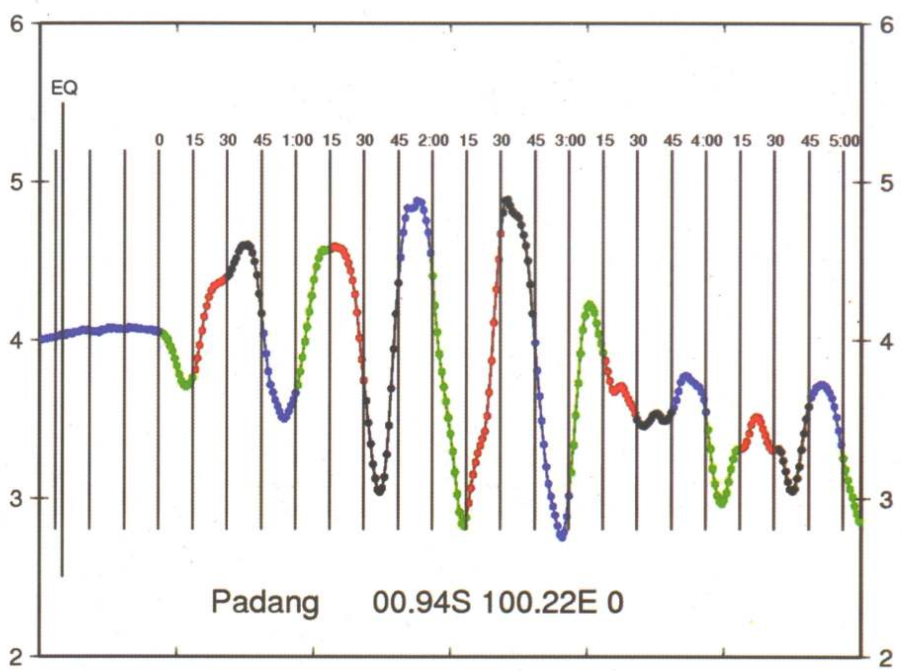


Figure 53. Tide Gauge data recorded in Padang of Bengkulu Earthquake September 12, 2007

Preparedness

If you live near the coastline :

1. Know your environment;
   - residence, the distance to the beach,
   - higher ground (5-30 m from sea surface)
   - route to safety area

2. If you feel strong earthquake more than 2 minutes or see the tide recede extremely quickly and far, do not wait for a warning. Evacuate to higher ground immediately.

3. Report this situation to local authority: village chief, sub-regency chief, police, civil defense, etc.

4. Save yourself, your family and neighbors. Manage to evacuate the community to a place of higher ground.

5. Listen for news reports and instructions from BMKG, local government, police, civil defense and other emergency organizations.

TSUNAMI EARLY WARNING SYSTEM

InaTEWS

INDONESIA