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LOCAL TSUNAMIS: CHALLENGES FOR PREPAREDNESS AND EARLY WARNING

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ABSTRACT: Due to the threat of local tsunamis warning times in Indonesia are very short. Therefore time is the most critical factor when defining procedures for early warning and evacuation.

The division of responsibilities within the Indonesian Tsunami Early Warning System poses a big challenge for local governments, as they are the ones in charge to translate warnings from the national warning center into guidance to the community at risk. They are challenged to set up a communication system and procedures which enable them to receive BMG warnings on a 24/7 basis, take decisions on how to react and disseminate guidance messages to communities at risk in the shortest time possible.

The current warning scheme depends on earthquake data. BMG can only advert that an earthquake has the potential to generate a tsunami, but cannot yet confirm whether a tsunami was actually triggered. In the future, the system will integrate GPS as well as ocean observation data from buoys and tide gauges, which can confirm whether a tsunami was generated or not. Although it still has to be proven how fast the system can provide the necessary data in order to allow delivering a warning which confirms that a tsunami was really generated.

Natural warning signs pose a similar challenge of uncertainty. Ground shaking during the earthquake provides the first opportunity for local authorities to react, but the level of uncertainty is high as it is not known yet whether the earthquake's location was under the sea and its parameters were beyond the thresholds which might generate a tsunami. However, waiting until seawater withdrawal confirms the arrival of a tsunami is definitely not an option, as this would not leave enough time for the evacuation of the community at risk.

Consequently there must be a trade off between the need to deliver a quick warning and guidance and the demand for a higher level of certainty.

1. THE CHALLENGE: SHORT WARNING TIMES AND UNCERTAINTY

Most tsunamis in Indonesia are caused by tectonic earthquakes. Along the Indian Ocean coastline these kinds of earthquakes are generated in the collision zone between the Indian-Australian Plate and the Eurasian Plate (Figure 1).

As this collision zone is located close to the Indonesian coastline travel times of tsunami waves from the source area to the coast are short. It has to be expected that tsunami waves will need only 30 to 60 minutes to reach the coast, in some cases this happened even faster. Hence warning times are very short.

Time is the most critical factor when defining procedures for early warning and evacuation!

Understanding tsunami hazard and the assessment of possible impacts to their community are preconditions for local decision makers and other stakeholder to initiate activities and plans to get better prepared for future tsunami events. Based on today's understanding of the hazard, there must be decisions and implementation - often difficult - as they involve choices, tradeoffs and risk. Some degree of risk must be acceptable for economic reasons.

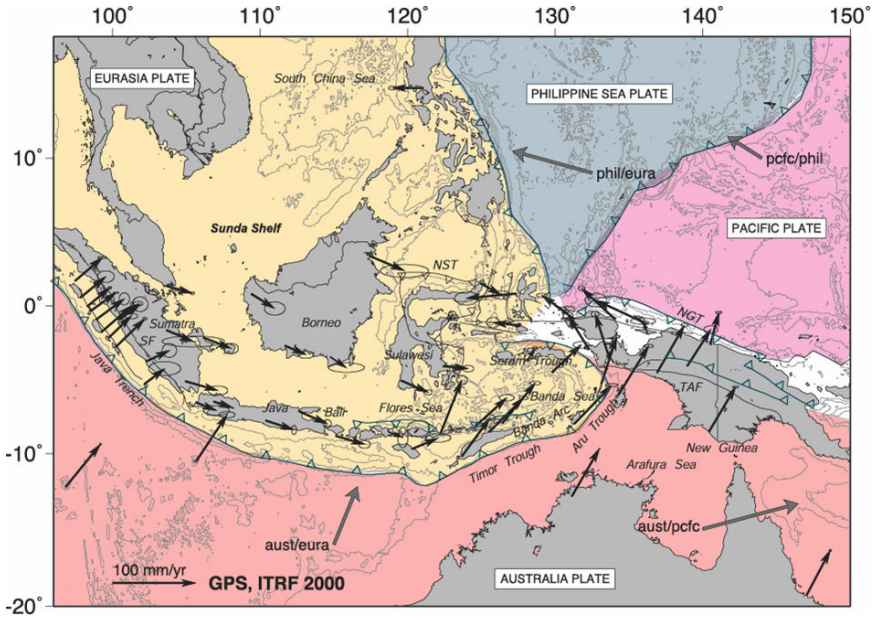

Figure 1. Active Tectonics of Indonesia: Crustal motions from GPS study (Bock et al, 2003)

Due to the infrequent occurrence of tsunamis, information regarding their possible impact, occurrence and run up heights is quite uncertain, and it must be assumed that no reasonable action can take into account all possible risk...

Most frequently tsunamis in Indonesia are triggered by tectonic earthquakes. But not all earthquakes in the collision zone cause tsunamis. Whether an earthquake has the potential to trigger a tsunami is currently evaluated by analyzing three factors:

1. Location: It has to be located under the sea
2. Magnitude: higher then 6.5 on the Richter Scale
3. Depth: less than 70 km deep

The thresholds mentioned above (M 6.5, 70 km depth) are currently used by BMG. Even if all three criteria are matched, it does not necessarily mean that a tsunami has been generated. A fourth criterion has to be fulfilled: the earthquake caused a vertical movement of the sea floor.

Nevertheless there are also possibilities that tsunamis are generated by submarine landslides. Submarine landslide can be associated to earthquakes and can add up to the effect of uplift by tectonic movements in the subduction zone.

In Indonesia earthquakes frequently occur also on land. In West Sumatra for example these earthquakes are associated to the Sumatra Fault Line and can be felt as strongly as the ground shaking from submarine earthquakes in the subduction zone (example: earthquake in West Sumatra on 6th of March 2007).

Ground shaking should be treated as the first warning sign! But since it is not possible to deduce earthquake magnitude and location from ground-shaking alone, there is a high level of uncertainty involved!

The Indonesian Tsunami Early Warning System (INA-TEWS) is designed to identify earthquake parameter and location within 5 to 7 minutes and to communicate this information to local decision maker. At a later stage (from mid 2009) INA-TEWS will integrate data from GPS, buoys and tide gauges to observe possible vertical movements of the plates as well as the ocean water in order to confirm whether a tsunami was generated or not. For this reason it is important to distinguish between the current and the future warning scheme.

As the current warning scheme depends only on earthquake observation, it is obvious that BMG can currently only advert that an earthquake has the potential to generate a tsunami, but cannot confirm whether a tsunami was actually triggered.

Local governments will not know with certainty whether a tsunami is on the way or not when they have to decide for evacuation.

Having clarified that, it is most important to understand that the moment of ground shaking during the earthquake provides the first opportunity to react, i.e. move away from the beach and to higher ground. The first warning from BMG, though it does not provide 100% certainty whether a tsunami will come or not, is probably the last chance to call for evacuation in case a tsunami becomes reality and hits the coast. Waiting until natural warnings signs (e.g. seawater withdrawal) confirm the arrival of a tsunami is definitely not an option, as it does not provide enough time for evacuation of the community at risk (see Figure 2).

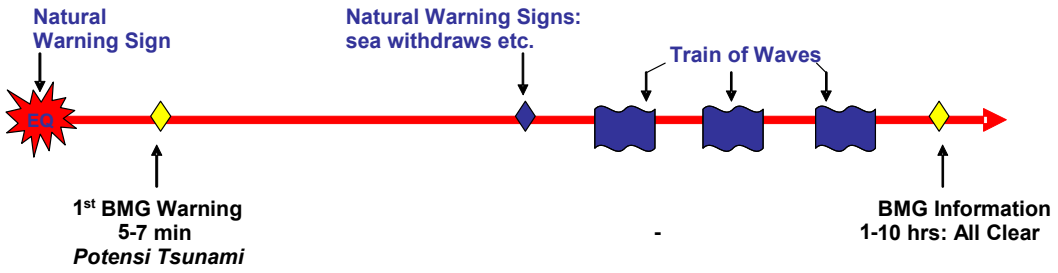

Figure 2. Current Warning Scheme: approximate time line of a tsunami event from the earthquake until a "All clear" message displaying available information (from nature and INA-TEWS) before, during and after the tsunami event. Note: time in minutes is just estimation, time can vary.

As already mentioned the current warning only provides information about the earthquake parameter and whether this presents a threat of a potential tsunami. The current warning scheme by BMG does not give any information whether a certain location might be affected in case of a particular warning and what level of impact to expect. The strong earthquake in Bengkulu on the 12th of September 2007 triggered a tsunami warning by BMG and Padang authorities called for evacuation, although the experience showed that this earthquake did not necessarily pose a serious threat for Padang.

With the future warning scheme - from mid 2009 on - this situation will change as the warning system will provide information about affected areas and the estimated impact. Additionally the system will facilitate additional information confirming whether a tsunami was generated or not (Figure 3). This confirmation will be based on the data from GPS, buoys and tide gauges. Once the future scheme is in place it has to be analyzed and discussed whether and how long it is worth waiting for a second

warning from message from BMG which might give more certainty about a tsunami occurrence but not leave enough time for evacuation and probably risk many lives.

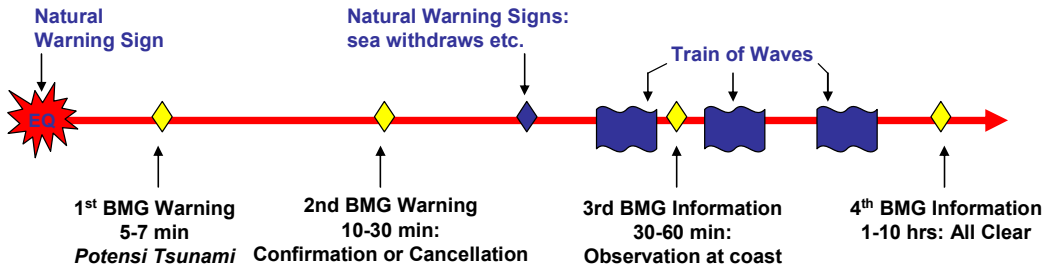

Figure 3. Future Warning Scheme: approximate time line of a tsunami event from the earthquake until "All clear" message displaying available information (from nature and INA-TEWS) before, during and after the tsunami event; Note: time in minutes is just estimation, time can vary.

Concluding: short warning times and uncertainties related to tsunami hazard and early warning represent a big challenge for Indonesian communities in its effort to improve tsunami preparedness and implement strategies for tsunami early warning. Recognizing this parameters and taking them into account should be the basis to develop a realistic preparedness strategy.

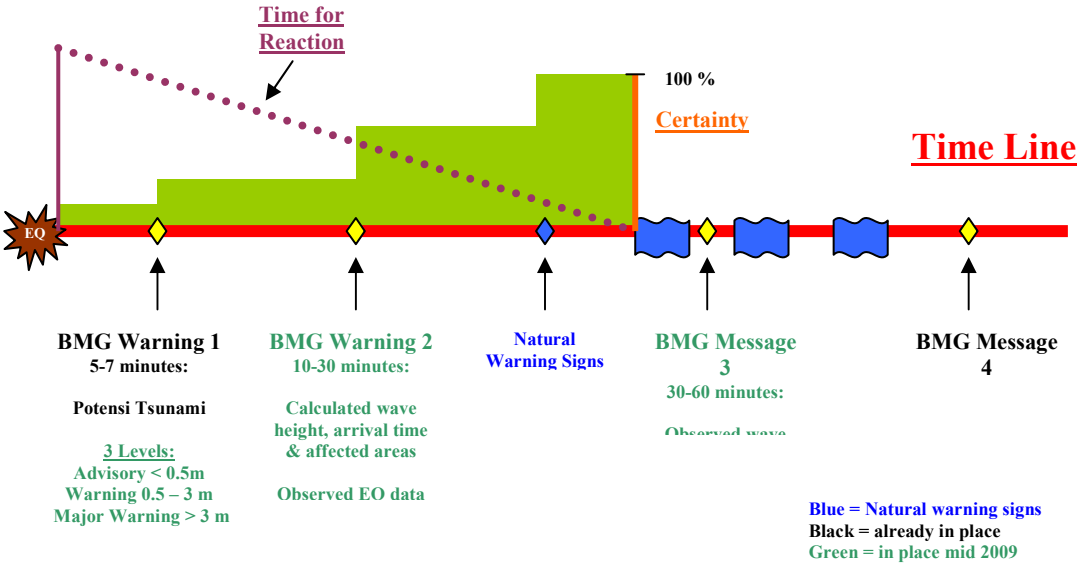

Figure 4: Relation between available information (uncertainty) and time for reaction along the tsunami time line. Note: time in minutes is just estimation, time can vary.

Dealing with tsunamis always means dealing with uncertainty. This is a big challenge and requires a preparedness strategy which takes it into account.

2. REFERENCES

Bock, Y., L. Prawirodirdjo, J. F. Genrich, C. W. Stevens, R. McCaffrey, C. Subarya, S. S. O. Puntodewo, and E. Calais (2003): *"Crustal motion in Indonesia from Global Positioning System measurements"*, J. Geophys. Res., 108(B8)