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Not That Kind of Doctor: A Story of Natural Disaster Prevention in Indonesia

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It was one of those rare, shining moments of feeling instrumental—of making a connection between what we love doing and the needs of others. Such was the case on a lazy Sunday afternoon, after church, in the village of Gelala, Ambon Island, Indonesia (Fig. 1). Many centuries ago, Gelala was one of the most important places in the world because it was where nutmeg, cloves and other spices, only known from eastern Indonesia, were loaded onto ships bound for Europe. If the ships made it back, the spices were worth more than their weight in gold.

Fig. 1. 17th century map of Ambon Island and the Dutch Colony established for the spice trade. Gelala is located at the narrowest part of the bay to the right of the fort (from spiceislandblog).

Gelala is also famous for the number of times it has been destroyed by earthquakes and tsunamis. The most recent event was on Sunday afternoon, the 8th of October 1950, after church.

A call for help came from Ambon Island because of a strong earthquake magnitude 7.3 and a gigantic tidal wave. A large number of victims is feared. The existence of this great wave (according to press accounts, it had a height of 200 m) could not be confirmed from the tide gauge records. (Soloviev and Go, 1974)

In November of 2013, I visited Gelala with others from WAVES, my tsunami disaster mitigation research team, to investigate this account of a 200m-high tsunami. At the same time we also received permission to inform the people there about this event and others from the past, and to help them prepare for the next time a tsunami strikes. This moment, of not only investigating natural hazards, but also communicating directly with those in harms way, and helping them implement protective measures, was a cathartic experience. The locations of most hazardous geological events are known in advance, but due diligence in preparedness is commonly lacking, which causes a crisis to become a disaster.

Fig. 2. My interview of Oma Esther Pung (behind window), who was 15 when she witnessed the 1950 earthquake and tsunami, about what happened. The village leader or Raja (stripped shirt) and many others helped me with the translation of the local language.

Our initial approach in investigating the Gelala tsunami was to seek out survivors that may have witnessed the event—people that were old enough at the time to remember what happened, people who were born in the 1930s.

We found two men and a woman (Fig. 2) still living in the village that remembered the event. They all gave a similar story even though we interviewed them separately. They said that after a minute or so of strong shaking, cries were heard throughout the village to run. A large wave was approaching and the people only had a few minutes to escape to the nearby hills. From the vantage point of the hill they watched multiple waves nearly to the tops of trees wipe out the village, leaving only one home standing. A metal Japanese ship was washed 200 meters inland and rested on the hill next to the only surviving home. Another survivor, who did not hear the cry to run because she was deaf, was swept by the tsunami into a tree. The tree is eight meters tall; the base is two meters above sea level.

The account had mistakenly mixed up the distance the wave had inundated (200 meters) with the height of the wave (8–10 meters). Eyewitness Esther Pung showed us the ruins of the home she had lived in at time. It, like all of the other homes in the city, was sheared from its foundations by the wave.

The WAVES team also examined the geological record in the village for evidence of not only the 1950 tsunami but also others that we have historical records of, and possibly even earlier events known as paleo-tsunamis. While I was interviewing eyewitnesses, volunteer geologists Rachel Dunn and Professor Nicole Cox, were excavating and logging a trench dug in the heart of the village next to where the ruins of homes are visible (Figs. 3–4). About 10 cm below the clayey village floor they found a layer of broken pieces of coral and shells mixed with coarse sand. Rachel asked the villagers, who had congregated around the excavation site, "When was the last time you dumped a layer of coral and shells over the floor of your village?" It was obvious to all that this material had been carried onshore and deposited by large waves.

Fig. 3. Volunteer geologists Rachel Dunn (red shirt) and Professor Nicole Cox (green shirt) logging a trench dug in the heart of Gelala Village. Several tsunami deposits were found from previous events.

Fig. 4. A reporter from the Ambon Ekspres (white shirt) observes the trenching investigation for tsunami deposits in Gelala. The article he published a few days later resulted in an emergency meeting of the Governor and his staff, and made the national news. Most of the people in Gelala and the Ambon region were unaware of the earthquake and tsunami hazards they face. Now they know, and they are actively preparing for the worst nature may bring.

We interrupted the investigation for a few hours in order to give a presentation about tsunami hazards at one of the local churches to a standing room only crowd. The word was spreading about our forecast of future earthquakes and tsunamis; many wanted to hear it for themselves. I know Indonesian well enough to give the talk in the national language—Bahasa. After the presentation, we were inundated with people asking when these things would happen. Even though we explained clearly that "when" is unknowable, they still pressed us for some kind of prediction.

One of those in crowd was a reporter for the Ambon Ekspres, the newspaper for the region. I apologized that we did not have time at that moment for a full interview, but if he came with us to Gelala he could hear the accounts of eyewitnesses and see for himself the layers of destruction Rachel and Nicole were excavating. On the way back to the excavation site, I showed him the catalog of natural disasters we had compiled for the region from 400 years of Dutch colonist records (Harris and Major, in press). One of my former Indonesian students had translated it into the Indonesian language. The catalog documents how Ambon was flattened four times by earthquakes and inundated five times by tsunamis.

Those who gathered at the excavation site and many others were able to see first hand—from historical records kept by colonists, the memories of forgotten citizens and deposits of shells and coral fragments that the threat of earthquakes and tsunamis in the region is real. Most importantly, those who most needed to hear the warning, those actually in harms way, were there at the site of the research. And many who were not there read about what we found in the headlines of the regional and national news.

Why Indonesia?

This rare moment of communicating directly and effectively with those in harms way is beauty from ashes. The people of the Indonesian region have suffered huge losses from natural hazards, as much or more than any other place on Earth. Yet, only recently have they been able to understand these hazards in a way that helps them prepare in advance for the worst nature can bring.

My role to educate and empower those in harms way of natural hazards in Indonesia started without me knowing. During my first scientific expedition to Indonesia (1987) I was able to learn the language and live among the local people for several months. I trained many of the locals to recognize geological hazards and show them how to build a resilient community. This approach has become known as liberation science (Emerman et al., 2012). Although most of my expeditions to Indonesia focused on academic questions (i.e. Harris, 1991 and 2011) it was obvious that the local people were in harms way of many natural hazards, and did not know it or what to do about it.

Most of Indonesia is an active tectonic maelstrom, and presents one of the most diverse natural laboratories of active tectonic processes on the planet. It is also one of the most densely populated places on the planet. This dangerous combination is amplified by an overall lack of awareness of natural hazards in the region. Year after year of observing the plight of those in harms way motivated me to make natural disaster mitigation the focus of my research.

This transition was hastened by a comment I overhead my son make to one of his friends. He explained that his dad "is a 'doctor,' but not the kind that helps people."

Although my first reaction was one of, "if he only knew," the comment caused me to reflect upon the underlying intent of my passion for what I did. In my son's mind there was an obvious disconnect between my research and the basic needs of others, which I eventually came to realize for myself. Within a few months I crafted a proposal to the U.S. Department of State identifying a new direction of geological research that still has few practitioners; it is called natural hazards.

Finding a way to connect my passion for geological research more directly with the needs of others was not a difficult stretch. Geology influences everyone on the planet everyday, especially in Indonesia, where more than one hundred million people live in harms way of explosive volcanoes, gigantic earthquakes and tsunamis.

Because of Indonesia's unique setting, it is the ideal testing ground to see if hazardous geophysical events can be forecast in order to save lives. At the time I wrote the proposal I fully accepted this illusion that successful forecasting is all that is needed to save lives, and all I am responsible for as a geoscientist.

My proposal was funded by the U.S. Department of State through a Fulbright Research Fellowship to Indonesia. This fellowship also provided funds for my family to travel with me and see for themselves how the geological sciences may directly help those in harms way.

A Year of Living Dangerously

My first glimpse of the scale of the problem of natural disasters in Indonesia came as I teamed with Indonesian colleagues and many students to conduct geological investigations and compile historical records of past natural disasters. Over the past 25 years we have completed 18 expeditions to various parts of Indonesia and translated hundreds of records kept mostly by Dutch colonists of the major earthquakes and tsunamis in Indonesia as far back as the 16th century.

We found evidence of more than 1,000 earthquakes—130 of which were destructive, and at least 95 tsunamis between 1600 and 2010. The records indicate that earthquakes left many cities in "rubble heaps" multiple times. Several tsunamis are recorded with run-up heights greater than 15 meters, which engulfed and washed away many coastal communities. One new problem is that the population has increased ten times what it was the last time most of these natural disasters happened.

Our geohazards research resulted in two publications that warned of reoccurring geophysical events and identified some of the most vulnerable places. The first paper was published in Indonesian (Harris et al., 1997) and the second in English (Harris and Prasetyadi, 2002).

The Sumatran region was identified as one of the most likely places for the next large (magnitude 8+) earthquake and tsunami. Our papers warned of hazardous regions in central Java where smaller, more frequent earthquakes occur and are commonly followed by devastating volcanic eruptions. We specifically warned of the dire consequences of a major eruption of Merapi volcano near Yogyakarta, based on data from nearby archeological sites.

When major earthquakes and tsunamis, and even major eruptions, will happen is unknowable. However, historical and geological records provide details over a large enough time window to recognize where these events are likely to reoccur. In other words, we thought we could address the question of "Who's Next" in a paper published in 2002 forecasting the likely recurrence of major earthquakes and tsunami in Sumatra and other parts of Indonesia. Carolus Prasetyadi, who is one of my former graduate students and now a professor, is the co-author. An earlier version of the paper was published in Indonesian in 1997.

The Beginning of the Earthquake Storm

Two years after the November 2004 publication, I was presenting about our earthquake and tsunami forecasts at a university in Dili, the capital city of Timor Leste. Timor is one the places we warned could be next to experience a large earthquake and tsunami. During the talk, I presented our research indicating that enough tectonic strain energy had already accumulated in the Timor region to produce a magnitude 7 earthquake. I mentioned that because most of the active faults in the region are underwater, the earthquake would likely produce a tsunami. To demonstrate this, I flicked a glass of water with my finger and noted that the earthquake would cause the ocean to slosh onto the land just like the water in the glass sloshed onto the podium. Few, if any, of those in attendance appeared to take me seriously.

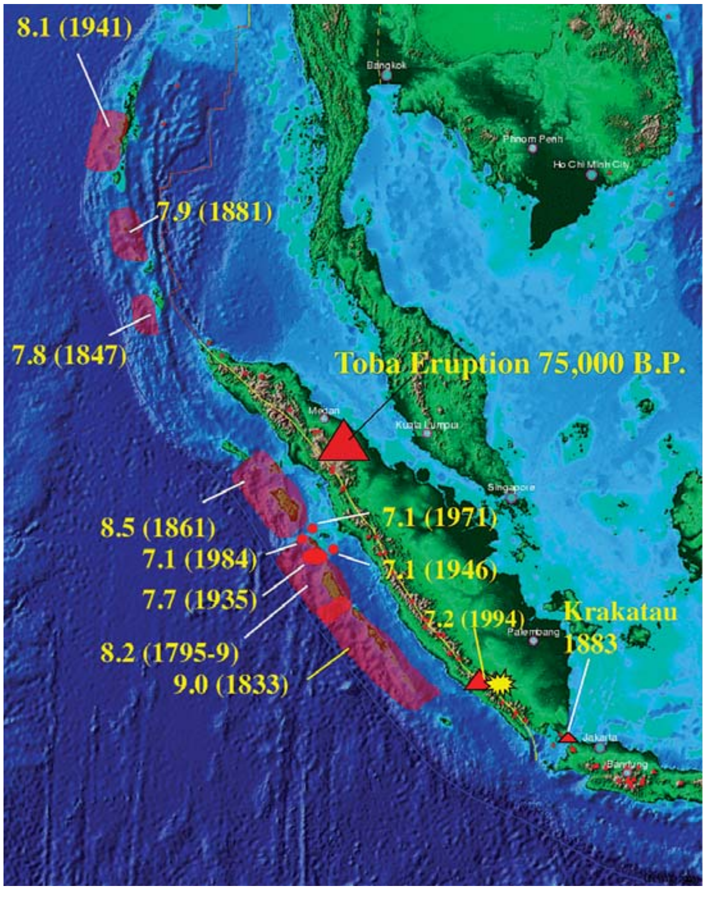
The next morning after the talk, a magnitude 7.6 earthquake struck near Dili and caused a tsunami that flooded parts of the city including the university where I spoke just hours before. I was bathing at the time the earthquake hit. Suddenly water began sloshing out of the container I was using. At the same time the unreinforced masonry walls of the bathroom started moving in a wave-like motion. Fortunately, the building held and I survived the awkward situation.

This earthquake, however, was the beginning of a "seismic storm" that is still raging today in Indonesia. Within a few weeks of the earthquake near Dili, a gigantic segment of the boundary between the Asian and Australian plates ruptured off the northwest coast of Sumatra. Pressure had been building along the plate boundary for hundreds of years without any large earthquakes, which is why we drew attention to it in our article.

> *The most dangerous seismic gaps in Indonesia exist in populated regions of western Sumatra, south-central Java, and Timor... The entire sixteen hundred kilometer length of the Sumatra fault system has not slipped significantly for 130–150 years. Since this time, seven to eight meters of potential slip have accumulated and will most likely be released suddenly to produce a magnitude 8.0 + event… (Harris and Prasetyadi, 2002)*

We were not the only scientists to forecast this event, so it was not a surprise to the geological community. Unfortunately, it was a surprise to those in harms way. The entire northern Sumatran and Andaman Islands, part of the Asian Plate which had been pushed eastward for hundreds of years, lurched back to the west more than 20 meters at nearly the speed of sound. The sudden release of this much pent-up energy ruptured a 1,600 km section of the plate boundary producing a magnitude 9.3 earthquake. This earthquake is the second largest ever recorded, and much larger than what we forecast. The rupture started near the northwest part of Sumatra and propagated northward at around 3 km/sec to the western shores of Burma. Even at this speed it took nine minutes for the rupture to make the 1,600 km journey. The nine minutes of shaking was so intense in the region that no one could stand.

The earthquake itself caused several buildings to collapse and killed hundreds of people. However, because the plate rupture occurred at an ocean depth of more than 3,000 meters, huge amounts of water was displaced, which produced the largest earthquake-generated tsunami in recorded history. The tsunami waves carried some of the immense forces released by the earthquake to nearly every shoreline on the globe—the closer the shoreline to the epicenter, the higher the waves (Fig. 5). There were at least 286,000 fatalities.



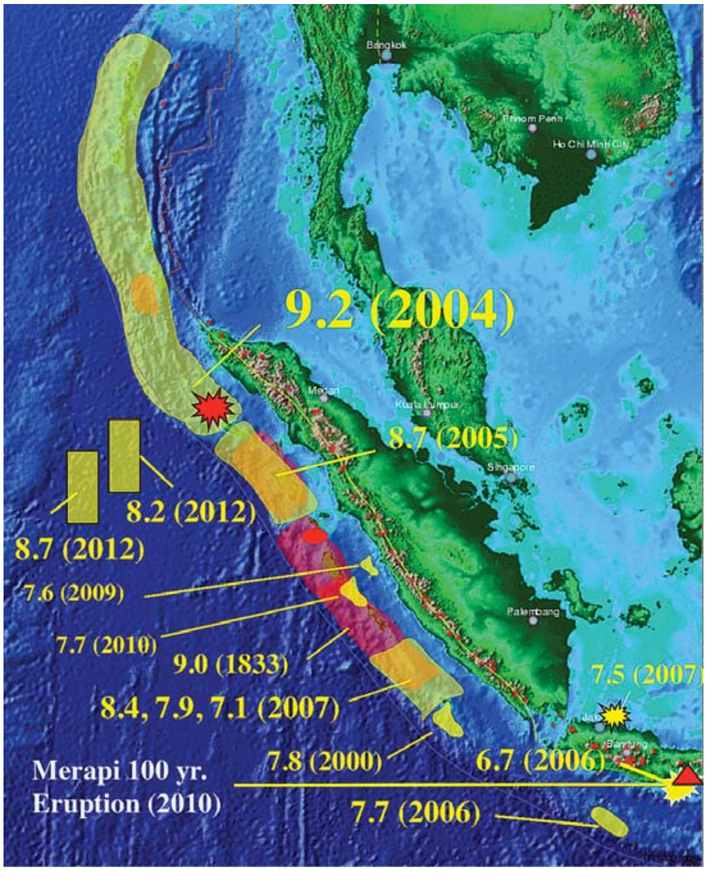


Fig. 5. Left–top: Map of Sumatra and part of Java with the estimated areas that ruptured to form giant earthquakes between 1795 and 1994. Fig. 5 Left–bottom: Same map with the major earthquakes and volcanic eruptions that have happened since we published our paper in 1997. Nearly 50 years had passed without an earthquake > magnitude 8.2 anywhere on Earth. Since the end of 2004 there have been 5 earthquakes > magnitude 8.2 in western Indonesian alone. A similar scenario occurred in the mid 1800s throughout Indonesia.

Lessons Learned from the 2004 Event

It is difficult to try to express my feelings as I watched video footage of the 2004 earthquake and tsunami event, and received updates from friends and colleagues in Indonesia who were impacted by the destruction. My son was right—I was still a "doctor" that did not help anyone. Even though we had successfully forecast this event, it made no difference to those actually in harms way. Most did not even know what a tsunami is or how to protect themselves from it. What adds to the tragedy is that it took an event of this scale to finally convince us of the uselessness of forecasting if those in harms way are not aware of the hazard or have no way of protecting themselves.

Immediately after the epic 2004 event, the press crafted a story that scientists had "predicted" the event and no one had listened to the warnings. Someone was to blame and it had to be the people of Indonesia. I was interviewed several times on television, radio, and for newspaper articles. One time, cameras and reporters from NBC, ABC, and FOX News were all set up at the same time in the conference room of the Geology Department at BYU. Instead of the story they were hoping to broadcast about how clever I was, what they got was a teary-eyed confession of the truth—that it did not matter how good our forecast was or where it was published. Those in harms way had no idea what was going to happen or how to respond. I left the communication and implementation to "someone else." Now I realize that I am the "someone else"!

AGU Statement

Within two weeks of the epic Sumatran earthquake and tsunami the American Geophysical Union (AGU) published a statement addressing the need for broadening the responsibility of the geoscience community for all aspects of natural disaster prevention. The statement makes the following points:

- Make fundamental research and monitoring of natural hazards a higher funding priority
- Disseminate the relevant results to the public, especially vulnerable communities
- Implement effective multidisciplinary mitigation strategies worldwide

This statement, the first to my knowledge made by a major geologic organization, articulated what I was already feeling—that I had to do more than just better forecasting and monitoring. It does not help that few, if any, funding agencies have adopted the AGU statement into their request for proposal descriptions. What agency is supposed to communicate which natural hazards are likely to happen to those in harms way and help them implement disaster prevention strategies? Most agencies that have anything to do with natural disasters are dedicated to relief with a focus on helping versus minimizing victims.

Currently, funding that includes the full spectrum of natural disaster prevention activities has to come from non-conventional sources, which translates into setting up non-profit organizations or some other non-governmental organization funded by mostly private money. To address this problem I set up a non-profit organization called "In Harms Way."

The purpose of In Harms Way is simple in concept—to focus on the second and third parts of the AGU statement, the parts few scientists have traditionally considered their responsibility. Most important is to learn from the mistakes and experience of the past—to do what was not done before the 2004 Indian Ocean tsunami disaster—tell those in harms way what is likely to happen and help them get ready. Through this approach hazards forecasting research joins with hazards education and preparedness, with the ultimate goal of saving lives and resources.

Recurring Earthquake Storm

One of the most interesting discoveries of our research of historical earthquakes and tsunamis in the Indonesian region is how these events commonly cluster in time and place. In other words, the rate of these events is not constant and the locations are not random. Various plate boundary segments of the Indonesian region experience several large earthquakes, tsunamis and volcanic eruptions, then set quietly for 30–50 years before another burst of intense activity.

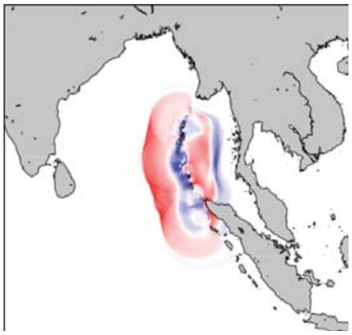


Fig. 6. Computer simulation of the 2004 South Asian Tsunami about one hour after the magnitude 9.3 earthquake. The red areas are positive waves and the blue areas are negative waves (sea withdrawal). The first positive waves struck Banda Ache within 20 minutes of the earthquake. Whereas, it took three hours for the waves to reach Thailand to the east and four hours to reach India to the west. Still, no warnings were issued.

The gigantic 2004 Sumatran earthquake released so much energy that it initiated another mega-cluster of events throughout the whole region. Three months after the 9.3 earthquake, the plate boundary segment immediately to the south of it ruptured to produce a magnitude 8.7 earthquake and large tsunami that claimed thousands of lives (Fig. 6).

In 2006, a mid-sized earthquake (M = 6.3) struck central Java, killing around 6000 and displaced nearly a half a million people. Immediately after the event, nearby Merapi volcano erupted killing many people. The string of events is nearly identical to what we found in historical records and warned would likely reoccur in central Java (Fig. 7).

Fig. 7. Ruins around the only home standing after a 10-meter-high tsunami struck the coast of Java. The tsunami reached the upper floor of the three-story home in the distance.

> *The collisional plate boundary near densely populated Java has some of the highest strain rates in the world… which is manifest by more frequent moderate earthquake events (M 5.5–7.5)… Although these moderate events are of lesser magnitude…they pose a greater threat due to the more frequent devastation and disruption they inflict…Poorly regulated development in these zones of high seismic flux poses a significant threat not only to the many cities with unfavorable site characteristics, but also densely populated rural regions that have rapidly expanded into seismically unstable hillsides and cities along shorelines vulnerable to tsunami destruction. Most buildings in these regions are incapable of withstanding even mild horizontal ground motions…As witnessed in recent moderate seismic events … a magnitude 6.4 quake near densely-populated regions with weak dwellings can cause thousands of deaths, billions of dollars of damage, sever gas and water lines, damage critical facilities … and cause sudden economic collapse. These types of damage initiate new disasters. (Harris and Prasetyadi, 2002)*

Two months after the seismic and volcanic disaster in densely populated Yogyakarta, a magnitude 7.7 earthquake struck offshore to the south of the city causing a large tsunami that killed hundreds of people.

In 2007 a magnitude 7.5 earthquake struck near Jakarta, a city of around 15 million people. Fortunately, the earthquake was 280 km deep and resulted in little damage. Two months later a series of earthquakes of magnitudes 8.5, 7.9 and 7.1 struck the SW coast of Sumatra causing more fatalities. In 2008, three aftershocks between magnitude 7.0–7.5 caused fatalities. In 2009, there were four destructive earthquakes between magnitude 7.0 and 7.9 that accounted for more than 2500 fatalities in Sumatra.

In 2010 there were three more earthquakes between magnitude 7.2 and 7.9 that accounted for hundreds of fatalities. A few hours before the 7.9 event, Merapi, a volcano in central Java, exploded with an intensity that had not happened since 1870. Hundreds of fatalities resulted, but it could have been much worse as close to 350,000 people were evacuated immediately before the eruption.

In 2012, a magnitude 8.6 earthquake struck off the coast of northern Sumatra, which was followed two hours later by a magnitude 8.2 earthquake near the same location.

Before the 2004 earthquake, there had not been a seismic event greater than magnitude 8.5 for nearly 39 years. Within the next seven years after the 2004 event, four earthquakes larger than 8.5 happened in western Indonesia alone. It has been a decade of utter seismic terror, and more is likely to happen before the seismic mega-cluster ends.

More troubling, is the greater rate of fatalities than in the past. Indonesia has had earthquake fatalities in 25 of the past 26 years. The previous record was only two consecutive years.

Prevention Pays Off

If the earthquake storm in Indonesia was not enough, on March 3, 2011, there was a replay of the 2004 Sumatra event, only this time it happened in prevention-minded Japan. Even though the size of the earthquake and tsunami in Japan was comparable to the 2004 event in Indonesia, and the population density nearly the same, one person died in Japan for every ten who died in Indonesia. Japan's preparedness saved thousands of lives. Tsunami is a Japanese word, and the people of Japan are well aware of what it is and how to respond. Tsunami evacuation sites are common, and most people in coastal communities had participated in tsunami evacuation drills before the 2011 event. Preparedness works!

Indonesia's Next Generation

Indonesia does not have the capital resources to build resiliency like Japan, but has the human resources. A mandatory scouting program in Indonesia, known as Pramuka, involves boys and girls ages 12–19 in activities dedicated to Siap dan Waspata, which translates to "readiness and awareness." In 2008, Carolus Prasetyadi and I were successful in linking our disaster mitigation activities with Pramuka. Since then we have led disaster prevention training seminars to groups of boy and girl scouts and their leaders in many of the islands of Indonesia. On some islands, special scout jamborees were held for the purpose of helping the scouts make a hazard map of their island, identify the most vulnerable areas and evacuation sites (Fig. 8).

Fig. 8. Pramuka scouts making geological hazards map of their island

The goal for working with Pramuka and government leaders is to help them build the capacity to conduct their own natural disaster prevention jamborees and activities throughout Indonesia. In 2012, one of the Indonesian geologists of the WAVES Team, Nova Roosmawati, and I worked with government disaster management leaders on densely populated Ambon

Fig. 9. Auditorium filled to capacity with Pramuka in uniform at one of the natural disaster prevention training jamborees held in Ambon, Indonesia. Volunteer geologist Rachel Dunn and I stand next to the head master of the school.

Island to try to mitigate the hazards of landslides threatening many neighborhoods in the city. Two days before we arrived an earthquake had caused a landslide that killed several people. Many families abandoned their homes and were living as refugees in local schools. We were able to train one of the government workers, Julian Fretha, how to identify unstable slopes and other hazards to prevent the disasters from happening.

After we left, Julian shared with us many success stories about how she had trained others in her office to make prevention presentations at schools, churches and other public meetings. She gave more than 40 presentations herself, including 10 seminars at various universities in Ambon and other islands (Fig. 9).

Julian Fretha Saves Thousands of Lives

When we met Julian in Ambon during our 2013 expedition, she was with the disaster prevention team she had assembled for Ambon. The team consists of the resident geophysicist from the Geophysical Survey of Indonesia (forecasting), the head of the Office for Social and Cultural Affairs for the island (communication), the head of the Red Cross, and the regional head of the Civil Defense Agency (Implementation).

Julian told an amazing account about a disaster averted due to her vigilance with implementing disaster prevention strategies. Here is her story.

Heavy rains during July 2013 caused unprecedented landslides and flooding (Fig. 10–12). One landslide was so large that it dammed a major river on the island above the city of Negri Lima. A lake formed behind the landslide that threatened to break the natural dam and flood the city downstream. Expecting the worst, Julian helped the citizens of Negri Lima to establish evacuation routes and conduct evacuation drills. She designed evacuation signs herself and hired local craftsmen to build and post the signs. A few days after the drills, the dam broke suddenly and sent a 15-meter-high wall of water down the valley. The people of Negri Lima only had seven minutes to evacuate before 425 homes in the city were completely washed away. Because the people of Negri Lima

Fig. 10. The flood destruction zone where homes in the city of Negri Lima were washed away by the 30 July 2013 flood.

Fig. 11. ABOVE: Dead jungle high-water mark from the lake that formed behind the landslide and (inset) one of several evacuation signs designed by Julian that guided the successful evacuation of more than 2,500 people

Fig. 12. Aerial view of landslide—the lake eventually spilled over the dam causing it to catastrophically fail. The flood reached the city below in ten minutes and swept away 258 homes.

knew what was happening, and had practiced where to go, nearly all of those in harms way were able to evacuate to safety. Approximately 2,500 lives were saved.

We visited the site of the disaster and the large refuge camps adjacent to where the Negri Lima used to be. Several of the people in the refuge camp commented that the people of Negri Lima owed their lives to Julian and her commitment to disaster prevention.

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