International Network on the Financial Management of Large-Scale Catastrophes

The Provision of Hazard Maps

Selected global good practices and an inventory of online hazard information in South East Asia

DRAFT

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Owen Gough

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South East Asia has many areas of high population density which, when combined with the lack of building codes and planning, are particularly vulnerable to hazards. A large disaster may set back a country’s economic and structural growth by many tens of years in a single moment, not to mention the loss of human life. The continued economic development of many South East Asian countries depends on proper hazard management.

The provision of mapped hazard information is essential to proper planning and development of evacuation plans and disaster risk management. Ideally such information should be available freely; both to residents, communities, NGOs and to those with an external interest, such as potential investors. This empowers the general public to make their own decisions regarding what is an acceptable level of risk and in many ways reduces the likelihood of a government dictating terms.

Many people still view natural disasters as an unavoidable divine act which man cannot attempt to manage. Through proper education this attitude can change, natural hazard events are inevitable but disasters can be avoided. Cyclone Nargis is a tragic example of a disaster which could have been largely prevented. Hundreds of thousands of people living in low lying areas of Myanmar were never made aware of their vulnerability to tropical storm induced surges, meaning that when Nargis formed in 2008 there were no attempts to evacuate or warn the public, resulting in a large number of casualties probably exceeding 130,000[1]. A simple storm surge hazard map may have been sufficient to make populations aware of the need to evacuate.

This report finds that, whilst hazard maps in South East Asia are not always easily available or made using probabilistic models, the majority of hazards in the majority of countries have been mapped. Notable exceptions are tsunami and tropical storm maps, both of which do not appear to be available online. In some countries it is not clear whether they have been produced but are only kept locally; in others there has been confirmation that they do not exist. Generally the best mapped hazard was flooding, although this rarely included off plain or sheet floods. Maps in Appendix 1 summarise the levels of online hazard information available for each country included in the report and the scope for improvement in South East Asia.

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1. Introduction

Many thousands of people are affected globally by natural disasters every year. Large-scale events cause significant problems for entire countries or regions. Damage to infrastructure can be very costly and loss of human life may remove skilled members of the workforce. A single event can lead to many months, or even years, of disruption as people are displaced and governments must provide aid and shelter for those affected.

The process of producing a thorough disaster risk management (DRM) plan in a country is long and requires significant focus and investment from government bodies. For any successful DRM scheme risk must first be identified, usually via data collection and mapping. Mitigation, response and development plans may then be constructed from this initial data. The disaster management cycle shows the various stages of hazard management and response. Whilst development is only specifically mentioned in the reconstruction phase, it can and should be incorporated in to all phases of DRM.

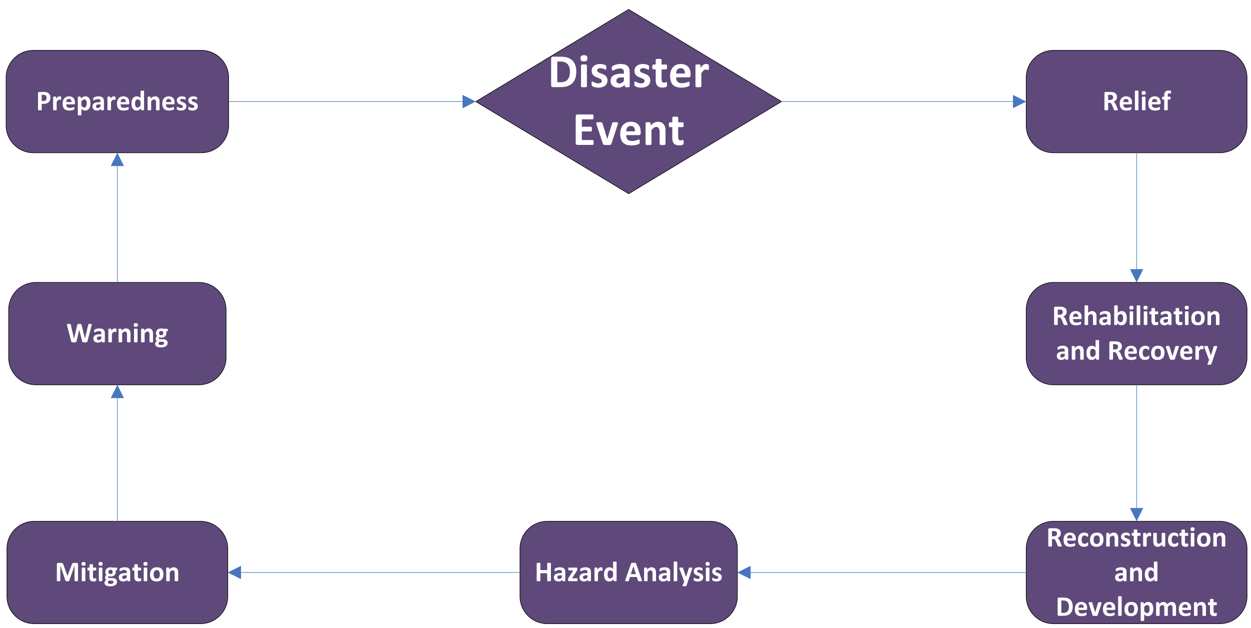


Fig. 1 Disaster management cycle

There is an important role for NGOs in raising hazard awareness and disaster risk education and preparedness, given the potentially inadequate resources dedicated to disaster risk management.

Whilst government plans for mitigation and response are essential, the mapped information should be made available at all levels in a country to empower individuals and communities to make their own decisions regarding risk. Provision of risk maps to a population may remove some of the challenges of producing effective response plans as a better informed population requires less guidance from a government in the event of a crisis.

In the developed world and increasingly in the developing world, the internet is becoming the primary source of information transfer. It provides a free and instant way of transmitting large amounts of data on demand to a user based on their research requirements/search criteria. Primary users of online information are likely to include: civilians, civil societies, those in the insurance industry, members of the scientific community, NGOs, local officials and potential investors.

In some areas internet penetration is still extremely low and therefore paper copies of local hazard maps should be provided to be displayed in community centres, such as village halls. Hazard warnings and other essential information should still be provided in widely available forms of media such as radio and television, as these ensure a more immediate response than the internet. As mobile phone coverage and ownership is so high, even in the poorest regions of countries, SMS text messages are a highly effective way of rapidly disseminating warnings and alerts. This has been acknowledged and many governments are exploiting the potential of SMS warnings.

Provision of risk information to a population is essential to allow for continued growth and development, as without proper hazard mapping and identification a hazard-prone country's progress will continually be set back by disasters.

The selected good practices section (section 2) proposes examples of online hazard mapping from developed countries, which regularly experience natural hazards. These countries have used high quality hazard information to drive significant DRM schemes but have also taken extensive steps to inform and educate the general public and other interested parties. These good practices do not necessarily apply to all South East Asian countries, as requirements and available resources may be very different. Depending on the target audience differing criteria apply. NGOs and those in the insurance industry and scientific communities may appreciate and require much more detailed and technical information than a resident only interested in the level of hazard to their home.

The final section of this report (section 3) surveys the current state of online hazard mapping in South East Asia, based on what is available remotely. Potential gaps in coverage and particularly good examples of mapping are highlighted.

For the purposes of the report South East Asia is defined as those countries within the Association of South East Asian Nations[2] (ASEAN) with the addition of Bangladesh as it is in a similar developing financial state and suffers from a hazard profile in common with many ASEAN countries. Brunei Darussalam, whilst a member of ASEAN, has no significant risk from the hazards being considered in this report and therefore has been excluded; it also does not have a recognisable natural disaster management program.

Fig. 2 Map of countries included in the report.

1.1 Parameters of Hazards

Each natural hazard may produce one or more damaging agents which combined cause a disaster. The risk of these different agents may not be equal in all areas for a single event, and so an ideal hazard assessment would deal with each damaging agent separately.

In many cases all forms of hazard are not considered during mapping; for example, floods are usually only mapped in terms of river overflow (slow) floods when in fact there are many types including: sheet floods (where high volumes of rain fall on sloping areas of impermeable ground), flash floods (either caused by extreme rainfall, sudden glacial melting or catastrophic failure of dams) and urban flooding (frequently caused, or worsened, by sewer overflow).

The widespread influence of humans in natural hazards is well documented, particularly relating to climate change, global warming and associated sea level rise. On a smaller scale logging may substantially increase the risk of landslides, both by reducing slope support and increasing the vulnerability to heavy rain.

The principal hazards considered in this report are listed below along with the main damaging agents that should be considered. Suitable hazard zones for maps are also suggested, based on likely areas that damaging agents will affect.

Floods

An ideal flood hazard map should include information on:

- Height of inundation
- Velocity of water
- Likelihood of wave action
- Likelihood of debris
- Risk of secondary hazards: Landslides (Mudslides)

Flood hazard zones may be divided in to those where:

- velocity is the primary damaging agent (near to the coast or in mountainous areas)
- height of inundation is the primary damaging agent (lowland flood plains)
- wave action may add to damage in coastal areas, particularly during storm surges as wind speeds will inevitably be high
- transported debris may cause additional damage (any populated areas where flood water is likely to have a high velocity)

Landslides (Mudslides)

An ideal landslide hazard map should include information on:

- Slump or subsidence of land
- Hazard zones for debris flows
- Risk of secondary hazards: tsunami (only if catastrophic landslides in to lakes, or submarine)

Landslide hazard zones may be divided into those at risk from:

- actual land slump (those on unstable slopes)
- run out of slides (those at the base of an unstable slope or in valleys some distance downhill)

Earthquakes

Whilst shaking obviously causes a great deal of damage and loss of life, in certain soils liquefaction can be just as damaging. Rupture and landslides are only likely to affect small areas. An ideal earthquake hazard map should include information on:

- Magnitude of shaking
- Likelihood of liquefaction
- Fault rupture
- Risk of secondary hazards: tsunamis and landslides

Earthquake hazard zones may be divided in to those at risk from:

- ground shaking (local amplification may occur in certain soil hardness profiles)
- liquefaction (depending on soil saturation)
- fault rupture and landslides (may affect small regions along faults or close to unstable slopes)
- large submarine earthquakes (have the potential to generate tsunamis)

Tropical Storms

In tropical storms the secondary hazard of a storm surge frequently causes the most damage and loss of life. An ideal tropical storm hazard map should include information on:

- Wind speed of gusts
- Damage from precipitation
- Risk of secondary hazards: Storm Surge, Floods, Landslides (Mudslides)

Tropical storm hazard zones may be divided in to:

- generally low lying coastal regions which are at risk from storm surges, although this may extend some distance inland via tidal inlets
- areas some distance in land which usually experience heaviest rainfall once wind speeds have diminished somewhat
- areas close to landfalling tropical storms which usually experience the strongest winds as these will rapidly lose strength once the storm is over land

Volcanoes

Volcanoes mix a suite of local hazards with the very wide reaching hazard of lahars. An ideal volcano hazard map should include information on:

- Hazard zones for flows (pyroclastic and lava)
- Ash fall
- Ballistics and lateral blast
- Risk of secondary hazards: earthquakes, landslides, lahars

Volcanic hazard zones can be split in to local, topographical and aerial:

- local hazards include lateral blasts, ballistics and toxic gas release and these only threaten a relatively small area in close proximity to the crater
- topographically constrained hazards include pyroclastic flows and surges (usually confined to 5-10km around the volcano) and lahars (volcano induced flash floods which may travel many hundreds of kilometres)
- aerial hazards are mainly caused by heavy falls of ash causing roof collapse and health problems, although in very large eruptions projectiles may be of a sufficient size to cause damage in themselves

2. Examples of current global good practice in the generation and online provision of hazard maps

In some parts of the developed world it may be acceptable to require a small payment to access information as if there is a financial incentive the commercial sector may improve the quality available. It is certainly not unreasonable to expect a user to provide a small fraction of the value of a property to ensure it is not at risk from hazards. In the developing world information should be available for free, as disposable income is very different. Some global good practices have been selected for being readily accessible, easy to understand for non-technical users and providing useful information. In some cases no ideal resource existed, and in these cases the examples that came closest to these criteria were included.

At a local level the Californian Emergency Management Agency[3] (CALEMA) website, which provides tabbed information on fires, earthquakes and floods, is an excellent example of how government bodies should present hazard information to the general public, particularly in a region where there is more than one substantial natural risk. For each level of risk from a particular hazard tailored information is easily available both on how to prepare and how to report and respond to an emergency, in a variety of formats. The tables at the end of the each good practice summarise the information provided and rate it. A key to the tables and colours used is provided below.

Hazard Map – Producing Authority	
Type of map	Either risk based (probabilistic/historical) or forecast
Parameters	**Damaging agent A**, damaging agent B, damaging agent C
Risk Boundaries	**Boundaries for damaging agent A**, boundaries for damaging agents B and C
Information	Preparedness, evacuation or response information
Retrieval Method	How the data is retrieved by the user (e.g. address search or coordinates)
Access	How the user initially locates the map or the search form
Coverage	Stars (✸) approximately represent the coverage of the risk area (out of 5)

Excellent	Very difficult to improve
Good	Minor improvements possible
Average	Functional but requires some improvement
Poor	Substantial improvement possible

2.1 Earthquakes

My Hazards – California Emergency Management Agency (CALEMA)

The CALEMA 'My Hazards' program[4] provides a search function based on location (address, zip code or city) or alternatively allows the user to set a location by clicking on a map of California. The page returned then lists risk of shaking along with an indication of the presence of landslide, liquefaction or fault rupture hazard. Advice on how to prepare is also provided tailored to the specific location, with links to leaflets explaining each step. The 'My Hazards' map also allows the user to view their wildfire and flood risk for the given location (with a similar level of detail and advice) giving a unified resource for the total risk to their property. The only criticism of this website is the lack of numerical probabilities for high and medium risk boundaries.

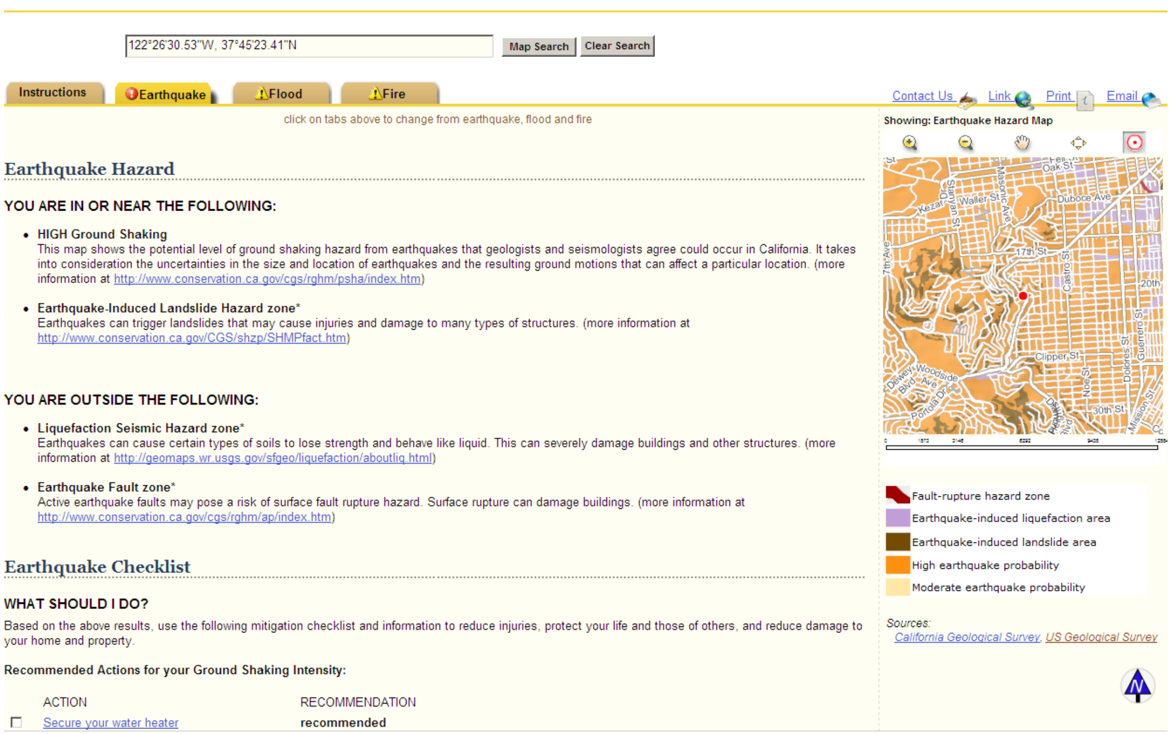


Fig. 3 Screenshot of the information page showing the risk level of hazards, the checklist of suggested steps to prepare and the tabs to view flood and fire risk

My Hazards – CALEMA	
Type of map	Probabilistic
Parameters	**Shaking**, liquefaction, landslide, fault rupture
Risk Boundaries	**High/medium**, *at risk areas*
Information	Preparedness information tailored to each risk level, multi-format
Retrieval Method	Search by zip/address/coordinates
Access	Prominent banner link from California state and emergency website
Coverage	✱✱✱✱✱ Covers all areas of the state of California

Fig. 4 Summary table of My Hazards – CALEMA

2.2 Floods

Flood Map – England and Wales Environment Agency

The Environment Agency online flood map[5] provides a postcode-based search and returns a map showing flood hazard at 1%, 0.5% and 0.1% annual chance. The map additionally shows areas which are protected by flood defences and would otherwise be at risk. Flood defences will protect against a 100 year river flood and a 200 year coastal flood. Information is available tailored to each risk zone, for how to plan and deal with flooding. The data used is provided and information is given on how the map is constructed. Current flood warnings may be accessed either by using the internet or, on registration, may be sent by text to those at risk. There is no information provided on the map for water depth, velocity or likelihood of wave action and the scheme does not make any attempt to model sewer over flow flooding.

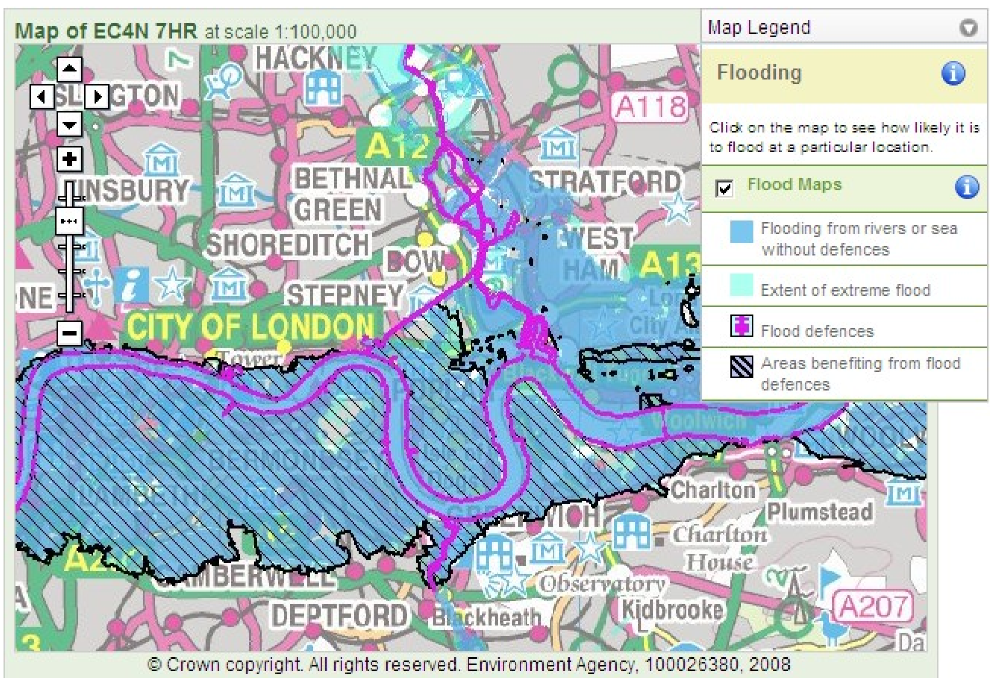


Fig. 5 Screenshot of map showing regions of likely flooding, extreme flooding and protected zones. Data on specific location risk is available by clicking on the map

Flood Map – England and Wales EA	
Type of map	Probabilistic
Parameters	No information
Risk Boundaries	1%/0.5%/0.1% annual chance of flooding (100/200/1000 year RP)
Information	Tailored information for each flood risk category
Retrieval Method	Search by postcode or browse map
Access	Prominent link from Environment Agency website
Coverage	★★★★★ Covers all of England and Wales

Fig. 6 Summary table of Flood Map – England and Wales EA

2.3 Landslides

Progetto IFFI – Istituto Superiore per la Protezione e la Ricerca Ambientale

The Italian project to map and predict landslides is available online to the general public[6] in the form of a layered GIS map. This can be searched by location or browsed. Information is given on various types of earth movement hazard, such as subsidence, expansion and collapse. Historical landslide data is available by selecting points on the map. Areas at risk of superficial landslides, subsidence, collapse and mass movement are marked on. Metadata for both landslide data and base layer mapping is given.

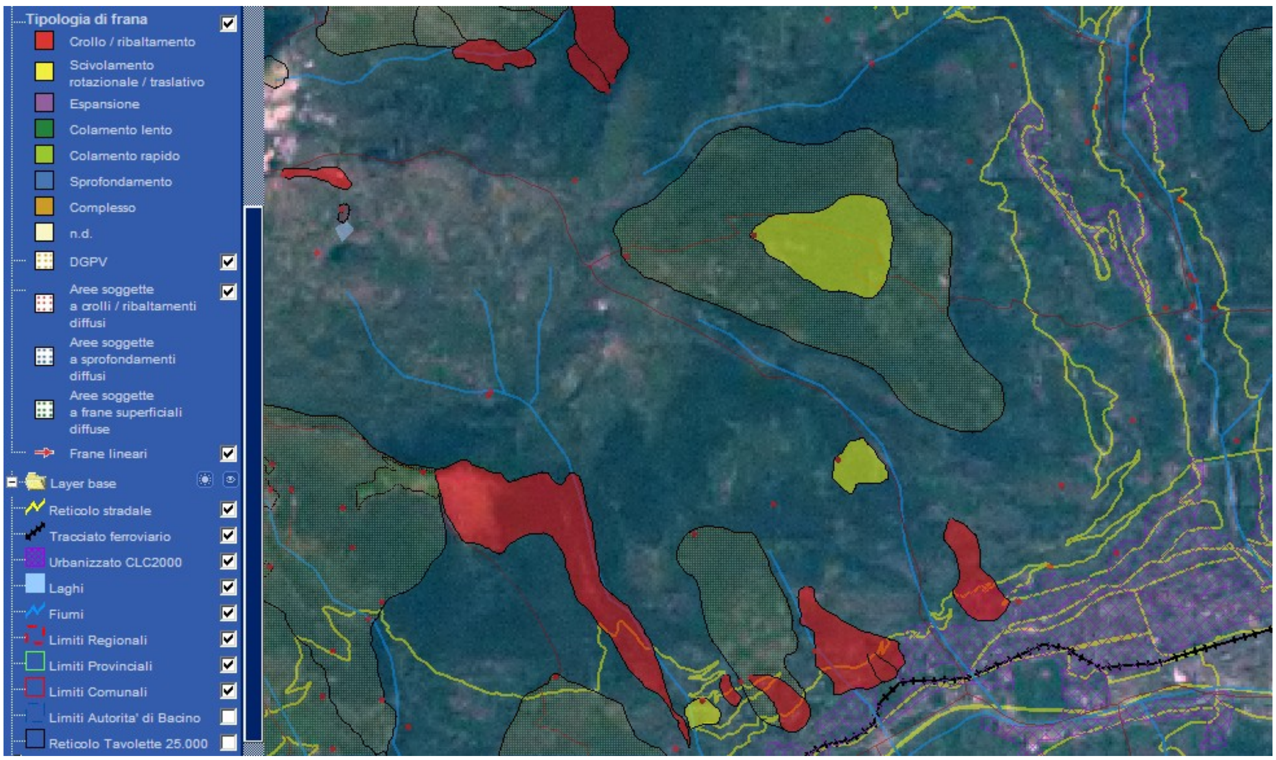


Fig. 7 Extract from the IFFI GIS map. Dark green areas are at risk from superficial landslides, light green areas experience creep, red areas have experienced collapse or tipping and purple hatching represents urban development

Progetto IFFI – ISPRA	
Type of map	Probabilistic/Historical
Parameters	Superficial landslides, subsidence, collapse, expansion
Risk Boundaries	Only given as 'at risk' areas
Information	None
Retrieval Method	By address or area
Access	Theoretically easily accessed but site frequently goes down
Coverage	✱✱✱✱✱ All regions of Italy covered

Fig. 8 Summary table of Progetto IFFI – ISPRA

Slope Information System – Hong Kong Slope Safety

The Hong Kong government has implemented a scheme of registration for some 57,000 substantial slopes to ensure that they meet a minimum standard of stability. Whilst this currently only covers man-made slopes, from 2010 onwards the project will expand to cover natural slopes which pose a risk to human settlement. Registered slopes are marked on a map, along with historical landslide data, which may be searched by location (building name, street or coordinates) or browsed by district[7]. Individual slope data can be viewed by clicking on slope registration numbers in the map. This includes detailed reports and diagrams of stability, along with a "consequence to life" rating. No indication is given of the individual risk to a property, although this can easily be worked out by viewing data for nearby slopes.

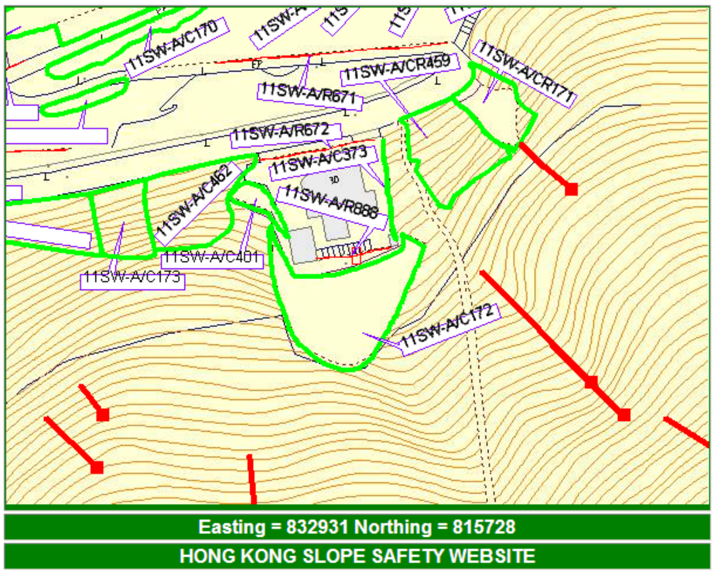


Fig. 9 Screenshot of a slope hazard map. Manmade slopes are marked in green with historic landslide scars in red

If government slope safety screening determines that a slope is at risk they may issue a "Dangerous Hillside Order" to the owner of the property on which the slope lies, requiring professional investigation and remedial measures to be arranged by the owner.

Slope Information System – HKSS	
Type of map	Historical
Parameters	None
Risk Boundaries	Poorly defined "consequence to life rating"
Information	Slope stability reports and diagrams, with preparedness etc. available in other sections of HKSS website
Retrieval Method	Search by street, building name or coordinates
Access	Prominent HKSS link on main Hong Kong city website
Coverage	✸✸✸ Only currently available for manmade slopes

Fig. 10 Summary table of Slope Information System – HKSS

2.4 Storm Surge

New Orleans Risk – US Army Corps of Engineers

An interactive map is available online[8] with the urban New Orleans area split into sections. For each section a selection of maps are shown giving likely inundation heights from hurricanes of 2%, 1% and 0.2% annual probabilities. Historical data for flooding before Katrina is also given, which shows the effect of flood defences implemented since 2005. A PowerPoint presentation gives very detailed information on how the maps were produced and the statistical modelling used.

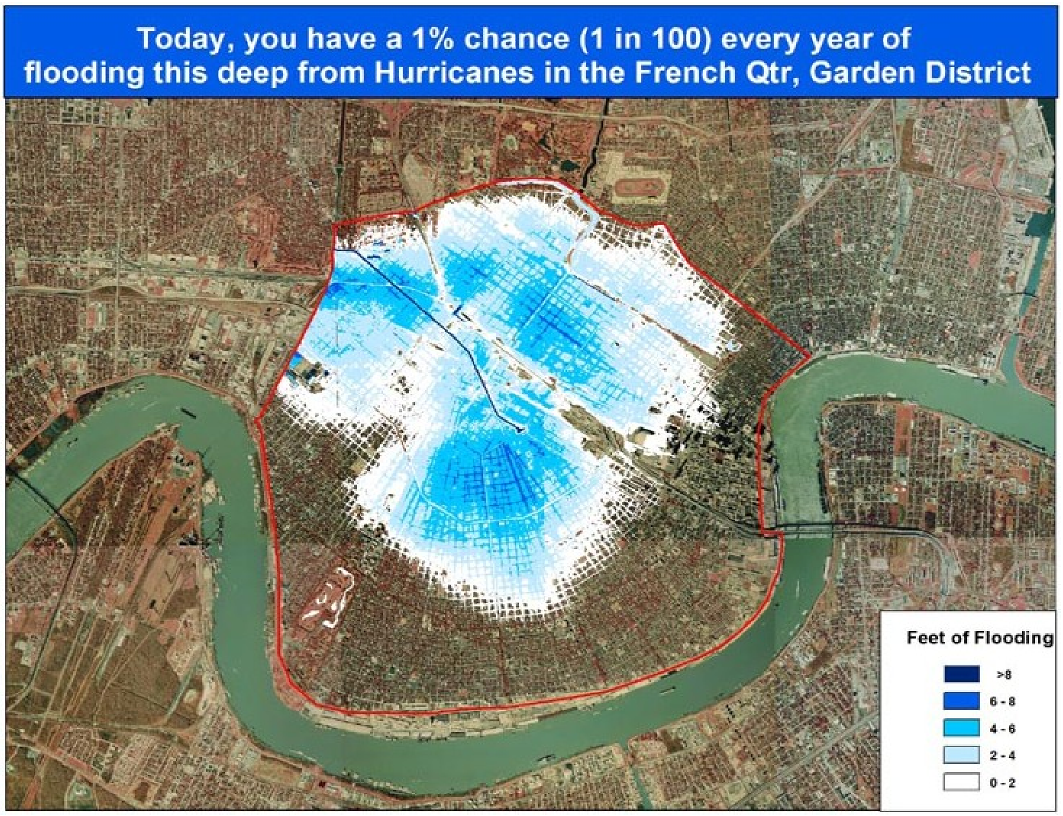


Fig. 11 1% flood height map for the French Quarter, New Orleans

New Orleans Risk – US Army Corps of Engineers	
Type of map	Probabilistic
Parameters	Height of inundation
Risk Boundaries	2%/1%/0.2% annual probabilities on separate maps (50/100/500 year RP)
Information	None (available in other sections of New Orleans Risk website)
Retrieval Method	Selectable by city area
Access	Whilst this is easily available on NOR website, links should be available from more obvious sites such as Louisiana or New Orleans disaster planning sites
Coverage	✶✶✶✶ Covers New Orleans and Plaquemines but not entire NO metro area

Fig. 12 Summary table of New Orleans Risk – US Army Corps of Engineers

2.5 Tropical Storms

Hurricane Preparedness – NHC/NOAA

The National Hurricane Centre (NHC) has constructed probabilistic risk maps of the US coast using data from the National Hurricane Centre Risk Analysis Program (HURISK). These are available on the NHC website[9] along with a detailed explanation of the concept of return periods. For each category of storm a map may be viewed of either the entire US coast or specific sections. These show return periods in years for the selected intensity of storm passing within 86 miles (75nm) of the point, they are also colour coded to give an indication of risk.

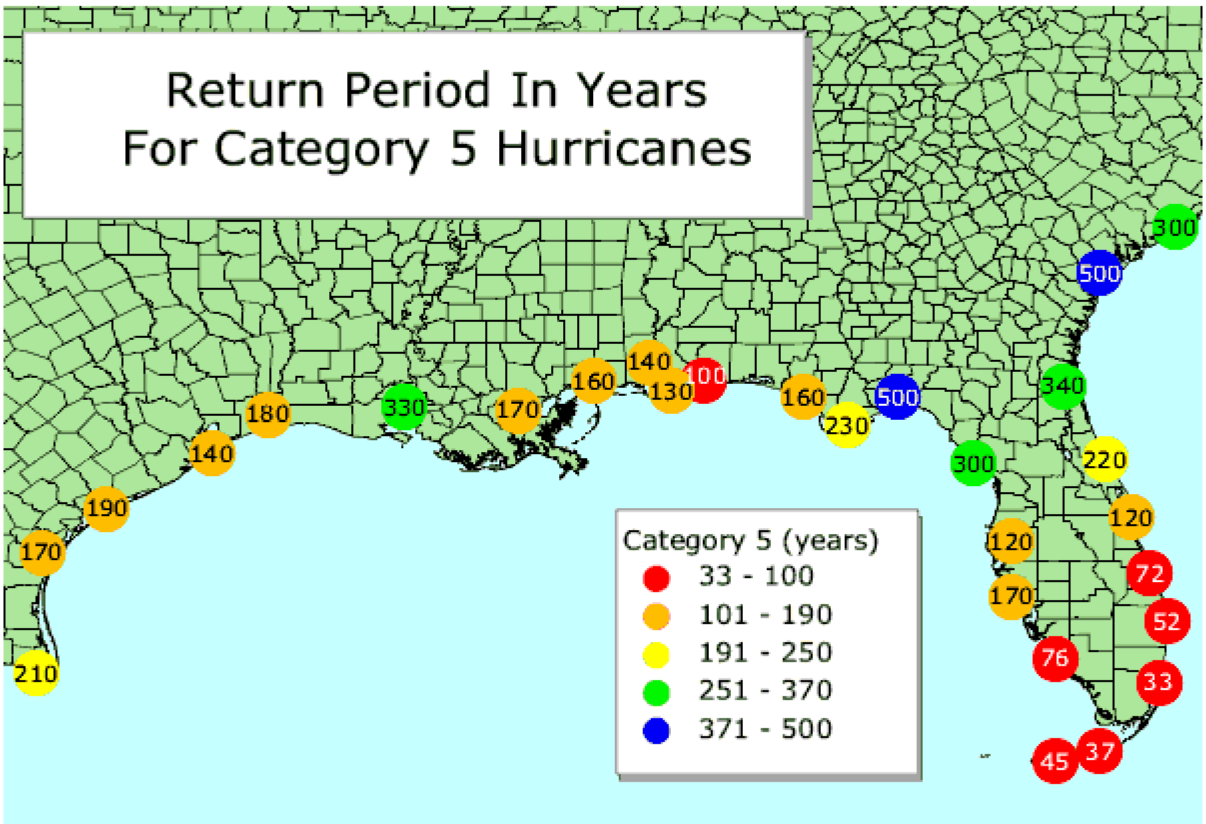


Fig. 13 NHC map of the Gulf Coast showing return periods for Category 5 hurricanes

Hurricane Preparedness – NHC/NOAA	
Type of map	Probabilistic
Parameters	Intensity (Saffir-Simpson scale)
Risk Boundaries	Exact return periods for 75nm areas
Information	None (available in other sections of NHC website)
Retrieval Method	Selectable by three areas of coast (Gulf, Southeast, Northeast)
Access	Link from NHC website
Coverage	✱✱✱✱✱ Covers all of East and Gulf coast but only at discrete points

Fig. 14 Summary table of Hurricane Preparedness – NHC/NOAA

2.6 Tsunamis

Tsunami Threat Map – Fire and Emergency Services Authority of Western Australia

A Probabilistic Tsunami Hazard Assessment for Western Australia Burbidge et al. (2008)[10] produced maps of maximum tsunami wave heights in Western Australia for various return periods. Whilst this paper is published in Pure and Applied Geophysics the results (maps) are available freely on the FESAWA website[11]. The entire report is linked from the publications section of the Geoscience Australia website[12].

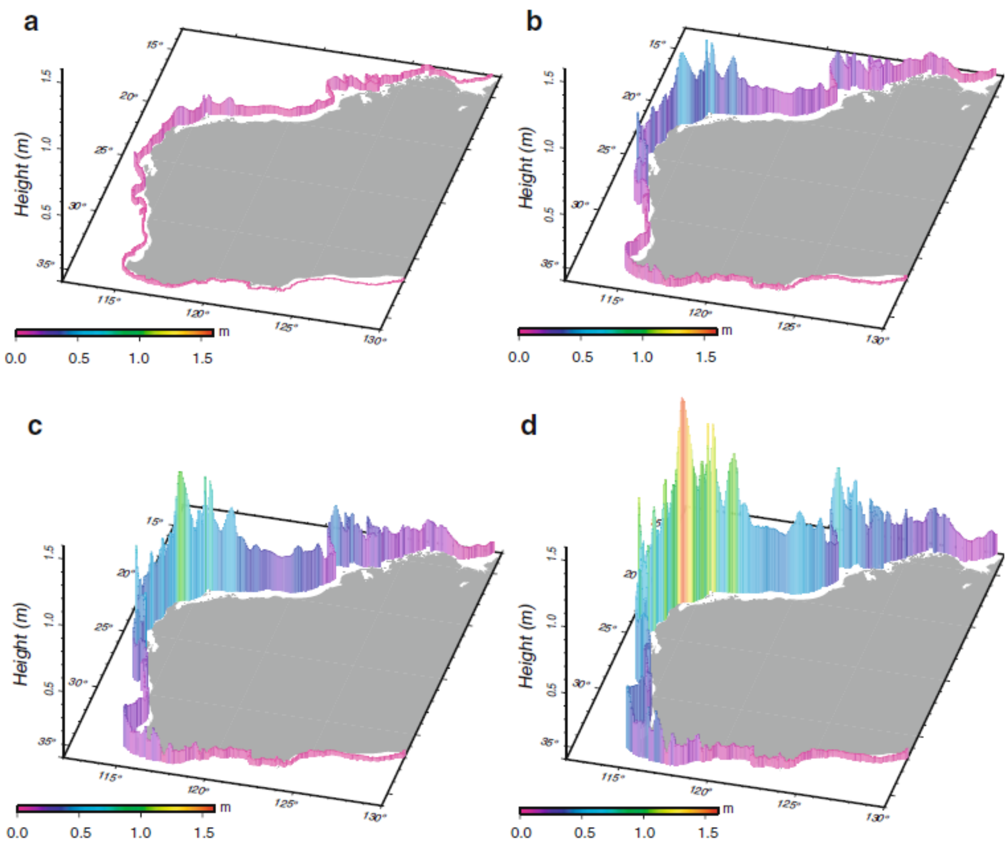


Fig. 15 Selection of return period maps for maximum wave heights along the WA coast a) 100 years, b) 500 years, c) 1000 years, d) 2000 years

Tsunami Threat Map – FESAWA	
Type of map	Probabilistic
Parameters	Wave height
Risk Boundaries	100/500/1000/2000 year RP
Information	None
Retrieval Method	Not searchable
Access	Map available on FESA website, full report linked from GA website
Coverage	✱✱✱✱✱ Covers entire area at risk from tsunamis

Fig. 16 Summary table of Tsunami Threat Map – FESAWA

Tsunami Hazard Map of the Elliot Bay Area – Washington Emergency Management Division

A comprehensive poster shows the various heights of inundation for a worst case local earthquake (magnitude 7.3) generated tsunami. A separate map gives the likely water velocity for the same event. Both water height and velocity are divided into easily understood categories; height is referenced anatomically and water velocity is divided at 1.5 m/s, the speed at which standing up would become difficult. 30 second snapshots of a tsunami inundation model give an excellent visual representation of how a wave would behave in the bay. The poster provides full transparency of the limitations of the map and model.

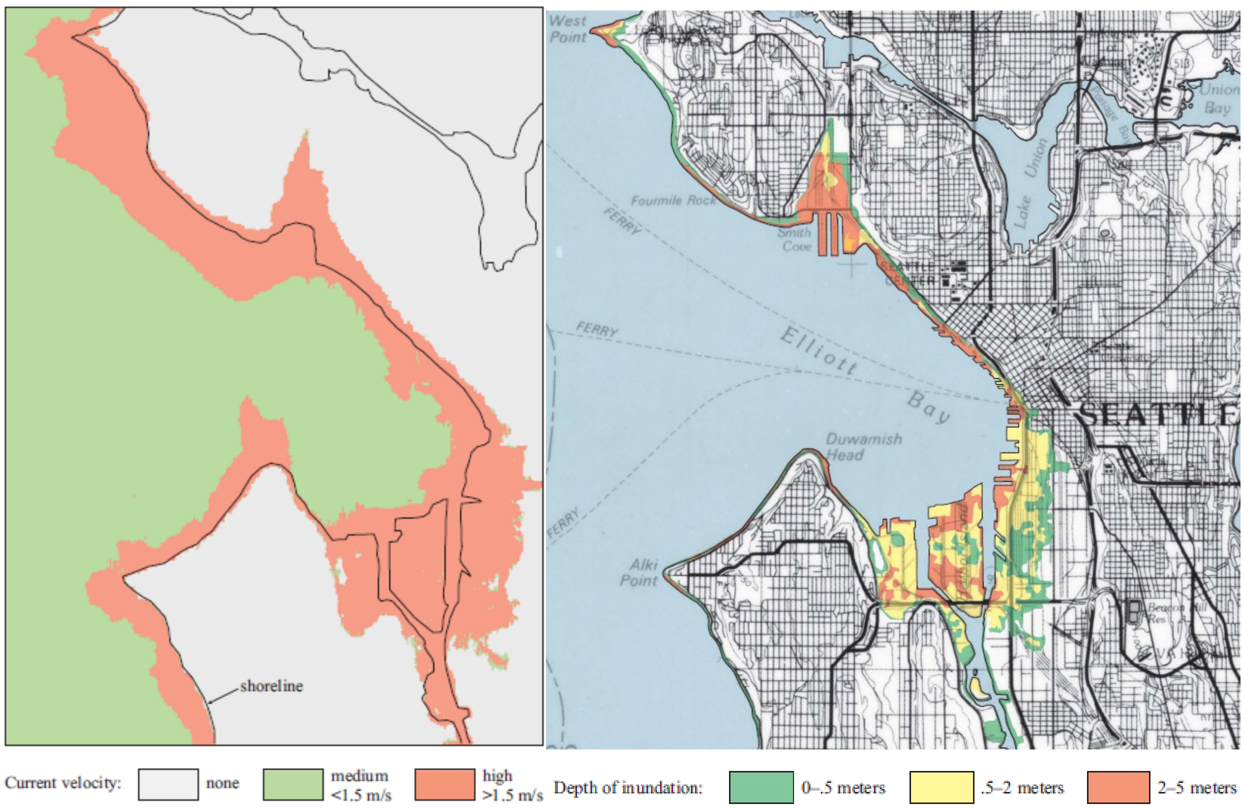


Fig. 17 Selection of hazard maps available on the tsunami poster for Elliot Bay Area, Washington

Tsunami Hazard Map – WEMD/NOAA	
Type of map	Worst case scenario
Parameters	**Inundation depth**, *velocity of water*
Risk Boundaries	**0-0.5/0.5-2/2-5 m depth**, *<1.5/>1.5 m/s velocity*
Information	Extensive info on production and limitations of map, but nothing else
Retrieval Method	Posters divided by coastal population area
Access	Map available on WEMD website
Coverage	✸ ✸ ✸ Only available at this level of detail for selected major populations

Fig. 18 Summary table of Tsunami Hazard Map – WEMD/NOAA

2.7 Volcanoes

Mt. Rainier Hazard Map – USGS

The USGS cascades volcano observatory site[13] has several hazard maps and information for active volcanoes in the Cascades range. The maps show areas which would be inundated by three lahar volumes each with different probabilities. These are separated into 500-1000 year, 100-500 year and 1-100 year return periods. Regions at risk from pyroclastic flows, surges, ballistics and lava flows are shown for a 100-1000 year return period. Whilst these boundaries are not as precise as would be ideal they represent the inherent uncertainties associated with volcanoes and their unpredictable activity.

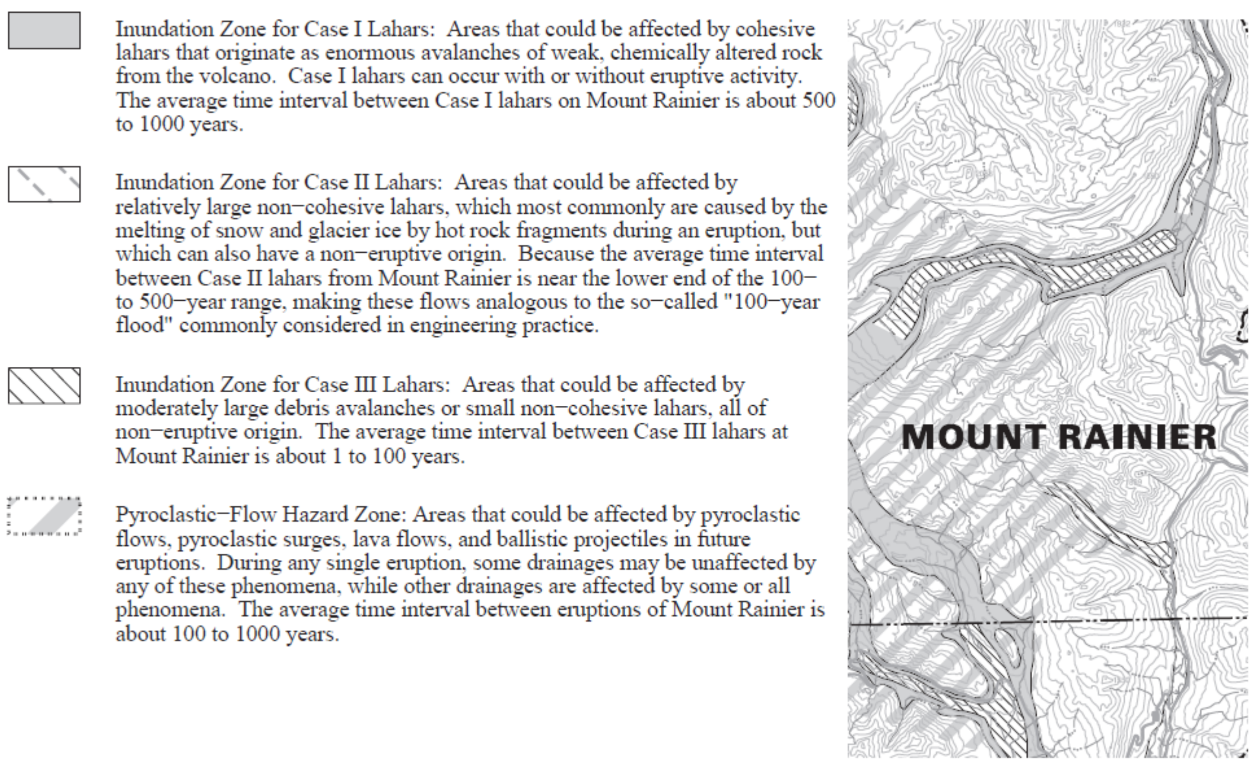


Fig. 19 Extract from hazard map for Mt. Rainier, Washington

Mt. Rainier Hazard Map – USGS	
Type of map	Probabilistic
Parameters	**Lahars**, all other volcanic hazards
Risk Boundaries	1-100/100-500/500-1000 year RP, *100-1000 year RP*
Information	None (available on other sections of USGS volcano site)
Retrieval Method	Viewed by volcano
Access	Easily located from main USGS hazards page
Coverage	✱✱✱ Detailed mapping only covers areas surrounding major volcanoes

Fig. 20 Summary table of Mt. Rainier Hazard Map – USGS

2.8 Examples of real time hazard mapping

Probabilistic Hurricane Storm Surge – NOAA/National Weather Service

This is an experimental product where the public may generate maps showing the probability of a storm surge of a certain height or the percentage surge exceedence heights online[14]. These maps only become available once a particular cyclonic event is in progress. Unfortunately they are not currently searchable by location, and the scale is fairly large. This low resolution reflects the inherent uncertainties of storm surge prediction.

Fig. 22 Summary table of Probabilistic Hurricane Storm Surge – NOAA/National Weather Service

2.9 Examples of evacuation mapping

Tsunami Hazard and Evacuation Map – Oregon Department of Geology and Mineral Industries

The Oregon DOGAMI website[15] provides a selection of tsunami evacuation maps for a worst case local and distant tsunami, with safe evacuation routes and assembly areas. Tsunami inundation maps for the height of wave produced by a magnitude 8.8 undersea earthquake are available from the same site, although these seem older. There is no information available on probabilities of tsunami inundation.

Fig. 21 Screenshot of an example storm surge risk map generated during Hurricane Katrina (2005) for the Central Gulf region

Probabilistic Hurricane Storm Surge – NOAA/National Weather Service	
Type of map	Probabilistic but only available during a tropical storm event
Parameters	Height of inundation
Risk Boundaries	May either be viewed as fixed probability of exceedence (2-25 feet) or fixed inundation height (10%-90% exceedence)
Information	None (available in other sections of NWS website)
Retrieval Method	Selectable by coastal region
Access	Available on National Hurricane Centre website during a storm
Coverage	✸✸✸✸✸ Covers all of East and Gulf coasts

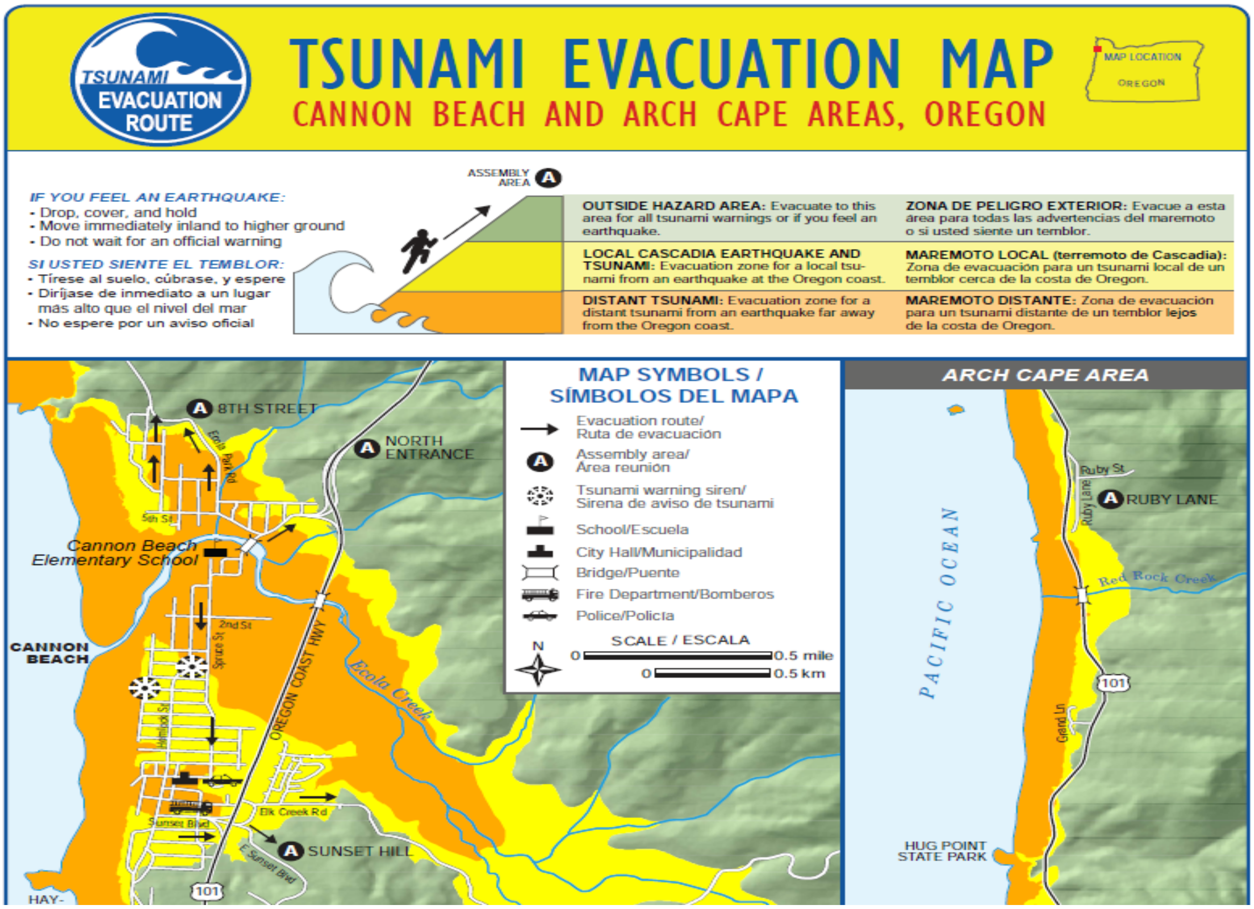


Fig. 23 Extract from the tsunami evacuation map for Cannon Beach and Arch Cape areas, Oregon

Tsunami Evacuation Map – Oregon DOGAMI	
Type of map	Evacuation zones based on worst case
Parameters	Hazard to life
Risk Boundaries	Distant/locally generated tsunamis
Information	Evacuation, preparedness and immediate response information
Retrieval Method	Posters divided by coastal population area
Access	Map available on Oregon state website
Coverage	✱✱✱✱ Covers all population centres along Oregon coastline

Fig. 24 Summary table of Tsunami Evacuation Map – Oregon DOGAMI

3. An inventory and survey of mapped hazard information in South-East Asia

For each hazard in each country the report has been structured in four sections, encompassing all facets of disaster mapping and risk management:

- **B:** Background information on the hazard in the country
- **M:** An inventory of the remotely available maps
- **P:** Ease of access and quality of information available to the public and any highlights of hazard education. This section also includes measures taken by governments and NGOs to mitigate the hazard.

- **F:** Availability and coverage of forecast information and provision of warnings, including the quality of reports for recent and in progress events.

The conclusions and summary tables at the end of each country's section concentrate on the state of hazard mapping and also provide an overview of disaster risk management, including mitigation and information. The maps for each hazard in Appendix 1 further summarise these tables to give each country a colour coded rating. A key to these tables and maps is provided below.

Country – Major Hazards				
Hazard	Map Type	Coverage	Damaging Agents	Boundaries
	Information/Reporting		Retrieval	Accessibility

Eq	Earthquake hazard
Fl	Flood hazard
Ls	Landslide hazard
Tr/Ss	Tropical storm and surge hazard
Ts	Tsunami hazard
Vo	Volcanic hazard

Excellent	Very difficult to improve
Good	Minor improvements possible
Average	Functional but some improvement possible
Poor	Significant improvement possible
✱✱✱✱	Approximate representation of area covered by hazard maps

3.1 Bangladesh: Earthquakes, Floods, Tropical Storms

Earthquakes

B: Bangladesh has a relatively high earthquake risk, but despite this online earthquake information appears to be limited. The Bangladesh Earthquake Society (a private organization mainly of civil engineers) conducted a study which suggested a major earthquake could destroy up to 30% of buildings in the heavily populated capital, Dhaka.

M: Global Seismic Hazard Assessment Programme (GSHAP) provides mapping for earthquake risk in Bangladesh; however there is no obvious link to the maps from any Bangladesh website. The Amateur Seismic Centre[16] has used GSHAP data to produce a more comprehensive earthquake risk map.

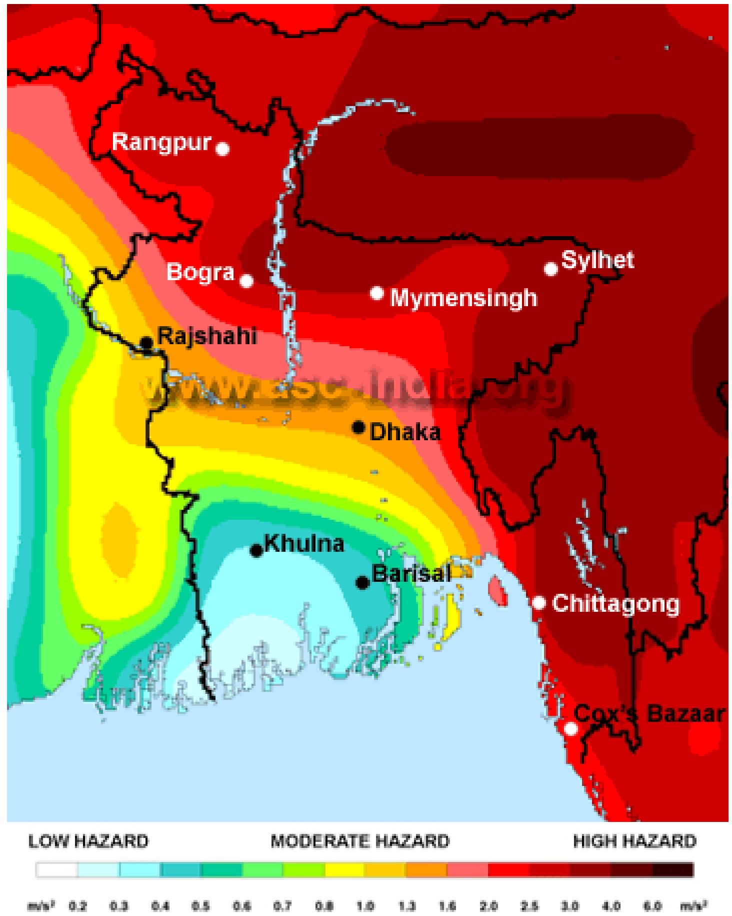


Fig. 25 ASC map of earthquake risk giving 475 year return period PGAs

P: A roundtable discussion was held in March 2008 to address the lack of earthquake preparedness in the country. Plans have been set out to significantly improve the capacity of hospitals, emergency services, blood banks and civil defence forces, to ensure that they can cope with catastrophic seismic events. A scheme has been scheduled to retrofit key buildings, such as schools and hospitals, to ensure they conform to the highest earthquake safety standards.

F: As with all earthquakes no forecasting is possible; however, up-to-date seismic event notifications are available on the Disaster Management Bureau[17] (DMB) website.

Floods

B: Monsoonal flooding in Bangladesh is essential to life; however, based on a number of factors, floods may extend over larger areas for long periods of time, causing substantial damage. On a 100 year return period inundation can be expected for over 60% of the country[18].

M: The Institute of Water Modelling[19] (IWM) has conducted extensive mapping of flood hazard in Bangladesh including 20 year return period flood heights and 100 year return period velocities for selected regions. They also produce a flood hazard map of Bangladesh giving each cell a combined vulnerability index which considers both flood depth and duration of flooding; these two parameters are also mapped separately. Unfortunately these maps do not appear to be available to the general public.

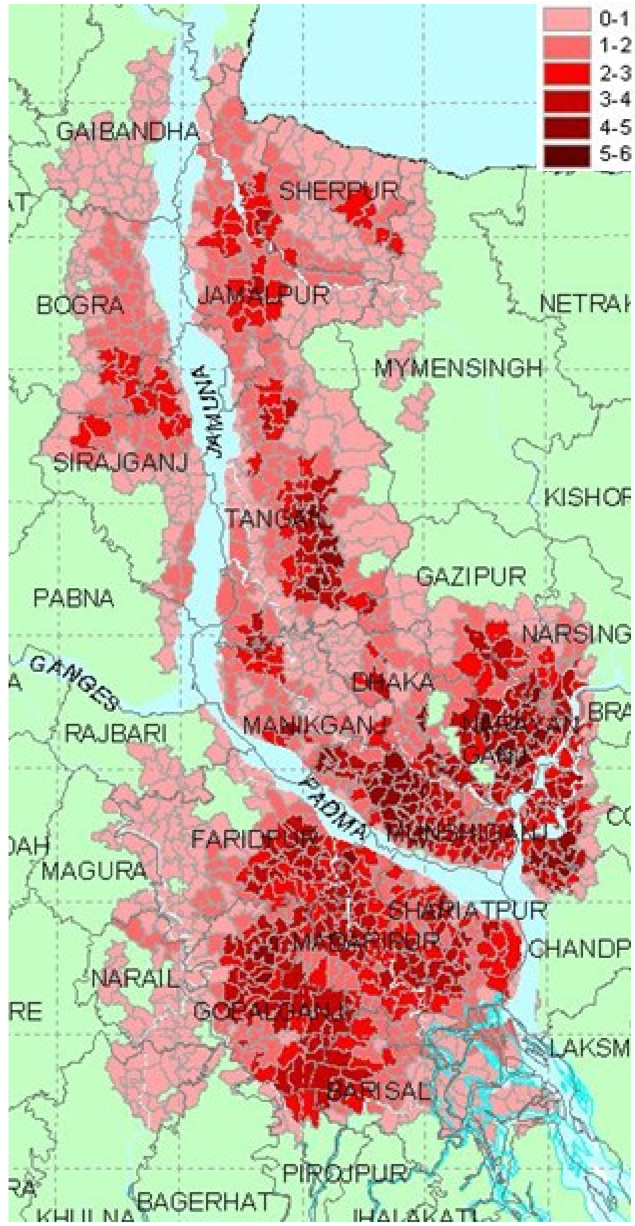


Fig. 26 IWM flood vulnerability map for the Chao Phraya river basin. Vulnerability index is shown in shades of red (see legend in top right corner).

P: High ground shelters have been built along with raised roads which act as levees. A joint effort from the Centre for Natural Resource Studies[20] (CNRS), CARE Bangladesh[21] (Cooperative for Assistance and Relief Everywhere) and the Swiss Agency for Development and Cooperation[22] (SDC) are ensuring that education and risk reduction are gradually reaching all areas of the country.

F: The Flood Forecasting and Warning Centre[23] (FFWC), in association with the Bangladesh Water Development Board, release daily online updates of areas flooded along with 24 and 48 hour forecasts. These inundation maps are at a fairly small scale and show height of flood water and elevation of surrounding terrain. They are easily available from the homepage which contains a large interactive map showing water levels at all river level stations. Flood warnings are also disseminated by fax (to local public buildings) and in the national and local media. Climate Forecast Applications in Bangladesh[24] (CFAB) is a consortium of both governmental and non-governmental organisations led by Georgia Tech University. They aim to provide short (1-10 days) to long-term (up to 6 months) forecasts both for rainfall and the probability of flood water exceeding a pre-determined "danger level". This information is then disseminated to the general population in the flood plains around the Ganges and Brahmaputra rivers, allowing for better agricultural planning and preparedness for disasters.

Tropical Storms and Storm Surges

B: The northern Indian Ocean frequently produces strong cyclonic events. When combined with a high tide storm surges up to 12m high have been recorded in the Bay of Bengal; given the high population density and low topography of Bangladesh these are clearly a great hazard. In the past 20 years tropical storms and their associated storm surges have caused upwards of 150,000 casualties in Bangladesh, making them the country's deadliest disaster.

M: The DMB provides a tropical storm risk map online. This does not include any numerical boundaries for risk; however it does give areas of high storm surge risk, storm surge risk and cyclonic wind risk. A EuropeAid case study[25] suggests that more detailed storm surge mapping has been undertaken; however this was not obviously available online.

P: Vulnerable populations have been provided with cyclone shelters, built to withstand strong winds on higher ground. In some regions sea walls have been raised and strengthened to provide better protection. There are also schemes being carried out as part of the Comprehensive Disaster Management Program[26] (CDMP) to raise awareness of storm surge hazard in low lying coastal areas.

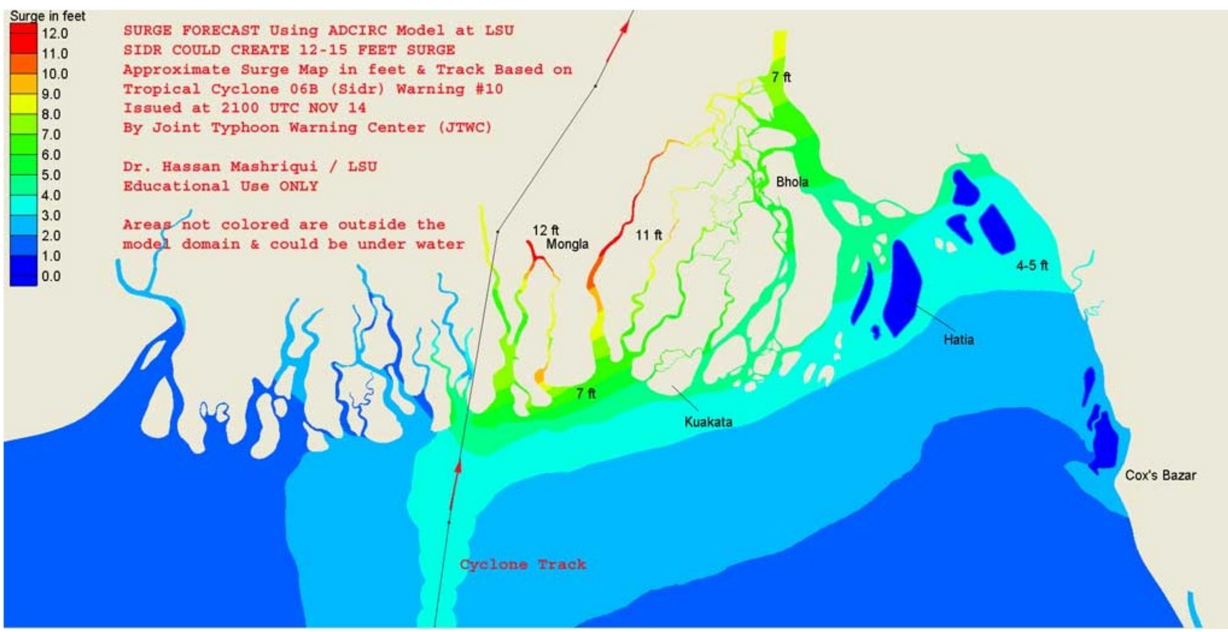


Fig. 27 Storm surge forecast for Cyclone Sidr created by the NOAA in association with the JTWC

F: The Bangladesh Meteorological Department[27] (BMD) issues storm warnings from their website which are relayed through national media to the general population. Up until 2007 very little existed by way of storm surge prediction and early warning. During Tropical Storm Sidr a chance series of events involving a Bangladeshi researcher for the NOAA based at Louisiana State University and the son of the head of the Ministry of Food and Disaster Management, a student at LSU, led to the development of *Experimental storm surge forecasting in the Bay of Bengal* Mashriqui et al. (2006)[28]. This utilised models already in place along the coast of Louisiana (a similar deltaic low lying coast) to successfully predict the likely storm surge from this category 5 tropical storm, allowing evacuation and significant reduction in casualty numbers compared to similar strength storms in the past (3,500 compared to 138,000+). Unfortunately this has yet to be developed into a fully fledged storm surge prediction model for the Bay of Bengal.

Conclusion

Floods are well considered and information is easily accessed; however no obvious risk maps are available online for future planning. The Bangladesh government through the FFWC needs to make probabilistic maps available to the general population. Tropical storm warning systems exist as do maps of storm surge and wind risk areas. Steps have been taken to reduce storm surge hazard. Whilst earthquake hazard reduction and disaster planning is not complete a thorough roadmap for future development has been developed. If this is followed then Bangladesh will have a very strong and comprehensive natural disaster management network.

Bangladesh – Eq, Fl, Tr/Ss				
Earthquakes	Probabilistic	✶✶✶✶✶	Shaking	475 year RP
	Local disaster action plans, road map for improvements		No search function	Less detailed version available on DBM website
Floods	Probabilistic	✶✶✶✶	Duration, depth	Combined vulnerability index
	Warnings and preparedness information		No search function	Not apparently available online
Tropical Storms Storm Surges	Probabilistic	✶✶✶✶✶	**Wind risk**, *storm surge*	**At risk**, high/med risk
	Warnings online, other information available to public but not online		No search function	Linked from DMB website

Fig. 28 Summary table of available hazard information in Bangladesh

3.2 Cambodia: Floods

Floods

B: A large proportion of Cambodia lies within the Mekong flood plain and is therefore vulnerable to flooding, particularly during the monsoon (May-Oct) when 80% of annual rainfall occurs.

M: The Mekong River Commission[29] (MRC) provides maps of maximum extent of floodwater from a combination of large historical floods. These maps are available to select by river station but can be zoomed out to cover 200km square areas (**see section 3.10** for an example of a map). The National Committee for Disaster Management (NCDM) has also produced a national map showing areas inundated by the extensive floods of 2000 and 2001.

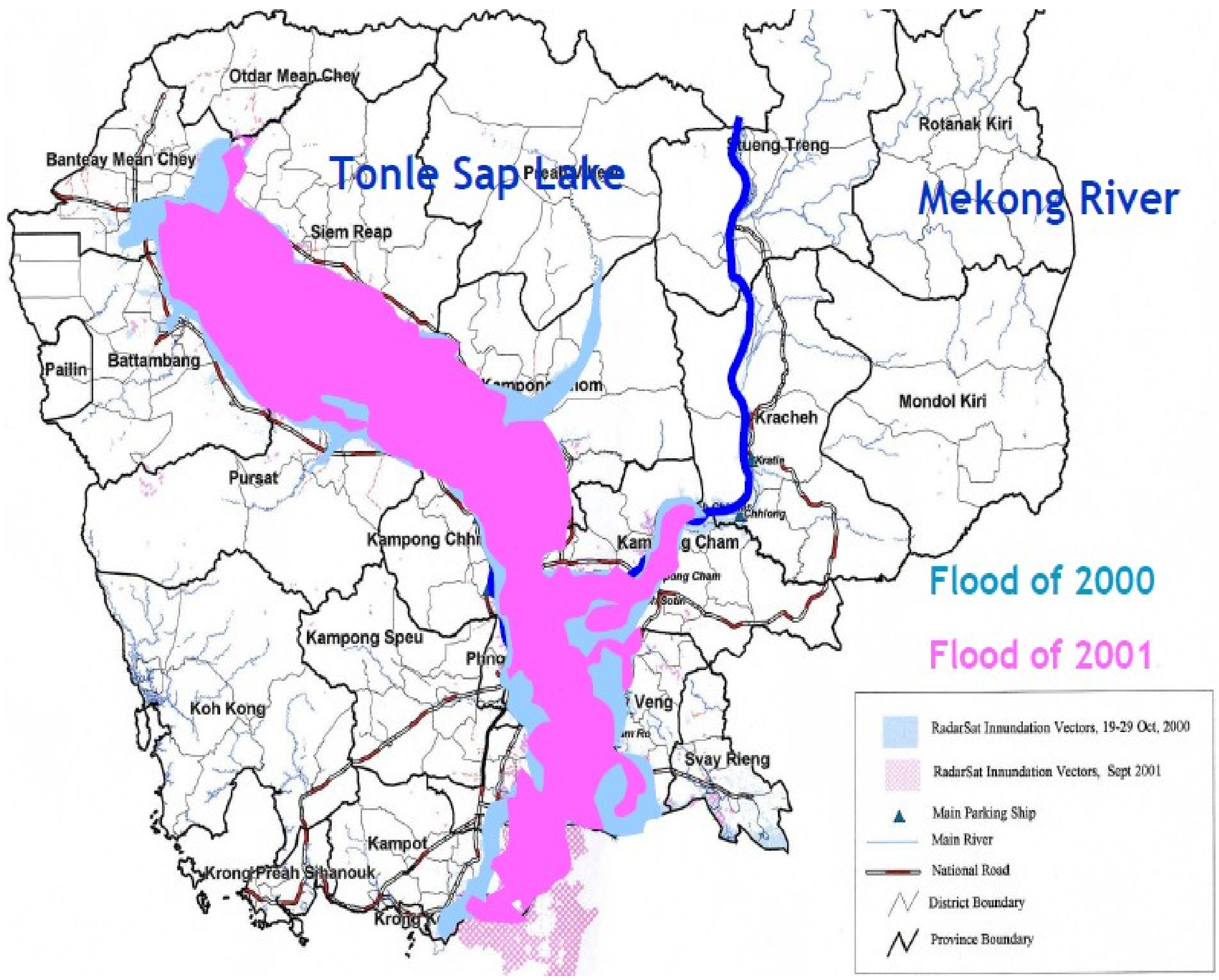


Fig. 29 NCDM map of maximum extent of 2000 and 2001 floods

P: The NCDM is responsible for coordinating hazard response and planning. The Cambodian Red Cross[30] (CRC) in collaboration with the NCDM have implemented the Community-based Disaster Preparedness Program which includes education of at risk communities and provision of elevated safe areas which livestock and populations can evacuate to. Some funding has been provided to raise houses and schools on pillars to prevent them being damaged during inundation. A well thought out scheme involves the distribution of dugout boats to families allowing transportation to continue during flooding, and enabling communities to recover much faster. Cambodia benefits from education and preparedness advice from the MRC.

F: Water level data for various river stations in Cambodia are provided by the MRC. Any stations with levels close to danger are highlighted, with warnings issued. Red Cross volunteers in each major village are trained to monitor river levels and report high water levels

Conclusion

The NCDM does not appear to have a functioning website. Online flood information is more easily available from the MRC and is relevant to most of the flood risk in Cambodia. The lack of online hazard information in Cambodia is somewhat less of a problem owing to the high quality of the MRC website. The NCDM report recommends the implementation of disaster planning acts and a national policy on disaster management. The availability of the MRC data should not be seen as removing the need for online availability of hazard information in Cambodia.

<table>
<tr><th colspan="5">Cambodia – Fl</th></tr>
<tr><td rowspan="2">Floods</td><td>Historical</td><td>✸✸✸✸</td><td>Maximum historic flood</td><td>At risk area</td></tr>
<tr><td colspan="2">Thorough warnings and preparedness info, along with forecast data</td><td>Selectable by river stations</td><td>Only available on MRC website</td></tr>
</table>

Fig. 30 Summary table of available hazard information in Cambodia

3.3 Indonesia: Earthquakes, Floods, Landslides, Tsunamis, Volcanoes

Earthquakes

B: Indonesia consists almost entirely of island arcs, raised out of the sea either by volcanic or tectonic activity. The entire region (with the exception of Borneo) is vulnerable to subduction related earthquakes.

M: Earthquake risk mapping exists from the USGS/GSHAP. Whilst the GSHAP map is not on a particularly large scale it can still be used for regional disaster planning, and covers all areas of the country. This map is linked from the Centre for Volcanology and Geological Disaster Mitigation[31] (PVMBG). The USGS have conducted a more detailed study of Sumatra, Java and Kalimantan, producing maps for 475 and 2500 year return periods of PGA, 5-Hz spectral and 1-Hz spectral; unfortunately, these do not presently include Irian Jaya and the islands east of Timor.

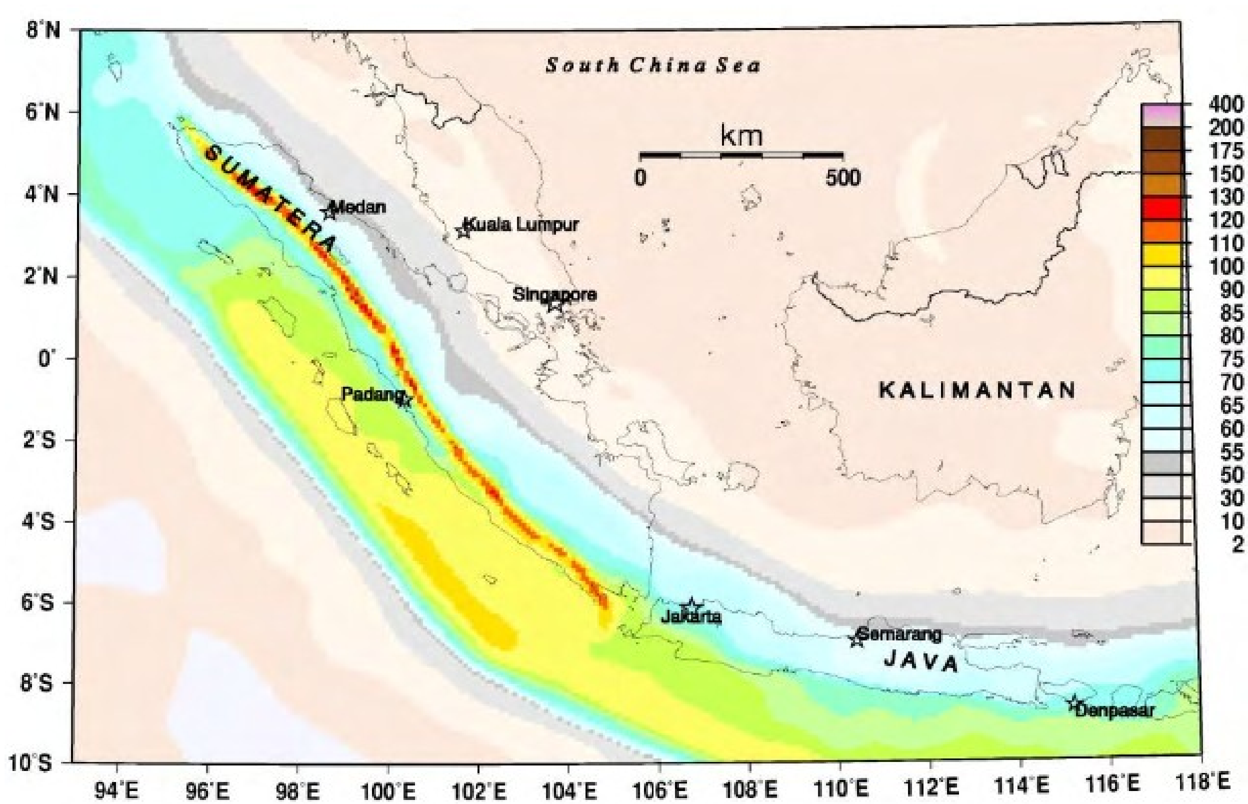


Fig. 31 USGS hazard map showing earthquake hazard as 5-Hz spectral acceleration with a 10% probable exceedence per 50 years (equivalent to a 475 year return period) as a % of gravity

P: The Agency of Meteorology, Climatology and Geophysics[32] (BMG) appears to be responsible for coordinating earthquake hazard mitigation. This website is well laid out with links to information on earthquakes and tsunamis. Earthquake proof building measures are being encouraged by authorities.

F: A real time updated map showing recent earthquakes is available on the BMG website. This gives details of seismic events and highlights any which have a high tsunami production risk.

Floods

B: In Indonesia heavy rain tends to cause two principal hazards, floods and landslides/mudslides. These heavy rains are often related to distant tropical storms.

M: Maps of flood prone areas are provided in an interactive product on the National Coordinating Agency for Surveys and Mapping website[33] (BAKOSURTANAL). Some of these maps also include landslide prone areas.

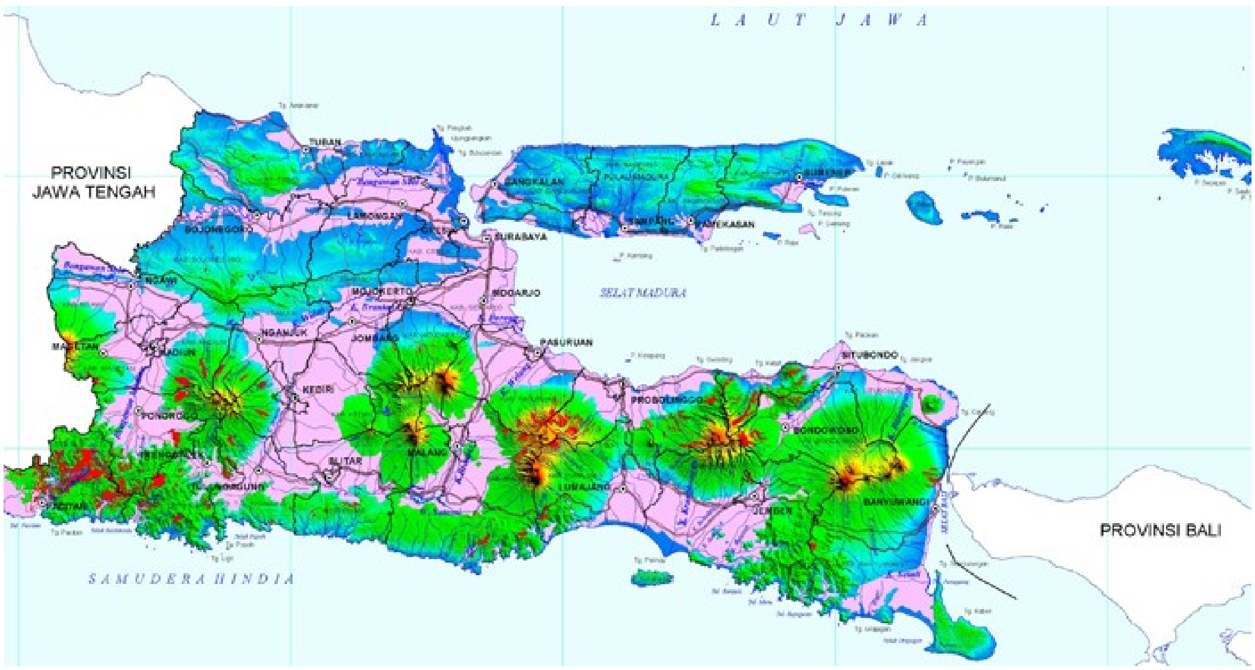


Fig. 32 Extract from BAKOSURTANAL multi hazard map of East Java. Elevation data is in greens and blues. Flood prone areas are in pink; landslide prone areas are in red

P: UNESCO[34], in association with the Centre for Community Agriculture, began a pilot scheme in 2003 to provide comprehensive flood education at all levels of the community; this includes awareness days and the production of information pamphlets, amongst other measures. Initially the scheme focussed on several urban areas of Jakarta; however, owing to its success, this has now expanded to cover a wider area. General information is available online via various websites including the BMG and the State Ministry of Research and Technology[35] (PIRBA).

F: Flood prediction and management is a joint operation between the BMG, the Directorate General of Water Resources and the Department of Public Works. The BMG provide flood risk maps by area for up to 2 months in advance. These show safe areas and those with low/medium/high risk. Flood warnings are issued by the BMG both on their website and through local media.

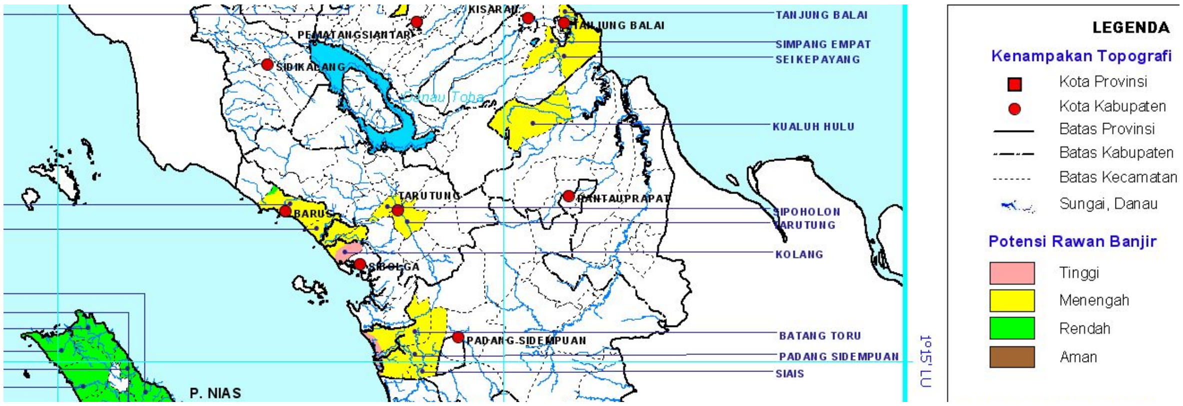


Fig. 33 Extract from a BMG flood hazard forecast map for North Sumatra

Landslides

B: The high rainfall, combined with steep sided volcanic terrain and frequent seismic activity, make landslides a regular occurrence in Indonesia. Every year landslides cause several hundred casualties and the destruction of large areas resulting in substantial financial losses.

M: The PVMBG website provides links to some of the better landslide risk maps available anywhere in the world. Every island has detailed maps showing landslide risk zones. Data may be available for the probabilities used for these boundaries; however, they could not be found.

Fig. 34 Extract from the PVMBG landslide hazard map for Bengkulu Province on the island of Sumatra

P: The PVMBG website has useful information about landslides and how to prepare for them, including extracts from the USGS guide to landslide preparedness. They also offer downloads of reports from recent disasters.

F: Landslides in themselves are not forecast; however, the BMG does provide rainfall level forecasts which can be used by those in landslide risk zones to determine their likely level of hazard. Various disaster management bureaus report on landslide events.

Tsunamis

B: Like much of maritime South-East Asia, Indonesia was caught by surprise and devastated by the Boxing Day Tsunami of 2004. Indonesia, and particularly the Banda Aceh region, suffered by far the most damage with estimates for casualties ranging between 100,000 and 150,000 with financial losses totalling $4.5 billion.

M: The BMG produce a map showing the coastlines which are at risk from tsunamis; there is no quantification of this risk. This map also does not show how far in land tsunamis are likely to inundate. The German Centre for Satellite Based Crisis Information[36] (CSBCI) has mapped the areas damaged by the 2004 tsunami and whilst these are historical, they can, as the event was so large, be assumed to approximately represent a worst case scenario. These maps cover the north and western coasts of Sumatra, which were worst hit.

Fig. 35 Extract from the CSBCI map of Banda Aceh, NW Sumatra showing areas damaged in red hatching and areas of settlement as green

P: The Tsunami Alert Community[37] (KOGAMI) is a local non-profit organization dedicated to improving education and preparedness in communities which are threatened by earthquakes and tsunamis. In collaboration with the government they run "National Exhibitions of Disaster Preparedness" which tour the major cities of the various islands, providing information and practical training on how to prepare for, and survive, a disaster. The Jakarta Tsunami Information Centre[38] (JTIC) has a lot of information on tsunamis and how to prepare for them.

F: The BMG provides tsunami warnings and also shows any earthquakes which may produce tsunamis. Internationally the International Ocean Tsunami Warning System (IOTWS) (see section **3.10**) has a network of warning stations and DART buoys which provide early warning to governments and local authorities in Indian Ocean countries.

Volcanoes

B: Indonesia has more active volcanoes than any other country owing to its close proximity to a major subduction zone; many of the Indonesian islands are threatened by eruptions. Tambora (1815) and Krakatoa (1888) were two of the largest global eruptions in recorded history. Sidoarjo is the largest mud volcano in the world, and has been erupting since 2006, displacing upwards of 24,000 people and causing 20 casualties.

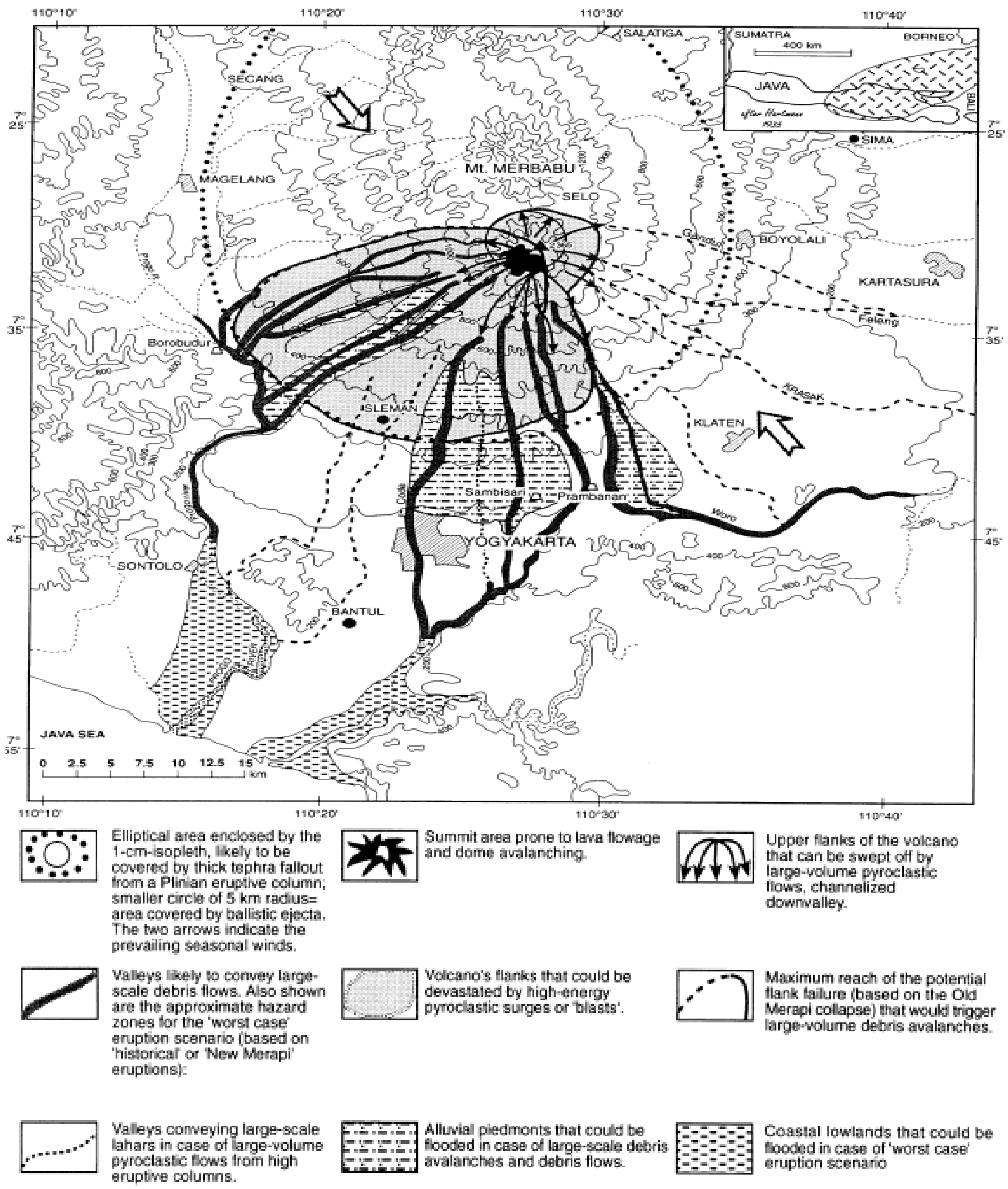


Fig. 36 Hazard map for "worst case" sub-plinian VEI 4 eruption at Mt. Merabi. Mt. Merabu also seen in the map is a neighbouring inactive volcano

M: The USGS provides a map of major volcanoes in Indonesia which have erupted in the past 100 years although this does not show any hazard maps for individual volcanoes. The actively erupting Mt. Merabi (also Merabu/Merapi/Marapi) in Central Java threatens the major city of Yogyakarta and its 3 million residents, and as such has been identified as one of the IAVECEI[39] "decade volcanoes". Independent research papers, notably *Toward a revised hazard assessment at Merapi volcano, Central Java* by Thouret et al. (2000)[40], have extensively studied volcanic hazards threatening Yogyakarta and the surrounding areas. Hazard zones are based on physical parameters (such as volume flux) rather than probabilities, although it is suggested that a large explosive eruption will occur on average once a century (100 year return period). Detailed mapping of lahar hazard zones based on volume flux has been carried out, as has some mapping of dome collapse pyroclastic flows.

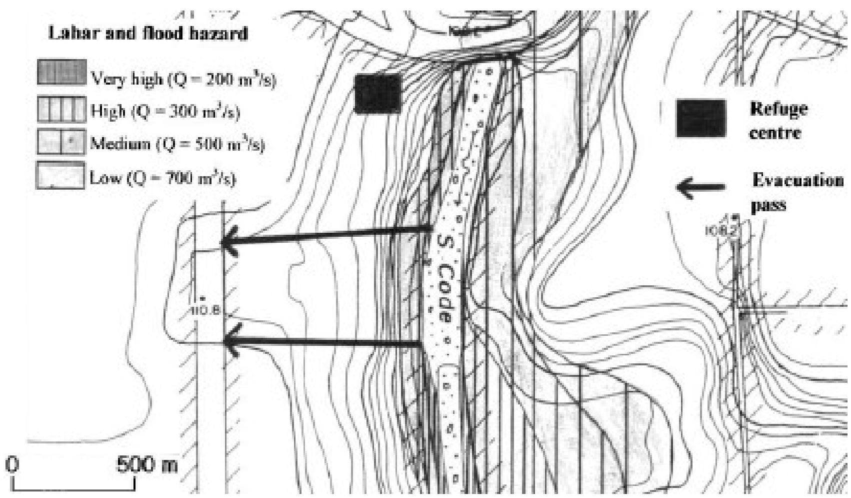


Fig. 37 Extract from a lahar risk map for urban Yogyakarta. Lahar/flood hazard is given by the volume flux required for inundation

P: The PVMBG website has general preparedness information and a very detailed explanation of the various hazards that are produced from different types of volcanoes. Each major volcano has several pages of information available on its geology, hazards and the demographics of surrounding populations.

F: The PVMBG homepage has a traffic light alert system for many Indonesian volcanoes. These flash for those which are considered at highest risk. All major eruptions are also reported.

Conclusion

Because of language difficulties it is likely that resources exist online which are not reported. Landslide and flood risk are well mapped, as these are frequent perils. Tsunami mapping does not appear to be available online other than a simple map of at risk coasts; however, along with the IOTWS, warning and education seem to be of a good standard. Online earthquake hazard mapping is limited to what is available globally (GSHAP, USGS etc.); however the reporting of earthquakes is efficiently carried out by the BMG map which is frequently updated. The main focus of future risk management needs to be in making available hazard maps for the major volcanoes which threaten populations. Even though some of these exist in papers they do not appear to be available online.

Indonesia – Eq, Fl, Ls, Ts, Vo				
Earthquakes	Probabilistic	✸✸✸✸	Ground shaking	475/2500 year RP
	Well reported on the BMG website, some information on hazards		No search function	Linked from the PVMBG website. More detailed map from USGS
Floods	Probabilistic	✸✸✸✸	Flooding	Prone areas
	Forecast for up to 2 months and information on hazards		Selectable by area	Maps available on BAKOSURTANAL website
Landslides	Probabilistic	✸✸✸✸	Landslide	High/Medium/Low risk
	Plenty of information available on PVMBG website		Selectable by area	Linked from the PVMBG website
Tsunamis	Historical	✸✸	Damaged area	-
	Preparedness road shows/online information and early warning		Selectable by area	Not directly available on Indonesian websites
Volcanoes	Worst Case	✸	Debris avalanches, pyroclastic flows, lateral blasts, tephra, *lahars*	**Worst case limits,** 200/300/500/700 m^3/s volume flux
	Hazard levels and information for major volcanoes is on PVMBG.		PVMBG information selectable by volcano	PVMBG information easily available. Detailed Merabi map in a paper.

Fig. 38 Summary table of available hazard information in Indonesia

3.4 Lao PDR: Floods

Floods

B: The majority of Laotians live below or on the poverty line in rural communities set within the Mekong basin. In a similar way to Cambodia almost all flood risk comes from overflowing of the Mekong River.

M: Historical maps are provided by the MRC website for many river stations within Lao PDR (see **3.10** for example map). United Nations Operational Satellite Applications[41] (UNOSAT) has carried out satellite mapping for maximum extent of waters during major flooding in 2008, although these only seem to be available for limited areas of the country.

P: The MRC in partnership with the Lao PDR government and the European Commission Humanitarian Aid Office[42] (ECHO) provides training to local officials and communities and helps to strengthen flood emergency management strategy.

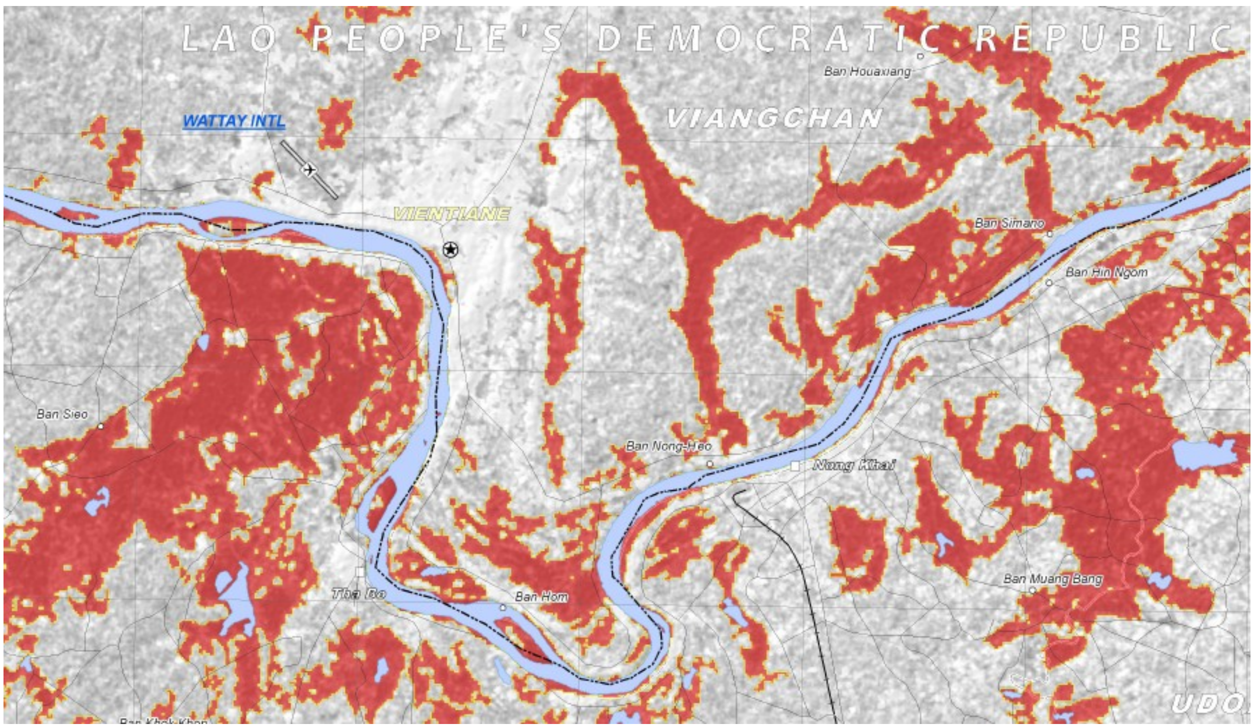


Fig. 39 UNOSAT map of flooding during 2008 in the Vientiane area of Lao PDR

F: The Department of Meteorology and Hydrology[43] (DMH) uses data from the MRC to provide forecast and current water levels for the Mekong River and its own stations on Mekong tributaries to provide local observed water levels. For all of these stations a warning level and danger level are provided. The front page of the DMH also shows any current flood warnings along with local weather forecasts.

Conclusion

Like all other countries covered by the MRC, Lao PDR has a comprehensive resource for flood planning. The government has improved on this data by also adding their own information for major tributaries. In 1997 the National Disaster Management Office was set up to form disaster management policies and coordinate government departments within Lao PDR. They have produced a comprehensive action plan to be completed by 2020, including provision of area risk maps for disaster planning, and real progress appears to be being made.

Lao PDR – Fl				
	Historical	✶✶✶✶	Maximum historic flood	At risk area
Floods	Thorough warnings and preparedness info, along with forecast data		Selectable by river stations	DMH website provides MRC and local data

Fig. 40 Summary table of available hazard information in Lao PDR

3.5 Malaysia: Floods

Floods

B: Malaysian floods tend to be caused by the remnants of tropical storms which have crossed the coastlines of Vietnam and the Philippines. Extensive urban development has narrowed many rivers and removed natural flood plains; this results in a higher risk of flash flooding particularly in built up areas.

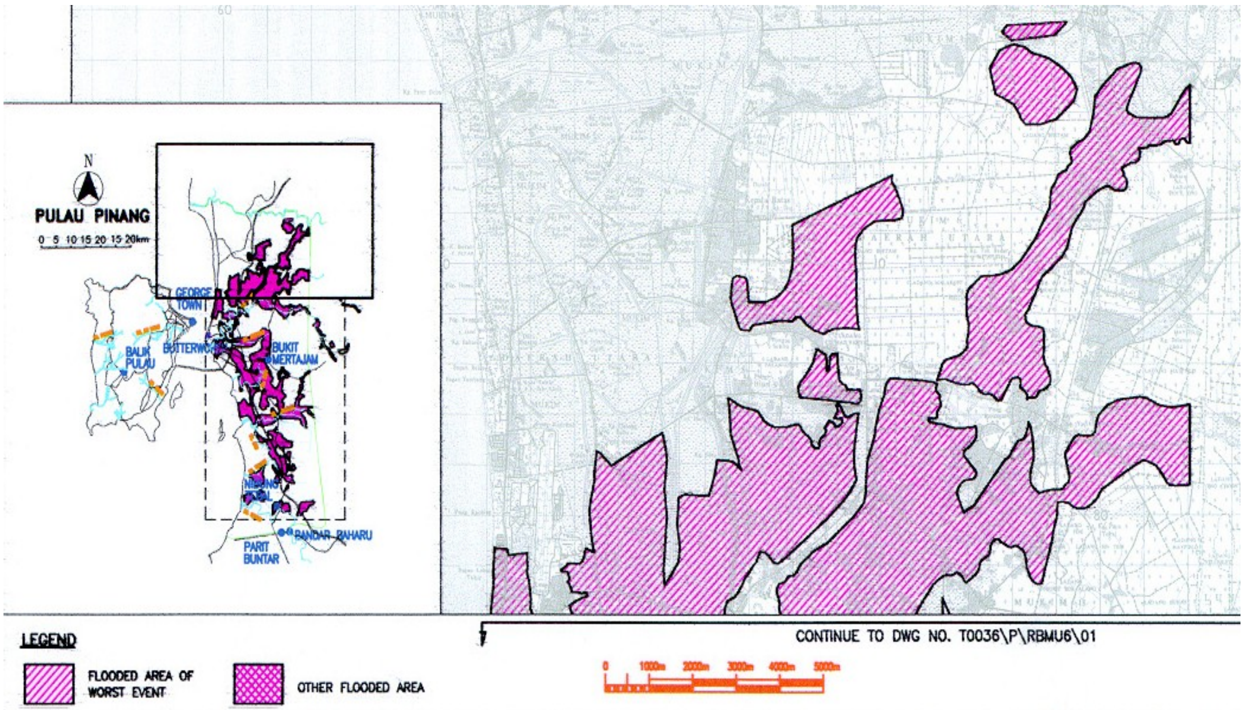


Fig. 41 Extract from the flood hazard map for Pulau Pinang RBMU produced by the DID

M: The Department of Irrigation and Drainage[44] (DID) is responsible for flood management. Flood planning responsibility is divided into River Basin Management Units (RBMU). Each RBMU has a flood hazard map for their area; these appear to be based simply on maximum historical flood data and not on any probabilistic model, but are very detailed. They are not available online to the public although they may be available locally. The extract above is from an example map provided on an online press release.

P: Information on preparedness and flood warnings are coordinated by the unified Malaysian Emergency Services website[45] (MES). This is very extensive and includes suggested emergency ration packs to prepare before an event and details of evacuation shelters.

F: In a very similar style to the MRC website (see section **3.10**) the DID provide information for water levels along with warning and danger boundaries for a wide selection of river stations. This data may either be viewed in a table or as cross sections of the river basin. Additionally real time updated webcams of selected river stations in the system allow viewing of current river conditions. Flood warnings are delivered on both the MES and DID websites. Members of the public may sign up to RSS feeds and SMS updates for real time flood risk warnings.

Conclusion

Warnings and information on water levels are easily available in multiple clear formats. Extensive reports have been produced giving details of historical flood data and the measures taken to mitigate flood hazard in each RBMU. The example hazard maps available seem of a very high standard; however these should be available online to the public and would benefit from some element of probabilistic modelling.

Malaysia – Fl				
Floods	Historical	✸✸✸✸	Maximum historic flood	At risk area
	Good information and warnings available		Selectable by regional map plate	Only a few example areas available

Fig. 42 Summary table of available hazard information in Malaysia

3.6 Myanmar: Earthquakes, Floods, Tropical Storms, Tsunamis

Earthquakes

B: Several faults run across Myanmar giving a high to very high risk of earthquakes in most inland sections but particularly in the north-west. In the past century 10-15 large (Magnitude > 7) earthquakes have hit the country.

M: A basic hazard map is available from GSHAP and boundaries are divided based on 475 year exceedence PGAs. The ASC have used GSHAP data to produce a more detailed map. Neither of these maps is easily available from any Myanmar websites. The Myanmar Geosciences Society has future plans to revise all geological mapping, including seismic risk, and make these available online but no timeline was available for this.

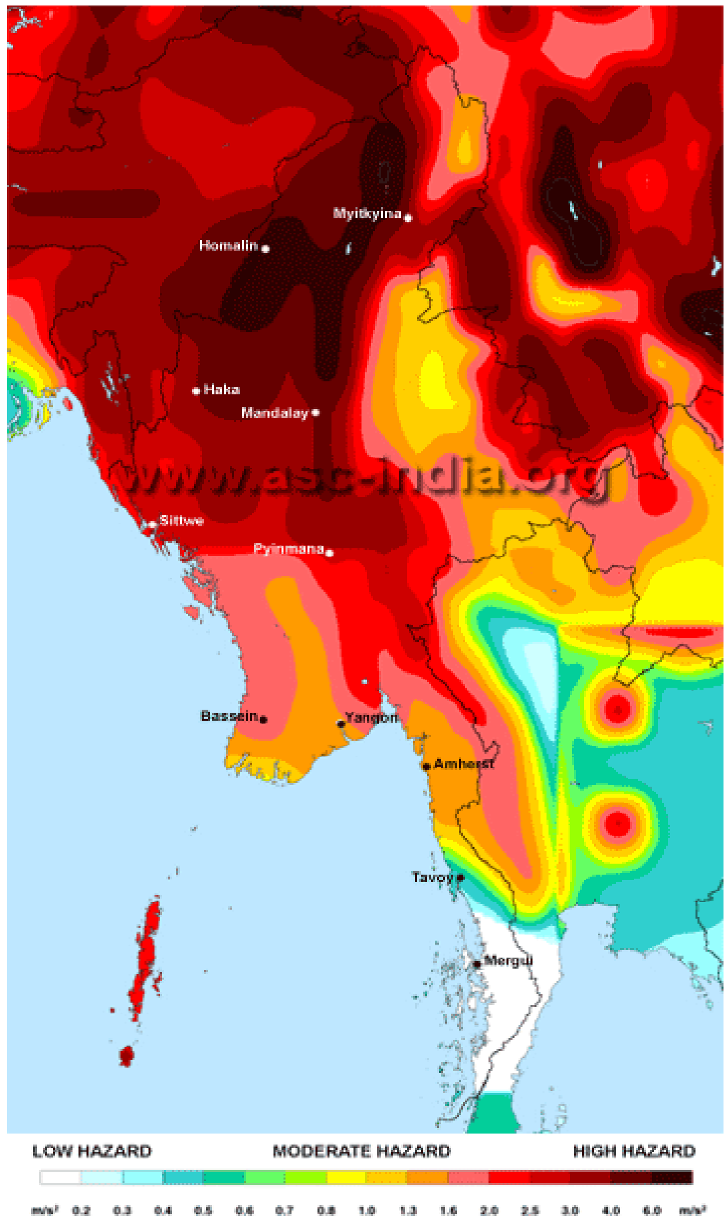


Fig. 43 ASC map for Myanmar showing PGAs with 475 year exceedence based on GSHAP data

P: Whilst there are options on the Department of Meteorology and Hydrology[46] (DMH) website to select public education information on a variety of hazards the links do not seem to function.

F: The DMH is responsible for earthquake warnings and publishes reports on any significant seismic activity on its website.

Floods

B: Much of the population of Myanmar is concentrated in the low lying Irrawaddy (also Ayeyarwady) river basin and delta. In 2007 substantial monsoonal flooding left thousands homeless; however, no accurate figures are available for casualties.

M: It would appear that mapping has been carried out by the Water Research and Training Centre[47] (WRTC); however, these maps do not seem to be available online and several emails received no response.

P: The Myanmar Red Cross[48] (MRCS) is actively involved (along with other international branches of the Red Cross) in implementing community based disaster risk reduction and management schemes.

F: Flood warnings are provided by the DMH website and are easily accessed although they seem to be several months out of date; however this may simply be because there has been no risk of flooding since March, although this is not clear.

Tropical Storms and Storm Surges

B: The threat to Myanmar from tropical storms is similar to that in Bangladesh. Populations are mainly concentrated in low lying river deltas which are particularly vulnerable to storm surges. Most recently Cyclone Nargis in May 2008 caused about 100,000 casualties and estimated losses of $4-6 billion.

M: No mapping of storm surge or wind risk seems to be available.

P: The MRCS undertakes the same program of education and mitigation for tropical storm threats as it does for floods.

F: The DMH appears to be responsible for all hazards in Myanmar; however there is no translation of the website available. They provide warnings of storms in progress over the Bay and the threat of them developing into tropical storms. Some forecast modelling has been carried out by Mashriqui et al. in *Experimental storm surge forecasting in the Bay of Bengal*[28] but this has not been taken any further, and mainly focused on risk to Bangladesh.

Tsunamis

Only a very small region of Myanmar coastline is exposed to tsunami risk, and during the 2004 tsunami very little damage was caused. It is not included in the IOTWS program (see section **3.10**), and the government does not appear to have any form of mapping or acknowledgement of tsunami risk.

Conclusion

There appears to be very little available online in terms of mapped hazard data, except for globally mapped earthquake maps. Substantial improvements in hazard planning and mapping should be a national priority.

Myanmar – Eq, Fl, Tr/Ss, Ts				
Earthquakes	Probabilistic	✱✱✱✱✱	Ground shaking	475 year RP
	Reports of significant seismic activity on DMH website. No information		No search function	Not linked from any Myanmar government website
Floods	None	-	-	-
	DMH provides flood warnings.		-	Information links on DMH website do not function
Tropical Storm Storm Surge	None	-	-	-
	DMH provides tropical storm and storm surge warnings.		-	Information links on DMH website do not function
Tsunami	None	-	-	-
	None		-	None

Fig. 44 Summary table of available hazard information in Myanmar

3.7 Philippines: Earthquakes, Floods, Landslides, Tropical Storms, Tsunamis, Volcanoes

Earthquakes

B: Similar to Indonesia, the Philippines lies on the Pacific "Ring of Fire", in a seismically unstable area with many subduction zones. This leads to a high incidence of earthquakes in the region, caused both by tectonic and volcanic activity.

M: National Disaster Coordinating Council[49] (NDCC) maps show more detailed hazard maps of earthquake damaging agents split in to; rupture, liquefaction, earthquake induced landslides and ground shaking. These are on a provincial scale and of the same format as maps for other hazards in the Philippines. On a national scale earthquake risk mapping is provided by GSHAP for 475 year exceedence peak ground accelerations (PGAs).

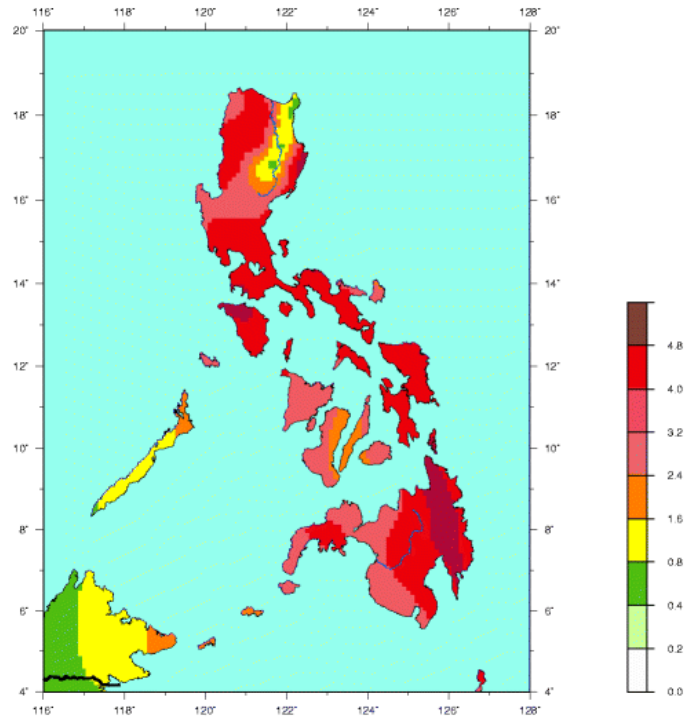


Fig. 45 GSHAP map for the Philippines showing PGAs with 475 year exceedence

P: The "Be Better, Build Better" scheme, run by the NDCC in conjunction with private sector companies, promotes hazard proof building standards in all buildings, but particularly large public properties (such as schools, hospitals etc.)

F: The Office of Civil Defence[50] (OCD) provides earthquake warnings and information on recent events as does the Philippine Institute of Volcanology and Seismology[51] (PIVS).

Floods

B: Frequent tropical storms in the Philippines are usually responsible for extremely heavy rainfall and these frequently cause flooding and landslides. As many parts of the islands are mountainous, flash floods caused by rainfall high up in the hills are also a substantial hazard.

M: Like other hazard maps, flood zones are published for various provinces on the NDCC website as part of Project Ready. Unfortunately, as high resolution copies of these maps were not available it is difficult to assess their quality.

P: The Philippines Red Cross[52] (PRC) provides training in disaster management with courses aimed at local officials and the general public. The "Be Better, Build Better" scheme, aims to ensure that all major public buildings are resistant to natural hazards. The NDCC aims to introduce natural hazard and disaster information into all levels of education.

F: Flood warnings are available on the ODC website. The Philippines Atmospheric, Geophysical and Astronomical Services Administration[53] (PAGASA) makes forecast data available for stations in major river basins.

Landslides

B: Tropical storms in the Philippines are usually responsible for extremely heavy rainfall and these frequently cause flooding and landslides. Earthquakes caused by volcanoes or fault movement may also trigger landslides, particularly on saturated ground.

M: The NDCC maps separate earth movement hazards into rain-induced and earthquake-induced, giving different areas of risk for both. These are available online as part of Project Ready. Unfortunately, as high resolution copies of these maps were not available it is difficult to assess their quality.

P: As with floods the PRC and NDCC are aiming to educate people at all levels, from local officials through to school age children. No mention of schemes to improve slope stability was found online; however this does not mean that they do not exist.

F: Landslides cannot effectively be forecast; however, PAGASA provides heavy rainfall warnings, which would indicate a risk to those in the vicinity of unstable slopes.

Tropical Storms and Storm Surges

B: The Philippines lies in the path of a very productive region for tropical storms. Most storms which form in the Western Pacific basin pass over either Taiwan or the Philippines on their way to making landfall in mainland Asia. 5-10 tropical storms a year make landfall somewhere along the Philippines 37,000km coastline (the longest in the world). Recently Tropical Storm Fengshen in June 2008 caused some 1400 casualties (including 800 on a capsized ferry) and an estimated $200million of losses.

M: The NDCC website provides storm surge maps as part of Project Ready. Unfortunately, as high resolution copies of these maps were not available it is difficult to assess their quality.

P: Divided by province, Typhoon2000[54] (MAYBAGYO) is a nongovernmental website which provides information to the general public including tropical storm tracking, historical data and any dangerous weather warnings. The Special Tropical Weather Disturbance Reconnaissance, Information Dissemination and Damage Evaluation (STRIDE) team aim to rapidly respond to damage caused by tropical storms, and assist in mitigation.

F: Both the OCD and the NDCC provide official warnings online for tropical storms and associated storm surges.

Tsunamis

B: With such a long distance of coastline and an isolated location with little between the east coast and Central America, Pacific tsunamis are a major hazard. The last major tsunami occurred in 1976 and caused some 5,000 casualties and an estimated $120million in damage.

M: NDCC maps show areas at threat from tsunami inundation. These are available online as part of Project Ready. Unfortunately, as high resolution copies of these maps were not available it is difficult to assess their quality.

F: Along with earthquake warnings the OCD website releases tsunami warnings, directly linked from the NOAA Pacific Tsunami Warning Centre[55] (PTWC).

Volcanoes

B: Being located on the Pacific "Ring of Fire" the Philippines has many active volcanoes, several of which threaten substantial populations. The 1991 eruption of Mt. Pinatubo was the second largest eruption of the 20th century and caused 880 casualties and an estimated $750 million of damage, along with global climate change.

M: NDCC maps include generalised volcanic risk, when the province contains a threatening volcano. The PIVS provides individual hazard maps for the largest and most threatening volcanoes. These maps are for all volcanic hazards; ashfall, pyroclastic flows, lava flows and lahars. Whilst they are fairly detailed they do not provide any boundaries for risk levels, instead they are either given as areas with vulnerability during medium sized eruptions (dashed red line) for pyroclastic and lava flows or low (beige), medium (purple) and high (red) risk levels for lahars and ashfall.

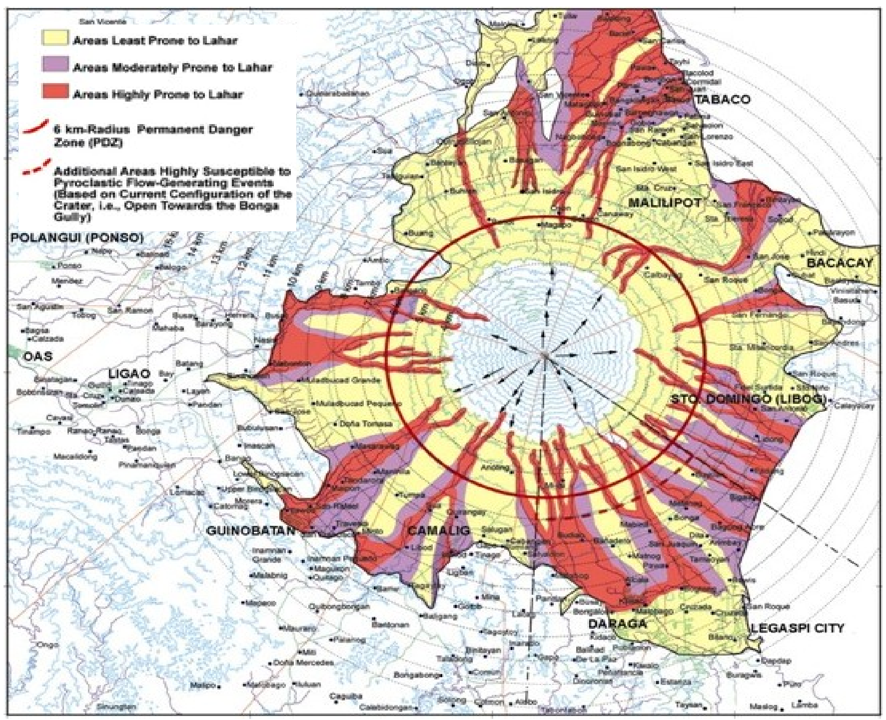


Fig. 46 Lahar hazard map from PIVS for the Mayon Volcano, Philippines

P: The PIVS give an online explanation of the principal volcanic hazards and how to prepare for them. This includes extracts from USGS information.

F: The PIVS monitors all active volcanoes through a network of seismic stations and observatories. There is detailed information on last eruptions and what various alert levels mean. They provide reports on any actively erupting volcanoes or those with high alert levels.

Conclusion

The Philippines has one of the highest incidents of natural hazards of any country in the world, given its relatively high population and low lying islands it also has one the highest vulnerabilities. Project READY was implemented in 2006 and on completion in 2010 will provide mapping for all primary hazards in some of the most at risk provinces. Currently this only covers 26 provinces; to be truly effective this scheme needs to be broadened to include all of The Philippines. Unfortunately, example maps available online were not of a sufficient resolution to make out the legend or any detail. Based on the low resolution copies available, an attempt was made to estimate the quality of these maps.

The Philippines – Eq, Fl, Ls, Tr/Ss, Ts, Vo				
Earthquakes	Probabilistic	✱✱✱✱✱	Ground shaking	475 year RP
	Warnings and information on preparedness available		NDCC maps selectable by province. GSHAP is not.	Linked from PHIVOLCS website
Floods	-	✱✱	-	-
	Warnings issued by PAGASA		Selectable by province	Only low resolution version available
Landslides	-	✱✱	-	-
	Severe weather warnings issued by PAGASA		Selectable by province	Only low resolution version available
Tropical Storms Storm Surges	-	✱✱	-	-
	OCD and NDCC issue storm warnings		Selectable by province	Only low resolution version available
Tsunamis	-	✱✱	-	-
	OCD relays warnings from the NOAA PTWC		Selectable by province	Only low resolution version available
Volcanoes	Probabilistic	✱✱✱✱	**Lahars, ash fall**, pyroclastic and lava flows	High/medium/low risk, *areas at risk*
	Information on hazards and recent activity for all volcanoes		Selectable by volcano	Clear links from PIVS website

Fig. 47 Summary table of available hazard information in the Philippines

3.8 Singapore: Floods

Floods

B: The only threat facing the small island of Singapore is flooding. During rapid economic growth in the 70s and 80s, urbanisation increased the risk of flooding by blocking off natural excess water relief channels. More recently substantial priority has been given to improving risk management, culminating in the construction of the Marina Barrage in November 2008, designed to protect the low lying of the cities from inundation during high tides.

M: The Singapore National Water Agency[56] (PUB) is responsible for drainage management and flood control; they provide information on the areas at risk from flooding, both as a list of individual roads and an overview map of the whole island.

P: Comprehensive information on how to act in the event of a flood is provided on the Singapore Civil Defence Force[57] website (SCDF), along with pictures and locations of nearby shelters. Suggestions are given for items to include in an emergency ration pack. Community Emergency Preparedness Programme training is provided for free, giving the general public a basic ability in first aid and how to react in the case of a disaster.

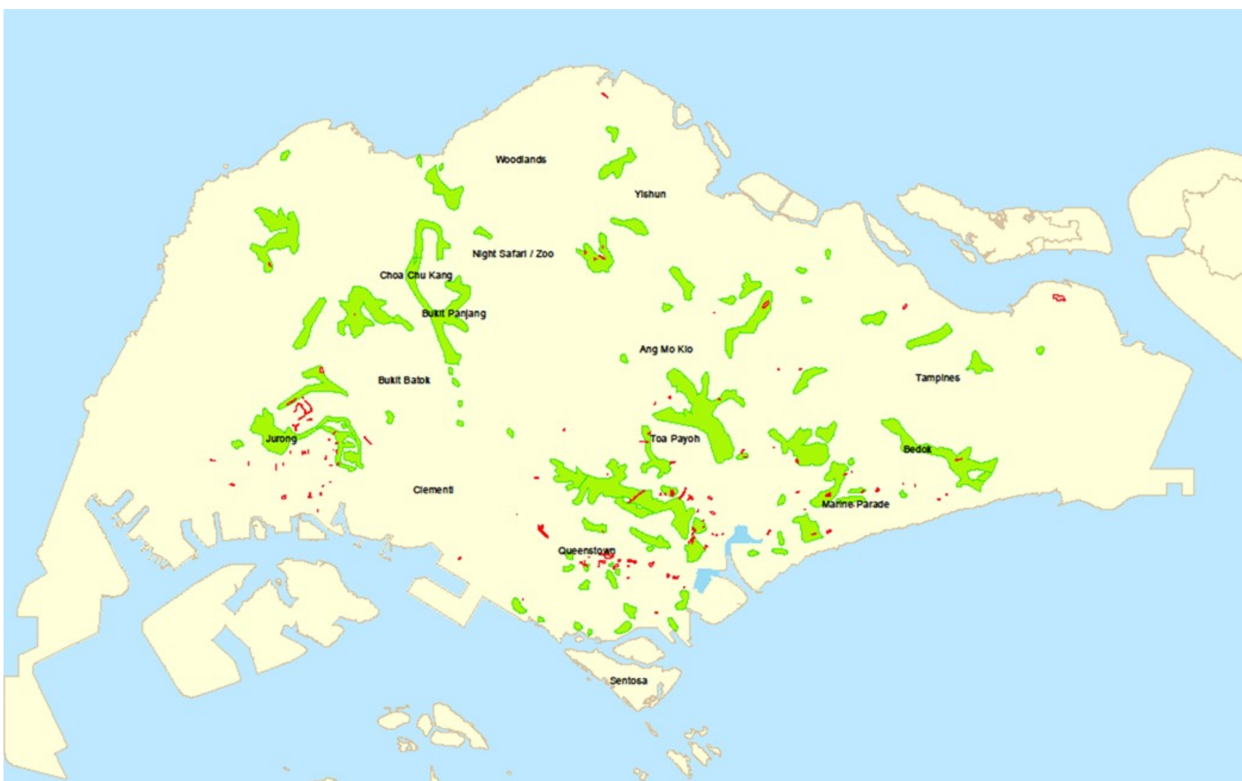


Fig. 48 Flood map of Singapore showing the recent improvements in flood protection and the reduction of at risk areas

F: 97% of residential areas are covered by some 300 Civil Defence siren towers. These provide an efficient way of communicating an imminent threat to the general public and indicate that evacuation to public shelters should occur. The National Environment Agency provides 12 hour and 3 day weather forecasts along with warnings of heavy rain.

Conclusion

Despite poor consideration for flood risk whilst the country was in its early stages of economic development, recent flood protection schemes have been highly effective. Over the past 30 years flood risk area has been reduced by some 97% (from 3178ha to 79ha) despite rising sea levels. Risk information and planning goes to the extent of planning for hazards the country barely has a risk from such as tsunamis.

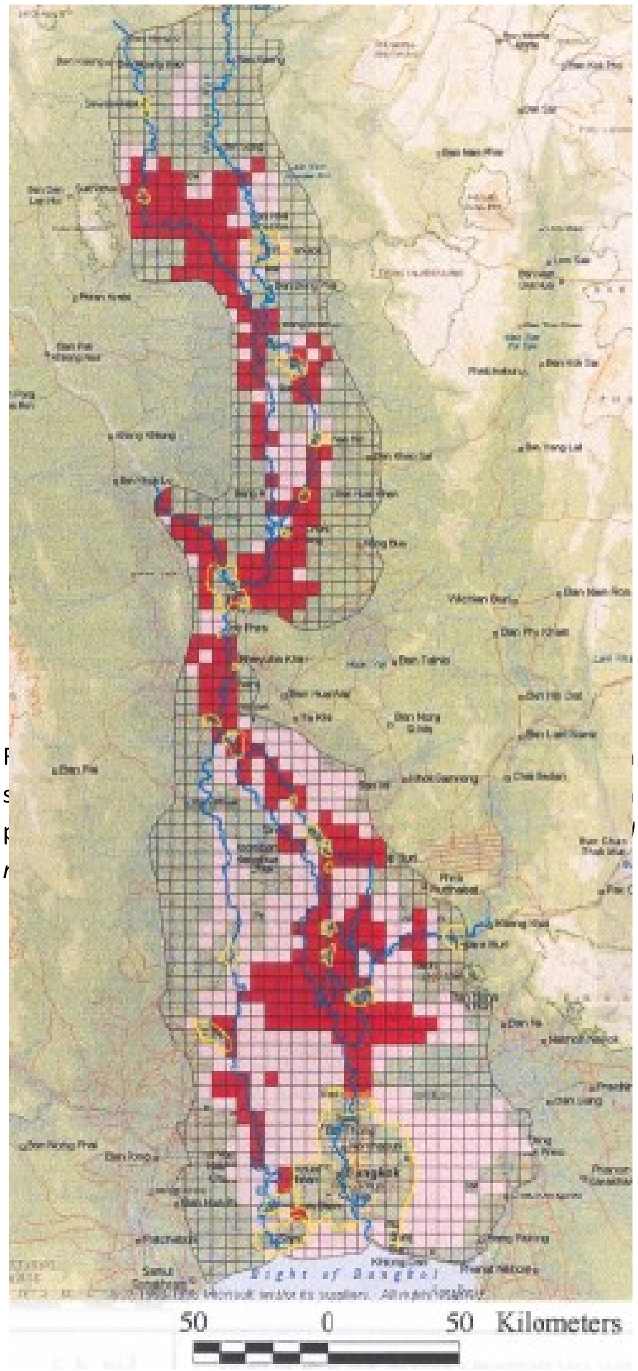
Singapore – Fl				
Floods	Probabilistic	✸✸✸✸✸	Flood hazard	At risk area
	Good information and warnings available		No search function but can be viewed by road	Well linked from PUB website but not from SCDF

Fig. 49 Summary table of available hazard information in Singapore

3.9 Thailand: Floods, Tsunamis

Floods

B: Thailand experiences heavy rainfall during two monsoon seasons and also frequently receives increased precipitation from the tail end of tropical storms which have made landfall in other countries and weakened to depressions. The lowlands of Thailand may be roughly divided in to those in the Mekong river basin to the east and those in the central plains of the country, including Bangkok, within the Chao Phraya river basin.



M: As the Mekong River forms the majority of the Laos-Thailand border the MRC is responsible for flood mapping in the east of the country (see section **3.10** for an example of a map). Some research has been done by the Geo-Informatics and Space Technology Development Agency[58] (GISTDA) to develop a GIS risk model for flooding in several northern Thai provinces; however, as this website has not been translated into English it is somewhat difficult to work out the full extent of this. As part of the Modernization of Water Management System project along the Chao Phraya River, historical mapping of maximum extents of large floods in 1995 and 2006 has been carried out. *Flood management in the Chao Phraya River Basin* by Hungspreug et al.[59] produced a map of flood hazard in a grid around the Chao Phraya River. It is not clear whether this paper and map were produced in conjunction with the Thai government or if it was an independent study.

P: Inlet and outlet structures have been expanded and strengthened to allow careful control of water flow in the lower Chao Phraya basin. Levees and raised roads along the banks have been inspected and improved where necessary. The MRC carry out education programs, to make the general public aware of flood hazard and how to prepare and react. Nationally the Department of Disaster Prevention and Mitigation[60] (DDPM) has six hazard training academies covering all areas of the country, in addition to online resources, which educate and prepare people for floods.

F: Water level information is available online for stations on the Mekong River from the MRC. The Royal Irrigation Department[61] (RID) provides data for current water levels both in the Chao Phraya river basin and for a major upstream reservoir. Additionally the National Disaster Warning Centre (NDWS, established in 2005) provides warnings of potential or current floods, although the NDWC does not appear to have a website.

Tsunamis

B: Whilst the 2004 tsunami hit Thailand and caused substantial damage, tsunamis are only a hazard along the Andaman Sea coastline. Even in this region the hazard is relatively low. The coastline bordering the Gulf of Thailand is not considered at risk.

M: The German CSBC has produced a map of the Khao Lak region, which suffered approximately 70% of the total Thai damage during the 2004 tsunami[62], showing areas affected. Unfortunately this does not extend along the whole of the Andaman Sea coastline.

P: DDPM academies in areas with tsunami hazards provide information on preparedness and how to react to a disaster, both to the general public and local officials.

F: The NDWC network of buoys and seabed monitors aim to detect tsunamis and earthquakes which may produce them. A series of tsunami towers have been constructed along low lying coastal regions to provide siren warnings.

Conclusion

Thailand's national disaster education schemes, run by the DDPM, provide comprehensive hazard training to people at all levels in the community. The NDWC is a unified hazard warning centre, which through a network of alert towers can quickly and efficiently communicate an impending disaster. In the east of the country Thai flood planning benefits from MRC data and assistance. Whilst education and warnings are well delivered, risk maps for both tsunamis and flooding (other than MRC maps) appear not to be available online.

Thailand – Fl, Ts				
Floods	Probabilistic	✶✶✶✶	Flood hazard	High/Med/Low risk
	DDPM hazard training academies and online resources.		MRC map selectable by river regions, Chao Phraya map is not	MRC map is easily available and well linked. Chao Phraya map may be linked.
Tsunamis	Historical	✶✶	Damaged area	-
	Tsunami warnings, preparedness info and evacuation routes		No search function	Not directly available on Thai websites

Fig. 52 Summary table of available hazard information in Thailand

3.9 Vietnam: Tropical Storms, Floods

Floods

B: Two of the largest rivers in South-East Asia have their deltas in Vietnam; the Mekong River in the south and the Red River in the north. As the flood plains of these rivers have such fertile soils they are heavily populated with significant amounts of agriculture.

M: Historical flood mapping has been carried out both by UNOSAT and the Central Committee for Flood and Storm Control[63] (CCFSC) in conjunction with UNDP. The UNOSAT maps focus mainly on recent floods in the north (red river basin) and include general overviews of the area and larger scale maps for Hanoi. CCFSC/UNDP mapping focuses on historical data from major floods in 1999 for the central provinces and again offers small scale overviews with more detailed maps for Da Nang and Hue City. Unfortunately hazard risk maps do not exist according to the CCFSC. In the south, the Mekong Delta has MRC historic flood maps for maximum extent of inundation.

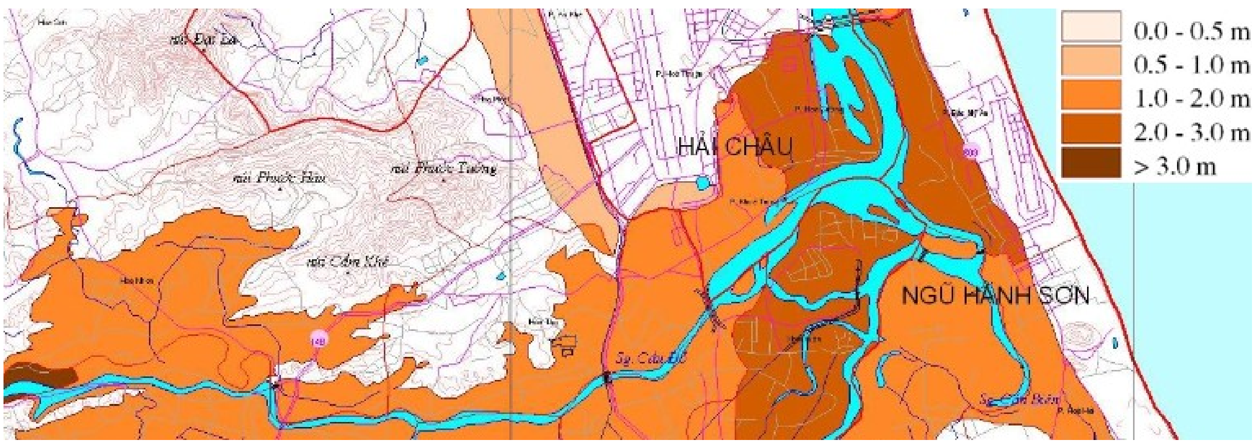


Fig. 53 Extract from CCFSC/UDNP map of Da Nang

P: The MRC, CCFSC and Vietnamese Red Cross[64] (VRC) all work together to implement a scheme of community based disaster risk management, including education of populations threatened by flooding and the provision of safe, elevated areas.

F: The CCFSC produces high water level and extreme weather warnings. Data is also available for a series of river stations spread around the country, giving actual, predicted and hazardous water level information. The Mekong delta is covered for information by the MRC (see **3.10**).

Tropical Storms and Storm Surges

B: Approximately 2 to 4 tropical storms make landfall along the lengthy coast of Vietnam a year. Storm surges can combine with tides to inundate estuaries and threaten areas a great distance inland. Frequently heavy rainfall from tropical storms causes flash floods and mudslides in the mountainous interior of the country.

M: Tropical storm maps could not be found online. According to the CCFSC no storm surge or wind hazard maps exist, even locally, for Vietnam.

P: The CCFSC and VRC are implementing a “Green Wall” scheme making use of natural defences to lessen the impact of tropical storms. Existing mangroves are being protected and bamboo forests re-planted along coastlines. The mangroves lessen the impact of storm surges and thick bamboo forests reduce damage from high winds.

F: The CCFSC provides warnings on tropical depressions and any storms that they produce. These are detailed and provide information on current and likely wind speeds at various locations.

Conclusion

Owing to lack of translation of some government sites, it is possible that information available online has been missed in this report. Between four agencies (UNOSAT, MRC, CCFC, UNDP) the majority of historical flood zones in Vietnam have been mapped; however this is not an ideal situation and a unified system should be implemented. If tropical storm mapping has occurred then the CCFSC do not seem to be aware of it. Warnings are issued online and the green wall of mangrove and bamboo will continue to provide protection as long as it is well managed.

Vietnam – Fl, Tr/Ss				
Floods	Historical	✶✶✶✶	**Flood height**, maximum flood extent	**Central maps**, north and south maps
	CCFSC and VRC provide information in conjunction with MRC		Selectable by area	Not obviously available online
Tropical Storms Storm Surges	None	-	-	-
	CCFSC and VRC both provide education and preparedness info		-	Warnings provided on the CCFSC website

Fig. 54 Summary table of available hazard information in Vietnam

3.10 Multinational Bodies

Given the global impact of earthquakes they are fairly easy to map remotely, making multinational monitoring possible. Satellite imagery can quickly reveal inundation from storm surges, flooding and tsunamis, even some time after the event through the study of defoliation. Where natural features, such as faults or rivers, cross borders it greatly facilitates DRM if there is a multinational body overseeing mapping and generation of information. As natural hazards do not obey political boundaries multinational bodies are important to proper DRM of all hazards.

Indian Ocean Tsunami Warning System

Following the 2004 Boxing Day Tsunami USAID in conjunction with the NOAA and other government organizations funded the development of the Indian Ocean Tsunami Warning System[65] (IOTWS) to provide a unified system for end to end communication of early tsunami warnings. They have several DART buoys set up in the Indian Ocean, monitoring pressure differences on the sea floor. Along with seismic data and sea level monitoring they aim to detect all potential tsunamis threatening the Indian Ocean area. On recording a potentially tsunami inducing seismic event experimental models aim to give maximum wave heights along with likely inundation levels along threatened coastlines

Dartmouth Flood Observatory

The Dartmouth Flood Observatory uses space-based measurement to plot historic extent of floods in various global regions; these maps are available online[66]. They show current flooding, average water coverage and maximum historical flood extent. Not all areas of the world have been covered yet, but most of those with high flood risks have.

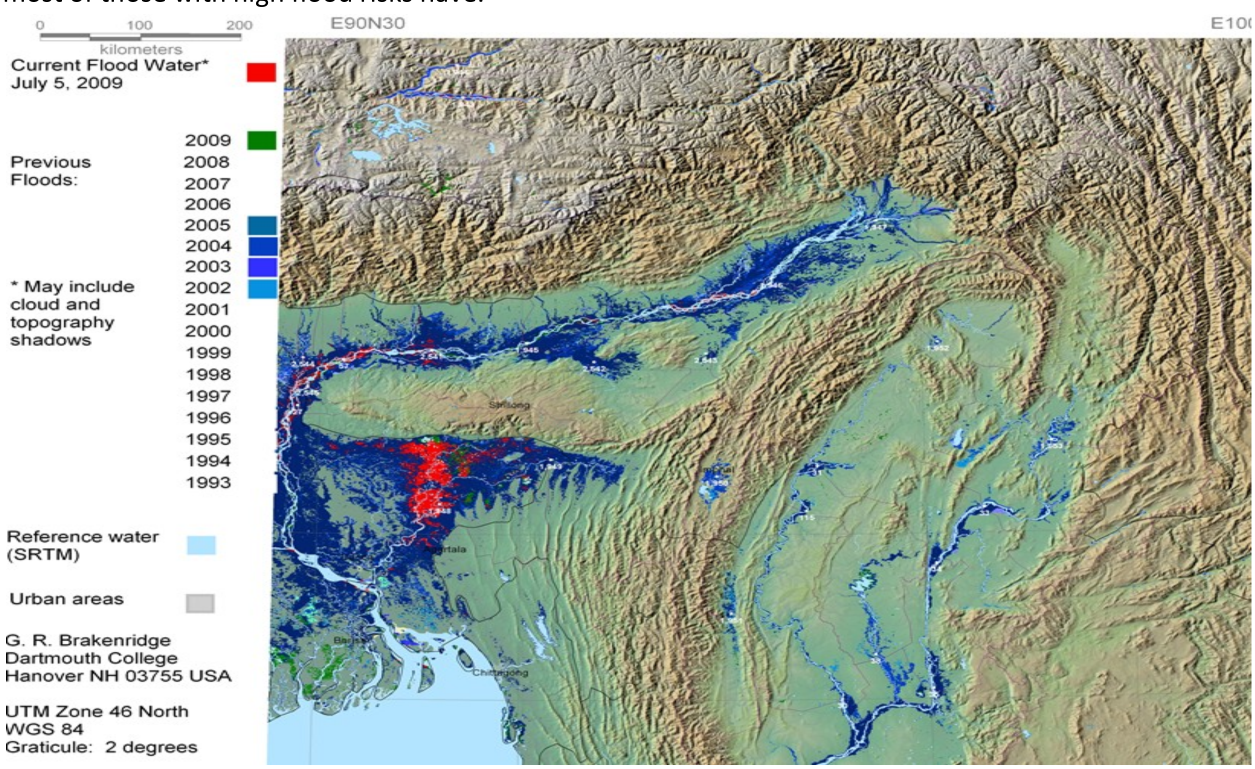


Fig. 55 Example of space based map of flood waters to the north-east of the Bay of Bengal

Mekong River Commission

The Mekong River is the 10th longest in the world. It flows from the Tibetan plateau through China, Myanmar, Thailand, Laos, Cambodia and Vietnam. To effectively manage such a vast natural feature it is essential to develop a unified multinational body. The Mekong River Commission was set up in 2005 with approximately $20million funding by a joint partnership of Thailand, Cambodia, Laos and Vietnam (whilst not initially members both China and Myanmar are now dialogue partners). The commission is responsible for ecological and hazard monitoring and for coordinating sustainable development of communities in the river basin.

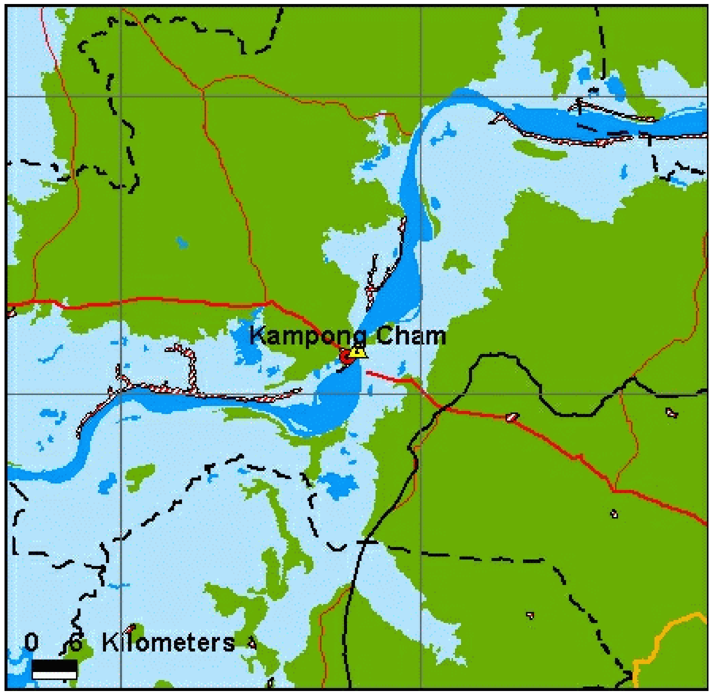
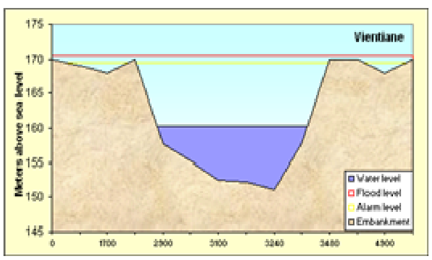
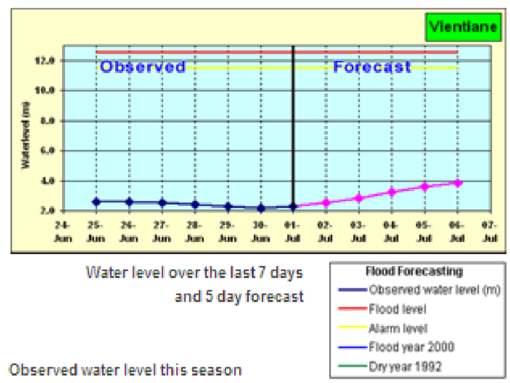


Fig. 56 MRC Map showing maximum historical flood (light blue) in the Kampong Cham area of Cambodia.

A well designed website provides information from approximately 25 monitoring stations over the course of the river. For each station current water level trend (rising/ steady/falling) may be viewed along with a range of graphical information on flood hazard. A series of maps are available centred on each station in a range of scales from 50x50km up to 200x200km. The maps provide information on; maximum extent of historical combined floods, current/forecasted flood areas and inundation heights, topography and land use. The commission also produces flood warnings which are available online or over local media. In collaboration with the USAID the MRC have implemented a program for early warning to the populations in the lower Mekong River basin. Initially this program will provide at risk communities in Cambodia, Laos and Vietnam with early warning of potential flash floods.





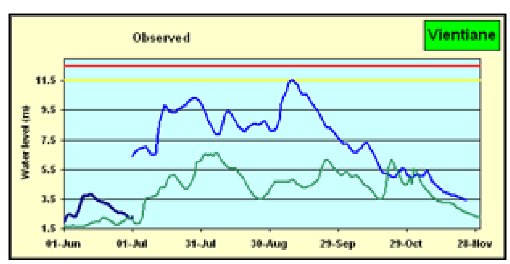


Fig. 57 A selection of data available for the Vientiane station

Clockwise from left: -The cross section of current river level and nearby topography -Recent history and forecast water levels -Seasonal history of water levels, with examples of plots from flood and dry years (for comparison)

Munich Re NATHAN

Munich Re has produced an interactive global resource for natural hazards using their own data along with some that has been locally sourced. The product is available free of charge either online[67] or as a DVD. The map may be selected either by coordinates or by country. Mapped data is provided for earthquakes and tropical storm wind velocities. In addition to this coastlines at risk from tsunamis and storm surges are highlighted. Major volcanoes are marked as; recent (last eruption post 1800), inactive (last eruption pre 1800) or particularly high risk.

A point selection tool allows the user to view hazard levels at a particular location. Similar hazard risk bar charts are selectable by country, along with major natural disaster casualty and loss data. In the map below tropical storms are mapped in green, earthquake risk in shades of red and yellow, volcanoes as triangles, coastlines at risk from storm surges in dotted light blue and those at risk from tsunamis in dotted red.

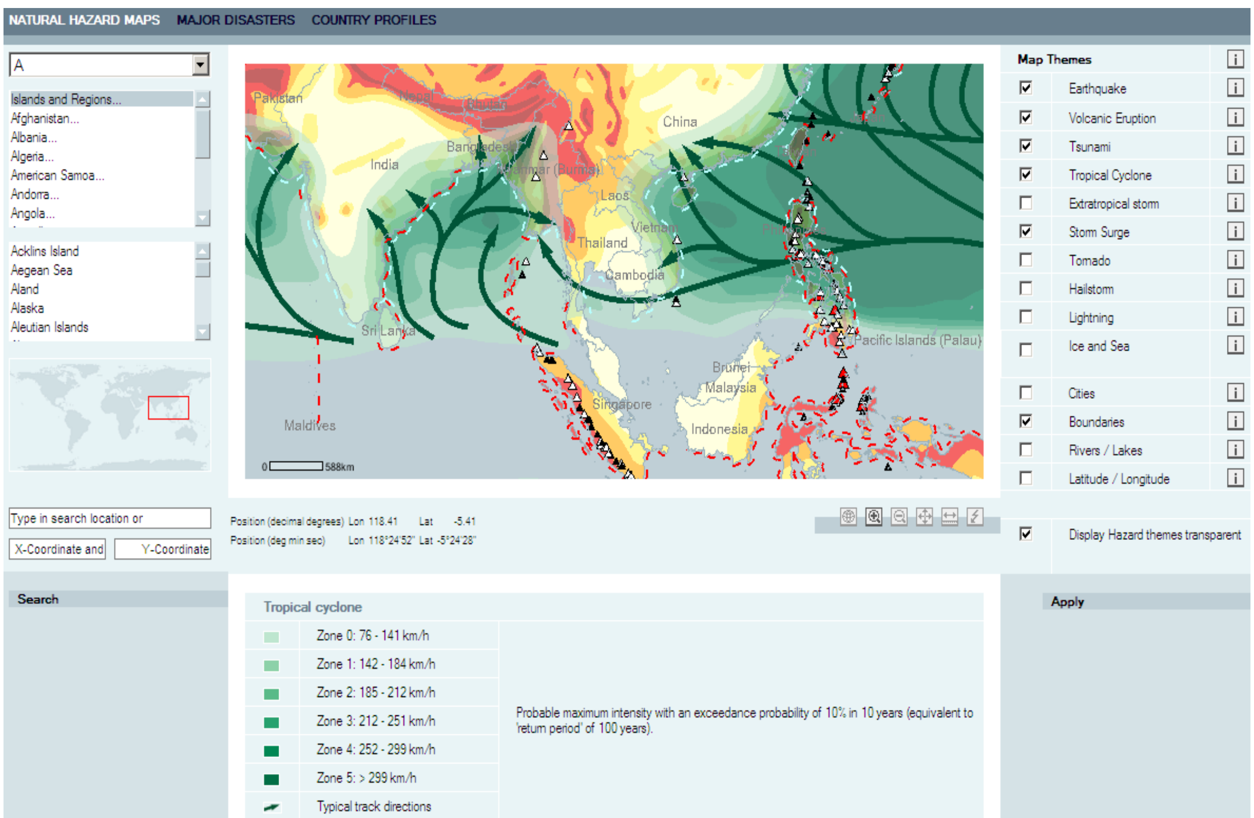


Fig. 58 Screenshot of the NATHAN global hazards map

GSHAP and GEM

GSHAP is a now defunct project, which existed from 1992-1999. It was run by the International Lithosphere Program in conjunction with the International Council of Scientific Unions as part of the United Nations International Decade for Natural Disaster Reduction. The culmination of the project was the publication of a global earthquake hazard map. In some areas they collected their own data and in others they used data already gathered by local organisations. Both the data and map seem to have been used a substantial amount by private organisations and governments.

GEM, a public/private partnership initiated and approved by the Global Science Forum of the OECD. aims to be the "uniform, independent standard to calculate and communicate earthquake risk worldwide"[68]. It will provide an open source model for global risk assessment of earthquakes, but does not yet appear to have been used for mapping by any South East Asian countries.

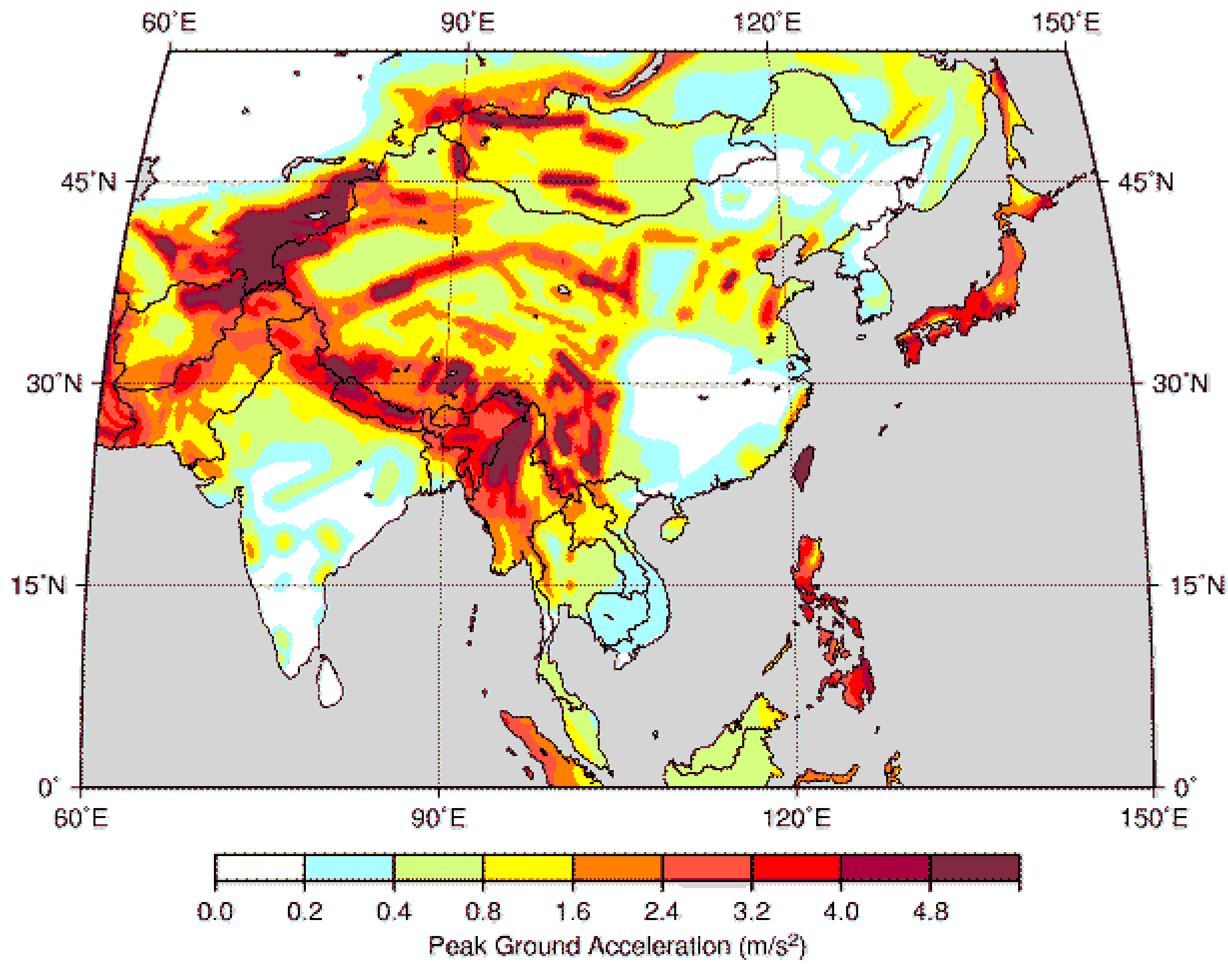


Fig. 59 GSHAP seismic hazard map for Asia, showing PGA with 475 year exceedence

Conclusion

The good practices section aims to give examples of how some of the most developed countries in the world have mapped hazard information and subsequently made this available online. The best of these combine probabilistic hazard zoning, geo coding data to provide a search function and preparedness and response information tailored to the individual's hazard zone all available in a convenient and easy to access online format. Hopefully these examples will provide guidance to those developing hazard maps in South East Asia.

Throughout South East Asia almost all countries have made, at least some, efforts to map hazards and produce DRM strategies. Poor online access, lack of a search function and limited use of probabilistic models are some common issues which were repeated through many hazards and countries. Online access, whilst essential to a remote researcher, is perhaps not required as long as local copies are provided to populations in hazard areas. The search function would require high resolution geo coding which probably is not available outside of major cities, and is unlikely to become available in the near future. The complexity of coding and extensive man hours required to create probability models combined with the need for accurate historical data make these models a rarity outside of developed countries. The best that can be realistically expected in many countries is to designate areas of high/medium/low hazard.

Maps in Appendix 1 give an approximation of the levels of online hazard information in each country included in the report. The colours chosen are not set around any definitive boundaries but are simply based on judgement and an average of the summary tables.

Summarised below is more detailed information for each hazard, including any global trends in its mapping and comments on the state of maps available:

Earthquakes

The established return periods for earthquake hazard mapping appear to be 475 and 240 representing 10% exceedence per 50 years and 10% exceedence per 25 years respectively. With projects such as GSHAP and GEM, global earthquake mapping is of a high standard. For most countries it is enough to simply use GSHAP data to construct their own maps.

Floods

Ideal flood maps look at 50 year, 100 year and 200 year return periods, with the "100 year flood" being the most commonly referenced. A lot of South East Asia still relies on historical maxima and simply stating that an area is at risk from flooding, without giving any information on an expected return period. It may be that governments have produced return period flood maps, but then do not feel them appropriate for public knowledge; or it may simply be that probabilistic flood mapping has not been carried out in this way. Whatever the case it seems insufficient simply to designate an area as at risk without giving any qualification of this hazard. Other forms of flooding such as sheet flooding and off-plain flooding do not appear to have been considered in most maps.

Landslides

No globally accepted return periods for mapping landslide hazard seem to have been established. This is likely because return periods are not applicable to landslides as they would rely on ever changing meteorological models. Whilst this report only focuses on those countries at the highest risk of landslides, to a certain extent all countries with any form of slope are exposed to landslide hazard. For landslide hazard a high/medium/low risk level seems sufficient, as given this information populations exposed to a high level of hazard can watch out for heavy rain warnings and react appropriately.

Tropical Storms

Tropical storms bring several hazards. In most areas very little attempt seems to have been made to map high wind speed hazard. A sustained wind speed boundary should be set globally, perhaps around 180kph (the transition from cat. 2 to 3 on the Saffir-Simpson index), and return periods for this boundary should be mapped. This wind speed is roughly equivalent to the intensity of storm at which gusts are likely to cause substantial damage. Storm surge inundation seems to have received much more attention globally. Return periods can be considered equivalent to those for floods (50/100/200), although modelling of storm surge behaviour is perhaps more complicated than that for river floods. Only a few countries have a significant risk from wind or surge impact, particularly populations in low lying deltas, such as the Irrawaddy (Myanmar), Ganges/Brahmaputra (Bangladesh) and Mekong (Vietnam). Ensuring that populations are made aware of the fact they lie within a hazard zone and that early warnings and evacuation to shelters occur may be sufficient for addressing low frequency catastrophic events such as tropical storms.

Tsunamis

Globally very few attempts have been made to provide probabilistic mapping for tsunami wave heights, with the Western Australia Emergency Services map being perhaps the only available example of this. As with tropical storms, no globally accepted return periods have been established. Again in a similar way to tropical storms and surges probabilistic inundation mapping may not be required. It is probably sufficient to make a population aware of risk and provide early warning systems and shelters.

Volcanoes

Volcanoes are very isolated hazards although lahars may travel some distance down river valleys. In a similar way to other low frequency high impact events (such as Tsunamis and Storm Surges) as long as populations are made aware of the various volcanic hazards which threaten them and proper observation provides early warnings, this can be considered an adequate level of hazard preparedness. Some comment on the return period of a major explosive eruption (Plinian and upwards) may be useful to determine levels of hazard; however, it should be remembered that some of the most damaging eruptions have occurred in volcanoes which have been dormant for several thousand years.

Appendix 1: Maps of hazard information levels

Fig. 60 Map of earthquake hazard information level

Fig. 61 Map of flood hazard information level

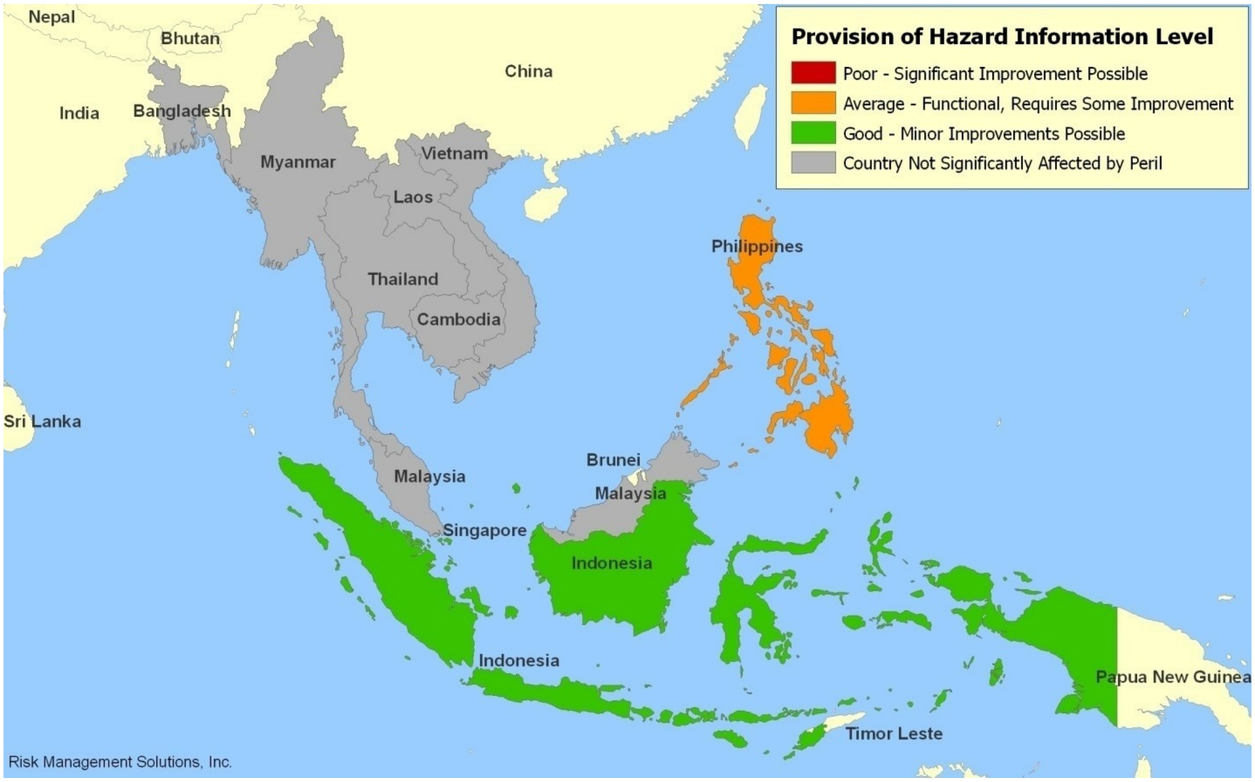


Fig. 62 Map of landslide hazard information level

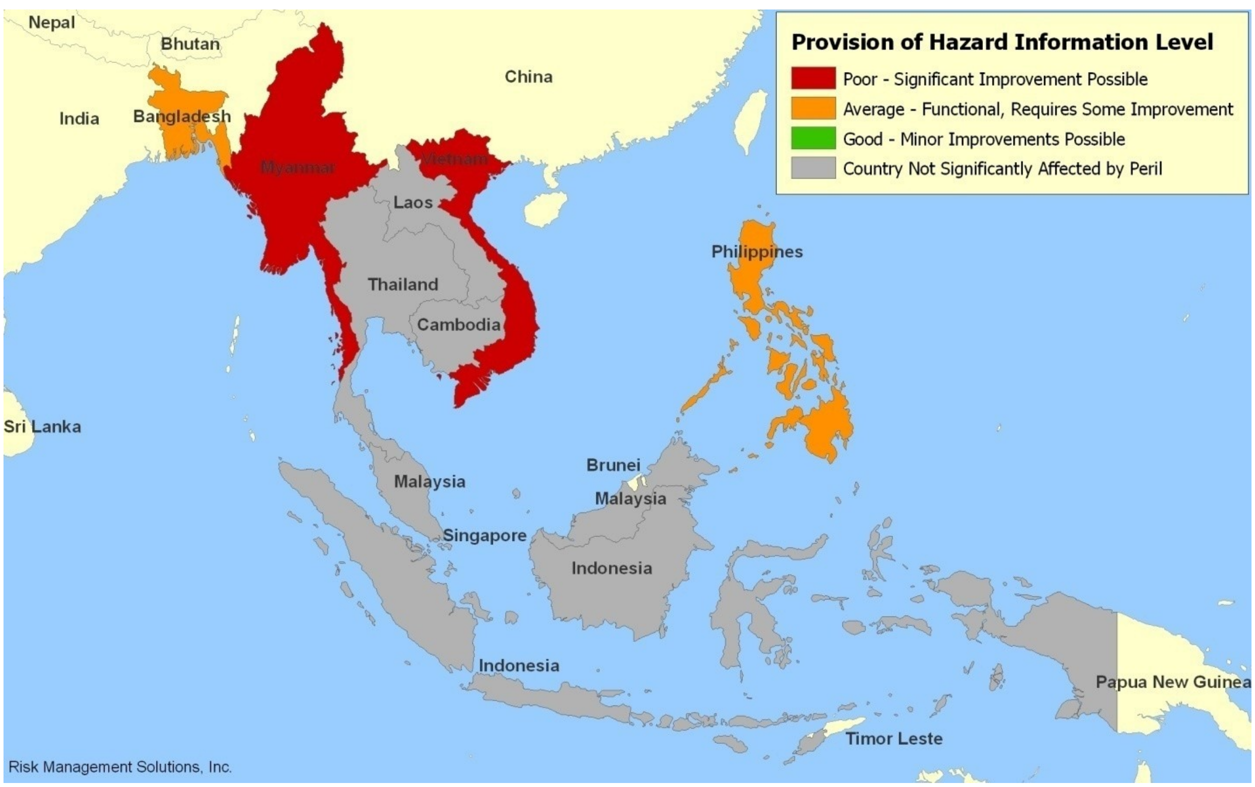


Fig. 63 Map of tropical storm hazard information level

Fig. 64 Map of tsunami hazard information level

Fig. 65 Map of volcanic hazard information level

Appendix 2: Alphabetical list of abbreviations

ASC	Amateur Seismic Centre
ASEAN	Association of South East Asian Nations
BAKOSURTANAL	National Coordinating Agency for Surveys and Mapping
BMD	Bangladesh Meteorological Department
BMG	Agency of Meteorology Climatology and Geophysics
CALEMA	CALifornian Emergency Management Agency
CARE	Cooperative for Assistance and Relief Everywhere
CCFSC	Central Committee for Flood and Storm Control
CDMP	Comprehensive Disaster Management Program
CFAB	Climate Forecast Applications in Bangladesh
CNRS	Centre for Natural Resource Studies
CRC	Cambodian Red Cross
CSBCI	Centre for Satellite Based Crisis Information
DART	Deep-ocean Assessment and Reporting of Tsunamis
DDPM	Department of Disaster Prevention and Mitigation
DID	Department of Irrigation and Drainage
DMB	Disaster Management Bureau
DMH	Department of Meteorology and Hydrology
DMHL	Department of Meteorology and Hydrology Lao
DOGAMI	Department Of Geology And Mineral Industries
DRM	Disaster Risk Management
ECHO	European Commission Humanitarian aid Office
FESAWA	Fire Emergency Services Authority of Western Australia
FFWC	Flood Forecasting and Warning Centre
GDP	Gross Domestic Product
GEM	Global Earthquake Model
GIS	Geographical Information System
GISTDA	Geo-Informatics and Space Technology Development Agency
GSHAP	Global Seismic Hazard Assessment Programme
HKSS	Hong Kong Slope Safety
HURISK	Hurricane Risk Analysis Program
IAVCEI	International Association of Volcanology and Chemistry of the Earth's Interior
IFFI	Inventaria dei Fenomeni Franosi in Italia
IOTWS	Indian Ocean Tsunami Warning System
ISPRA	Instituto Superiore per la Protezione e la Ricerca Ambientale
IWM	Institute of Water Modeling
JTIC	Jakarta Tsunami Information Centre
JTWC	Joint Typhoon Warning Centre
KOGAMI	Tsunami Alert Community
LSU	Louisiana State University
MAYBAYGO	Typhoon2000

MES	Malaysian Emergency Services
MRC	Mekong River Commission
MRCS	Myanmar Red Cross
NATHAN	NATural Hazards Assessment Network
NCDM	National Committee for Disaster Management
NDCC	National Disaster Coordinating Council
NDWC	National Disaster Warning Centre
NGO	Non Governmental Organisation
NHC	National Hurricane Centre
NOAA	National Oceanic and Atmospheric Agency
NWS	National Weather Service
OCD	Office of Civil Defence
PAGASA	Philippines Atmospheric, Geophysical and Astronomical Services Administration
PGA	Peak Ground Acceleration
PIRBA	State Ministry of Research and Technology
PIVS	Philippine Institute of Volcanology and Seismology
PRC	Philippines Red Cross
PTWC	Pacific Tsunami Warning Centre
PUB	Singapore National Water Agency
RBMU	River Basin Management Unit
RID	Royal Irrigation Department
RP	Return Period
RSS	Really Simple Syndication
SCDF	Singapore Civil Defence Force
SDC	Swiss agency for Development and Cooperation
SMS	Short Message Service
UNDP	United Nations Development Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNOSAT	United Nations Operational SATellite applications
USAID	United States Agency for International Development
USGS	United States Geological Survey
WEMD	Washington Emergency Management Division
WRTC	Water Research and Training Centre

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