Guidebook

Tsunami Hazard Mapping for the District Level

gtz IS International Services

GITEWS

The GTZ IS (German Technical Cooperation – International Services) project "Capacity Building in Local Communities" is part of the German-Indonesian Cooperation for a Tsunami Early Warning System (GITEWS). Jointly with its partners at national level and in the GITEWS Pilot Areas of Bali, Java and Padang, the pilot project accompanied the implementation of the Indonesian Tsunami Early Warning System (InaTEWS) from 2006 to 2010 and developed various tools that help coastal communities to link effectively to the warning system and prepare for tsunamis. The TSUNAMIKit presents the project's products. It can be accessed at: www.gitews.org/tsunami-kit. Links in this document refer the reader to specific content of the kit.

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German-Indonesian Cooperation for a Tsunami Early Warning System (GITEWS)
Capacity Building in Local Communities

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Introduction

Purpose of this Guidebook

Understanding the tsunami hazard, and assessing the possible local impact to communities in tsunami prone areas, is a prerequisite for local decision makers and other stakeholders to anticipate future tsunami events and get prepared. Knowledge about the local tsunami hazard is necessary for risk assessment, as the risk describes the relation between the vulnerability of people, their assets and the hazard. Tsunami hazard maps are the basis for evacuation planning. Maps that indicate different zoning provide information to identify priorities for differentiated action, and serve as a basis for designing mechanisms to implement Tsunami Early Warning at the local level.

Several initiatives from Indonesian and international institutions are on the way to provide models and maps, which describe the propagation of tsunami waves and their impact on land. In the framework of the GITEWS project, broad scale tsunami hazard maps at the scale of 1:100.000 have been developed for the Indian Ocean coastlines of Sumatra, Java and Bali. However, these multiscenario maps might not be detailed enough for local planning purposes due to the broad scale and non-corrected remote sensing data.

- ***Fact Sheet: Tsunami Hazard Maps for Indonesia***
- ***Fact Sheet: Tsunami Hazard Maps for Bali***

For most Indonesian communities, little information is available right now. At the same time, there is no standard approach to tsunami hazard mapping in Indonesia and no well developed common methodology for the assessment of tsunami hazard at the sub-district level. In other countries, we have found just solitary attempts to assess the tsunami hazard for selected coastal locations based on different approaches and methodologies.

Local tsunamis are a constant threat to Indonesian coastlines. It is still very difficult to determine the probability of a tsunami event in a given location as historical data in Indonesia is very limited and current estimates for the return periods of tsunamis vary a lot. Efforts in tsunami preparedness, however, require an estimation of the tsunami hazard and the possible local impact. Under such circumstances, initial steps to gain a better understanding of the potential impact of a tsunami event, and thinking about methods on how to estimate this impact in a simple and practical way, has become inevitable.

Considering the above situation, the GTZ IS GITEWS project decided to develop and try out a participatory, simple and low-tech tsunami hazard mapping methodology that can be applied at the district level in order to provide local stakeholder with a better understanding of the local tsunami hazard and, in this way, create a basis to improve preparedness for future disasters. The approach aimed at developing a methodology and learning from the practical implementation together with representatives of local authorities (members of district working groups appointed for tsunami preparedness) in cooperation with national experts.

The hazard mapping exercise involved national experts from the Ministry of Marine Affairs and Fisheries (DKP), the Gajah Mada University of Yogyakarta (UGM), and the Meteorological and Geophysical Agency in Yogyakarta (BMKG-DIY). This inter-institutional team of experts worked in close cooperation with representatives of local government and non-governmental organizations who belong to working groups that had been appointed in order to work towards the strengthening of local tsunami preparedness and early warning.

The Tsunami Hazard Mapping Exercise took place in October, 2007 in the districts of Bantul, Kebumen and Cilacap. It was followed by a series of consultations and joint workshops among all the districts up until June, 2008. The primary output of the mapping exercise was a tsunami base and hazard map for each of the three districts that provided a reference for evacuation planning and early warning strategies. The exercise increased knowledge and awareness among the participants about the potential tsunami threat along the southern coast of Java, and developed capacity for tsunami preparedness.

Fact Sheet: Where is the safe area? Experiences from Hazard Mapping in Java Pilot Area

The experience of the mapping exercise has been documented and shared with institutions involved in tsunami hazard assessment in Indonesia and beyond in order to review the methodology and receive further feedback from experts.

The experience from the hazard mapping exercise, as well as the feedback received from various institutions, served as the main input for the tsunami hazard mapping methodology which is presented here.

Some hints for the Mapping Process and the use of the Guidebook

The Guidebook leads the user with a step-by-step approach through the whole mapping process. Examples from a mapping exercise completed in three districts of Java illustrate the possible results of each of the steps.

The methodology is designed as an alternative for those regions with a lack of adequate hazard maps that are based on solid tsunami expertise.

The hazard mapping methodology combines local and expert knowledge. The exercise needs to be led by a team of experts. Before applying the methodology, it needs to be clarified how the needed expertise can be made available and who would lead the process.

Digitizing base and hazard maps requires skills in Geographical Information Systems (GIS) which is often not available at the local level. This is the part of the mapping exercise that requires a bit more than a "low-tech" approach. Using GIS, however, is optional. Maps can also be drawn by hand.

Lessons learnt

The hazard mapping exercise provides an opportunity for collaboration between experts and local representatives. Besides the final result, tsunami hazard maps for a certain district, a process like the one described in this Guidebook provides an opportunity for all participants to learn. The following points highlight the lessons learnt from the application of the method used in the three districts in Java:

- **Build upon existing work** regarding the tsunami hazard, gather all the information available and **involve experts and local stakeholders.**
- Promote **cooperation between representatives of the local authorities and experts** who provide technical input and expertise. Tsunami hazard mapping can only be done with solid knowledge and expertise.
- The collaboration process requires **leadership and facilitation** in order to keep the process on track.
- A joint **evaluation** after certain steps of the methodology helps to check the progress and the need for clarification and improvement of the process and methodology.
- **An explanation about the methodology** repeatedly throughout the process for each step helps to keep participants on board. Process and discussion is as important as output since it supports **knowledge** transfer and creates **awareness.** Questions and discussions about terms and concepts are welcome!
- **Field trips** before (to become familiar with the area) and after the mapping (field check to verify information) are an important part of the methodology.
- **A hazard map is a "living document"** that has to be updated according to changing conditions, for example, dynamic features (e.g. sand dunes) and the construction of coastal protection.
- In case **mapping results by other organizations** are available, the final tsunami hazard maps need to be compared with these other maps. One district should only have (and only needs) one official tsunami hazard map. It is the responsibility of local authorities to **coordinate** this matter.


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A Step by Step Methodology for Tsunami Hazard Maping

The methodology consists of four major steps that are further divided into several activities, as shown in the table below:

Table 1: Steps of the Tsunami Hazard Mapping Methodology

No.	Step	Activity	Output
1.	Getting started	a. Preparation of team of experts b. Preparation with the district representatives c. Arrange logistics for mapping exercise	• Agreed work plan for mapping exercise • List of participants • Compilation of all relevant information / data (incl. maps)
2.	Introduction, Work Plan and Field Trip	a. Introductory meeting in district b. Field trip	• Confirmed work plan for mapping exercise • Short description and photo documentation of relevant features of the mapping area
3.	Development of Base Map for Hazard Mapping	a. Clarify working process, inputs and outputs b. Compile tsunami hazard data from different sources of information c. Define and delineate horizontal distances from coast and rivers d. Delineate vertical component: contour lines and elevation points e. Describe and map geomorphological features, anthropogenic features and vegetation f. Combine geomorphological features and elevation data with horizontal distances from coastline and river banks g. Visualize results of zoning in base map	• Matrix combining geomorphological features, elevation data and horizontal distances • Document describing the mapping process and arguments for delineations • Base Map
4.	Development of Zoned Hazard Map	a. Sum up progress, explain further working process, inputs and output b. Discuss and define scenarios c. Identify affected geographic areas and produce single scenario tsunami hazard maps d. Produce multiscenario hazard map	• Document describing the parameters of considered scenarios and hazard estimation • Zoned Single Scenario Hazard Maps • Zoned Multiscenario Hazard Map

Step 1
Getting started

a. Preparation of the team of experts for the mapping exercise includes the following activities:

- Clarify and agree on objective, methodology, and schedule for the mapping exercise
- Define and confirm participants
- Coordinate with stakeholders at district (and community) level
- Arrange modalities for field trip and invite community members knowledgeable on local conditions to join the trip
- Prepare all resources for the mapping exercise (see Annex)
- Compile available data on local, regional, and national tsunami hazard
- Document all information that is still needed (including topo graphic and thematic maps, GIS data, etc)
- Arrange logistics for mapping exercise (incl. transport, meeting at district level and field trip)

b. Preparation with the district representatives and participants of the mapping exercise needs to address the following aspects:

- Invite decision makers and other stakeholders, in other words, resource persons and members of government and non-government institutions involved in disaster preparedness and mitigation (incl. people skilled in mapping), to the introduction meeting and the mapping exercise
- Present overall objective and agree on schedule the mapping exercise
- Review all available data together with local stakeholders
- Gather additional data (as mentioned above) from district authorities and other sources
- Request missing data to be compiled until introduction meeting at district level
- Prepare all resources (see Annex)

c. Logistics required for the mapping exercise involve:

- Financial resources
- Transport
- Meeting venue
- Accommodation (etc.)

NOTE:

Most districts in Indonesia do not possess the necessary expertise to conduct Tsunami Hazard Mapping on their own. The installation of new, local Disaster Management Bodies (BPBD) has only just started and Disaster Management and Risk Reduction is a new field for most local authorities. The capacity for tsunami preparedness – and hazard mapping – is very limited. Producing official tsunami hazard maps for the district level, however, is the responsibility of local governments and requires external expertise. Hazard assessment and mapping entirely driven by community based approaches (without external input) is not sufficient due a lack of experience with tsunami events and / or missing technical expertise. In the case of the documented mapping exercise in Java, the initiative came from a capacity building project that has existing cooperation's with local stakeholders and national institutions. An external team was formed that brought together experts who cooperated with local representatives appointed for tsunami preparedness.

The way the hazard mapping exercise is introduced in other cases depends on the particular preconditions. The impulse for hazard mapping could either come from local authorities and/ or NGOs (or other stakeholders) who request assistance from national or regional institutions (e.g. universities) that can provide expertise; or regional (national) stakeholders and institutions take the lead and approach district actors. In all cases, the methodology presented here can serve as guidance for these efforts in preparedness. The annex of this document offers links to institutions in Indonesia where external support could be acquired.

Step 2 Introduction, workplan, and field trip

a. An introduction meeting at the district level among experts and local stakeholders prepares the ground and addresses the following issues:

- Present, discuss and agree on objectives and work plan
- Share and discuss basic knowledge about tsunami hazard, including concepts and definitions as well as the purpose of hazard mapping
- Provide detailed description of methodological steps for mapping exercise etc
- Review all data
- Involve resource persons who can provide additional information and skills regarding tsunami hazard, in other words, previous experience (local knowledge) and skills related to mapping
- Confirm participants who will join the mapping exercise, highlighting that participation from beginning to end is crucial
- Confirm modalities for field trip and reconfirm with community representatives

Defining the nature of a tsunami hazard and discussing the basic concepts:

It is important that all participants have the same understanding about the nature of the tsunami hazard. Clear definitions are required. The following key aspects serve as an input for an initial discussion about the tsunami hazard in general, and the tsunami hazard in Indonesia:

- **Trigger mechanism of tsunamis** (earthquake generated, tectonic uplift, etc.)
- **Characteristics of tsunami waves** in the open sea as well as in shallow water (height, speed and energy)
- **Factors that influence tsunami propagation in the sea** (bathymetry, islands, coral reefs, etc.) **and close to the coast** (orientation and structure of the coast, etc.) and **tsunami impact** on land (topography, etc.)
- **Probability and frequency of** tsunami events
- **Tsunami source areas** in Indonesia
- **Local tsunamis** and arrival times

Introduction to Risk Knowledge

Hazard mapping requires understanding some technical terms and concepts that are used to describe wave characteristics and tsunami propagation on land. In order to create a common understanding amongst the participants, these basic concepts need to be presented and discussed.

NOTE:

Although Indonesia has experienced the most devastating tsunami disaster in recent history, detailed knowledge about the tsunami hazard might still be limited amongst participants of the exercise. The process of hazard mapping is an opportunity to create a better understanding and awareness about the nature of tsunamis. It is recommended to reserve enough time for a thorough explanation of tsunami characteristics, and to allow for discussion.

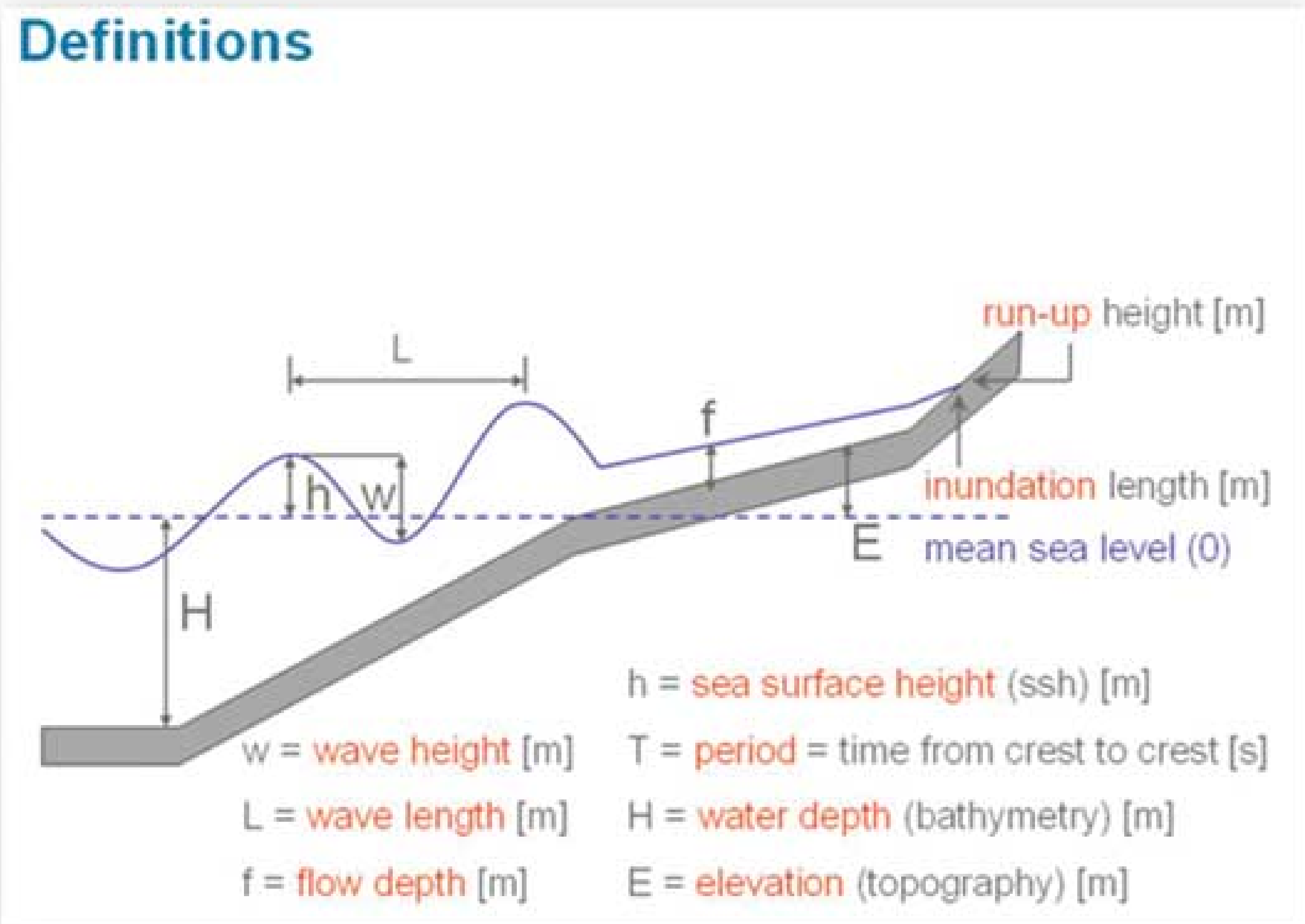


Figure 1:
Definition of basic terms corresponding to the UNESCO-IOC Tsunami Glossary (source: AWI 2007)

Figure 2:
The line marks the tsunami flow depth
in Banda Aceh

Figure 1 shows the most important terms. Four of them: wave height, inundation, flow depth and run up, are clarified in further detail below:

- **Inundation** refers to the horizontal distance the sea water penetrates inland during a tsunami event, generally measured perpendicularly to the shoreline.
- **Flow depth** refers to the height of the sea water penetrating inland during a tsunami event, and could also be referred to as inundation height. The flow depth declines the further the water reaches inland.
- **Run up** is the rush of water up a structure or a beach/land surface. The maximum run up is the vertical height above still water that the rush of water reaches as it climbs onshore. Some times, the term tsunami height is used to refer to the run up height.
- **Tsunami wave height (at the coast)** is measured from the trough to the crest of a tsunami wave.

Inundation, flow depth and run up describe the horizontal and vertical extent in which the tsunami waves impacts when it propagates inland. These three terms are the essential parameters of the presented methodology.

b. A field trip provides the opportunity to jointly assess the mapping area, get a first hand impression of its characteristics and involve resource persons with local knowledge:

- Conduct a field trip to the coastal area, either on foot or by car. Moving perpendicular towards the coastline will allow for a transect passing different landscape features; choose areas where all representative features can be directly assessed.
- Identify geomorphological, anthropogenic and vegetation features in mapping area (in addition, get an overview of human settlements and assets, infrastructure, etc).

- Let local representatives guide and talk to individuals in the area, in other words, local community representatives or villagers (e.g., fishermen who are local experts on the coast and the sea), about things like tide characteristics, coastal geomorphology (dynamic of sand dunes and walls), bathymetry, previous tsunami events and their effects, the impact of storm waves and anything else that seems relevant.
- Discuss interesting aspects within the team and with local stakeholders.
- Use a map to locate geomorphological features.
- Document the field trip with photographs and make notes.

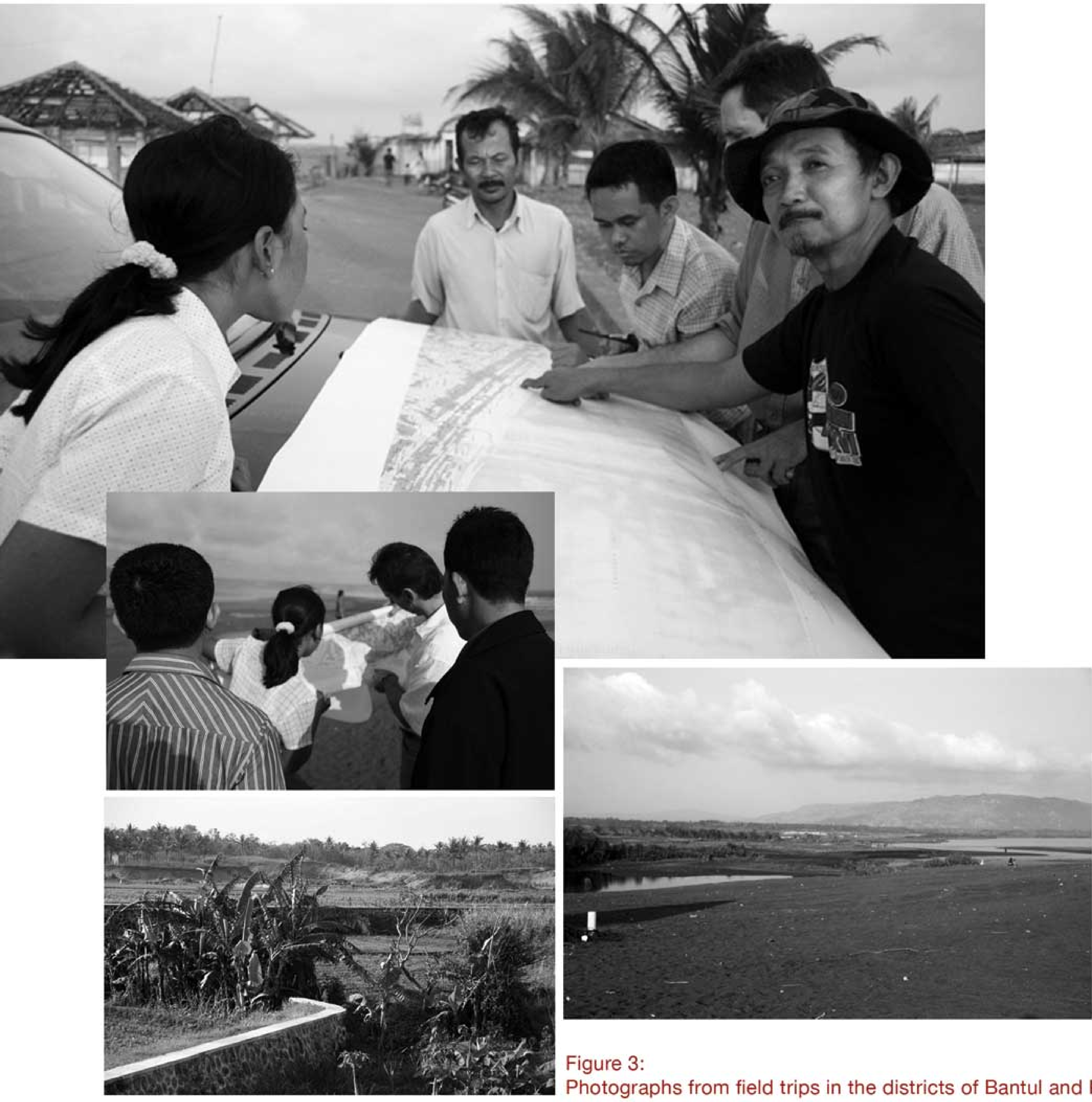


Figure 3:
Photographs from field trips in the districts of Bantul and Kebumen

Step 3 Development of base map for hazard mapping

a. Clarify the working process, inputs and outputs

The presented methodology requires teamwork among all participants, including the team of experts who will most often take the lead. Before starting each step of the process, clarification is required on what needs to be done and what input is necessary. The following activities from b. to g. will result in a base map for the actual hazard mapping.

b. Compile tsunami hazard data from different sources of information

Firstly, before the exercise starts, all data on the tsunami hazard is gathered. The methodology uses data on inundation and run up to approximate the tsunami hazard in the mapping area. This includes local tsunami hazard data (if available). Secondly, local modelling results (if available) are considered. Thirdly, the methodology incorporates data on tsunami propagation on land from other tsunami events in Indonesia. This reference data is the main input for the whole hazard mapping process:

Figure 4:
Local historical data on 2006 in Cilacap

- **Record of local historical data on previous tsunami events**

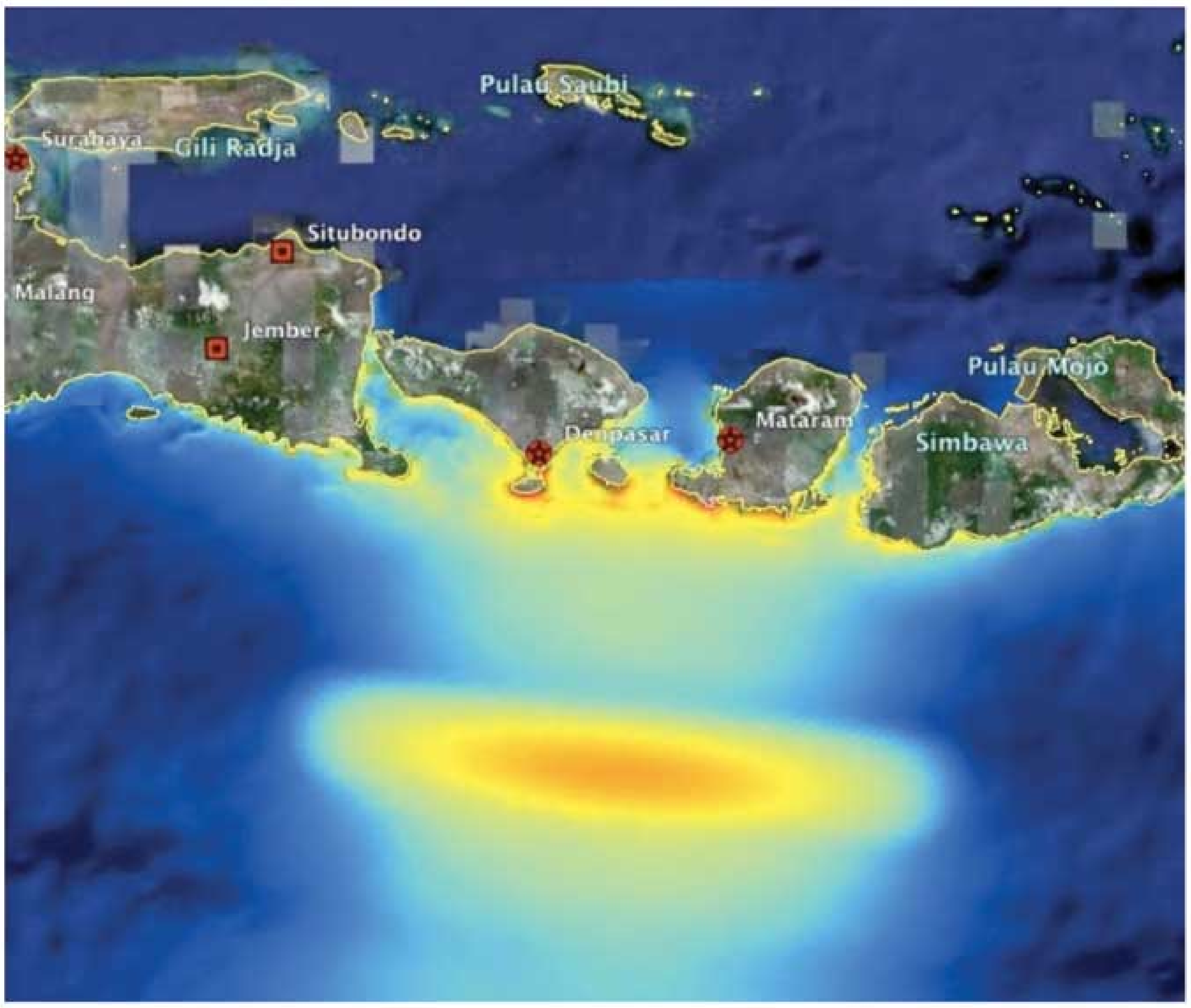
  This source of information includes data regarding inundation and run up that can be gathered from previous tsunami events, which occurred in the area where the hazard mapping is being conducted. This data depends on the quality of post-tsunami assessments (conducted in Indonesia only since the 1980s). While the team of experts might contribute references from scientific surveys, local stakeholders can add local knowledge. In order to trigger effective teamwork, the available information is visualized for all participants.

- **Tsunami modelling results for the mapping area**

  To date, modelling results for tsunami inundation on land are available for some Indonesian coasts. Several Indonesian institutions (e.g., ITB, BPPT, LIPI, and DKP) have conducted tsunami modelling for different areas across the country. The Ministry of Marine Affairs and Fisheries (DKP), for example, concentrates on fishery facilities. The GITEWS programme focuses on tsunami modelling along the Sunda Trench, from Sumatra down to Bali. Especially, the eastern parts of Indonesia are still highly underrepresented. Some of the approaches use models to visualize affected coastlines, but only a few institutions do modelling of the impact on land.

  If modelling data is on hand for the mapping area, it should be used. However, never trust a model alone! It is always important to check the quality of the data, the scale and the modelling approach. Results from modelling can only be as good as the data is. In addition, always remember that a model is always a simplification and, therefore, never represents reality.

Figure 5:
Samples of modelling results visualizing affected areas (left),
and an impact on land (below)
(Source: AWI-GITEWS)



- **Reference data from previous tsunami events in other locations**

  The table below is an example for a compilation of data from different tsunami disasters that occurred in Indonesia. Due to the long recurrence intervals of tsunami events, local information on inundation and run up is limited. Therefore, data from other locations also serves as reference data for potential future events and is used as an input during the mapping exercise.

Table 2: Example of reference data from the last 15 years in Indonesia

Date	Magnitude (SR)	Depth of EQ hypo-centre	Run up (max.)	Inundation (max.)	No. of victims (tsunami impact)	Disaster area (Indonesia)
Sept. 12, 2007	7.9	10 km	3.6 m	No data	-	Bengkulu and West Sumatra
June 17, 2006	7.7	6 km	7.6 m	500 m	668	West and Central Java, DI Yogyakarta
Dec. 26, 2004	9.3	30 km	34 m	5.000 m	> 210.000 (oceanwide)	Aceh and North Sumatra
Feb. 17, 1996	8.2	32 km	13.7 m	No data	107	Biak, Papua
Dec. 12, 1992	7.8	36 km	26.2 m	No data	-2.000	Pulau Babi, Flores

Main source: Subandono Diposaptono and Budiman (2008)

Historical data on tsunamis in Indonesia can be found in Hamzah Latief et al, 2000

Tool 1 (below) shows the example of a matrix that brings together the different sources and data. It provides an inventory for tsunami hazard data and highlights the most important components: horizontal (inundation) and vertical (run up) extent of the tsunami event on land. It is a documentation tool as well as a visualization tool:

Tool 1 Matrix: Overview of available referance data for tsunami hazard (Cilacap)

Information Source	Horizontal (inundation)		Vertical (run up)	
	Length (in m)	Location and data source	Height (in m)	Location and data source
1. Local historical data about previous tsunami events	100-500 m	Cilacap District, 2006 Tsunami	2-4 m	Range gathered from several locations on the coast of Cilacap district (source: local tsunami assessment)
2. Modelling results for the mapping area	Up to 4.000 m	Maximum inundation in eastern part of Cilacap District (source: AWI, EQ magnitude 8.5)	-	-
3. Reference data from previous tsunami events in other locations	Up to 5.000 m	Maximum inundation of Aceh Tsunami on west coast	Up to 34 m	Maximum run up of Aceh Tsunami on west coast

In addition to the data gathered from the above sources, statistical data can be used as reference. You may find further information about historical data in the Tsunami Catalogue from Latief et al (2000) or Subandono and Budiman (2008).

As a rule of thumb, you could refer to historical data. It shows that the "average" destructive tsunami in Indonesia does not exceed a maximum inundation of 500 m. The average run up ranges between 5 to 10 m.

c. Define and delineate horizontal distances from the coast and rivers

In order to facilitate the mapping, as well as group discussions, hard copies of a topographic map should be used during the exercise (source: BAKOSURTANAL). As a first step in the mapping process, the team draws lines at certain horizontal distances from the coastline on a copy of the topographic map. It is recommended to start with a 500 m line that represents the inundation area of the average destructive tsunami, and a 4.000 m line that refers to the maximum inundation of the Aceh Tsunami. Additional lines, at a distance of 1.000 and 2.000 m, are useful to create more detailed zones. They are drawn parallel to the coastline showing the distance a particular tsunami event reaches inland (see figure 6 below). The team may decide to delineate additional horizontal distances from the coast using Tool 1 as a reference.

Figure 6:
Mapping in Kebumen and Cilacap

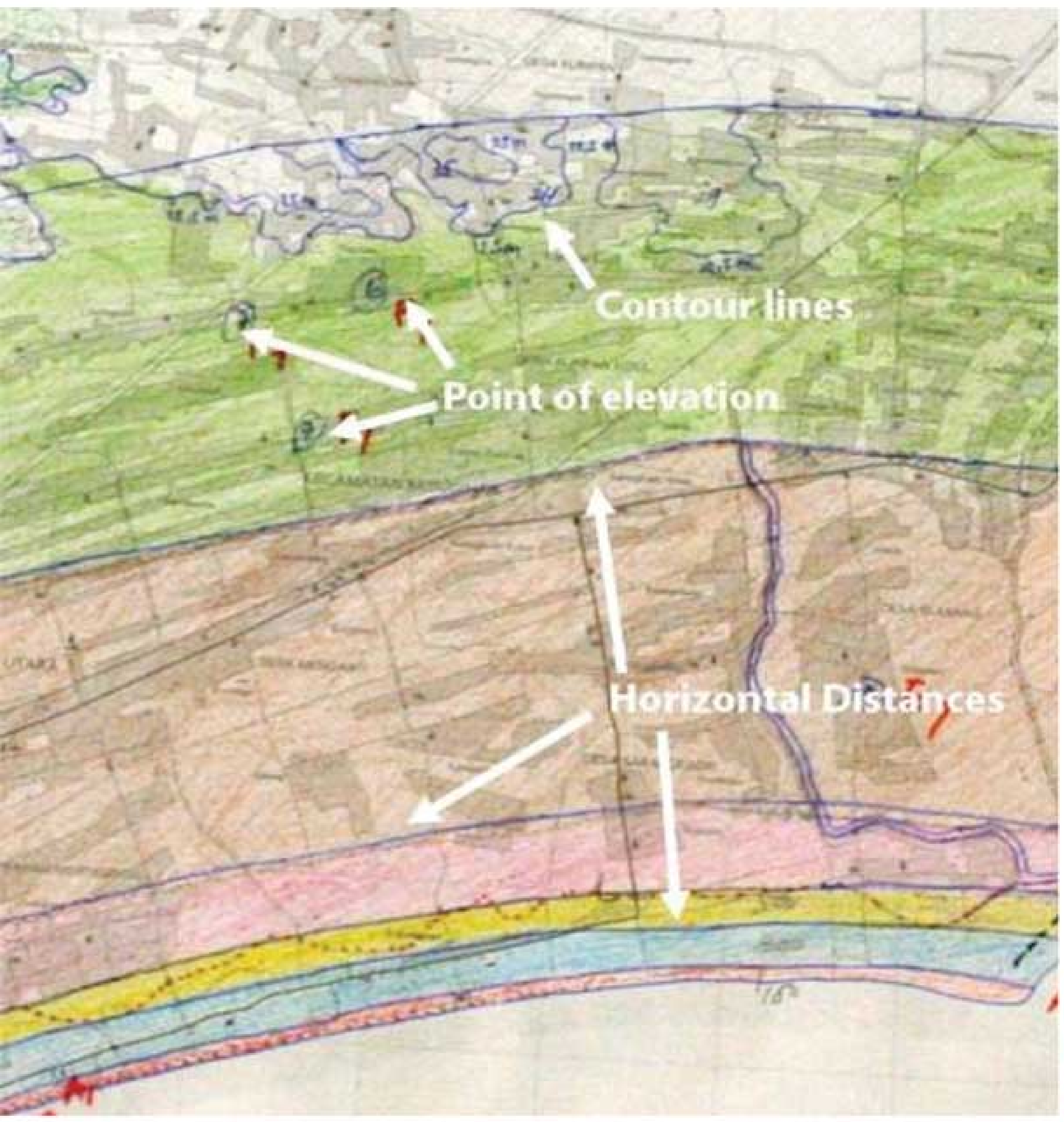


Figure 7:
Initial base map with horizontal distances and elevation (contour lines)

As a second step, the horizontal distances from the coast inland in rivers are defined and mapped. Rivers allow tsunami waves to travel further inland than they travel on land. This is due to the lower friction when the wave travels on water, compared to movement on land. So-called tsunami bores are steep, turbulent, rapidly moving tsunami wave fronts, typically occurring in a river mouth or estuary. During the exercise, factor 2 has been used to describe the distance a tsunami travels inland in rivers, as compared to propagation on land (e.g., 500 m on land = 1.000 m in rivers).

River banks and adjacent flood areas are particular hazard zones. The horizontal distances (left and right) from a river are drawn parallel to the river banks indicating the potential flooding area in a tsunami event. Reference data about the flooding of river banks (and adjacent flood plains) in case of a tsunami event is limited. Throughout the mapping exercise, the flooding area has been estimated at 200 m (left and right of rivers).

d. Delineate the vertical component: contour lines and elevation points

The delineation of horizontal distances (referring to potential tsunami inundation) on the topographic map creates the first important input for a base map for hazard mapping. In the next step, the vertical aspect is added. The team highlights contour lines and elevation points (see figure 6). The extent of detail when highlighting vertical lines depends on the data provided on the topographic map. The topographic map used during the exercise provides contour lines at 12.5 m intervals and additionally indicates some points of elevation below 12.5 m. The 37.5 m contour line was used as the maximum elevation during the exercise, referring to the maximum tsunami run up recorded during the Aceh Tsunami.

The map now shows an initial zoning that describes areas of similar elevation and distance from the coast.

e. Describe and map the geomorphological features, anthropogenic features and vegetation

By looking at the map, satellite images (e.g., Google Earth images), the photos of the field trip and any other relevant information (e.g., flood events), geomorphological features (e.g., sand dunes, rivers, and flood plains), anthropogenic features (e.g., dikes and dams) and also relevant vegetation (e.g., mangroves and forest belt) can be identified and described. Here, it is most important to include local knowledge of the mapping area. Coastal features are very dynamic. Local resource persons can often provide updates on how the coastal landscape has changed and thus make the mapping result more accurate. The team lists and describes the above features using Tool 2 and highlights them on a copy of the topographic map. The column on the right of the matrix is used to indicate whether or not a feature potentially reduces the energy of a tsunami (see Tool 2).

Vegetation, like coastal forests or mangroves, reduces flow depth and inundation length considerably. Studies show that each 200 m of the width of a coastal forest reduces inundation length behind the forest by 50% the inundation length (Harada et al. 2004). This aspect will be taken into account once the affected areas are identified to produce the single scenario map (Step 3.c)

Figure 8:
Belt of coconut trees (source: Google Earth 2008)

Sand dunes in Kebumen (taken during a field trip in 2007)

Tool 2 **Matrix: Description of geomorphogical features, antrophogenic features and vegetation**

EXAMPLES FROM PILOT AREA JAVA

Features: • geomorphological • anthropogenic • vegetation	Description (length, height and other characteristics)	Influence on tsunami impact (reducing / not reducing)
Flood plains	Often inundated during rainy season (Bantul)	Do not reduce the energy of the tsunami during the rainy season
Sand dunes	6-10 m above water level during low tide and 3-7 m during high tide (Kebumen)	Reduces the energy of a tsunami
Dam	Length 5 km, height 2 m (Cilacap, Tegal Kamulyan – PLTU)	Reduces the energy of a tsunami
Forest belt	Belt of coconut trees surrounding settlements; almost along the whole coast, starting at a distance from the sea of about 1 to 1.5 km (Kebumen)	Reduces the energy of a tsunami

f. Combine the geomorphological features and the elevation data with the horizontal distances from the coastline and river banks

An important step in order to finalize the base map for tsunami hazard mapping is the combination of the results of the previous activities in one matrix: Tool 3 (see below). This matrix allows for a combination of different parameters characterizing the mapping area. It shows geographic areas of distinct elevation and geomorphological features in relation to horizontal distance from the coastline. The matrix uses the following logic:

- The left column indicates elevation classes based on the contour lines of the topographic map, points of elevation and elevation values that are the result of interpolation (see box).
- The geomorphological features are categorized in accordance to their elevation class (2nd column from left) and numbered (1 to …).
- The agreed horizontal lines (resulting in zones, e.g. 0-500 m) are recorded and assigned a letter (A to …).
- In a final step, each resulting area (geomorphological features in elevation class x horizontal distance) is assigned a code by combining the parameters (e.g., A1, C3).

NOTE:
Due to the lack of detailed elevation data in the topographic map, some data had to be interpolated. Local representatives conducted field checks and provided important input for verification.

Tool 3 Matrix showing distinct geographical areas that are definded by: (1) Elevation in combination with (2) Geomorphical features, and (3) Zones of horizontal distance from the coastline

EXAMPLE FROM BANTUL

Elevation in m	Geomorphological features		Horizontal distance from the coastline			
			-500 m	500 - 1.000 m	1.000 - 2.000 m	2.000 - 4.000 m
		No.	A	B	C	D
0.5	River banks	1	A1	B1	C1	D1
	Sand dune	2	A2	B2	C2	-
	Flood plain (river)	3	-	B3	C3	D3
	Flood plains (rain)	4	-	B4	C4	D4
	Plain	5	A5	B5	C5	D5
5-12.5	River banks	6	A6	B6	-	D6
	Sand dune	7	A7	B7	C7	-
	Flood plain (river)	8	-	B8	-	D8
	Flood plains (rain)	9	-	-	-	D9
	Plain	10	A10	B10	C10	D10
12.5-20	River banks	11	-	-	-	D11
	Sand dune	12	A12	B12	C12	-
	Plain	13	A13	B13	C13	D13
	Flood plains (rain)	14	-	-	-	D14
20-25	Sand dune	15	-	B15	-	-
	Plain	16	A16	B16	C16	-
25-37.5	Plain	17	A17	B17	C17	D17
>37.5	Hill Area	18	A18	B18	C18	D18

g. Visualize results of zoning in the base map

As stated above, the matrix describes distinct geographic areas of elevation and geomorphological features in relation to the horizontal distance from the coastline. Since these areas refer to defined areas on the map, the information can be visualized by assigning the codes (e.g., for the District of Bantul) A1 to D18. This can be done on the hard copy of the topographic map or digitally with the GIS.

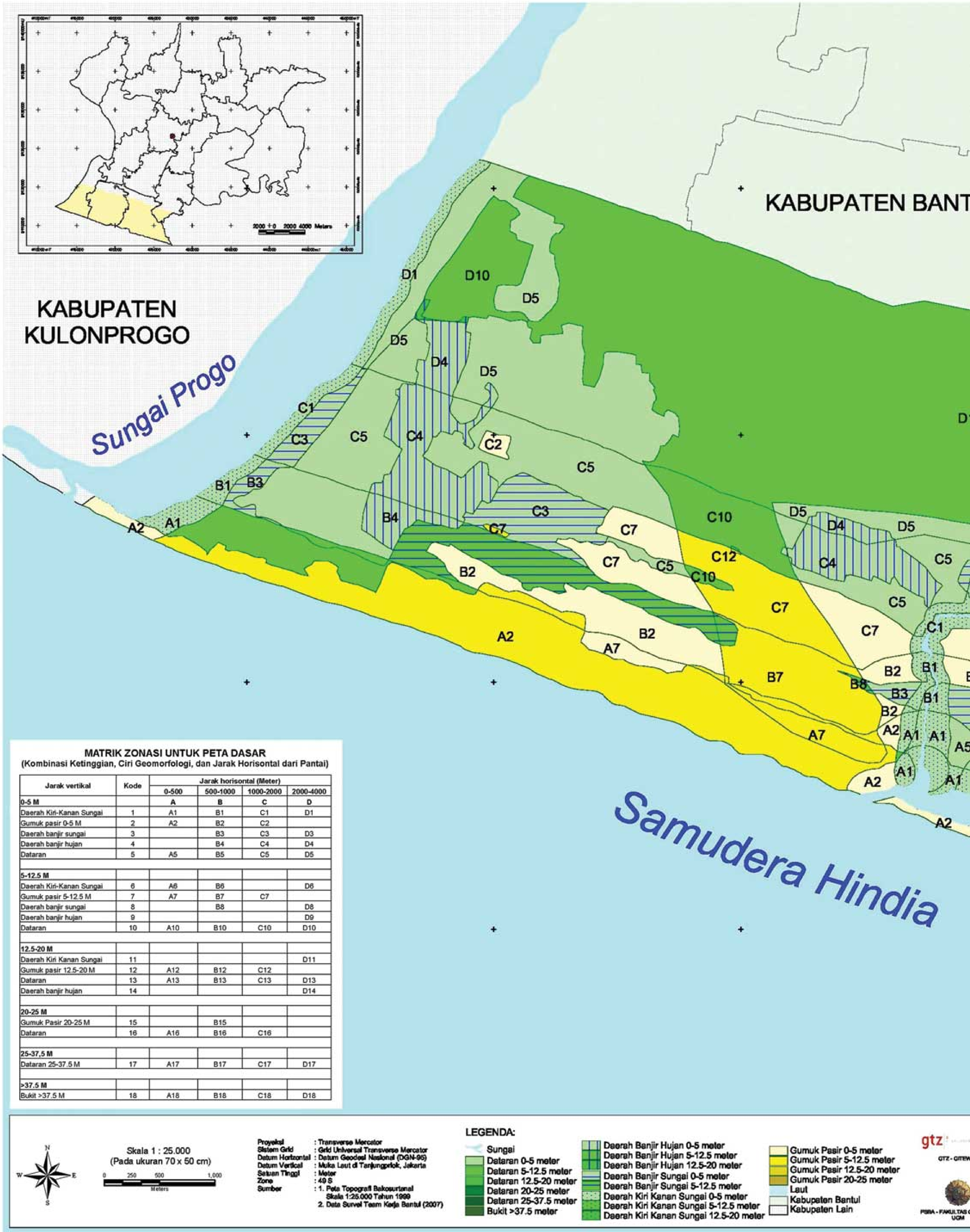
It is important to highlight that this thematic base map does not yet provide an estimation of tsunami hazard. It is a thematic map that simply combines references from other tsunami events in the form of horizontal and vertical information (as compiled in Tool 1) and topographic data of the mapping area in order to set the frame for local hazard estimations.

Both a combination matrix and base map are used to produce the tsunami hazard map. The following section (step 4) explains how this is done.

NOTE:

The lack of skills in Geographic Information Systems (GIS) is often a bottleneck with regards to practical mapping at the local level. During preparations for the mapping exercise, it is advised that the team of experts together with local stakeholders acquire access to a (preferably local) institution that can provide technical support.

However, if such support is not available, and does not seem sustainable, the methodology also works without GIS. In this case, the hard copies of topographic maps can be used.



MATRIK ZONASI UNTUK PETA DASAR
(Kombinasi Ketinggian, Ciri Geomorfologi, dan Jarak Horisontal dari Pantai)

Jarak vertikal	Kode	Jarak horisontal (Meter)			
		0-500	500-1000	1000-2000	2000-4000
0-5 M		A	B	C	D
Daerah Kiri-Kanan Sungai	1	A1	B1	C1	D1
Gumuk pasir 0-5 M	2	A2	B2	C2	
Daerah banjir sungai	3		B3	C3	D3
Daerah banjir hujan	4		B4	C4	D4
Dataran	5	A5	B5	C5	D5
5-12.5 M					
Daerah Kiri-Kanan Sungai	6	A6	B6		D6
Gumuk pasir 5-12.5 M	7	A7	B7	C7	
Daerah banjir sungai	8		B8		D8
Daerah banjir hujan	9				D9
Dataran	10	A10	B10	C10	D10
12.5-20 M					
Daerah Kiri Kanan Sungai	11				D11
Gumuk pasir 12.5-20 M	12	A12	B12	C12	
Dataran	13	A13	B13	C13	D13
Daerah banjir hujan	14				D14
20-25 M					
Gumuk Pasir 20-25 M	15		B15		
Dataran	16	A16	B16	C16	
25-37,5 M					
Dataran 25-37.5 M	17	A17	B17	C17	D17
>37.5 M					
Bukit >37.5 M	18	A18	B18	C18	D18

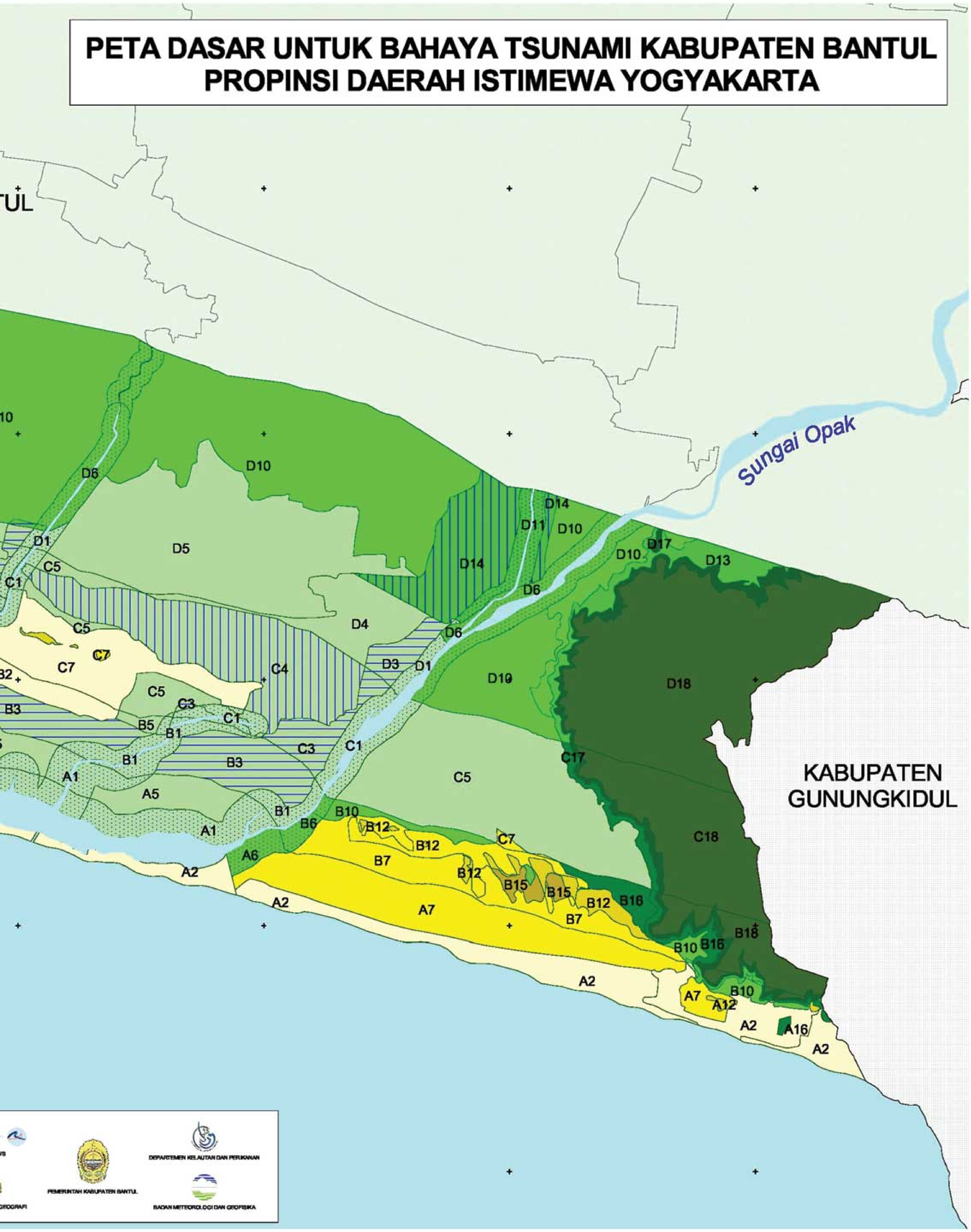


Figure 9:
Base Map-Bantul District

Step 4 Development of (zoned) tsunami hazard map

NOTE:
Due to a lack of knowledge on tsunami scenarios at the local-level, the team of experts needs to lead the scenario discussion, actively involving local stake-holders

a. Sum up progress, explain further working process, inputs and outputs

Before moving into the steps for the development of the tsunami hazard map, it is worth summing up the results and activities so far. Then, the forthcoming sequence of activities (4 b. to d.) for estimating and mapping the tsunami hazard needs to be clarified.

b. Discuss and define scenarios for tsunami events as input for hazard classification and zoning

In order to get to an idea about the impact from a range of possible tsunami events, tsunami scenarios need to be discussed. A scenario discussion can take on different parameters to describe potential tsunami events. The presented methodology drew on 'inundation and flow depth' as the primary descriptive parameter for tsunami scenarios. The mapping team decided to make use of two different scenarios (see table 2 and 3):

- **Scenario I** describes a 'medium' (or average) destructive tsunami event. This scenario corresponds to tsunami events that statistically occur every two to three years along Indonesian coastlines, representing the majority of all tsunamis in Indonesia (not exceeding a maximum inundation of 500 m, nor an average tsunami run up between 5 to 10 m). It is estimated from the run up data that flow depths for these kinds of events do not exceed 5 m.
- **Scenario II** describes the 'worst case', corresponding to the extent of the Aceh Tsunami.

The mapping team estimates tsunami propagation on land in the two given scenarios. Propagation on land is described with maximum flow depth and maximum inundation. The following estimation represents a conservative approximation of maximum tsunami propagation on land in accordance to scenario I and II:

Table 3: **Estimated propagation of tsunami on land in accordance to Scenario I**

Parameter:	Estimated max. inundation	Estimated max. flow depth
Value:	500 m	5 m

Table 4: **Estimated propagation of tsunami on land in accordance to Scenario II**

Parameter:	Estimated max. inundation	Estimated max. flow depth
Value:	4.000 m	10 m (< 1.000 m)
		5 m (> 1.000 m)

c. Identify the affected geographic areas and produce single scenario tsunami hazard maps

The above data on flow depth and inundation provides the reference for identifying which areas of the base map are affected in a respective scenario. Tool 3 (the combination matrix) allows one to systematically classify the geographic areas (described with codes like A1, C3, D8, etc...).

In order to apply a standard approach for the identification of the affected areas in a respective scenario, the following rules were defined:

Table 5: Overall rules for identifying affected geographic areas

1.	All clusters within 500 m from the coast are considered part of the hazard zone, if they are lower than 25 m.
2.	Only clusters that are directly affected by inundation are classified as part of the hazard zone.
3.	All the other zones in the matrix are left blank.
4.	In rivers (and along river banks), inundation maximum is twice as long as on land.
5.	Areas behind coastal forests, each 200 m of the width of a coastal forest, reduce inundation length behind the forest by 50%.

First, the team produces the matrix for **scenario I**, then that of scenario II. Both matrices are used to produce single scenario hazard maps. Keeping the above rules in mind, the leading question for identification is:

> Which geographic area (as described in Tool 3) is affected by inundation in a tsunami event in each of the two scenarios?

The result of this exercise for **Scenario I** can be seen in the matrix below with an example from Bantul District:

Tool 4 **Hazard matrix showing affected geographic areas in Scenario I**

EXAMPLE FROM BANTUL

Elevation in m	Geomorphological features		Horizontal distance from the coastline			
			-500 m	500 - 1.000 m	1.000 - 2.000 m	2.000 - 4.000 m
		No.	A	B	C	D
0.5	River banks	1	A1	B1	C1	D1
	Sand dune	2	A2	B2	C2	-
	Flood plain (river)	3	-	B3	C3	D3
	Flood plains (rain)	4	-	B4	C4	D4
	Plain	5	A5	B5	C5	D5
5-12.5	River banks	6	A6	B6	-	D6
	Sand dune	7	A7	B7	C7	-
	Flood plain (river)	8	-	B8	-	D8
	Flood plains (rain)	9	-	-	-	D9
	Plain	10	A10	B10	C10	D10
12.5-20	River banks	11	-	-	-	D11
	Sand dune	12	A12	B12	C12	-
	Plain	13	A13	B13	C13	D13
	Flood plains (rain)	14	-	-	-	D14
20-25	Sand dune	15	-	B15	-	-
	Plain	16	A16	B16	C16	-
25-37.5	Plain	17	A17	B17	C17	D17
>37.5	Hill Area	18	A18	B18	C18	D18

Tool 5 Hazard matrix showing affected geographics areas in Scenario II

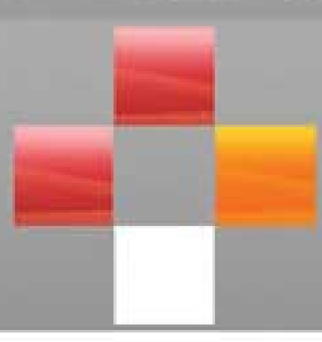
EXAMPLE: BANTUL

Elevation in m	Geomorphological features	No.	Horizontal distance from the coastline: -500 m (A)	500 - 1.000 m (B)	1.000 - 2.000 m (C)	2.000 - 4.000 m (D)
0.5	River banks	1	A1	B1	C1	D1
	Sand dune	2	A2	B2	C2	-
	Flood plain (river)	3	-	B3	C3	D3
	Flood plains (rain)	4	-	B4	C4	D4
	Plain	5	A5	B5	C5	D5
5-12.5	River banks	6	A6	B6	-	D6
	Sand dune	7	A7	B7	C7	-
	Flood plain (river)	8	-	B8	-	D8
	Flood plains (rain)	9	-	-	-	D9
	Plain	10	A10	B10	C10	D10
12.5-20	River banks	11	-	-	-	D11
	Sand dune	12	A12	B12	C12	-
	Plain	13	A13	B13	C13	D13
	Flood plains (rain)	14	-	-	-	D14
20-25	Sand dune	15	-	B15	-	-
	Plain	16	A16	B16	C16	-
25-37.5	Plain	17	A17	B17	C17	D17
>37.5	Hill Area	18	A18	B18	C18	D18

d. Produce multiscenario hazard map

The final objective of the mapping methodology is to produce a multiscenario tsunami hazard map. In order to achieve this objective, the results for the two different scenarios need to be combined into one map, and one matrix. The matrices for scenario I and II already contain the input that is now combined in one single matrix. This step follows the rule that all zones which are affected in scenario I are also affected in scenario II. Consequently, the results from the two scenarios overlap in those areas affected in scenario I. The latter keeps the colour **red** as in the first hazard matrix. The remaining hazard zones of scenario II are coloured **orange**. Therefore, the hazard zone of scenario II is described by **red** and **orange**, while the hazard zone of scenario I is **red**. Areas without hazard attribution in either scenario are left blank, and are considered no-hazard zones (see table 6).

Table 6: Hazard attribution in accordance with Scenario I & II



Potentially impacted in a **Scenario I** tsunami event
Potentially impacted in a **Scenario II** tsunami event
No potential impact in either scenario

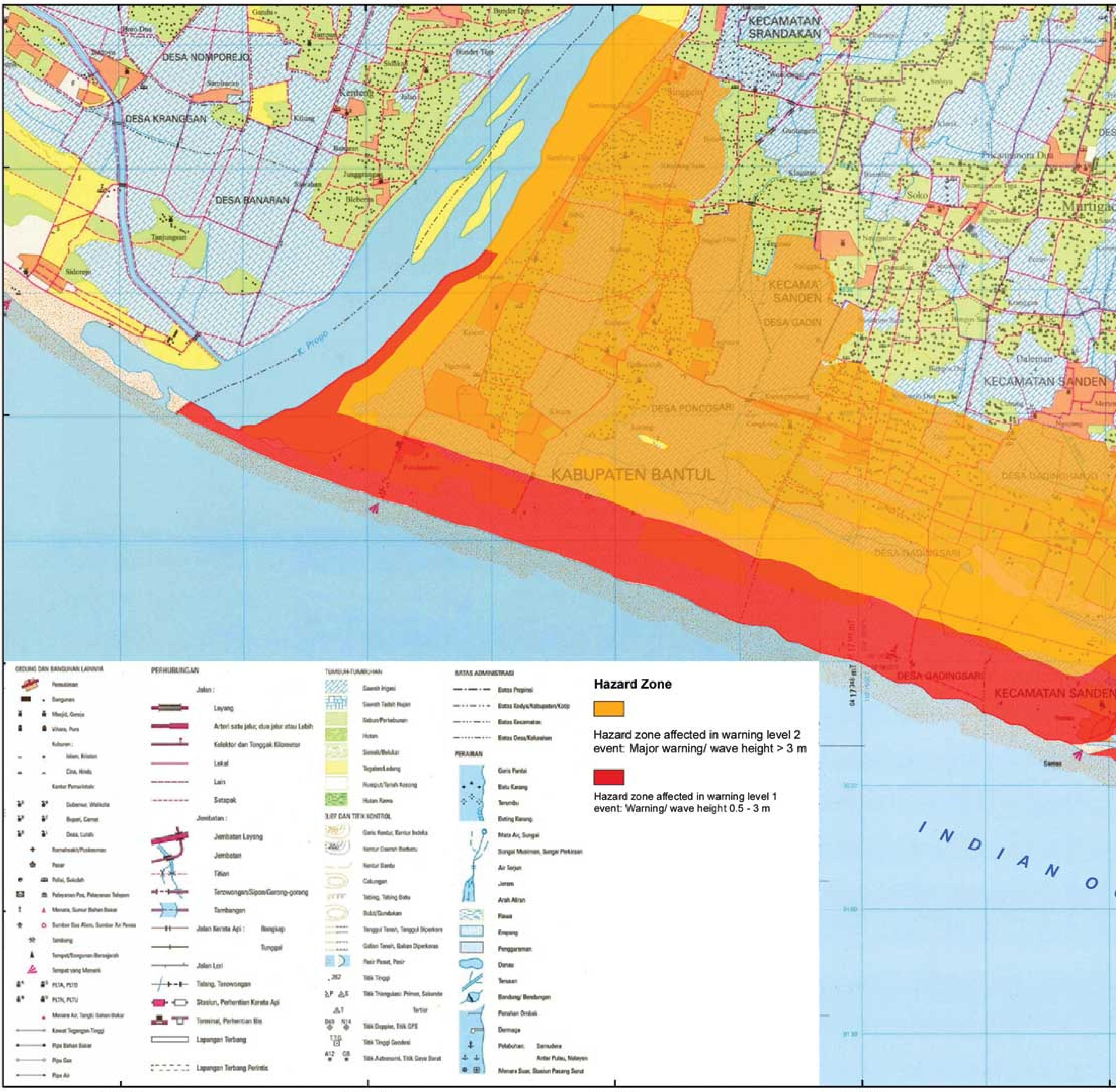
The resulting final hazard matrix for a multiscenario map can be seen below. The **Zoned Multiscenario Tsunami Hazard Map** (see example from District of Bantul on the next page) is produced by simply translating the outcome of the hazard matrix into the base map. For this purpose, the zones in the already digitalized base map are assigned hazard classification (**red** or **orange**) in line with the hazard matrix.

Tool 6 Hazard matrix showing affected geographics areas in Scenario I&II

EXAMPLE: BANTUL

Elevation in m	Geomorphological features		Horizontal distance from the coastline			
			-500 m	500 - 1.000 m	1.000 - 2.000 m	2.000 - 4.000 m
		No.	A	B	C	D
0.5	River banks	1	A1	B1	C1	D1
	Sand dune (0-5m)	2	A2	B2	C2	-
	Flood plain (river)	3	-	B3	C3	D3
	Flood plains (rain)	4	-	B4	C4	D4
	Plain	5	A5	B5	C5	D5
5-12.5	River banks	6	A6	B6	-	D6
	Sand dune (5-12.5m)	7	A7	B7	C7	-
	Flood plain (river)	8	-	B8	-	D8
	Flood plains (rain)	9	-	-	-	D9
	Plain	10	A10	B10	C10	D10
12.5-20	River banks	11	-	-	-	D11
	Sand dune (12.5-20m)	12	A12	B12	C12	-
	Plain	13	A13	B13	C13	D13
	Flood plains (rain)	14	-	-	-	D14
20-25	Sand dune (20-25m)	15	-	B15	-	-
	Plain	16	A16	B16	C16	-
25-37.5	Plain	17	A17	B17	C17	D17
>37.5	Hill Area	18	A18	B18	C18	D18

TSUNAMI HAZARD MA
D.I. Yogyakar



Scale 1 : 25.000
(at 70 x 50 cm Size)
0 255 510 1,020
Meters

Projection : .... Geographic
Datum : .... WGS - 84
Grid Units : .... Lat/Long
Production of Hazard Map : .... June 2008

Topographic Map :
Rupa Bumi Indonesia (RBI), Scale 1:25.000,
BAKOSURTANAL, 1999

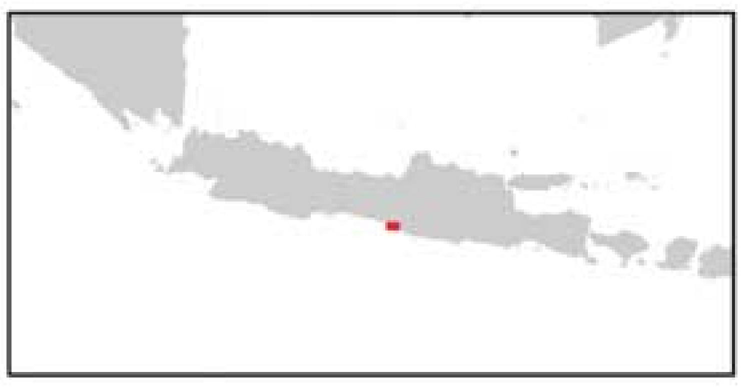
Hazard Map Information and Methodology

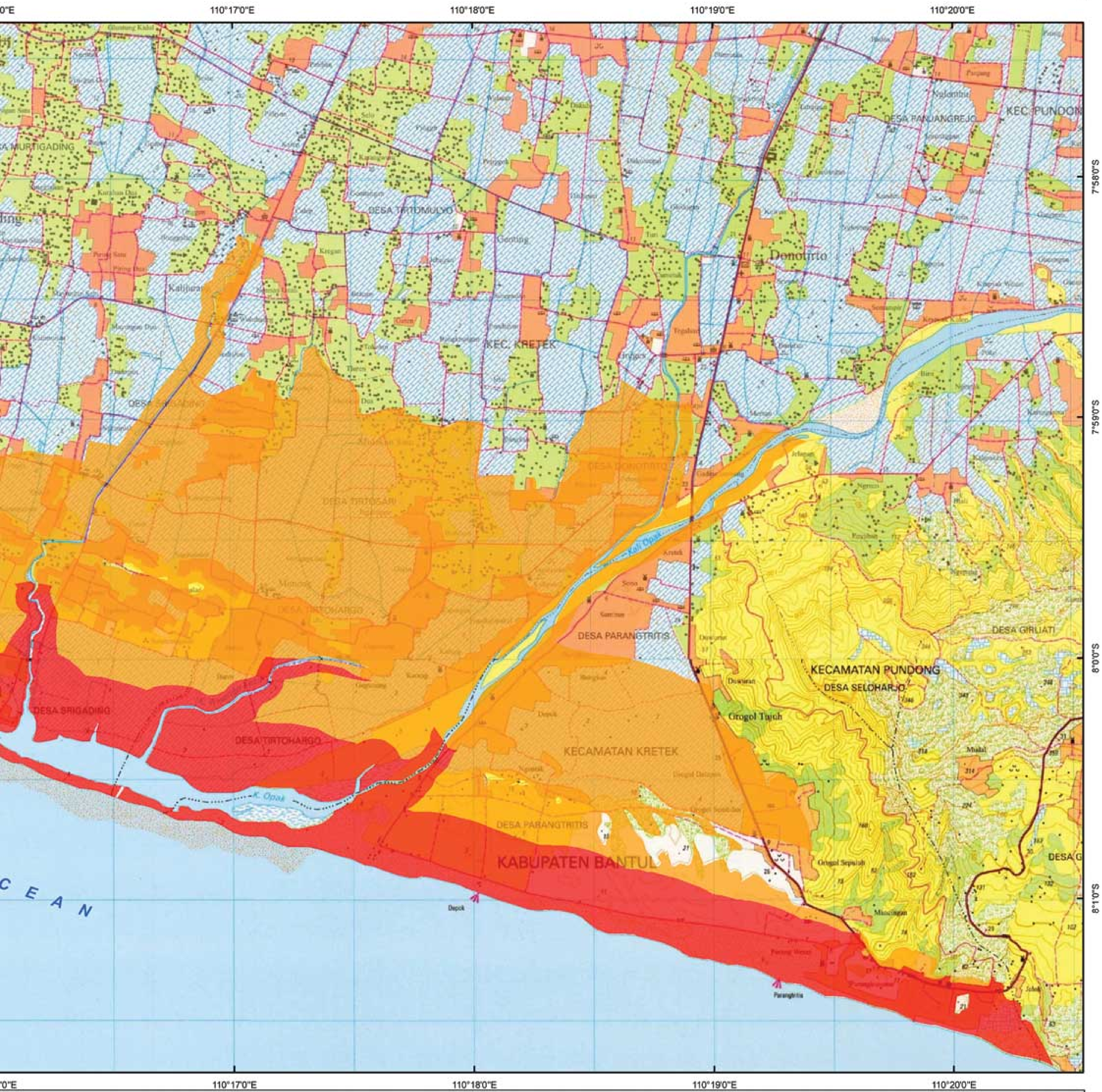
The hazard map was developed on the basis of a zoned base map. The zones i
inundation data and geomorphologic features in different elevation levels taken

Using this zoned base map the potential impact on land in two different scenario
0.5-3m. For estimation of impact on land a max inundation of 500m was used (a
"Major Warning", with a wave height of >3m and an estimated max inundation o

The estimated impact on land of these two scenarios was combined in the single
shown in orange are pote ntially affected in a Warning Level 2 event.

P BANTUL DISTRICT
rta Province





in the base map are the result of the combination of distances from the coast delineating historic tsunami from the topographic map.

os was estimated. Scenario I represents BMG Tsunami Warning Level 1: "Warning", with a wave height of average max inundation in Indonesia) for Warning Level 1. Scenario II corresponds to BMG Warning Level 2: f 4000m (max inundation from Aceh-Tsunami).

e tsunami hazard map. All areas in red are potentially affected in a Warning Level 1 event while the areas

In cooperation between :

PEMERINTAH DAERAH KAB. BANTUL

GTZ GLG

DEPARTEMEN KELAUTAN DAN PERIKANAN

PSBA FAKULTAS GEOGRAFI UNIVERSITAS GADJAH MADA

Figure 10:
Base Map-Bantul District

Annex

Resources needed for Tsunami Hazard Mapping

Several resources are needed for this kind of tsunami hazard mapping. The participants, external experts and local representa tives should make sure that the following resources are readily available for the mapping:

- All relevant topographic maps available, scales: 1:25.000 and 1:5.000 (and 1:1.000, if available) and GIS data
- Existing tsunami hazard information and maps
- Other hazard and thematic maps, such as a flood hazard map
- Photocopies of maps that serve as a primary visualization and mapping tool (the mapping exercise used the topographic map: Rupa Bumi (RPI) with a scale of 1:25.000, produced by BAKOSURTANAL, 1999)
- Plotted or printed satellite images (if available, e.g., from Google Earth)
- Multicoloured crayons, ruler
- Flip chart, pin board and cards, whiteboards (depending on availability)
- Camera

The team that conducts the hazard mapping should consist of national experts and local stakeholders (representatives from local authorities, governmental and non-governmental organisations, local experts and other resource persons).

Institutions in Indonesia involved in Tsunami Hazard Assessment and Mapping

Institution	Address and website
Badan Nasional Penanggulangan Bencana, (BNPB)	Jl. Ir. H. Juanda No. 36 Jakarta Pusat T: +62-21-3458400 F: +62-21-3458500 Email : posko @ bnpb.go.id www.bnpb.go.id
Badan Koordinasi Survei dan Pemetaan Nasional, (BAKOSURTANAL)	Jl. Raya Jakarta - Bogor KM. 46 Cibinong 16911 T: +62-21-875 3155 F: +62-21-875 2062-63 ext 3608, 3609, 3611 and 3103 www.bakosurtanal.go.id
Badan Pengkajian dan Pengembangan Teknologi, (BPPT)	Jl. M.H Thamrin 8, Jakarta 10340 T: +62-21-316 8200 F: +62-21-316 8219, +62-21-319 24319 http://portal.bppt.go.id
Dinas Kelautan dan Perikanan , (DKP) - Ministry of Marine Affairs and Fisheries	Jl. Medan Merdeka Timur No.16, Gedung DKP Lt.10 Jakarta Pusat 10110 T: +62-21-351 9070 F: +62-21-352 2059 www.dkp.go.id
Departemen Energi dan Sumber daya Mineral, (ESDM) - Ministry of Energy and Mineral Resources	Jl. Medan Merdeka Selatan No.18, DKI Jakarta 10110 T : +62-21-351 9881 F : +62-21-351 9881 www.esdm.go.id
Institut Teknologi Bandung, (ITB) – Bandung Insitute of Technology	Kantor: Jl. Tamansari 64, Bandung 40116 Kampus: Jl. Ganesha 10, Bandung 40132 T : +62-22-250 0935 F : +62-22-250 0935 www.itb.ac.id
Lembaga Ilmu Pengetahuan Indonesia, (LIPI) – Indonesian Insitute of Science	Jl. Gatot Subroto 10, Jakarta 12710 T: +62-21-522 5711 F: +62-21-526 0804 www.lipi.go.id
Lembaga Penerbangan dan Antariksa Nasional, (LAPAN)	Jl. Pemuda Persil No.1, Jakarta 13220 T: +62-21-489 2802 F: +62-21-489 2815 www.lapan.go.id
Pusat Vulkanologi dan Mitigasi Bencana Geologi – Center of Vulcanology and Geological Hazard Mitigation, (CVGHM) and – Center for Geological Survey, (CGS).	Diponegoro 57, Bandung 40122 T: +62-22-727 2606 F: +62-22-720 2761 http://portal.vsi.esdm.go.id/joomla Diponegoro 57, Bandung 40122 T: +62-22-727 2606 F: +62-22-720 2761 http://portal.vsi.esdm.go.id/joomla
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RISTEK

German - Indonesia Cooperation for a Tsunami Early Warning System

Federal Ministry of Education and Research