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TSUNAMI PREPAREDNESS

INFORMATION GUIDE FOR DISASTER PLANNERS

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TSUNAMI PREPAREDNESS
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This guide is prepared based on the Japanese document titled 'Guidebook for Tsunami Preparedness in Local Hazard Mitigation Planning' developed in March 1998 by the Government of Japan with the cooperation of the National Land Agency, the Ministry of Agriculture, the Forestry and Fisheries Structural Improvement Bureau, the Fisheries Agency, the Ministry of Transport, the Japan Meteorological Agency, the Ministry of Construction, and the Fire and Disaster Management Agency.

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PLANNING for a threat of local, regional and global reach

Where and when will the next tsunami strike?

Even with today's sophisticated technology, much remains to be learned about tsunamis. Unfortunately, their location and magnitude are very difficult to predict.

When a tsunami is generated, its height and arrival time vary according to local coastal configurations. The resulting types of damage can further complicate safety planning.

United Nations Educational, Scientific and Cultural Organization

Intergovernmental Oceanographic Commission

The Intergovernmental Oceanographic Commission (IOC) of UNESCO recommends that planners use this guide as a basis for forming a strong community tsunami readiness policy. It provides a general plan of action and basic framework for dealing with the unique hazards resulting from tsunamis. This guide outlines the construction and maintenance of defensive structures and discusses how current disaster prevention and emergency response planning can be improved by using research on past tsunamis.

We strongly recommend that local authorities take into account each community's unique circumstances and periodically review current action plans. In this way, planners will be able to adapt each community's unique topography, special circumstances, changes in the social environment and scientific research to the proposed overall strategy contained in this guide.

Disaster planners need to be ready

The greatest proportion of the world's surface is water and the vast majority of the world's population lives in coastal areas.

Alarmingly, millions of lives are potentially at risk from the threat of tsunamis.

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TSUNAMI hazard mitigation planning*

Signs like this one shown here on a beach in Thailand alert coastal residents to head for high ground in case of earthquake.

PROTECTING LIFE AND PROPERTY IN AT-RISK COMMUNITIES

When a tsunami strikes, the lack of a defined preparedness policy will leave a community's emergency response confused and unclear. The combination of vigorous planning and an effort to make people aware of the danger of tsunamis can protect our communities.

We too often fail to learn the lessons of history from coastal areas that are vulnerable to repeated tsunami attacks. The fact that tsunamis are relatively uncommon further contributes to the complacency in our society.

In order to put preparedness measures in place, residents, users of coastal areas, private enterprises and governments need to achieve a common understanding. In the face of a tsunami hazard, individuals need to know how to protect themselves. Communities must be responsible for their own protection.

** The term 'tsunami hazard mitigation plan' used throughout this guide refers specifically to tsunami readiness and is intended to represent just one part of overall local disaster planning.*

LOCAL PLANNING

Tsunami preparedness is just one part of a comprehensive plan covering a broad range of possible local damage, including that caused by earthquakes, wind and rain, storm surges and volcanic eruptions.

When a tsunami is generated in a local area, there is little or no warning time before it strikes. Consequently, the building blocks of tsunami readiness are advance planning and the establishment of evacuation areas, maintenance of evacuation routes, communication systems and the rapid dissemination of accurate information.

The two key areas that officials need to set up are:

- URBAN PLANNING to strengthen at-risk communities' preparedness, including zoning restrictions, relocation to higher ground, renovation and reconstruction of dilapidated structures;
- EMERGENCY READINESS forming the organizational structure and activity behind tsunami readiness, such as warning systems, establishing evacuation zones and routes, public educational programmes and protection of the fishing industry.

THE BASIS OF TSUNAMI READINESS

In assessing the risk, namely, configuring the magnitude of a theoretical tsunami and identifying vulnerable areas, officials should make projections based on the largest tsunami possible. Using this as a hypothetical benchmark fosters the maximum safety for planning purposes.

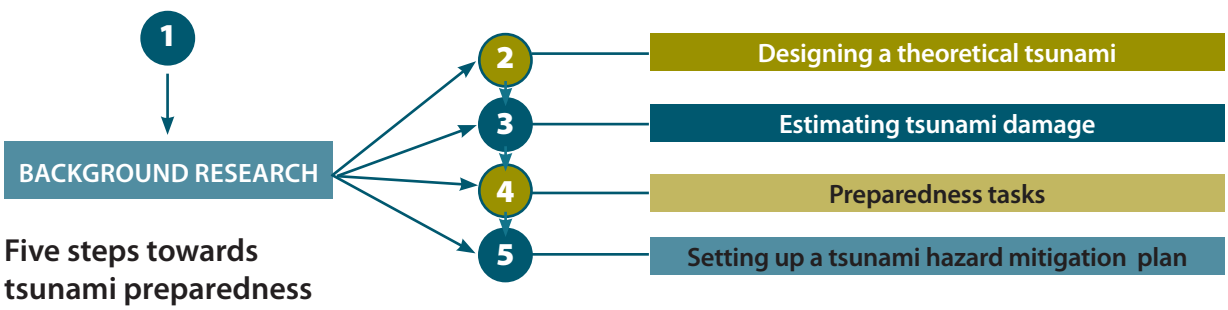
Recent scientific research on earthquakes generating tsunamis along high-risk coasts and data from the largest tsunamis (for example, water mark heights for recent and geological evidence for older ones) provide us with scientific evidence, sometimes very accurate. This information enables us to make projections and assess the potential threat for tsunamis in a given area.

FIVE STEPS towards tsunami preparedness

Flooding along the coast of Banda Aceh, Indonesia just after the December 2004 tsunami. Tsunami damage is greatly influenced by topographical factors, such as coastal configuration.
Photo by Agustinus Wibowo

A number of vital factors are involved in assessing potential danger to an area, including coastal topography, land use, population, concentration of industry, resident attributes, progress of pre-planning, and other unique features of the area.

This guide broadly organizes the procedure of establishing a tsunami hazard mitigation plan into **FIVE STEPS**. In this way, the planner can follow the process of developing tsunami preparedness from start to finish, comprising:



Five steps towards tsunami preparedness

STEP ONE
BACKGROUND RESEARCH

1.1 FOCUS OF RESEARCH

Planners need to understand the unique features of each at-risk region. To this end, the following surveys and research need to be conducted:

- **Survey of socio-economic factors**
  Coastal regions are among the most important in terms of production and distribution of goods, housing and recreation activities. Their many purposes lead to extremely varied development and usage. As the information in **Table 1 'Use of coastal land and points of confirmation'** (on page 20) illustrates, the damage caused by a tsunami in terms of type and scale depends greatly on the unique features of each coastal region, as well as its configuration, usage and urban development. A survey of socio-economic factors must include the variance of coastal configuration and incorporate both present and future intended types of land usage, concentrations of population and industry, and the percentage of elderly people in the population. The survey must also be sure to outline public attitudes and awareness towards tsunami preparedness, the progress of plans underway, and tasks and measures to be adopted.

- **Research on the effects of topography**
  Tsunami damage is greatly influenced by topographical factors, such as coastal configuration (coastline and inland topography) and sea floor topography. These factors are listed in **Table 2 'Potential effects of topography'** (on page 20). For example, if a bay is v-shaped, the concentration of the tsunami's energy tends to be amplified and the water level throughout the bay tends to be higher.

At the outermost point of the cape and inland, the effect of topography and the diffraction from the cape tend to concentrate and magnify the wave (increasing the force of the tsunami by a concentrated effect). As the tsunami approaches shallow water, its water level tends to become higher (increasing the force of the tsunami by shallow water effect). When the natural period of a bay and the periodicity of the tsunami are proximate, the water surface movement is reverberated by the tsunami, and the result is a higher water level in the bay (increasing the force of the tsunami due to reverberation effect). Once the tsunami has breached natural or human-made defences, the area of inundation will be increased by low-lying flat land beyond the shore. As such, even easily accessible cliffs and high ground that would normally serve as useful evacuation sites during a tsunami emergency may be difficult to reach if flat ground or gentle hills are located immediately behind the shore. Consequently, escape routes should not follow a parallel track to the sea side.

1.2 DAMAGE ASSESSMENT FROM PAST TSUNAMIS

By obtaining a clear understanding of the extent and causes of life and property damage (including secondary damage) of past earthquakes and tsunamis, we are able to develop a profile of the largest historical earthquake. This not only helps to design a theoretical tsunami, but also permits us to assess potential damage to coastal areas.

The IOC's Ocean Mapping Programme enhances the capabilities of Member States to model the advance and impact of a tsunami wave by developing bathymetry in coastal areas as well as in the high seas.

New scientific research and updated land surveys, as well as the latest seismic information on earthquake-free areas and earthquake periodicity should be incorporated into this profile. **Table 3 'Survey items and their purposes'** (on page 21) lists examples of some of the types of information needed for this assessment.

Planners will consult surveys, reports and historical records in local archives to develop accurate profiles of past earthquakes and tsunamis. Such archives often describe the reconstruction efforts following earthquakes and tsunamis. From these records, we can learn much about the features and extent of damage caused by a tsunami. Other valuable sources of information include direct interviews with historians and witnesses. There will of course be far fewer witnesses for earthquakes that occurred long ago. Consequently, planners should bear in mind that historical details may often be more legendary in nature and not always so reliable.

1.3 REVIEWING TSUNAMI PREPAREDNESS PLANS

To better understand the current state of a given tsunami hazard mitigation plan, planners should undertake a systematic review of existing safety plans. **Table 4 'Items for review'** (on page 21) provides an essential frame of reference for each stage of this planning.

Public hearings, with groups or individuals, are important to this review process. They will give you insights and evaluations of planning and tsunami readiness based on day-to-day community life. Make efforts to consult a wide range of residents, including younger residents too, and avoid selectively choosing well-known or important people in the community.

Drills are a unique opportunity to check tsunami preparedness at the community level. Evacuation exercises have proven to be an effective way of building citizens' trust in safety plans.

Be sure to visit the site in person rather than relying solely on secondary sources such as records and hearings. Seeing the site with your own eyes is an indispensable way to form a complete understanding of how the land is used, the location and usage of nearby facilities and how well defence structures and escape routes are maintained.

1.4 ASSESSMENT OF COASTAL AREAS

Three aspects of coastal and inland areas should be examined in order to assess the risk of danger accurately:

a. Natural environment

Table 5 'Research items and purpose' (on page 22) outlines the items to be considered at each planning stage. These concern the natural characteristics of target areas, including topography, gradient and depth of the sea floor, sea conditions, sea level (especially lunar month high tide averages) and ocean waves as well as inland topography.

b. Socio-economic structure

Table 6 'Research items and purpose' (on page 23) outlines the items to be considered at each planning stage. These relate to the attributes of the population and the economic activity of the community (e.g. type of business, number of employees and production output). How resistant buildings are to earthquakes, their size and date of construction must all be determined. Other items include the level of community awareness and distribution of households and higher-risk groups, such as elderly and physically challenged residents.

c. Patterns of land usage

Table 7 'Research items and purpose' (on page 23) outlines the items to be considered at each planning stage. These include the condition of coastal land and ground, urban form, the location and distribution of city facilities, land usage plans in action, development plans, most recent trends and long-term planning. The location of lifeline facilities and networks, as well as hospitals and schools, is critical for tsunami preparedness.

STEP TWO
DESIGNING A THEORETICAL TSUNAMI

ASSUMPTION OF A THEORETICAL TSUNAMI

A theoretical tsunami can be designed using two main sources of information:

a. Data from the largest past tsunami (as identified by relatively precise high water marks or geological evidence). Estimating highest water levels is necessary, but insufficient without an accompanying estimated arrival time of the tsunami (determined by the distance between the wave source and the coastline in question), and an evacuation time for people, ships and boats;

b. Recent seismic (or earthquake) data relating to the possible generation of tsunamis along specific coasts. It is worth noting that the largest earthquake does not necessarily generate the largest tsunami; even a relatively small magnitude earthquake can provoke a tsunami. Therefore, evaluations of an earthquake's epicentre, scale, depth and location, energy direction and displacement of fault motion are used in designing a theoretical tsunami.

A special note on distant tsunamis

Distant tsunamis, caused by undersea earthquakes far off the coast, can take four hours or more to arrive onshore. Those registering high waves are infrequent. This lack of data means making a projection for a theoretical tsunami based on the statistical analysis of a distant tsunami is very difficult. However, among those that have been observed, the Lisbon earthquake and tsunami of 1755 in the northeast Atlantic, the Great Chile Earthquake of 1960 in the Pacific Ocean and the Great Sumatra Tsunami of 2004 in the Indian Ocean are considered valid to use as the basis for a theoretical tsunami..

Secondary damage caused by tsunamis includes floating debris, fires and damage by chemicals such as oil. *Photo by Hellmut Issels*

STEP THREE
TSUNAMI DAMAGE ASSESSMENT

In order to protect life and property from the damage caused by a theoretical tsunami, the type and scale of potential damage must first be estimated.

This estimate is derived from evaluations of damage caused by past tsunamis, along with current land use,

population, and agglomeration of buildings and industries in the at-risk community. These factors are then compared to the estimate of a theoretical tsunami's inundation (calculated from the numerical analysis of approximate water height) and existing shore protection structures, the results of which can effectively indicate the extent of danger.

Nevertheless, there will still be considerable uncertainty in regard to the secondary damage that tsunamis cause, namely floating debris, fires and damage by chemicals, such as oil. With this in mind, the estimate itself should only be used as a bare outline of all the potential hazards.

3.1 ITEMS TO BE USED IN THE ESTIMATION OF TARGET AREAS

To evaluate the potential damage caused by a theoretical tsunami, surveys detailing the characteristics of the target area should be conducted as outlined in **Table 8 'Items and standards of evaluation'** (on page 24).

3.2 METHODS OF ESTIMATING AN INUNDATION AREA

An effective tsunami inundation projection map assists planners to make informed decisions for the protection of life and property in high-risk areas.

- **Estimating maximum height of a tsunami**
  Along each shoreline, the maximum height of the tsunami is established according to the numerical calculations of the theoretical tsunami.

- **Estimating inundation**
  Inundation is assessed by comparing the maximum height of the tsunami along each shoreline including the crest height of shoreline protection structures.

Projecting the area of inundation for the target area is an extremely important part of tsunami hazard mitigation. Inundation data for recent tsunamis are relatively available, whereas there are practically none for others.

High water marks of past tsunamis are one of the most reliable sources of information. However, they are solely indicators of the extent of the inundation and tell us little about the water level or spatial distribution of the flow velocity. Therefore, in assessing the danger, the area of inundation projected by the theoretical tsunami is indispensable. Inundation scenarios are essential because they are not dependent on the presence of high water marks.

The feasibility of evacuation is evaluated by comparing the time required to escape to safety zones from the start of the evacuation to the estimated arrival time of a tsunami.

Assessing the dangers of tsunamis is possible through this general framework. However, when a detailed survey of population, concentration of industry, topography and characteristics of inland areas is available, the following numerical outputs of the tsunami (including runup calculations) will help improve mitigation measures:

Items for projection to determine area of inundation:

- Tsunami coastal water level (including the maximum water level);
- Precise time of tsunami arrival;
- Depth of inundation on land;
- Increase of velocity at the edges of inundation areas.

3.3 FEASIBILITY OF EVACUATION

The warning and disaster evacuation system is the most important element in ensuring the public's safety. In the evacuation plan, the theoretical tsunami's time of arrival provides only a limited time for people to move safely to refuge areas. Great care must therefore be taken in the selection of evacuation sites and routes.

The first wave may not necessarily produce the highest runup; safety plans should anticipate a series of waves.

a. Determining evacuation sites and safety zones
The availability of safety zones that can be used as evacuation sites *within walking distance* must be inspected. Potential safety zones are hills over ten metres in elevation or open land outside the inundation area. These zones must be safe from the threat of fire. Consider using high buildings for vertical evacuation in areas without such zones.

b. Estimating evacuation time
Evacuation time is calculated using the distance to the safety zone and the speed of the evacuees.

- A road that meets these necessary conditions and represents the shortest route possible must be designated. When the safety zone borders a river or hills, it may be necessary to make a large detour. Narrow or dangerous points along routes that could present obstacles during an evacuation must be accounted for.
- The time required to evacuate is set at human walking speed. For the sake of safety, adjust this speed to the pace of the elderly or physically challenged in areas where many such residents live.

3.4 COMPARISON OF THE TSUNAMI ARRIVAL TIME

The feasibility of evacuation is evaluated by comparing the time required to escape to safety zones from the start of the evacuation to the estimated arrival time of a tsunami. The starting time for evacuation should be set based on the warning system and evacuation plan of the target area.

STEP FOUR
PREPAREDNESS TASKS

Once the basic survey, research and damage estimate have been carried out, the vulnerability of the target area can be assessed. Two protective measures that should be assessed are profiled in **Table 9 'Items for identifying tasks'** (on page 25) and comprise:

1. Urban planning based on tsunami preparedness; and
2. The organizational system for dealing with emergencies.

Based on weaknesses found in these two measures, planners will be able to determine and assess problem areas needing attention.

STEP FIVE
SETTING UP THE TSUNAMI HAZARD MITIGATION PLAN

Implementing a tsunami preparedness plan should form just one part of a local authority's overall hazard mitigation plan.

Planners will be responsible for determining content, organization, method, schedule, and required funding.

The most effective plan, however, will be based directly on local socio-economic conditions and will incorporate the two main areas of preparedness outlined in Step Four, taking into account the problems and tasks described therein. Financial restrictions, effectiveness of readiness measures and their effects on the community's daily life also need to be incorporated.

In this way, a comprehensive plan can be adopted based on measures prioritized according to urgency, importance and feasibility.

INCREASING tsunami preparedness

Waves lose much of their strength when they hit breakwaters like this one, built to protect a harbour along the Pacific coast.

1. DEFENCE STRUCTURES

Defence structures reduce the damaging effects of tsunamis. They include:

- Tsunami control forest belts;
- Tsunami-resistant buildings;
- Others (sea walls, tsunami breakwaters, tsunami tidegates, river dikes, etc.).

Tsunami breakwaters and tsunami-resistant buildings are based on the premise that the tsunami will undoubtedly breach existing sea barriers. Their construction largely depends on civil planning, so they are mentioned here as reference points. They can be effective by blocking floating debris. Exactly how effective they are, however, is difficult to quantify. If the tsunami runup depth is over four metres, these defence structures have practically no beneficial effect.

2. URBAN PLANNING

The main task of urban planning based on tsunami readiness is to reduce the amount of damage as much as possible through appropriate land use and relocate the most important facilities that protect life and property to areas (such as higher ground) that are safe from tsunami attack.

This strategy is summarized in **Table 10 'Outline for urban planning and tsunami preparedness'** (on page 26), and includes land use, public facilities and transportation.

It is of course extremely difficult and in many cases almost impossible to relocate residential homes and important facilities to safer locations. This being the case, medium and long-range planning based on a safer use of land in at-risk areas should aim to reduce structural damage (by appropriate land usage and reinforced construction). Restrictions should be placed on at-risk areas to alleviate the concentration of structurally vulnerable buildings, whilst new construction in these areas should be avoided altogether.

Nevertheless, construction needs in inland and coastal areas depend on usage and location for the promotion of business, commerce and residential life. As such, it is important to advocate tsunami safety based on land usage that maintains a balance between the promotion of safety standards and the function of land in each area. Any construction in dangerous areas should be tsunami-resistant so as to prevent damage to the structure itself and also reduce the amount of damage inland.

Tsunami readiness should also feature prominently in the design and construction of transport networks and public facilities. Encouraging the use of land in this way is essential for effective evacuation and rescue efforts.

Modern business and society is rapidly changing. Tsunamis, by contrast, occur relatively infrequently. Records of past tsunamis may not reflect certain problems we face today, such as locating and dealing with dangerous substances. To assure maximum tsunami preparedness, planners must also deal with the challenge of assessing the potential of new dangers associated with the target area's future development and convenience of daily life.

2.1 PROMOTING DEFENSIVE LAND USE IN URBAN AREAS

- **Relocation to higher elevation**
  This possibility should be considered and be a part of government reconstruction policy when houses are located in areas expected to receive extensive damage.
- **Planned land use**
  A restricted land use policy is an effective alternative in at-risk coastal areas where relocation is a difficult option, although current patterns of land use, future development of the area and the convenience of local residents must be taken into account.

2.1.1 Land use planning and introduction of anti-tsunami or buffer districts

Urban planning should also include measures to restrict land use in areas that could serve as buffer districts.

When evacuation/anti-tsunami construction is planned along the coast, or when unused fields must be secured as part of a defence programme, it is important to seek a balance between the everyday use and that required during an emergency.

The placement of centres for evacuation and rescue in safe areas is of the highest importance in designing community-based tsunami preparedness. *Photos by Rendy Maulana*

2.1.2 Protection and construction of safety facilities

Generally, forests are ineffective against large tsunamis. However, a forest that is wide and well maintained can reduce the flow velocity of a tsunami by creating a block against floating debris and helping to reduce damage to houses further inland. Indeed, there are numerous cases of people saving themselves by holding onto trees as the tsunami retreats.

2.1.3 Vital public facilites

City halls, schools, public halls, and parks will become centres for evacuation during a tsunami. Their placement in safe areas is accordingly of the highest importance in designing community-based tsunami preparedness. In areas that have been attacked before and/or areas at high risk, public facilities are often already placed in safe locations; if not, appropriate steps should be taken to ensure construction is tsunami-resistant. Sensitive facilities, such as hospitals or police/fire department buildings, should be relocated to safer places if the survey shows they are in areas at risk.

At-risk areas must be able to locate and access their existing public facilities. If these facilities are located far from residential areas, ensure that evacuation routes do not pass through hazardous areas.

2.1.4 Transportation and urban infrastructure

In building community-based tsunami preparedness, road and rail networks and maritime routes will serve as evacuation and emergency supply routes and should consequently be strategically placed. Planning should be geared towards strengthening the safety of ports because following a tsunami they may function as rescue and reconstruction centres.

Main roads

Main roads, such as national and prefectural routes, are critical as supply routes during an emergency. As much as possible, their passage through hazardous areas should be avoided; if this is impossible, roads must be fortified against earthquakes and flooding. In extreme cases where main roads are inaccessible during a tsunami, an alternative network of detours must also be built and fortified in order to be in place and ready for emergency transportation.

Development tends to occur along main roads. Main roads in safe areas therefore serve as an inducement to safe land usage. In cases where elevated roads and heavy traffic cross coastal areas, alternative evacuation route measures must be in place.

Local roads

Local roads also need to be fortified in order to serve as escape routes. The construction of direct routes linking ports to safe residential areas located further

inland on higher ground is key to promoting safe land use.

Railroads
Railroads need to be built in safe areas. When they traverse hazardous areas, they should be properly fortified.

Transportation lines as dual levees
Some communities have the advantage of effectively having two levees by roads and railways. In such cases, it is necessary to reinforce levees by elevating the roadbed and stone or concrete pitching of the embankment. The gap in the junction between the embankment filling and the wing wall of the concrete abutment is a weak point. Lightweight beams on railroad bridges are also susceptible to damage by floating debris.

Maintaining safety in ports and harbours
Being able to ship emergency supplies by sea is vital in areas that might be cut off from emergency relief transport, such as those surrounded by mountains or peninsulas. Accordingly, ports or harbours must be fortified against earthquakes so that they can be used as supply, rescue and reconstruction centres. Attention must also be paid to the safety of anchored and sailing vessels, as well as improving the function of the port and harbour as a relief centre.

2.2 COASTAL FACILITIES AND SAFE LAND USE

2.2.1 General planning

Tsunami-proofing construction
Houses, businesses, public buildings, fishery processing plants, and petrol supply stations, to name just a few, are usually located in protected areas, whereas fishing and recreation facilities are generally found on the ocean side of an embankment. The fishing cooperative, fishery processing plant, and market should be tsunami-proofed by effective methods such as steel-framed reinforcement. During past tsunamis, strong buildings at the water's edge have functioned to shield the buildings behind them.

Much damage will be caused during a tsunami by boats colliding or being cast upon the shore. *Photo by Oliver Mannion*

Hazardous Materials
Hazardous materials, such as spills of oil and gasoline, cause secondary damage during a tsunami. Great care should therefore be taken to ensure they are protected and safely stored.

Storage tanks should be buried and steps to prevent spills should be taken in order to make them less susceptible to tsunamis. Another measure is to store such materials in tsunami-proofed warehouses, but volume and size are often in excess of the capacity available, in which case little can be done.

Improvements to timber yards are an immediate concern. Tsunami waves often turn timber, fishing boats and equipment into projectiles. They are carried on the waves as they surge inland and easily destroy embankments, bridges, facilities and houses.

The safety of residents is of paramount importance. Sufficient supplies for the rapid recovery of spills and/or extinguishing fires should be stored and ready and procedures carefully planned. Management and public authorities in charge of hazard mitigation should cooperate during the design and construction phase of such facilities to create a functioning system for such emergencies.

2.2.2 Coastal communities and improving safety

Coastal areas are usually highly populated and developed; they represent an important part of national life and productivity. Planners should use these characteristics to their advantage for improving safety in the following areas:

- **Residential areas**: In coastal regions where the population is dense at night, stress public safety awareness and active participation in safety drills.

- **Commercial districts**: In tourist areas along the coast, large numbers of visitors gather to enjoy leisure activities. Clear systems (developed in conjunction with local residents and owners of tourist facilities) for guiding visitors towards evacuation routes and sites must be in place.

- **Manufacturing and distribution centres**: Ports and adjacent areas, plants and factories, warehouses and distribution facilities must be protected. When the land faces a port with significant sea traffic, much damage will be caused during a tsunami by boats colliding or being cast upon the shore.

2.2.3 Safety planning for ships and boats in ports and harbours

When a tsunami warning is issued, the harbour authority will issue warnings, orders and restrictions for offshore evacuation. Port authorities, ship and boat

owners and fishing cooperatives should meet and agree on pre-planned safety measures. The following points should be organized based on the tsunami's estimated time of arrival:

- Medium and large vessels will be evacuated outside the port;
- Vessels that cannot be evacuated will be safely moored;
- Medium and large vessels will be withheld from entering the port.

Fishing boats
Three main objectives relating to boat safety measures are the protection of life, the protection of property (the boat itself) and the prevention of secondary damage caused by a drifting vessel. During a tsunami, the evacuation of fishing boats endangers those involved and this fact makes it impossible to draw up general guidelines for their evacuation.

Pay close attention to the advisory issued by the National Tsunami Warning Centre regarding the tsunami's estimated time of arrival. If there is enough time, fishing boats preferably should evacuate to deeper waters (around 100 metres depth); if not, it will be extremely dangerous to evacuate to offshore waters. Instead, a combination of loose mooring and loose anchorage can reduce the risk of boats drifting onto land.

There is no best method for boats that are being unloaded on land. If there is time, a boat is advised to lower its anchor outside to make it more stationary during a tsunami. Keeping the mooring and anchor cables loose is widely believed effective in preventing them from being severed by the collision of the first wave or strain from buoyancy.

2.2.4 Protection of lifelines

Telecommunications
Telephone and communication infrastructures are vital during and after a tsunami. Protect cables and switchboards by placing them in safe locations and building secure configurations. Above all, do not build them in high-risk zones. Those already located in hazardous areas must be buried underground or reinforced against tsunamis.

Utilities
Just like telecommunications, electric utilities must be built in safe areas and those in hazardous areas should be reinforced.

Guaranteeing electricity supplies and potential water water sources during an emergency, such as well water and swamp water to evacuation and relief areas, is absolutely indispensable. Communities that draw water from a river should be advised that damage to intake facilities from tsunami runup has been observed in the past.

Creating a civil defence organization and ensuring regular practice of its activities is a fundamental necessity for disaster preparedness.
Photo by Rendy Maulana

There are also cases where tsunami runup has gone through sewage outlet works into sewage pipes and flooded urban areas. Measures both to prevent runup through sewage outlets and prevent damage to terminal facilities located along the coast are essential.

3. DISASTER ORGANIZATION

3.1 BUILDING ORGANIZATIONAL STRUCTURE

Governments should form emergency organizations, if they do not already exist, clearly outline their authority and establish disaster mitigation programmes. This will facilitate a comprehensive and planned administration both for overall safety procedures and a tsunami hazard mitigation plan.

a) Basic disaster planning
The establishment of a central emergency board to consider the overall safety programme is recommended. Its mandate should include establishing emergency organizations, promoting disaster relief initiatives, expediting suitable reconstruction, promoting scientific research related to disasters and finally, administering disaster programmes, including policy directives to develop local disaster planning. At sub-national level the highest political authority (i.e. Governor, Major) should coordinate police/fire departments and public entities. A commission should also determine safety plans at the regional and local levels. Similarly, local authorities should have a safety commission, which is the pivotal organization at the community level.

b) Local hazard mitigation planning
The central government, local government and public organizations are responsible for making and adminis-

tering disaster planning up to city level. Local planning is broader in scope and is based on deliberations by local disaster committees.

c) Disaster headquarters and defence organizations

Rapid mobilization is critical when a tsunami warning is issued or a disaster has occurred. Clear guidelines must therefore be in place for implementing decisions and measures to deal with the command and control of defence organizations when those in charge are absent. To ensure smooth operations, a disaster headquarters should be established to coordinate local organizational structures. A clear division of labour will enable the establishment and deployment of special teams within a cooperative framework. Depending on the circumstances, mobile response teams of an on-site disaster headquarters may be necessary.

d) Civil defence

Creating a civil defence organization and ensuring regular practice of its activities is a fundamental necessity for disaster preparedness. Smooth relief efforts and the prevention of further damage depend heavily on community residents working well together.

An efficient civil defence organization is essential, amongst other things, for:

- Assisting the sick, elderly or disabled to evacuate to higher ground or upper stories of solid buildings;
- Increasing public awareness of tsunami safety through disaster drills and educating the community about evacuation sites and routes; and
- Deployment of emergency centres.

3.2 WARNING AND COMMUNICATION SYSTEM

a) Monitoring tsunamis

In order to understand better the effects of various coastal features on tsunamis and to improve readiness, one of the highest priorities should be to develop and/or enhance a system for monitoring tsunamis.

The National Tsunami Warning Centre will make efforts to strengthen tsunami monitoring. However, the magnitude of a tsunami could be greater than that announced in some areas due to local conditions. In addition, dedicated monitoring networks have different configurations depending on the distance to tsunamigenic sources from the actual risk area.

In all cases the basic components of a tsunami monitoring unit are the following:

- Seismic monitoring;
- Sea level monitoring;
- Updating redundant communications networks.

Is it possible for the warning to reach all households or are there areas where communication is difficult?

b) Warning system

The tsunami warning system must be rapid and accurate. The following issues need to be addressed:

- Is it possible for the warning to reach all households or are there areas where communication is difficult?
- Are there areas where television and radio reception is impossible?
- Are there areas that do not have fixed lines or mobile phone coverage?
- Are residents complacent about the threat of a tsunami? Do they tend to ignore tsunami warnings?
- Is it possible to warn fishing boats at sea?

These issues must be confirmed at the local level. As for tsunami warning systems, expansions of networks between the issuing source and those of mobile and local wireless communications have reinforced the overall wireless warning system. Networks can further be improved by installing wireless communication between integral parts of community life, such as the town hall, schools and hospitals.

c) Building and improving the warning system

To reduce fatalities as much as possible, a rapid and accurate warning system is essential. The system for issuing watches and warnings should be strengthened and diversified. Redundant emergency communications systems should be strengthened not only through the wired system, but also through appropriate combinations of technologies such as satellite and mobile communications.

3.3 EVACUATION OF RESIDENTS

Local authorities should have a system in place for rapid and safe evacuation when an evacuation advisory is issued.

When a disaster occurs or when a warning is issued necessitating an evacuation, the authorities will issue an

order to evacuate. In areas with no history of tsunamis, however, and even in areas that have been struck in the past, public complacency and the passage of time since the last occurrence of a tsunami can negatively affect residents' willingness or speed to evacuate. To counter this, the promotion of public awareness and the practice of tsunami emergency drills are key in building a rapid and safe evacuation system.

When a large earthquake tremor is felt, residents should not wait for a warning to be issued; they need to already understand that evacuation is required. Such knowledge can only be developed through educational programmes that teach communities to leave the shore, head for a safe area and evacuate vessels from the port immediately. This simple message forms the basis of tsunami awareness and should be stressed throughout educational programmes.

What to do in case of a tsunami (general public)

- If you feel strong earthquake tremors or if the tremors are weak and/or slow and continue for a long time, leave the shore immediately and evacuate to a safe area.
- If a warning is issued but you did not feel an earthquake, leave the shore immediately and evacuate to a safe area.
- Listen for accurate information from the radio and television.
- If a tsunami watch has been issued, it is dangerous to continue swimming or fishing.
- Tsunami waves attack repeatedly. Don't move from the place where you are safe until the warning is over.

a) Evacuation routes

During a tsunami, a rapid, safe evacuation saves lives. Planning evacuation routes from residential districts must take into account public daily life to ensure that the evacuation can be carried out smoothly.

The shortest and most direct route to a temporary evacuation site should be the highest priority. When the topography is unsuitable for such a route, an agreement to use public property as shelters in the event of an emergency and the installation of emergency stairways should be considered. The following issues must be addressed:

- Is the selected route suitable?
- Is the road wide enough?
- Are there enough signs indicating the evacuation route?
- Have lights been installed? Lighting and clearly marked signs are especially important during a nighttime evacuation. Emergency power sources for street lighting are effective during a power outage caused by the earthquake.
- Is the public sufficiently aware of the routes?

During an evacuation, vulnerable residents such as children, the elderly, the sick or physically challenged need to be handled differently than the rest of the population.
Photo by bennyhidayat@ft.unand.ac.id

b) Evacuation areas

Evacuation areas should be designated as part of local tsunami hazard mitigation plans.

A safe area should be selected by its topography and elevation outside the estimated inundation area. The evacuation site should have sufficient capacity for the distribution and number of evacuated households, be accessible from escape routes and have a guidance system for evacuees. Frequently used evacuation sites include schools, community halls, temples or shrines, kindergartens, and parks. The designated sites should be checked for safety and ability to withstand earthquakes.

There are three categories of evacuation areas:

- **Temporary evacuation sites**
  A temporary site is a collection point for evacuees. It evaluates the circumstances before moving evacuees on to a wider-area evacuation site. It offers some protection for evacuees, is used for forming groups for further evacuation and is a

centre for volunteer activity. It is usually placed at a park, green tract of land, school grounds or apartment house commons.

- **Wider-area evacuation sites**
  Wider-area evacuation sites refer to parks or tracts of land large enough to protect evacuees from surrounding areas during a large earthquake, fire or tsunami.

- **Evacuation sites**
  Evacuation sites temporarily house and protect evacuees after their homes have been destroyed or threatened by earthquake or fire. Schools and community halls are commonly used.

Depending on the topography and local circumstances, residents and private enterprises should have an understanding concerning the use of high-rise buildings and similar structures during an emergency. In commercial districts where the population is much greater during the day than at night, evacuation sites for non-residents must be established. The same applies for recreational and tourist areas.

In city centres and older housing districts, residents are usually well acquainted with evacuation areas, whereas residents in newer developments tend to be less knowledgeable. Local authorities should therefore choose suitable locations and mark them clearly. Food, blankets, and other supplies should be planned for and stored. Storage facilities should be built to house other emergency supplies.

c) Caring for vulnerable people
During an evacuation, vulnerable residents such as children, the elderly and the sick or physically challenged have special needs and require different handling than the rest of the population.

Along the coasts, schools and kindergartens are frequently built on higher ground. However, some schools, clinics and hospitals are located within inundation areas of past tsunamis, and measures should be taken to relocate them to safer, higher ground. Verify that people in facilities located in high-risk zones (e.g. medical staff, patients, teachers and students) have manuals on evacuation procedures and conduct regular drills.

d) Caring for visitors
Tourists and other visitors generally have little knowledge or awareness about the dangers of tsunamis. Communication systems along the beaches must be readied and awareness of evacuation procedures promoted through educational programmes.

Memorial service in Khao Lak, Thailand for the anniversary of the 2004 tsunami: one light sent into the sky in remembrance of every one of the 2,000 people there who perished in the disaster.

e) Transportation issues
Local hazard programmes generally prohibit residents from evacuating by personal automobiles during any type of disaster. During a tsunami emergency, time is limited and fleeing vehicles not only block roads but also pose a threat to life. For these reasons, evacuation by car is generally not allowed; however, exceptions may be made when safety zones are not within walking distance given the time available to evacuate.

3.4 PROMOTING PUBLIC AWARENESS

a) Collecting data from past tsunamis

- Collection of damage assessments: A number of activities can be carried out. For example, information from interviews with survivors can be included in local defence planning and pamphlets detailing the damage and survivors' eyewitness accounts can be published.
- Public memorials and monuments are effective at promoting awareness among local residents and visitors in areas that have been struck by a tsunami.
- Clear demarcation of inundation areas on maps (used in pamphlets and display panels) and high water marks are effective ways of promoting awareness and improving participation in tsunami preparedness.

b) Educational programmes
The legacy of past tsunamis forms the basis of public safety education and improving public knowledge. Personal experiences with tsunamis are a valuable part of safety education and should be included in the social studies curriculum of elementary and junior high

schools. Tsunami preparedness should be mainstreamed into educational curricula in zones that are at risk. These accounts, combined with the latest scientific research and an understanding of the current state of preparedness are part of an organized and continued effort towards safety education. Participation by local government, industry and public organizations, such as community associations, youth and women's groups make programmes even more active.

c) Developing a safety manual

In addition to general knowledge about tsunamis, the public must know what to do in the event of a tsunami. A manual with simple explanations should be distributed among residents. The manual should include maps of evacuation sites and routes, as well as evacuation procedures and other pertinent information tailored to local needs and features.

d) Public awareness programmes

Public safety depends on cooperation between the government and the public. As awareness decreases, safety measures become increasingly difficult to implement. In view of this, planners should make use of local media sources and public venues, including:

- Media, such as television, radio, newspapers, magazines, public bulletins and notices;
- Permanent displays, memorials, tsunami museums;
- Commemorative activities, symposia, guest speakers and lectures;
- High water marks and danger signs in low-lying exposed areas.

3.5 SAFETY DRILLS

Tsunamis occur so infrequently that safety precautions can easily be forgotten during an actual emergency. Drills, however, will reveal flaws or weaknesses in current systems. They provide important feedback as to whether current evacuation measures, emergency response and mobilization procedures are appropriate and verify if information is given out rapidly enough and accurately. By staging regular public safety drills, as described below, communities can sustain and improve readiness and therefore reduce the amount of potential damage:

a) Tsunami monitoring drills

- Gain experience of tsunami monitoring;
- Accustom participants to relaying monitoring orders and results.

b) Transmission and relay of information drills

- Gain experience of starting up and switching to emergency utilities
- Accustom participants to tsunami forecast transmissions
- Gain experience of gathering information related to damage and the tsunami

c) Public communication system drills

- Test sound level and prompt mechanisms for warning sirens
- Confirm contents for emergency public information
- Confirm channels and timeline for giving out public information
- Make sure public information bulletins are understood
- Check effectiveness of public announcement vehicles or portable radios
- Measure reception area for wireless communication
- Test emergency broadcast systems
- Check relay modes to remote areas and children not in school

In the wake of a tsunami, the local emergency headquarters must be ready to respond. *Photo by Rendy Maulana*

3.6 EMERGENCY RESPONSE SYSTEM

a) Response efforts

In the wake of a tsunami, the local emergency headquarters must be ready to respond in the following areas:

- Gathering/disseminating disaster information;
- Securing roads and transportation networks;
- Distributing food, water and medical supplies;
- Providing emergency medical treatment;
- Conducting rescue and relief operations;
- Assessing hygiene of affected area and preventing the spread of disease;
- Extinguishing chemical or other fires;
- Carrying out emergency rescue of stranded victims by plane or sea.

These response efforts will be coordinated between national, regional and local governments through close cooperation with the police, the Coast Guard, medical personnel and civil engineers. By practicing joint drills, the safety response system should operate more smoothly.

b) Cooperation from the general public

The general public's cooperation is intrinsic to tsunami preparedness. In affected areas, rescue and response are required as follows:

- Draining water from the levees after a tsunami warning is lifted;
- Extinguishing fires;
- Aiding and rescuing the injured and stranded;
- Searching for the missing;
- Informing relief headquarters of the situation on the ground;
- Alleviating public distress by giving out accurate information;
- Conducting night-watches, fire protection, public safety and mutual aid;
- Providing drinking water, food and medical supplies;
- Assessing damage;
- Protecting housing.

Rescue and relief efforts encompass a broad range of responsibilities. Assistance from neighbouring, unaffected areas can be extremely effective. This emergency response system can only be built up through everyday activities and efforts over an extended period of time.

LOOKING forward

People in all regions of the world are entitled to lead safer, more productive lives.

Disasters similar to that of the Indian Ocean tsunami in December 2004 may be mitigated in the future by better warning systems.

Planners can empower their communities to cope with ocean-related natural hazards by designing and implementing local disaster mitigation programmes.

Working together, we can improve tsunami warning readiness in all regions at risk. Our hope for the future is never again to witness a disaster of the magnitude of the December 2004 Indian Ocean tragedy.

UNESCO-IOC's continuing commitment

Based on forty years of experience with the Pacific Tsunami Warning System (PTWS), the Intergovernmental Oceanographic Commission (IOC) of UNESCO is leading a global effort to develop and implement ocean-based tsunami warning systems as part of an overall multi-hazard disaster reduction strategy.

To date, Intergovernmental Coordination Groups (ICGs) have been established for three more regions: the Indian Ocean (IOTWS), the Northeast Atlantic, Mediterranean and Connected Seas (NEAMTWS), and the Caribbean Sea and Adjacent Regions (CARIBE-EWS).

At the present time, the Japan Meteorological Agency (JMA), the Pacific Tsunami Warning Center (PTWC) and West Coast and Alaska Tsunami Warning Center (WC/ATWC) are providing interim information services to these regions until they can assume full responsibility for their own coverage.

The IOC's International Tsunami Information Centre (ITIC) is supplying regions with required material and resources. A tsunami information centre has already been established in Jakarta, Indonesia; another is planned for the Caribbean region.

The UNESCO-IOC Tsunami Coordination Unit

The IOC Tsunami Coordination Unit was established expressly to coordinate early warning system efforts for tsunami and other natural ocean-related hazards with other UN agencies and NGOs and to assist in the development of a common governance structure. The Unit's mission is to ensure adequate design and development of tsunami warning systems and to provide coverage at local, regional and global scale.

For more information

http://www.ioc-tsunami.org
The UNESCO-IOC's one-stop resource for all tsunami related information.

www.tsunamiwave.info/
International Tsunami Information Centre

http://ioc.unesco.org/TsunamiTeacher/
Information kit providing reliable and verified tsunami warning, response and mitigation information and tailored training modules.

http://ioc.unesco.org
The Intergovernmental Oceanographic Commission of UNESCO

REFERENCE tables

Table 1. USE OF COASTAL LAND AND POINTS OFCONFIRMATION IN THE EVENT OF A TSUNAMI

Use of coastal land	Important points for a checklist
Ports and airports, railways and roads	• Concentration of people and goods contribute to risk of greater danger • Paralysis of the transportation network has an enormous socio-economic effect • Risk of human casualties increased by number of passengers and visitors • Evacuation area for larger vessels and tankers
Fishing harbours and fisheries	• High danger of collapse and fire in wooden housing and building developments • Small-scale fishermen will be adversely affected • Safe evacuation sites (elevated platforms, etc.) are relatively few • Evacuation areas for fishing vessels and equipment are few • Danger of blockage in the port, and obstacles in sailing routes caused by debris from fisheries, fishing equipment and nets
Coastal manufacturing and energy storage	• Increased danger of secondary damage caused by flow of lumber • Increased danger of fires in inland industrial areas • Environment could be polluted by leakage of dangerous chemicals
Developed areas (e.g. commercial office buildings and residential districts)	• Increased risk of greater human casualties in densely populated areas • Areas of concentrated housing or construction often have extremely narrow roads, causing difficulty in event of evacuation • Huge adverse socio-economic impact during aftermath • Runup from tsunami possible through inland water supply and sewage lines • Hospitals and nursing care facilities are concentrated in one area, making it difficult to evacuate especially weak/vulnerable people
Coastal parks, recreation and tourism facilities	• Increased risk of casualties due to tourist population • Lack of awareness of designated evacuation areas • Lack of sufficient evacuation areas
Agriculture, forestry and aquaculture in coastal areas	• Increased danger to agriculture and aquaculture • Important socio-economic damage • Forestry belts may help to mitigate damage
Buried waste disposal	• Leads to environmental pollution
Undeveloped coastlines	• Increased risk of casualties involving leisure fishing people

Table 2. POTENTIAL EFFECTS OF TOPOGRAPHY

Topography	Potential effects
V-shaped bay	Tsunami's energy is concentrated and the water level throughout the bay is higher.
Tip of the cape	Sea floor topography effects and cape diffraction amplify the force of tsunamis.
Within the bay	Reverberation effects can amplify the force of tsunamis. A relatively short bay can amplify a local tsunami; a long bay can amplify a distant tsunami.
Ria shoreline	A shoreline full of angles can result in some of the above effects.
Islands	The waves are captured by the perimeters of the island; clockwise and counter-clockwise waves meet, raising the water level. Even when the rear of the island does not face the wave source, this situation results in a higher water level.
Shallow continental shelf	The water height of the tsunami is in inverse proportion to the fourth root of the water depth. The propagation velocity also depends on the water depth; the shallower the water, the slower the speed. Accordingly, the tsunami tends to concentrate towards shallow water and amplification can occur.
Distant shoal	In longer distant shoals, a single tsunami wave is broken up into multiple waves.
Inland topography	If evacuation areas are scarce because inland topography is flat, cliffs or high ground can be used if access roads are good.
Coastal roads	If roads along the coast are high enough, they can become effective levees.
Rivers and water channels	High risk of tsunami runup into the mouths of rivers or channels facing the ocean.

Table 3. SURVEY ITEMS AND THEIR PURPOSES

General description	Items	Purpose
Characteristics of the earthquake	Epicentre and areas of no effect	• Create a theoretical tsunami and profile of largest earthquake-generated tsunami • Determine the point of generation
	Time and frequency	
	Magnitude	
	Fault parameters*	
	Affected area	
	Generation of tsunami	
Tsunami characteristics	Frequency of occurrence	
	Amplification (wave form, periodicity, propagation velocity)	
	Refraction and resonance	
	Time of arrival following the earthquake	As above, including evacuation
	Water level and high water mark	• Determine the theoretical tsunami • Assessment of the largest past tsunami • Projection of inundation and danger areas
	Sedimentology studies	
	Area of inundation (including water depth)	
	Amount of runup	
Human and property damage assessment**	Scale of the damage	Hazard assessment
	Characteristics of the damage	
	Causes	
	Reconstruction efforts (including emergency response and rebuilding)	Plan accordingly

* Fault parameters are determined by the position of the fault lines, depth, length, width, amount and angle of displacement.
** Damage to life and property includes the following categories: (1) Casualties; (2) Housing; (3) Ports and coastal defence structures; (4) Disruption of transportation (rail, road, water); (5) Essential services (water and sewage, electricity, gas, communication networks); (6) Commerce and industry; (7) Fishing and maritime industry; (8) Agriculture; (9) Acqualculture; (10) Forestry; (11) Damage from fire; and (12) Damage to the land foundation.

Table 4. ITEMS FOR REVIEW

General area	Items	Purpose
Tsunami warning system	• Organization responsible (structure and authority) • Warning system (recipients of the warning, method, channels, transmission and reception) and transmission time	Assessment of starting time for evacuation and feasibility of emergency measures
Emergency organizations	• Report of fire/police department activities • Coast Guard or its equivalent (Navy) • Community based emergency organizations • Location and distribution of fire/police departments/Coast Guard/ Navy and facilities, disaster readiness	Assessment of emergency capability and general public awareness of mitigation programme
Educational programmes	• Promoting public awareness through television, radio and newspaper media • Publishing in public information bulletins • Placement of tsunami warning signs, boards, and memorials • Commemorative events to promote tsunami hazard awareness • Distribution of tsunami-related pamphlets • Placement of evacuation route signs • Distribution of evacuation manuals • School curricula with tsunami preparedness content • Rural schools as centres for community preparedness	
Tsunami hazard mitigation programme drills	• Drill contents, frequency of drills • Degree of participation by local residents	Assessment of emergency capability
Organizational system for dealing with emergencies and evacuations	• Issuing evacuation advisory and orders, communications systems, evacuation assistance (identify authorities and organizations in charge) • Local/distant tsunamis	Assessment of evacuation system

(Continued on next page)

Table 4. ITEMS FOR REVIEW (*continued*)

Preparation and maintenance of evacuation areas and evacuation routes	Evacuation sites, designation of evacuation routes, distribution of evacuation sites, location of evacuation routes, topography and altitude of evacuation sites, evacuee capacity, evacuation areas (including their relationship to residential zones), evacuation site structures, readying the approach routes, road width, potential problem spots (bridges, tunnels, etc.)	Evaluation of evacuation feasibility, sites, routes and safety
Urban planning measures related to tsunami preparedness	• Relocation to higher ground • Land usage, including bulwarking • Establishment of buffer zones • Future development plans	Assessment of the danger of tsunamis
Defence structures	• Process of construction • Rationale (within the context of the overall programme) • Type of structure (dikes, shoreline protection, parapets) • Location • Basic structure • Date of construction • Length • Crest height • Basic policy of construction • Installation of evacuation stairways • Method of natural water drainage • Type of beach in front of structure (include post construction alterations) • State of old dikes and other defences • Progress of plans being implemented • Future development plans	Assessment of danger of inundation Projection of the area of inundation Check for safety during evacuation Check for maintenance of defensive capability
Other emergency measures	• System for the collection and dissemination of information • Securing roads and emergency relief delivery • Distribution system for food, water and medical supplies • Medical response system • Rescue response system • Firefighting • Evacuation for ships, boats, and fishing vessels	Assessment of emergency capability

Table 5. RESEARCH ITEMS AND PURPOSE (NATURAL ENVIRONMENT)

Category	Items	Purpose
Shoreline	• Sea-bottom topography • Sea-bottom gradient • Depth • Shoreline topography	To project the area of inundation and understand the topographical effect on the tsunami
	Sea conditions (including sea level and waves)	Estimation of inundation
Inland area	Topography	Predicting the extent of tsunami damage
	Altitude with respect to Mean Sea Level (MSL)	Evaluating the feasibility of evacuation

Table 6. RESEARCH ITEMS AND PURPOSE (SOCIO-ECONOMIC STRUCTURE)

Category	Items	Purpose
Demographics	Population, number and distribution of households	Projection of tsunami damage in rural versus urban areas
	• Ratio of elderly, children and other high-risk people • Community lifestyles, awareness and attitudes toward hazard preparedness • Daytime and nighttime populations and their respective age distribution • Incoming and outgoing population (tourist areas)	In addition to the above, evacuation feasibility, estimation of difficulty of evacuation, consideration of best response
Buildings and structures*	• Structure • Size • Location • Years since construction	Projection of tsunami damage
	How the structure is being used	In addition to the above, evacuation feasibility
Economic activity	• Type of business • Facility holdings • Productive output of each facility	Projection of tsunami damage
	Number of employees at each facility	In addition to the above, evacuation feasibility

*Types of construction include: (1) houses; and (2) facilities for public and official use.

Table 7. RESEARCH ITEMS AND PURPOSE (PATTERNS OF LAND USAGE)

Category	Items	Purpose
Land and ground	Presence and state of land subsidence, land at or under Mean Sea Level (MSL), reclaimed land, weathered land	Estimation of tsunami runup depth and duration of the damage
Urban form	• Historical development of the city (i.e. resettlement) • Land usage • Overcrowding and blockage • Green and undeveloped areas • Facilities housing dangerous materials and residential areas • Special/reserved areas (military, heritage, religious areas)	Predicting the extent of tsunami damage Grasping potential causes of damage Assessment of the possibility of increased damage
Urban facilities	State of port and harbour facilities • Transportation facilities and type of network • Lifeline facilities and type of network (pipelines, natural gas lines) • Distribution of facilities with dangerous materials (factories, etc.) • Distribution of manufacturing facilities • Distribution/capacity of train terminals or underground shopping centres • Distribution of tourist resources (including beaches, etc.) • Distribution of hospitals, nursing care facilities to house people at higher risk • Distribution of schools • Presence of rivers and channels	Predicting the extent of tsunami damage Grasping potential causes of damage Assessment of the possibility of increased damage
Urban and local development planning	Review of plans being implemented (objective, contents, implementation time) and degree of completion	Predicting the extent of tsunami damage

Table 8. ITEMS AND STANDARDS OF EVALUATION

Contents	Items	Standards
Safe and smooth evacuation of residents and visitors (tourists, sunbathers, fishermen, etc.)	Evaluation of the safety of evacuation sites and routes	1. Distribution and time fluctuations of areas of inundation 2. Presence of safe evacuation sites a. Designation and capacity of evacuation sites and routes b. Presence of topographical and elevation-safe areas 3. Resident population figures 4. Areas where visitors are located, fluctuations by season and time of day 5. Location of elevated roads, bridges, tunnels and other risk points during times of emergency
	Comparison between the tsunami's time of arrival and the time required to evacuate (from residences to evacuation sites)	1. Starting time for residents' evacuation 2. Organizational aspects for evacuation (role and functions of fire/police department, Coast Guard) 3. History of hazard damage to the community, spread of safety education 4. Evacuation infrastructure a. Outdoor speakers to issue tsunami warnings b. Presence of signs indicating evacuation areas and routes, visibility at night c. Distance from residences to evacuation sites 5. Topography and current road conditions a. Check emergency stairways b. Residents' walking speed during evacuation 6. Number of elderly and disabled 7. Traffic capacity on evacuation routes for pedestrians and vehicles
Protection of residences and public property	Assessment of inundation	1. Distribution of water levels and time fluctuations 2. Tsunami defence by shore protection structures a. Type of construction, crest height, length, etc. b. Plans for future construction 3. Sea conditions (average lunar high tide, winter winds, etc.) 4. Altitude with respect to Mean Sea Level (MSL)
	Potential for physical damage	1. Areas of inundation and time fluctuations 2. Grouping of facilities by type and function a. Present use of land along the shore and coastal area and distribution of buildings b. Accumulation of oil, lumber, etc. in ports and harbours

Table 9. ITEMS FOR IDENTIFYING TASKS

Category	Item	Considerations based on the current situation
Urban planning based on tsunami preparedness	Use of land inside and immediately next to the area of inundation	1. Accumulation of dangerous materials, location of facilities related to dangerous materials 2. Presence of lumber, vehicles, etc. that could increase damage when carried by the waves 3. Lack of evacuation sites and routes
	Development of residential areas	1. Concentrations of aged housing, urban sprawl effect 2. Housing materials and structure
	Location and structure of public facilities	1. Concentration and altitude of coastal hospitals, nursing homes, etc. with at-risk residents 2. Concentration and altitude of municipal buildings, fire/police departments, Coast Guard along the coast 3. Concentration and altitude of schools along the coast
	Construction of roads and railways	1. Location of stations and bus terminals 2. Location of road and rail bridges which will be affected by tsunami river runup
	Location and structure of lifelines, communications and distribution centres	1. Possibility of runup in drinking water and sewage lines 2. Disruption of lifelines, i.e. flooding of transformers and pump stations, broken oil and gas pipelines
	Location and structure of fishing facilities	Possibility of closing of the harbour and shipping lanes due to floating debris of fishing tools and fish farming materials
	Location and structure of port and harbour facilities	1. Blockage of shipping lanes by floating obstacles 2. Depletion of shipping ability due to destruction of port facilities
	Location and structure of storage sites with dangerous materials	1. Potential for secondary damage caused by leakage 2. Lack of space for oil tankers to evacuate 3. Environmental pollution
Organization for dealing with emergencies	Evacuation system for residents and fishermen	1. Distance between evacuation site and residential areas, route conditions and suitability of evacuation site 2. Distribution of elderly and physically challenged 3. Knowledge of evacuation site locations, level of safety awareness 4. Participation in evacuation drills
	Safety organizations	1. Level of community involvement 2. Number and activities of volunteer safety organizations, fire squadrons
	Warning system	1. Current tsunami warning system 2. Updating safety authorities' wireless communication system, outdoor speakers
	Information for beach	1. Signs indicating routes to evacuation areas 2. Faulty tsunami warning system
	Evacuation of port and ship employees	1. Lack of evacuation sites and routes 2. Exit strategy
	Protection of fishing	Lack of evacuation space for fishing boats, storage lockers
	Safety education	Public knowledge of evacuation sites, safety awareness, community awareness

Table 10. OUTLINE FOR URBAN PLANNING AND TSUNAMI PREPAREDNESS

(1) Promotion of land usage that is tsunami-resistant	Tsunami readiness in use of land and zoning laws	Guidance for relocation to safer zones: • Guidance for established city areas (including relocation to higher ground) • Promotion of appropriate land use during development of coastal land
		Introduction of anti-tsunami and buffer zones
		Construction and protection of safety facilities: • Protection of tsunami control forests • Protection of old levees
(2) Increasing safety through correct use of land in coastal areas	General planning	Tsunami-resistant construction
		Dealing with dangerous materials
	Increasing safety along the shoreline	Residential districts
		Commercial districts
		Manufacturing and shipping districts
		Safety in maritime industries
	Preservation of lifeline facilities	Communications
		Distribution centres

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