United Nations
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Intergovernmental Oceanographic Commission

Manuals and Guides 82

PREPARING FOR COMMUNITY TSUNAMI EVACUATIONS

From Inundation to Evacuation Maps, Response Plans, and Exercises

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UNESCO 2020

IOC Manuals and Guides, 82
Paris, February 2020
English

For bibliographic purposes, this document should be cited as follows:

UNESCO/IOC. 2020. *Preparing for Community Tsunami Evacuations: from inundation to evacuation maps, response plans and exercises.* Paris, UNESCO. (Manuals and Guides, 82)

Guide prepared by: International Tsunami Information Center
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This IOC Manuals and Guides publication consists of a Guide (IOC/2020/MG/82) and two Supplements. The Guide presents a high-level summary of each programme module and the rational behind them. Supplements contain additional detailed information, templates, reference to specialized documents, tutorials and best practice examples.

Supplement 1: Programme Modules and Specialized Documents

Supplement 2: How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS: Manual and Tutorial

Published in 2020
by United Nations Educational, Scientific
and Cultural Organization
7, Place de Fontenoy, 75352 Paris 07 SP

(IOC/2020/MG/82)

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Acknowledgements

This guide has been developed as an activity of the IOC Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) and its Working Group on Disaster Management and Preparedness (changed to Disaster Management, Preparedness, and Risk Reduction in 2017), with input from the IOC Working Group on Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems (TOWS-WG) Task Team on Disaster Management and Preparedness. It was generously supported by the United States Agency for International Development (USAID) Office of U.S. Foreign Disaster Assistance (OFDA), US National Oceanic and Atmospheric Administration (NOAA), and the Intergovernmental Oceanographic Commission (IOC) of UNESCO.

The contents are based on best practice papers and presentations prepared for a programme of training workshops on how community and government can work together to create reliable and practical tsunami evacuation maps. TEMPP (Tsunami Evacuation Maps, Plans, and Procedures) was a pilot course under the direction of the International Tsunami Information Center (ITIC) from 2015 to 2017 in Honduras, Central America. Many international and national practitioners and experts in tsunami inundation modelling, earthquake scenario source identification, emergency response planning and exercising, and community awareness and preparedness, contributed to this pilot, including Dr Diego Arcas, Christopher Moore, and Marie Eble (NOAA Center for Tsunami Research, NCTR), Dr Edison Gica (University of Washington Joint Institute for the Study of the Atmosphere and Ocean, JISAO), Christa von Hillebrandt and Carolina Hincapié (Caribbean Tsunami Warning Program, CTWP), Nicolas Arcos (NOAA National Centers for Environmental Information, NCEI), Bernardo Aliaga (UNESCO/IOC, Technical Secretary for the ICG/PTWS and ICG/CARIBE-EWS), Laura Kong (ITIC), David Coetzee (New Zealand Emergency Management Agency, NEMA), Ardito Kodijat (UNESCO/IOC, Indian Ocean Tsunami Information Centre, IOTIC), Dr Srinivasa Kumar (UNESCO/IOC, Technical Secretary and Head of the ICG/IOTWMS Secretariat), Mylene Villegas (Philippine Institute of Volcanology and Seismology, PHIVOLCS), Tim Walsh (retiree, Washington State Department of Natural Resources, DNR), George Crawford (retiree, Washington Military Department, WMD), Dr Yohko Igarashi (Japan Meteorological Agency, JMA), Masahiro Yamamoto (retiree, Senior Advisor, UNESCO/IOC Tsunami Unit and JMA), Irina Rafliana (Indonesian Institute of Science, LIPI), Dr Harkunti Pertiwi Rahayu (Institut Teknologi Bandung (Bandung Institute of Technology), ITB), Dr Charles McCreery (Pacific Tsunami Warning Centre, PTWC), Alison Brome (UNESCO/IOC, Caribbean Tsunami Information Center, CTIC), Harald Spahn (formerly, German-Indonesia Cooperation for a Tsunami Early Warning System (GITEWS), GTZ-International Services), the PTWS Task Teams on Evacuation Planning and Mapping, and TEMPP and Tsunami Ready, and the IOC/TOWS-WG Inter-ICG Task Team on Disaster Management and Preparedness.

Production of the guidelines has benefitted from a wealth of published and unpublished information, including technical and guidance documents from national and international organizations, Manuals and Guides of the IOC and the United Nations Office for Disaster Risk Reduction (UNISDR), and individual country contributions.

We thank the participants from the five TEMPP training workshops, the national and local government of Honduras and its tsunami warning and emergency response agency (COPECO), as well as non-governmental organizations that supported Cedeño during the tsunami drill.

We thank Ingrid Pastor Reyes (UNESCO/IOC) for assisting in the translations of materials into Spanish and English during the TEMPP Pilot, and Rena Kikuchi (Intern, UNESCO/IOC) for assisting in the translation of Japanese documents into English.

A special acknowledgement goes to Julie Leonard, Vice-Chair of PTWS WG 3 (retiree, USAID/OFDA/LAC, passed away in 2016), whose vision and commitment to community disaster risk reduction in 2013 allowed us to formulate and then carry out the TEMMP pilot course.

The contents are dedicated to the many who lost their lives from tsunamis, especially from local tsunamis that hit in minutes. The painful lessons we learned, most recently from the 2009 Samoa, American Samoa and Tonga, 2010 Chile, 2011 Great East Japan, and 2018 Palu and Anak Krakatau, Indonesia tsunamis, underscores the critical importance of pre-disaster evacuation planning and practice that can save lives in tsunamis.

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Foreword

Since the Indian Ocean Tsunami of 26 December 2004, much progress has been made in establishing regional tsunami early warning and mitigation systems in the Indian Ocean, Caribbean and Northeast Atlantic & Mediterranean. The systems complement the one that had been operational in the Pacific since 1965. We continue, however, to face very significant challenges with the tsunami readiness and preparedness, in particular for locally generated tsunamis.

Community preparedness is vitally important because it enables a rapid appropriate response to both official warnings and the natural signs of a possible tsunami. This is critical for saving lives for all tsunami events, and it is even more essential for locally generated tsunamis. Without tsunami community preparedness, chances of people top escape and survive a locally generated tsunami are minimal.

Two important components of community preparedness are science-based tsunami inundation maps and participatory-developed tsunami evacuation plans and maps. Only when you are well aware of the tsunami hazard, your community can be prepared against this natural threat. This guide describes how to develop tsunami inundation and evacuation maps and how to increase the community tsunami readiness and preparedness, including through drills and exercises.

With active participation of the governments of Central America, and through multiple partnerships with funding and technical agencies, the Pacific Tsunami Warning and Mitigation System (PTWS) developed over the period 2015–2017 the technical and practical basis for the guide.

I extend my warmest thanks to all PTWS Member States, the many experts that contributed to this guide, and to the partners who provided financial support for IOC of UNESCO for producing this tool.

Dr Vladimir Ryabinin

Executive Secretary of the Intergovernmental
Oceanographic Commission of UNESCO,
Assistant Director-General of UNESCO

Background

In July 2014, the Steering Committee of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (PTWS-SC) endorsed the recommendation of Working Group 3 (Disaster Management and Preparedness) that the next priority of the PTWS was to focus on 'preparedness'. The primary focus was for communities to know 'what to do' and 'where to go' when a tsunami warning alert is issued.

The International Tsunami Information Center (ITIC) recommended a capacity building focus on evacuation and proposed a new course, Tsunami Evacuation Maps, Plans, and Procedures (TEMPP), that was accepted by the PTWC Steering Committee, and then affirmed by Member States at the Twenty-sixth session of the ICG/PTWS in April 2015. ITIC enlisted a Course Development Team with practicing expertise in tsunami inundation modelling, scenario identification for evacuation mapping, emergency planning, response and exercising, and community preparedness to help develop the course.

An ICG/PTWS-XXVI (2015) Task Team on Evacuation Planning and Mapping, and an ICG/PTWS-XXVII (2017) Task Team on TEMPP and Tsunami Ready, provided guidance. At the global level, the IOC/TOWS Inter-ICG Task Team on Disaster Management and Preparedness and international experts provided the final review.

The TEMPP training course is intended to be a standardized course and process for the production of reliable and practical community-level tsunami evacuation maps. Targeted trainees were Tsunami National Contacts, National Tsunami Warning Centres and Tsunami Warning Focal Points, staff from Disaster Management Agencies and other governmental institutions (local and national) and leaders from civil society organizations. Tsunami modelling training targeted physical scientists and oceanographers in governmental institutions and universities. The direct outcomes for the participating country include:

- Communities that know what to do and where to go when a tsunami warning is issued, or when self-responding to the natural warning signs of a tsunami, and
- Country capability and tools to replicate the community evacuation map process elsewhere.

From July 2015 to February 2017, the ITIC, NOAA Caribbean Tsunami Warning Program (CTWP), and the IOC collaborated to develop and pilot the course in Honduras, inviting Central America and Mexico to participate. The TEMPP course and process built upon previous efforts, and consisted of a linked set of five 1-week training workshops, each building upon the previous, that applied global standardized tools and methodologies on:

- Inundation Modelling and Inundation Map Development (TEMPP 1 and 2)
- Evacuation Map Development and Evacuation Planning (TEMPP 3)
- Tsunami Warning and Emergency Response Standard Operating Procedures (SOPs). (TEMPP 4)
- Conducting Community Tsunami Exercises (including evacuation) (TEMPP 5)

Altogether, 34 participants attended the trainings that were supported by 11 instructors; 8 experts participated in the Seismic Tsunami Sources Expert meeting. Evaluations or feedback sessions at the end of each training workshop provided valuable advice for finalizing the course. In addition, a "Tsunami Ready" pilot was conducted for the town of Cedeño, Honduras, and the community was recognized as Tsunami Ready in February 2017 (http://www.tsunamiready-international.org).

In February 2017, after the completion of the last TEMPP training, the TOWS-WG noted with satisfaction the progress made during the intersessional period on Tsunami Evacuation Mapping, specifically that:

- PTWS had successfully completed the TEMPP pilot over two years in Honduras
- ITIC, CTWP, and IOC are ready to provide guidance to countries that want to implement similar projects
- Existing best practice and evacuation mapping guidelines have been identified
- PTWS will finalise project documentation and make it available to other regional tsunami Intergovernmental Coordination Groups, noting the interest of Indian Ocean Tsunami Warning and Mitigation System (IOTWMS) and Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (CARIBE-EWS).

This guide concludes the above-mentioned courses and aims to disseminate its methodologies widely.

PART I

1. INTRODUCTION

1.1 STRATEGY FOR TSUNAMI DISASTER RISK REDUCTION

Effective early warning systems will save lives. To be effective, there must be synergy among all levels of the warning system, with international, national, and community actions harmonized to effect a seamless warning and response chain —an end-to-end warning system from detection to safe evacuation. Warnings are most effective when there is continuous public awareness and preparedness to support appropriate public action. The eight elements of an effective warning system can be summarized as follows:

1. Proper instruments that enable the early detection and assessment of threat of potentially harmful earthquakes and tsunamis. The data obtained by these instruments must be readily available to all nations continuously and in real-time.

2. The National Warning Centre must be able to analyse and forecast the impact of tsunamis on coasts in advance of the waves' arrival, and the local, regional, and/or national Civil Protection or Disaster Management Agencies must be able to immediately disseminate the alerts and enable evacuation of all vulnerable communities. The communications methods must be reliable, robust, and redundant, and work closely with the mass media and telecommunications providers to accomplish this broadcast as well as integrate social media. Vulnerable populations must be informed in an understandable and culturally appropriate way.

3. Awareness that educates and informs a wide populace on how to recognize a tsunami natural warning signs and what to do, from ordinary citizens to lifeline and critical infrastructure services. The public must know a tsunami's natural warning signs and where to evacuate immediately because a local tsunami may hit within minutes and before an official tsunami warning can be issued and received. Respect for and use of indigenous knowledge is important.

4. Preparedness arrangements that practice procedures and actions necessary to save lives and reduce impact. Drills and exercises, and proactive outreach and awareness are essential for reducing tsunami impact. The inclusion of natural hazards science and disaster preparedness subjects in the school curriculum will prepare and carry awareness to the next generations. Gender-related issues in preparedness and family responses in emergencies need to be accommodated.

5. Response planning that identifies and creates the public safety procedures and products that enable fast action. This includes both land evacuations of people and marine evacuations in ports, harbours, and protection of airports and critical and lifeline facilities. It is necessary to create and widely disseminate tsunami evacuation maps that include instructions on when to go, where to go, and how to go. Evacuation zones, shelters, and evacuation routes need to be clearly identified, and widely known by all segments of the coastal and marine population.

6. Tsunami-resistant engineering and building codes, and prudent land-use policies that are implemented as pre-disaster mitigation. Tall, reinforced concrete buildings, or natural berms, can offer safe places to which people can vertically evacuate if there is no time to reach higher ground. Long-term planning to avoid placing critical infrastructure and lifeline support facilities in inundation zones will reduce the time needed for services to be restored and reduce economic impact.

7. Stakeholder coordination to facilitate effective, seamless actions in warning and emergency response. Clear designation of the national or local authority from which the public will receive emergency information is essential to avoid public confusion, which would compromise both public trust and safety.

8. High-level advocacy at community, national, and international levels that ensures a sustained commitment to prepare for what are infrequent, but high-fatality natural disasters such as tsunami.

1.2 END-TO-END TSUNAMI WARNING – EVACUATION

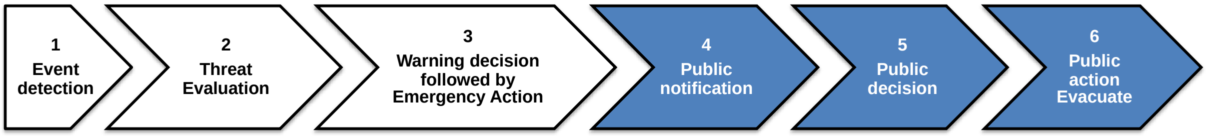

Figure 1. End-to-end tsunami warning chain

The end-to-end tsunami warning chain requires key operational agencies to work together in a coordinated manner. Each must have a good understanding of each other's roles, responsibilities, authorities, and action, especially for fast-evolving local tsunamis that can attack in minutes. The chain should operate seamlessly, following a predetermined set of procedures. Throughout the event, there should be an on-going and continuous flow of information amongst the operational agencies.

The end-to-end tsunami warning chain covers the activities of event monitoring and detection, threat evaluation and warning decision-making followed by emergency action, public notification, decision, and finally public action. However, a tsunami warning will only be successful when all people in vulnerable coastal communities have prepared beforehand, and then respond appropriately and in a timely manner upon recognizing that a potential destructive tsunami may be approaching.

This means that every person must know and understand when to evacuate (self-evacuate) and where to evacuate to. The 'where to' solution is reliable and practical community-level tsunami evacuation plans, maps and procedures. Tsunami evacuation planners must consider the different responses for a local, regional and distant source event. A distant source tsunami allows for more than three hours for evacuation. A regional tsunami is particularly challenging, as only one to three hours exist to decide and conduct an evacuation. A local tsunami (less than one hour between tsunami trigger and wave arrival) will require immediate self-evacuation based on ground shaking or other natural warning signs observed by community members. Local tsunamis and earthquakes should be planned for together, as earthquake impact may make evacuation challenging. The time required to execute an evacuation should be analysed, and built into the decision-making procedure. Tsunami evacuation plans, maps, and procedures should be developed with community and government input so that evacuation advice (or orders) to evacuate are clear and the evacuations themselves orderly.

Tsunami evacuation maps are a critical product of the tsunami evacuation planning process. Evacuation maps, based on the expected inundation maps, must delineate zones that need to be evacuated when a dangerous tsunami is imminent. The evacuation zones are typically indicated using contrasting colours. Multiple evacuation zones (and colours) can be used, depending on the hazard assessment for the area (for instance where there is significant difference between a local or distant tsunami, or an extreme tsunami threat). In high density locations, the maps should indicate the optimum evacuation routes to safe areas. As not all areas will have access to natural high ground, some locations may need to consider adopting a policy of vertical evacuation to a designated (and sign posted) strong building, or for sheltering in place. Ideally, the public should evacuate by foot when possible to avoid creating traffic congestion. Evacuation plans and maps should be vetted at community meetings and corresponding authorities, and an educational tsunami evacuation brochure developed for wide distribution.

Evacuation planning is the process for identifying areas potentially at risk from tsunami, and the actions required to ensure the safety of people while evacuating from those areas. It is fundamental that evacuation plans are integrated with the tsunami early warning system, as well as with other public and private sector emergency plans. Evacuation plan components should cover: types of evacuation (e.g. voluntary, mandatory) and the management of the respective phases (e.g. decision, notification, process, shelter, return).

Special planning considerations must be given to the portion of affected communities that are incapable of or will have difficulty evacuating without assistance, such as hospitals. In addition, tsunami response plans, including shutdown of services and evacuation of personnel, should be in place for critical facilities and infrastructure.

Evacuation procedures should include guidance to emergency services at the local level; thereby, ensuring evacuation zones are closed off and secured until the tsunami warning is cancelled and the threat of a tsunami no longer exists. Once areas have been evacuated, roadblocks, barricades, and/or a system of patrols should be set in place to keep the public from returning to evacuation zones and to keep people with malicious intent out. The decision to allow re-entry (e.g. all-clear) will be made by Emergency Management officials.

Signage is an effective mechanism for public education on the risk posed by tsunamis and the appropriate evacuation response to a tsunami event. Stakeholders, including the public, should examine signage locations and types during the planning process. Four basic categories of tsunami sign types are: evacuation zone, evacuation route, evacuation safe-location/assembly areas and information board. Many different tsunami signs are available around the world, though three basic signs (hazard / evacuation zone, horizontal safe point, and vertical shelter) were agreed upon and adopted by the International Organization for Standardization (see ISO 20712). Signage must be in sync with local community education, preparedness, and mitigation programs.

Exercising these plans and procedures helps to validate, increase and sustain awareness and preparedness. Tsunami exercises can range from orientation workshops and straightforward communications tests to full-scale alerting and evacuations of people from tsunami hazard zones. A perfectly executed warning will be useless if people, agencies and organizations do not know how to respond to the warning. Exercise also support the planning process through review and assessment.

1.3 UNESCO/IOC TSUNAMI READY PROGRAMME

Coastal communities can be better prepared for tsunamis through planning, education and awareness, and the strengthening of their local emergency actions. Recent tsunamis in Samoa (2009), Chile (2010), Japan (2011), Solomon Islands (2013), and Indonesia (2012, 2018) attest to the importance of readiness: when a tsunami arrives and communities are ready to respond, lives are saved and fewer people die.

Under the auspices of UNESCO/IOC and facilitated by the IOC's Tsunami Information Centres, Tsunami Ready is an international performance-based community recognition pilot empowering communities to better prepare themselves for the next tsunami. The Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions (ICG/CARIBE-EWS) at its Tenth session (19–

21 May 2015, Philipsburg, Saint Martin), approved ten guidelines for Tsunami Ready recognition by UNESCO/IOC (Recommendation ICG/CARIBE-EWS-X.6). In 2017, the IOC, on the recommendation of its Working Group on Tsunamis and Other Hazards Related to Sea-Level Warning and Mitigation Systems during its Tenth meeting (IOC/TOWS-WG-X), instructed Member States to consider piloting the CARIBE-EWS Tsunami Ready guidelines and report back to the TOWS Working Group with a view to develop harmonized consistent global guidelines.

Coastal communities seeking the Tsunami Ready recognition should meet all ten guidelines[1]. For each ICG region (CARIBE-EWS, IOTWMS, NEAMTWS, PTWS), the regional Tsunami Information Centres (CTIC, IOTIC, NEAMTIC, ITIC, respectively) will assist countries interested in piloting Tsunami Ready. The specific actions required to meet each guideline will vary among communities depending on the types of tsunami hazards and related vulnerability, and as determined by the National or Regional Tsunami Ready Board. Determination of the range of plausible local, regional, and distant tsunami threats in a particular community rests with the designated Board, who will consult tsunami experts, TICs, IOC Tsunami Service Providers (TSPs), National Tsunami Warning Centres (NTWCs), and emergency managers, universities or consultants. For recognition, a community must complete and submit the Tsunami Ready application form to the corresponding Tsunami Ready Board. Once approved, the UNESCO/IOC will grant the recognition.

As of April 2019, UNESCO/IOC Tsunami Ready has been piloted (or pilots were underway) in 12 countries with Caribbean coasts, 12 countries with Pacific coasts, 2 countries on both their Caribbean and Pacific coasts, and two countries in the Indian Ocean. Additionally, 25 countries around the world have indicated interest in conducting pilots.

MITIGATION (MIT)
MIT–1. Have designated & mapped tsunami hazard zones
MIT–2. Have a public display of tsunami information
PREPAREDNESS (PREP)
PREP–1. Have a tsunami evacuation map developed in collaboration with communities and local authorities
PREP–2. Develop and distribute outreach and public education materials
PREP–3. Hold at least three outreach or educational activities annually
PREP–4: Conduct an annual tsunami community exercise
RESPONSE (RESP)
RESP–1. Address tsunami hazards in the community's emergency operations / response plan
RESP–2. Have the capacity to manage emergency response operations during a tsunami
RESP–3. Have redundant and reliable means to receive official tsunami warnings 24x7
RESP–4. Have redundant and reliable means to disseminate official tsunami warnings and information to the public 24x7

Table 1. UNESCO/IOC Tsunami Ready Guidelines – ICG/CARIBE-EWS and ICG/PTWS[2].

[1] Note: The ICG/IOTWMS at its Eleventh session decided to establish an 11th guideline: *Have a tsunami risk reduction plan.*

[2] Note: Although the guidelines are at an advanced stage and are used for implementation, they may be subject to change given the Pilot status of the Programme at the time of development of this Guide.

2. PURPOSE AND READER'S GUIDE

2.1 PURPOSE

This guide focuses on actions that communities can take to build resilience to the next tsunami. It effects actions with the end goal of saving lives and reducing tsunami impact by, focusing on coordinated Stakeholder Response Planning and Preparedness, accompanied by continuous Awareness on the End-to-End Warning System to sustain Advocacy. The actions and products of this guide —tsunami hazard assessments, inundation and evacuation maps, response plans and procedures, awareness, and exercises— assist communities in making themselves more prepared. The guide, formatted to support the training of people who are responsible for these deliverables, can be used as part of the process to become UNESCO/IOC Tsunami Ready, or simply to enhance preparedness.

2.2 READER'S GUIDE

This guide is completed with a supplement consisting of digital-only files. The guide provides a summary on tsunami disaster risk reduction, evacuation, and the UNESCO/IOC Tsunami Ready community preparedness recognition pilot. It is followed by four evacuation planning modules (Modules 1 to 4) describing the how-to-steps, objectives, target participants, requirements, methodology, tools, templates, expected results, module references and examples. Finally, the document contains four annexes: a general bibliography, the TEMPP Pilot course, the content of supplement 1 and a list of acronyms.

The supplements contain detailed Module explanations and guidance, and Specialized Documents that include how-to manuals, templates, and examples to support both training and the delivery of outputs.

This guide assumes that adequate digital elevation models (DEMs) and the earthquake tsunami sources have been identified through separate process, and therefore it does not cover these two topics.

Module 1 describes the identification of inundation areas, including the identification of credible and/or worst-case scenarios that should be modelled. It also includes guidance for situations where there is no known or little tsunami hazard, or where the available bathymetry is too coarse to permit credible tsunami inundation modelling.

Module 2 describes the development of evacuation maps from inundation maps. Best practice guidance is provided on how to choose evacuation zones and routes. Geographic information systems are used with standard symbology to create the map and the process of 'ground-truthing' the map through community engagement is outlined.

Module 3 describes the development of Tsunami Response Plans and Standard Operating Procedures (SOPs) focusing on the community evacuations, but including the tsunami warning chain from the national tsunami warning centre to local authorities and the execution of evacuation during a warning. A key element of tsunami response involves evacuation including self-evacuation of exposed people and key assets to safer areas. Effective and successful evacuation requires pre-planning by the relevant authorities.

Module 4 describes the use of exercising to practice tsunami evacuations.

The general bibliography includes documents and best practices that were used in the development of this guide.

The Annexes contain detail on evacuation planning and capacity building.

Annex I describes the Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) Pilot Training that was conducted between 2015 and 2017. The TEMPP Pilot provided much of the content for this guide.

Annex II lists the contents of the Supplement, which consists of the Programme Modules, and the Specialised Documents.

The most current versions of the Supplement to the Programme Modules and the Specialized Documents are available from the IOC and ITIC, or can be downloaded from the ITIC Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) website http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2166&Itemid=2640.

3. ACTIONS TO REDUCE COMMUNITY RISK FROM TSUNAMIS

3.1 INTRODUCTION

Community tsunami risk is reduced through pre-event evacuation planning. A key element of tsunami response involves evacuation including self-evacuation of exposed people and key assets to safer areas. Effective and successful evacuations are subject to proper planning by the relevant authorities. Evacuation planning involves four foundation blocks:

Module 1: Identifying Inundation Areas.

Module 2: Developing Tsunami Evacuation Maps.

Module 3: Developing Tsunami Response Plans and Standard Operating Procedures (SOPs).

Module 4: Tsunami Exercising.

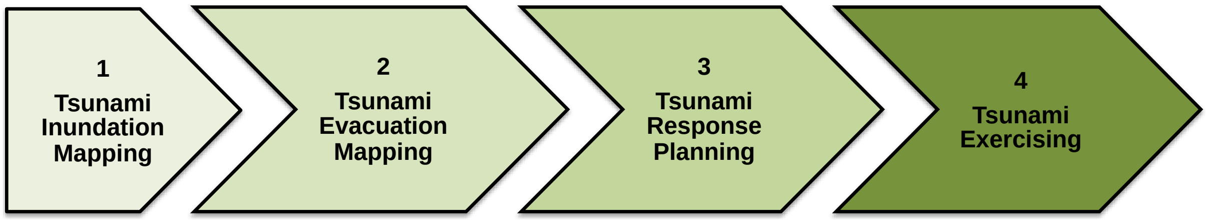

Figure 2. Foundation blocks (modules) for tsunami evacuation planning.

This guide has been prepared to support the training of people who are responsible for the development of each foundation block. Each Module has two main components:

- The training approach with the intent to facilitate trainers to deliver the specific foundation block; and

- The step-by-step process involved in the implementation of the Module. The intent is to serve as an easy reference when the training is being put to practice.

This guide is supported by an electronic Supplement that offers more detail, examples and resource references to support both training and the delivery of outputs.

The rationale and requirements for participating in each Module of the programme are provided below[3].

3.2 OVERVIEW OF PROGRAMME

Module 1: Identifying Tsunami Inundation Areas

A tsunami inundation map identifies areas expected to be flooded by tsunamis based on available historical evidence and/or modelling. This information is essential to:

- Awareness of the tsunami hazard,
- Development of evacuation plan,
- Undertaking mitigation measures to minimize the impact of tsunami.

The inundation along the coast will vary depending on several factors like the magnitude of the earthquake generating the tsunami, the shape and morphology of the coast and near-shore bathymetry (i.e. geographical features), infrastructure, and the type and extent of development along the coastal areas.

This Module will equip participants with knowledge to develop an inundation map, with or without the use of modelling. Participants should have a computer with a minimum of 2GB memory (RAM), hard drive space, and knowledge or background in either:

- Seismology,
- Oceanography,
- Numerical simulation,
- Geographic Information System (GIS).

Module 2: Developing Tsunami Evacuation Maps

In the end-to-end tsunami warning chain, once a tsunami forecast is known and a warning issued, communities must know what to do and where to go when a tsunami is imminent. The ‘what to do’ will be to evacuate to a safe place, and the ‘where to go’ is answered using a tsunami evacuation map.

The knowledge about inundation (Module 1) is used to produce the tsunami evacuation map. Evacuation maps, which include evacuation zones, evacuation routing, assembly areas, signage and critical or special-need facilities and infrastructure are developed by emergency management agencies in consultation with the community. This Module will equip participants with knowledge about the process to develop an evacuation map, and the content of evacuation maps. Participants should include relevant emergency managers and GIS practitioners.

Delivery of the Module is subject to the existence of inundation maps (Module 1).

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[3] Note: A basic understanding of earthquake and tsunami science and behaviour by participants will support the delivery of each Module. Therefore, a training session on basic earthquake and tsunami science may be required depending on the level of understanding of those undertaking each Module.

Module 3: Developing Tsunami Response Plans and Standard Operating Procedures (SOPs)

Emergency Management must plan in advance for tsunami response. Not only must they have a process for receiving official warnings and recognizing natural warning sign to make appropriate decisions in response to them, they must also understand the challenges and procedures that will apply during evacuations, as well as with regards to the loss of critical and sensitive infrastructure. Closely associated is public awareness to ensure the public understand where official warnings will come from, when they can expect them (and when not, for example during a local source earthquake), how to evacuate and where their safe areas are.

The Tsunami Response Plan covers the arrangements for warnings and evacuations, and public awareness on these arrangements. It must align with higher level, generic all-hazards emergency management plans.

This Module will equip participants with knowledge to develop a tsunami response plan and associated Standard Operating Procedures (SOPs). They will also understand the considerations in relation to public awareness about tsunami warnings and evacuations. Participation is aimed at local and regional emergency managers, National Tsunami Warning Centre (NTWC) staff, and local authority staff.

Delivery of the Module is subject to the existence of evacuation maps (Module 2).

Module 4: Tsunami Exercising

Tsunami evacuation exercises bring planning to practice. They serve two purposes:

- Test the effectiveness of, and identify improvements to be made in regards to tsunami warnings and evacuation maps, plans and procedures.
- Promote public awareness and preparedness.

Exercises can be carried out by a single stakeholder in the end-to-end tsunami warning chain, or by several stakeholders exercising together. They can be simple (i.e. a discussion or a drill), or complex (i.e. an operational exercise over several days). In all instances the post exercise process as equally important as the exercise itself in order to register lessons identified and corrective actions to implement.

This Module will equip participants with knowledge about exercise options, the development of exercises and the post-exercise process. Participation is aimed at local and regional emergency managers, emergency services, local community leaders, and critical infrastructure representatives.

Delivery of the Module is subject to the existence of a Tsunami Response Plan and SOPs (Module 3) and evacuation maps (Module 2).

3.3 STAKEHOLDER RESPONSIBILITIES

The local authority, through its Emergency Management Office (EMO), is responsible for evacuation planning. However, the Emergency Management Office cannot do the planning in isolation of other stakeholders and experts. It is therefore critical to the success of the Programme and its eventual implementation that a core group representative of all the key stakeholders be established to oversee and ensure its participation, continuity and implementation.

Experts/Stakeholder	Roles
Local Mayor	Sponsor evacuation planning process, approve and sign off on the Evacuation Map and Plan
Local Emergency Management Agency	Lead planning process, own and manage the Plan
Regional Emergency Management Agency	Contribute to planning; set regional arrangements
National Emergency Management Agency	Set national arrangements
National Tsunami Warning Centre	Contribute to planning for warnings
Earthquake and Tsunami Experts	Advise on tsunami sources, threat and behaviour
Local Authority	Make available relevant staff (i.e. community planners)
Emergency Services	Contribute to planning, management of evacuations and warning notification
Utilities & critical infrastructure	Advise on tsunami impact and needs
Community Groups	Advise on needs and Evacuation Maps
Non-Government Organizations	Contribute to planning for their role in management of assembly areas, relief, and awareness
Media	Contribute to planning for their role in warnings
Numerical modellers	Develop Inundation Map
GIS Mapping Experts	Support development of Inundation and Evacuation Maps
Residents	Contribute and participate in tsunami evacuation mapping, planning, and exercises
Education Community	Teach tsunami and disaster preparedness curricula in schools; Participate in evacuation, planning and exercising of school and extended communities
Tourist/Visitor Industry	Share information on tsunami awareness and evacuation. Each hotel should have an evacuation plan
Business Organizations and Private Sector	Share information on tsunami awareness and evacuation
Maritime Groups, Port and Harbour Authorities	Share information on tsunami awareness and evacuation of ports and harbours. Prepare evacuation plan for marine vessels, including for tourist cruise ships

Table 2. The above table describes the stakeholders and experts that have to be involved in the process, and their roles.

PART II
PROGRAMME MODULES

MODULE 1: IDENTIFYING TSUNAMI INUNDATION AREAS

1.1. INTRODUCTION

A tsunami inundation map identifies areas expected to be flooded by tsunamis based on available historical evidence and/or modelling. These maps provide awareness of tsunami hazard and assist communities and local/national government in developing evacuation plans and mitigation measures to minimize the impact of the tsunami.

The inundation along the coast will vary depending on several factors like magnitude of the earthquake generating the tsunami, fault type, location of earthquake relative to the community, type of coasts, structures built along the coasts and other geographical features.

This module focuses on learning the basics of tsunami science and numerical modelling, required data and information needed, conducting tsunami modelling, and creating an inundation map that will be used in Module 2: Evacuation Mapping.

1.2. CONTENT

Step 1. Acquire needed data/information.

Step 2. Learn basics of tsunami science and numerical modelling.

Step 3. Conduct tsunami numerical modelling.

Step 4. Create an inundation map.

1.3. OBJECTIVES

Participants will:

- Learn the basics of tsunamigenic sources, tsunami generation/propagation/inundation, and tsunami wave characteristics;
- Conduct tsunami inundation modelling based on near- and far-field tsunamigenic sources;
- Develop an inundation map based on numerical modelling or no modelling.

1.4. TARGET PARTICIPANTS

The target audience are:

- Numerical modellers,
- Local/National Seismologists and tsunami experts/scientists,
- Oceanographers,
- Civil, Mechanical, and Hydraulic Engineers,
- Mathematicians,
- GIS experts.

Optional participants are:

- Local Emergency Managers,
- Local Authorities Staff,
- Disaster mitigation personnel.

1.5. REQUIREMENTS

Target participants should have a computer with a minimum of 2GB memory (RAM), some numerical models may require more RAM, hard drive space, and knowledge or background in:

- Seismology,
- Oceanography,
- Numerical simulation,
- Geographic Information System (GIS).

1.6. METHODOLOGY

The module will entail lectures, discussions, hands-on exercises on simulating tsunami scenarios, inundation map generation, and presentation of results with the group. Listed below is a typical or suggested duration and time allocation for each activity. If no modelling is possible, then group discussions are needed to determine the inundation level. Step 4 provides information on the 'no modelling' option.

Activity	**Suggested time**	
	Train the Trainer	**End User**
Lecture on basics of tsunami science and numerical models	1 day	2.5 days
Numerical modelling of tsunamis	1.5 days	3 days
Generating the inundation map	1 days	4 days
Presentation of simulated results to the group	0.5 days	

Table 3. Activities and suggested time

1.7. EXPECTED RESULTS

Agencies/participants will be able to produce their own inundation maps.

1.8. MODULE CONTENT

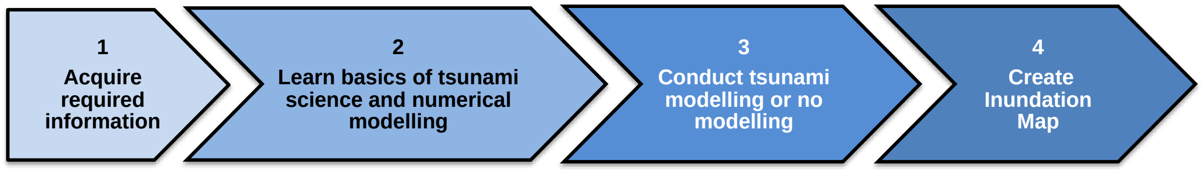

Figure 3. Steps for Module 1 – Inundation Mapping

Step 1: Acquire Required Information

Determining the maximum credible, worst-case, or all realistic earthquake scenarios and creating a high-resolution DEM sufficient for inundation mapping takes a significant amount of time and effort. Therefore, it is important to note these two items need to be established well ahead of time before numerical modelling can be conducted.

It is highly recommended that the regional and local authorities, in cooperation with national authorities, have already conducted research and identified the most credible and realistic earthquake or other source(s) that will be used. It is suggested that international experts be included in the discussions or committee. The regional and local jurisdictions can provide their own model based on their own criteria and understanding if the national level has no recommendation. However, every effort should be made to consult with national/international experts. For areas where a fault model has not been provided, the fault model should be chosen based on research on past tsunamis.

The committee needs to develop a comprehensive list of active subduction zones, tsunami earthquakes and other tsunamigenic zones around the basin where the generated tsunami would possibly impact the coastal area of interest. Best examples of earthquake generated tsunamis that had local as well as basin wide impacts are Chile in 1960, Alaska in 1964, Sumatra in 2004, Chile in 2010, and Tohoku in 2011. For more earthquake data, seismicity maps are available from United States Geological Survey (USGS) website (earthquake.usgs.gov). Local earthquake scientists should be consulted to identify the maximum credible or worst-case credible scenarios to be used for inundation modelling. The larger the earthquake magnitude, the larger tsunami it produces is not entirely correct. Slow earthquakes are also capable of generating large tsunamis in comparison to their magnitude, thus should be included on the list. Smaller magnitude earthquakes should never be underestimated especially near-field/local sources since it has the potential to affect near-field coastal areas. These slow earthquakes and near-field earthquakes are sources that should be considered and be included in conducting numerical simulations (IOC/TOWS-WG-IX/3 Rev., 2016).

To support regional efforts, the IOC has convened Expert Workshops to discuss and identify maximum credible and/or worst-case earthquake scenarios for tsunami inundation modelling for evacuation planning. To date, workshops have been held for Haiti (IOC, 2013), South China Sea (IOC, 2015), Dominican Republic (IOC, 2016), Central America (Caribbean and Pacific, IOC, 2016b), Tonga-Kermadec Trench (IOC, 2019), and the Lesser Antilles Trench (IOC, 2019b). Additional IOC workshops are planned in 2020 for the Ecuador-Colombia Trench, and New Guinea, New Britain, South Solomon, and New Hebrides Trenches.

The Tsunami Coastal Assessment Tool (TsuCAT, NOAA, ITIC, v.4 2019) is a useful tool for worst-case scenario identification. TsuCAT provides access to a Pacific, Caribbean, and Indian Ocean database of tsunami modelling results from NOAA's pre-computed catalogue of sources (Propagation Database, Gica, et al., 2008), and for the Pacific and Caribbean the RIFT model (IOC/2013/TS/105 Rev.3) to assist a country in its tsunami hazard assessment, tsunami exercise and response planning, and warning decision-making. Simulations for historical tsunami sources from NOAA's National Centers for Environmental Information (NCEI) and U.S. Geological Survey earthquake archive are included, as well as the sources identified through the IOC Expert Workshops on Tsunami Sources.

The characteristics of a tsunami waves are very sensitive to bathymetric features; therefore, it is very important that high quality, high resolution bathymetric and topographic data (Digital Elevation Model (DEM)) are obtained before conducting tsunami simulations. A grid resolution of at least 3 arc-sec (90 m) or finer is recommended for an accurate hazard inundation mapping. A 1/3 arc-sec (10 m) grid resolution is preferable especially for ports and harbours. It has to be kept in mind that using grid resolution coarser than 3 arc-sec (90 m) will produce inaccurate results since coastal features might not be properly resolved. A coarser grid resolution will also have less points per tsunami wavelength and will not properly resolve the nearest-coast shorter-wavelength waves and could miss the highest/lowest tsunami wave amplitude.

A LIDAR survey that covers both the subaerial and submarine portions of the study area is the preferred data requirement for a hazard assessment, and a multi-beam survey is the minimum requirement. If coral reefs and shallow lagoons are present in the study area, the multi-beam survey data might need to be augmented by LIDAR or aerial photography.

For the DEM, all available bathymetric and topographic data should be used. The NOAA NCEI, which serves as the ICSU World Data Service for Geophysics (WDS-G), and the IHO Data Centre for Digital Bathymetry (DCDB, https://www.ngdc.noaa.gov/iho/), is an international resource for coastal DEM development. It freely distributes a wide variety of DEMs online, from global to community scale, and provides portal access to DEMs built by other U.S. and international agencies.

The WDS-G includes includes Bathymetry and Global Relief (https://www.ngdc.noaa.gov/mgg/bathymetry/relief.html) and Natural Hazards (tsunami database, https://www.ngdc.noaa.gov/hazard/). The DCDB contains oceanic soundings acquired by hydrographic, oceanographic and other vessels during surveys or while on passage. Data are publicly available and used for the production of improved and more comprehensive bathymetric maps and grids, particularly in support of the GEBCO Ocean Mapping Programme.

Search for available DEMs for the region of interest and determine if the grid resolution and area coverage is sufficient. If a higher grid resolution is needed, then the regional/local jurisdiction needs to check with National authorities if the data are available. Otherwise this should be a separate project that accomplished before conducting inundation modelling study to generate an inundation map.

Step 2: Learn Basics of Tsunami Science and Numerical Models

Participants will be taught some basics on tsunami science in order to gain some understanding on the process of how tsunamis are generated, how it propagates in the deep ocean, and why it becomes destructive as it reaches a coastline.

Background on the development of a tsunami numerical model will be discussed and comparison with historical events and lab experiments are presented. This is important to show the reliability of the numerical model and provide confidence on the simulated results.

Step 3: Inundation Modelling

1. Numerical Modelling

The tsunami simulation will be conducted using a numerical model. The general procedure in conducting tsunami numerical simulation with any code is to first define the seismic source parameters, i.e. epicentre, focal depth, fault length, fault width, dip-, rake-, strike- angle, and slip. The seismic source parameters are then applied to a deformation source model to define the shape of the earth's vertical displacement. The most common method to define the initial tsunami generation is that the sea surface displacement replicates the final vertical displacement of the earth's sea bottom.

The numerical code then takes the initial sea surface displacement and propagates it across the deep ocean basin and then into the coastal areas of interest, where the high-resolution DEM is used, to simulate tsunami wave amplitude, inundation, run-up and other tsunami wave characteristics in shallower areas. It is recommended to conduct the simulation for more than 6 hours. This could be time consuming especially if there is insufficient computing power and the type of numerical model used. However, this is necessary since the later waves could possibly be of equal or higher magnitude compared to the first couple of waves due to wave reflections from other coastal areas.

The simulated results should be reviewed for possible instabilities. This can be accomplished by generating an animation and look for unusually extreme high tsunami wave amplitude or unnatural wave pulsing at a certain location(s). These instabilities need to be addressed since they can alter the simulated tsunami waves and produce unrealistic results. The file format of the DEM to be used will also depend on which numerical code is used. Read thru the manual of the specific numerical model used on how to fix this issue of instability and DEM format. Table 4 lists different tsunami numerical codes that have met the benchmark requirements of the United States National Tsunami Hazard Mitigation Program/Mapping and Modelling Subcommittee (NTHMP/MMS, 2017).

The total number of simulations to be conducted depends on the regional, local, or national authorities' decision, discussed with seismic and tsunami experts, determined during the discussion on tsunamic sources. A thorough tsunami hazard analysis should also consider far-field source regions which pose a threat to the coastal region of interest.

2. No Numerical Modelling

It is highly recommended to conduct tsunami inundation modelling in generating the inundation map since it provides guidance that is based on science. However, if modelling resources are not yet available, an inundation map can still be generated by following certain guidelines.

The Module 1 Supplement, Guidelines for Establishing Tsunami Inundation Zones for Evacuation Mapping and Planning in Regions without Tsunami Modelling (ITIC, USA NOAA, NZ, Philippines, Japan, 2016), provides guidelines and details on the recommended process, and is summarized below.

A 'No Modelling' requires a careful and thorough study for historical inundation information. The study should:

- Consult regional, local, or national experts in seismology or tsunamis,
- Verify if markers of historical events are available,
- Check regional, local, or national newspaper archives and town bulletins reporting about tsunamis,

- Check local folklores or stories passed down through elders about the ocean attacking the coast,
- Search tsunami catalogues, such:
    - National Center for Environmental Information/World Data Service (NCEI/WDS) Global Historical Tsunami Database, accessible at: https://www.ngdc.noaa.gov/hazard/,
    - Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Tsunami Laboratory, Novosibirsk, Russia, accessible at http://tsun.sscc.ru/.

If historical evidence of past tsunamis is available, it is recommended to add buffer zones to the maximum inundation evidence and also account for storm surge and maximum tidal level. For added safety, the US NTHMP Guidelines recommends adding an extra 1/3 of the area that corresponds to the maximum historical run-up. (https://nws.weather.gov/nthmp/documents/3nonmodeledregionguidelines.pdf)

In deciding the distance (inundation) and elevation (run-up) from the shoreline, it must be kept in mind that local tsunamis will generally produce larger tsunami waves along the coast than a far-field one. The community can decide whether there will be separate maximum inundation lines for ‘local’ and ‘far-field’ tsunami or use one that covers a larger extent of inundation or higher run-up for both cases.

If there is no reference information, the US NTHMP Guidelines recommended safe elevation is 10 meters or higher. (https://nws.weather.gov/nthmp/documents/3nonmodeledregionguidelines.pdf).

For distance inland from the shoreline, the US guidelines suggest that at 3 km (~2 miles) inland from the shoreline, most local tsunamis are no longer destructive while for a distant tsunami the distance is about more than 1.6 km (1 mile). However, as was documented in Japan in 2011 where many maximum runups were 20-30 m and inundation was observed more than 5 km inland, a local tsunami could far exceed ‘recommended’ levels and also vary from one location to the next.

Step 4: Create an Inundation/Flooding Map

From the simulations, the maximum tsunami wave amplitude distribution can then be obtained for each simulated case. A composite can be generated defining the maximum extent of flooding from all credible scenarios (maximum of maximum) which will then be translated into a tsunami inundation map. A discussion is needed whether to define two zones for the inundation map; one for near-field/local source or far-field source, or establish only one zone. The final maximum flooding extent can then be retrieved in GIS/QGis to create the inundation map.

After having produced a draft inundation map, validation should be undertaken through expert review and a field check that includes local knowledge.

Table 5 shows the relationship of tsunami inundation height in relation to its potential damage and can be used as a guideline.

For Honduras, ComMIT (Community Modelling and Interface for Tsunamis, Titov et al., 2011, https://nctr.pmel.noaa.gov/ComMIT/) was used to generate an inundation map. Simulating different tsunami scenarios for the same location (as long as it is using the same DEM), a composite maximum wave amplitude file can be created showing all the inundation extents. The combined results can then be used to generate an inundation map for creating an evacuation map. The final product was exported into GIS to produce a more professional looking inundation map.

A sample of an inundation map developed for Cedeño, Honduras is shown in Figure 4.

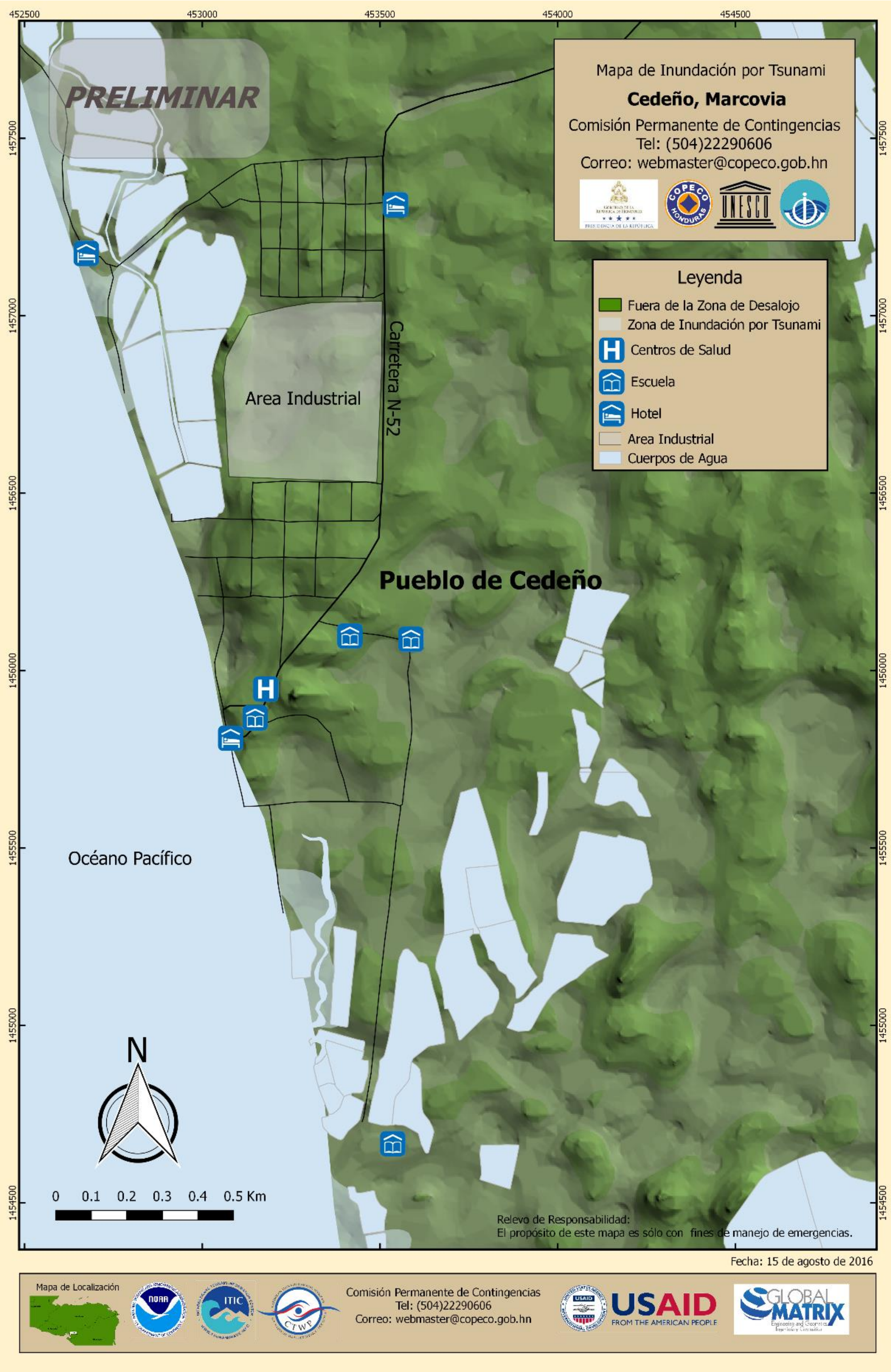

Figure 4. Inundation/flooding map developed for Cedeño, Honduras.

#	Model Name	Usable Sources		NTHMP Benchmarks		Available for download			Relative run-time	Model Physics[4]
		Seismic	Landslide (including volcanic, mass failures, underwater, over water)	Propagation	Inundation	Documentation	Available thru website	User interface	Hrs–Days* Days** Month***	
1	ALASKA GI'T	√	√	√	√	Limited	√	√	*	SW
2	BOSZ	√		√	√	Limited			**	B
3	COMCOT	√		√	√	Good	√		**	SW
4	FUNWAVE-TVD, v.10	√		√	√	Good	√		**	B
5	GeoClaw	√		√	√	Good	√		**	B
6	MOST (ComMIT)	√		√	√	Limited		√	*	SW
7	NEOWAVE	√		√	√	Good			**	B
8	SELFE	√		√	√	Good	√		***	CFD
9	TSUNAMI3D	√	√	√	√	Limited			***	CFD
10	TUNAMI/TUNAMI-N2	√		√	√	Good			**	SW

Table 4. List of Numerical Tsunami Models benchmarked by the USA NTHMP/MMS.

[4] **Model Physics**
SW = A 2D model which employs linear and non-linear **Shallow Water (SW)** equations for tsunami generation, propagation and wave runup/drawdown. Pressure field is hydrostatic and the formulation ignores viscous effects, so these models are not recommended for landslide-generated tsunamis. No vertical velocity and the modelled horizontal velocities are depth-averaged. Physical tsunami dispersion is often mimicked through numerical model dispersion. A practical choice for tsunami propagation and inundation simulations, however, models using depth-averaged wave equations cannot adequately address all the wave-structure interaction issues near the coast.

B = A 2D model which uses **Boussinesq-type (B)** approximations, to parametrize the vertical wave characteristics allowing for non-uniform horizontal velocities in the vertical. A non-hydrostatic model with a multi-layer approach, where more layers used increases the model accuracy, but also the computation time and complexity. Includes dispersion and can better simulate tsunami waves near the seismic source and the coastline and inside harbours as well as wave-structure interactions.

CFD = A 3D **Computational Fluid Dynamic (CFD)** model which employs non-linear Navier-Stokes, or Euler equations, and is computationally quite intensive. Generally, CFDs are parallelized to decrease runtime. Pressure field is non-hydrostatic, viscous effects are included, and since the model is 3D the depth profile of the horizontal velocity is not averaged. Fully nonlinear CFD models can simulate wave breaking and overtopping. They are often necessary for civil engineering applications, such as tsunami force and scour on local infrastructure. The most complex model choice - it includes dispersion and can better simulate tsunami waves near the coastline and inside harbours as well as wave-structure interactions.

Links or contacts for each numerical model:

- Alaska GI'-T: Alaska Geophysical Institute, Dmitry Nicolsky (djnicolsky@alaska.edu)
- BOSZ: Volker Roeber, University of Pau (volker@hawaii.edu)
- COMCOT (https://pdfs.semanticscholar.org/401d/e93588d6c28d0c3984044ad1f95b75dadab0.pdf)
- FUNWAVE-TVD, v1.0 (https://www1.udel.edu/kirby/programs/funwave/funwave.html)
- GeoClaw (https://depts.washington.edu/clawpack/geoclaw/)
- MOST (https://nctr.pmel.noaa.gov/model.html)
- NEOWAVE: University of Hawaii, Kwok Fai Cheung (cheung@hawaii.edu)
- SELFE (http://www.stccmop.org/knowledge_transfer/software/selfe)
- Tsunami3D (http://www.tamug.edu/tsunami/Researcher.html)
- TUNAMI/TUNAMI-N2: Tohoku University, Fumihiko Imamura, (imamura@irides.tohoku.ac.jp, http://irides.tohoku.ac.jp/eng/organization/faculty/risk/imamura.html)

Sample publication:

- Alaska GI'-T (https://link.springer.com/article/10.1007%2Fs00024-010-0231-9)
- BOSZ (http://www.sciencedirect.com/science/article/pii/S0378383912001081)
- COMCOT (http://tsunami.ihs.ncu.edu.tw/tsunami/Forecasting_the_wrath_of_a_tsunami.htm)
- FUNWAVE-TVD, v1.0: Wei, G. and Kirby, J. T. 1995. Time-Dependent Numerical Code for Extended Boussinesq Equations" in *Journal of Waterway, Port, Coastal and Ocean Engineering*, 120, 251-261. https://ascelibrary.org/doi/abs/10.1061/%28ASCE%290733-950X%281995%29121%3A5%28251%29
- GeoClaw (https://arxiv.org/abs/1410.2884)
- MOST: Titov, T.V., C.E. Synolakis. 1997. "Extreme Inundation Flows During the Hokkaido-Nansei-Oki Tsunami". *In Geophysical Research Letters*, 24 (11), 1315-1318. (https://nctr.pmel.noaa.gov/titov97.html)
- NEOWAVE (http://onlinelibrary.wiley.com/doi/10.1002/2014GL061232/full)
- SELFE (https://www.sciencedirect.com/science/article/pii/S1463500307001436)
- Tsunami3D (https://link.springer.com/article/10.1007/s00024-014-0988-3)
- TUNAMI/TUNAMI-N2 (http://onlinelibrary.wiley.com/doi/10.1002/2014GL062577/full)

Inundation Height (meters)	Damage Description
1+	Most of the people caught by the tsunami may perish. People can lose their balance and vehicles begin to float in as little as 30 cm of water.
2+	More than half of structures may be completely damaged
3+	Evacuation will be difficult or not possible. More than half of structures may be completely damaged or washed away.
5+	Second floor and part of the third floor of buildings will be under water.
10+	Third floor and part of fourth floor of buildings will be under water. Many structures may be washed away.

Table 5. Inundation height in relation to potential damage it could cause.

1.9. SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. See also the section 'Specialized Documents' in the Supplement 1.

- Using ComMIT (MOST model) for tsunami inundation modelling for evacuation mapping: Summary, Manual, Appendices (abridged requirements, in Spanish), tool ComMIT was used in the TEMPP1 Pilot training course for inundation modelling to support evacuation map-making. General information on ComMIT can be found at USA NOAA, https://nctr.pmel.noaa.gov/ComMIT/
- Tsunami Coastal Assessment Tool (TsuCAT) for scenario identification, v4, USA NOAA, ITIC, 2019, Summary, Manual, tool. Also pertinent to Modules 3 and 4. TsuCAT can be used to identify worst-case scenarios, and to develop scenarios for tsunami exercises using the PTWC Enhanced Products as message triggers for national and local tsunami warning decision-making. http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2239&Itemid=2763

1.10. REFERENCES AND EXAMPLES

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MODULE 2: DEVELOPING TSUNAMI EVACUATION MAPS

2.1 INTRODUCTION

In the end-to-end tsunami warning chain, once a tsunami forecast is known and a warning issued, communities must know what to do and where to go when a tsunami is imminent. The 'what to do' will be to evacuate to a safer place, and the 'where to go' is answered using a tsunami evacuation map. The tsunami inundation map is used as a base to produce the tsunami evacuation map. Evacuation maps, which include evacuation zones, evacuation routing, assembly areas, and signage are developed by emergency management agencies with the involvement of the community.

2.2 CONTENT

Step 1: Acquire required information (tsunami inundation and travel time, map or plan of the community).

Step 2: Identify Evacuation Zone.

Step 3: Identify Evacuation Assembly Sites or Areas, and Routes.

Step 4: Engage community to solicit feedback.

Step 5: Finalize Tsunami Evacuation Map and Signage.

Step 6: Obtain Official Approval.

2.3 OBJECTIVES

Participants will:

(1) Learn how to use a tsunami inundation map to create an evacuation map

(2) Learn the information to be included on a tsunami evacuation map

(3) Understand and use best practices to determine evacuation zones, sites or assembly areas, routes, and signage

(4) Understand how to engage the local community to develop a community-owned tsunami evacuation map and response procedures, and enhance tsunami awareness.

2.4 TARGET PARTICIPANTS

The target audience is:

- Local Emergency Managers,
- GIS mapping experts,
- Tsunami Inundation Map Developer,
- Community Representatives (schools, hoteliers, tourism, etc.).

Optional participants are:

- Local Authorities Staff,
- Emergency Services First Responder Agency Staff,

- Disaster mitigation personnel.

2.5 REQUIREMENTS

- Tsunami inundation map (gives flooding extent) – deliverable of Module 1.
- Tsunami wave arrival time (gives time available to evacuate) – deliverable of Module 1.
- Geospatial data layers.
- GIS software, such as QGIS or ArcGIS (recommended).

2.6 METHODOLOGY

The combination of presentations, plenary, group discussions, and site visits are used, as well as working through examples and minimal hands-on activities. The total training time commitment is 16 hours, including breaks.

2.7 EXPECTED RESULT

At the end of this module, participants will know how to produce a community tsunami evacuation map, tsunami signage and placement approved by local government officials.

2.8 MODULE CONTENT

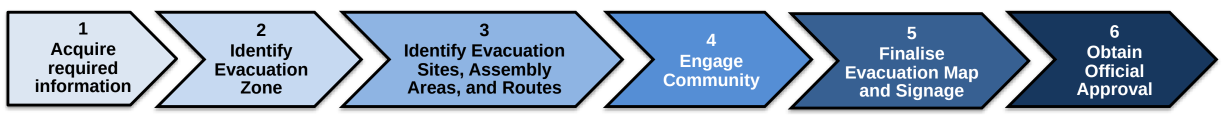

Figure 5. Steps for Module 2 – Evacuation Mapping

Important Considerations:

Evacuation maps should be simple and easy to read and should include essential information only. These are:

- Evacuation Zone: Areas threatened by tsunami inundation (flooding);
- Evacuation Sites or Assembly Areas: Location of designated assembly locations or areas, and/or vertical evacuation structures, where people should go to in case of an imminent tsunami inundation;
- Recommended evacuation routes to the safe place for people to follow. These are normally indicated as arrows, or by other significant information such as local landmarks or past run-up levels, that identify locations.

Key decisions that tsunami emergency response and evacuation planners must make are:

- Whether there should be one or more than one evacuation zone. Use of a single tsunami evacuation zone has the advantage of simplicity for planning and public awareness and understanding. However, because a single evacuation zone must accommodate the very wide range of risk scenarios that may exist, this can result in 'over-evacuation' of the entire zone for more regular small-scale events.

- Whether the evacuation map includes distant, regional, local, or all tsunami scenarios. Local tsunamis would cause extreme nearby inundation, but if they are very infrequent, then 'over-evacuation' may result.

The amount of time before the first tsunami wave arrives, and the amount of time required to execute an evacuation will form the basis for planning evacuation routes, identification of appropriate assembly sites, or the use of vertical evacuation, if there is no time for evacuation inland (e.g. evacuation upstairs in/on buildings or structures).

- Evacuation should be on foot wherever possible. Realistically, however, the public will instinctively drive vehicles during evacuations. Some modes of evacuation may be permissible if there is time (such as a distant tsunami). Planners should consider this in deciding on evacuation instructions and guidelines.

- To facilitate the development of evacuation maps from inundation maps using evacuation criteria, it is often desirable to organize and convene a Tsunami Evacuation Mapping Task Team. As a general rule, communities should be engaged early and often in the development of evacuation maps, with opportunities provided for the community to lead local evacuation plans. It will take several meetings with community to obtain input and 'buy-in'.

The Committee should consider to include:

- Provincial/State/local jurisdictions, with support of national/provincial/local government;
- Scientists (National, Provincial, Local Geological Survey or equivalent, universities, etc.); and
- Other government and NGO stakeholders, including community representatives.
- Lastly, the use of GIS software tools is often extremely helpful in the map-making. In recent years, GIS tools have been used by researchers and emergency management planners to quantitatively assess the feasibility and viability of different evacuation scenarios, including where vertical evacuation structures may be needed (Wood et. al., 2007; Wood and Schmidtlein, 2013 a, b; Wood et al., 2017)

STEP-BY-STEP INSTRUCTIONS

Step 1. Acquire required information

- Tsunami inundation and tsunami travel time map. The inundation data set should include the expected flooding extent (horizontal) from worst case and credible tsunami scenario event. The inundation zone is the minimum evacuation zone. The travel time data set should include the tsunami travel time from potential sources to the coast. These maps are outputs of the Training Module on Inundation Mapping.

- Detailed community map. The community data set should include geospatial information on the natural and built environment, as well as population demographics. Especially important is an estimate of the vulnerable population (number and location) to evacuate, and up-to-date information on road systems, infrastructure and critical facilities, and houses. It should be possible to interface a detailed community map with the tsunami inundation map.

Step 2. Identify Evacuation Zone (Hazard Zone) based on Inundation Map

In case of a tsunami, people should evacuate the designated Evacuation Zone into the Evacuation Site or Assembly Area. As the key goal is to save lives, the Assembly Site or Area should be the location(s) that are not likely to be affected, based on the Tsunami Inundation Map.

Safety factors to consider when drawing the evacuation zone line are:

- Proximity and location of high ground (hills, cliffs, man-made vertical refuges (berms, tall buildings, etc);
- Safety buffer for potential uncertainties in the inundation map;
- Knowledge of flood zones, types of roadways and locations;
- Availability of identifiable landmark locations for easier evacuation routing;
- Hazardous Materials (HAZMAT) sites and other potential hazards (secured gates or high fences, lumber yards or harbours with potential floating debris etc.) that could cause evacuation problems;
- Locations of special needs population in evacuation zone (i.e. hospitals, elder care or nursing facilities, schools, day care centres, non-English speakers, transient populations, etc.).

Step 3. Identify Assembly Sites (or Areas) and Evacuation Routes

The Tsunami Evacuation Map should can optionally show assembly sites and/or the best routes (safest, shortest, fastest way) for people to evacuate. Locations of vertical evacuation areas can also be marked. These locations are used when there is insufficient time to get outside the evacuation zone. Appropriate tsunami signage to facilitate evacuation should also be identified and located.

Decide criteria for determining assembly sites and evacuation route. The following are possible bases for selection of the site:

- Site is outside of identified Tsunami Evacuation Zone;
- Site can be reached by foot within the shortest possible time. Ease of egress by foot is the first priority, including for special needs populations;
- The total area of site can hold the expected number of people (or certain percentage of population of the community if several sites are selected);
- Site can be easily identified by residents, for example a prominent hill, a school, an open park among others
- Evacuation routes should avoid areas that could suffer damages from strong earthquakes such as collapsed bridges, buildings, power lines and landslides, which may block routes and cause hazardous conditions.
- Route and site can accommodate special needs populations (portion of the public sector that is willing, yet incapable of leaving the Evacuating Zone).

The following are some characteristics of ideal evacuation routes:

- Wide streets. Narrow and heavily used routes in densely populated areas should be avoided to prevent bottlenecks in traffic.
- If possible, no bridges.
- Away from landslide and liquefaction prone areas.
- Limited overhead power lines and similar hazards.

While in the process of designing the map, it is best to walk along routes to the safe evacuation area or sites to identify hazards and check on ground conditions that may not be obvious on maps.

Step 4. Engage community to solicit feedback

At least one meeting should be held with the community and its leaders to obtain their input. Invite all stakeholders who have a response, coordination, or special needs requirement (e.g., hospitals, schools). They may represent local government, transportation, response, NGO, and/or the private sector.

Engage and explain inundation mapping results and draft evacuation zone, evacuation areas, assembly sites, refuges, or shelters, evacuation routes, and signage. The community input is needed to finalize the drawing of the lines, evacuation/areas and routes, and signage.

Field visits to view topographic and built environment conditions may be needed. Evacuation routes should be walked by the community to confirm ease and timing for successful egress.

Step 5. Finalize Tsunami Evacuation Map and Signage

Finalize Evacuation Map

Finalize map using community inputs from the workshop. The map should be approved by the appropriate political authority (local, provincial, and/or national).

Map components should be nationally consistent. These include the following:

- Colours (zones, streets, routes, signage, symbols, topography if shown),
- Legend,
- Inclusion of tsunami warning and safety information (awareness),
- Inclusion of evacuation information (instructions, guidelines).

The map should be accompanied by simple procedures for the public, such as when to evacuate (ground shaking, sirens etc.), how to evacuate (walking/vehicles), where to evacuate to (inland, high ground, vertical), and until when (all clear message). These instructions should be developed and displayed together with the map and should be validated by the community.

Module 3 covers standalone tsunami awareness materials (including tsunami warning and safety information, and evacuation information) which need to be developed to provide information to the public on what a tsunami is, how to recognize a potentially dangerous tsunami, and what to do. They must know how to prepare their family and when, how, and where to evacuate safely.

Finalize Tsunami Signage

Finalize types of signage to be used, and locations to install the signage.

Signage is an integral part of practical tsunami risk management. Signage depicting evacuation zones and routes raises public awareness of local tsunami risk and provides information to increase the efficiency and effectiveness of an evacuation. Signage should be nationally consistent; some ISO tsunami (water safety) signage is available. Well-placed evacuation signage is often the critical factor enabling successful evacuation in an actual event.

Types of signage are (*highest priority):

- Information Board. Content examples are:
  - Evacuation Map, Instructions and guidelines,
  - Tsunami characteristics,
  - Tsunami warning process,
  - Previous Tsunami Event – local history and images.
- Evacuation Zone (Hazard Zone) *
- Evacuation Route *
- Evacuation Site (Assembly Area, vertical evacuation building) *
- Previous Tsunami Event – Wave height marker.

Signage will need to comply with national road signage standards (size, shape, colour, font, etc.) when they are placed along roads or highways.

Step 6. Obtain Official Approval

Evacuation maps are public safety products that should be approved by the appropriate local governing authority. The type and placement of signage should also be approved by the appropriate authority.

2.9 SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. These are found as Annexes of the Supplement Specialized Documents.

- How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS (manual, tutorial). *This manual describes the export of ComMIT results into the open-source QGIS software to digitally create tsunami evacuation maps using standard formats, color palettes, and symbology.*
- Town-Watching Tsunami Evacuation Checklist (example). *This example provides a template for ground-truthing tsunami evacuation maps through community engagement and actual tsunami evacuation route walking*

2.10 REFERENCES AND EXAMPLES

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[5] This document, translated with permission from the FDMA, represents a best practice example on how to make practical and reliable tsunami evacuation maps and plans. The practice focuses on the importance of community input as the most effective way in which to build awareness and response capability in residents who may have to act immediately to save their lives from tsunami.

[6] Same than above.

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MODULE 3: DEVELOPING TSUNAMI RESPONSE PLANS AND STANDARD OPERATING PROCEDURES

3.1 INTRODUCTION

Emergency Management must plan in advance for tsunami response. Not only must they have a process for receiving official warnings and make appropriate decisions in response to them, they must also understand the challenges and procedures that will apply during evacuations, as well as with regards to the loss of critical infrastructure. Closely associated is public awareness to ensure the public understands where official warnings will come from, when they can expect them (and when not, for example during a local source earthquake), how to evacuate and where their assembly areas are, and when it will be safe to return.

The Tsunami Response Plan covers the arrangements for warnings and evacuations, and public awareness on these arrangements. It must align with higher level, generic all-hazards emergency management plans.

This module will focus on the development of tsunami response plans with a specific focus on evacuation planning, based on the evacuation maps developed in Module 2.

Note: This Module can be combined with Module 4 (Evacuation Exercising) if preferred.

3.2 CONTENT

Step 1: Acquire required information,

Step 2: Develop Response Plan,

Step 3: Develop Standard Operating Procedures (SOPs),

Step 4: Develop Public Awareness.

3.3 OBJECTIVES

Participants will:

- Understand the components and content of a tsunami response plan.
- Be able to develop a tsunami response plan.
- Be able to develop Standard Operating Procedures (SOPs) in relation to tsunami warning and evacuations.
- Understand what the public should know about tsunami warnings and evacuations and methods to convey this information.

3.4 TARGET PARTICIPANTS

The target audience is:

- Local and Regional Emergency Managers,
- Emergency Services,
- Local Authorities staff,
- NTWC representative(s).

Optional participants are:

- Critical infrastructure representatives,
- Representatives from local businesses and hotels,
- Representatives of civil society, NGO's, vulnerable community groups,
- Representatives of government agencies,
- Local community leaders.

3.5 REQUIREMENTS

- Evacuation map(s) - deliverable of Module 2.
- Mandate for a Tsunami Response Plan from the Local Government.

3.6 METHODOLOGY

A combination of presentations, plenary and group discussions are used, as well as working through examples and hands-on activities. The total training time commitment is 16 hours (including breaks).

3.7 EXPECTED RESULT

At the end of this module, participants will be able to produce a tsunami response plan and be aware of public awareness needs.

3.8 MODULE CONTENT

Figure 6. Steps for Module 3 – Response Planning

Step 1: Acquire required information

The following information is required to support the development of a Tsunami Response Plan and Standard Operating Procedures (SOPs):

- The end-to-end tsunami warning process: The Tsunami Response Plan must state the end-to end warning process, and how information is communicated between the respective stakeholders. Stakeholders include: Regional Tsunami Service Providers (TSPs), NTWCs, National, Regional & Local Emergency Management, Critical Infrastructure and the Public. Subsequent planning and procedures must be based on this information.
- Roles and responsibilities: The roles and responsibilities of each stakeholder in the end-to-end warning process must be agreed as part of Policy development. The Tsunami Response Plan must re-confirm these. Specifically, the Plan must identify who monitors TSP information, who assess this information to determine local threat, and who initiates and disseminates warnings at the respective levels (national, regional and local).

- Evacuation triggers: The trigger for commencing an evacuation process at the local level by emergency managers may be the receipt of a tsunami warning (from the NTWC or National Emergency Management Agency). For the public in exposed areas the trigger may be the activation of public alerting mechanisms. Alternatively, the trigger for the public could be the natural warning itself (feeling a strong earthquake) or observing an abrupt change of sea level.
- Emergency managers should therefore keep in mind that the planning required for local, regional and distant source tsunamis will differ. A distant source tsunami will allow several hours to evacuate, while a regional source tsunami will allow much less and local source tsunami may not allow a timely official instruction. The amount of time required to execute an evacuation should therefore be analysed and factored into the planning for the respective scenarios.
- Evacuation zones concept: A key consideration for tsunami emergency response planning is the number of evacuation zones used for evacuation management and shown on evacuation maps. While the concept is established as part of the development of evacuation maps (Module 2), the Tsunami Response Plan must base its planning on them.
- It is also important to remember that where more than one zone is used, people should evacuate all the zones in "natural" warnings. In official warnings, people are expected to evacuate the zone(s) stated in the warning message.
- Vulnerability profile: Emergency managers must have a good understanding of the demographic and geographic realities inside the evacuation zones to properly plan for evacuations. Census data can assist with this; more specifically it is important to identify the critical community and sensitive infrastructure vulnerabilities.

Step 2: Develop Response Plan

- Establish the writing team: The local Emergency Management Agency must lead the planning process but will require representation of all the key stakeholders to contribute to, and share ownership of the Plan. Key stakeholders include the Emergency Services, relevant government agencies, critical infrastructure, and selected NGOs and members of civil society.
- Format and Design: A response plan is effective when emergency managers understand it, are comfortable with it, and are easily able to locate the information they need from it. The following points are things to keep in mind when designing a response plan:
    - Organization: The document must be structured so that it is easy for users to find relevant information. Separate subdivisions will support this, while it also enables revisions of particular sections without the requirement to re-publish the entire plan.
    - Progression: The document needs to have a logical sequence and avoid needless duplication. It should be written such that the user can grasp the sequence and easily locate the information that is needed.
    - Consistency: Terms and concepts must be used consistently throughout the document so that users do not have to re-orient themselves at different sections.
    - Adaptability: Plans are developed based on the anticipated consequences of an event, supported by experience of previous events. However, the consequences of no future events cannot be anticipated with 100% certainty, and threat assessments may change during an event. Emergency managers must therefore be ready to adapt as appropriate.

- Compatibility: The plan must recognise and align with other plans (including those of other agencies) so that it will not hinder coordination among the respective stakeholders.

Tsunami Response Plan Template. The following template is suggested:

Plan Status (date last reviewed, signed by Chairman of Emergency Committee or similar)

- Introduction (purpose of the plan).
- National arrangements:
  - Emergency Management structure (national, regional, local);
  - Arrangements for tsunami warning (end-to-end process; roles & responsibilities; natural warnings)
  - Tsunami warning levels.
- Local arrangements:
  - Municipality Characteristics (i.e. location, evacuation area demographics, map);
  - Vulnerability assessment (inside evacuation area – special needs groups, critical infrastructure, geographical challenges);
  - Local public alerting arrangement (mechanisms used, where they are and who manage them);
  - Evacuation map(s);
  - Evacuation routes;
  - Evacuation signage (types used, meaning, placement);
  - Local tsunami warning and evacuation thresholds & activation.
- Public awareness (see Step 3 below):
  - Public evacuation map displays and placement (must contain evacuation zones, routes & safe areas);
  - Tsunami warning arrangements education;
  - Identification of key social and community organizations;
  - Schools, aged care facilities & hospital preparedness in evacuation areas;
  - Community exercises and drills;
  - Preparedness recognition programs.
- Annexes
  - Flowcharts (i.e. chain of actions according to warning level);
  - Letter from the Mayor authorizing the activation of the Response Plan;
  - Letter from the Mayor approving the Evacuation Map(s);
  - Agreements (e.g. Radio station, radio amateur group, private places of assembly).

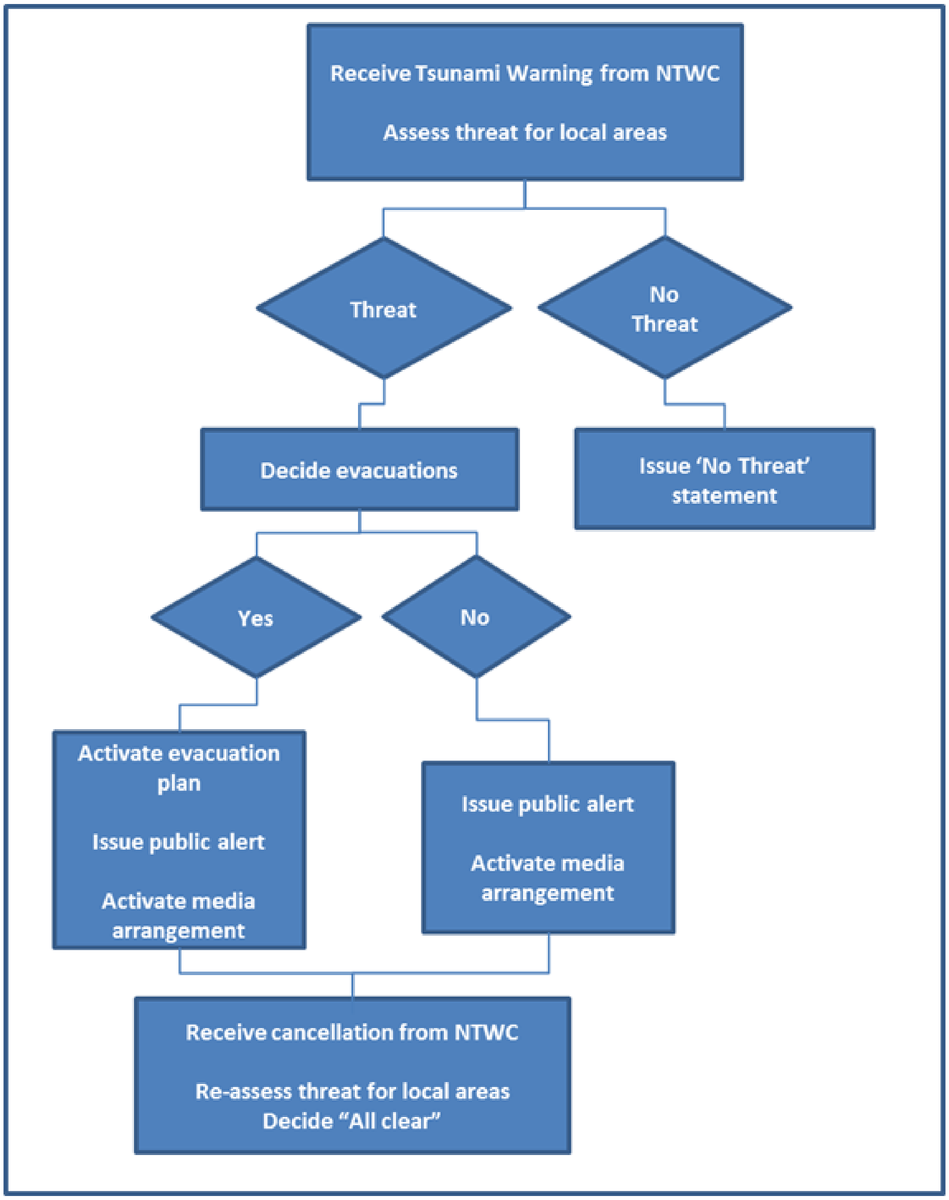

Figure 7. Simplified flow chart for tsunami response
(Source: Plans and procedures for tsunami warning and emergency management, IOC Manuals and Guides 76 rev., 2017, IOC/2017/MG/76 REV.).

Step 3: Develop Standard Operating Procedures

Once the Tsunami Response Plan is developed and approved, more detailed procedures must be developed for specific activities in the Plan. These may include:

- Tsunami Warning Standard Operating Procedures:
    - Duty arrangements, responsibilities, target times,
    - Key warning points (i.e. call trees, contact numbers),
    - Warning mechanisms & processes,
    - Contact lists maintenance.

- Tsunami Evacuation Standard Operating Procedures:
    - Types and Phases of evacuations,
    - Decision to evacuate- thresholds, timing, auto-evacuation,
    - Evacuation routes and assembly areas (per sector or neighbourhood),
    - Call trees and contact lists,
    - Management of evacuations: Transportation, movement control, cordons, security,
    - Return.

TSP Notification	**Earthquake**	**Wave forecast**	**ETA**	**NTWC Alert Level**	**Emergency Response Action**
Tsunami Threat Message	**Magnitude:** >7.0 **Depth:** <100km	**≥ 1 m**	**<3 hrs**	WARNING	Evacuate xxx zones
			3 - 6 hrs	WATCH	Prepare to evacuate
			>6 hrs	INFORMATION	Monitor for subsequent forecasts
		0.3 to 1 m	**<3 hrs**	ADVISORY	Evacuate beaches and harbours
			3 - 6 hrs	WATCH	Prepare to evacuate
			>6 hrs	INFORMATION	Monitor for subsequent forecasts
		< 0.3 m	**-**	INFORMATION	Monitor for subsequent forecasts

Table 6. Example of a thresholds table showing alert level and emergency action

- Emergency Operations Centre (EOC) Procedures:
    - Activation,
    - Agencies/stakeholders required,
    - Role assignments (Operations, Intelligence, Planning, Logistics, Relief, Public Information),
    - Collection and consolidation of information products and displays,
    - Coordination of action plans,
    - Coordination of public information.

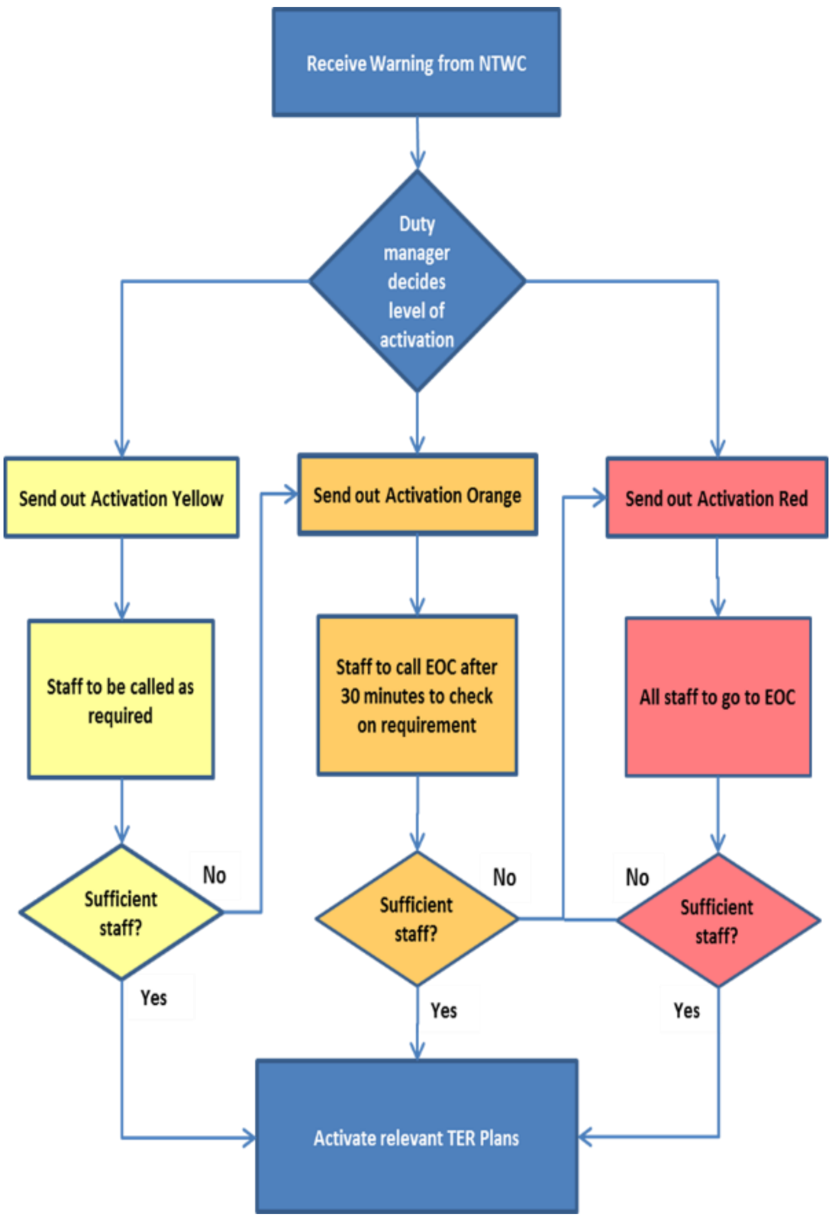

Figure 8. Example of flow chart for the activation of an EOC
(Source: IOC Muals and Guides 76 rev., 2017)

Step 4: Develop Public Awareness

The following are important considerations in developing awareness material and campaigns:

- Local or traditional knowledge: This can be a powerful tool to support scientific knowledge in community preparedness. Although it may be the most effective means in a more traditional or remote community, in general, local traditional knowledge alone will not be enough to ensure an effective response. Additional information on warning systems and evacuation and return arrangements is required.

- Community needs: To be effective, awareness activities and material should be tailored to the country or area-specific community needs. Factors such as geography, demographics, language, cultural, religious and social orientations should influence the awareness approach. They will present both strengths and opportunities.

- Coordination and collaboration: Working together among the different agencies involved is essential. Involvement and commitment by all stakeholders will support sustainability.

- Public policy: A formal tsunami education and awareness programme that is able to sustain itself over political cycles and generations can be highly effective, and may be the only feasible (funded) mitigation for localities where the occurrence of tsunamis is infrequent.

- A multi-faceted approach: The awareness programme should target a variety of formal and informal education, and awareness-building and preparedness activities such as exercises or drills

- Content: Campaigns and material should anticipate and answer the obvious questions of the target audience simply and clearly. It must include:
  - Basic information about the tsunami hazards, with specific reference to the country or area. This is best supported by information on historical tsunami events and their impacts, including local and/or traditional knowledge of past events. In the absence of this, tsunami modelling results will be key.
  - The country's tsunami warning system – where will warnings come from, how and when will they be communicated and what information will they contain (and not contain).
  - Tsunami evacuation arrangements – what the evacuation zones and routes are, how the instruction to evacuate will be issued, what to take, where the assembly sites are, and where to listen or look for the all-clear.
  - Understanding natural warning signs and how to respond to them (self-evacuations).
  - Tsunami safety rules (for people on land, in the water and in small boats).

3.9 SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. These are found as Annexes of the Supplement Specialized Documents.

- How to Create Community Tsunami Response Plans (example of response plan, template)

- Awareness Materials – Warning and Evacuation information, Family Plan card (examples). Also pertinent to Module 4.

3.10 REFERENCES AND EXAMPLES

The following are references and examples covering both this module summary and the Supplement to Programme Modules.

Guidance

Japan Fire and Disaster Management Agency (FDMA). 2013. *Guideline for the Municipality to Make Tsunami Evacuation Plan (Chapter 2).* Civil Protection and Disaster Management Department[7].

Japan Fire and Disaster Management Agency (FDMA). 2013. *Tsunami Evacuation Planning Manual for each Region (Chapter 3), Report from Study Group for Promoting Guidelines for Tsunami Evacuation Countermeasures*. Civil Protection and Disaster Management Department[8].

Pacific Tsunami Museum. 2012. *Tsunami Evacuation Guidelines for Schools in Hawaii, Hawaii Tsunami Education Curriculum Program*, *August 2012*, 12 pp.

Scheer, S. et al. 2011*. Handbook of Tsunami Evacuation Planning, Scenarios for Hazard-induced Emergencies Management, Project n° 030963, Specific Targeted Research Project, Space Priority* (ISBN 978-92-79-19086-5, doi: 10.2788/34292)

Spahn, H. et al. 2010. *Planning for Tsunami Evacuations, A Guidebook for Local Authorities and other Stakeholders in Indonesian Communities*, GTZ IS-GITEWS, 88 pp.

UNESCO/IOC. 2017. *Plans and Procedures for Tsunami Warning and Emergency Management*. Paris, UNESCO, IOC Manuals and Guides No. 76. (IOC/2017/MG/76 REV.)

USA, California Office of Emergency Services. 1998. *Local Planning Guidance on Tsunami Response, 2nd Edition, A Supplement to the Emergency Planning Guidance for Local Governments*. 206 pp. (Accessed 22 March 2019)

USA, Oregon Tsunami Working Group. 2012. *Local Planning Guidance on Distant Tsunami Response*. 77 pp. Available at:
https://www.oregongeology.org/tsuclearinghouse/resources/pdfs/2013-01-14_Guidance_for_Distant%20Tsunami_Response_FINAL.pdf (Accessed 22 March 2019)

[7] This document, translated with permission from the FDMA, represents a best practice example on how to make practical and reliable tsunami evacuation maps and plans. The practice focuses on the importance of community input as the most effective way in which to build awareness and response capability in residents who may have to act immediately to save their lives from tsunami.

[8] Same than above.

Examples

New Zealand

- Ministry of Civil Defence & Emergency Management. 2018. *National Tsunami Advisory and Warning Plan, Supporting Plan [SP 01/18]*. New Zealand. Available at: https://www.civildefence.govt.nz/assets/Uploads/publications/Tsunami-Advisory-and-Warning-Plan-Supporting-Plan-Update-OCT-2018.pdf (Accessed 22 March 2019)
- Selwyn District Council. 2006. *Tsunami Response Plan, Civil Defence, Selwyn District Emergency Management*, 37 pp. Available at: https://www.selwyn.govt.nz/services/civil-defence-And-emergency-management/natural-disasters/tsunami (Accessed 22 March 2019)

Samoa

- Government of Samoa. 2006. *National Tsunami Plan*.
- Standard Operating Procedure: Activating and Maintaining the Emergency Siren Network, 2014.
- Savaia Village Disaster Response Plan, 2009, 2017.

United States of America (USA)

- State of California
    - City and County of San Francisco. 2008. *Tsunami Response Annex, Emergency Response Plan, An element of the City and County of San Francisco Emergency Management Program*, 44 pp.
    - City of Manhattan Beach. 2014. *Emergency Response Plan for Tsunami Operations, Emergency Preparedness Division*, 29 pp.
    - Ventura County, CA Operational Area Tsunami Evacuation Plan, 2011 (draft), 28 pp.
- State of Hawaii
    - Emergency Alert System (EAS) Plan, 2003.
    - Hawaii Emergency Management Agency, Distant Advisory/Watch/Warning Checklist, 2016.
    - Hawaii Emergency Management Agency, Local Tsunami Response Checklist, 2016.
    - City & County of Honolulu, Emergency Operations Plan, Tsunami Standard Operating Guidelines, 2014; Annex T-Appendix 2, Tsunami Evacuation & Sheltering, 2007.
- State of Oregon
    - Distant Tsunami Procedures, Lincoln County School District, 2014, 2016.

MODULE 4: TSUNAMI EXERCISING

4.1 INTRODUCTION

Tsunami evacuation exercises bring planning to practice. They serve two main purposes:

- To test the effectiveness of, and identify improvements to be made in regards to tsunami warnings and evacuation maps, plans and procedures.
- To promote public awareness and preparedness.

Exercises can be carried out by a single stakeholder in the end-to-end tsunami warning chain, or by several stakeholders exercising together. They can be simple (i.e. a discussion or a drill), or complex (i.e. an operational exercise over several days). In all instances the post exercise process is equally important as the exercise itself in order to register lessons identified and corrective actions to implement.

This module will focus on exercises specifically in relation to tsunami evacuation, their development and conduct, and the post exercise process.

4.2 CONTENT

Step 1: Acquire required information.

Step 2: Plan exercise.

Step 3: Conduct exercise.

Step 4: Evaluate exercise.

Step 5: Implement recommendations.

4.3 OBJECTIVES

Participants will:

- Understand the types of evacuation exercises,
- Know how to plan for the respective types of exercises,
- Understand the post-exercise process.

4.4 TARGET PARTICIPANTS

The target audience are:

- Local and Regional Emergency Managers,
- Emergency Services,
- Local Community leaders,
- Critical infrastructure representatives.

Optional participants are:

- Representatives of civil society, NGO's, vulnerable community groups, business, tourism industry,

- Representatives of government agencies,
- Media.

4.5 REQUIREMENTS

- Evacuation Maps: deliverables of Module 2.
- Tsunami Response Plan: deliverables of Module 3.
- Warning & Evacuation SOPs: deliverables of Module 3.

4.6 METHODOLOGY

A combination of presentations, plenary and group discussions are used, as well as working through examples and hands-on activities. The total training time commitment is 16 hours (including breaks).

4.7 EXPECTED RESULT

At the end of this module, participants will be able to conduct tsunami evacuation exercises at community level.

4.8 MODULE CONTENT

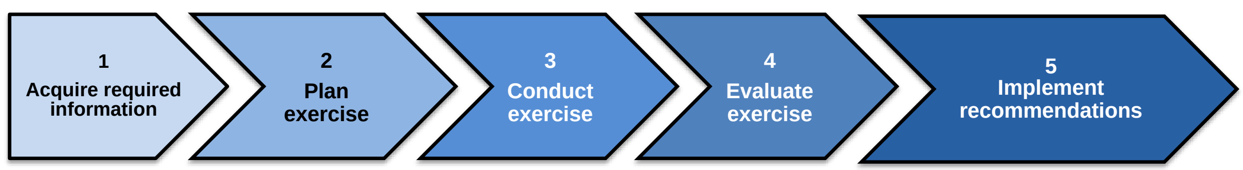

Figure 9. Steps for Module 4 – Tsunami Exercising

Step 1: Acquire required information

- Analyse the need**:** All exercises emerge from an identified need. A needs assessment identifies whether an exercise activity is required. The needs assessment is informed by reviewing existing plans and SOPs (were there changes, are there areas of concern?), past exercises (when were the Plan and SOPs last exercised, who participated and what were the findings?), and available resources.
- Establish the aim, objectives, and scope of the exercise:
  - The aim is a broad statement of intent. It provides the direction for what is to be achieved by the exercise.
  - The objectives must be in line with the aim but they are more specific and performance based. They therefore state what elements of the response will be exercised and according to what standards. Objectives should be ‘SMART’ (Specific, Measurable, Achievable, Realistic, Task oriented or Time driven). They form the basis for the exercise design and delivery.
  - The scope determines the boundaries of the exercise (geographical area and processes it will cover), when and where it will be held, and who will participate.

- Determine the exercise type best suited to deliver the aim and objectives: There are five types or levels of exercising; the level of planning and resourcing required for each increase exponentially:
    - Type 1: Orientation Workshop**:** An Orientation Workshop provides an overview of policies, plans, and procedures. They are useful to orientate new staff and/or leadership, agencies, NGOs etc. and are a good starting point for jurisdictions that are developing or making major changes to their plans and procedures.
    - Type 2: Drill**:** Drills involve the testing of a specific operation or function in a single agency, facility, or organization such as a hotel, school, village, etc. Drills are used to test the **response** time with regards to a specific activity, train personnel, assess the capabilities of equipment, assess the cooperation between agencies, and determine whether the capabilities of the resources and personnel staffing is sufficient. They also serve as a useful public awareness activity, for example a tsunami 'WalkOut'. This type of drill stresses simplicity and fun, and is suitable for both coastal residents and visitors.

Image 1. Phases of a tsunami drill.

- Type 3: Tabletop Exercise**:** A Tabletop exercise involves key staff members of stakeholder agencies and/or organizations working jointly through a scenario in a slow paced, discussion format. Tabletop exercises are used to assess plans and procedures, and to consider specific problems or issues introduced to the scenario. Discussions may also be in small-group format and feedback given to the larger group for conclusion of outcomes and decisions. An exercise facilitator is required.
- Type 4: Functional Exercise**:** Functional exercises are designed to test and evaluate capacities and/or activities and coordination against the real time simulation of a specific period of a response. 'Exercise injects' are released into the exercise accordance by an exercise control function in the form of tsunami warning products, consequence information, media enquiries etc. in accordance to a time-driven 'Master Schedule of Events' list. Functional exercises may or may not include public evacuations.
- Type 5: Full-Scale Exercise: A Full-scale exercise is used to test and evaluate the culmination of a programme of work involving multiple stakeholders and layers of government (national, provincial, local). It involves actual field mobilization and deployment of response personnel, activation of command and coordination centres and usually includes all aspects of emergency response.

- Obtain a mandate and commitment**:** A mandate for the exercise must be given by the Local Government (or the highest relevant principal) - by signing off on the exercise aim, objectives and scope. This ensures budget, resourcing, time and participation is appropriately committed towards the exercise.

Step 2: Plan exercise

- Establish the Exercise Task Team: The Exercise Task Team is responsible for the successful execution of all aspects of the exercise, including exercise planning, implementation, and evaluation. They will develop the exercise narrative, Master Schedule of Events List, and the exercise injects. Technical specialists and subject matter experts must be involved to help provide realistic information to the scenario and injects. The Task Team uses the exercise aim and objectives to determine the evaluation criteria and evaluation tools for the exercise, and will also develop appropriate promotion and media strategies prior to the exercise. Afterward, the Task Team is responsible for collating the post-exercise evaluations and writing the Summary Report. The Team must have representatives from the key participating agencies but should be kept to a manageable size.
- Establish the scenario**:** The scenario is a narrative that describes the event to which the participants should respond. Tsunami technical specialists are required to develop a scenario that will facilitate realisation of the exercise objectives. Once developed, the scenario must only be known to the Exercise Task Team and not to the participants.
- Develop the exercise documents**:** Documents include the exercise announcement, the Exercise Manual or General Instruction, the Master Schedule, injects and promotion. The NTWC will make the corresponding simulated messages.
- Develop the evaluation plan**:** The evaluation plan will determine the evaluation method that will be applied. This may be in the form of internal and/or combined debriefs, or the appointment of exercise evaluators, or both. If exercise evaluators are appointed, they must be provided with consistent instructions and tools to conduct the evaluation. Tools may include forms with specific questions and reference materials.

Step 3: Conduct exercise

The Exercise Control Function is responsible for the conduct of the exercise. They enforce the exercise rules and boundaries, disseminate exercise injects, fill gaps (i.e. simulating agencies or elements that are not represented), are available for clarifications, control the pace of the exercise, and starting and stopping the exercise.

The exercise must start with a briefing to all participants to ensure they are aware of timings, exercise boundaries (scope), locations, expected outcomes, exercise control arrangements, evaluation arrangements, safety and exercise logistics.

Step 4: Evaluate exercise

Post exercise debriefs are used to afford participants the opportunity to offer a critical review of the exercise by noting (in their opinions) the areas that went well, and those areas where issues were experienced. These are collated to identify the recommendations for improvements. If post debriefs are held by each participating agency it is preferable that a combined debrief also be held to share and collate all the observations.

If exercise evaluators were appointed their individual evaluation forms and/or reports must be collected and collated.

While all individual debriefs and evaluation reports must be filed, they are collectively used to determine the evaluation that will be represented in the Exercise Report.

A suggested format for the Exercise Report is:

1. Aim, objectives and scope of the exercise,
2. The scenario,
3. Summary of the exercise (format, where, when, timeline, participating agencies),
4. Exercise evaluation (against the objectives),
5. Recommendations.

Step 5: Implement recommendations

The final exercise report must be accepted/adopted by the Local Government and its recommendations must be followed up. The corrective actions identified in the report must be assigned to appropriate managers for implementation and report-back to the Sponsor(s) against agreed timelines for each action. Coordination and oversight of the implementation of the corrective actions might also be assigned to the Exercise Task Team.

4.9 SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. These are found as Annexes of the Supplement Specialized Documents.

- Awareness Materials - Warning and Evacuation information, Family Plan card (examples) Also pertinent to Module 3.

- How to Create Community Tsunami Exercises (example of exercise plan and evaluation forms, template).

- How to conduct Tsunami Drill flyer (example).

4.10 REFERENCES AND EXAMPLES

The following are references and examples covering both this module summary and the Supplement to Programme Modules.

Guidance

New Zealand Ministry of Civil Defence & Emergency Management. 2009. *CDEM Exercises, Director's Guidelines for Civil Defence Emergency Management (CDEM) Groups [DGL 10/09*]. New Zealand (ISBN: 978-0-478-25490-7).

Oregon Office of Emergency Management. 2017. *Tsunami Evacuation Drill Guidebook: How to Plan a Community-Wide Tsunami Evacuation Drill, 41 pp (https://www.oregongeology.org/tsuclearinghouse/resources/pdfs/OEM_Tsunami_Evacuation_Drill_Guidebook_FINAL_12-19-2017.pdf (Accessed 12 November 2019).*

Philippine Institute for Volcanology and Seismology (PHIVOLCS). 2012. *How to Conduct a Tsunami Drill.*

Rahayu, Harkunti P, Wahdiny, II, Mariany, A. 2008. *Guideline Tsunami Drill Implementation for City and Regency*. Indonesia, 159 pp.

Spahn, H. et al. 2010. *Planning for Tsunami Evacuations, A Guidebook for Local Authorities and other Stakeholders in Indonesian Communities*, GTZ IS-GITEWS, 88 pp.

UNESCO/IOC IOTIC. 2015. *Module on Tsunami Exercises*, 98 pp.

UNESCO/IOC IOTIC and Myanmar Department of Meteorology and Hydrology of Ministry of Transport, and Relief and Resettlement Department of Ministry of Social Welfare, Relief and Resettlement. 2015. *Guidebook, How to Plan, Prepare for, Conduct and Evaluate national and local Tsunami Exercises to improve Tsunami Preparedness in Myanmar*, 84 pp.

UNESCO/IOC IOTIC and Timor Leste National Disaster Management Directorate of the Ministry for Social Security. 2015. *Guidebook, How to Plan, Prepare for, Conduct and Evaluate national and local Tsunami Exercises to improve Tsunami Preparedness in Timor Leste*, 74 pp.

UNESCO/IOC. 2013. *How to Plan, Conduct and Evaluate UNESCO/IOC Tsunami Wave Exercises*. Paris, UNESCO, IOC Manuals and Guides No. 58 rev. (English, Spanish). (IOC/2012/MG/58 REV.)

UNESCO/IOC. Tsunami Wave Exercises, Manuals and Summary Reports:

- Caribbean and Adjacent Region: Exercise Caribe Wave/Lantex (2011, 2013, 2014, 2015, 2016, 2017, 2018, 2019),

- Indian Ocean: Exercise IOWave (since 2009, 2011, 2014, 2016, 2018),

- North Atlantic and Mediterranean: Exercise NEAMWAVE (2012, 2014, 2017),

- Pacific Ocean: Exercise PACWAVE (2006, 2008, 2011, 2013, 2015, 2016, 2017, 2018).

UNESCO/IOC. 2017. *Methodological guidelines: How to prepare, conduct and evaluate a community-based tsunami response exercise (draft).* English, Spanish, French. (http://www.ioc-tsunami.org/index.php?option=com_oe&task=viewDocumentRecord&docID=19139,er (Accessed 12 November 2019)

<u>Examples</u>

Chile (Accessed 22 March 2019)

- Exercises: http://www.onemi.cl/simulacros/

India (national and local example)

- IOWAVE16, National Tsunami Exercise Plan, 2016.
- Odissa, Indonesia Community Drill Exercise Plan, 2016.

United States of America (local example)

- Oregon, Tsunami Drill Post-Exercise Report, Taft and Cutler City, Lincoln City, 31 May 2006.
- Hawaii, Kekaha Elementary School Tsunami Drill, 7 March 2008.

ANNEX I

TSUNAMI EVACUATION MAPS, PLANS, AND PROCEDURES (TEMPP) PILOT

The Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) training course covered the standard process for the production of reliable and practical community-level tsunami evacuation maps. The course was developed in collaboration the US NOAA, New Zealand and the IOC, with funding support from USAID/OFDA, US NOAA and IOC, from 2015 to 2017. A Course Development Team assisted in identifying best practices worldwide and provided input to the Pilot Course.

The Pilot Course was conducted in Honduras using the communities of Cedeño (Pacific coast) and Sambo Creek (Caribbean coast). While the ITIC and partners led the effort, significant commitments from Honduras as the beneficiary country were required for the Pilot. The Pilot was structured to enable the relevant national agencies to work at the local level with communities and authorities in the development of tsunami evacuation plans, maps, and procedures. At the Pilot's completion, the host country should have received sufficient training to replicate the community evacuation map process in other tsunami-prone communities.

Targeted trainees are Tsunami National Contacts, National Tsunami Warning Centres and Tsunami Warning Focal Points, disaster management and other governmental institutions staff (local and national) and civil society organization leaders. Tsunami modelling training targets physical scientists and oceanographers in governmental institutions and universities. The direct outcomes for the trained country include:

- Communities that know what to do and where to go, and
- Country capability and tools to replicate the community evacuation map process elsewhere

For each Honduras training, one representative for the other Central American Countries (Guatemala, El Salvador, Nicaragua, Costa Rica, and Panama), and Mexico was also invited to participate in order to learn the process so that they might replicate it in their own country. The typical class size was 15–20 persons.

1. TEMPP PROJECT TIMELINE

Overall Timeline	Planned dates	Project Responsibility
New Course and Pilot	2015 – 2017	ITIC
IOC Circular letter to select host	11 May 2015	ITIC, PTWS WG 3, USAID, IOC, CTWP
Countries submit questionnaire to host	11–22 May 2015	Central America - Pacific Coast Countries
Host country selected	Week May 25, 2015	Pilot Selection Committee
Course Development	Throughout 27 April 2015 (Honolulu) 22–25 June 2015 (Honolulu)	Course Development Team

Overall Timeline	Planned dates	Project Responsibility
	11–14 April 2016 (Honolulu) Email–Google Hangout	
Course Guidance	Throughout 23 February 2016 (Paris) 28 June 2016 (Honolulu) 22 February 2017 (Paris, TOWS WG Inter-ICG TT DMP) Email	PTWS Task Team on Evacuation Planning and Mapping
Pilot Summary Report Course Manual	September 2017 November 2017	ITIC ITIC and Course Dev Team
IOC Guideline – Tsunami Evacuation Maps, Plans, and Procedures	2019	ITIC and Course Dev Team

Table A–1. TEMPP project timeline

2. TEMPP PILOT COURSE – TRAINING WORKSHOPS

The Course consisted of a series of five linked training workshops that took one Honduran community (Cedeño, Pacific coast) through the process of creating community-owned evacuation maps, plans, and procedures. A second community (Sambo Creek, Caribbean coast) was examined, but tsunami evacuation mapping was not done due to the lack of adequate bathymetry for inundation mapping.

The Training Workshop topics were:

- Tsunami Inundation Modelling,
- Earthquake Tsunami Scenarios and Tsunami Inundation Map Development,
- Evacuation Map Development,
- Tsunami Warning & Emergency Response Planning and Standard Operating Procedures (SOPs), and
- Tsunami Exercising.

The Course covered cases where modelling was and was not possible, demonstrated the application of different levels of tsunami modelling to construct inundation maps, worked through the process of creating a community-owned evacuation map, with appropriate routing, safe area assembly, signage, and tsunami response and evacuation plan, and finally, used an exercise to test emergency response operational readiness of communities.

3. SUMMARY OF TRAINING WORKSHOPS

For each training, participants were given pre-training and post-training 'homework.' During each 1-week training, participants engaged in hands-on learning activities that utilized their pre-training homework. Agenda, presentations, references, and working documents for each training are available for download from the IOC. Following each training, participants were expected to complete what they had started – the next training would use that product, and so on. Between the workshops, remote meetings were also held.

Workshop/Training	Dates	Purpose	Outcome / Post-Training homework
TEMPP 1: Tsunami Inundation Modeling – ComMIT/MOST tool	27–31 July 2015	Inundation modeling training – How to use ComMIT tool with MOST model	Able to use ComMIT Homework: run scenarios
Post-TEMPP 1: ComMIT Homework review	19 October 2015 Teleconf	Review of TEMPP 1 homework exercises (create high- and low-resolution models and run up to 24 scenarios)	Participants understand how to use ComMIT
Post-TEMPP 1: ComMIT Homework review	3 Nov 2015 Webinar	Progress report and troubleshooting with Pilot country.	Honduras prepared to use ComMIT for inundation mapping
TEMPP 2: Seismic Tsunami Sources for Honduras Meeting	29 Feb–1 March 2016	Identify and agree on credible worst-case tsunami scenarios to use for inundation mapping	Honduras inundation mapping scenarios list
TEMPP 2: Inundation Mapping for Evacuation – process	2–3 March 2016	How to create Inundation Map as ensemble of inundation scenarios; How to output results in GIS format	Inundation Map for evacuation mapping (GIS results layers)
Pre-TEMPP 3: Preparation of Evacuation Maps	2 August 2017 Webinar	Data needs and other needs to be able to create evacuation maps	Requirements to make evacuation maps met
TEMPP 3: Evacuation Mapping – process, Tsunami Ready community recognition guidelines, Tsunami Awareness	15–19 August 2016	How to create Evacuation Map from Inundation Map using GIS tools with community engagement; Building preparedness using a Tsunami Ready (TR) program; Creating Essential Awareness materials	Evacuation map; TR recognition program, TR Board; Essential tsunami awareness materials developed (Info, signage, maps)
TEMPP 4: Warning and Emergency Response, Socialization - Education &	7–11 November 2016	How to create a Tsunami Response Plan (SOPs for warning and community evacuation); How to	Tsunami Response Plan; Community Tsunami Exercise Plan

Workshop/Training	Dates	Purpose	Outcome / Post-Training homework
Awareness, Exercise planning		conduct a Tsunami Exercise	
Pre-TEMPP 5: Exercise Preparation, Socialization and Awareness, Tsunami Ready progress visit	30 January–3 February 2017	Plan for successful exercise, and Tsunami Ready guidelines completion, e.g., Exercise format and conduct agreed, Evacuation Map and signage deployed, Education and Awareness materials created, and outreach to be conducted	Ensure successful exercise and Tsunami Ready guidelines met
TEMPP 5: Functional Exercise, Tsunami Ready Recognition Ceremony	15–17 February 2017	Official Adoption of Maps, Functional Tsunami Exercise, including evacuation, Tsunami Ready Board review and approval, Tsunami Ready Recognition ceremony, Pilot Wrap-up meeting	Official Evacuation Map, Tsunami Ready Recognition
Post-TEMPP5: Cedeño Exercise Debrief	17 March 2017 Webinar	Post-exercise evaluation - Exercise Observer/Evaluator results, discussions, and lessons learned.	Exercise hot wash and debrief

Table A–2. Summary of training workshops

Training information and materials can be found on the IOC website at:

TEMPP 1:
http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1705

TEMPP 2:
http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1803

TEMPP 3:
http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1891

TEMPP 4:
http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1943

TEMPP 5:
http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1984

4. COURSE DEVELOPMENT TEAM

- Bernardo Aliaga, PTWS Technical Secretary, Programme Specialist, UNESCO/IOC.
- Dr Diego Arcas, Head, Tsunami Group, NOAA Pacific Marine Environmental Laboratory (PMEL).
- David Coetzee, Manager, Capability & Operations, NZ Ministry of Civil Defence and Emergency Management.
- Dr Laura Kong, Director, ITIC.
- George Crawford, Community Preparedness, retired from Earthquake and Tsunami Program Manager, USA Washington State Military Department Emergency Management Division.
- Christa von Hillebrandt-Andrade, Manager, NOAA Caribbean Tsunami Warning Program (CTWP); Carolina Hincapie, CTWP.
- Mylene Villegas, Chief Science Research Specialist, Geologic Disaster Awareness & Preparedness Division (GDAPD), Philippine Institute of Volcanology and Seismology (PHIVOLCS).
- Tim Walsh, Chief Hazards Geologist, USA Washington State, Dept of Natural Resources.

Additional details for each Training, as well as Lessons Learned from the TEMPP Pilot were reported in full TEMPP Pilot Summary Report (found in Supplement 1).

ANNEX II

SUPPLEMENT TO THIS GUIDE

The Supplement to this guide consists of a package of different content that provides additional background, detailed explanation, best practice and useful real-world guidance, and step-by-step instructions to assist in completing the Action Steps within each Programme Module. All Supplement materials are electronic, and available from the IOC or ITIC.

The Supplement consists of two types of content:

- Supplement to Programme Modules that compiles materials in support of each of the four Modules: Identifying Tsunami Inundation Areas, Developing Tsunami Evacuation Maps, Developing Tsunami Response Plans and Standard Operating Procedures (SOPs), and Tsunami Exercising.
- Supplement Specialized Documents on each of the four Modules, including how-to-manuals, templates and guidance.

The most current versions of the Supplement to the Programme Modules and the Specialized Documents are available from the IOC and ITIC, or can be download from the ITIC Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) web site http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2166&Itemid=2640 (Accessed 7 November 2019)

1. SUPPLEMENT TO PROGRAMME MODULES

The Supplement to Programme Modules covers the following topics in detail (as given in Table of Contents):

MODULE 1 – IDENTIFYING TSUNAMI INUNDATION AREAS

- Acquire Required Information
- Learn Basics of Tsunami Science and Numerical Modelling
    - Terminology
    - Tsunami Generation
    - Tsunami Propagation
    - Tsunami Impact
    - Tsunami Numerical Modelling
    - Computing Tsunami Impact Using Numerical Models
- Conduct Tsunami Modelling or No Modelling
    - Tsunami Modelling Requirements
    - Methods of Determining Inundation/Flooding Extents
- Create Inundation Map
    - Tsunami Inundation Map
    - Practical uses of Tsunami Hazard and Inundation Maps
    - Role in Tsunami Disaster Risk Reduction

    - Guiding Principles
    - Relating Inundation to Tsunami Impact
- Additional Resources

MODULE 2 – DEVELOPING TSUNAMI EVACUATION MAPS

- Acquire Required Information
- Identify Evacuation Zone (Hazard Zone) Based on Inundation Map
    - Designation of Areas
    - Evacuation Obstacles
    - Determine Evacuation Time
    - Difficult-to-Evacuate Areas
- Identify Evacuation Assembly Sites (Areas) and Routes
    - Evacuation Assembly Sites or Areas
    - Vertical Evacuation Buildings
    - Vertical Evacuation Building Codes
    - Tsunami Evacuation Routes
- Engage Community to Solicit Feedback
    - Community Engagement in Developing Tsunami Evacuation Map
    - Community Presentation
    - Town Watching
- Finalise Evacuation Map and Signage
    - Tsunami Hazard Evacuation Map Guidelines
    - Symbols and Icons
    - Thematic Layers
    - Example Tsunami Evacuation Maps
    - Signage
- Obtain Official Approval
    - Approval
    - Review
    - Printing
    - Ensuring Effectiveness of Evacuation Map
- Pedestrian Evacuation Simulation and Planning
    - Methodology
    - Evacuation Simulation Analysis
- Additional Resources

MODULE 3 – DEVELOPING TSUNAMI RESPONSE PLANS AND STANDARD OPERATING PROCEDURES

- Acquire Required Information
- Develop Response Plan
  - Format and Design
  - Tsunami Notification and Activation
  - Tsunami Alert System
  - Phases of Operational Activities
- Develop Standard Operating Procedures (SOPs
  - Examples of Tsunami Warning SOPs
  - Example of Emergency Operations Centre (EOC) Roles and SOPs
  - Evacuation Planning and Procedures
- Develop Public Awareness
  - Content of Public Awareness
  - Strategies for Successful Awareness and Education of Public Awareness
  - Effective Dissemination
  - Ensuring Effectiveness of an Evacuation Map
- Additional Resources

MODULE 4 – TSUNAMI EXERCISING

- Acquire Required Information
  - Analyse the Need
  - Establish Aims, Objectives, and Scope
  - Types of Exercise
- Plan Exercise
  - Exercise Task Team
  - Scenario
  - Exercise Documents
  - Media Involvement
  - Preparing and Setting Up
- Conduct Exercise
  - Starting the Exercise
  - Controlling the Exercise
  - Concluding the Exercise
- Evaluate Exercise

- ○ Participant Debriefs
- ○ Exercise Task Team Debrief
- ○ Exercise Validation and Report

- Implement Recommendations

- Additional Resources

2. SUPPLEMENT SPECIALIZED DOCUMENTS

The following table summarizes the Supplement Specialized Documents:

Number	Specialized Document Name	Module(s)
I	Using ComMIT (MOST model) for tsunami inundation modelling for evacuation mapping: Summary, Manual, and Appendices (abridged requirements, in Spanish) *ComMIT was used in the TEMPP1 Pilot training course for inundation modelling to support evacuation map-making.*	**1**
II	Tsunami Coastal Assessment Tool (TsuCAT) for scenario identification, v4, USA NOAA, ITIC, 2019, Summary and Manual. *TsuCAT can be used to identify worst-case scenarios, and to develop scenarios for tsunami exercises using the PTWC Enhanced Products as message triggers for national and local tsunami warning decision-making.*	**1, 3, 4**
III	How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS, Manual and Tutorial. *This Manual describes the export of ComMIT results into the open-source QGIS software to digitally create tsunami evacuation maps using standard formats, color palettes, and symbology.*	**2**
IV	Town-Watching Tsunami Evacuation Checklist *This example provides a template for ground-truthing tsunami evacuation maps through community engagement and actual tsunami evacuation route walking. A copy is also contained within the Supplement to Programme Modules.*	**2**
V	How to Create Community Tsunami Response Plans (example of response plan, template)	**3**
VI	Awareness Materials – Warning and Evacuation information, Family Plan card (examples): TEMPP3 and TEMPP4.	**3, 4**
VII	How to Create Community Tsunami Exercises (example of exercise plan and evaluation forms, template): TEMMP4 and TEMMP5.	**4**
VIII	How to conduct Tsunami Drill flyer (example)	**4**

Table A–1. Supplement specialized documents

ANNEX III

GENERAL BIBLIOGRAPHY, NATIONAL RESOURCES AND BEST PRACTICES

The following is a general bibliography on tsunamis, tsunami early warning systems, disaster risk reduction, and on national and community tsunami response and evacuation planning (Modules 1 to 4):

Kong, Laura S.L. 2007. *A Global Tsunami Reduction Strategy: Building Effective Tsunami Warning and Mitigation Systems, Proceedings, 4th International Workshop on Coastal Disaster Prevention, Future Disaster Management of Tsunami and Storm Surge in Asia, 1-2 December 2007, Yokohama, Japan.*

Port Technology Group, ASEAN-Japan Transport Partnership. 2009. *Guideline for Development and Utilization of Tsunami Disaster Management Map for ASEAN and Indian Ocean Tsunami Affected Countries, v1.0*, 69 pp. (Outline by Japan Port and Airport Research Institute, (PARI).

Scheer, S. et al. 2011. *Handbook of Tsunami Evacuation Planning, Scenarios for Hazard-induced Emergencies Management, Project n° 030963, Specific Targeted Research Project, Space Priority*. (ISBN 978-92-79-19086-5, doi: 10.2788/34292).

Tanaka, S, and Istiyanto, D. 2010. *Tsunami Hazard Mapping in Developing Countries, An Effective Way of Raising Awareness for Tsunami Disaster Risk Reduction*. ICHARM Pub No. 21, 40 pp.

UNISDR. 2006. *Third International Conference on Early Warning, Developing Early Warning Systems: A Checklist, 27-29 March 2006*.

UNISDR. 2017. *Report of the open-ended intergovernmental expert working group on indicators and terminology relating to disaster risk reduction, adopted by the United Nations General Assembly on February 2nd, 2017*. Available at: https://www.unisdr.org/we/inform/publications/51748 (Accessed 24 March 2019).

UNESCO/IOC. 2008. *Tsunami Preparedness: Information Guide for Disaster Planners*. Paris, UNESCO. IOC Manuals and Guides No. 49. (SC.2008/WS/5) Available at: http://unesdoc.unesco.org/images/0016/001600/160002e.pdf (Accessed 21 March 2019).

UNESCO/IOC. 2010. *Strengthening Tsunami Warning and Emergency Responses: One-week Training Workshops on the Development of End-to-End Tsunami Standard Operating Procedures (SOPs): Course Manuals on Tsunami Warning, Tsunami Emergency Response, Alerting, Media and Local Preparedness.*

UNESCO/IOC. 2014. *Tsunami, The Great Waves, Revised Edition*. Paris, UNESCO. 16 pp., illus. IOC Brochure 2012-4 (English, French, Spanish), revised 2014.

UNESCO/IOC. 2017. *Plans and Procedures for Tsunami Warning and Emergency Management*. Paris, UNESCO, IOC Manuals and Guides No.76, 72 pp. (IOC/2017/MG/76 REV).

UNESCO/IOC. 2019. *Tsunami Glossary, Four Edition*. Paris, UNESCO, IOC Technical Series, No. 85. (English, French, Spanish, Arabic, Chinese) (IOC/2008/TS/85 rev.4)

Examples

Indonesia

Spahn, H. et al. 2010. *Planning for Tsunami Evacuations, A Guidebook for Local Authorities and other Stakeholders in Indonesian Communities*, GTZ IS-GITEWS, 88 pp.

Japan

Japan Fire and Disaster Management Agency (FDMA). 2013. Guideline for the Municipality to Make Tsunami Evacuation Plan (Chapter 2). Civil Protection and Disaster Management Department. (in Japanese, translated with permission into English).

Japan Fire and Disaster Management Agency (FDMA). 2013. Tsunami Evacuation Planning Manual for each Region (Chapter 3), Report from Study Group for Promoting Guidelines for Tsunami Evacuation Countermeasures. Civil Protection and Disaster Management Department. (in Japanese, translated with permission into English).

Japan Cabinet Office. 2011. *Report of the Committee for Technical Investigation on Countermeasures for Earthquakes and Tsunamis Based on the Lessons Learned from the "2011 off the Pacific coast of Tohoku Earthquake".*

New Zealand (Accessed 22 March 2019)

- Evacuation: https://www.civildefence.govt.nz/home/SearchForm?Search=evacuation&searchlocale=en_NZ&action_results=Search
- NZ Civil Defence Emergency Management, National Tsunami Advisory and Warning Plan, 2018. https://www.civildefence.govt.nz/cdem-sector/guidelines/national-tsunami-advisory-and-warning-plan/
- Public Awareness: https://www.civildefence.govt.nz/get-ready/get-tsunami-ready/

Philippines

Philippine Institute for Volcanology and Seismology (PHIVOLCS). 2008. *Developing Tsunami Prepared Communities.*

United States of America (Accessed 22 March 2019)

National Tsunami Hazard Mitigation Program, NTHMP

- Benchmarked Tsunami Numerical Models, https://nws.weather.gov/nthmp/documents/TsunamiModelSummary.pdf
- Evacuation Modelling and Mapping Guidelines, 2011, rev 2016:
  - Part I: Tsunami Inundation Modelling https://nws.weather.gov/nthmp/documents/1inundationmodelingguidelines.pdf
  - Part II: Tsunami Inundation Maps, https://nws.weather.gov/nthmp/documents/2inundationmapguidelines.pdf
  - Part III: Tsunami Inundation Determination for Non-Modelled Regions (draft), https://nws.weather.gov/nthmp/documents/3nonmodeledregionguidelines.pdf
  - Part IV: Tsunami Evacuation Maps, https://nws.weather.gov/nthmp/documents/4evacuationmapsguidelines.pdf
  - Checklist for Tsunami Modelling and Mapping Reports and/or Metadata, https://nws.weather.gov/nthmp/documents/guidelineschecklist.pdf

- Signage, https://nws.weather.gov/nthmp/signs/signs.html
- Exercises, https://nws.weather.gov/nthmp/tsunamiexercises.html
- TsunamiReady® Program (National Weather Service), https://www.weather.gov/tsunamiready/

ANNEX IV

LIST OF ACRONYMS

CFD	Computational Fluid Dynamic
ComMIT	Community Modelling and Interface for Tsunamis
COPECO	Comisión Permanente de Contingencias de Honduras
CTIC	Caribbean Tsunami Information Center
CTWP	Caribbean Tsunami Warning Program
CTWP	Caribbean Tsunami Warning Programme
DCDB	Data Centre for Digital Bathymetry
DEM	Digital Elevation Model
DNR	Department of Natural Resources
EMO	Emergency Management Office
FDMA	Japan Fire and Disaster Management Agency
GDAPD	Geologic Disaster Awareness & Preparedness Division
GIS	Geographic Information System
GITEWS	German-Indonesia Cooperation for a Tsunami Early Warning System
HAZMAT	Hazardous Materials
ICG	Intergovernmental Coordination Group
ICG/CARIBE-EWS	Intergovernmental Coordination Group for the Tsunami and other Coastal Hazards Warning System for the Caribbean and Adjacent Regions
ICG/PTWS	Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System
IHO	International Hydrographic Organization
IOC	Intergovernmental Oceanographic Commission
IOTIC	Indian Ocean Tsunami Information Centre
IOTWMS	Indian Ocean Tsunami Warning and Mitigation System
ITB	Bandung Institute of Technology
ITIC	International Tsunami Information Center

JISAO	Joint Institute for the Study of the Atmosphere and Ocean
JMA	Japan Meteorological Agency,
LIPI	Indonesian Institute of Science
MCDEM	New Zealand Ministry of Civil Defence & Emergency Management
NCEI	NOAA National Centers for Environmental Information
NCTR	NOAA Center for Tsunami Research
NGO	Non-governmental organization
NOAA	US National Oceanic and Atmospheric Administration
NTHMP/MMS	United States National Tsunami Hazard Mitigation Program/Mapping and Modelling Subcommittee
NTWC	National Tsunami Warning Centre
OFDA	U.S. Foreign Disaster Assistance
PHIVOLCS	Philippine Institute of Volcanology and Seismology
PMEL	NOAA Pacific Marine Environmental Laboratory
PTWC	Pacific Tsunami Warning Centre
PTWS	Pacific Tsunami Warning and Mitigation System
PTWS-SC	Pacific Tsunami Warning and Mitigation System
SMART	Specific, Measurable, Achievable, Realistic, Task oriented or Time driven
SOP	Standard Operating Procedures
SW	Shallow Water
TEMPP	Tsunami Evacuation Maps, Plans, and Procedures
TOWS-WG	Working Group on Tsunamis and Other Hazards related to Sea-Level Warning and Mitigation Systems
TsuCAT	Tsunami Coastal Assessment Tool
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNISDR	United Nations Office for Disaster Risk Reduction
USAID	United States Agency for International Development
USGS	United States Geological Survey

WDS World Data Service

WDS-G ICSU World Data Service for Geophysics

WMD Washington Military Department

IOC Manuals and Guides

No.	Title
1 rev. 2	Guide to IGOSS Data Archives and Exchange (BATHY and TESAC). 1993. 27 pp. (English, French, Spanish, Russian)
2	International Catalogue of Ocean Data Station. 1976. *(Out of stock)*
3 rev. 3	Guide to Operational Procedures for the Collection and Exchange of JCOMM Oceanographic Data. Third Revised Edition, 1999. 38 pp. (English, French, Spanish, Russian)
4	Guide to Oceanographic and Marine Meteorological Instruments and Observing Practices. 1975. 54 pp. (English)
5 rev. 2	Guide for Establishing a National Oceanographic Data Centre. Second Revised Edition, 2008. 27 pp. (English) *(Electronic only)*
6 rev.	Wave Reporting Procedures for Tide Observers in the Tsunami Warning System. 1968. 30 pp. (English)
7	Guide to Operational Procedures for the IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring. 1976. 50 pp. (French, Spanish)
8	*(Superseded by IOC Manuals and Guides No. 16)*
9 rev.	Manual on International Oceanographic Data Exchange. (Fifth Edition). 1991. 82 pp. (French, Spanish, Russian)
9 Annex I	*(Superseded by IOC Manuals and Guides No. 17)*
9 Annex II	Guide for Responsible National Oceanographic Data Centres. 1982. 29 pp. (English, French, Spanish, Russian)
10	*(Superseded by IOC Manuals and Guides No. 16)*
11	The Determination of Petroleum Hydrocarbons in Sediments. 1982. 38 pp. (French, Spanish, Russian)
12	Chemical Methods for Use in Marine Environment Monitoring. 1983. 53 pp. (English)
13	Manual for Monitoring Oil and Dissolved/Dispersed Petroleum Hydrocarbons in Marine Waters and on Beaches. 1984. 35 pp. (English, French, Spanish, Russian)
14	Manual on Sea-Level Measurements and Interpretation. (English, French, Spanish, Russian)
	Vol. I: Basic Procedure. 1985. 83 pp. (English)
	Vol. II: Emerging Technologies. 1994. 72 pp. (English)
	Vol. III: Reappraisals and Recommendations as of the year 2000. 2002. 55 pp. (English)
	Vol. IV: An Update to 2006. 2006. 78 pp. (English, Arab)
	Vol. V: Radar Gauges. 2016. 100 pp. and Supplement: Practical Experiences. 100 pp. (English, French, Russian, Spanish)
15	Operational Procedures for Sampling the Sea-Surface Microlayer. 1985. 15 pp. (English)
16	Marine Environmental Data Information Referral Catalogue. Third Edition. 1993. 157 pp. (Composite English/French/Spanish/Russian)
17	GF3: A General Formatting System for Geo-referenced Data
	Vol. 1: Introductory Guide to the GF3 Formatting System. 1993. 35 pp. (English, French, Spanish, Russian)
	Vol. 2: Technical Description of the GF3 Format and Code Tables. 1987. 111 pp. (English, French, Spanish, Russian)
	Vol. 3: Standard Subsets of GF3. 1996. 67 pp. (English)
	Vol. 4: User Guide to the GF3-Proc Software. 1989. 23 pp. (English, French, Spanish, Russian)

No.	Title
	Vol. 5: Reference Manual for the GF3-Proc Software. 1992. 67 pp. (English, French, Spanish, Russian)
	Vol. 6: Quick Reference Sheets for GF3 and GF3-Proc. 1989. 22 pp. (English, French, Spanish, Russian)
18	User Guide for the Exchange of Measured Wave Data. 1987. 81 pp. (English, French, Spanish, Russian)
19	Guide to IGOSS Specialized Oceanographic Centres (SOCs). 1988. 17 pp. (English, French, Spanish, Russian)
20	Guide to Drifting Data Buoys. 1988. 71 pp. (English, French, Spanish, Russian)
21	*(Superseded by IOC Manuals and Guides No. 25)*
22 rev.	GTSPP Real-time Quality Control Manual, First revised edition. 2010. 145 pp. (English)
23	Marine Information Centre Development: An Introductory Manual. 1991. 32 pp. (English, French, Spanish, Russian)
24	Guide to Satellite Remote Sensing of the Marine Environment. 1992. 178 pp. (English)
25	Standard and Reference Materials for Marine Science. Revised Edition. 1993. 577 pp. (English)
26	Manual of Quality Control Procedures for Validation of Oceanographic Data. 1993. 436 pp. (English)
27	Chlorinated Biphenyls in Open Ocean Waters: Sampling, Extraction, Clean-up and Instrumental Determination. 1993. 36 pp. (English)
28	Nutrient Analysis in Tropical Marine Waters. 1993. 24 pp. (English)
29	Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. 1994. 178 pp . (English)
30	MIM Publication Series:
	Vol. 1: Report on Diagnostic Procedures and a Definition of Minimum Requirements for Providing Information Services on a National and/or Regional Level. 1994. 6 pp. (English)
	Vol. 2: Information Networking: The Development of National or Regional Scientific Information Exchange. 1994. 22 pp. (English)
	Vol. 3: Standard Directory Record Structure for Organizations, Individuals and their Research Interests. 1994. 33 pp. (English)
31	HAB Publication Series:
	Vol. 1: Amnesic Shellfish Poisoning. 1995. 18 pp. (English)
32	Oceanographic Survey Techniques and Living Resources Assessment Methods. 1996. 34 pp. (English)
33	Manual on Harmful Marine Microalgae. 1995. (English) [superseded by a sale publication in 2003, 92-3-103871-0. UNESCO Publishing]
34	Environmental Design and Analysis in Marine Environmental Sampling. 1996. 86 pp. (English)
35	IUGG/IOC Time Project. Numerical Method of Tsunami Simulation with the Leap-Frog Scheme. 1997. 122 pp. (English)
36	Methodological Guide to Integrated Coastal Zone Management. 1997. 47 pp. (French, English)
37	International Tsunami Survey Team (ITST) Post-Tsunami Survey Field Guide. 2nd Edition. 2014. 120 pp. (English)
38	Guidelines for Vulnerability Mapping of Coastal Zones in the Indian Ocean. 2000. 40 pp. (French, English)
39	Manual on Aquatic Cyanobacteria – A photo guide and a synopsis of their toxicology. 2006. 106 pp. (English)
40	Guidelines for the Study of Shoreline Change in the Western Indian Ocean Region. 2000. 73 pp. (English)

No.	Title
41	Potentially Harmful Marine Microalgae of the Western Indian Ocean Microalgues potentiellement nuisibles de l'océan Indien occidental. 2001. 104 pp. (English/French)
42	Des outils et des hommes pour une gestion intégrée des zones côtières - Guide méthodologique, vol.II/ Steps and Tools Towards Integrated Coastal Area Management – Methodological Guide, Vol. II. 2001. 64 pp. (French, English; Spanish)
43	Black Sea Data Management Guide *(Cancelled)*
44	Submarine Groundwater Discharge in Coastal Areas – Management implications, measurements and effects. 2004. 35 pp. (English)
45	A Reference Guide on the Use of Indicators for Integrated Coastal Management. 2003. 127 pp. (English). *ICAM Dossier No. 1*
46	A Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management. 2006. iv + 215 pp. (English). *ICAM Dossier No. 2*
47	TsunamiTeacher – An information and resource toolkit building capacity to respond to tsunamis and mitigate their effects. 2006. DVD (English, Bahasa Indonesia, Bangladesh Bangla, French, Spanish, and Thai)
48	Visions for a Sea Change. Report of the first international workshop on marine spatial planning. 2007. 83 pp. (English). *ICAM Dossier No. 4*
49	Tsunami preparedness. Information guide for disaster planners. 2008. (English, French, Spanish)
50	Hazard Awareness and Risk Mitigation in Integrated Coastal Area Management. 2009. 141 pp. (English). *ICAM Dossier No. 5*
51	IOC Strategic Plan for Oceanographic Data and Information Management (2008–2011). 2008. 46 pp. (English)
52	Tsunami risk assessment and mitigation for the Indian Ocean; knowing your tsunami risk – and what to do about it. 2009. 82 pp. (English)
53	Marine Spatial Planning. A Step-by-step Approach. 2009. 96 pp. (English; Spanish). *ICAM Dossier No. 6*
54	Ocean Data Standards Series:
	Vol. 1: Recommendation to Adopt ISO 3166-1 and 3166-3 Country Codes as the Standard for Identifying Countries in Oceanographic Data Exchange. 2010. 13 pp. (English)
	Vol. 2: Recommendation to adopt ISO 8601:2004 as the standard for the representation of date and time in oceanographic data exchange. 2011. 17 pp. (English)
	Vol.3: Recommendation for a Quality Flag Scheme for the Exchange of Oceanographic and Marine Meteorological Data. 2013. 12 pp. (English)
	Vol. 4: SeaDataNet Controlled Vocabularies for describing Marine and Oceanographic Datasets – A joint Proposal by SeaDataNet and ODIP projects. 2019. 31 pp (English)
55	Microscopic and Molecular Methods for Quantitative Phytoplankton Analysis. 2010. 114 pp. (English)
56	The International Thermodynamic Equation of Seawater—2010: Calculation and Use of Thermodynamic Properties. 2010. 190 pp. (English)
57	Reducing and managing the risk of tsunamis. Guidance for National Civil Protection Agencies and Disaster Management Offices as Part of the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas Region – NEAMTWS. 2011. 74 pp. (English)
58	How to Plan, Conduct, and Evaluate Tsunami Exercises / Directrices para planificar, realizar y evaluar ejercicios sobre tsunamis. 2012. 88 pp. (English, Spanish)
59	Guide for designing and implementing a plan to monitor toxin-producing microalgae. Second Edition. 2016. 63 pp. (English, Spanish)
60	Global Temperature and Salinity Profile Programme (GTSPP) — Data user's manual, 1st Edition 2012. 2011. 48 pp. (English)

No.	Title
61	Coastal Management Approaches for Sea-level related Hazards: Case-studies and Good Practices. 2012. 45 pp. (English)
62	Guide sur les options d'adaptation en zone côtières à l'attention des décideurs locaux – Aide à la prise de décision pour faire face aux changements côtiers en Afrique de l'Ouest / A Guide on adaptation options for local decision-makers: guidance for decision making to cope with coastal changes in West Africa / Guia de opções de adaptação a atenção dos decisores locais: guia para tomada de decisões de forma a lidar com as mudanças costeiras na Africa Ocidental. 2012. 52 pp. (French, English, Portuguese). *ICAM Dossier No. 7*.
63	The IHO-IOC General Bathymetric Chart of the Oceans (GEBCO) Cook Book. 2012. 221 pp. (English). *Also IHO Publication B-11*
64	Ocean Data Publication Cookbook. 2013. 41 pp. (English)
65	Tsunami Preparedness Civil Protection: Good Practices Guide. 2013. 57 pp. (English)
66	IOC Strategic Plan for Oceanographic data and Information Management (2013-2016). 2013. 54 pp. (English/French/Spanish/Russian)
67	IODE Quality Management Framework for National Oceanographic Data Centres. 2014; revised edition 2019 (English)
68	An Inventory of Toxic and Harmful Microalgae of the World Ocean (in preparation)
69	A Guide to Tsunamis for Hotels: Tsunami Evacuation Procedures (North-eastern Atlantic and the Mediterranean Seas). 2016 (English)
70	A guide to evaluating marine spatial plans. 2014. 96 pp. (English)
71	IOC Communication Strategy for Marine Information Management (2015-2017). 2015
72	How to reduce coastal hazard risk in your community – A step-by-step approach. 2016
73	Guidelines for a Data Management Plan. 2016
74	*Standard Guidelines for the Tsunami Ready Recognition Program*. (in preparation)
75	ICAN (International Coastal Atlas Network) - best practice guide to engage your CWA (Coastal Web Atlas) user community. 2016
76	Plans and Procedures for Tsunami Warning and Emergency Management – Guidance for countries in strengthening tsunami warning and emergency response through the development of Plans and Standard Operating Procedures for their warning and emergency management authorities. 2017
77	IOC Strategic Plan for Data and Information Management (2017-2021). 2017
78	Harmful Algal Blooms (HABs) and Desalination: A Guide to Impacts, Monitoring and Management. 2017
79	IOC Communication and Outreach Strategy for Data and Information Management (2017-2019). 2017
80	Ocean Literacy for All – A toolkit. 2017
81	Procedures for Proposing and Evaluating IODE Projects and Activities. 2018
82	Preparing for community tsunami evacuations: From Inundation to Evacuation Maps, Response Plans, and Exercises (English and Spanish) and Supplement 1 and 2 (English only), 2020.

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Intergovernmental Oceanographic Commission
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PREPARING FOR COMMUNITY TSUNAMI EVACUATIONS

From Inundation to Evacuation Maps, Response Plans, and Exercises

SUPPLEMENT 1

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PREPARING FOR COMMUNITY TSUNAMI EVACUATIONS:

From Inundation to Evacuation Maps, Response Plans, and Exercises

SUPPLEMENT 1

Programme Modules and Specialized Documents

UNESCO 2020

IOC Manuals and Guides, 82 Supplement 1
Paris, July 2019
English

For bibliographic purposes, this document should be cited as follows:

UNESCO/IOC. 2020. *Preparing for Community Tsunami Evacuations: from inundation to evacuation maps, response plans and exercises. Supplement 1: Programme Modules and Specialized Documents.* Paris, UNESCO. (Manuals and Guides, 82)

Guide prepared by: International Tsunami Information Center (ITIC)
New Zealand Ministry of Civil Defence & Emergency Management,
US NOAA Pacific Environmental Laboratory / NOAA Center for Tsunami Research (PMEL/NCTR), Caribbean Tsunami Warning Program (CTWP)
Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) Working Group on Disaster Management, Preparedness, and Risk Reduction

This IOC Manuals and Guides publication consists of a guide (IOC/2020/MG/82) and two supplements. The guide presents a high-level summary of each programme module and the rational behind them. Supplements contain additional detailed information, templates, reference to specialized documents, tutorials and best practice examples.

Supplement 1: Programme Modules and Specialized Documents

Supplement 2: How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS: Manual and Tutorial

Published in 2020
by United Nations Educational, Scientific
and Cultural Organization
7, Place de Fontenoy, 75352 Paris 07 SP

(IOC/2020/MG/82 Suppl.1)

TABLE OF CONTENTS

page

Preface

This IOC Manuals and Guides publication consists of a guide (IOC/2020/MG/82) and two supplements. This document is Supplement 1.

IOC Manuals and Guides N° 82 focuses on actions that communities can take to build resilience to the next tsunami. It effects actions with the end goal of saving lives and reducing tsunami impact by focusing on coordinated Stakeholder Response Planning and Preparedness, accompanied by continuous Awareness on the End-to-End Warning System to sustain Advocacy. The actions and products of this guide — tsunami hazard assessments, inundation and evacuation maps, response plans and procedures, awareness, and exercises — assist communities in making themselves more prepared. The guide, formatted to support the training of people who are responsible for these deliverables, can be used as part of the process to become UNESCO/IOC Tsunami Ready, or simply to enhance preparedness.

It provides a summary on tsunami disaster risk reduction, evacuation, and the UNESCO/IOC Tsunami Ready community preparedness recognition pilot. It is followed by four evacuation planning modules (Modules 1 to 4) describing the how-to-steps, objectives, target participants, requirements, methodology, tools, templates, expected results, module references and examples, and finally a general bibliography and annexes on the Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) Pilot course.

Module 1 describes the identification of inundation areas, including the identification of credible and/or worst-case scenarios that should be modelled. It also includes guidance for situations where there is no known or little tsunami hazard, or where the available bathymetry is too coarse to permit credible tsunami inundation modelling.

Module 2 describes the development of evacuation maps from inundation maps. Best practice guidance is provided on how to choose evacuation zones and routes. Geographic information systems are used with standard symbology to create the map and the process of 'ground-truthing' the map through community engagement is outlined.

Module 3 describes the development of Tsunami Response Plans and Standard Operating Procedures (SOPs) focusing on the community evacuations, but including the tsunami warning chain from the national tsunami warning centre to local authorities and the execution of evacuation during a warning. A key element of tsunami response involves evacuation including self-evacuation of exposed people and key assets to safer areas. Effective and successful evacuation requires pre-planning by the relevant authorities.

Module 4 describes the use of exercising to practice tsunami evacuations.

This supplement, consisting of digital-only files, is comprised of:

Part A. Supplement to Programme Modules, containing background information and detailed explanations on each of the Guide's four Modules. The Additional Resources section at the end of each Module lists guidance, templates, best practice examples, and other information to support both training and the delivery of outputs.

Part B. Compilation of Specialised Documents, which are the resources listed in the 'Additional Resources' section of the Supplement to Programme Modules. These documents are how-to manuals, templates, and examples that support both training and the delivery of outputs.

The most current versions of the Supplement to the Programme Modules and the Specialised Documents are available or can be download from the ITIC Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) website

PART A
SUPPLEMENT TO PROGRAMME MODULES

This part consists of four programme modules for evacuation planning.

Module 1: Identifying Tsunami Inundation Areas describes the identification of inundation areas, including the identification of credible and/or worst-case scenarios that should be modelled. It also includes guidance for situations where there is no known or little tsunami hazard, or where the available bathymetry is too coarse to permit credible tsunami inundation modelling.

Module 2: Developing Tsunami Evacuation Maps describes the development of evacuation maps from inundation maps. Best practice guidance is provided on how to choose evacuation zones and routes. Geographic information systems are used with standard symbology to create the map and the process of 'ground-truthing' the map through community engagement is outlined.

Module 3: Developing Tsunami Response Plans and Standard Operating Procedures describes the development of Tsunami Response Plans and Standard Operating Procedures (SOPs) focusing on the community evacuations, but including the tsunami warning chain from the national tsunami warning centre to local authorities and the execution of evacuation during a warning. A key element of tsunami response involves evacuation including self-evacuation of exposed people and key assets to safer areas. Effective and successful evacuation requires pre-planning by the relevant authorities.

Module 4: Tsunami Exercising describes the use of exercising to practice tsunami evacuations.

MODULE 1 – IDENTIFYING TSUNAMI INUNDATION AREAS

1. INTRODUCTION

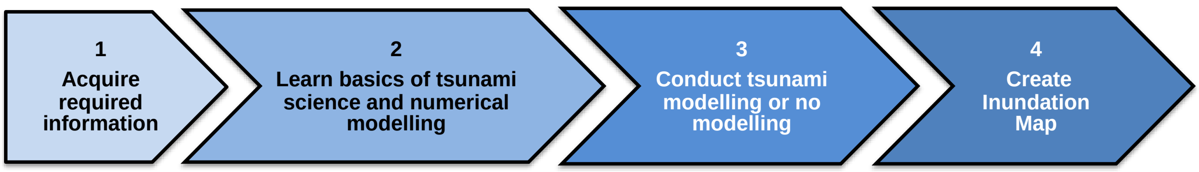


Figure S.1 Steps for Module 1 – Inundation Mapping

Prior to developing a tsunami evacuation plan and procedures, the community needs to first generate a tsunami inundation map for the region. The development of a tsunami inundation map identifies which areas will be affected by the tsunami and provides awareness of tsunami risk (Figure S1). It also assist communities and local/national government in developing evacuation routes and mitigation measures to minimize the impact of the tsunami.

To understand the hazards and risks of tsunami, it is important for the community to have a clear knowledge of what a tsunami is, how it is generated, and the damage that it could cause. The tsunami risk is normally estimated through a thorough analysis of previous occurrences and numerical simulations of past and predicted tsunamis using physical data (i.e., bathymetry, topographical data). This information would then assist in identifying vulnerable areas, preparing evacuation procedures, and constructing essential facilities. Although a tsunami cannot be prevented, the impact of a tsunami can be mitigated through community preparedness, timely warnings, and effective response.

2. MODULE CONTENT

2.1 ACQUIRE REQUIRED INFORMATION

No input.

2.2 LEARN BASICS OF TSUNAMI SCIENCE AND NUMERICAL MODELLING

津波

Figure S.2. Japanese word for tsunami

Tsunami (soo-NAH-mee) is a Japanese word that consists of two characters: “tsu” and “nami”. The first character “tsu” means harbour, and the second character “nami” means wave. In the past, many people have erroneously referred to “tsunami” as “tidal wave”, which is not correct. Tides, featuring the rising and falling of water level in the ocean in a daily, monthly and yearly cycle, are caused by the gravitational influences of the moon, sun, and planets. Tsunamis are not generated by these gravitational forces and are unrelated to the tides, although the tide level influences the height of the tsunami striking a coastal area.

In South America, the term "maremoto", or moving sea, is often used. However, the word "tsunami" is most commonly accepted by scientists and by most of the lay public.

2.2.1 Terminology

2.1.1.1 *Local, Regional and Distant Tsunamis*

A tsunami may be categorized as local, regional (near-field), or distant (far-field, ocean-wide). These terms generally describe how far away the effects of the waves are expected or were observed.

Most destructive tsunamis can be classified as local or regional. It follows that many tsunami-related deaths and considerable property damage result from these tsunamis (Table 1). In fact, 90% of all tsunami deaths (99% in the Pacific) in the historic record occurred in the local or regional area within the first 3 hours of the event. Between 1980 and November 2019 there were 37 local or regional confirmed tsunamis that resulted in deaths and property damage.

- Local tsunami (near-field)

A local tsunami is one with destructive or life-threatening effects usually limited within a 100–200 km (60–100 mi) range of the epicentre, or less than 1 hour tsunami travel time from its source. Local tsunamis occur soon after the generating event and allow little time for warning and evacuation, arriving in minutes to 1 hour. Their impact may be large, but in a limited area. Local tsunamis may be caused by large earthquakes, submarine volcanic eruptions, or non-seismically triggered landslides. The first indication that a local tsunami may have been generated is strong ground shaking along the coast. If an earthquake has generated a local tsunami, strong shaking related damage may complicate tsunami response.

- Regional tsunami

A regional tsunami is one with destructive or life-threatening effects usually limited within a 1000 km (621 mi) range of the epicentre, or 1-3 hours travel time from its source is considered a regional tsunami. Regional tsunamis are the most common, and can make landfall within 1 to 3 hours after the generating event. Destruction may be limited in areal extent either because the energy released was not sufficient to generate a destructive ocean-wide tsunami, or because the source was within a confined sea. Areas affected by regional tsunamis may not have felt the generating event.

- Distant tsunami (far-field, ocean-wide, tele-tsunami)

A distant tsunami is one with destructive or life-threatening effects more than 1000 km from the epicenter, or more than 3 hours tsunami travel time away. Ocean-wide destructive tsunamis are much less frequent, but still occur a several times each century. They usually start as a local tsunami that causes extensive destruction near the source; the waves then continue to travel across the entire ocean basin with sufficient energy to cause additional deaths and destruction on distant shores. Generally, the tsunami generated from a distant source will be smaller than the local tsunami. From 1700 through November 2019, there have at least 43 confirmed damaging tsunamis and 18 caused deaths more than 1,000 km from the source. A typical distant tsunami scenario would allow time for an official warning and evacuation.

2.1.1.2 *Tsunami Wave Measurement Terminology*

- Measuring Waves on Marigrams

The following are terms used to describe tsunami waves as observed on sea level records recorded on tide gauges, or mareograms. See also Annex I, Glossary of Technical Terms.

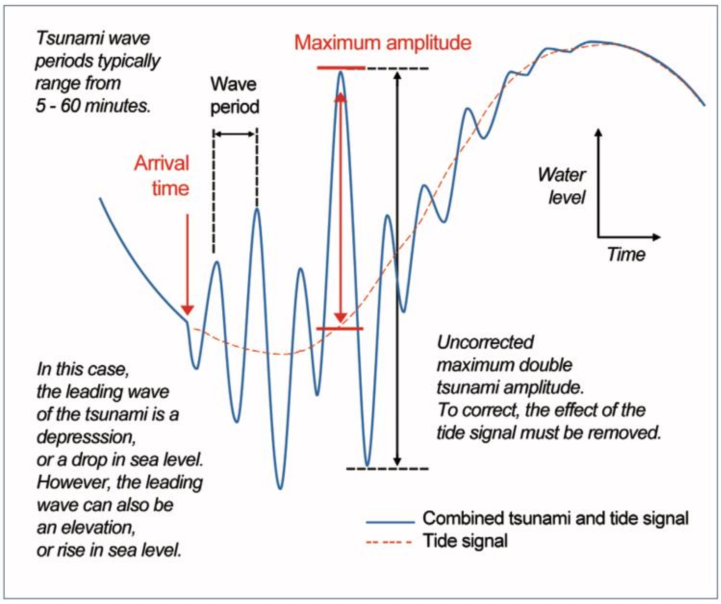


Figure S.3. Mareogram (sea level) record of a tsunami
Source: Tsunami Glossary, 2019 (IOC/2008/TS/85 Rev.4)

A tsunami's wave period is the time it takes from one full wave length to pass a stationary point (Figure S.3). A tsunami's wavelength is the distance measured from one peak to the next peak.

A tsunami wave height is the vertical distance from the wave peak to the wave trough of the same wave. Tsunami wave amplitude is approximately one-half of the tsunami wave height.

Tsunami travel time is the time that the waves take to travel from the generating source. Tsunami arrival time is the time that the waves arrives at a specified coastal area from the tsunami generating source.

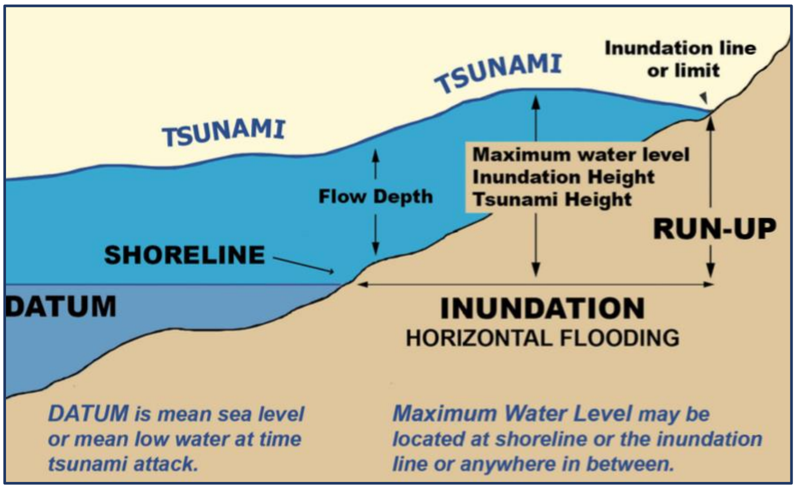


Figure S.4. Tsunami wave field measurements
Source: Tsunami Glossary, 2019 (IOC/2008/TS/85 Rev.4)

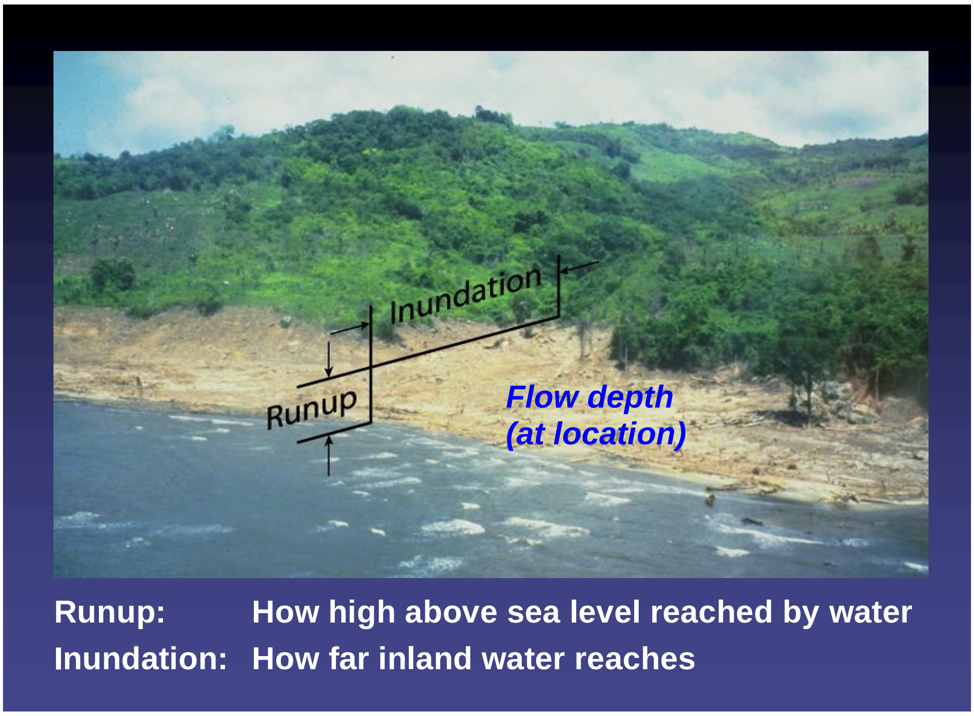


Figure S.5. Field example of tsunami measurement terminology
(Source: International Tsunami Information Center, ITIC)

- Measuring Waves in the Field

The following are terms used to describe tsunami wave observations in the field, such as those measured during post-tsunami surveys. See also Annex I, Glossary of Technical Terms.

2.2.2 Tsunami Generation

A tsunami is a series of extremely long wavelength and long period water waves usually formed as a result of a large-scale vertical displacement in a body of water (e.g., ocean, bay, fjiord, lakes, etc) over a short duration in time. Gravity returns the water to equilibrium through a series of oscillations or waves that propagate outward from the source region.

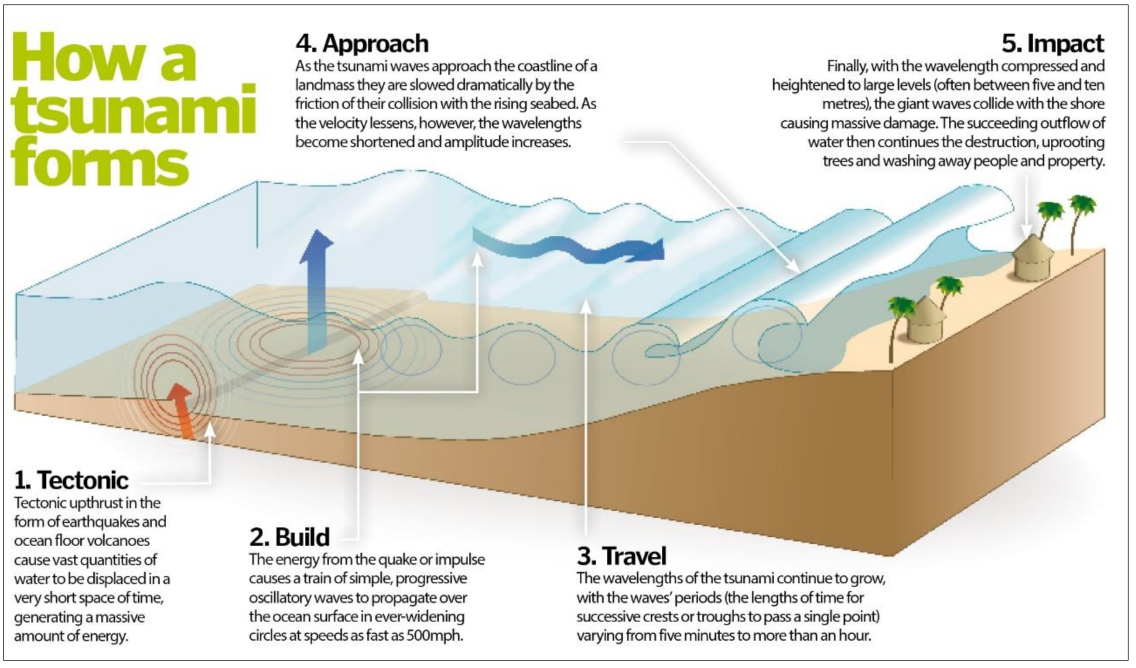


Figure S.6. Illustration on tsunami generation, propagation, and inundation.
(Source: How It Works)

A wave is characterized as a shallow-water wave when the water depth is less than 5 percent of the wavelength. The forward and backward wave motion under the shallow water wave is felt throughout the entire water depth.

A tsunami's wave period, the time it takes from one full wave length to pass a stationary point (Figure S.6), can range from five minutes to an hour. A tsunami's wavelength, measured from peak to peak, can be up to hundreds of kilometres.

A key characteristic that makes tsunami waves differ from other ocean waves such as wind waves or tides is their period -- the time of one wave cycle. Tsunami wave periods range from 5 minutes to as much as 60 minutes. Wind waves have periods of tens of seconds and corresponding wavelengths of 100 to 200 meters in deep water, and tides have periods of about 12 hours.

A tsunami is not one wave, but a series of waves. The time that elapses between passage of successive wave crests at a given point can range from 5 to 60 minutes. Oscillations of destructive proportions may continue for several hours, and even several days may pass before the sea returns to its normal state.

2.1.1.3 Historical Tsunami Sources

The International Council of Science (ICSU) World Data System World Data Service for Geophysics, hosted by NOAA's National Centers for Environmental Information (NCEI), manages global geophysical, sea floor, and natural hazards data, including the global historical tsunami events and runups, significant earthquake, and significant volcanic eruptions databases (https://www.ngdc.noaa.gov/hazard/tsu.shtml).

Since 1610 BC through November 2019, there are have 1271 confirmed tsunami source events, with a 255 confirmed deadly tsunamis. The majority of the confirmed tsunamis occurred in the Pacific Ocean, specifically Japan and the Pacific Islands.

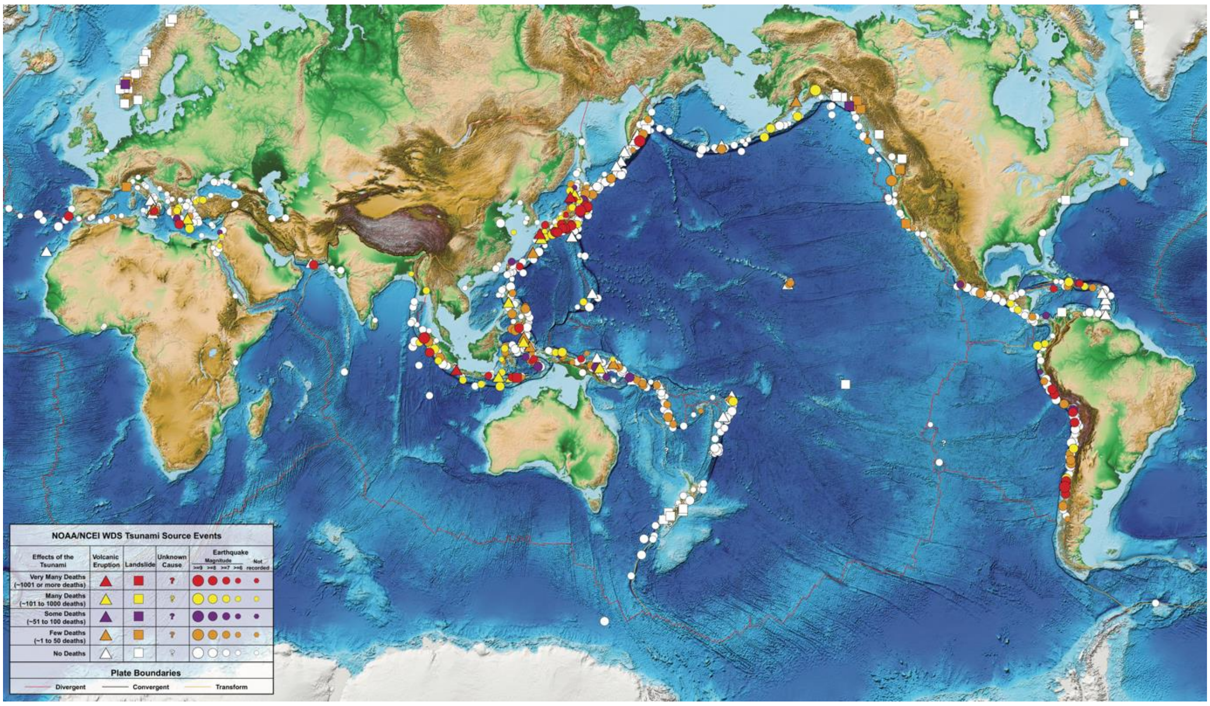


Figure S.7. Global Tsunami Sources from earthquakes, volcanic eruptions, landslides, and other causes, 1610 BC to AD 2017 (Source: NCEI, ITIC, 2018)

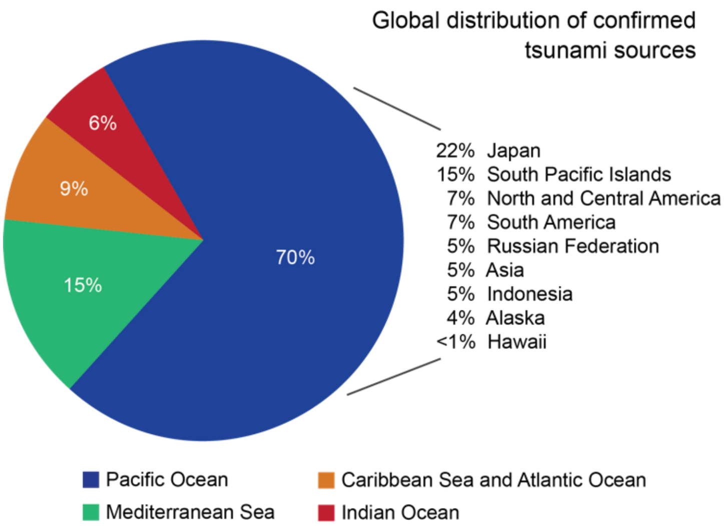


Figure S.8. Global distribution of confirmed tsunami sources (Source: NCEI, ITIC, 2018)

Most tsunamis are caused by vertical displacements of the seafloor associated with the occurrence of great earthquakes.

Tsunamis can also be generated by submarine volcanic eruptions, by the movement of submarine sediments, by coastal landslides, and even by meteor impacts. Tsunami-producing landslides can occur on and offshore, but are less common than the earthquake generated tsunamis. A subaerial rockslide in Lituya Bay, Alaska, in 1958 generated a 525 m local tsunami. Submarine slope failures are documented and cracks along the outer shelf detected in bathymetric surveys hint of future large-scale failures. Volcanic eruptions can also cause tsunami even though they are infrequent. Eruptions induce failure along the flanks of a volcano or collapse of the magma chamber. These displace a great volume of water and can generate destructive tsunami in source area. Examples are the 2018 Anak Krakatau (426 deaths) and 1883 Krakatau (35,000 deaths) volcanic eruption / landslide tsunamis. A tsunami-producing meteorite impact has never been recorded, but there is still a chance, though very unlikely. Most meteorites burn as enter Earth's atmosphere.

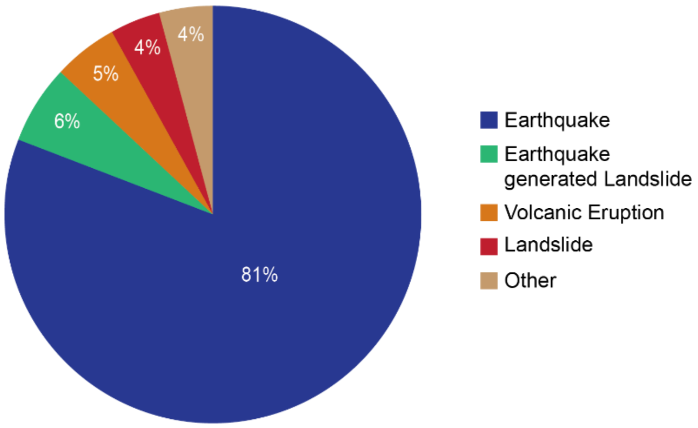


Figure S.9. Distribution of confirmed tsunamis by generation mechanism (Source: NCEI, ITIC, 2018)

Since we cannot predict when and where earthquakes, landslides, or volcanic eruptions will occur, we cannot determine exactly when a tsunami will be generated. However, with the aid of historical records of tsunamis and numerical models, scientists can get an idea as to where they are most likely to be generated. Past tsunami height measurements, and paleotsunami sediment deposits, and numerical modelling help to "forecast" future tsunami impact and flooding limits at specific coastal areas.

2.1.1.4 Earthquake Tsunami Sources

While tsunamis threaten lives and property in coastal regions around the world, they are most commonly a hazard near subduction zones, particularly along the Pacific Rim, also known as the Ring of Fire. As one plate dives beneath the other in a subduction zone, strain is generated at the interface of the two plates. That strain is eventually released during an earthquake, which displaces a large area of the ocean floor ranging from few kilometres to 1,000 kilometres or more. This sudden displacement of the sea bottom over a large area disturbs the surface of the ocean and displaces a column of water creating a tsunami that will radiate away from the source (Figure S.10) or tsunami propagation.

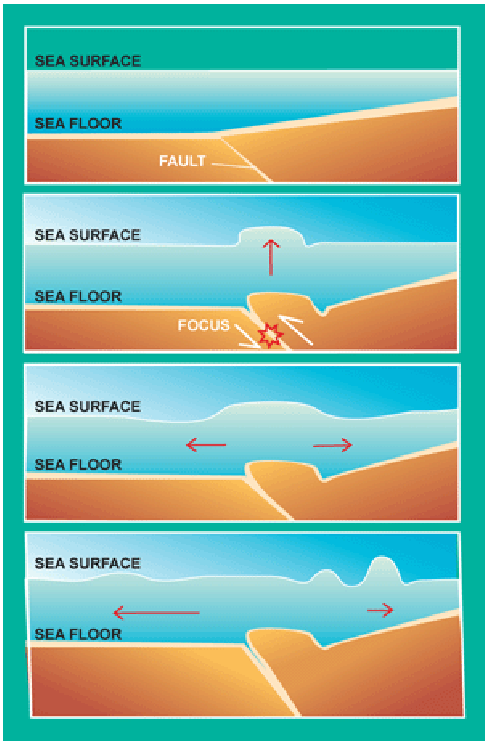


Figure S.10. Generation of a tsunami from an earthquake along a subduction zone. When an earthquake occurs under seabed, the overlying water is thrusted up and down by movements of the earth's crust, thereby generating the tsunami. (Source: ITIC).

There are three types of plate tectonics boundaries that can generate an earthquake: divergent, convergent, and transform plate boundaries (Figure S.11). When two tectonic plates moves away from each other, it is considered a divergent boundary while two plates coming together is classified as a convergent boundary. This collision buckles either one or both edges of the plates up to form rugged mountain range or bends the other plate into a deep seafloor trench. When one of the colliding plate is topped with an oceanic crust then it is pushed down into the mantle where it melts due to extreme pressure and temperature. When two plates just slides past each other, then it is classified as a transform plate boundary.

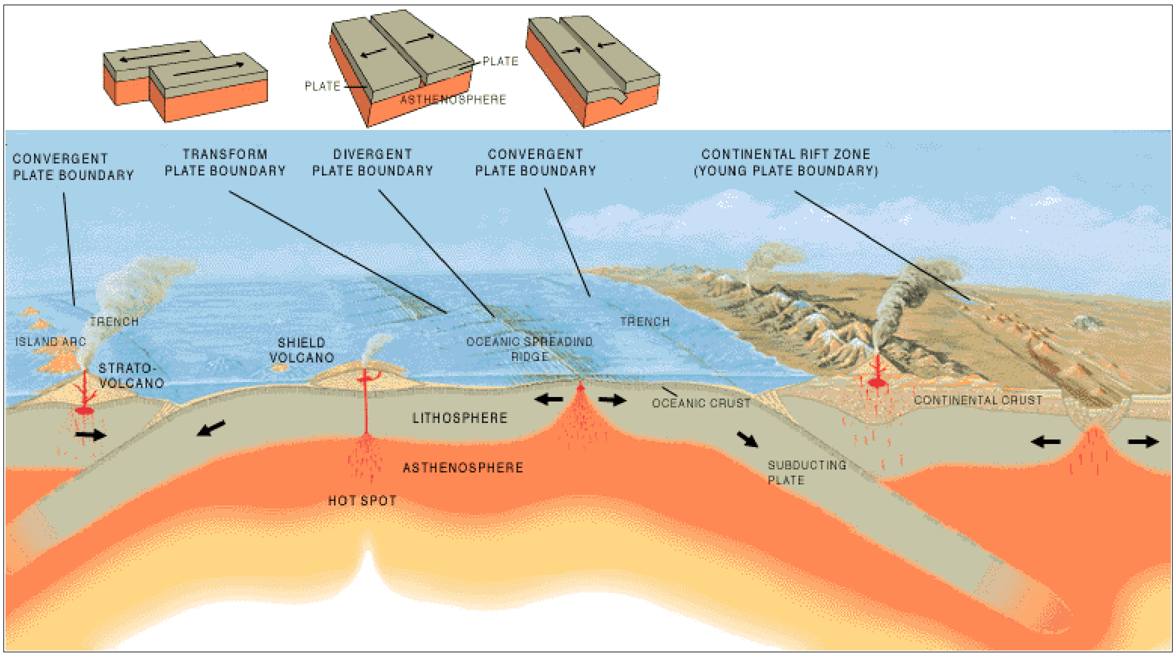


Figure S.11. Types of tectonic plate boundaries. Spreading ridges, such as the East Pacific Rise, are locations where plates diverge or spread apart. Subduction zones, such as the Chile-Peru Trench, are location where plates converge or where one plate subducts beneath the other (Source: USGS Dynamic Earth).

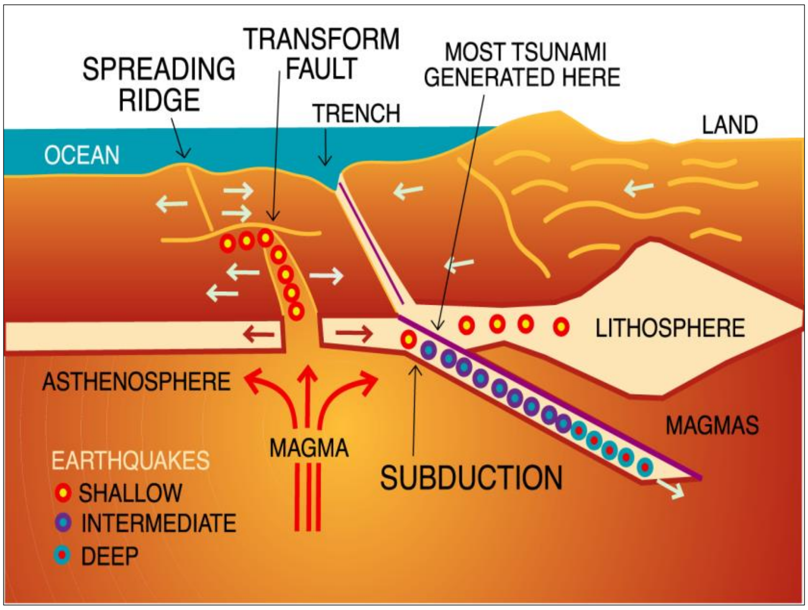


Figure S.12. Most tsunamis are generated by shallow large undersea earthquakes that occur at active subduction zones. (Source: ITIC).

Not all earthquakes generate destructive tsunami. Destructive tsunami are usually generated by large (with a moment magnitude exceeding 7.2), shallow (at or near the seafloor, <100 km) earthquakes that occur along the subduction plate, i.e. convergent boundary (Figure S.10).

2.2.3 Tsunami Propagation

Tsunami waves travel outward in all directions from the generating area, with the direction of the main energy propagation generally being 90° to the line of the earthquake rupture. The rate at which the tsunami wave loses its energy is inversely proportional to its wavelength, and so the long-wavelength tsunami will lose little energy as it propagates. The tsunami wave motions extend through the entire water column from sea surface to the ocean bottom, even in mid ocean. It is this characteristic that accounts for the great amount of energy transmitted by a tsunami.

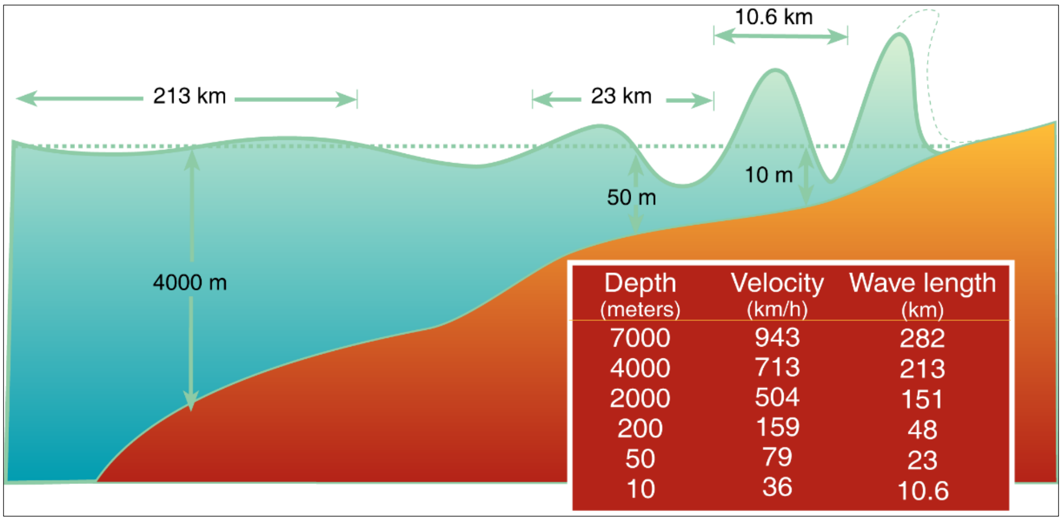


Figure S.13. Tsunami velocity and wave length (Source: ITIC).

The speed of propagation of tsunami waves and their height depends on the depth of water. Consequently, the speed and direction of the tsunami waves change as they pass through the ocean because of its varying depth.

The speed of a tsunami is calculated as $\sqrt{gh}$; where g (9.81 m/s) is the acceleration due to gravity and h is the water depth in meters. With an average ocean depth 10,994 m, the average tsunami wave speed in the deep ocean is 328.4 m/s (734.61 mph).

Waves of a tsunami in the deep ocean will travel at high speeds (that of a jetliner) and over great transoceanic distances with limited energy loss. These waves have such great length and so little height that they are not visually recognizable from a surface vessel or from an airplane, and will generally not be felt aboard ships. They travel at the speed of a jetliner but the waves are only a few centimetres high and are not felt aboard ships. The passing of each wave produces only a gentle rise and fall of the sea surface over a long time – usually tens of minutes.

2.2.4 Tsunami Impact

As a tsunami leaves the open ocean basin and propagates into shallower waters near the coast, it undergoes a rapid transformation. The speed of an advancing tsunami wave diminishes to the speed of more ordinary wind-driven swell, and its wave length decreases, and its height may increase greatly, owing to a compression of its energy and a piling up of the water. People cannot out-dive or out-run these waves. Tsunamis reach to the seafloor and steepen in shallow water. Generally, they are not steep enough to break, so they flow over land like a wall of water. Because of this shoaling effect, a tsunami that was imperceptible in the deep water (few cm to 1 m) may grow to be several meters or as much as 30 m in height.

Tsunami waves can come ashore in many different ways among which are: a wall of water (resembling white wash), a rapidly rising tide, and a series of surf-like breakers. The first wave may not be the largest and the series of waves may impact coastlines for several hours. Figure S.10 illustrates the process of tsunami generation to inundation. Along a coast, tsunami may be preceded by a rapid receding sea level as the ocean retreats exposing fishes and corals on the sea bottom. In many instances, a strange loud sound (i.e. sound resembling that of a loud roar) coming from the sea may also be heard.

The configuration of the coastline, shape of the ocean floor, and character of the advancing waves play an important role in the destruction wrought by tsunamis along any coast, whether near the generating area or thousands of kilometres away. Consequently, there can be a great variation in the level of destruction along a single coast, with one area being hard-hit while an adjacent area is not affected.

The force and destructive effects caused by tsunamis should not be underestimated. The first wave to make landfall is not necessarily the most damaging. Under certain conditions, the crest of an oncoming wave can overtake the trough of a previous wave, creating a vertical wall of water referred to as a bore, a wave with a churning front. At times, the advancing turbulent front may be the most destructive part of the wave. At other times, the outflow of water back to the sea may be rapid and the most destructive part of the wave, sweeping all before it and undermining roads, buildings, and other works of man with its swift currents. Debris picked up and carried by the strong and persistent currents can cause great damage. Most people killed by tsunamis are crushed, not drowned. Ships, unless moved away from the shore to deep water, can be thrown against breakwaters, wharves, and other craft, or washed ashore and left grounded during withdrawals of the sea. Areas such as sounds and inlets may cause funnelling effects that magnify the initial wave and then, through resonance, subsequent waves, and tsunamis may wrap-around small islands so the wave heights are just as large on the backside as the front.

In the shallow water of bays and harbours, a tsunami frequently will initiate seiching – an almost frictionless slow oscillation of the body of water back and forth. If the tsunami period is related closely to that of the bay, the seiche is amplified by synchronous forcing from succeeding tsunami waves. Under these circumstances, maximum wave activity can be observed much later than the arrival of the first wave.

Tsunamis can occur at any time and depending on the location, there might only a few minutes for people to evacuate. To assess this hazard, one has to understand the geophysical condition of the source, to know how the tsunami is generated by the source, and to know the extent of the inundation that can happen as the tsunami reaches the coast. Thus, it is very important to develop a tsunami inundation map and a tsunami evacuation plan to establish a precise tsunami warning and communications systems.

2.2.5 Tsunami Numerical Modelling

Once the initial size and shape of a tsunami is known, the transformation of tsunamis as they travel across the ocean can be accurately predicted by a set of mathematical equations. These equations are based on the fundamental concept that the mass and energy of the tsunami must be conserved. Powerful computers are used to solve these equations: this process is called numerical modelling.

Numerical modelling is an important contributor to mitigating the impact of tsunamis. Using numerical modelling, hazards in areas vulnerable to tsunamis can be assessed, without the area ever having experienced a devastating tsunami. These models can simulate a tsunami approaching a coastline, and they can predict which areas are most at risk to be flooded.

Products include inundation maps that are then used to develop tsunami evacuation maps. Government agencies assess the tsunami risks of their coastlines by considering tsunami scenarios and conducting numerical simulation studies that calculate expected tsunami heights, velocities, wave forces, and inundation areas. These results can be used to estimate potential damage and for evacuation planning. Geographical information systems (GIS) are useful tools that allow a visual understanding of the affected area. Numerical modelling is also used by the tsunami warning centres to forecast wave heights and the results used for warning decision-making.

Numerical models use mathematical equations to describe physical processes. For the purposes of tsunami warnings, numerical models estimate the expected tsunami wave height, run-up, and inundation based on the description of the tsunami source and modelling technique. To get the best results, the model needs to have specific descriptions of the initial source location and an estimate of the seismic ground deformation. A first estimate of these parameters is obtained using data reported by instruments on the field that can either measure seismic or hydrodynamic waves near the source. In addition, all models need to be validated to ensure that the model will provide reasonable values for future events. Model validation is accomplished by comparing their solutions to problems for which a well-known solution exists. These include idealized problems that have an analytical solution, experiments performed in a laboratory setting, and observations from historical tsunami events. A list of numerical tsunami models that have met the benchmark requirements of the United States National Tsunami Hazard Mitigation Program (NTHMP, 2017) can be found in Table 4 of the main document (IOC/2020/MG/82).

A tsunami can be broken into 3 components: the source that generated the tsunami, the process in which the waves propagate across the ocean, and the process of inundation as the wave impact coasts and floods inland (run-up) or retreats seaward (recession).

In order to mathematically describe the earthquake tsunami source, seismologists specify the mechanical, geometrical, and dynamic characteristics of the fault movement. Alternatively, DART or other deep-ocean sensor systems, designed to measure tsunami waves near the source, can also be used to provide a description of the initial water surface deformation in the generation area. Tsunamis can also be caused by volcanic eruptions or subaerial or submarine landslides that cause a sudden displacement of water.

Tsunami characteristics change as they propagate from their source. For tsunamis propagating in the deep ocean over long distances, numerical modelling can utilize linear equations for long period and small amplitude waves to enable simpler and faster computations. In shallow water, coastal areas, refraction and shoaling (shortening of the wavelength and increasing of amplitude) will occur and nonlinear models are necessary to adequately capture tsunami physics. Linear tsunami propagation models, such as RIFT (Wang et al., 2012; UNESCO/IOC, 2014) are usually very computationally efficient, whereas nonlinear models, such as MOST, allow for computation of tsunami evolution in coastal regions, where wave amplitudes are no longer considered small.

Within the family of nonlinear codes, there are two main groups depending on the mathematical model they use to describe tsunami dynamics: Nonlinear Shallow Water (NSW) codes (such as MOST, COMCOT, ATFM and HySea), that solve the NSW mathematical model, and Boussinesq codes (such as FUNWAVE, NEOWAVE and BOSZ), which solve the namesake equations. Boussinesq models are capable of including wave dispersion effects that are not included in NSW models, but at a significantly greater computational cost (time).

Techniques for solving the mathematical equations describing tsunami evolution include Finite Difference, Finite Volume, and Finite Element Methods. Finite Difference and Finite Volume Methods are typically used in combination with nested structured grids to calculate wave effects when tsunami waves approach and hit the shore. Finite Difference methods can be coded with great computational efficiency, making them particularly suitable for warning and forecasting in real-time. Finite Volume methods tend to exhibit better mass and momentum conservation properties than Finite Difference models, especially in regions with hydraulic jumps. Finite Element Methods apply unstructured grids, most commonly constructed with triangular or trapezoidal elements, to model the wave propagation. The Finite Element grids can adjust to changes in depth and conform to the irregular coastlines better than structured grids. However, as the wave enters shallow water, computation time increases significantly to the point where it may become inefficient. Examples of Finite Difference codes widely used in tsunami simulation are: MOST and RIFT. GeoClaw, NEOWAVE and HySea are examples of Finite Volume codes and ADCIRC is a Finite Element-based code.

2.2.6 Computing Tsunami Impact Using Numerical Models

Tsunami simulation models are computer codes capable of providing a good approximation to tsunami behaviour once good initial and boundary conditions have been provided. Tsunami models are based on a set of mathematical equations often referred to as the “governing equations”, “field equations” or the “mathematical model”.

In physics, there is a set of equations that describe the motion of any type of fluid. They are known as the Navier-Stokes (NS) equations (Fox and McDonald’s, 1992) in honour of the two scientists who independently derived them. The NS equations are a formulation of the conservation of mass principle and of Newton’s second law for any fluid (i.e. liquids or gases). They represent the relationship amongst the relevant variables that describe fluid motion (velocity components, density and pressure or surface elevation) expressed as functions of space and time, and their derivatives. A set of equations like this that relate several functions to its derivatives is called a set of differential equations, therefore the NS equations are a set of differential equations that describe fluid motion.

For the particular case of tsunami dynamics, the NS differential equations can be further simplified because the horizontal length scale of tsunami waves is much, much greater than the vertical length scale. In other words, the distance between two consecutive wave crests (i.e., the wavelength) in the deep ocean is much greater than the depth of the water that the waves propagate in, or move through, so pressure in the fluid column always remains constant, or hydrostatic. This assumption make modelling tsunami waves easier because the NS equations can be simplified to the NLSW equations below (in Cartesian coordinates).

$$h_t + (uh)_x + (vh)_y = 0$$

$$u_t + uu_x + vu_y + gh_x = gd_x$$

$$v_t + uv_x + vv_y + gh_y = gd_y$$

where *h* is the height of the water column, *d* is the depth, and *u* and *v* are the two horizontal velocity components.

The NLSW differential equations retain much of the physics that govern tsunami behaviour and are easier to solve than the NS equations. However, even the NLSW equations are too complex to be solved exactly in anything other than idealized and simplified cases that are not really of much real-life interest.

In order to find a solution to the NLSW equations with real-life initial and boundary conditions, that is with the initial water surface deformation created by a real seismic event and with propagation over the complex geometry of a real bathymetric relief; the set of “differential equations" has to be transformed into a set of "difference equations". One way of doing this is by making approximations to the derivatives appearing in the "differential equations" based on Taylor series expansions. In order to accomplish this, it is also necessary to discretize the computational domain in space and time. In other words, we will no longer be solving the equations in a continuous domain, but we will solve the equations at grid nodes that will dot the computational space. The solution to the "difference equations" we obtain in this manner is known as a "numerical solution" as opposed to the solution of the "differential equations" which is known as an "exact solution" of the system. The numerical solution is, therefore, an approximation to the "exact solution" since the derivatives in the differential equations have been approximated by terms in a Taylor series expansion.

The smaller the distance between nodes in our computational space (i.e., the higher the resolution of the grid), the better the numerical approximation will be to the exact solution. Nevertheless, it is important to remember that any numerical solution obtained with a computer code, is always an approximation to the exact solution of the equations. This is particularly important to keep in mind when interpreting results of the simulations.

2.3 CONDUCT TSUNAMI MODELLING OR NO MODELLING

2.3.1 Tsunami Modelling Requirements

There are two essential data/information needed before any tsunami modelling is conducted: tsunamigenic earthquake sources and a high-resolution Digital Elevation Model (DEM). Establishing these two takes significant time and effort and should be planned well ahead of time.

Numerical simulations can yield tsunami hazard and vulnerability of the community against tsunamis under various conditions. Numerical simulations, in particular, have the capability to estimate disaster risk due to the expected tsunamis, which will strike in the community. To establish comprehensive measures to prevent and reduce the expected disaster risk, numerical simulations are also a crucial tool to evaluate and analyse the effect of each measure and combination and integration of measures on disaster prevention and reduction.

Tsunami inundation or hazard areas in a community are estimated through tsunami numerical simulation based on bathymetric data, topographic data, and tsunami scenarios including the occurrence of tsunami generation and magnitude of tsunami. Inundation areas estimated through the numerical simulations are used to indicate tsunami risk areas on the tsunami disaster management maps. The most basic and essential indication procedure of tsunami hazards is that of colouring the inundation areas on the map. Red is usually used to represent the inundation areas on the map. When inundation depth is predicted by the numerical simulation, the depth is indicated by the strength of the red.

2.3.1.1 Historical or Seismic Sources

A committee should be formed by the Regional and local jurisdictions in cooperation with National/International authority to discuss or research in identifying realistic tsunamigenic earthquake sources. A comprehensive list of active subduction zones and other tsunamigenic zones in the basin that has the potential of generated great tsunamigenic earthquakes (~M8.0 to M9.0+) should be developed. The list should also include tsunami earthquakes zones (slow earthquakes). Slow earthquakes are those that are capable of generating large tsunamis in comparison to their magnitude. In conducting tsunami hazard assessment, probability and uncertainty should be included in the study.

Small magnitude near-field or local earthquake sources should not be discounted due to their proximity to the coast of interest. There are documented events where the near-field earthquake was not felt and a devastating tsunami occurred. For example, the 1896 Sanriku, Japan earthquake. The earthquake was felt along the coast as a weak intensity not exceeding Modified Mercalli Intensity (MMI) IV; however, it was followed by a devastating tsunami with a run-up of 30 m causing a death toll of more than 20,000 people (Kanamori, 1972, Soloviev and Go, 1984). Other smaller scale earthquakes that had similar characteristics are: Nicaragua (1992), Java (1994 and 2006), Chimbote, Peru (1996), and Mentawai (2010) (Abe et al., 1993; Tsuji et al., 1995; Bourgeois et al., 1999; Fritz et al., 2007; Hill et al., 2012).

Researching for historical tsunami is a good first step to determine the features of the tsunami, the extent of damage, and loss of lives that occurred in the region of interest. The local government should look into reports and historical records to check if such events have occurred in the past. Interviews with eyewitnesses or survivors would also be useful. The tsunami source needs to be determined if it was due to a local source or from a distant source.

If no information is found in the historical archives, the local government should check with tsunami researchers or seismologist at local universities or seek assistance from the national government to bring in experts.

It should be noted that tsunamis that occurred long ago might not provide reliable information so care should be taken in interpreting these data. In addition, the topographic and coastal features of the region of interest when the tsunami occurred should be taken into consideration. Coastal modification such as the development of harbours, breakwaters, marinas, etc. can possibly either attenuate or increase the damage caused by a tsunami.

Regardless of whether historical tsunami has occurred or not in the region of interest, additional simulations of possible credible seismic sources is highly recommended. Depending on the parameters (i.e., epicentre, depth, fault size, and fault displacement), a relatively small earthquake with its energy directed towards a coast of interest can possibly wreak havoc. This is very likely for a local tsunami-generating seismic source and possible even for a distant source.

Tsunami/seismological expert needs to look into archives of earthquakes along the region of interest and at distant earthquakes where the tsunami generated had affected the region. Good examples to start with are the Chile 1960, Alaska 1964, Chile 2010, and Tohoku 2011 earthquake-tsunami. A number of published research manuscripts are available to obtain the source parameters needed to conduct tsunami simulation for these events. Seismicity map is also available from United States Geological Survey (USGS) website (earthquake.usgs.gov). For example, USGS website provides a finite fault solution for certain earthquakes like the Tohoku 2011 earthquake. Seismic parameters like fault size; strike, dip, and rake angles, epicentre, and corresponding slip values can be used for tsunami simulation (https://earthquake.usgs.gov/earthquakes/eventpage/official20110311054624120_30#finite-fault).

To support the inundation mapping, the IOC has convened expert workshops to discuss and identify maximum credible and/or worst-case earthquake tsunami sources. To date, workshops have been held for Haiti (IOC, 2013), South China Sea (IOC, 2015), Dominican Republic (IOC, 2016), Central America (Caribbean and Pacific, IOC, 2016), Tonga-Kermadec Trench (IOC, 2018), and the Lesser Antilles Trench (IOC, 2019). Additional IOC workshops are planned in 2020 for the Ecuador-Colombia Trench, and New Guinea, New Britain, South Solomon, and New Hebrides Trenches.

2.3.1.2 Determining Seismic Worst-Case Scenarios when there are No Credible Sources

This section outlines a method for identifying the worst-case seismic scenarios for locations where no rigorous seismic analysis of worst-case sources is possible (Figure S.16). The methodology is based primarily on the proximity of potential scenarios and their tsunami directivity to the area of study, and makes use of a propagation database of pre-computed tsunami scenarios that has been developed at the NOAA Center for Tsunami Research (NCTR) in recent years. The database is that which is utilized by the ComMIT / MOST modelling software.

Generally deterministic tsunami hazard assessment studies have been focused on the impact of historical tsunamis, under the assumption that the worst scenario for a particular community would be found in the set of scenarios included in the historical record. The main deficiency of using the historical record to decide on the worst-case scenario is that the record may be incomplete or not long enough, to have included the worst-case scenario due to the long recurrence intervals of great earthquakes. For example, the recurrence interval for the 2004 Sumatra, Indonesia earthquake (Indian Ocean tsunami) was determined from tsunami deposits in Thailand to be 550-700 years ago (Jankaew et al., 2008), and for the 2011 Tohoku, Japan earthquake (Great East Japan earthquake and tsunami), the last great earthquake was the Joban earthquake in 869.

Because of the risk of underestimation of the worst-case seismic scenario, NOAA NCTR has developed methodology to identify more conservative worst-case tsunami scenarios using the ComMIT / MOST modelling software.

1. Considering Geist et al. (2007) and Bird and Kagan (2004), the method assumes that an Mw 9.3 mega seismic-event or larger is possible in any subduction zone of the Pacific and Indian Oceans, and Caribbean Sea where the NOAA propagation database unit sources exist. These events are reconstructed in terms of a combination of propagation database unit sources, so that the tsunami propagation solution in the entire basin is available within seconds. The event epicentre location is then gradually shifted from one unit source to the next, by a distance of 100 km to account for the varying directionality of different event locations. This process produces, within minutes, solutions for the deep-water propagation of hundreds of tsunami scenarios, whose computation would be prohibitive without the pre-computed propagation database.

2. Next, local tsunami inundation models are computed with just enough resolution to give a coarse estimate of maximum wave height and inundation in the area, including the capture of the non-linear dynamics likely to develop in shallow waters. These models are similar to the inundation forecast models used for operational tsunami forecasting by the US Tsunami Warning Centers (Pacific Tsunami Warning Center, US National Tsunami Warning Center). During this step, it is important to inspect the animations of the tsunami simulations to ensure that no instabilities develop that could generate fictitious results. Due to the relative low resolution, a full suite of tsunami scenarios identified in the previous step can be calculated within a reasonable amount of time.

3. Next, a map of the sensitivity of the community to tsunami waves coming from different directions (Figure S.14) is generated. During this step, if sudden changes in the sensitivity trend or tsunami wave heights outliers are observed without a clear explanation, the animation of that particular case should be investigated in more detail to guarantee an adequate quality control of the computations. If any instability is found in a simulation, this should be corrected and the simulation re-computed.

4. Based on the results of step 3, a small subset of potential worst-case scenarios is selected on the basis of their potential to generate high tsunami waves at the community of study. This small subset of scenarios is then simulated using high-resolution grids. Note that these high-resolution simulations will be more time-consuming than those performed in step 2, but the total number of scenarios has been reduced to a very small subset. The use of the high-resolution grids will mean that the results will have the level of detail and accuracy necessary to select a final worst-case scenario for the community.

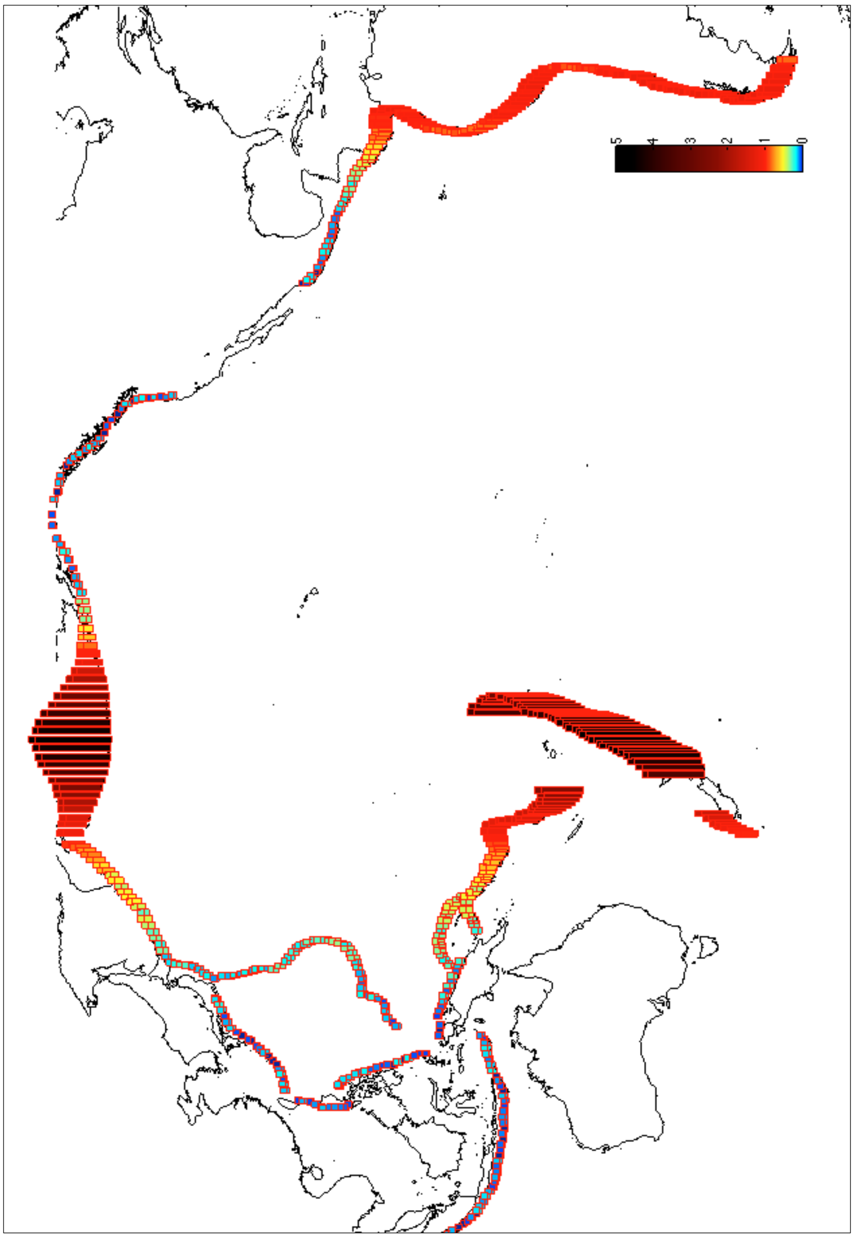


Figure S.14. Distribution throughout the Pacific Ocean of the sources evaluated as potential worst-case scenarios for an arbitrary location. Bar height at a particular source location indicates maximum tsunami wave height at the community of interest. A small subset of all these scenarios will be selected and simulated at high-resolution to arrive to a final scenario representing the worst-case for that community.

2.3.1.3 Bathymetric and Topographic Data

For an accurate modelling of tsunami inundation, high-resolution bathymetric/topographic data, also called Digital Elevation Model (DEM) is required especially the area where the community inundation will be computed. The coastal DEM depicts the Earth's land surface and ocean bottom, and need to be as accurate as possible to minimize error in the modelling of coastal processes.

A DEM resolution of less than 3 arc-sec is advisable. A 1/3 arc-sec (10 m) grid resolution is preferable especially for ports and harbours. It has to be kept in mind that using grid resolution coarser than 3 arc-sec (90 m) will produce inaccurate results since coastal features might not be properly resolved. A coarser grid resolution will also have less points per tsunami wavelength and will not properly resolve the nearest-coast shorter-wavelength waves and could miss the highest/lowest tsunami wave amplitude.

While several public data sets provide this level of resolution for topography, obtaining bathymetry data of this resolution in the shallow areas is more difficult to find. While some reasonable grids have been made with single-beam surveys, it usually takes either a multi-beam bathymetric survey or a LIDAR (LIght Detection and Ranging) survey of the study location, to produce satisfactory results.

A LIDAR survey that covers both the subaerial and submarine portions of the study area is the preferred data requirement for a hazard assessment, but a multi-beam survey is the minimum requirement. If coral reefs and shallow lagoons are present in the study area, the multi-beam survey data might need to be augmented by LIDAR or aerial photography.

The NOAA NCEI builds and distributes high-resolution, coastal digital elevation models (DEMs) that integrate bathymetry and topography to support tsunami modelling, forecasting, and warning efforts. Their high-resolution coastal DEMs meet the requirements of the US MOST model, relying upon high-resolution multibeam swath sonar bathymetric and aerial topographic lidar data where available. The requirements include: (i) a global, geographic coordinate system rather than a local system (e.g., UTM zone), as tsunamis can propagate across ocean basins; (ii) a mean high water (MHW) vertical datum for modelling of maximum flooding; (iii) the ESRI ArcGIS ASCII grid file format; and (iv) "bare earth" (i.e., buildings and trees are excluded from the DEM). Every cell in the DEM must be square in the geographic frame and contain an elevation value. The DEM also must be "seamless" at the coast. In other words, the DEM should not introduce a false ledge or step at the coastline.

Good practices throughout DEM development help to ensure this. The following steps followed by the NCEI in creating DEMs to support tsunami forecasting and hazard assessment (https://www.ngdc.noaa.gov/mgg/inundation/tsunami/general.html):

1. Gather elevation data from multiple sources, e.g., use the best available digital elevation data, obtaining coastline, bathymetric, topographic, and shoreline-crossing data from numerous international, national, and local agencies, universities, and private companies.

2. Convert data to common file format and common horizontal and vertical datums (reference frames). Building of accurate, reliable, and seamless coastal DEMs requires that the data be converted to common horizontal and vertical datums and to common units and file formats (for gridding and visualization). Horizontal datums include: (i) geographic coordinates, such as the World Geodetic System of 1984 (WGS 84) and North American Datum of 1983 (NAD 83), measured in latitude and longitude degrees; and (ii) local datums, such as UTM zones (Universal Transverse Mercator), usually

measured in meters from specified positions on Earth's surface. Vertical datums include tidal, geodetic, geoid, and ellipsoid.

3. Visually evaluate and edit the data. Data are assessed for quality and accuracy both within each dataset and between datasets to ensure consistency and gradual topographic transitioning along the edges of datasets. Dataset problems fall into several broad categories: (i) gross errors in the elevation of single points; (ii) values representing the water surface, rather than the seafloor; (iii) values representing buildings or vegetation, not the ground surface; (iv) morphologic and anthropogenic change that has occurred since the survey data were collected; and (v) incorrect or incomplete metadata, such as misidentified or undefined datums.

4. Build and evaluate the DEM. A gridded digital surface (blanket) over the scattered data is created. The process includes the averaging of multiple points into a single value if they fall within one grid cell (the fundamental DEM unit), or interpolating between cells if the point data are far apart. Data is collected that lie within a box that is at least 5 percent larger than the final DEM boundary is collected to provide a data buffer surrounding the DEM to avoid edge effects and ensure that gridding algorithms correctly.

   The DEM is evaluated through visual inspection, comparison with source and independent datasets. Steps three and four are repeated iteratively numerous times as anomalies or inaccuracies are found in preliminary DEMs, their cause determined, data corrected, and a new version of the DEM is created. Depending on the DEM size, it may take 20 or more preliminary DEMs before a DEM is considered acceptable.

5. Document the DEM development. The processing procedures, data sources, and analyses information should be thoroughly documented in a technical report. The technical report allows DEM users to understand the quality and accuracy of the DEM; it also allows anyone to replicate the DEM development process. NCEI creates a detailed metadata record for the DEM, which meets the U.S. Federal Geographic Data Committee (FGDC) standards.

6. Distribute the DEM on the internet for public access and delivery. Documentation and metadata accompany each of the DEMs.

2.3.2 Methods of Determining Inundation/Flooding Extents

Different numerical methods with varying degrees of sophistication have traditionally been used in the determination of flooding zones and the construction of "inundation maps". All methods adopt a conservative approach, which is that all uncertainties that could potentially result in more extreme values of inundation are assumed to be credible. This approach, which errs on the side of safety, can be taken as necessary and justifiable in order to protect life and property. However, this approach also has the potential to substantially overestimate inundation areas, which in turn, could result in the unnecessary evacuation of areas that will be beyond the reach of tsunami waves. The resulting overestimation ("over evacuation") comes at an economic cost to coastal communities since business and government in the evacuation zone must close, resulting in lost commerce and revenue. In addition, in the long run, repeated "over evacuation" can undermine confidence in the tsunami warning and response system because of the overly conservative tsunami evacuation maps.

2.3.2.1 "Bath-Tub" Line Methods

Amongst some of the crudest methods used for the determination of tsunami inundation areas are "bath-tub methods". "Bath-tub" methods, in their simplest form, are based on the historical maximum tsunami run-up ever recorded in a specific community. This maximum run-up value, expressed as a maximum elevation above mean sea level is assumed to determine the maximum possible water level from a tsunami anywhere in the community of interest. The topographic contour line associated with this specific elevation will then determine the separation between inundation and non-inundated areas.

There are two main weaknesses in this approach. The first is that determination of maximum run-up is highly dependent on the length of the historical record for that community. For coastal areas where written records of historical tsunamis are only a few centuries old, this shortcoming could lead to substantial underestimation of the inundation areas. The second weakness is in the assumption that the maximum recorded run-up could be reached anywhere in the region of interest. This assumption ignores the effects that local bathymetric features and the directionality of tsunami waves could have on the geographical run-up distribution along a coast, and could thus lead to imprecise inundation line estimates.

More refined "bath-tub" approaches have traditionally been based on numerical simulations of tsunami wave elevations computed in coastal waters but without an inundation component. In this approach, a reflective boundary condition located at a specified depth is used to model the interaction of tsunami waves with the coastline (i.e., no run-up calculations). The main advantage over the crude "bath-tub" approach is that the set of events investigated to determine the maximum inundation line is no longer restricted to historical events. Through the use of numerical simulation codes, any event could be simulated that has some probability of generating a tsunami that could affect the region of interest. Once the simulation has been conducted, the maximum offshore elevation at the closest bathymetric contour to the coastline where the numerical simulation provided a solution is used to decide on the maximum regional run-up anywhere in the locality of interest. This is similar to the previous "bath-tub" approach except that, in this case, the maximum run-up value is determined by coastal, offshore model results.

2.3.2.2 *Establishing Tsunami Inundation Zones for Evacuation Mapping and Planning in Regions without Tsunami Modelling*

In 2011, the U.S. National Tsunami Hazard Mitigation Program compiled guidelines for establishing tsunami inundation zones. In 2016, under the TEMPP Pilot training, current guidance was reviewed and adapted for international use by USA (ITIC, CTWP, PMEL), New Zealand, Philippines, and Japan.

Purpose

This guidance should be used for tsunami evacuation mapping and planning in areas where any of the following conditions exist:

- The hazard is considered to be low based on historical occurrence of tsunamis, and no tsunami modelling exists or none is planned.
- The risk is considered to be low due to a small population and lower infrastructure vulnerability.
- Tsunami modelling does not exist but a community wishes to initiate planning and preparedness efforts.

- There is a high level of uncertainty in the model simulation results. Possible reasons include limited knowledge of the tsunami sources and/or topographic and bathymetric data with poor resolution (minimum 3 arc-sec data spacing (approx. 90 m at Equator)).

Guiding Principles

Tsunami impact (loss of life and property damage) can be reduced by building communities resilient to natural disasters, and especially tsunamis. Government Agencies worldwide have an important a responsibility to these coastal communities and an important role in facilitating this process by helping communities a process to aid in the assessment and mitigation of their risks.

Tsunami inundation modelling provides scientifically based guidance to enable communities to address their tsunami risk and develop products for planning, education, and training. One such product, the tsunami inundation map, provides the information necessary for making tsunami evacuation maps and plans. In some locations, the estimation of tsunami inundation is required, but modelling resources are not (yet) available. In this case, it is recommended that agencies use the guidance given in this document to develop their evacuation maps and plans now. Later, when required resources become available, the technical accuracy can be improved with modelling and their evacuation maps updated.

The guidelines in this document were adapted for global use from the 2011 United States (US) guidelines. The 2011 guidelines were prepared by the US National Tsunami Hazard Mitigation Program (NTHMP) Mapping and Modelling Subcommittee to assist at-risk communities, especially lower-risk states along the US East and Gulf Coasts, prepare for and mitigate tsunami impact.

Recommended Guidelines

As the first step, it is important to consult with scientists and emergency managers for advice on the community hazard and risk. The general guidelines and recommended process outlined below is considered best practice for estimating the most hazardous areas. When advised by experts, it is recommended to develop separate evacuation procedures for local (felt events with only minutes to evacuate) and distant (non-felt events with more time to evacuate) scenarios. The reference *Preparing Your Community for Tsunamis–A Guidebook for Local Advocates* (Dwelley L. et al. 2008) contains many of the recommendations below and can be further consulted.

General guidelines and recommended process:

1. Apply historical inundation information:

   a. Where information about historical tsunami events exist, use the maximum inundation evidence and add a safety buffer appropriate for the location. The inundation value can come from actual events, from geological evidence for past tsunami inundation, or from local experts. The National Centers for Environmental Information / World Data Service (NCEI/WDS) Global Historical Tsunami Database can be accessed at http://www.ngdc.noaa.gov/hazard/. An alternative database developed by the Institute of Computational Mathematics and Mathematical Geophysics SB RAS, Tsunami Laboratory, Novosibirsk, Russia, is available at tsunami- database/index.php. Regional tsunami catalogs are available in the literature as well.

b. The safety buffer should take into account potential storm surge and maximum tide level that would add to the historic event source(s) inundation, other known sources for local tsunamis, and local topography. The US Guidelines recommended adding another 1/3 of the area corresponding to the historical maximum run-up for safety.

c. In situations where there is regional similarity in earthquake seismicity, source characteristics, tectonic regime, and off- and on-shore coastal morphology, using regional historical events as a proxy for country historical events is reasonable.

2. Choose an elevation and distance from the shoreline keeping in mind the following:

a. Tectonic setting. Local tsunami sources typically generate larger tsunami waves along nearby coastlines than distant sources. Locations near subduction zones are more prone to large earthquakes, co-seismic subsidence, and thus larger tsunami waves. Establish the relative threat from local, distant, or both local and distant potential sources of tsunami.

b. Local topography. The consensus among US tsunami modelling experts is that coastal morphologies (e.g. shorelines, areas along bays, inlets, rivers with direct ocean outflow) that are below 10 m (~33 ft) in elevation are at risk of tsunami impact. Therefore, in the absence of reference information, the "reasonable" safe elevation in these areas should be at least 10 m.

c. Local tsunamis. It is possible for large local tsunamis to flood land that is above the "reasonable" safe elevation, so careful consideration is needed in deciding on the elevation for evacuation, particularly in regions where no local historical tsunamis have occurred. Maximum local run-ups of 30-40 m were measured in M9.1 2004 Indian Ocean tsunami in Sumatra, Indonesia, (Run-up Measurements of the December 2004 Indian Ocean Tsunami, Synolakis and Kong, 2006) and the 2011 Great East Japan tsunami in Tohoku, Japan, (National Field Survey of the 2011 Off the Pacific Coast of Tohoku Earthquake Tsunami, 2011, Tohoku Earthquake Tsunami Joint Survey Group, 2011). For the 2011 Great East Japan tsunami, run-ups and inundation averaged 10–20 m, and up to 30 m at locations nearest the earthquake epicentre (see following summary in section 2.3.2.3).

d. Distance from the shoreline. Low-lying areas along rivers or channels that connect to the ocean should be designated as tsunami inundation zones. For large, flat coastal rivers, the zone should be at least three kilometres inland and up to ten kilometres inland (Sendai plain inundation was 8 km in the 2011 Great East Japan tsunami). The US Guidelines noted that most local tsunamis would no longer be destructive by 3 km (~ 2 miles) inland, and most distant tsunamis generally affected beaches and waterfront areas within ~1.6 km (1 mile) of the open coast.

e. Once the elevation or distance from shoreline is reached, this will determine the potential inundation/evacuation zone.

3. Use tsunami modelling for nearby areas. In situations where there are regionally-similar earthquake, tectonic, and coastal regimes, and numerically-acceptable inundation modelling has been conducted for other nearby locations, define inundation based on maximum modelled inundation in nearby / bounding areas.

a. If available, use low resolution, regional simulations to estimate the relative amplification of tsunamis by offshore bathymetric effects.

b. Consideration should be given to the behaviour of tsunamis of similar size for terrain analogous to that of the target area, even for tsunamis from other parts of the world.

4. Take a conservative approach if using lower-resolution tsunami model results by adding a safety buffer to estimates of both inundation and evacuation zones.

   a. US Guidelines for require a minimum grid resolution of 3 arc-sec (90 m at latitude of Equator) for inundation modelling and 10 m for determination of tsunami currents. If modelling has been completed at a lower resolution, it is advisable to apply a safety factor to both inundation and run-up.

   b. Account for the behaviour of tsunamis of similar size for terrain analogous to that of the target area, even for tsunamis from other parts of the world.

5. In the absence of other tsunami hazard information, and where Hurricane Storm Surge Maps are available, storm surge inundation may be considered as a proxy, in consultation with scientists, for tsunami evacuation planning.

6. If inundation modelling shows that inland areas will not be affected, but strong offshore currents are possible, consider developing safety and response procedures for recreational areas (e.g., ‘clear the beaches’) and port facilities.

2.3.2.3 Observed Run-Up and Inundation Measurements from the 11 March 2011 Tohoku, Japan Tsunami

Maximum run-up and inundation measurements from observed tsunamis may serve as a proxies for worst-case values if no other local or regional information exists. For recent events, the 2011 Tohoku, Japan, tsunami provides the most extensive measurements of the impact from a local tsunami along a long stretch of coast. Measurements were taken at 296 points on the Sanriku coasts of Aomori, Iwate, and Miyagi Prefectures, and the Pacific coasts of Ibaraki and Chiba Prefectures by the 2011 Tohoku Earthquake Tsunami Joint Survey Group (Tsuji et al., 2011; 2014). Along the Northern Sanriku coast (Aomori and Iwate), most of the 141 heights range between 10 m and 30 m. Run-up heights exceeding 30 m were measured at one location in Noda Village (maximum 38 m) and nine locations in Miyako City. On the Southern Sanriku coast in Miyagi, most of the 76 measurements range between 4 and 20 m. On the Ibaraki coast, 36 measurements range from 2.8 to 8.1 m, and the heights generally decease toward the south. On the Chiba coast, 43 measurements range from 0.7 to 7.9 m, with the maximum height near Iioka, Asahi City.

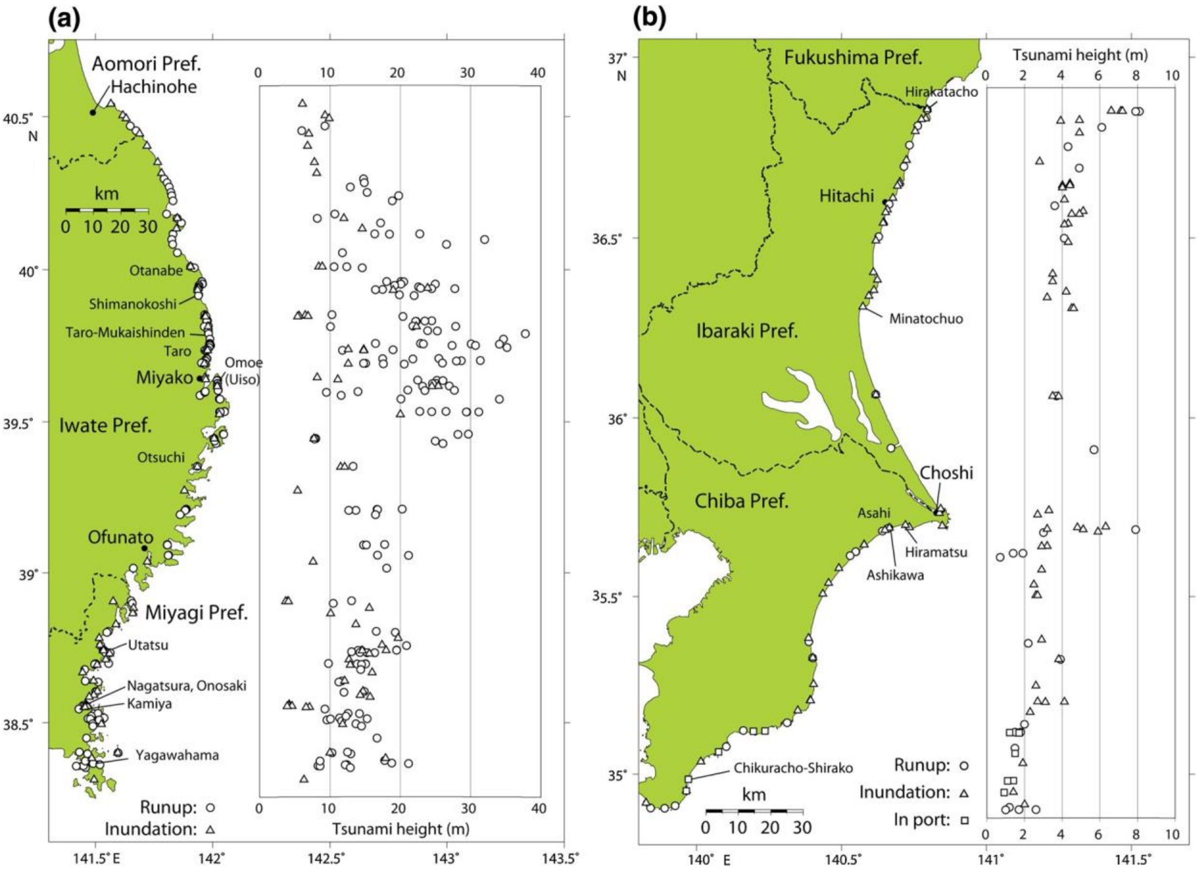


Figure S.15. Distribution of tsunami heights from the 2011 Tohoku tsunami (from Tsuji et al. 2011 and 2014)

(a) Distribution of tsunami heights in Aomori, Iwate, and Miyagi prefectures (Tsuji et al. 2011). Circles and triangles indicate run-up and inundation heights, respectively. The dashed lines indicate prefectural boundaries.

(b) Distribution of tsunami heights in Ibaraki and Chiba prefectures. Circles, triangles, and squares indicate run-up heights, inundation heights, and tsunami heights in ports, respectively.

2.3.2.4 Inundation Modelling Codes

Inundation modelling is the most sophisticated approach to identify what areas tsunami waves will flood. Inundation modelling methods require the use of complex numerical codes capable of accurately simulating the nonlinear evolution of tsunami waves in shallow coastal waters and inundation onto dry land. The use of these methods reduces the level of uncertainty in the problem.

Inundation modelling requires high-resolution bathymetry and near-shore topography in order to mimic variations in coastal and shallow seafloor morphology, which drastically affect a tsunami wave's height and energy. Like the "bath-tub" methods based on offshore water elevation values from scenario sources, inundation modelling methods are not restricted to historical events. Additionally, inundation modelling methods will compute run-up values everywhere in the gridded study domain, thus resulting in more realistic inundation zones. Another advantage of the use of tsunami inundation codes is that additional information regarding tsunami flow depth and expected strength of tsunami currents anywhere in the domain can be obtained from the simulations. The most common type of tsunami inundation codes used for tsunami hazard assessment fall within two categories: Nonlinear Shallow

Water (NLSW) wave codes (Johnson, 1997) and Boussinesq codes (Wu, 1981). (See Table 4 in the main document [IOC/2020/MG/82] for benchmarked models)

NLSW codes (e.g., hydrostatic codes; the qualifier "hydrostatic" indicates that the pressure field in the fluid is assumed to behave as if the fluid was at rest), assume no physical frequency dispersion takes place during wave propagation. This is a reasonable assumption in the simulation of tsunamis generated by seismic events. Most of the tsunami wave energy generated from earthquake-generated tsunamis is contained in long-period waves that experience little to no frequency dispersion during the propagation stage.

When frequency dispersion effects are present, waves of different wavelengths propagate at different speeds. This results in the spreading of tsunami energy over an increasingly longer wave-train as the tsunami propagates. Tsunami energy impact on the coastline is, therefore, expected to be more gradual and less destructive when dispersion effects are included than in the case of non-dispersive NLSW codes. In NLSW numerical codes, tsunami energy tends to remain concentrated in individual wave pulses that concentrate and deliver their energy at the coastline more destructively.

Boussinesq codes (e.g., non-hydrostatic codes) are capable of including the physical effects of frequency dispersion. These effects are particularly noticeable when a significant amount of tsunami energy resides in waves whose wavelength is of the same order of magnitude as the local water depth. Inclusion of frequency dispersion effects is particularly important in modelling tsunamis generated by submarine landslides, where the deformation area is usually smaller than that for earthquakes. Submarine or sub-aerial landslides that enter the water result in the generation of shorter wavelengths that can easily be similar in length to the local water depth exhibiting strong physical dispersive effects.

Furthermore, even for a tectonically generated tsunami, short waves often ride on the main body of the long tsunami, due mainly to shoaling effects, and these short waves might be important to assess impact forces on coastal structures. It is noted that the maximum run-up height might be determined primarily by the long-wave characteristics of the incident tsunami, since the majority of the tsunami energy resides in the long wave component. Nonetheless, shorter waves may affect the distribution of wave forces. The coastal engineering community has developed robust numerical algorithms for solving Boussinesq-type models. It is possible to extend the existing Boussinesq-type models to include the tsunami run-up phase.

Usually, numerical modelling of tsunami inundation/flooding does not include the effects of tides. The tidal level at the tsunami arrival time can have an impact on the extent of tsunami inundation/flooding. Once a decision has been made on which numerical model will be used for simulation, it should be determined whether the numerical model includes or excludes tides. One solution is to use a conservative approach by using Mean High Water in the DEM. It is also recommended to read peer-reviewed published manuscripts on the numerical model on its accuracy by comparing with historical tide gauge records of tsunami events.

2.4 CREATE INUNDATION MAP

The outcome of a tsunami numerical modelling study for evacuation mapping is an inundation map that shows the maximum extent flooding from all credible scenarios. The number of scenarios modelled must be enough to cover the range of expected inundation. Exclusion, or misrepresentation, of the most dangerous sources in a hazard assessment study will inevitably result in an inaccurate determination of maximum tsunami impact, or maximum inundation.

In order to produce meaningful estimates of the expected tsunami inundation for a particular community, there are two inputs, regardless of the numerical model chosen, that are required:

1. Identification of credible worst-case scenarios, or "tsunami sources" for the community;

2. Availability of accurate, high-resolution bathymetric and topographic data, or a digital elevation model (DEM) for the area.

Before conducting an inundation modelling study, a comprehensive science-based list of all potential tsunami sources (distant, regional and local and range of magnitudes, including historical tsunamis) must be assembled (Historical or Seismic Sources, Programme Module 2.3.1.1).These potential scenarios should then be simulated. The results are then used to decide whether the final inundation line for evacuation zone mapping is to be based on a combination, or envelope of inundation lines from different scenarios, or on a single worst-case scenario.

Additionally and importantly, simulation results obtained with numerical codes are only accurate to the degree that the Digital Elevation Model (DEM) of the bathymetric and topographic data accurately represents the local of topography and submarine terrain. The accuracy and the level of detail of the modelling results are controlled by the level of accuracy and detail of the DEM used in the simulation (NCEI, 2016). A resolution of 3 arc-sec (90 m) or finer is recommended for accurate hazard inundation mapping.

If an acceptable DEM is not available, Programme Module 2.3.2.2 gives guidance for Establishing Tsunami Inundation Zones for Evacuation Mapping and Planning in Regions without Tsunami Modelling

2.4.1 Tsunami Inundation Map

The Tsunami Inundation Map shows areas that are expected to become inundated, and the extent or degree of inundation. The map can be classified in three ways based on its (i) spatial coverage, (ii) contents, and (iii) utilization purpose.

Spatially, the inundation map can be prepared national and locally. A national map shows spatial distribution of tsunami hazard level over the country. For countries having wide archipelago, and therefore with high potential of tsunami hazard over many areas, inundation maps are very useful for setting priorities for implementing disaster countermeasures and local or regional disaster response centres. Because various versions of such a map may be created, the central government should determine a single reference map on which all disaster management plans and decisions should be based on.

The tsunami inundation map shows the flooding extent in both the horizontal (kilometres inland) and vertical (elevation) directions. This type of map is a basic requirement for the development of local tsunami disaster mitigation plan, or tsunami response plan, and countermeasures, such as vertical evacuation structures or sea walls. The Tsunami Evacuation Map (Module 2) is created from the Tsunami Inundation Map (Module 1) and shows the evacuation zone, sites and assembly areas, routes and other tsunami safety information.

In this guide (IOC/2020/MG/82), identical to its used in New Zealand and the USA, the terms tsunami hazard, tsunami inundation map, and tsunami evacuation map will be used, and identified as separate products (e.g., Programme Module 1 and 2, respectively). In Japan, however, the tsunami hazard or inundation map can includes both the historical hazard, the inundation line and evacuation information.

In Japan, municipalities prepare the tsunami inundation or hazard map, and it is freely distributed to all residents in the potentially affected area. The map may also be freely downloadable by the citizens through the internet. For a smaller jurisdiction, such as a town or village, the community can develop their own hazard map based on the map provided by the municipality. The process involves multiple consultations between town or village level preparers and the municipality. The municipality then distributes the final hazard map to all households in the area.

An example of a Japanese hazard map (Figure S.16**)** shows the three major types of information: (1) tsunami inundation line, (2) location of residents' houses, and (3) location of houses that should be evacuated during tsunami. Houses that should be evacuated are numbered and house owner names are listed, respectively. In this town, evacuation route directions are not necessary since the residents are very familiar with their local environment. Very simple maps like this one assist in tsunami preparedness.

Figure S.16. A simple hazard created by local residents of Tanohata village (Oosaku, Kawamukai, and Matsumae area) in Sanriku area of Japan. (Tanaka and Istiyanto, 2010)

2.4.2 Practical Uses of Tsunami Hazard and Inundation Maps

During the development of tsunami evacuation maps for a community, specific local information is added to meet effectively local residents' needs. To determine such information, many types of information should be collected, e.g., residents' awareness levels of tsunami disasters, status of the area's infrastructures, potentially dangerous sites that cannot be identified using inundation risk area maps, opposition to the public release of detailed tsunami-related information, etc.

The inundation map has many practical uses, such as:

1. An awareness tool. The map provides information on expected worst-case tsunami inundation for the community. This information (map) may be useful to share disasters among the administrative organizations and disaster-related authorities. It also is a good way to communicate the risks from the tsunami.

2. An analysis and investigation tool to support the establishment of structural and non-structural measures. The map is a way to analyse disaster prevention and plan disaster reduction for a community. It is a useful way to analyse and investigate the location of evacuation sites and routes.

3. A tool for risk communication. The map can be used for risk communication between governments and residents on future disaster prevention measures. Because a tsunami does not recur frequently, this type of disaster can be easily forgotten or taken for granted. The availability of an inundation map could be used as a tool to make people see the hazards associated with both historical and worst-case scenarios.

4. A planning tool. The map is used as a reference tool and for connecting people in tsunami disaster mitigation action planning. Local leaders can use inundation map when they publish progress reports on tsunami disaster countermeasure planning (such as for land use planning in relation to tsunami disaster prevention and mitigation).

5. A tool to enhance residents' self-defence capabilities and for drawing up evacuation plans. The map is a tool to ease tsunami disaster mitigation and is a part of proactive measures in disaster mitigation cycle that enables the society become well prepared before the disaster happens. In the formulation of mitigation measures, participation and coordination among the government, community leaders, and citizens are indispensable.

6. A tool for setting structural and non-structural countermeasures and communicating these measures to the public. The map can be utilized for drawing comprehensive disaster prevention measures, both structural and non-structural aspects (Figure S.17). The map serves as a medium or a reference tool by which stakeholders can cooperatively discuss the most appropriate countermeasures for their localities based on accurate information of potential hazard. Figure S.18 shows the illustration of TIM role as a medium or reference tool for stakeholders to communicate and plan comprehensive tsunami disaster countermeasure.

    (a) Identification of potential tsunami inundation (inland flooding extent, and elevation waves will reach)

    (b) Planning of necessary structural countermeasure (where, what and how)

    (c) Disaster-safe land use planning and management (residential relocation, buffer zone)

    (d) Emergency plan in a tsunami disaster event (e.g., evacuation map)

    (e) Public education on the danger of tsunami

    (f) Coordinating measures related to other potential disaster in the respective area (development of multi-hazard map)

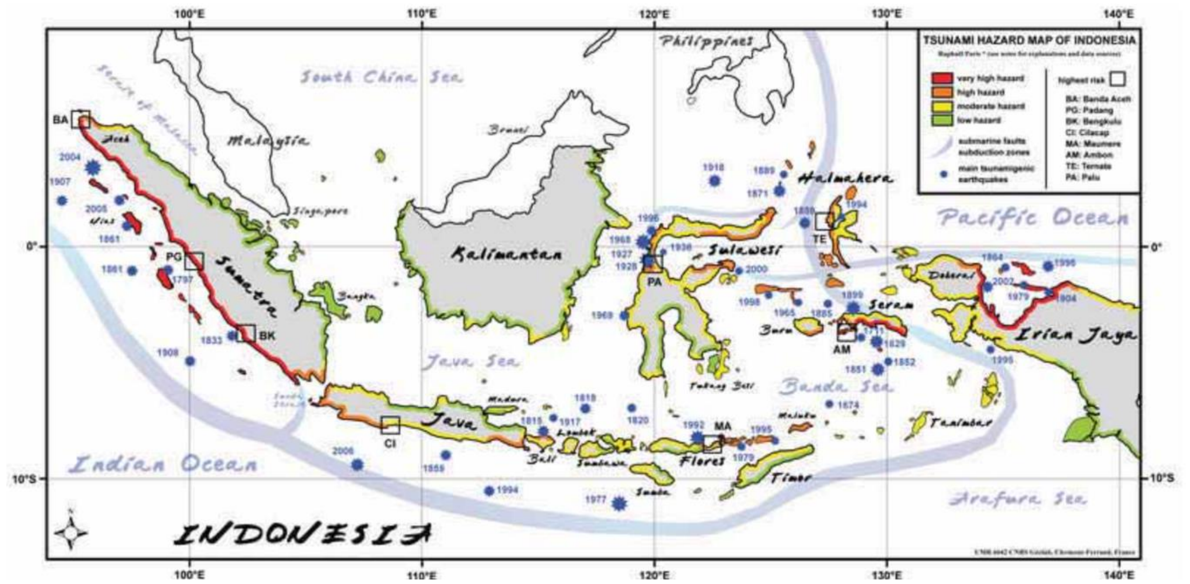


Figure S.17. A national tsunami hazard map for Indonesia.
(Tanaka and Istiyanto, 2010).

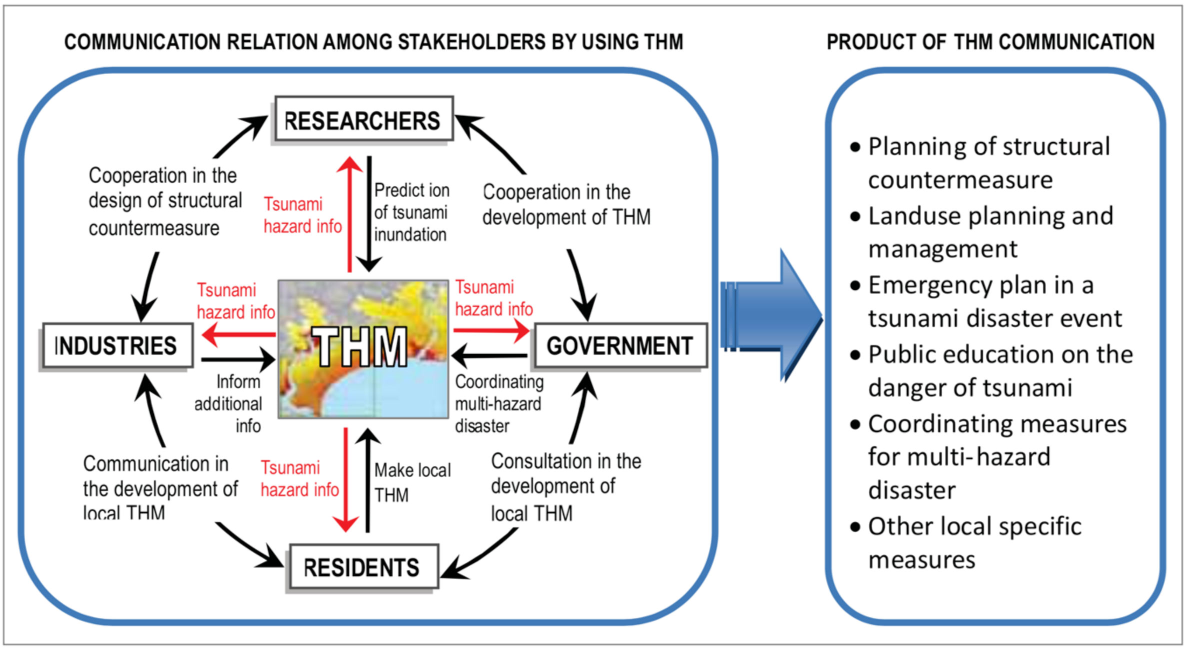


Figure S.18. Illustration of Tsunami Inundation Map (TIM) role as a medium or reference tool for stakeholders to communicate and plan comprehensive tsunami disaster countermeasure. (Tanaka and Istiyanto, 2010).

As Figure S.18 shows, the tsunami inundation map plays a necessary role in all stages of the disaster (before, during, and after the tsunami). For example, before disaster, the inundation map is used to develop the emergency plan (e.g., tsunami evacuation map and response plan) After the tsunami, the inundation map can be used to confirm the recovery and rehabilitation measures with the government or to collect information for future land use planning purposes.

2.4.3 Role in Tsunami Disaster Risk Reduction

Tsunami Inundation Maps play an important role in tsunami disaster risk reduction. The five key activities that should be conducted to reduce risk are:

- Immediately implement mitigation before people forget or lose seriousness that tsunamis are deadly;
- Obtain best science-based knowledge on the danger of tsunami hazard;
- Plan for effective and immediate evacuation as the priority response;
- Protect assets since they are important for life protection; and
- Engage community participation to raise awareness.

Below are brief descriptions of these key activities, including description about the potential role of tsunami inundation maps in achieving the target and a summary is provided in Figure S.19 below.

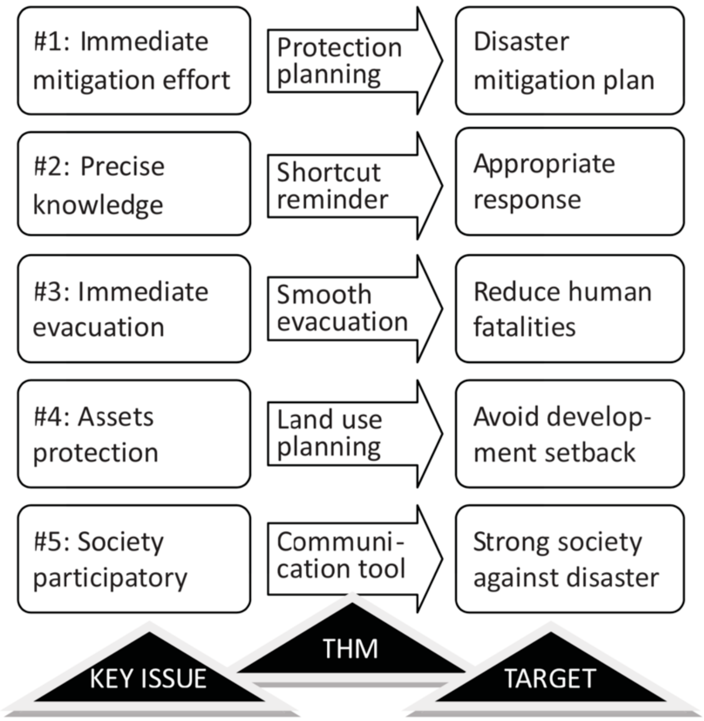


Figure S.19. Role of tsunami inundation maps in tsunami disaster risk reduction. (Tanaka and Istiyanto, 2010).

Issue #1: Maintaining awareness and enhancing preparedness especially for those who have never experienced an earthquake and/or tsunami disasters is challenging. Past experience plays a deciding role on whether people purchase insurance or not. Tsunami mitigation efforts should be done immediately before society (government, community, and individuals) forgets or becomes complacent about preparing for the next disaster. This is the time when it is easier to educate and convince people about the hazards of tsunami and in devising necessary countermeasures. These activities should be done in cooperation with those who had previously experienced a tsunami disaster.

Issue #2: Having the best science-based knowledge and understanding of the tsunami hazard is crucial for enhancing people's awareness on tsunami risks and for implementing tsunami-readiness plans. Proper response will be difficult if a tsunami disaster occurs without a clear understanding of the tsunami danger. Likely, only those who had prior experience of a tsunami disaster can fully comprehend the dangers of tsunami. Communication modes such as, but not limited to, videos, photo documentations, illustrative materials, or any facts about previous disasters should be systematically disseminated to the public to increase awareness and preparedness.

Issue #3: Immediate evacuation action plans is a priority response that will reduce impacts of the tsunami disaster. Where needed, evacuation plans should include the building of structural countermeasures in place. It is important to note that tsunami hazards may be stronger than the capacity that the structural countermeasures had been designed for.

Issue #4: In the event of a disaster, saving lives is foremost although protection of assets is also important. Huge damage to assets, especially critical infrastructure and facilities, will have significant economic impacts, especially for the developing countries and low-income communities. Without working infrastructures, development progress will be severely hampered. Efforts to reduce asset destruction by the tsunami will be different for each locality depending on social and environmental conditions. In addition to engineering measures, land use management is also a good way of reducing infrastructure damage and consequent economic losses due to a disaster.

Issue# 5: Public participation plays an important role in tsunami disaster risk reduction. Both the disaster awareness and the initiative to implement countermeasures should come from all stakeholders. A well-formulated disaster mitigation strategy incorporates the society's contributions and responsibilities in disaster mitigation planning and implementation. Self-help, mutual support, and public assistance are key concepts that should be emphasized in formulating disaster mitigation strategies as these represent different stakeholders' perspectives.

For example, "self-help" is related to the public, whereby each individual protects him/herself or initiates the evacuation without relying for help from anyone else. Meanwhile, "mutual support" is related to friends, neighbours, voluntary disaster management organizations and communities, whereby such groups of people work together to protect their communities among themselves. Finally, "public assistance" is related to administrative bodies or government leaders at the local, regional, and national levels, whereby support and funding for disaster mitigation strategies are decided. For example, projects such as the construction of disaster mitigation structures and the development of disaster mitigation systems are approved for funding and implementation by governing bodies. A conceptual representation of the correlation among self-help, mutual support and public assistance is shown in Figure S.18.

2.4.4 Guiding Principles

The tsunami height at the coast will vary depending on the quay walls, sea walls, coast types, and other topographical conditions. In addition, when a tsunami comes ashore, the tsunami may have already attenuated and so the inundation height (height of water at specific location) becomes lower. The damage at inland areas depend on the inundation height. Therefore, if tsunami mitigation measures are considered, it should take account not only the tsunami height at the coast but also the inundation height once it enters inland.

Guiding Principles

- The responsible agency should provide an estimate of the inundation and height of the maximum possible tsunami in worst case.
- The maximum possible tsunami is set using an earthquake fault model for the tsunami.
- For areas where a fault model, or models, have not been provided, the fault model(s) should be chosen based on research on past tsunamis, or other science-based criteria. (See Guidelines for Establishing Tsunami Inundation Zones for Evacuation Mapping and Planning in Regions without Tsunami Modelling, section 2.3.2.2).
- A fault model, or models, for the maximum possible tsunami inundation is usually investigated at the national level first and then recommended regionally and locally. If there is no national level recommendation, the regional and local jurisdictions may select the model by themselves based on their own criteria and understanding.
- Although tsunami hazards may be similar along coastal areas, each community's vulnerability could differ depending on local variations in population density, economy, land use, social condition, and topography. For example, coastline communities located in low-lying areas are more vulnerable to a tsunami disaster. More populated communities tend to be more greatly affected from a tsunami due to its increased difficulty in evacuating residents. In communities where there are greater numbers of elderly and/or children, evacuation may be more complicated as more support will be required than for ordinary population.
- Thorough awareness-raising to the residents is required through public outreach, distribution of printed materials, signage, and through the internet.

2.4.5 Relating Inundation to Tsunami Impact

2.4.5.1 Expected Tsunami Damage by Inundation Height

A 'Tsunami Warning' has nominally been called when a tsunami height is expected, or has been observed to be more than 1 metre. When a warning is issued, people are recommended to quickly leave the evacuation zone. In Japan, 'Major Tsunami Warming' is issued when the height is greater than 3 m at the coast.

Laboratory studies complementing empirical structural damage and casualty data collected from recent tsunamis show that tsunami inundation or flow depths of less than one meter, and as small as tens of centimetres, can be dangerous and destructive (e.g., Arikawa et al., 2006; Suppasri et al., 2013). The data suggest that a lower level of warning for a marine threat may be desirable.

In the United States, a 'Tsunami Advisory' is issued when more than 0.3 m (1 foot) is expected. When an advisory is issued, people are recommended to move away from beaches and low-lying coastal areas, and boats and ships may move to deep water if there is time. Strong currents and some dangerous waves are expected in coastal areas and waterways, but significant land flooding is not expected and no evacuation of the evacuation zone is needed.

Inundation height can be generally correlated to the amount of destruction on land. People can lose their balance and in the worst case, drown, and automobiles and trucks begin to float in as little as 0.3 m depth of strongly flowing water, house are damaged when flow depths reach 2 m, and buildings damaged when flow depths reach 5 m.

Damage Level	Classification	Description	Condition
1	Minor damage	There is no significant structural or non-structural damage, possibly only minor flooding	Possible to be use immediately after minor floor and wall clean up
2	Moderate damage	Slight damages to non-structural components	Possible to be use after moderate reparation
3	Major damage	Heavy damages to some walls but no damages in columns	Possible to be use after major reparations
4	Complete damage	Heavy damages to several walls and some columns	Possible to be use after a complete reparation and retrofitting
5	Collapsed	Destructive damage to walls (more than half of wall density) and several columns (bend or destroyed)	Loss of functionality (system collapse). Non-repairable or great cost for retrofitting
6	Washed Away	Washed away, only foundation remained, total overturned	Non-repairable, requires total reconstruction

Table S.1. Damage levels, classification description and condition of building (Suppasri et al., 2013)

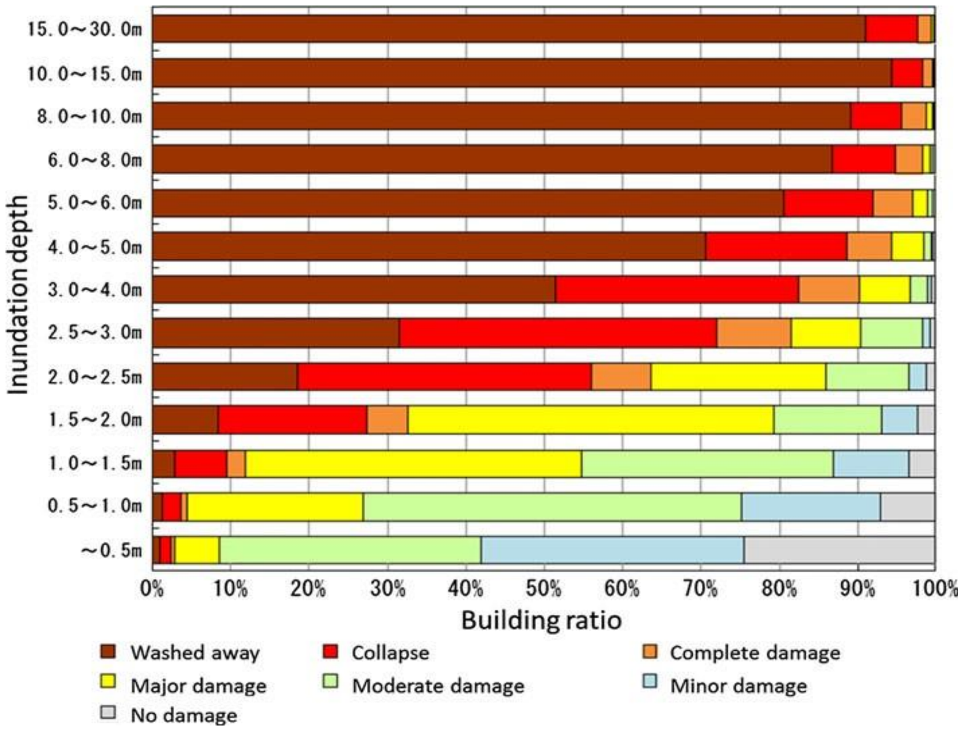


Figure S.20. Distribution of the total 251,301 building data surveyed by the Japan Ministry of Land, Infrastructure and transportation (MLIT) after the 11 March 2011 Tohoku Tsunami (Survey of tsunami damage condition, http://www.mlit.go.jp/toshi/toshi-hukkou-arkaibu.html. Accessed 4 July 2012) (Suppasri et al., 2013). About 55% of the buildings suffered major damage for inundation depths of 1–1.5 m, and more that 70% were washed away when depth exceeded 5 m.

Inundation Height (meters)	Expected Impact
1+	Most of the people caught by the tsunami may perish. People can lose their balance and vehicles begin to float in as little as 30 cm of water.
2+	More than half of structures may be completely damaged
3+	Evacuation will be difficult or not possible. More than half of structures may be completely damaged or washed away.
5+	Second floor and part of the third floor of buildings will be under water.
10+	Third floor and part of fourth floor of buildings will be under water. Many structures may be washed away.

Table S.2. Inundation height in relation to expected impact.

2.4.5.2 Tsunami Arrival Time considerations for Evacuation

There are locations exposed to near-field tsunamis (up to 1 hour tsunami travel time, or a distance to source up to about 300 km) while other locations are vulnerable to distant tsunamis. In the case of near-field sources, the disadvantage of having short warning times is compensated with the possibility to directly feel the earthquake shocks and to directly see the eventual anomalous retreat of the sea. In such cases, the population should be trained properly in their behaviour, e.g., everyone should be self-evacuating when they see, feel, observe and of the natural tsunami warning signs. When the near-field sources are local, earthquake considerations for rescue and escape organization as well as for shelter selection should be taken. For areas affected by distant tsunamis, tsunami warning may precede several hours before the arrival of the striking waves.

The shortest expected arrival time of the first tsunami wave is a key input to the overall calculation and map generation procedures since it defines the response time the evacuation deployment has to achieve. For practical reasons, it is the time interval between a warning was issued and the arrival of the first wave. For obvious reasons, extremely short “Expected Time of Arrival” (ETA) - i.e., below 5 minutes - can be neglected since an orderly evacuation procedure will not be able to work well.

Similarly, Tsunami ETA values above 1 hour must be considered critically and especially trans-oceanic tsunamis that could take hours or up to 1 day in the Pacific. People often ignore how dangerous the situation is and they try to avoid evacuation or they tend to return back before the “All clear” statement is given by the Emergency Management Officials (EMO).

Lack of knowledge or the unavailability of appropriate calculation tools has to be compensated with an assumed default value (normally 15 minutes).

2.4.5.3 Effect of Coastal and Oceanic Landforms on Tsunami Hazard

The extent of inundation and character of the incoming tsunami wave are strongly influenced by the local topography along the coast. Five categories of coastal and oceanic landforms, or land use, are uniquely prone to tsunami impact: islands, rivers, bays, low and flat coastal areas, and harbour/fishing ports/marinas.

Classification	Tsunami hazard	Examples (year of tsunami)
Island	When islands have diameters less than the tsunami wavelength, waves will 'wrap around' the island, e.g., inundation distance and depth can be just as high on the backside as on the frontside of the island.	Male, Maldives (2004); Okushiri, Japan (1993); Niuatoputapu, Tonga (2009); many Pacific Islands.
Rivers and adjacent flood plain	Flood plain area and coast are vulnerable to inundation when rivers overflow blanks. Tsunami may travel far upriver as bores.	2011 Japan tsunami are Minami-Sanriku and Ishinomaki, Japan.
Bay	Bays that have a 'U' or 'V' shape, sometimes called ria, are highly vulnerable due to the focusing of tsunami energy thereby increasing tsunami run-up. Depending on the size and shape, resonance may further amplify and/or prolong the time period that waves are dangerous.	Hilo, Hawaii (1946, 1960, etc); Pago Pago, American Samoa (2009); Talcahuano, Chile (2010); Kesenuma, Japan (2011).
Low and flat coastal area	With flat terrain, the tsunami can inundate far inland. Areas that are unobstructed from ocean may also experience strong tsunami currents.	Banda Aceh, Indonesia (2004) and Sendai and Natori, Japan (2011)
Harbour, Fishing Port, Marina	Ships, boats, and floating vessels will break their moorings and docks break apart. All become projectiles that are carried by the advancing and receding tsunami waves. Wave eddies may form, especially around protruding docks or jetties. Fires may start if fuel lines rupture.	2011 Japan tsunami are Otsuchi, Japan; Long Beach and Crescent City, California.

Table S.3. Effects of tsunami hazard in relation to coastal and oceanic landforms (modified from Tanaka and Istiyanto, 2010).

2.4.5.4 Tsunami Exposure by Land Use

The social uses of lands of coastal communities may be classified into three types: urban, tourism and fishery/agricultural. Each type is exposed to different tsunami hazards due to their activities, behaviour, and facilities. In the aftermath, facilities and services may not be available, and supplies may be in short supply to support the survivors (Table S.4).

Classification	Tsunami Exposure	Examples (year of tsunami)
Urban area	• High population density and associated critical infrastructure (power, fuel, shipping, airport) • Located in flood plain areas with flat terrain (no nearby high ground for evacuation) • Public facilities also in evacuation zone (hospital, police/fire station, television/radio, government office, schools, community centres, etc.)	Galle, Sri Lanka; Banda Aceh, Indonesia; Nagapattinam, India;
Tourism area	• Beaches, Hotels, restaurants and shops, boardwalks, etc. along a coast used by tourists and residents • Cruise ships dock daily or weekly, with daily land influx of tourists	2004 Indian Ocean tsunami: Phi Phi and Phuket Islands, Thailand; Penang Island, Malaysia. 2009 Samoa tsunami: Aleipata, Samoa; many Caribbean and Pacific Islands.
Fishery and/or agricultural area	• Fishing ports and seafood processing plants • Aquaculture within (shallow) inlets, lagoons, 'sheltered' areas behind land banks • Agricultural areas (flat areas with fertile soils)	Anpara, Sri Lanka; Andaman Islands, India; Iwate Prefecture, Japan (2011)

Table S.4. Tsunami exposure by land use
(modified from Tanaka and Istiyanto, 2010).

2.5 SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. These are found in Part B (Specialized Documents).

- Using ComMIT (MOST model) for tsunami inundation modelling for evacuation mapping: Summary, Manual, Appendices (abridged requirements, in Spanish), tool ComMIT was used in the TEMPP1 Pilot training course for inundation modelling to support evacuation map-making. General information on ComMIT can be found at USA NOAA, *https://nctr.pmel.noaa.gov/ComMIT/* (Specialized document no I).

- Tsunami Coastal Assessment Tool (TsuCAT) for scenario identification, v4, USA NOAA, ITIC, 2019, Summary, Manual, tool. Also pertinent to Modules 3 and 4. TsuCAT can be used to identify worst-case scenarios, and to develop scenarios for tsunami exercises using the PTWC Enhanced Products as message triggers for national and local tsunami warning decision-making. *http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2239&Itemid=2763* (Specialized document no II).

MODULE 2 – DEVELOPING TSUNAMI EVACUATION MAPS

1 INTRODUCTION

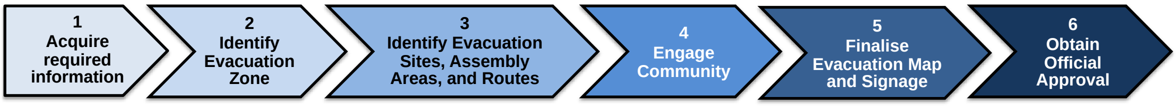


Figure S.21. Steps for Module 2 – Evacuation Mapping

The tsunami hazard is complex in nature as it can happen at any time and depending on the location, there may be very limited time for people to evacuate. The priority is to have a safe and quick evacuation.

Tsunami countermeasures for saving lives can be divided into structural or non-structural mitigation. Structural measures include breakwaters, seawalls, and coastal embankments, which can minimize a tsunami intensity, reduce its inundation height, and/or slow its speed of arrival. Tsunami vertical evacuation shelters, which provide a safe location for evacuated individuals, as well as evacuation stairs/railings, which allow for faster evacuation of residents, also fall into the structural category. Non-structural measures include the development of tsunami early warning systems, tsunami evacuation planning (this guide), land-use planning, education and awareness.

For a distant source tsunami, there is sufficient time for evacuation. However, for a locally-generated tsunami (earthquake shaking will normally be felt), time is of the essence and the public will need to evacuate without waiting for official tsunami information or warning. For especially this case, it is essential for every coastal community to have tsunami evacuation maps and plans so that people will know the safest and quickest way to move out of the evacuation or tsunami hazard zone (or area) to the evacuation site or assembly area.

The flowchart below (Figure S.22) is an example from Japan showing the important requirements and steps for developing a Tsunami Evacuation Map and Evacuation Plan.

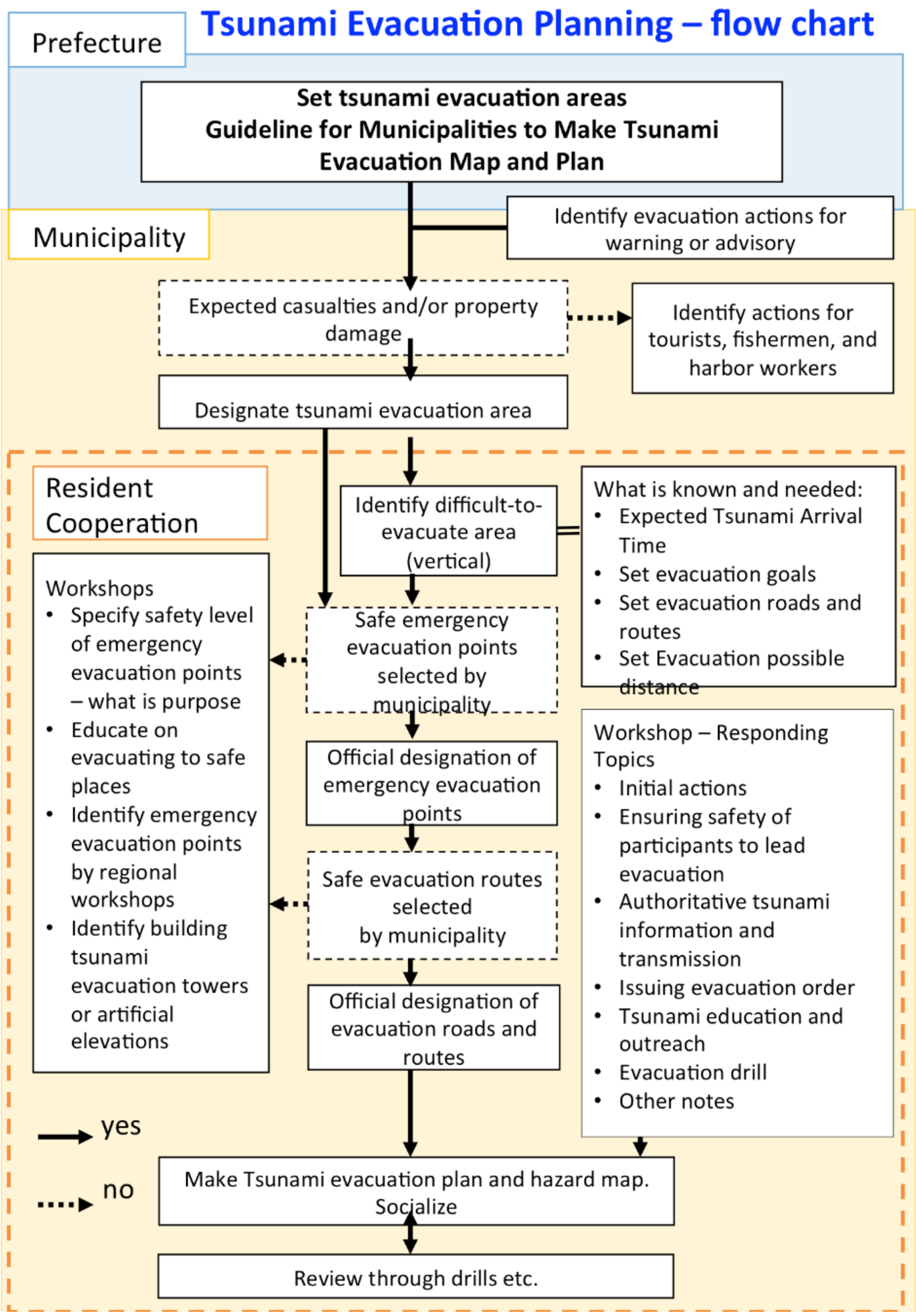


Figure S.22 Tsunami Evacuation Planning Flow Chart
(Source: Fire and Disaster Management Agency, Japan, 2013).

2 MODULE CONTENT

2.1 ACQUIRE REQUIRED INFORMATION

Evacuation planning involves the developing of evacuation maps, procedures that tell how citizens will know that a dangerous tsunami is approaching and how and where they will go to evacuate away from the danger, and associated awareness materials.

Preparing evacuation maps begins with inundation modelling to generate the inundation map (Module 1). The modelling should consider all possible worst-case, or maximum credible tsunami scenarios. These results are then aggregated, and the composite shows the maximum extension of the expected inundation.

Evacuation (or tsunami hazard) zones are then drawn using the inundation map, considering the amount of time available to evacuate (e.g., tsunami travel time from the source to the community) and the different community data, such as population demographics, roads and streets, emergency facilities or critical infrastructure / schools / police / fire / hospitals, land use, building types, and other factors that might affect and orderly and efficient evacuation.

Graphical Information System (GIS) tools are an effective tool to assist in developing evacuation maps as they enable a number of different layers to be overlayed. GIS software, such are ArcGIS (commercial) or QGIS (open source), can be used to create preliminary maps, and then to finalize the map for approval and printing.

2.2 IDENTIFY EVACUATION ZONE (HAZARD ZONE) BASED ON INUNDATION MAP

2.2.1 **Designation of Areas**

Evacuation zones are designated based on the expected maximum tsunami inundation areas, geographical features, and the area of responsibility of emergency management organizations. Tsunami evacuation zones are those areas where damage will occur from a tsunami and therefore, where residents should evacuate from. They are the target areas for evacuation orders or advisories. For this reason, it is important that residents are involved in, and agree on, the tsunami evacuation zones to be designated.

Tsunami evacuation zones are based on records of historical tsunamis and the results of tsunami inundation modelling. However, the expected inundation area may not be entirely correct, thus a safety margin must be allowed for to compensate for possible under-estimation. In Hawaii, the City and County of Honolulu uses a ~250 foot wide buffer zone in drawing its evacuation lines.

During the evacuation, community cooperation is needed to help people requiring assistance. For this reason, the tsunami evacuation areas are also based on the coverage of applicable community or volunteer organizations.

2.2.2 **Evacuation Obstacles**

List the possible problems for the evacuation. This could include issues such as insufficient number of evacuation signs, too great distance to evacuation points, insufficient support for the handicapped and elderly, or in case of a blackout, difficulties in evacuating at night.

2.2.3 **Determine Evacuation Time**

It is normally assumed that residents can start evacuation within 2–5 minutes after an earthquake or after a warning is issued. However, this may differ depending on the local situation. In night or winter, it takes more time to prepare for evacuation than usual, and people's walking speed can be slower. It is important to examine and verify an evacuee's walking speed, evacuation distance, and evacuation start time through evacuation drills.

In setting the evacuation distance, the expected tsunami wave arrival time and evacuee's walking speed are considered.

- <u>Evacuee's walking speed</u>

The standard for the evacuee's walking speed is 1.0 m/s (same as walking speed of normal elderly people in a crowd, and people not familiar with the area). However, it is important to also consider the walking speed of handicapped, small children, and other vulnerable residents, which is slower (0.5 m/s). Research showed that evacuees' average walking speed was 0.65 m/s for the Great East Japan Earthquake, while walking speed decreased at night by up to 80% compared to daytime.

Reference walking speed:

Elderly: 1.1 m/s	People pushing baby buggy: 0.9 m/s
Handicapped or seriously sick people	Flat areas: 0.8 m/s
Stairs: 0.4 m/s	

Walking speed for people not familiar with areas or routes:

Flat areas: 1.0 m/s	Stairs: 0.5 m/s

Handicapped people in a hurry:

Handicap level C1: 1.2 m/s	Handicap level C2: 0.44 m/s

Average walking speed during the Hokkaido Nansei Earthquake tsunami (1993) in Japan:

Age	20–29	30–39	40–49	50–59	60 and older
Average Speed	0.87 m/s	1.47 m/s	1.03 m/s	0.68 m/s	0.58 m/s

Average walking speed and evacuation start time during the Great East Earthquake (2011):

All areas: 0.62 m/s	Flat areas: 0.78 m/s

- <u>Evacuation distance</u>

The standard for the maximum evacuation distance is 500 m. However, it might be greater than 500 m, and should be set taking into account the local situation or community conditions, such as the number of people requiring evacuation assistance, nearest sufficient high ground or structures, and/or the evacuation routes.

Evacuation distance can be calculated as:

(Evacuation distance) = (walking speed) x ((expected tsunami arrival time) – (evacuation start time))

For example, if we assume that the expected tsunami arrival time is 10 minutes, walking speed is 1.0 m/s, and evacuation start time is 2 or 5 minutes, then the evacuation distance is calculated as follows:

60 m/s x (10-2) minutes = 480 m	60 m/s x (10-5) minutes = 300 m

- Evacuation Start Time

The average evacuation start time of people who anticipated a tsunami was 18 minutes. On the other hand, the average start time of people who did not think about a tsunami and instead responded to sirens or others evacuating, was 26 minutes - a difference of 8 minutes. Thus, it is very important to emphasize the natural warning signs so that people start evacuation early.

2.2.4 Difficult-to-Evacuate Areas

Areas that are in the evacuation zones, but which will not allow timely and/or safe evacuation, are designated as difficult-to-evacuate areas. For people in difficult-to-evacuate areas, tsunami vertical evacuation structures or buildings will need to be identified.

The method discussed above used evacuation distance to identify difficult to evacuate areas. For a more precise identification, it is necessary to take into account the local population since that may indicate different evacuation times, as well as the capacity of evacuation points. In areas where many people gather, such as commercial areas, it is desirable to formulate appropriate evacuation measures based on the precise estimate of the spatial distribution of the population during daytime and at night.

2.3 IDENTIFY EVACUATION ASSEMBLY SITES (AREAS) AND ROUTES

2.3.1 Evacuation Assembly Sites or Areas

Local government leaders (e.g. mayors) and residents should not only select, but also maintain tsunami evacuation assembly sites or areas. They should select places that ensure orderly evacuation and work with residents to ensure and improve the functionality of the evacuation assembly sites.

For safety, the maximum possible tsunami should generally be considered. At the minimum, evacuation assembly sites must be safe from relatively frequent tsunami occurrence, while still providing for continued evacuation (further inland) to a safer place in the case of a maximum possible tsunami. As such, it is important to clearly mark the level of safety of each emergency point ('normal', or 'extreme' evacuation). Installation of sea-level height signs, e.g. distance from the coast and expected inundation depth (for flow depth) at that point.

Tsunami evacuation assembly sites should be selected after taking into account the evacuation distance and capacity of tsunami evacuation routes, and the accessibility of the evacuation assembly sites. It is expected that such sites should function as only short-term shelters. Minimum standards in water supply, sanitation, food security, and non-food items can be found in the widely known, internationally recognized Sphere Handbook (2018) for the delivery of quality humanitarian response.

In terms of functionality, it is necessary to ensure that there is enough space for evacuees and that communication means are available in order to keep evacuees informed of the situation. If possible, evacuees should take with them a radio, essential medication, and appropriate clothing.

Assembly Site Characteristics

- Outside evacuation areas.
- Generally, open spaces or buildings that are earthquake resistant.

- Appropriately marked.
- Not be at risk from landslides or other dangers.
- Sufficient space for each evacuee (at least, 1 sq. m per evacuee).
- Equipped with lights and communication equipment.
- Additional evacuation is possible if a tsunami is larger than expected.
- Can be accessed via more than one route.

2.3.2 Vertical Evacuation Buildings

For people in difficult-to-evacuate areas, tsunami vertical evacuation structures or buildings will need to be identified. These buildings or structures must be tsunami-resistant, and the structural components of the building or structure must have been designed for vertical evacuation. Such structures have the following general attributes:

- Strong systems with reserve capacity to resist extreme forces,
- Open systems to allow water to flow through the ground floor to resist forces without failure,
- Redundancy to allow partial failure without progressive collapse,
- Circular columns designed to reduce and withstand lateral wave loads,
- The orientation of shear walls planned to minimize load,
- Floor systems designed to reduce buoyant force.

In more detail, the relevant forces that must be considered in existing or new structures are (Yeh, et al., 2005):

- Hydrostatic Forces. This occurs when standing or slowly moving water encounters a building or its component acting as a lateral load perpendicular to the surface.
- Buoyant Forces, also be referred to as vertical hydrostatic force. A partial or total submergence will create a vertical force forcing the surface in contact to float. This is a concern for basements, empty above/below ground tanks, and swimming pools. This force is resisted by having the weight of the object be heavier than the force causing it to float.
- Hydrodynamic Forces, usually called drag forces. These are generated when water flows around an object and is a combination of lateral loads created by impact of moving mass of water and friction forces as the water flows around the object.
- Surge Forces. These forces are generated by the leading edge of a surge of water impinging on a structure.
- Impact Forces. These forces are generated by floating debris striking against buildings or its components.

- Breaking Wave Forces. These forces are generated when the wave breaks against the elements of a building.

In addition, the selected buildings must have a height sufficiently above the maximum water height. Usually this additional height is set to 5 m. An empirical formula for estimating the height above which vertical evacuation is considered safe is the following:

Safe height = (Max Wave height x 1.30) +1 m.

A vertical shelter does not necessarily have to be a closed building. The use of multi-stories reinforced concrete or structural steel buildings or of artificial mounds as vertical shelters is an appropriate policy for all near-source tsunamis or for remote-source tsunamis in densely populated areas where horizontal evacuation is not possible.

Some common requirements apply to vertical evacuation shelters, which are that they should be easily accessible, and that access routes (e.g., stairs, ramps) to the high floors should have appropriate capacity (e.g., wide enough, steps/slope not too steep). Ideally, vertical shelter sites should also have access to lifelines if they are used for long-term stays.

2.3.3 Vertical Evacuation Building Codes

In 2016, the Tsunami Loads and Effects Subcommittee of the US American Society of Civil Engineers (ASCE)/Structural Engineering Institute (ASCE/SEI) 7 Standards Committee incorporated a new Chapter 6 entitled “Tsunami Loads and Effects,” in the 2016 edition of the ASCE 7 Standard, *Minimum Design Loads and Associated Criteria for Buildings and Other Structures* (7-16) (American Society of Civil Engineers, 2017) The ASCE 7-16 chapter on “Tsunami Loads and Effects” is the first US national, consensus-based standard for tsunami resilience, and is applicable to the states of Alaska, Washington, Oregon, California and Hawaii. This new tsunami design standard was then adopted by reference in the 2018 International Building Code. Taller structures in a community can provide effective refuge when evacuation out of the evacuation zone is not possible in time, nor practically achievable for the entire population.

The ASCE 7 provisions for tsunami loads and effects implements a unified set of analysis and design methodologies with design maps based on probabilistic hazard analysis, loads based on tsunami physics, and a structural ultimate strength basis of design. Probabilistic offshore tsunami amplitude maps and tsunami design zone inundation maps were developed using a method consistent with probabilistic seismic hazard analysis in the treatment of seismic source uncertainties. Procedures for tsunami inundation analysis are based on using mapped values of offshore tsunami amplitude or the runup and inundation limit shown in tsunami design zone maps. The ASCE 7 “Tsunami Loads and Effects” chapter is consistent with the principles of probabilistic hazard analysis, tsunami physics, and fluid mechanics, integrated into a comprehensive set of design provisions. Additional information can be found in the article *Design for Tsunami Loads and Effects in the ASCE 7-16 Standard* (Chock, 2016).

In 2019, the Federal Emergency Management Agency (FEMA) published the third edition of Guidelines for Design of Structures for Vertical Evacuation from Tsunamis (FEMA P-646) (FEMA, 2019). The guideline provides additional background, guidance and commentary on the technical design provisions now contained in ASCE/SEI 7-16, and incorporates community resource planning related to vertical evacuation (previously contained in Vertical Evacuation from Tsunamis: A Guide for Community Officials (FEMA P646A/June 2009)).

2.3.4 Tsunami Evacuation Routes

Local government, in consultation with the community, should plan the evacuation routes, and alternate routes bearing in mind a worst-case scenario, such as when a local earthquake might generate landslides at the base of steep slopes, or rainfall might create flood conditions along local streams, storm sewers or flood canals. Tsunamis follow streams and flood canals and may therefore propagate much farther inland than noted on some current evacuation maps.

Evacuation Route Considerations

In selecting evacuation routes, the following should be considered:

- Routes must be the fastest and safest routes to evacuation points.
- Evacuation routes and roads should be as wide as possible. They must be wide enough, especially in heavily populated areas.
- There should be alternate routes and roads in case the primary routes and roads are blocked (e.g. by debris such as collapsed houses, eroded logs, landslides, etc.). Evacuation routes should be free from the risk of having landslides, building collapses, and falling objects.
- Do not select routes along the coast or a river, because the tsunami may arrive sooner than expected and/or travel up-river as a fast-moving, turbulent tsunami bore.
- If evacuation routes include bridges, the bridges should be earthquake-resistant.
- Evacuate in the same direction that the tsunami moves. Even if there is a high place in the direction of the coast, do not evacuate towards the coast.
- It is desirable to have designated tsunami evacuation buildings in case evacuees have insufficient time to evacuate.
- Evacuation route signs must be installed. Consider also installation of loudspeakers giving public information.
- For night time evacuation, streetlights are necessary.
- It is desirable to have balustrades where there are steep slopes and stairs.
- Do not select evacuation routes and roads that will be difficult to pass in bad weather.

2.4 ENGAGE COMMUNITY TO SOLICIT FEEDBACK

2.4.1 Community Engagement in Developing Tsunami Evacuation Map

The development of tsunami evacuation maps by the national and local governments and/or authorized organizations should include active involvement and collaboration with the community. During an actual event, it will be up to each individual to decide whether to evacuate or not, and especially if there has been no official warning. By including the community in the making of the evacuation map, each person will become very aware of their tsunami hazards and will know where to go to be safe.

Ultimately, communities should be both self-supporting and mutually supportive. Mutual-support among neighbouring communities has been shown to be effective at the local level in reducing disasters. An example was 2 April 2007 Solomon Islands earthquake and tsunami where most persons evacuated the area (thus saving their lives) before the official tsunami warning was issued. Someone from a neighbouring community alerted residents that a tsunami would likely strike.

It is a best practice to involve communities from very beginning of the development. Figure S.23 schematically illustrates the two paths for evacuation map development. The red-arrow path is without active involvement by communities, and the blue arrow shows the involvement of community from the initial stage.

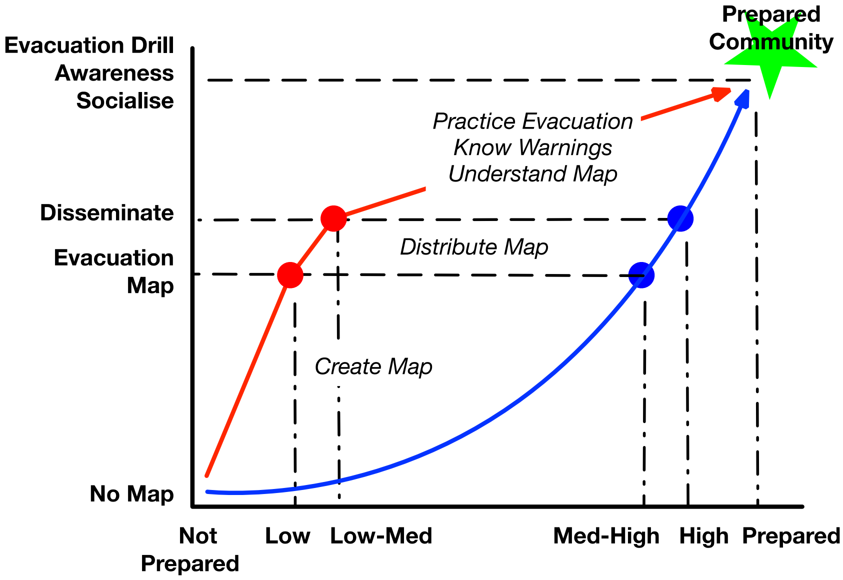


Figure S.23. Diagram illustrating two different paths for map development. The red arrow does not involve the community while the blue arrow has community involvement (after Tanaka and Istiyanto, 2010).

By following the red-arrow path, the government or municipality can develop the map quickly and efficiently, but community understanding and awareness will be low, and the socialization process will likely require more time. Additionally, a lower overall preparedness may result since people will only passively receive the end-product (one-way direction from the government to the citizens). In contrast, if the community is involved from the beginning and in all aspects of the map creation, then socialization, awareness building and preparedness are a single inclusive process. In this case, the community is empowered, is active throughout, and is engaged in the building of their community's preparedness. The community-based path should involve not only the residents, but also all community stakeholder, including the private sector and non-government organizations.

2.4.2 Community Presentation

Acceptance issues and community responsiveness should be gathered over time and analysed by responsible authorities.

A presentation to the community on the development of a tsunami evacuation map is essential. The following key stakeholders need to be involved:

1. Community Leader. Often, this person (a tsunami 'champion') is the most useful person when distributing information and establishing education programs to explain the

issues/problem, suggest solutions and coordinate actions to take before, during, and after a tsunami.

2. Emergency Volunteers. They are typically from the local community who participate with passion and desire to keep the community safe. They are the link between the community and the government.

3. Emergency Managers. They are public servants in the area who are entrusted to serve the community. They need to clearly understand the dynamics of managing a tsunami evacuation.

4. Mayor or Elected Representative. He/she is the major political figure in the local area. This person has decision-making power and is responsible for establishing official public policy in their area. This person would likely be the person who officially approves the evacuation map.

After identifying the key stakeholders, a public meeting should be held to share and convey the importance of the work that is being carried out. Co-involvement and active participation of the community is critical in the process of developing the tsunami evacuation map, as they are a valuable source of information to help identify shortcomings and improvements. With their understanding and acceptance, the presentation to the community will be more effective.

The community presentation should be clear and limited in agenda covering:

- Tsunami Inundation Flood Area Map. This map should inform the community of the tsunami inundation modelling that was done. If there was no modelling conducted, a clear explanation should be provided on how the expected flooded area was obtained.

- Tsunami Evacuation Zone Map. The development of the tsunami evacuation zone map must be presented and communities' input obtained. This zone may be modified based on the communities' input.

- Tsunami Evacuation Routes. The proposed evacuation routes must be presented once the tsunami evacuation zone has been finalized and accepted by the community.

- Tsunami Evacuation Assembly Sites or Areas, and Vertical Shelters. These are the places where people evacuate to and where they will receive on-going official information from the local authority.

- Tsunami Warning and Evacuation procedures. The community should be informed on how they will receive tsunami warnings and how they will know to evacuate, and when they will know it is safe to return.

2.4.3 Town Watching

'Town Watching' is an effective way to develop an evacuation map and plan. In 'Town Watching', those involved in developing an evacuation map walk around the inundation area to understand the area features. In 'Town Watching', evacuation routes, dangerous sites and other factors have to be considered since evacuees have to move fast to save their lives from the tsunami. Observations from 'Town Watching' are used in finalizing the evacuation map and plan.

Participants should be organized into groups. Each group selects evacuation points and routes, and walks the routes giving attention to the following:

- Places that could cause traffic congestion or accidents, especially involving motorcycles and bicycles;
- Routes that are narrow and could cause people to have to stop; and
- Where to place evacuation signage is not clearly visible or where evacuation signage is needed.

Town-Watching Tsunami Evacuation Checklist			
District		Date	
Name of person		Evacuation Point	

Evacuation route	**Situation**
Traffic? (e.g, heavy traffic in the morning, what type of traffic, motor cycles, cars, buses)	
Width/Type of roads? (e.g., narrow, wide, asphalted)	
Stairs? (e.g., yes, no, required)	
Street lights? (e.g., sufficient, insufficient, blackout possible)	
Evacuation signs? (e.g., few, absent, sufficient, obscured, more necessary)	
Time required to evacuate? (e.g., 30 – 40 minutes for elderly)	
Other (e.g., concrete block walls that could fall and block routes, power lines that could fall - so dangerous to evacuate)	

Evacuation points	**Situation**
High ground or a structure/building? (e.g., high ground)	
Is the elevation high enough compared to the expected tsunami height? (e.g., OK, elevation 38 m)	
Easily accessible? (e.g., yes)	

Other (e.g., this point is on the top of mountain, so measures for cold temperatures are necessary; is there a roof in case of rain)	

Evacuation Route Obstacles **(Yes, No, Details, such as few, many, etc.)**	**Situation**
Block concrete walls (Risk of collapse)	
Utility poles (Risk of falling over)	
Power lines (Risk of falling)	
Old trees (Risk of falling over)	
Vending machines (Risk of overturning?)	
Signboards (Risk of falling)	
Area with high density of wooden buildings (Risk of fire)	
Area with inflammables (gas station, boiler) (Risk of fire and explosions)	
Railway crossing (Risk of being impassable)	
Bridge (Risk of collapse and unpassable)	
Multi-level crossing (Risk of collapse and unpassable)	
Other (areas prone to liquefaction, landslides)	

Table S.5. Town-Watching: Tsunami Evacuation Checklist

2.5 FINALISE EVACUATION MAP AND SIGNAGE

Enabling a smooth evacuation is the most important tsunami hazard countermeasure. This can be accomplished by having an evacuation map that clearly shows the hazard or evacuation zone, evacuation routes, and evacuation assembly sites or areas. Evacuation maps should provide the shortest path to safe places (higher ground) from any point of the land area that will be inundated by a tsunami.

Preparing evacuation maps begins with generating the aggregated scenario, which synthesizes the effect of all possible worst-case credible tsunami scenarios, and results in the maximum extension of the inundated area. Information on evacuation routes, evacuation assembly sites (including vertical evacuation structures), safe areas, and warning details have to be included in the evacuation maps. A tsunami evacuation map needs to show the tsunami evacuation zone, which is where dangerous tsunami flooding is expected. The map should include information that will enable residents to find the evacuation assembly site by themselves (e.g. include well-known landmarks, buildings, and/or sea level or building heights).

2.5.1 Tsunami Hazard Evacuation Map Guidelines

The U.S. National Tsunami Hazard Mitigation Program (NTHMP) provides the following guidelines for tsunami evacuation mapping (NTHMP, 2011).

All evacuation maps should include a title, scale, geographic location (coordinates), intended use, and appropriate explanatory information.

- Evacuation maps should reference technical documentation on how the map was made and its intended use.
- Evacuation maps should delineate zones that should be evacuated in the event of a tsunami.
- When a detailed tsunami inundation assessment (i.e., inundation map) is available, the evacuation zone should encompass all areas the assessment indicates will be inundated. To create an evacuation zone for operational purposes, the evacuation zone should include a safety buffer that extends the evacuation zone beyond the modelled inundation zone (e.g., to the next street or intersection).
- If this is not the case as determined by collaboration between modellers and emergency managers, then a detailed explanation shall be provided.
- Evacuation maps should include streets, bridges, escape direction arrows, assembly areas, and well-known landmarks to help people identify the venues of egress and safe locations.
- Evacuation zones should be legible for all users, including people with colour vision disabilities.
- When possible, evacuation maps should identify all appropriate modes of evacuation (e.g., via foot, vehicle, vertical, and marine evacuation).
- When possible, maps should identify features that may impede evacuation during or after an event such as terrain obstacles, areas of unstable land, or other earthquake-related ground or structure failures. These areas should be identified by professional geologists with the purpose to inform the public of unstable areas.
- Evacuation zone boundaries should, wherever possible, conform to logical administrative boundaries (e.g., roads, property lines, etc.).
- Communities should consider developing evacuation maps that delineate both distant and local tsunami evacuation zones.
- Communities should consult with the producers of inundation maps when developing evacuation plans so that the intended accuracy and limitations of the tsunami inundation maps are considered.
- In addition to printed form, evacuation maps should be made available digitally, considering the scale limitations and appropriate base maps, to facilitate outreach."
- Where the coastline is not mapped, or has low-hazard, refer to the Mapping and Modelling Subcommittee’s Tsunami Inundation Determination for Non-Modelled

Regions. Note: This US guidance was reviewed and international guidance developed as part of this publication (see Module 1).

2.5.2 Symbols and Icons

In generating the evacuation map, it is highly recommended to use standard evacuation or tsunami evacuation map symbols and icons. The United Nations Office for the Coordination of Humanitarian Affairs (UNOCHA) has created freely downloadable symbols that include natural disasters such as tsunamis and earthquakes. Download link for True type fonts, ESRI stylesheets, and QGIS XML file at https://mapaction.org/resources/ocha-humanitarian-icons/. Further information is available at https://reliefweb.int/report/world/world-humanitarian-and-country-icons-2012.

The manual *How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS, Manual and Tutorial,* was newly created through the TEMPP pilot training course (Document no III of the Specialized Documents). The practical Manual describes the export of ComMIT results into the open-source QGIS software to digitally create tsunami evacuation maps using standard formats, colour palettes, and symbology.

2.5.3 Thematic Layers

The following thematic layers are basic spatial input that will be needed for tsunami evacuation planning and evacuation map creation:

- Digital elevation model (DEM): This is one of the input data to compute the expected inundation areas and thus for assessing the potential safe locations.

- Population distribution map: This map shows how the population is usually distributed within an inhabited area. For practical reasons, a maximum of persons (including temporarily residing as people at work or tourists) is taken as basis. The population distribution map will indicate the magnitude of evacuees potentially to be expected. For this purpose, potentially affected town areas are sub-divided into districts, quadrants or segments. On the population distribution map, every such subdivision will be presented as a class of population size indicated by a specific colour.

- Road and major paths map**:** This map will show selected roads, paths or routes that can realistically serve as escape-routes. Additionally, these roads could be classified according to their capacity and color-coded for comprehensive presentation of their content. For practical reasons only roads or paths having a minimum size should be considered in this map.

- Classified buildings map: This map shows the classification of all buildings (within the probably to be evacuated areas) according to the vulnerability classification scheme.

- Map of special places: This map shows all those places and buildings that may be subject of special care procedures. In particular, schools and hospitals, very frequented places (e.g. markets), highly vulnerable places (e.g. harbours, beaches, estuaries) but also buildings of concern for the emergency response, police, fire, or other first responders.

- Hazardous and dangerous areas: All industrial facilities or installations that are located within the area of concern may be marked separately in a map. It should be separately assessed whether there could be an impact on such installations, whether this could lead to a hazardous situation, and consequently evacuation shelters and escape routes could be affected.

- Map showing evacuation-hindering particularities**:** There are particularities that can be decisive for efficient evacuation and that for these reasons should be marked separately in a map such as:

    - Barriers, (wired) fences that may inhibit inland evacuation,

    - Stairs and other bottlenecks at the edge between beaches and the hinterland,

    - Crowded roads and places (people, cars, shops, etc.) in the immediate neighbourhood of beaches, and

    - Airports, Prisons, or other ‘locked’ gates or fences that prevent egress.

2.5.4 **Example Tsunami Evacuation Maps**

It is recommended that the final evacuation map indicates the evacuation routes, the direction evacuees should take, tsunami vertical evacuation buildings, tsunami evacuation sites and/or areas, meeting points, tsunami shelters for long-term use, essential facilities, and if desirable the extent of inundation based on the tsunami modelling conducted. Examples of maps indicating tsunami shelters and evacuation facilities/areas and evacuation routes for Cedeño, Honduras, Samara, Costa Rica, and Sendai, Japan, are shown in Figures S.24, S.25, S.26.

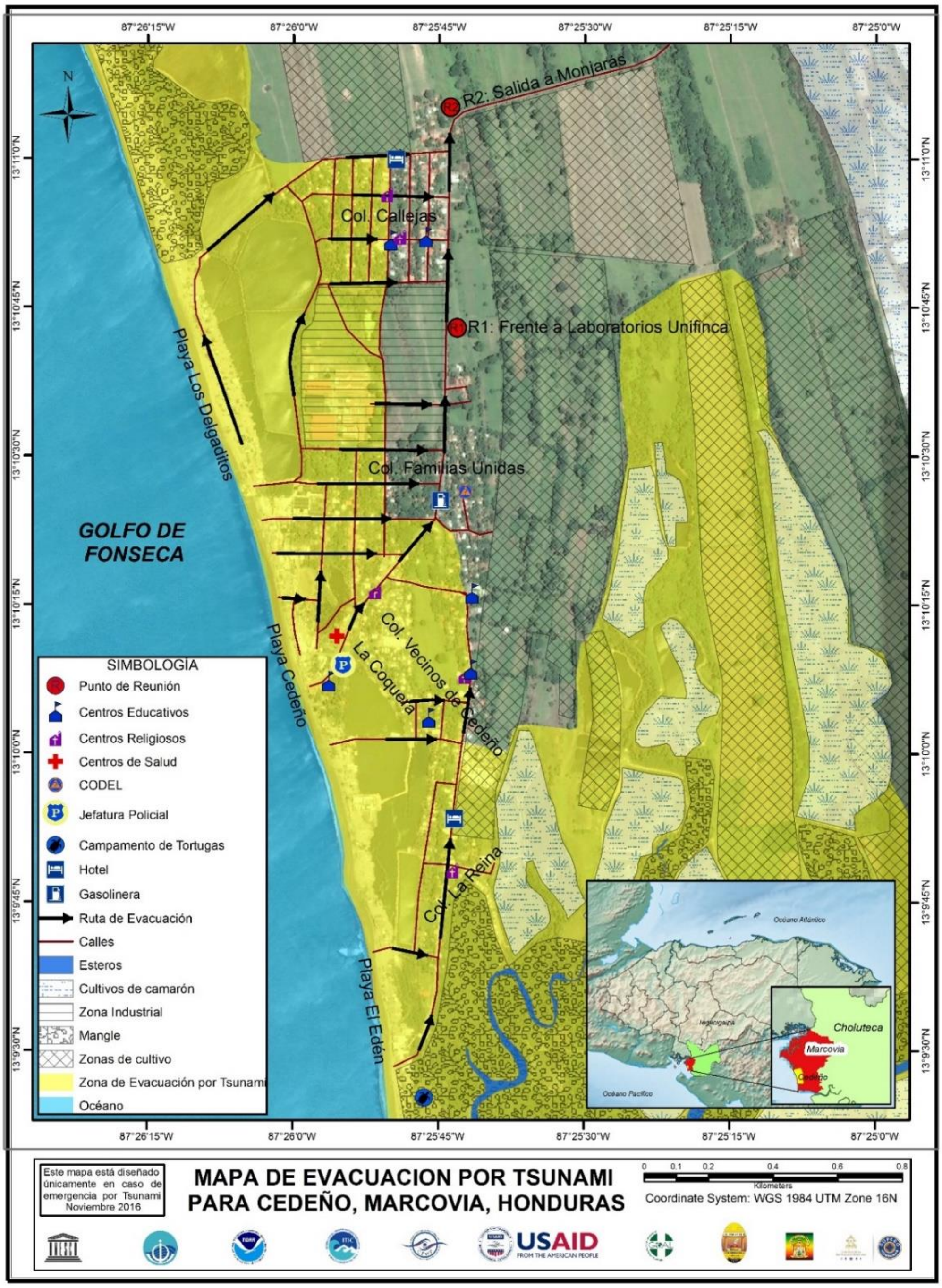
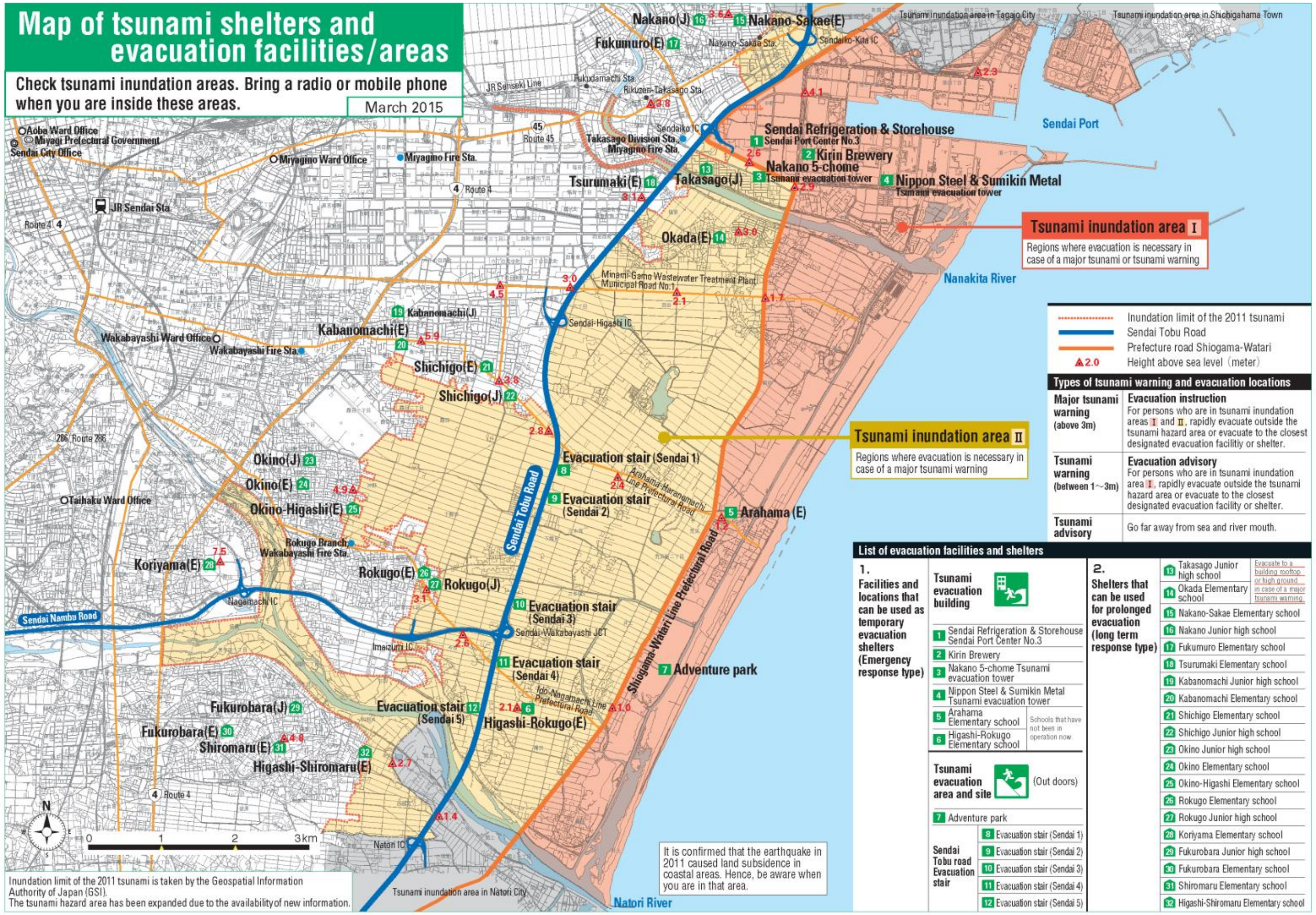


Figure S.24. Evacuation map developed for Cedeño, Marcovia, Honduras.

Figure S.25. Evacuation map (top) and tsunami awareness and evacuation information (bottom) developed for Samara, Costa Rica (S. Chacon, 2019). The map shows 2-levels of evacuation corresponding to evacuation for a near-field or local tsunami (orange) and far field or distant tsunami (yellow). Information is provided in both Spanish and English, and distribution as a tri-fold brochure with the map on the front and information on the back.



<u>Figure S.26</u>. Map showing the tsunami shelters and evacuation facilities/areas developed for Sendai, Japan.

2.5.5 Signage

Detailed evacuation guide signs indicating tsunami evacuation zones, sea level, tsunami arrival time, direction of evacuation and evacuation assembly sites or areas must be installed so that local people, as well as people not familiar with the area (such as tourists), know what to do and where to go.

An example of tsunami signage guidelines for New Zealand (MCDEM, 2008a) are as follows:

1. 'Evacuation Zone' signs are to be placed within the evacuation zones, especially at the coast. This is to clearly indicate that the place is within the evacuation zone.

2. 'Information Boards' houses evacuation maps and supporting information. Informational and alert messages used during an event should be clearly laid out such that it will be visualized quickly.

3. 'Evacuation Route' signs delineates the route from within the zone to beyond the boundary of the evacuation zone. These signs are to be placed only when the evacuation routes have been approved.

4. 'Safe Location' signs are placed only at the designated safe areas. If driving is possible along the evacuation route, these signs should be placed at a substantial distance within the safe areas to avoid drivers to stop at the sign and block those behind.

5. 'Previous Event' signs are used to mark the maximum events that occurred in the area.

Additional information on signs and symbols can be found on the ITIC web site at http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=1406&Itemid=1406.

Signage background and Placement

There are many different types of signs and no consistent standards. Most of the existing signs used by countries are similar in design and colour to the signage used in the USA. Signs were originally developed by the State of Oregon, USA, in 1994, and then adopted by the States of California, Washington, Alaska and Hawaii in 1997 under the US National Tsunami Hazard Mitigation Program (Oregon Geology, 1997). Tsunami sign placement guidelines were published by Oregon in 2003 (Darienzo, 2003), and further standards (such as size, material, colour, font type and size, and placement) published by the State of California, USA, (California Office of Emergency Services in 2007.

The California Department of Transportation uses the US Federal Highway Administration's policy as described in the *Manual on Uniform Traffic Control Devices* (Section 2N.03) for evacuation route signs, along state highway transportation corridors. An example of tsunami sign placement guidance for the City of Pacifica, San Mateo County, California, USA, (Miller et al., 2013) can be downloaded from the ITIC TEMPP website.

Oregon Emergency Management (OEM) and Department of Geology and Mineral Industries have published the *Oregon Tsunami Evacuation Wayfinding Guidance* (2019) to assist communities in developing their wayfinding system, including on the use and placement of signage (e.g., tsunami hazard zone, evacuation route, assembly site, and entering/leaving tsunami hazard zone signs). Proper use of wayfinding signage will help people, both residents and tourists, evacuate safely and quickly no matter the time of day or weather conditions.

Signage Examples

The US NTHMP signage are provided below:

Figure S.27. Tsunami Hazard Zone

These signs indicate that you are in a tsunami hazard zone (evacuation zone) and should evacuate to higher ground or inland in the event of an earthquake or a tsunami.

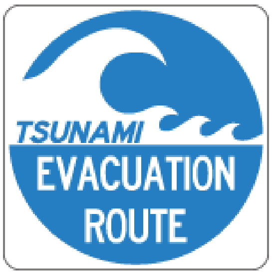


Figure S.28. Tsunami Evacuation Route

This sign is used together with arrows indicating the direction to the evacuation site or assembly area.

Figure S.29. Evacuation Site

This sign indicates that this location is an evacuation site or assembly area

Figure S.30. Entering/Leaving
Tsunami Hazard Zone

These signs are to delineate the boundary of designated tsunami hazard or evacuation zones on highways, streets, roads, and other routes. Right: These signs used in Oregon use a slightly different design and format (Darienzo, M., 2003).

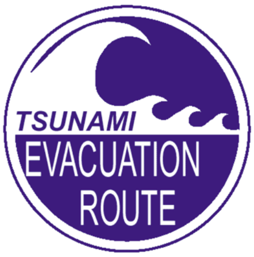


Figure S. 31. Tsunami Hazard Zone and Tsunami Evacuation Route, ITIC.

The Intergovernmental Coordination Group of the Pacific Tsunami Warning and Mitigation System adopted two signs during its 19th Session in 2003 (International Tsunami Information Center).

Figure S.32. Tsunami Hazard Zone

Figure S.33. Tsunami Evacuation Area

Figure S.34. Tsunami Evacuation Building

The International Standards Organization (ISO) approved International Tsunami Signs in 2008 for tsunami hazard zones, evacuation areas and evacuation buildings are shown above (International Tsunami Information Center).

To be most effective, signage should be understood by the community. This means that pictographs should be simple and easily interpreted, depict the hazard (such as dangerous waves) and/or show the desired action or response. If text is used, then it should also be in the local language of the community, and should also be in the national or international language if visitors are expected to that location.

A 2019 inventory (signage type, size, materials) of tsunami evacuation signs and symbols used in the Caribbean and internationally can be found at the document entitled *CARIBE EWS Tsunami Signage Inventory and Report.*

Examples of tsunami signage in different countries are given below.

- In Samoa, since 2009, signage was adapted from the USA and New Zealand signage, and translated into the local language.

Figure S.35. Tsunami Hazard or Evacuation Zone, Samoa (ITIC, Samoa DMO)

Figure S.36. Tsunami Evacuation Route, Samoa (ITIC, Samoa DMO)

Figure S.37. Tsunami Evacuation Site or Assembly Area, Samoa (ITIC, Samoa DMO)

- Indonesia signage follows a national standard that was developed after the 2004 Indian Ocean tsunami. Several examples are provided below.

Figure S. 38. Evacuation direction sign in Ciamis, Indonesia (Rahayu, et al., 2015).

Figure S.39. Tsunami direct impact zone in Pangandaran, Indoesnia (Rahayu, et al., 2015).

Figure S.40. Evacuation route sign (ITIC)

- Costa Rica examples, following the ISO standard with additional language in Spanish, are provided below (courtesy S. Chacon, 2019):

Figure S.41.
Tsunami Hazard Zone

Figure S.42.
Tsunami Evacuation Area

Figure S.43.
Tsunami Evacuation Building

- National Tsunami signage used in New Zealand was published in 2008 (Ministry of Civil Defence & Emergency Management, 2008) following recommendations from a study published by the New Zealand Geological and Nuclear Sciences (2007).

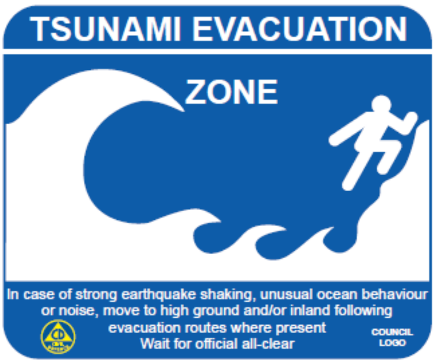


Figure S.44. Generic tsunami evacuation sign

Figure S.45. Generic tsunami evacuation route sign

Figure S.46.
Tsunami evacuation walking sign

Figure S.47.
Tsunami evacuation driving route sign

Figure S.48.
In-place vertical tsunami evacuation route sign

Figure S.49.
Safe location for walking evacuation routes sign

Figure S.50.
Safe location for in-place vertical evacuation sign

Figure S.51.
Previous event sign

2.6 OBTAIN OFFICIAL APPROVAL

2.6.1 Approval

The final Tsunami Evacuation Map needs the official approval of authorities, such as by the Mayor or Director of the Emergency Management Agency. In addition, the map and evacuation plan needs to be understood by responsible stakeholder.

As part of the approval process, presentations should be given to both key stakeholders and to the public summarizing on the development of the community tsunami evacuation map. With their understanding and acceptance, the tsunami evacuation map will be more effective. The community presentation should be clear and outline the evacuation zone, evacuation routes and assembly site or areas, and show the final evacuation map.

2.6.2 Review

After approval, each municipality or region should review their Tsunami Evacuation Map after each tsunami event requiring evacuation, and conduct regular (annual or every few years) reviews generally. When changes are significant, an update to the approved evacuation map and plan will be necessary. For example, there could have been significant changes in the number of potentially affected people that could mean the capacity of identified evacuation routes or shelters is no longer sufficient. Changes in the road network may have occurred thus having an effect on existing or possible new evacuation routes. New construction could serve as additional vertical shelters. Modified provisions could mean that new standards (e.g. layout of evacuation routes, signposting, etc.) have to be followed. Other elements to consider are new tsunami hazard studies, and the overall integration of the local evacuation plan with the tsunami warning system, the regional emergency plan, and with the evacuation procedures associated with other hazards.

2.6.3 Printing

Once the tsunami evacuation map has been thoroughly reviewed by the community, local and/or national government and finalized, it is ready for widespread distribution electronically (website, social media, radio, television, etc.), and through printed media (map, brochure, large display, etc.) (Programme Module 3, Section 2.4, Develop Public Awareness). Any modifications would require a re-print and re-distribution to the corresponding agencies/stakeholders.

In addition to printing maps, billboards of the maps enable easy viewing by the population.

Figure S.52. Tsunami Evacuation Information billboard, Poutasi, Samoa.
(Disaster Management Office, Samoa)

2.6.4 Ensuring Effectiveness of Evacuation Map

The Tsunami Evacuation Map is a useful tsunami safety product because it contains information on the tsunami hazard, tsunami warning, the evacuation zone and where to evacuate to, and other safety rules. To be effective, however, the tsunami evacuation map:

- Must be well-communicated and well-understood by the community. Even if the evacuation map is extensively distributed, people may not evacuation or evacuate incorrectly if they do not understand the map or its instructions. People must know where it is unsafe (evacuation zone) and where they must go to be safe (evacuation sites, assembly areas, vertical evacuation structures).

- Should not be distributed only once and never updated. It must be regularly reviewed, revised/updated, and distributed to the citizens as a reminder and to ensure that it incorporates any changes to the disaster-related environment and planned mitigation measures. Even if only minimal changes or updates are included in the revision, the distribution of new "updated" TIM is very valuable to refresh the community's awareness on tsunami hazard potential in their area.

- Should be integrated into tsunami disaster management and community development planning as a whole. Residents will have greater appreciation if they know that tsunami hazard information was well-considered and integrated into the development planning (e.g., land use policy, non-structural measures, construction of structural measures) of their community. Such actions lets residents feel that they are part of the community planning process.

2.7 PEDESTRIAN EVACUATION SIMULATION AND PLANNING

Over the last five years, techniques have been developed to quantitatively assess the feasibility and viability of different evacuation scenarios, and thus improve the evacuation planning process. Pedestrian evacuation simulation and planning provides emergency managers with evacuation routing options, assessment of the performance of implementing the existing evacuation plan, and the capability of overlaying layers of data regarding assembly points, position of the vertical shelters, and evacuation routes.

If evacuation simulation is done in real time, then planning maps may not need to be printed nor produced as composite maps (as the evacuation maps for the public need to be), but could instead be dynamic maps using the actual tsunami event and created during the event to support more information decision-making during evacuation operations.

Pedestrian evacuation potential in an at-risk community can also be investigated using graphical information system tools, wherein pedestrian travel time and inundation layers can be overlaid on information layers such topography, streets, schools, police and fire stations to determine whether there will be enough time to evacuate on-foot during a tsunami warning. Although evacuation to naturally occurring high ground is desirable, evacuation modelling has demonstrated some communities may require vertical-evacuation structures within a hazard zone, such as berms or buildings, for at-risk individuals to survive some types of sudden-onset hazards, such as local tsunamis, debris flows, lahars (volcanic mudflows) and flash floods.

The US Geological Survey has developed GIS tools to assist researchers and emergency managers in examining the pedestrian-evacuation potential of an at-risk community. The USGS Pedestrian Evacuation Analyst Tool (https://www.usgs.gov/software/pedestrian-evacuation-analyst-tool) uses an anisotropic path-distance approach for pedestrian evacuation from sudden-onset hazards, such as for local tsunamis (Wood et al., 2007; Wood and Schmidtlein, 2013 a, b; Wood, 2015)

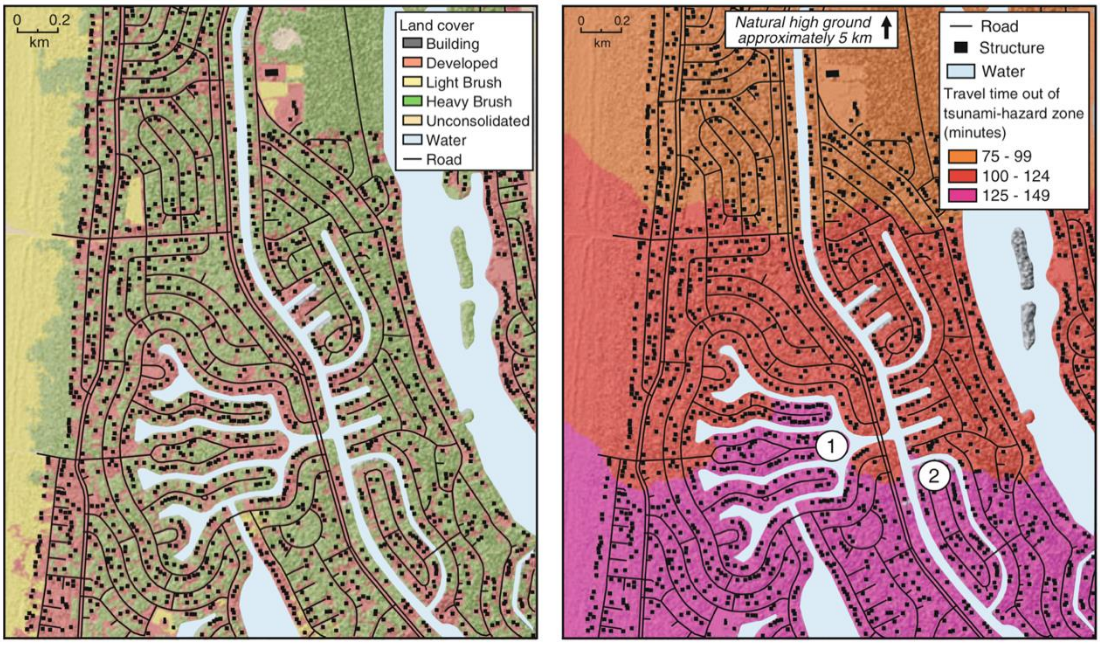


Figure S.53.Maps showing modelling inputs (left) and calculated 'least-cost', pedestrian-evacuation travel times (based on a travel speed of 1.1 m/s, right) for the central portion of the incorporated city of Ocean Shores, Washington (Wood and Schmidtlein, 2013a). 'Least-cost' refers to the calculation of the 'cost' (in terms of travel time) due to the varying landscape (roads, landcover, elevation, buildings, etc.),

Evacuation potential is estimated based on elevation, direction of movement, land cover, and travel speed, and creates a map showing travel times to safety throughout the hazard (evacuation) zone.

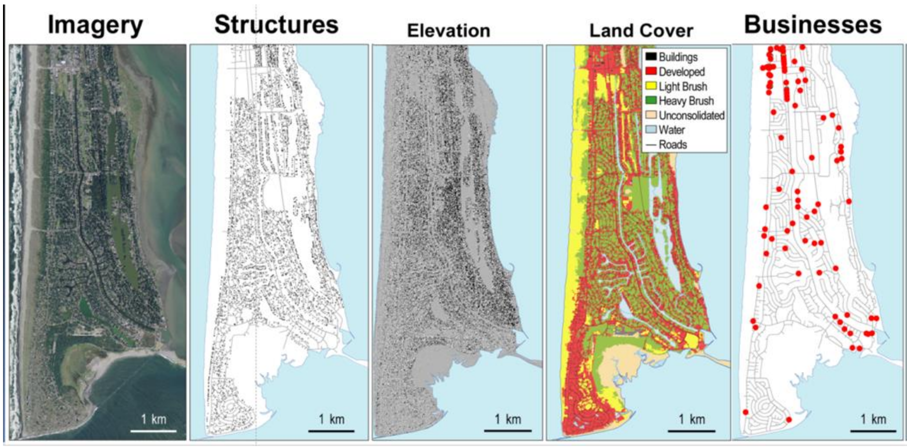


Figure S.54. Data used for pedestrian evacuation modelling (Wood, 2015).

The two key parameters used for evacuation simulation and planning maps are:

- Tsunami Estimated Time of Arrival (ETA) and
- Tsunami Estimated Wave height.

Using the previously computed travel time and wave height forecast maps, the following maps can be produced:

1. Inundation & Evacuation Areas map.

The inundation map is calculated by merging the digital elevation model with the estimated wave height. The estimated inundated area is then considered as “The evacuation zone” or “tsunami hazard zone”, and in principle, all non-inundated land (i.e., areas out of the tsunami hazard zone) could then be considered as safe location.

Further restrictions (or ‘rules’) may be applied depending on each situation, such as:

- Areas that are completely surrounded by inundated land can be excluded from further calculations, and/or
- Land that, although not flooded, is extremely flat, and could be excluded from further calculations, too.

For this technique, the results should be analysed in order to validate and confirm that the estimated inundation or flow depths are reasonable for the baseline bathymetry and topography set. To accomplish this, a range of maps of scale 1:25.000 to 1:10.000 should be prepared with a grid of 100 m and of 20 m, respectively, with color-coded 1 m inundation depth lines.

2. Emergency Evacuation Points map.

Evacuation assembly sites are designated locations or areas can host in a safe way a sufficient amount of evacuees for the time of inundation. They must be sites located outside the evacuation area. Further restrictions may apply to these sites, including the requirement of being easily accessible, placed at a reasonable distance from the point of departure. The site should have substantial capacity to accommodate the designated number of persons. If they are shelters and long-term, these sites should have access to lifelines, such as drinkable water, phone, electricity, emergency kits, etc. so that these sites can continue to be used during the response phase.

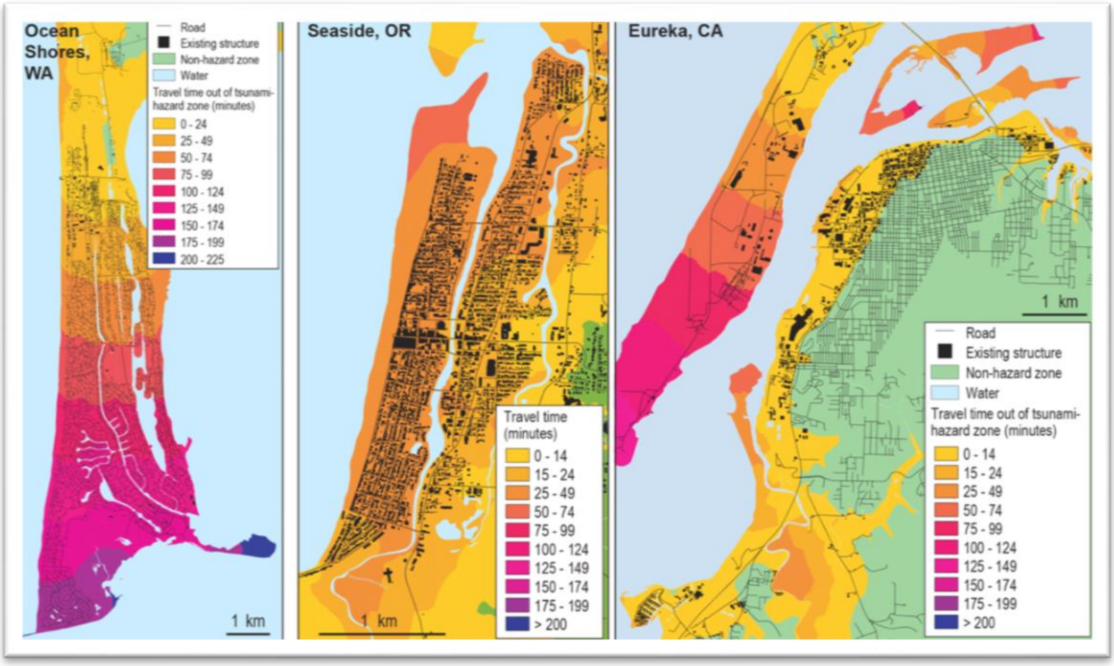


Figure S.55. Pedestrian evacuation times for several communities in Oregon and Washington (Wood, 2015).

The result is a view of evacuation landscape at different pedestrian travel speeds and is useful for identifying areas outside the reach of naturally occurring high ground (e.g., places where vertical evacuation structures will be needed). If population information is provided, the tool will integrate this data and produce tables and graphs of at-risk population counts as a function of travel time to safety.

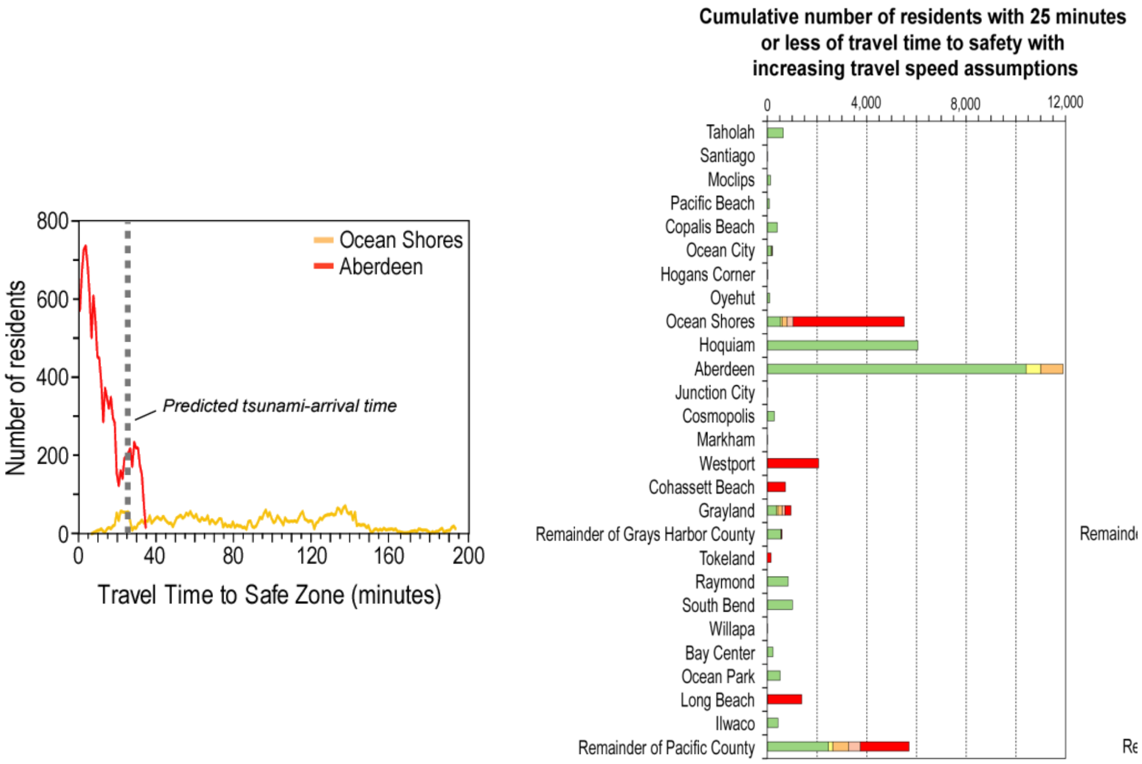


Figure S.56. Example of USGS Pedestrian Evacuation Analyst outputs summary graphs showing the number of residents who would be able to evacuate safely for towns in Washington (Wood and Schmidtlein, 2013a).

2.7.1 Methodology

The methodology for creating the aforementioned specific layers/maps for pedestrian evacuation is implemented according to the following steps (A to G):

A. Definition of a cost surface layer.

All further GIS analyses require the introduction of a fundamental thematic layer, the “cost surface” layer. The cost surface layer is a raster layer which represents the time-cost of the travelling element (evacuee) for crossing a distance unit (one meter) of the raster layer.

The cost surface layer considers only those areas in which the pedestrians are expected moving during an organized evacuation process (i.e. road network, beach zone). All the other areas (mainly buildings, rivers, fields, etc.) are excluded from further consideration. In order to create, as much as possible generic (unit independent) evacuation maps/layers, the time-cost value, assigned to each cell of the cost surface layer, represents a unit-less size that derives its meaning in relation to the costs assigned to other cells. Thus, in the analyses which follow, for expressing a time-cost for each cell, the concept of non-specific “time-unit” is introduced instead of real units of time (seconds, minutes, etc.).

B. Definition of evacuation shelter points.

The “Vertical Shelters Map” shows suitable buildings in the flooded area that could temporarily host a sufficient number of evacuees. On the other hand, horizontal shelters are indirectly defined through an analysis of the “Inundation and Evacuation Locations Map”. As these horizontal shelters may be located far outside the flooded area, it is for calculation purposes more convenient to mark the interfaces of escape routes with the flooded area boundary as “horizontal shelter locations”.

C. Definition of the time map.

Using the layers of the “Cost Surface” and the “Evacuation Shelter Points”, a Cost-Weighted Distance map can be calculated using the appropriate GIS tools. In this map the value of each cell represents the cost needed to go to the nearest (in terms of cost) source point, following the costless (i.e., with a minimum of costs) path.

D. Definition of the area/zone covered
by each shelter point (allocation of shelters/region).

The aim of the analysis is to delineate the area/neighbourhood, which can be assigned to the shelters (refuges) which have been selected for inclusion in the evacuation plan. The “time-cost surface” is used in the GIS “cost allocation” analysis and it is further combined with the “shelters” layer in order to compartmentalize the whole area into small zones, which represent the borders of the neighbourhoods within the whole area that could be served by the respective shelter buildings. Each zone is assigned a unique ID, which is relative to, and identical to the Building ID considered as a vertical shelter in the context of the Tsunami Evacuation Plan.

E. Time-distance from closest shelter.

The purpose of this analysis is to provide an indication of the proximity of each shelter to the respective road/street segment. Such an indication is an indicator of the performance of the shelter for the evacuation purpose. The analysis is based on the “Shelter/streets allocation” map presented above.

The “Time Distance from closest Shelter” map represents the time units needed to reach the closest shelter from any point on the road/street network. The analysis identifies road segments and locations that are distant from shelters and where special attention should be paid during evacuation, since people from these areas will not have enough time to evacuate. This map can be combined with the Tsunami Risk maps (maps visualizing the time of arrival of the first wave, flow depth, maximum water elevation), in order to estimate the available time for the evacuation procedure scenario adopted for the simulation) due to time limitations for the residents in reaching safe places/buildings (insufficient time for evacuation).

F. Definition of the area served by exit/escape points (allocation of exits/region).

The following analysis is conceptually similar to the definition of the area/zone covered by each shelter point, presented above; the focus is put on the most critical zones (e.g. beaches) where there are no shelters and where residents have to be evacuated as a priority because they are in greater danger. The geographic features (e.g. stairs, underpasses, ramps, etc.) that lead outside of this critical zone are considered as exit or escape points. All the other area is considered as obstacles (i.e. fences or walls).

The results of this analysis show the division of the critical zone into sub-areas that correspond to the closest escape point. Additionally, each sub-area has a unique ID, which is identical to the escape point ID.

G. Time distance to reach the closest escape point.

The "Time-Distance from closest escape point" also focuses on the most critical zones for tsunami evacuation (e.g. beaches, roads near the beach) where there are no shelters and which need to be prioritized for evacuation because residents there are in greater danger. This analysis calculates the time units required for reaching the closest point/location, which can be considered as exit point from the endangered area towards the inner and safer area. The legend (colour code) expresses time units in seconds based on the assumption of an average walking-speed of 3600 m/hour (1m/sec) on the road surfaces, and a speed of approximate 1800 m/hour (0.5 m/sec) on the roughest (i.e. difficult) surfaces (e.g. beach, stairs, etc.).

2.7.2 Evacuation Simulation Analysis

Evacuation simulation analysis aims at identifying whether an existing network of evacuation routes (towards evacuation assembly sites and vertical shelters) will satisfy the needs of a full evacuation within the required time. Hence, evacuation simulation analysis assesses the performance of evacuation plans and as such, it is an excellent tool for decision support.

The geographic data together with other important information that may play a decisive role during the evacuation simulation are analysed spatially using GIS, in order to produce a series of maps, which can provide the decision makers with answers on:

- General coverage of vertical shelters in the inundation area.
- Elaboration of the performance (i.e. throughput of evacuees) of the existing network of streets/roads to be used for accessing the horizontal and vertical shelters considered in the evacuation plan.
- Assessing the distribution of the residents against the network of shelters established (taking into account the capacity of the shelters).
- Assessment of the overall adequacy of the network of shelters (number / positioning /capacity) and identification of inadequacies and gaps.

Based on the aforementioned maps, an evacuation of the exposed population is simulated. Thus, for all districts (or quadrants or subdivisions) of the tsunami hazard area, the residing population is assessed in order to:

1. Walk to the nearest road or path segment and follow the evacuation routes up to the nearest evacuation assembly site or vertical shelter, or
2. Stay (and move up) in the building where the building is part of the vertical shelters network.

For practical reasons the following assumptions are adopted:

- The capacity of every evacuation route segment does not play a significant role unless for particular cases (e.g. if too many persons arrive at an evacuation route segment at the same time and start running). Nevertheless, this situation should be handled properly, especially in the case of very short clearance time. An "indirect" solution may be to apply an increase of time to the next shelter for those evacuees.

- Not all persons per district/quadrant/subdivision will present themselves at the same time (i.e. within the first minute of evacuation) on the nearest evacuation route segment, thus allowing for some flexibility with respect to the necessary segment capacity.

- An average human speed as of 1 m/sec is taken as granted; a reduction of this will be taken up within the cost-surface layer (see below). For example, on difficult ground like on beaches, an average human speed of 0.5 m/sec is granted.

- Only pedestrian evacuation is considered thus excluding the use of cars.

- People with special needs are not considered in this simulation exercise; however, they have to be considered separately by the authorities.

2.8 SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. These are found in Part B as Specialized Documents.

- How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS (manual, tutorial). This manual describes the export of ComMIT results into the open-source QGIS software to digitally create tsunami evacuation maps using standard formats, color palettes, and symbology. (Specialized document no III)

- Town-Watching Tsunami Evacuation Checklist (example). This example provides a template for ground-truthing tsunami evacuation maps through community engagement and actual tsunami evacuation route walking. (Specialized document no IV)

MODULE 3 – DEVELOPING TSUNAMI RESPONSE PLANS AND STANDARD OPERATING PROCEDURES

1 INTRODUCTION

Figure S.57. Steps for Module 3 – Response Planning

A tsunami response plan needs to be developed for the evacuation of populations living in coastal areas, inland waterways, and other areas that can be affected by a tsunami. The response plan comprise the arrangements for an effective disaster response. The response plan focuses on saving and protecting the general public, critical infrastructure, communities, and the environment.

The Tsunami Response Plan is supported by detailed, agency-specific Standard Operating Procedures (SOPs) that are activated on receipt of a tsunami warning or during a local source earthquake that may generate a tsunami (i.e. in the period before an official warning can be issued). The sequence of actions to be taken will depend on the type of warning and the amount of warning time available.

In this Module, much of the structure is modelled after emergency organizational structures presented in the tsunami response plans of various coastal cities in the U.S. (City of Manhattan Beach CA, San Francisco CA, San Mateo CA), Honduras (Municipality of Cedeño), and New Zealand. The structure, names, and hierarchy of such organizations may vary from country to country and among regional and local jurisdictions.

The New Zealand's Tsunami Advisory and Warning (Supporting Plan SP 01/18) is an example of a national tsunami response plan. This plan describes the procedures to receive, assess and disseminate tsunami notifications at the national level. At the local level, authorities maintain public alerting systems and procedures to communicate tsunami advisories or warnings received from the national level further downstream to local communities.

Closely associated with response is public awareness to ensure the public understands where official warnings will come from, when they can expect them (and when not, for example during a local source earthquake), how to evacuate and where their assembly areas are, and when it will be safe to return.

A template and examples of a community response plan, as well as awareness materials are available as part of this Supplement Specialized Documents.

2 MODULE CONTENT

2.1 ACQUIRE REQUIRED INFORMATION

The following should be considered by stakeholders involved in the end-to-end warning chain, and the emergency management agency responsible for developing the national and community response plans and associated standard operating procedures for warning and evacuation:

- Major tsunamis can cause numerous fatalities and injuries, property damage and loss, and disruption of normal life-support and services. It can also have a significant impact on regional economic, physical, and social infrastructures.

- The extent of casualties and damage will reflect factors such as the time of occurrence, severity of impact, weather conditions, population density, building construction, and the possible triggering of secondary events such as fires and floods.

- The capabilities of the local government to respond will quickly be overwhelmed by the large number of casualties, heavy damage to buildings and basic infrastructure, and disruption of essential public services.

- Local Emergency Management Officials should act on tsunami warning information on their own initiative and responsibility, especially for local tsunamis.

- In areas where early warning systems are not in place, response plans will be provisional, and procedures should be continually revised and updated to take advantage of developing plans and capacities.

- In areas where tsunami information or awareness is limited, warning content quality, accuracy, and timeliness will need to be considered and compensated for in response planning.

- Authorities should remain in alert status for at least two hours' time after the estimated arrival time irrespective of whether a tsunami has arrived or not.

Due to the increasing levels of sophistication in organization and coordination, alert procedures, communications, and response capabilities, the response plan is not permanent and should be reviewed regularly (for e.g. an annual review).

Prior to or as part of developing the response plan, all agencies, special groups, or committees that have a role in the end-to-end tsunami warning should already have been formed, and each should have formulated and finalized their operational procedures (Standard Operating Procedures).

The emergency management agency is be responsible for developing and maintaining the response plan. Stakeholder departments, agencies and authorities should work cooperatively with the emergency management agency, since multi-agency, multi-disciplined coordination will be required in response to a tsunami threat or event.

Emergency management agencies should have a 24/7 (24 hours, 7 days a week) watch. Tsunamis can come day or night, and people need to be ready to respond at any given time. Workers conducting overnight operations should be qualified to do so, and should involve at least one person with experience.

2.2 DEVELOP RESPONSE PLAN

2.2.1 Format and Design

Poor organization of information can limit the plan's effectiveness. A response plan is effective if those who are intended to use it can understand it, are comfortable with it, and are able to locate the information they need from it. The following points are things to keep in mind when designing the response plan.

- Organization: The response plan document should be written such that it is easy for users to find relevant information needed.
- Progression: The document needs to have a logical sequence and topics should not needlessly repeat itself. In addition, it should be written such that a reader can grasp the sequence in locating information that is needed.
- Consistency: Terms, ideas, and progression of elements should be consistent throughout the document so that readers are not required to re-orientate at each section.
- Adaptability: Information in the response plan should be written that it could be used during unanticipated situations.
- Compatibility: The response plan should be developed that it will support alignment and coordination between different organizations. They must be consistent with other functional response plans.

2.2.2 Tsunami Notification and Activation

It is the responsibility of the relevant emergency management agency to evaluate the tsunami information received from the warning centre and decide on the appropriate action. A significant challenge associated with tsunami warnings is the decision-making about evacuations, which can be costly and disruptive. Decision-making may be further hindered by false alarms due to the lack of adequate sea level data. Response plans should describe the responsibilities and arrangements for:

- Rapid notification of decision-making authorities,
- Decision-making regarding the ordering of evacuations and other protective measures, and
- Rapid and comprehensive notification of the public at risk.

Countries using internationally collected data should be aware of differences in time and accuracy. Countries should pay full attention to the possibility of a tsunami when strong earthquakes occur in or near the area. If travel times are indicated, countries should expect later and/or continuous wave arrival. Note that the calculated travel times are estimates – the actual tsunami could arrive a little earlier or later.

2.2.3 Tsunami Alert System

All response plans should incorporate the public alert system (or systems) that apply. Because tsunamis are infrequent, many people at the coast will either not know when to expect a tsunami, and/or how to respond, or apply poor judgement. When designing an alert system, some things to consider are:

- How does the warning get to the emergency management agency?
- Who can authorise an official alert?
- Who will process and send the official alert?
- Do the media or public receive the warning at the same time as the emergency management agency?

- What kind of communications systems are already in place and can they be used?
- What are the official tsunami alerting mechanisms or channels?
- Who can hear or read the alert?
- How do people who cannot hear or read the alert be notified?

Figure S.58. Left. An empty propane tank and stick is used to sound the alert, Savaia, Samoa. Right. Omnidirectional sirens, with solar power backup, are used in Hawaii, USA. Photos courtesy of ITIC.

Interim Alert system - The first priority should be to put together a formal, functioning public alert system. Regardless of whether an interim system may be manual, rudimentary, or improvisational, the point is that it is planned for, organized, routine, and executable. Planners should expedite any conventional means available. The designated alert should be something audible and recognizable (i.e. a system of amplifiers, loudspeakers, radios, and microphones, church or school bells, foghorns, public announcement speakers, etc.). Planners should also educate the coastal communities on a tsunami's natural warning signs.

2.2.4 Phases of Operational Activities

The sequence of operational activities for a tsunami event is categorized below:

(i) Warning Phase. In the U.S., potential tsunamis are monitored by the Tsunami Warning Centers (TWCs) in Alaska (US National Tsunami Warning Center) and Hawaii (Pacific Tsunami Warning Center). The information is received by a State Emergency Management Agency or State Warning Point (State EMA) via the National Warning System (NWS). All information received from the TWCs is passed directly to the local operational areas (County EMA, City EMA, or other 24x7 emergency contact) via an established local warning systems and/or Emergency Digital Information System (EDIS). The State EMA disseminates the information to the local jurisdiction through the Police or Sheriff's Department. If the first wave is expected to reach the coast with enough time for evacuation, the decision to make a complete, immediate evacuation may be necessary. However, if the wave is expected in 3–6 hours, a phased evacuation is possible with the closing of beaches and removal of emergency equipment and personnel from coastal areas. It should be noted that the decision to evacuate populations and to close businesses might be questioned if the tsunami does not occur. In order to reduce individual liability, the City (local jurisdiction) may elect to declare a local emergency.

(ii) Public Alert Phase. In the U.S., the County uses the Emergency Alert System (EAS), and Emergency News Network (ENN) to warn the public about an anticipated tsunami. The City utilizes the Reverse 911 telephone advisory system. Additionally the City uses its Public and Cable TV breaking news, Hazard Advisory Radio System (NOAA Weather Radio), Emergency Alert E-mail system and Wireless Emergency Alert (WEA) system, website and telephone Hotline, and in some places, sirens. Social media (Twitter, Facebook) may also be used

(iii) Evacuation Phase. The County Operational Area (County EMA) is responsible for developing evacuation plans for all jurisdictions to be implemented in response to local or distant events. A local tsunami requires immediate self-evacuation possibly through areas damaged by earthquake and at risk of after-shocks. Distant events may allow several hours to implement emergency procedures and evacuation. Evacuation routes must take into account potential earthquake damage. The County EMA, in association with the local jurisdiction (city, town, village, etc.) and Police Department, will establish proposed evacuation routes and coordinate these routes with the Public Works department, and Fire department. Public input and comment is also taken in.

(iv) Damage Assessment Phase. Damage and Safety Assessment will be performed by City / Town staff (local jurisdiction in association with auxiliary trained personnel as available). All reports will be received by the Operations Section in the City / Town Emergency Operations Centre (EOC). Completed reports will be forwarded to the County EOC via computer system or through the Police or Sheriff Station for forwarding to the County EOC.

(v) Emergency Public Information (all phases). All official Emergency Public Information emanating from the City / Town will be handled by the Public Information Officer under the direction of the Director of Emergency Services or EOC Director. Information will be disseminated via TV channel, Hazard Advisory Radio System, Emergency Alert E-mail system or WEA system, website and telephone Hotline, and other authoritative media. In an emergency, the Emergency Alert System (EAS) may be utilized by the County to interrupt normal radio and television broadcasts for special announcements.

2.3 DEVELOP STANDARD OPERATING PROCEDURES (SOPS)

2.3.1 Examples of Tsunami Warning SOPs

National Tsunami Notifications

In the U.S., Tsunami Watches, Warnings, and Cancellation Notices, are usually generated by the National Weather Service's Tsunami Warning Centres, a division of the National Oceanic and Atmospheric Administration (NOAA). These messages are transmitted in a variety of different ways by several sources and agencies.

It is possible to sign-up to receive these advisories directly by e-mail or via pager or cellular phone. However, the official notification system is established by each State's Governor; for example, in the State of California, the Governor's Office of Emergency Services (OES) has established a system called the California Law Enforcement Telecommunications System (CLETS). CLETS is used by law enforcement agencies and also by the Operational Area EOCs (County or Provincial). It is the Operational Area that will make Official notification of any messages received via CLETS to the Cities (or Towns and the public), regardless of whether that information had already been received by staff via another delivery system on their cell phones or pagers.

From the legal standpoint, all staff should understand that any messages received from sources other than the Operational Area should be taken as advisory in nature, and do not constitute an Official warning from the Operational Area.

City/Town Notifications

Personnel involved are:

- City Manager,
- Fire Chief,
- Police Chief,
- Public Works Director,
- School District ,
- Dispatch Centre.

Warning Procedures and Initial Actions:

- Tsunami warnings are issued through the National Warning System.
- These warnings are distributed by means of Text Message and E-mail to the Local Authorities (Provincial/County, City/Town).
- Confirm with Local Authorities that they have received the warning. Ensure that other Key Stakeholder Agencies are aware of the warning. City or Town EOC (Disaster Management Office) has the responsibility to ensure that its communities are aware of the warning.
- Broadcast the warning on media (Radio Stations, Televisions, etc.) and ensure that a standard message is given to residents in the potential emergency area. Although every effort would be made for these warning to be broadcast, it cannot be assumed that all residents have received the message. This is especially true at night.

Emergency Status

There are three levels of emergency status:

1. Case “A”: Tsunami Warning: Tsunami is imminent or has occurred (Warning and evacuation).

2. Case “B”: Tsunami Watch: A potentially hazardous situation is developing. (Precautionary alert to prepare to evacuate inundation area).

3. Case “C”: Tsunami Watch/Warning has been cancelled.

Note: A fourth case (A.2), Tsunami Advisory, may also be considered. This situation would be lower level of warning which may produce strong currents or waves dangerous only to those in or near the water. Coastal regions historically prone to damage due to strong currents induced by tsunamis are at the greatest risk. The threat may continue for several hours after the arrival of the initial wave, but significant widespread inundation is not expected for areas under an advisory, and a land evacuation is not required. Appropriate actions to be taken by local officials may include closing beaches, evacuating harbours and marinas, and the repositioning of ships to deep waters when there is time to safely do so. Advisories are normally updated to continue the advisory, expand or contract the affected areas, upgrade to a warning, or cancel the advisory.

Emergency Actions

1. Case "A"– Tsunami Warning: Reports from responsible authority indicate that "Tsunami Inundation or flooding is Imminent or Has Occurred".

   a. Provincial or County Actions (typically):

      1. Staff Duty Officer (SDO) will verify that tsunami inundation or flooding is imminent or has occurred.
      2. Provincial / County EOC will activate.
      3. SDO will make designated initial notifications.
      4. Coordinate information with Police or Sheriff's Office, City or Town EOC, and appropriate Police departments concerning evacuation from the inundation areas, including designated critical infrastructure.
      5. Alert Red Cross or volunteer organizations for the need for mass care shelters.
      6. Make contact with City or Town Manager or Emergency Services Coordinator for status report and designated shelter area locations.
      7. Broadcast Emergency Alert System (EAS) evacuation notices indicating inundation areas and locations of mass care shelters.
      8. Activate communications support to Command Posts and mass care shelters.
      9. Monitor situation and assess damages, casualties and number of homeless.
      10. Coordinate mutual aid, if necessary.
      11. Keep National or State EOC informed of situation.
      12. Assist in re-entry, recovery operations and planning with other agencies as requested.

The primary concern of the Fire Departments is rescue of victims and saving lives. The Police Department is primarily concerned with perimeter control and the prevention of looting within the City or Town. Law enforcement agencies are responsible for ensuring transportation for the disabled, the elderly and persons without vehicles.

   b. City / Town Actions:

      1. Verify the situation with Police or Sheriff's department or County EOC.
      2. Make emergency notifications to the public.
      3. Alert City / Town emergency response staff
      4. Alert City Council (or other local government authority)
      5. Declare a State of Emergency (if appropriate)

6. Establish on-going communications with County via established information/communication system
7. Open a City / Town EOC to help manage the emergency.
8. Ensure safety & logistical support for City / Town staff.
9. Send a representative to State / County Unified Command Post as a Liaison
10. Alert volunteers for additional support if necessary
11. Anticipate and provide for Mutual Aid requirements
12. Begin planning for the Recovery phase
13. Continue public notifications

2. Case "B" – Tsunami Watch: Reports from responsible authority indicate that a "Tsunami Watch Has Been Issued".

a. Provincial or County Actions (typically):

1. Verify the Information
2. Activate EOC
3. Make designated notifications
4. Ensure all county resources are moving to safety

b. City or Town Actions:

1. Verify the situation, and anticipated tsunami wave arrival time
2. Alert City or Town emergency response staff
3. Alert City or Town Council (or other local government authority)
4. Make preliminary "Watch" notifications to the public
5. Monitor media for confirmation of tsunami wave arrival
6. Move available resources to pre-designated higher ground
7. Open a City / Town EOC to help manage the emergency

3. Case "C" - Stand Down: Reports from responsible authority indicate that the "Tsunami Threat No Longer Exists".

1. Notify staff members and City or Town Council (or other local government authority)
2. Make necessary public notifications
3. Ensure documentation of all actions taken, for future reference
4. Return all resources that were relocated to their original locations
5. If Operational Area Response and Recovery System (OARS) was used, ensure system is properly logged off.

2.3.2 Example of Emergency Operations Centre (EOC) Roles and SOPs

Figure S.59. Example of National EOC, Oficina Nacional de Emergencia del Ministerio del Interior (ONEMI), Chile (left) and Local EOC, La Libertad, El Salvador (right). (Photos courtesy of ITIC)

On receipt of a warning that a tsunami threat is immediate or has occurred, the Emergency Operations Centre (EOC) will be activated by the emergency management agency to perform the following functions:

- Control

The local Controller is in charge of the response and coordinates all the response activities, including those performed and managed by other agencies.

- Operations

Agencies or organizations that normally activate to respond to a tsunami event are the following: Fire Department, Hazardous Materials, Law Enforcement, Medical and Health, Care and Shelter, and Public Works and Utilities. Each agency/organization plays a specific role with its own operational procedures. During the tsunami emergency, all agencies must work seamlessly together to ensure a smooth operation. To perform a safe operation during a tsunami response, there must be no confusion. Below are some of the important guidelines:

  - Personnel should be staged outside the tsunami evacuation zone (potential tsunami inundation area) until an 'All clear' message has been received. The exceptions may be the Fire Department, Law Enforcement, and authorized organizations to assist in the evacuation of the affected population. Note that a tsunami is not a single wave event; it consists of multiple waves and could continue to inundate the coastal area for several hours. Usually the first wave is not the largest and the succeeding waves can be more destructive especially when debris are already carried by the waves.
  - Natural Hazard response protocols and/or existing plans should be reviewed to ensure that they specifically include a tsunami response. This is especially important because of no-notice, fast-evolving nature of tsunamis (unlike hurricanes/cyclones, which can be tracked for days before).
  - Personnel training and/or regular refresher training might also be needed to prepare for a tsunami event. Tsunamis are relatively infrequent, so practice drills are important to maintain readiness.
  - Determine if special instructions are needed to respond to a tsunami threat.

- Evaluate if each agency will require additional technical support teams, mutual aid, and extensive logistical support during the tsunami response.
- Determine what is needed to be able to expand the agency's operations to respond to a tsunami threat as compared to their day-to-day operations.
- Evaluate whether the personnel is able to handle a situation in case they become secondary casualties while responding to the tsunami threat.
- Should each agency's functions be co-located with other disciplines/agencies to ensure proper coordination? Should a tsunami expert be included in your tsunami warning decision-making team?
- Determine if decontamination procedures are in place for personnel who will be handling the deceased to prevent contamination of other facilities.
- Is the agency able to handle a massive, instantaneous, and concurrent response during a tsunami event?

Some operational procedures that need to be reviewed are specific to certain agencies.

- Coroner:
  - Review or update decontamination procedures prior to transporting of the deceased to the incident morgue or central morgue facility.
  - Determine if there are provisions for the recovery and identification of the deceased especially is there is a dismemberment issue.
- Medical and Health:
  - Determine if establishment of contacts with the private sector is needed to have quicker access to supplies and additional personnel.
  - Determine if mental health support personnel, which is part of 'Medical', have the required training to handle disasters, tsunamis, and trauma. They will also support the victims, incident response personnel, and also staff at the Emergency Management Agency. Also, if they have an understanding of governmental response roles.
  - Determine also if they are trained to function as part of a multi-disciplinary team.
  - Determine what mental health resources are available at each community level and whether additional resources will be needed during the tsunami event.
  - Determine how the mental health resources can provide services like crisis counselling, screening, diagnosis, treatment, and stress management for personnel of Emergency Management Agency and people who needs such services.
  - Determine how the mental health resources can provide/address psychological impacts of responders or volunteers in the activities of body recovery, identification, family notification, and transportation of the injured.
- Care and Shelter:
  - Determine the level of facility security required for the care and facility during the tsunami incident.

  - Determine the level of emergency response for ‘care and shelter,’ and whether there should be representation at the EOC.

- Public Works and Utilities:
  - Determine how to include building inspectors and other professional in the incident response.
  - Both public and private utilities sectors can work together in establishing potable water, wastewater and sewage treatment, gas, and electricity.
  - Determine the vulnerabilities of the utilities prior to a tsunami incident.
  - Determine the level of emergency response for ‘utilities,’ and whether there should be representation at the EOC.

- <u>Planning and Intelligence</u>

Two main areas that need to be considered are threat analysis and determining gaps and shortfalls in the response.

- Threat Analysis determines the threats to humans, lifelines, infrastructures, and critical facilities that are exposed to the tsunami threat.
- Determining gaps and shortfalls in the plans and procedures will look into whether the local jurisdiction need to create new protocols or improve on the existing ones. They need to address what needs to be done, what the action items are, who should implement the actions, and establish a timeline. Transient populations and their needs should also be considered.
- Determine the existing assets available to the local jurisdiction to deal with a tsunami threat.
- Determine what is needed if there is a shortfall.
- Determine if the local jurisdiction knows how to access or request resources from other sources.
- Determine whether the local jurisdiction has a resource database (e.g. tsunami inundation studies, evacuation maps, evacuation routes, etc.) to respond to a tsunami threat and how it is accessed.

- <u>Finance and Administration</u>

The ‘Finance and Administration’ function needs to ensure that there is continuity in operations that includes payroll processing and keeping track of the costs of the incident.

- Confirm that the existing system of the local jurisdiction can be used for tracking personnel responding to the incident and for payroll operations.
- Establish the protocol for staff recall and recall procedures for the tsunami response.
- Track the costs of responding to the tsunami incident.

2.3.3 Evacuation Planning and Procedures

Significant intervention by local level emergency management is crucial for effective evacuations. Local emergency management are familiar with their region and community, therefore their local lead is imperative. Below are some of the specific considerations that local emergency management should plan for:

- Evacuation Routes and Traffic Control

Planners should identify optimum evacuation routes inland towards higher ground. Not all areas will have access to higher ground. In this case, vertical evacuation structures should be identified or may need to be built. Evacuation routes should avoid narrow and heavily used routes in densely populated areas to avoid bottlenecks in traffic. Ideally, the public should evacuate by foot as much as possible, to avoid creating more traffic congestion. Once areas have been evacuated, roadblocks, barricades, and/or a system of patrols should be set in place to keep the public from wandering into evacuation zones. Public and volunteer involvement in evacuation and traffic control procedures free up emergency workers to handle more critical tasks.

Special planning considerations must be made concerning crowded areas near shore, potential bottlenecks, and the portion of the public that may need support (such as schools, hospitals, and other care facilities).

Road blocks will have to be established to close tsunami hazard zones and diversion of traffic after evacuations.

- Signage

Evacuated areas to be cordoned off by road closure signs. If no signs are available, any other type of barrier (i.e. cones) can be used to show road closure. If resources are available, people should be kept out of evacuated areas until the danger is over.

- Communications

Communications may be by telephone (cell or landline), satellite phones, the emergency management radio network, and public alerting mechanisms and public radio stations. Communications should also be provided for special needs populations, including those that cannot see or hear, or walk.

- Animals/Stock

Small pets may be evacuated with owners. Larger animals, unless owners can make immediate arrangements, may want to be turned loose to fend for themselves.

- All Clear or Safe to Return

Evacuated areas should remain closed to the public until after the tsunami warning is cancelled and the threat of a tsunami no longer exists and the authorities have declared ‘Safe-to-Return’ or ‘All-Clear.’ A tsunami is a series of waves that arrive every 5–60 minutes, and it may be several hours before impacted areas can be inspected and then even more hours to be declared safe for re-entry. The decision to allow re-entry will be made by the local emergency management agency. Residents should re-enter through control points to ensure safety.

- Other considerations
    - How and when are the evacuation assembly structures activated? It may be desirable to designate assembly areas that are open spaces and that do not have gates or locks (such as fields or parks).
    - Who will be recalled?
    - What instructions will be given for non-emergency management workers?

- What areas need to be evacuated? Every jurisdiction should have an evacuation map that identifies evacuation zones and also evacuation assembly locations.
- Will people be evacuated entirely on foot, or will mass-transport be available for parts of the population, or for part of the time before tsunami wave arrival?
- Evacuees will need support at shelters/evacuation assembly sites. Support may be minimal if sites are intended to be temporary.
- Guidance should be available on whether boats should be secured in the harbour or put out to sea?
- How will incoming marine vessels be notified not to proceed inland?
- What training and procedures can be tested prior to an event?

- Evacuation orders

Sometimes the community will need to be the “eyes and ears” of a tsunami alert system. In the event of a local tsunami, there is little time to coordinate, respond, and provide an official warning. Technology designed to detect a tsunami and then alert (siren) may not always work, and communication lines could be affected by the earthquake. Therefore self-evacuation by the public should begin immediately upon the tsunami’s natural warning signs (feel earthquake shaking, see ocean receding, hear ocean roar). Planners should help communities to be prepared to self-evacuate, without any official warning.

Once a tsunami warning has been received, the affected areas identified, and a decision made to evacuate, **ALL** residents in the affected areas are required (or strongly recommended) to evacuate the danger area as soon as possible through an Evacuation Order (Recommendation). The area covered by this Evacuation Order (Recommendation) should ideally be shown in an evacuation map and evacuation instructions should also be included. These should be pre-prepared in an Evacuation Order template.

Evacuation Instructions may include:

- Evacuate by foot or bicycle, or request assistance from the emergency management agency (provide a phone number to contact this agency).
- If applicable, evacuation by vehicle may be allowed under certain situations.
- Listen to your local radio station, or other local communication channels, for information updates.
- Evacuate to a friend’s or relative’s location, rather than an official assembly location or shelter, outside the danger area may be the most comfortable arrangement. If applicable, advise emergency management of your whereabouts.
- The locations of evacuation assembly sites.
- Check that friends and neighbours are aware of the evacuation order (recommendation).
- When leaving your home:
  - Turn off power, water, gas, etc.;
  - Secure home;
  - Take with you a radio, personal items, medicines, clothing and important papers;

  - Take pets with you. For larger animals, unless you can make immediate arrangements, they will need to fend for themselves.
  - Tell the emergency management agency where you have gone to, if possible.
- You will not be allowed to return until the threat has passed and the evacuated areas opened.
- You may not be able to return for some period of time depending on damage caused by the event. Plan for the worst.
- Follow instructions of emergency management.

2.4 DEVELOP PUBLIC AWARENESS

Awareness, education and preparedness programmes should at least address the following objectives:

- Increase people’s understanding of why tsunamis happen and its nature.
- Raise awareness on the important role of communities in preparedness and mitigation.
- Build capacity in planning and preparing to minimize the tsunami impact.
- Create empowerment and encourage communities to become more self-reliant.
- Focus on collective action instead of individual action.

The local emergency management agency, in cooperation with other departments and agencies, will establish public education campaigns and materials to prepare the public for tsunamis. There are many excellent examples of tsunami awareness materials from around the world. Mere distribution of tsunami evacuation maps to residents is not sufficient; it is important for residents to understand the tsunami risks and evacuation procedures. Information should also be tailored for disaster-vulnerable people, such as the handicapped, elderly, and children, as well as for foreigners and tourists.

There is no one best method or practice, and beyond some very basic key information that can be conveyed in many ways, there is no one best awareness publication or educational textbook.

Some formats building public awareness are: booklets, leaflets, flyers; posters; stickers; special interest stories – survivors, events; roadside signboards; public service announcements and media; advertisements (such as in telephone books).

Some methods of conveying information to the public are community meetings and workshops; assemblies & special event meetings; toys & games; drills, simulations, and exercises; publications, printed and electronic media; exhibitions; fairs, booths, and window displays; museums and videos to commemorate disaster

Some formats for education materials are: Books; teaching materials; booklets leaflets, flyers; newsletters; comics; toys & games; video, CD / DVD Rom; posters, stickers.

Some methods of educating (outside classes that are part of school education) are: Face-to-face teachings; training for trainers; community events and awareness days; memorials, assemblies & special meetings; drills and exercises; focus events for special needs communities (disabled, elderly, women and children); youth group activities.

2.4.1 Content of Public Awareness

Tsunami information that should be given includes:

- General tsunami science – what is a tsunami, what causes a tsunami, how fast does it travel, how big are the waves, how long are the waves dangerous.
- What are my tsunami hazards – historical tsunamis and their impact, local or indigenous knowledge.
- How to recognize a tsunami – natural warning signs.
- When and how, and from whom, will I receive tsunami warnings?
- What do I do when a tsunami warning is issued?
- Where do I go when I have to evacuate – on land, in the water, on boats.
- When and how will I know it safe to return to my home?

2.4.2 Examples of Public Awareness Materials

Materials should be provided in the national, and where pertinent local, language. If there are locations that are visited by tourists, then additional languages will be needed. Content should be customized to the national, and where pertinent, local situation for the tsunami hazard, tsunami warning dissemination, and for evacuation.

Examples of material created for the TEMPP Pilot in Honduras are part of the Specialized Documents (Part B) available for download.

The following are examples from different countries or regions covering what is a tsunami, safety rules, and the natural tsunami warning signs.

Figure S.60. Tsunami Warning Signs and Family Emergency information, front and back, size of business card, Honduras. Specialized document no VI.

Figure S.61. Tsunami Awareness materials, Honduras. Top left: What is a Tsunami; Top right: Tsunami natural warning signs; Bottom: What to do in a tsunami? Specialized document no VI.

The Tsunami Information Centre for the North-Eastern Atlantic, the Mediterranean and Connected Seas (NEAMTIC) created a tsunami information poster on ‘What is a Tsunami?’

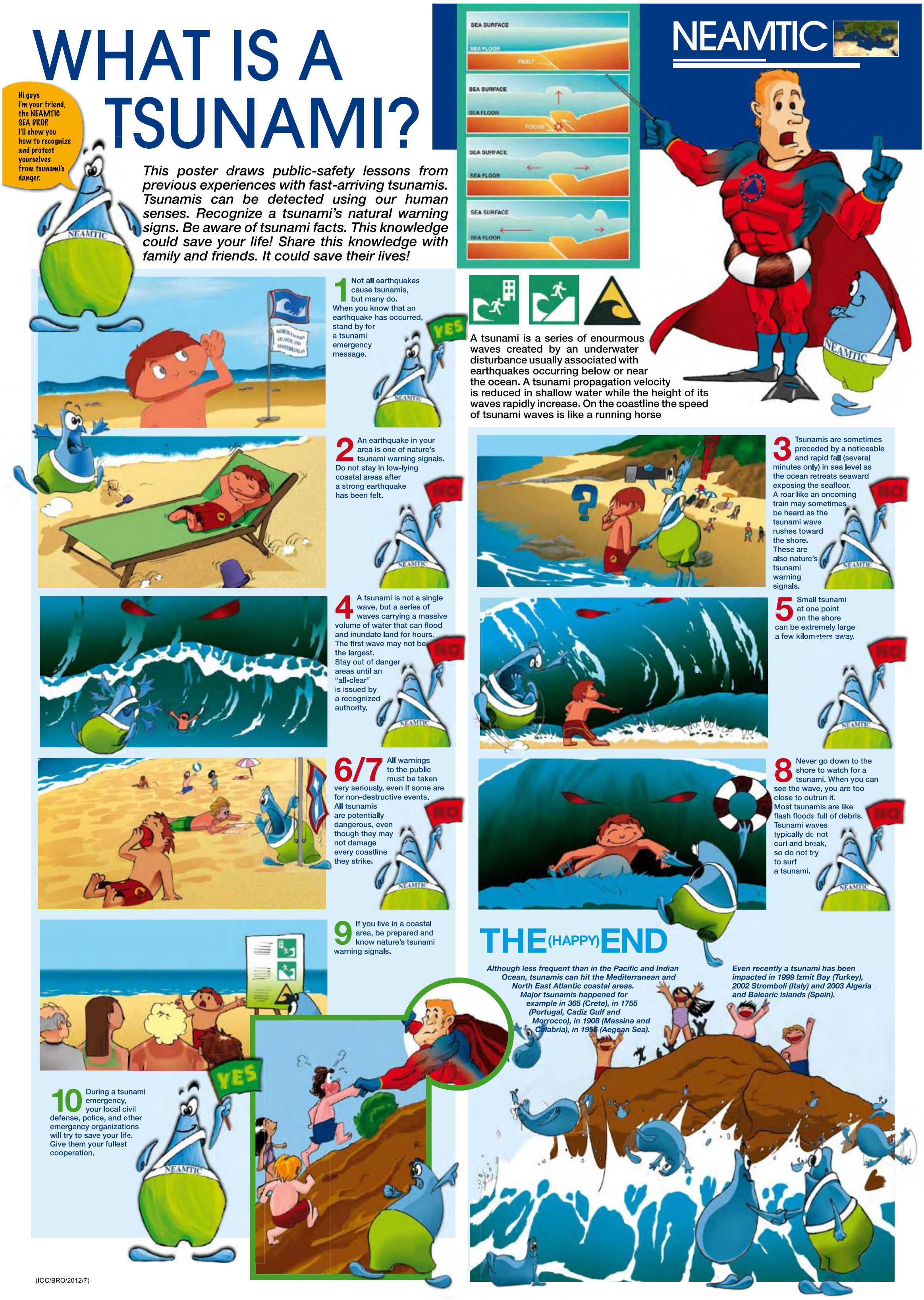


Figure S.62. What is a tsunami?
(Source: NEAMTIC)

Tsunami Safety Rules were developed by the [University of West Indies Seismic Research Unit]() under the Caribbean Tsunami Smart project. Materials are available in English, French, and Spanish and can be downloaded from the Caribbean Tsunami Information Center web site (https://www.ctic.ioc-unesco.org).

Figure S.63. Tsunami Safety Rules. (Source: CTIC)

Many countries have created simple to understand materials on a tsunami's natural warning signs. Examples are shown from Indonesia (Figure S.64, GIZ, BMKG), New Zealand (Figure S.65, MCDEM/NEMA), and the USA (Figure S.66).

Figure S.64. Awareness Flyer showing natural tsunami warning signs, alert status for evacuation, and example of media broadcast of tsunami information. (Source: Meteorological, Climatological and Geophysical Agency (BMKG), Indonesia.)

New Zealand Public Education resources are available for download at:
https://www.civildefence.govt.nz/cdem-sector/public-education/public-education-resources/tsunami-public-education-resources/

They include basic information on earthquakes and tsunamis in English and 22 other languages. Media include posters, video, radio public service announcements, and social media shareable.

Figure S.65. New Zealand Public Education resources (Source: MCDEM/NEMA)

In the US, communities are prepared if they are aware of their tsunami hazard and warning signs, know their evacuation zone, and regularly practice through drills – they are Tsunami Ready communities. TsunamiZone is a web resource that encourages knowing your zone and participating in exercises (https://www.tsunamizone.org/). Resources are available in multiple languages.

Figure S.66. TsunamiZone resources. (Source : The TsunamiZone, USA)

2.4.3 Strategies for Successful Awareness and Education of Public Awareness

In developing an awareness and education plan, important strategies include:

- Traditional knowledge. This can be a powerful tool in community preparedness. Although it may be the most effective means in a more traditional / rural / remote community, in general, traditional knowledge alone will not be enough to assure an effective response to early warning systems that are developing in countries. Additional information on early warning alerts and education on response and safe evacuation and return are needed.
- Community focus. Each country will have different priority issues related to education and awareness so that in general, education and awareness products should be tailored to the community-specific needs (hazards, geography, demographics, cultural/religious/social, etc.).
- Multi-faceted approach. To be effective, materials need to answer the questions of the target audience simply and clearly. These can be achieved through a variety of formal and informal education, awareness-building and preparedness activities, or programmes.
- Coordination and collaboration. Working together and coordination between the different agencies involved is essential. Involvement and commitment by all stakeholders will help to ensure sustainability.
- Sustainability through public policy. A tsunami education and awareness programme that is able to sustain itself over generations can be highly effective, and may be perhaps the only feasible (funded) mitigation for localities where tsunamis are infrequent.

Successful programmes take into account at least the following themes:

- Culture: Sensitivity to develop understanding and approaches that are built and based on local culture, beliefs and practices.
- Locality: Where possible and resources available, use of local context and language effectively to assure clear understanding and good communication.
- Diversity: Knowledge on the structure of the community and society to take advantage of its strengths.

2.4.4 Effective Dissemination

Below are suggestions on how to effectively disseminate and inform the community on warnings and tsunami evacuation maps.

1. Use various methods and tools to disseminate and inform on the evacuation maps:
    - Printed evacuation maps (posters, brochures, leaflets, inclusion in telephone books or other widely distributed public information books): Distributing a tsunami evacuation map to each household is the most basic way to inform residents. However, careful attention should be paid to the size of the map and the way it is distributed. The best size may be just large enough to post on a refrigerator.
    - Public displays of information: Large displays, signage, and bulletin boards can be especially helpful in reminding the public of what has happened in the past and what they should do in the future to save their lives. Display boards that show

the tsunami evacuation map for the community will immediately help. These can be specifically for disaster prevention, or it is also possible to use already existing community bulletin boards. Posting tsunami disaster management maps at bus stops, railway stations, and other public spaces, is also effective in informing tourists and visitors.

- Public or Community Meetings and Workshops: Local officials and scientists may want to offer citizens opportunities to learn and ask questions about their tsunami hazards, warnings, evacuation routes and assembly areas, vertical evacuation buildings (if there are any), and all-clear.
- Media (radio, television): Public Service Announcements, coverage of evacuation exercises or drills, coverage of meetings can reinforce tsunami safety and warning arrangements, as well as when, how, and where to evacuate too.
- The Internet: Due to the recent rapid spread of personal computers for home use, a large number of people are now able to acquire various information through the Internet and cable or satellite television on a daily basis. Many national and local governments are opening and operating web pages specifically tsunami awareness and tsunami evacuation. Tsunami evacuation maps are posted online, and often include tools for plotting your address to show if you are in the tsunami evacuation zone, or not.
- Mobile phone alerting: The proliferation of mobile phones over the last decade is enabling many to receive tsunami warnings anywhere through cell broadcast telecommunications. Often, these are embedded within emergency management phone apps that provide both the warning and also evacuation maps showing the individual where to go and how much time they have.

Over the last five years, mobile and electronic technologies have become a commonplace media for quickly and widely sharing information. Social media networks, such as Facebook and Twitter, and video sharing through YouTube, are popular and accepted around the world. Unlike information printed on paper, which requires time and cost for revision and redistribution, electronic information can be updated frequently and delivered immediately, and can be customized for the individual. The vital safety information should be short, concise, and actionable, and additionally visually interesting to hold the public's attention.

2. Implement ways to promote understanding of residents:

Tsunami evacuation maps must be prepared to be easy for the normal public, handicapped, elderly, children, and people speaking foreign languages to understand and use. Use of the maps by people who cannot read and write should also be considered, as well as transient populations. Universal design, such as pictograms, should be used for signs on maps, because it ensures easy understanding for all sorts of people.

Tsunami evacuation maps should not be unilaterally prepared by local authorities and distributed to residents, but should be prepared together with residents. Residents' should be encouraged to share local information and to provide recommendations on evacuation sites and routes. Community leaders play an important role because they will normally have a strong influence on the community's acceptance of maps and information.

- Conduct workshops: Local officials and scientists should offer citizens opportunities to learn and ask questions about their tsunami hazards, warnings, evacuation routes and assembly areas, vertical evacuation buildings (if there are any), and all-clear. A display of the evacuation maps during a workshop is an effective way to explain the threat and evacuation areas to residents. Volunteer disaster prevention organizations can assist with workshops to promote the residents' understanding.

- Promote learning at school: Tsunami evacuation maps can be used in learning disaster-related topics at school. By teaching children about the tsunami and other hazards from elementary school, a system can be developed to continuously educate people about disasters and related issues from childhood. It also creates opportunity for family members to talk about disaster prevention. School drills that practice tsunami evacuations are extremely valuable.
- Use of information technology (IT): To encourage residents understand and know how to use tsunami evacuation maps, measures should be taken to make people take ownership. An interactive evacuation map system can be constructed in which a user can see their risk, appropriate evacuation sites and routes, and video clips, just by clicking on their property.
- Training programs: Since damage by tsunamis varies depending on conditions of each region, experts can be trained as advisors on tsunami disaster prevention. Tsunami evacuation maps will be useful tools for the advisors to educate audiences about tsunamis, and to support teachers in delivering disaster prevention topics.

2.4.5 Ensuring Effectiveness of an Evacuation Map

To be effective, the tsunami evacuation map:

- Should not be distributed only once and never updated. It must be regularly reviewed, revised/updated, and distributed to the citizens as a reminder and to ensure that it incorporates any changes to the disaster-related environment and planned mitigation measures. Even if only minimal changes or updates are included in the revision, the distribution of new "updated" TIM is very valuable to refresh the community's awareness on tsunami hazard potential in their area.
- Must be well-communicated and well-understood by the community. Even if the evacuation map is extensively distributed, no evacuation or an incorrect evacuation may happen if the citizens do not understand the map. People must know where it is unsafe (evacuation zone) and where they must go to be safe (evacuation sites, assembly areas, vertical evacuation structures).
- Should be integrated into tsunami disaster management and community development planning as a whole. Residents will have greater appreciation if they know that tsunami hazard information was well-considered and integrated into the development planning (e.g., land use policy, non-structural measures, construction of structural measures) of their community. Such actions lets residents feel that they are part of the community planning process.

3 SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. These are found in Part B of the document.

- How to Create Community Tsunami Response Plans (example of response plan, template) (Specialized document no V)
- Awareness Materials - Warning and Evacuation information, Family Plan card (examples) Also pertinent to Module 4. (Specialized document no VI).

MODULE 4 – TSUNAMI EXERCISING

1. INTRODUCTION

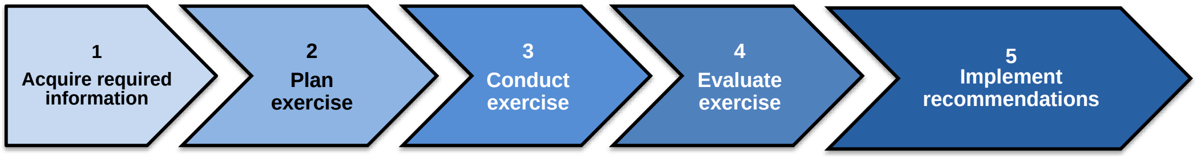


Figure S.67.Steps for Module 4 – Tsunami Exercising

A tsunami exercise helps in assessing the ability of an agency or system to respond to a local, regional, or ocean wide tsunamis. Exercises test communications, plans and standard operating procedures, and promote emergency readiness. Exercises can be carried out within a community, an agency, among several agencies, or jointly by all stakeholders. Pre-exercise planning and coordination and post-exercise evaluation are as important as the actual conduct of the exercise. Regular exercises are essential to maintain staff familiarity and efficiency for the real event, and especially important for tsunami response because of the infrequent occurrence of tsunamis.

Panic and chaos can be expected during a real tsunami event. A drill to create a practiced response can help minimize or prevent panic. Conducting unannounced drills can also help highlight areas that need fine-tuning or events for which the plan and procedures did not account for.

It is important that local authorities, emergency services, local utility and infrastructure providers, government agencies and other local partner agencies (such as the Red Cross and volunteer organizations) plan, train, exercise and respond together. Research shows that people generally respond to an emergency in the same way that they have been trained. International and more importantly, national and local exercises provide opportunities to practice training and skills in a simulated emergency environment. An example of an international exercise is the UNESCO/IOC Tsunami Wave exercises. While these exercises are an international undertaking, they allow for adaptation and customization at the national, regional and/or local levels to:

- Improve coordination,
- Improve operational readiness,
- Improve response time, especially important for local tsunamis,
- Identify planning weaknesses,
- Identify resource gaps,
- Improve inter-agency coordination and communications,
- Provide training,
- Clarify roles and responsibilities,
- Evaluate plans, policies and procedures,
- Test equipment, especially communications methods to the last one kilometre or one mile,
- Improve individual performance,
- Demonstrate capability,

- Develop the knowledge and skills,
- Promote public awareness, and
- Gain recognition of preparedness programs.

Organized since 2006, the UNESCO/IOC Tsunami Wave exercises are annual and bi-annual international exercises coordinated through the regional intergovernmental coordination groups (ICG/PTWS, ICG/CARIBE-EWS, ICG/IOTWMS, ICG/NEAMTWS)

For example, the Pacific-wide tsunami exercises have been an effective tool for evaluating the readiness of PTWS (Pacific Tsunami Warning and Mitigation System) countries and to identify changes that can improve its effectiveness. The exercises, using a multitude of Pacific scenarios and accompanied by tsunami message products from the PTWS Tsunami Service Providers (Pacific Tsunami Warning Center [PTWC], Japan Meteorological Agency's Northwest Pacific Tsunami Advisory Center [JMA/NWPTAC], the South China Sea Tsunami Advisory Centre [SCSTAC], and Central America Tsunami Advisory Center [CATAC]) have been used to measure the readiness of countries to respond, as national tsunami warning centres and emergency response agencies and the public, to distant and local tsunamis. In many countries, the Pacific Wave exercises have been conducted down to the local levels where communities practice their disaster response and evacuation plans.

Under the UNESCO/IOC Tsunami Ready Pilot Programme (http://www.tsunamiready-international.org), annual community drills that build a community's readiness to evacuate during a tsunami warning, as well as public awareness outreach, are requirements.

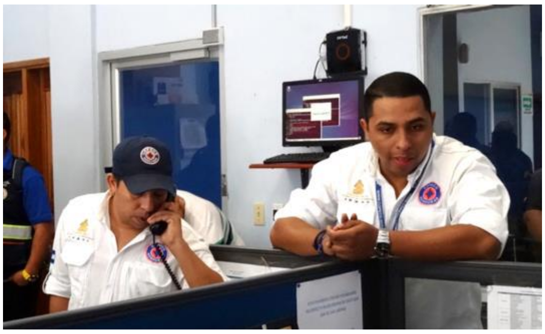


Figure S.68. Tsunami Drill, Honduras, February 2017. Top left: Honduras National Tsunami Warning Center (COPECO), Exercise Pacific Wave, 16 February 2017; top right and middle: Cedeño, Honduras, Community and School Tsunami Drill, 17 February 2017; bottom: left: Teacher conducting head count at Assembly site; right: Students reading Tsunami Warning! Comic book (IOC/INF-1223). (Photos courtesy of (top) © ITIC; (middle) © COPECO, Honduras; (bottom) © UNESCO/B. Aliaga)

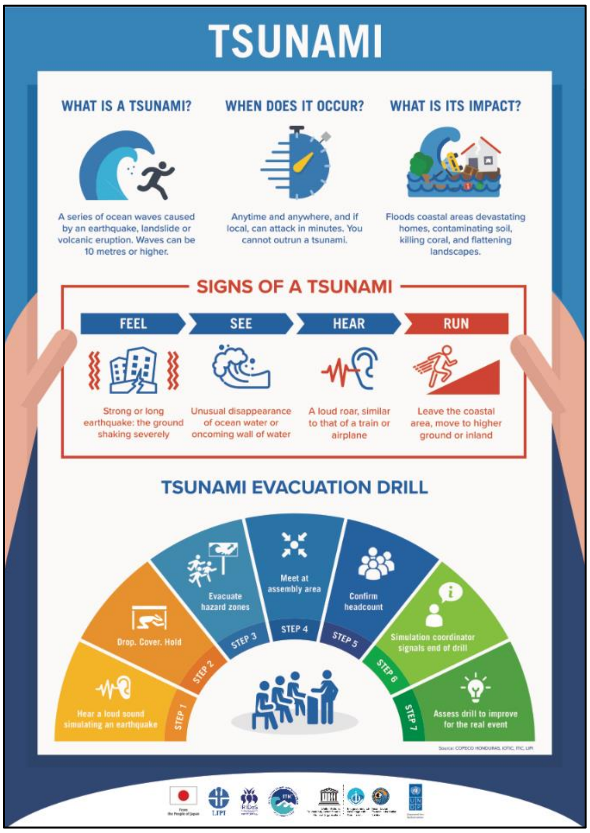


Figure S.69. Tsunami Awareness and Evacuation Drill Poster (UNDP and partners, 2017)

For schools located in evacuation zones, annual drills are held, wherein the school principal and teachers will take the responsibility to evacuate the school-children in case of a real tsunami. Since 2017, the United Nations Development Organization (UNDP), with the support of Japan, has led a regional initiative to strengthen school tsunami awareness and preparedness in the Asia and Pacific (Strengthening School Preparedness for Tsunami in Asia and the Pacific).

The #90Drills and #PrepareToWin global advocacy campaign has supported more 115 school drills reaching over 60,000 students, teachers, and school administrators in 18 countries. The drills are not an end in themselves. They must be conducted regularly, as each year new students enter schools. The school tsunami preparedness is part of a broader initiative targeting whole of society preparedness.

The IOC document entitled Methodological guidelines: How to prepare, conduct and evaluate a community-based tsunami response exercise (draft, 2017, English, French, Spanish) is available, and templates and examples of an exercise flyer, exercise plan, evaluation questionnaire, and awareness materials are available as part of the Supplement Specialized Documents (Part B).

2. MODULE CONTENT

2.2 ACQUIRE REQUIRED INFORMATION

2.2.1 Analyse the Need

All exercises emerge from an identified need. A needs assessment is conducted to identify whether an exercise activity is required. For example, at the Twentieth session of the Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS), Member States recognized that the Pacific Tsunami Warning System (PTWS) requires regular testing and review and noted that simulating scenarios and identifying lessons through exercises is an effective way to improve tsunami preparedness. Before 2008 there had never been a Pacific-wide exercise before, it consequently recommended that Exercise Pacific Wave be conducted and that tsunami exercises be carried out at regular intervals in the future.

In each international exercise, it has been left to Member States to decide and select their level of involvement in the Tsunami Wave exercises in accordance with their needs. Undertaking a needs assessment at a country-wide or provincial/local level provides an opportunity to:

- Understand a country/agency's requirements,
- Identify issues,
- Establish the reasons to do an exercise, and
- Identify the parts of the end-to-end process to be exercised.

2.2.1.1 Conducting Needs Assessment

To conduct a needs assessment for your country/agency, the following steps serve as a guide:

1. Review your country/agency's emergency management plans at the national, provincial, local/village levels, addressing:
    - What hazards and risks associated with tsunami is the country/ agency most likely to face, and what are the priority levels of these?

- What area(s) are most vulnerable?
- Are 24/7 alert communications systems and Tsunami Emergency Response Plans / Standard Operating Procedures (SOPs) connected from the national to provincial to the local/village levels?
- What functions or components in the plan need some practice?
- What are the country/agency's current priorities?

2. Consider past exercises:
    - When particular functions or aspects were last exercised and what type of exercise was conducted?
    - Who (staff and agencies) participated in the previous exercise(s) and who did not?
    - To what extent were previous exercise objectives achieved?
    - What lessons were identified?
    - What problems were identified, and what was needed to resolve them?
    - What improvements were made following the past exercise(s), and have they been tested?

3. Identify available resources:
    - Is there a budget to deliver the exercise?
    - Does the agency have the resourcing to tailor the exercise further, and what staff and time commitment will be required to do this?
    - What are the country/agency's liabilities? (e.g. lack of trained staff)
    - What limitations could the country/agency face in developing or delivering the exercise?

4. Review the finding: The needs assessment should reveal the following issues if they exist:
    - Primary and secondary hazards that the country/agency faces,
    - Issues that need to be resolved,
    - Issues that recur,
    - Skills that need to be practiced,
    - Functions that are weak or uncertain,
    - Improvements made that need to be tested,
    - New facilities, personnel, or equipment that have not been included in an exercise before,
    - Weaknesses (such as gaps, conflicting policies, or vague procedures) in the emergency plan or the standard operating procedures,
    - The need to clarify exercise coordination and working with other agencies,
    - The need for a certain type of exercise,
    - Budgetary and resourcing issues,
    - Risks.

2.2.2 Establish Aims, Objectives and Scope

2.2.2.1 Aims

The aim is a broad statement of intent. It provides the direction for what is to be achieved by the exercise.

Writing the exercise aim

The aim should begin with a verb and should be positive, clear, concise and achievable. It must be broad rather than specific. There should be only one aim for a tsunami exercise. However, each participating country/agency may wish to develop a specific country/agency aim to complement the overall aim of the exercise. Examples of exercise aims:

- To improve local and regional source tsunami warning capability in the Pacific.
- To participate in the international tsunami warning exercise.

2.2.2.2 Objectives

An objective is a statement of what is to be done and should be stated in terms of results. In other words, an objective should state who should do what, under what conditions, according to what standards. Objectives go hand-in-hand with the aim but are more specific and performance based. Objectives should be expressed in a way that informs participants what they will be working towards, evaluating or observing. They form the basis of the exercise design process and the eventual exercise delivery. Writing the objectives is also the starting point for the evaluation process. During the exercise, the evaluators assess whether the exercise is meeting the objectives.

(i) Identify how many objectives:

There can be as few as two or three objectives in a small exercise, or they can be many in a large complex exercise that includes multiple agencies. No more than ten objectives per agency are recommended. Each participating agency is encouraged to develop its own specific objectives in addition to the main exercise objectives to serve its specific needs.

(ii) Characteristics of good objectives:

Objectives must be clear, concise, and focused on participant performance. They should contain:

- An action or behaviour stated in observable terms,
- The conditions under which the action will be performed (including any tools or assistance to be provided), and
- Standards (or levels) of performance.

(iii) SMART objectives:

Objectives can also be tested against the ‘SMART’ guidelines described below:

S	**Specific**	Objectives should specify what they want to achieve, i.e., what results is the agency looking for?
M	**Measurable**	How will the objective be measured? The objective should set the level of performance, so that results are observable, and you can

		identify when the objective has been achieved. Depending on the objective, it can set a quantifiable standard or it can simply be stated in a way so that people can agree on whether they succeeded.
A	**Achievable**	The objective should not be too difficult to achieve. For example, achieving it should be within the resources that the agency would reasonably be expected to commit to in a in a real event.
R	**Realistic**	The objective should present a realistic expectation for the situation. Even though an objective might be achievable, it might not be realistic for the exercise.
T	**Task oriented or time driven**	The objective should focus on a behaviour or procedure. With respect to exercise design, each objective should focus on an individual function. Objectives should also be time driven stating when something should be completed by.

(iv) Examples of objectives:

For Exercise Pacific Wave 2011, the following objectives were selected:

- Utilize PTWC experimental products, including forecast models and other science information, for timely national hazard assessment.
- Validate that the dissemination of warnings and information/advice by National Tsunami Warning Centres to relevant in-country agencies and the public is accurate and timely.

2.2.2.3 Key Performance Indicators

Key Performance Indicators (KPIs) are tools used to help an agency define and measure progress towards exercise objectives. A KPI may further define an objective, and is helpful when formulating the evaluation tool or measures.

Examples of KPIs are:

- The information issued by our national decision-making and dissemination point was timely.
- Arrangements to assemble the in-country disaster management group relevant to decision-making on tsunami warning and response were in place before the exercise.

2.2.2.4 Exercise Participants

<u>Category 1 Participants:</u>

The ‘players’: those participants that will play their role as they would in real-life situations (e.g. agency individuals, people affected by tsunami).

<u>Category 2 Participants:</u>

Exercise control and delivery teams: they define the rules, boundaries, and timeline for the exercise, deal with all practicalities and logistics, and ensure an appropriate level of realism in the exercise. They also monitor and modify the way in which the simulation runs, with safety always a priority.

Category 3 Participants:

Evaluators and Observers – individuals invited to analyse the performance of the Category one participants and the conduct of the exercise. Should not take part in the exercise. Their findings are used to develop an exercise report and post-exercise corrective action plan.

2.2.3 Types of Exercise

There are five types of Tsunami Exercises identified by UNESCO (2008 and 2013), see also Table S.6.

Type #1: "Orientation" Workshop

- A simple Orientation Workshop lays the foundation for a comprehensive exercise programme.
- Provides an overview of relevant authorities, strategies, plans, policies, procedures, protocols, resources and ideas, for example for new staff and/or leadership.
- Brings together organizations (government, NGO's, private sector) in developing emergency response planning, problem solving, SOP's, and resource integration, or for refreshers.
- Offers a good starting point for jurisdictions that are developing or making major changes to their plans and procedures.
- Is a useful method to determine exercise objectives, scenarios, evaluation elements and standards of performance.

Type #2: "Drill"

- Drills involve emergency response of single organizations, facilities, places, or agencies such as a hotel, school, village, or testing of a single operation or function (i.e. internal communications and/or field activities).
- Performance can be evaluated in isolation or as a subset of full-scale exercises.
- Drills are used to test response time, train personnel, assess the capabilities of the equipment, assess the cooperation between agencies, or to determine whether the capabilities of the resources and personnel staffing are sufficient.

An example of a drill is a Tsunami 'WalkOut'. This type of drill stresses simplicity and fun, and is suitable for coastal schools, work places, residents, or visitors. 'WalkOut' participants will be made aware of tsunami danger zones and tsunami safe zones - and that they can walk from one to the other, creating a long-lasting tsunami awareness.

Type #3: "Tabletop Exercise"

- Takes place in an informal, slow paced environment, and is used to assess plans, policies, and procedures.
- May involve senior and key staff members of government and non-government organizations, elected or appointed officials gathered in one location.
- An Exercise Controller (moderator) introduces a simulated tsunami scenario to participants via a written message, simulated telephone or radio call, or other means, and questions or problems (injects) are introduced for discussion.
- Participants will examine and resolve the questions and problems, and discuss their actions based on their organization's SOP's.

- Participants conduct group discussions, and resolution is generally agreed upon, and then summarized by a group leader.

Type #4: “Functional Exercise”

- Conducted by responding to real time simulation tsunami notifications and other injects.
- Designed to test and evaluate specific or multiple activities within an agency, or interdependent groups of activities among various agencies.
- Used to practice and test the performance of SOP’s, communications, and/or EOCs.
- May or may not include drills (i.e. public evacuation drills).

Type #5: “Full-Scale Exercise”

- Largest, costliest and most complex exercise type.
- Involves all stakeholders in the end-to-end warning and response process at national, provincial, and local levels.
- Involves activation of EOCs and mobilization and deployment of response personnel.
- Tests all aspects of emergency response and interagency cooperation.
- Will likely include drills (i.e. public evacuation drills).

Types of Exercise	Orientation	Drill	Table Top	Functional	Full Scale
FORMAT	Informal discussion in group setting. Various presentation methods.	Actual field or facility response of a specific element or function. Actual equipment is used or a physical action performed.	Group discussion of a scenario or problem. Presented narrative scenario; can be facilitated by exercise control. Players note or present their solutions or outcomes	Players respond to a scenario in real or condensed time and in a realistic environment. Narrative scenario facilitated by exercise control. Players are evaluated. Interactive and complex.	Players respond to a scenario (with simulated enactments) in real time. Visual narrative, players exercise in actual centers and/or impact site(s). Tsunami Warning Centre (TWC) actions trigger Emergency Operations Centre (EOC) actions. EOC actions trigger community actions. Actions at scene serve as input to EOC simulation. Interactive and simple or complex.
LEADERS	Manager, supervisor, department head, or exercise coordinator	Manager, supervisor, department head, or exercise coordinator	Facilitator	Exercise Coordinator	Exercise Coordinator
PLAYERS	Single agency/ department or cross-functional staff	Functional staff	Normally staff of the same level with a warning/response role for the type of situation	All staff with warning/response roles for that function	All or specific staff with warning/response roles
FACILITIES	Conference room	Facility, field, or Emergency Operations Centre	Conference room(s)	Tsunami Warning Centre, Emergency Operations Centre, or other operating centre.	Realistic 'on the ground' setting TWC, EOC, or other operating centre.

Table S.6. Types of Exercises
(Source: UNESCO/IOC – NOAA International Tsunami Information Center, www.tsunamiwave.info)

2.3 PLAN EXERCISE

2.3.1 Exercise Task Team

The Exercise Task Team members should be experienced in exercise management and project management, and be capable and able to dedicate a considerable amount of time to the exercise planning. The team is responsible for the successful execution of all aspects of the exercise, including exercise planning, conduct, and evaluation. They will develop the exercise narrative, Master Schedule of Events List, and exercise injects. Technical specialists and subject matter experts will be involved to help provide realistic information to the scenario and messages and injects. The team uses the exercise aim and objectives to determine the evaluation criteria and evaluation tools for the exercise and will also develop appropriate promotion and media strategies prior to the exercise. Afterwards, the Task Team is responsible for collating the exercise evaluations and writing the Exercise Report.

The Exercise Task Team must have representatives from participating stakeholders but should be kept to a manageable size. External agency representatives act on behalf of their agency during both the design and delivery phases of the exercise; their responsibilities include:

- Being the main point of contact for their agency.
- Providing expert advice and input from the department or agency, they represent.
- Having input into the scenario and providing control documents as required.
- Ensuring their agency input is consistent with that of other agencies, and the aims and objectives of the exercise.
- Responding to requests from exercise participants through either prepared control documents or the creation of new control documents.

During the delivery of the exercise, agency representatives may become simulators or role players where they will respond to requests from exercise participants through either prepared control documents or the creation of new control documents.

Generally, Exercise Task Team members are not exercise players. Instead, due to their high-level involvement, members are ideal for exercise control roles and/or evaluator positions during the exercise, described below.

(i) Exercise Control staff: Exercise control staff are responsible for:

  - Managing the inputs into the exercise.
  - Facilitating the progress of the exercise scenario through the controlled flow of information, using control documents/injects as per the Master Schedule of Events List.
  - Representing stakeholders that do not participate in the exercise through role-play.
  - Providing corrective advice to agencies to facilitate the momentum and flow of events.
  - Ensuring appropriate risk management considerations during the exercise.

(ii) Exercise Director: The overall Exercise Director is in charge of the execution of the exercise. This could be the chair(s) of the Exercise Task Team, or the leader of the relevant tsunami warning centre. On completion of the exercise, the exercise director will produce the Exercise Report and may oversee the implementation of recommendations made in the report.

(iii) Evaluators: Evaluators should be subject matter experts in the field they are evaluating, such as in warning centre operations, emergency response, or in specific agency areas of responsibility. The Exercise Evaluators are responsible for:

- Evaluating against objectives and/or key performance indicators (KPIs).
- Observing and assessing processes, procedures and techniques.
- Evaluating and reporting on achievement of outcomes and the extent to which the overall exercise objectives have been met.
- Evaluating the effectiveness of exercise facilitation and management.
- Providing input into the exercise debrief.

Note: An evaluator does not generally mentor, coach or act as exercise controller.

2.3.2 Scenario

The scenario is a narrative that describes a tsunami event to which the exercise participants will need to respond to. It provides a brief description of the events that have occurred up to the minute the exercise begins. The scenario must be both realistic and practical.

The scenario has two important functions:

- It gives the background and sets the mood for the exercise, captures the participants' attention, and motivates them to continue their participation.
- It sets the stage for the information (injects) that the participants will need during the exercise.

The Exercise Task Team develops the exercise scenario (or series of scenarios). The Task Team calls on technical expertise to produce the tsunami scenario(s), and to decide on the warning arrangements that will trigger the exercise. Each agency is expected to use the scenario to further refine and add detail to describe the event's impact on specific services or sections of their business (such as the warning centres or emergency operations centres) and/or community. They may also address effects beyond the immediate impact area, along with a timeline for restoration of key infrastructure and utilities. Further details could include a clear definition of the number of victims and displaced people and the extent of damage.

The details of the scenario is not normally made available to exercise participants before the exercise. Instead, it is used by the Exercise Task Team to develop the exercise. The scenario will also help in the writing of the Master Schedule of Events List.

The outline of the scenario (for example 'an earthquake generated off the coast of Chile, causing a Pacific-wide tsunami') would be sufficient information to provide to exercise participants before the exercise.

2.3.3 Exercise Documents

2.3.3.1 Exercise Announcement

When the exercise aim, objectives, date and time are established it must be announced to stakeholders and if appropriate, the media. Tsunami Wave exercises, for example, are announced via a Circular Letter which is ideally distributed to members at least 180 days in advance of the exercise. The Circular Letter provides overview information on:

- Date of the exercise,
- Aim and objectives,
- Exercise scenario(s),
- General conduct and arrangements, and
- Further information on additional resources available, such as the Tsunami Wave Exercise Manual, Tsunami Wave website, press releases, etc.

2.3.3.2 Exercise Manual

Once the outline scenario has been developed by the Tsunami Wave Exercise Task Team, the Exercise Tsunami Wave manual is produced. The Exercise Tsunami Wave manual is the major exercise document produced and is used to inform members and agencies involved about the basic details of the exercise. The Tsunami Wave Exercise Manual is made available to Tsunami Wave National Contacts at least 90 days in advance of the exercise. The Manual provides detailed information about the conduct of the exercise to exercise participants, including:

- An exercise overview,
- Scenario(s) details,
- Parameters and assumptions describing how the exercise will be carried out,
- Master Schedule of Events List (timeline listing all messages and injects, including the exercise start and exercise end messages),
- Products issued, including how they will be disseminated,
- Post-exercise evaluation method and questionnaire forms.

The manual can be printed in hard copy, or if voluminous, distributed electronically to the Tsunami National Contact (TNC), Tsunami Warning Focal Point (TWFP), and National Exercise Coordinators in each country. Each National Exercise Coordinator should distribute the Manual to the National Exercise Planning Team, and is encouraged to forward it also to all relevant in-country agencies' representatives.

2.3.3.3 Exercise Injects

Exercise injects are the individual notifications and messages that will trigger exercise activities. All injects should be clearly marked with 'EXERCISE' so as not to be confused by real events. The table below shows the timeline and injects issued by COPECO for the Cedeño, Honduras exercise. Times were compressed to facilitate this exercise.

Date	Local Time	Issuer	# Message	Type of Bulletin/Comments
16-Feb-2017	9:10	COPECO	001-2017	Informational Bulletin. Earthquake parameters will be provided (Based on Message 1 of PTWC–14:07 UTC)
16-Feb-2017	9:25	COPECO	002-2017	Green Alert (Based on Message 2 of PTWC–14:35 UTC)
16-Feb-2017	10:00	COPECO	003-2017	Yellow Alert (Based on Message 3 of PTWC–15:00 UTC and Local Observations)
16-Feb-2017	10:25	COPECO	004-2017	Red Alert (Based on Message 6 of PTWC–18:00 UTC and local observations)
16-Feb-2017	11:00	COPECO	005-2017	Red Alert /End of Threat (Based on Message 26 of PTWC–14:00 UTC–16 FEB 2017)
16-Feb-2017	11:10	COPECO	006-2017	End of Drill (Based on local inspection and in consultation with national authorities)

Table S.7. Timeline of Messages issued by COPECO for Cedeño, Honduras exercise.

2.3.4 Media Involvement

Media involvement will vary from country to country, from a paragraph in a newspaper to television coverage of an evacuation drill to information transmitted to the public via media networks. It is important, however, to ensure that the media and public know about the exercise beforehand so that they do not mistake it for a real tsunami warning.

If the media will be invited to cover the exercise, complete details of the activities should be provided, such as special events or ceremonies. Media may be invited to participate and/or be simulated by Exercise Control staff. The role of the media should not be underestimated in raising tsunami awareness to the public.

2.3.5 Preparing and Setting Up

2.3.5.1 Timeline and Milestones

An exercise timeline outlines the timeframes for reaching significant milestones. This is particularly important when planning major exercises. For example, the Exercise Tsunami Wave Task Team uses a project management approach to ensure all the steps happen in the right order. When developing the timeline, the Exercise Tsunami Wave Task Team selects a date for the exercise and then, working backwards, inserts the key milestones into the timeline. There are certain timeframes that must be adhered to such as issuing the Exercise Manual no later than 90 days before the exercise – these must be worked into the timeline.

2.3.5.2 Exercise Briefings

Briefings needs to be provided to all participants involved to orient them on the upcoming exercise. The types of briefings are Initial, Exercise Control staff and Evaluator briefings.

Initial Briefing.

Initial briefing needs to focus all the participants on the key points of the exercise, which are:

- Timings: timings and durations of participation needed.
- Exercise boundaries: What can and cannot occur in terms of role playing and also operational response. The physical boundaries of the exercise.
- Locations: Locations of key venues or activities where relevant.
- Expected outcomes: what is expected as a result of the exercise?
- Safety: What emergency procedures for the exercise are.
- Exercise logistics: What the logistical and administration arrangements for the exercise are. What will happen in case of a real warning or emergency?

Exercise Control Staff Briefing

A briefing is needed for the Exercise Control Staff that expands on the initial briefing to cover the exercise control duties/activities. This briefing is only for the exercise control staff and will not include other participants of the exercise.

Evaluators Briefing

A briefing for exercise evaluators is required to familiarize them with the exercise objectives and KPIs, the exercise venues and their task and boundaries. This is also the evaluators' opportunity for clarification or questions and make sure that they have a complete understanding of their roles and responsibilities.

Once all briefings are done, the exercise can commence.


Figure S.70. National (left) and local (right) stakeholder briefings prior to Cedeño, Honduras Community Drill, 17 February 2017. Photos courtesy of COPECO, Honduras (left) and C. Cardenas-Hincapie (right).

2.3.5.3 Setting Up

The Exercise Task Team will be responsible for the preparation and setup of the exercise, including room setup and physical facilities. Simple exercise types may require very little in the way of setup; the more complex the exercise the more setup will be required.

It is important to conduct the exercise in the location(s) where normal operations would take place and to set it up as it would be for a real event in order to simulate reality. The type of setup will vary depending on the size and complexity of the exercise. When using control staff, a separate exercise control room or facility must be set up from where Exercise Control can send, receive and track messages and other communications with players. The exercise control room will need to be equipped with the necessary communications equipment, e.g. radios, fax, computers and phones, as well as display and map boards or other means to keep track of exercise progress. Control staff may require large printouts of the master schedule of events.

Exercise venue(s) should be organized well in advance with consideration given to:

- Site or location selection and suitability,
- Approval to use site or location,
- Pre-planning site inspection,
- Site access,
- Site control and security,
- Site realism and detailed staging to suit the scenario,
- Damage control requirements,
- Site safety requirements and arrangements,
- Staging areas,
- Car parking,
- Power/gas,
- On site amenities,
- Role players and moulage (i.e. victim simulations for field exercises),
- Documentation (videography, photography).

Appropriate communications and Information Technology must be in place at venues. Examples are:

- Telephone lines,
- Internet Broadband access,
- Fax machines,
- Cellular phones,
- Commercial radio and/or television monitors,
- Computers,
- Printers,
- Photocopiers,
- Radio communications, and/or other dedicated or direct communications methods,
- Satellite phones,
- Exercise log,
- Display boards,
- New technologies such as motion hazard maps and smart devices (Kawai, et al., 2016), and smart glasses (Kawai, et al., 2015).

Maps are important decision-making and response aids. Examples that may be required are:

- Topographical maps.
- Cadastral maps, including shelters, safe assembly areas, critical facilities, schools and special needs populations and first responder locations.
- Historical seismicity and tsunami maps.
- Pre-calculated scenario maps (tsunami travel times, energy distribution, offshore wave heights).
- Inundation maps.
- Evacuation maps.

Other set up considerations include:

- If the media are involved, an appropriate facility and communications,
- Accommodation for visiting staff, evaluators and observers,
- Transportation – ground, air, and transfers,
- Catering – Meals and refreshments,
- Identification and access control to exercise venues,
- Access arrangements – players, visitors and observers,
- Office supplies – stationery, forms, clipboards,
- Documentation – plans and SOPs, duty manuals,
- Finance – authorisations and accounts,
- General administration – cleaning, security, toilets, liabilities and insurance,
- Public relations – media and other coverage before the exercise, during the exercise, and after the exercise (newsprint, exercise website, etc.).

2.4 CONDUCT EXERCISE

Exercise Control staff are responsible for running the exercise. This includes starting and stopping the exercise and introducing injects (e.g., tsunami notifications or products) into exercise play.

2.4.1 Starting the Exercise

The exercise may be started immediately following the last participant briefing. The Exercise Director ensures that all Exercise Control staff are in place and are ready to begin. Exercise Control are responsible for sending the initial "Exercise Start Message" in the form of the first inject.

2.4.2 Controlling the Exercise

Exercise Control use the Master Schedule of Events List (MSEL) to facilitate the exercise. They ensure that any problems are rectified to keep the exercise flowing. The Exercise Director can modify the flow of the exercise to ensure objectives are met.

Exercise Control staff have a range of responsibilities in order to keep the exercise running; they need to stay in contact with the Exercise Director throughout the exercise. Activities involve:

(a) Introducing injects

Once the exercise has started and participants are in place the exercise injects are introduced into exercise play in accordance with the Master Schedule of Events List. The injects may be disseminated via the international and regional tsunami warning centre or by each agency Exercise Control. Control staff must mark off on the Master Schedule of Events List when injects are 'sent'. Injects are marked with an exercise inject serial number (e.g. #001).

(b) Encouraging spontaneity

Players should be able to decide among the full range of options normally available to them during an emergency. To allow for participant spontaneity Exercise Control staff must be well trained and prepared to handle the unexpected so that actions and activities can be brought back into the exercise objectives if required. If there is a danger that free-play or a reaction will have a negative effect on the exercise, the spontaneous addition of a problem or solution inject may correct the flow.

(c) Sustaining and controlling exercise activities

Sustaining exercise activity is achieved by the continuous inject of exercise information to the participants. This needs to be closely monitored to ensure that the information is released at appropriate intervals or times. Depending on how well participants react to the injects, the rate of injects may need to be increased or slowed down. It may be necessary to add or remove injects to accommodate the pace of the exercise.

In case of a real event during the exercise

In the case of a real event occurring during the exercise, the corresponding notifications for that event will be issued as usual, and must be given priority above the exercise. An announcement must be made in this regard to all exercise participants by the Exercise Director, including a decision whether to continue with the exercise.

Avoiding false alarm

While an exercise is conducted the potential exists for the public or media to interpret the event as real ("false alarm"). The media and local communities must therefore be made aware of the exercise before it starts, and all exercise documents and communications must be clearly prefaced by " Exercise [name of exercise]" to ensure that there will be no misinterpretation.

2.4.3 Concluding the Exercise

Ending the exercise is a controlled activity. The Exercise Director stops the exercise at a pre-planned time either through a formal announcement to all exercise participants. If filed staff were involved, they must be accounted for.

Following the end of exercise an immediate hot debrief should be facilitated for all players at the respective exercise venues to capture information and feedback while it is still fresh in their minds. The feedback must be collated and written up so that it can be available for the Exercise Report. (See Hot Debrief below).

2.5 EVALUATE EXERCISE

Figure S.71. Exercise evaluators (left) and post-exercise hotwash (right) for Cedeño, Honduras Community and School Tsunami Drill, 17 February 2017. (Photos courtesy of ITIC)

The objective of the exercise evaluation is to validate the strengths and identify opportunities for improvement of participating organization. This will be accomplished by obtaining feedback data from evaluators and participant debriefs, and the subsequent analysis of the data against the objectives of the exercise.

Whilst the evaluation is conducted during the actual exercise, the evaluation tool and/or associated forms are developed by the Exercise Task Team during the design phase of the exercise.

In IOC Tsunami Wave exercises, the evaluation plan is contained in the IOC Exercise Tsunami Wave manual. The manual will provide information on the exercise scenario, schedule of events, conduct, and evaluation tools and schedule. The format and content of evaluation tools for Tsunami Wave exercises may vary over the course of time. The overall evaluation tool/forms are prepared and disseminated by the Exercise Tsunami Wave Task Team.

The exercise is evaluated through the following activities:

- Exercise Evaluators forms/reports,
- Participant debriefs,
- Exercise Task Team debrief, and
- Validation and Report.

Each agency is responsible for appointing its own exercise evaluators. An evaluation guideline or analysis form will prompt the exercise evaluator(s) to look for certain actions in the exercise and will allow them to determine whether objectives and key performance indicators were met.

The Exercise Task Team should provide them with a document in writing that provides:

- Evaluator instructions: step-by-step instructions for evaluators regarding what to do before they arrive (e.g. review exercise materials, wear appropriate clothing for assignment), as well as how to proceed upon arrival, during the exercise, and following its conclusion.
- Evaluator tools include:
    - Exercise Aims and Objectives,
    - Exercise-specific evaluation guidelines and analysis forms,
    - The Master Schedule of Events List,

- Reference materials such as Plans and SOPs, and background information with regards to decision-making, and
- Clocks or other quantitative measures of performance, or video/photographic equipment.

Exercise Evaluators must be debriefed to allow them an opportunity to share and test their observations and findings with each other, and to allow Exercise Control to start identifying finding themes. This can happen immediately after or a few days after the exercise. Following the debrief they are given an opportunity to finalize their evaluations before the evaluation forms are collated by Exercise Control.

When writing their analyses, evaluators should consider the following questions:

- Were the objectives of the exercise met?
- What were the key decisions associated with each activity?
- Did observations suggest that all personnel would be able to successfully complete the tasks necessary to execute each activity? If not, why?
- Did observations suggest that all personnel are adequately trained to complete the functions, activities or tasks needed to demonstrate a capability?
- Did observations identify any resource shortcomings that could inhibit the ability to execute a function or activity?
- Did observations suggest that the current plans, policies, and procedures appropriately support performing the respective functions or activities? Are players familiar with these documents?
- Did observations indicate that the agreements or relationships in place to support the coordination required between agencies?
- What strengths were identified for each function or activity?
- What areas for improvement are recommended for each function or activity?
- How was the exercise run?
- What should be learned from this exercise?

2.5.1 Participant Debriefs

A post exercise debrief is a critical review of the entire exercise by participants and exercise control staff. It identifies those areas that were handled well and those areas where issues were experienced and can be improved. Depending on the size of the exercise, debriefs can be conducted by each agency individually, or jointly by all agencies/participants. If individual agency debriefs are held, they should follow a consistent process and format to support the collation of the respective debrief findings into the Exercise Report.

It is important that all staff are involved regardless of seniority, and understand that the debrief is about improving performance of the system as a whole, and not about assigning fault or blame. The expectation to participate in the debrief process should be communicated to all agencies prior to the exercise.

If agencies chose to involve members of the community in the exercise, these participants should also be given an opportunity to be part of the debriefing process. This might take the form of a separate debrief through a public meeting. The feedback from the participating public or community must be fed into over-all debrief findings.

Debriefs should be run by an experienced facilitator to:

- Determine what went right, what went wrong and why, without laying blame.
- Note specific questions that arise with regards to achievement or non-achievement of objectives.
- Acknowledge good performance.
- Ensure constructive feedback from those being debriefed.
- Focus on procedures.
- Summarize and confirm key points with the audience.
- Record the feedback to enable reports to be compiled.

Depending on the size of the exercise and the number of participants, there may need to be a series of debriefs building on one another.

Participant debriefs are usually held in two stages:

- Hot debrief

Held immediately after an exercise, a hot debrief (or ‘hotwash’) is an opportunity for all participants to provide feedback while the exercise is still fresh in their minds.

A suggested format for a hot debrief is:

    - Allow a short break of about 10 minutes after the end of the exercise.
    - The Exercise Director thanks participants for their participation and gives their initial impression of the exercise.
    - Participant round-table feedback – per function or per topic.
    - Exercise Evaluators provide their initial feedback.
    - Other comments (open agenda).
    - Acknowledgements.

- Cold debrief

A cold debrief is a more formal debrief held within four weeks after the exercise. The cold debrief involves all participants (excluding Exercise Evaluators) and the agenda should include:

    - Introduction: Rules of the debrief and agenda (Facilitator).
    - What happened during the exercise? (Exercise Control).
    - What went well? (All).
    - What needs improvement? (All).
    - What plans, procedures or training programs need amendments? (All).
    - What follow-up is required, including identifying any capability gaps for future capacity building? (All).
    - Was the exercise realistic? (All).
    - How could the exercise have been improved? (All).

- ○ Next steps with regards to the Exercise Report (Exercise Control).

Exercise Evaluators do not participate in the cold debrief; as described above their evaluations are received separately to supplement the debrief findings. Topics identified via the Exercise Evaluator debrief may be used as prompts in the cold debrief.

2.5.2 Exercise Task Team Debrief

A debrief with Exercise Task Team (including Exercise Control Staff) should be held as soon as possible following the exercise. The aim of this debrief is to identify lessons that can be learnt about the exercise planning and conduct, and whether there were factors that could have had an effect on the outcomes. The focus should be on the following:

- Did the exercise run as planned?,
- Were injects sufficient to support the exercise objectives?,
- Did the Exercise Evaluators perform as expected?,
- Were the facilities and logistics appropriate?,
- Did the exercise address the identified need(s)?,
- Did the exercise provide an opportunity for agencies and participants to perform in a manner closely resembling that expected in the real world?,
- Did the exercise support an improvement in performance?.

2.5.3 Exercise Validation and Report

2.5.3.1 Exercise Validation

The final stage of the exercise process is to determine whether the exercise has met the objectives identified in the needs assessment. Validation use the inputs received from Exercise Evaluators and through the respective debriefs to compares the performance of agencies and participants during the exercise against the exercise objectives. Further clarifications may be sought through interviews with individual participants or supervisors.

The validation will be conducted by the Exercise Task Team and presented in the form of an Exercise Report. Each agency may elect to produce an exercise report in addition to the overall Exercise Report**.**

After validation, agencies may change or develop plans, procedures, and training programs Exercise findings may be re-tested in future exercises, or new exercises may be designed to meet specific newly identified development areas.

2.5.3.2 Exercise Report

The focus of the Exercise Report should reflect the scale and complexity of the exercise, i.e. for a Drill it will focus on the detailed arrangements, execution and performance, while for a Functional or Full-Scale exercise its focus will be less detailed and instead formulate findings towards a higher level system or strategic focus.

The Exercise Report should:

- Provide a description of what happened.
- Describe best practices or strengths.

- Identify areas for improvement.
- Provide recommendations for improvement.
- Collate and provide a summary of agency evaluations.

The Exercise Report must be submitted for consideration by the governance body that agreed the conduct of exercise in the first instance, and that have the power of decision making with regards to the recommendations.

All improvements should be tracked to check on progress.

2.6 IMPLEMENT RECOMMENDATIONS

Following approval of the recommendations of the Exercise Report by the appropriate governance body, the recommendations must be assigned to a responsible person or agency for implementation. Coordination and oversight of the implementation of the recommendations must be carried out by the particular governance body.

The following process applies:

- Assign responsibility: Clearly assign tasks and schedules, and designate responsibility for each recommended action point.
- Monitor: Establish a monitoring plan to track the progress of implementing recommended improvements.
- Report: Provide regular reports to the governance body on the progress of implementing recommended improvements.

Other post-exercise follow-up actions may include:

- Return of equipment,
- Payment of exercise related accounts,
- Letters of appreciation.

3. SPECIALIZED DOCUMENTS

The following are guidance and tools that were identified for use or newly created for this guide through the TEMPP pilot training course. These are found in Part B as Specialized Documents.

- Awareness Materials - Warning and Evacuation information, Family Plan card (examples) (Specialized document no VI) Also pertinent to Module 3 of the main document (IOC/2020/MG/82).
- How to Create Community Tsunami Exercises (example of exercise plan and evaluation forms, template). (Specialized document no VII)
- How to conduct Tsunami Drill flyer (example). (Specialized document no VIII)

PART B
COMPILATION OF THE SPECIALIZED DOCUMENTS MENTIONED IN THE GUIDE

The Specialized Documents complement the Programme Modules. They consist of how-to-manuals, templates and examples that will support both training and the delivery of outputs.

All documents can be downloaded from the ITIC Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) website.

SUMMARY OF SPECIALIZED DOCUMENTS

The following lists and describes the specialized documents or tools, and the Modules in which they are used.

Number	Specialized Document Name	Module
I	**Using ComMIT (MOST model) for tsunami inundation modelling for evacuation mapping: Summary, Manual, and Appendices (abridged requirements, in Spanish)** ComMIT was used in the TEMPP1 Pilot training course for inundation modelling to support evacuation map-making. http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1705 (Accessed 7 November 2019) ComMIT was subsequently used and updated through TEMPP trainings in 2017-2019. General information on ComMIT can be found at USA NOAA, https://nctr.pmel.noaa.gov/ComMIT/ (Accessed 7 November 2019)	1
II	**Tsunami Coastal Assessment Tool (TsuCAT) for scenario identification, v4, USA NOAA, ITIC, 2019, Summary and Manual.** TsuCAT can be used to identify worst-case scenarios, and to develop scenarios for tsunami exercises using the PTWC Enhanced Products as message triggers for national and local tsunami warning decision-making. http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2239&Itemid=2763 (Accessed 7 November 2019)	1, 3, 4
III	**How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS, Manual and Tutorial** This Manual describes the export of ComMIT results into the open-source QGIS software to digitally create tsunami evacuation maps using standard formats, colour palettes, and symbology. This document is available as Supplement 2 of the guide (IOC/MG/2019/82). This Manual was used in the TEMPP 2 Pilot training. http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1803 (Accessed 7 November 2019) The Manual was subsequently reviewed and updated through TEMPP trainings in 2017-2019. The most recent version is	2

Number	Specialized Document Name	Module
	available from ITIC TEMPP web site. http://itic.ioc-unesco.org/index.php?option=com_content&view=category&layout=blog&id=2166&Itemid=2640	
IV	**Town-Watching Tsunami Evacuation Checklist** This example was used in the TEMPP 2 Pilot training. http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1803 (Accessed 7 November 2019) This example provides a template for ground-truthing tsunami evacuation maps through community engagement and actual tsunami evacuation route walking. A copy is also contained within the Supplement to Programme Modules.	2
V	**How to Create Community Tsunami Response Plans (example of response plan, template)** This template was used in the TEMPP 3 Pilot training. http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1891 (Accessed 7 November 2019)	3
VI	**Awareness Materials – Warning and Evacuation information, Family Plan card (examples)** These materials was developed in the TEMPP 3 and 4 Pilot trainings. TEMPP 3: http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1891 TEMPP 4: http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1943 (Accessed 7 November 2019)	3, 4
VII	**How to Create Community Tsunami Exercises (example of exercise plan and evaluation forms, template).** This example and template was developed in the TEMPP 4 Pilot training. TEMPP 4: http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1943 TEMPP 5: http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1984 (Accessed 7 November 2019)	4
VIII	**How to conduct Tsunami Drill flyer (example)** This example and template was developed in the TEMPP 4 Pilot training. http://ioc-unesco.org/index.php?option=com_oe&task=viewEventRecord&eventID=1943 (Accessed 7 November 2019)	4

ANNEX I

GLOSSARY OF TECHNICAL TERMS

Additional tsunami terms and their definitions can be found in *Tsunami Glossary*, 2019 (IOC Technical Series, 85, English, French, Spanish, Arabic, Chinese, IOC/2008/TS/85 rev.4, UNESCO, 2019).

TERM	DEFINITION
Arrival time	The time when the first tsunami wave is observed at a particular location, typically given in local and/or universal time, but also commonly noted in minutes or hours relative to the time of the earthquake.
Assembly Area	(see Evacuation Assembly Area)
Bathymetry	Underwater terrain measured as water depth relative to sea level, or the undisturbed fluid surface level.
Bathtub method	A simplistic approach to modelling flooding extent that results from a specific trigger, such as a tsunami. The approach assumes that an area which lies under a certain height, gets flooded like a bathtub.
Boussinesq Approximation	A 2-dimensional approximation of fluid flow that includes multiple fluid layers and dispersion yet ignores density differences. The approach can better simulate tsunami waves at coastlines near a generating source and inside harbours than simpler shallow water wave models. The increased accuracy however is offset by greater computation time.
ComMIT	Acronym for 'Community Modeling Interface for Tsunamis.' ComMIT is a graphical user interface through which flooding from a tsunami along any coast can be modelled.
Convergent boundary	One of three types of plate tectonic boundaries in which the earth's plates converge, or move towards one another.
DEM	Acronym for 'Digital Elevation Model.' A digital representation of bathymetry, topography, or the combination of both based on survey data or satellite imagery. Data are arrays of regularly spaced elevations referenced to a map projection of the geographic coordinate system.
Dispersion	Fluid waves of different wavelengths travel at different phase speeds.
Distant (tele- or far-field) tsunami	Most commonly, a tsunami originating from a source greater than 1000 km away from a particular location. In some contexts, a distant tsunami is defined as one that propagates through the deep ocean before reaching a particular location without consideration or distance separation.

TERM	DEFINITION
Divergent boundary	One of three types of plate tectonic boundaries in which the earth's plates diverge, or move away from one another.
Epicentre	The point on the surface of the earth that is directly above the focus, or point of earthquake rupture.
Evacuation Assembly Site	Pre-identified specific bounded location designated as a meeting place for populations evacuating from locations vulnerable to flooding.
Evacuation Mapping	The process of developing an evacuation map for a community based on scenario modelling of inundation or flood potential or other methods when modelling is not an option.
Evacuation Route	Marked pathway(s) that have been pre-identified as the fastest routes for populations to move from locations vulnerable to tsunami impact to Evacuation Assembly Areas or locations outside the Evacuation Zone during the threat of tsunami flooding.
Evacuation Zone	Pre-identified region determined to be a safe distance away from locations vulnerable to tsunami impact.
Estimated Time of Arrival (ETA)	Date and time that the first tsunami wave will arrive at a specific location.
Far-field	Region outside of the source of a tsunami where no direct observations of the tsunami-generating event are evident, except for the tsunami waves themselves.
Focus	The point beneath the surface of the earth where a rupture or energy release occurs due to a build-up of stress or the movement of earth's tectonic plates relative to one another.
Flow Depth	Vertical height of the tsunami above the ground, at a specific location, as indicated by flow markers such as piles of debris, impact scars on tree trunks, dead vegetation on trees or electric wires, or mud marks on building walls. The inundation height is the sum of the flow depth and local topographic height.
GIS	Acronym for 'Geospatial Information System.'
GUI	Acronym for 'Graphical User Interface.' A GUI provides a user with access to computer-based capabilities and tools, including tsunami modelling and output display.
HAZMAT	Acronym for 'Hazardous Materials.'
Inundation	The inland or horizontal extent of normally dry land that tsunami waves reach. Inundation (or flooding) is generally measured perpendicular to a shoreline.
Inundation height	Elevation reached by seawater measured relative to a stated datum such as mean sea level or the sea level at the time of tsunami arrival,

TERM	DEFINITION
	at a specific inundation distance. Inundation height is the sum of the flow depth and the local topographic height. Sometimes referred to as tsunami height.
Inundation Mapping	The process of determining inundation or flooding extents either from numerical modelling of a suite of plausible scenarios or by use of other methods when modelling is not an option.
LIDAR	Acronym for ‘LIght Detection and Ranging.’ LIDAR is a remote sensing technique that uses a laser to accurately measures topographic (land forms) elevations on the Earth’s surface.
Local Tsunami	A tsunami from a nearby source for which its destructive effects are confined to coasts within 200 km or less than 1-hour travel time away from the generating source. Local tsunamis are typically generated by earthquakes, but can also be caused by landslide or pyroclastic flow from volcanic eruption. It is estimated that ~90% of tsunami casualties throughout history have been caused by local tsunamis.
LSW	Acronym for ‘Linear Shallow Water.’ Refers to equations that exclude nonlinear convective terms to more simply describe the propagation of tsunamis.
Moment magnitude (M_w)	The magnitude of an earthquake on a logarithmic scale in terms of the energy released. Moment magnitude is based on the size and characteristics of a fault rupture as determined from long-period seismic waves.
NCEI	Acronym for ‘National Centers for Environmental Information’
NCTR	Acronym for ‘NOAA Center for Tsunami Research’
NOAA	Acronym for ‘National Oceanic and Atmospheric Administration’
NTHMP	Acronym for ‘National Tsunami Hazard Mitigation Program.’ The program is a coordinated U.S. national effort to assess tsunami threat, prepare community response, issue timely and effective warnings, and mitigate damage.
Near-field (or local)	Region of primary tsunami generation and impact. The destructive effects of a tsunami in the near-field or local area are confined to coasts along which tsunami travel time is less than 1 hour, or are typically within 200 km of the tsunami generating source. Earthquakes are the typical generating mechanism of tsunamis in the near-field but landslides or pyroclastic flows from a volcanic eruption can, and have, caused tsunamis that mainly affect near-field coastlines.
NSW	Acronym for ‘Nonlinear Shallow Water.’ Refers to assumptions made in numerical codes for modelling tsunami propagation and flooding of normally dry land.

TERM	DEFINITION
Numerical Simulation	A computer run of a mathematical representation of a physical system that is too complex to model or solve analytically (or exactly). Non-linear systems, such as the oceans, are commonly modelled numerically.
Oceanography	The study of the biological, chemical, geophysical, and physical characteristics of the world oceans and seas.
Plate Tectonics	The theory that twelve (12) rigid plates make up the surface of the earth and slide atop the earth's mantle sliding past, into, or away from one another thereby changing the physical features of earth over very long or geologic time scales.
PMEL	Acronym for 'Pacific Marine Environmental Laboratory.' PMEL is one of NOAA's seven research laboratories and is located in the Pacific Northwest city of Seattle, Washington
Regional Tsunami	A tsunami capable of destruction in a particular geographic region, generally within 1,000 km or 1–3 hours of travel time from the generating source. Regional tsunamis may have limited and localized effects outside the primary region.
Response Plan	A set of written instructions and actions to be taken in response to the threat of tsunami impact that limits effects and saves life. Response plans typically assign roles and responsibilities and may include evacuation procedures, shelter in place criteria, personnel lists and contact information.
Run-up	Vertical difference between the elevation of tsunami inundation at the highest point of land reached and the sea level at the time of a tsunami. Run-up is measured relative to a stated datum, such as mean sea level and in practice, is measured only where there is clear evidence of the inundation limit on a shore. Where the elevation is not measured at the maximum of horizontal inundation, this is often referred to as the inundation height.
Seismology	The study of earthquakes, their sources, and the resulting types of seismic waves that move both through the interior of the earth (body waves) and around earth's surface (surface waves).
Seismic Source Parameters	The parameters that uniquely characterize an earthquake. Typical parameters are magnitude, epicentre, dip, slip, and rupture length.
SOP	Acronym for 'Standard Operating Procedures'.
Subduction zone	A submarine region of the earth's crust along which two or more tectonic plates converge forcing one plate under another. The under-riding plate is said to be subducting beneath the plate that remains at the earth's crust. Subduction zones are regions of high seismic or earthquake activity.
SW	Acronym for 'Shallow Water.' Typically refers to 2-dimensional numerical codes that use linear and non-linear shallow water wave

TERM	DEFINITION
	equations for tsunami generation, propagation and wave run-up or drawdown. Shallow water wave equations assume a constant pressure field, no dispersion of wave frequencies, and no vertical velocity.
Synthetic event	One that has not occurred at any time in history yet has been determined to be theoretically possible based on earthquake source studies. Computer simulations of synthetic events broaden the suite of cases that inundation extents are based on.
TEMPP	Acronym for 'Tsunami Evacuation Maps Plans, and Procedures.' TEMPP is a project aimed at standardizing the process for development of community evacuation maps.
Tidal wave	Term frequently used incorrectly as a synonym for tsunami. A tsunami is unrelated to the predictable periodic rise and fall of sea level due to the gravitational attractions of the moon and sun (see **Tide**, below).
Tide	The predictable rise and fall of a body of water (ocean, sea, bay, etc.) due to the gravitational attractions of the moon and sun.
Tide gauge	Instruments that measure the rise and fall of a column of water over time at a particular location. The earliest technology utilized the marigraph to produce analog or paper records of the tides, known as marigrams.
Topography	Natural terrain and artificial features measured as height above sea level.
Transform plate boundary	One of three types of plate tectonic boundaries in which roughly parallel earth's plates slide or move past one another.
Travel time	The wall clock time it takes for the first tsunami wave to travel from the generating source to a particular location.
Tsunami	A Japanese term that translates literally to 'harbour wave.' A tsunami is sometimes mistakenly referred to as 'tidal wave' but is actually a series of waves caused by the sudden displacement of water from earthquakes, submarine landslides, volcanic eruptions, meteorological forcing, and meteoric impact. Tsunamis are classified as local, regional, or distant, depending on the relative area of generation and the coastlines impacted. Once generated, all tsunami waves increase in height as they enter shallow water near land and can therefore cause great loss of life and property damage where they come ashore.
Tsunami height	Inundation height.
Tsunamigenic (Tsunami Earthquake)	Having the potential to produce a tsunami, especially a large tsunami relative to earthquake magnitude.

TERM	DEFINITION
Tsunami hazard assessment	A systematic investigation of seismically active regions of the world oceans to determine their potential tsunami impact at a particular location. Numerical models are typically used to characterize tsunami generation, propagation, and inundation, and to quantify the risk posed to a particular community from tsunamis generated in each source region investigated.
Tsunami Modelling	Mathematical representations of the physics needed to simulate tsunami propagation and flooding of normally dry land. Tsunami specific numerical codes or models usually solve the same or similar equations but often employ different numerical techniques and make different assumptions depending on the focus of study.
Tsunami propagation	The directional movement of tsunami waves outward from the source of generation. The speed at which a tsunami propagates depends on the depth of the water in which the wave is traveling. Tsunamis travel at a speed of 700 km/hr (450 mi/hr) over an average Pacific Ocean depth of 4000 m.
Tsunami source	Location of tsunami origin, most typically an underwater earthquake epicentre. Tsunamis are also generated by submarine landslides, underwater volcanic eruptions, or, less commonly, by meteoric impact of the ocean.
USGS	Acronym for 'United States Geological Survey.' USGS is a scientific agency of the US government that develops new methods and tools to supply timely, relevant, and useful information about the Earth and its processes.
Validation	The process of confirming model results by comparing with actual measurements, as from coastal tide gauges.
Wave amplitude	The vertical difference between a defined mean water level and either the wave crest (peak) or wave trough. Maximum amplitude is mean water level to wave crest and minimum amplitude is the measured from mean water level to wave trough. Wave amplitude is commonly approximated as ½ wave height.
Wave crest	The highest or peak of a wave or maximum rise above a defined mean water level state, such as mean sea level or mean lower low water.
Wave height	The vertical difference between a wave peak (crest) and its corresponding wave trough.
Wavelength	The horizontal distance between two successive wave crests or troughs.
Wave period	The length of time between the passage of two successive wave crests or troughs as measured at a fixed location.

TERM	DEFINITION
Wave trough	The lowest part of a wave or the maximum drop below a defined mean water level state, such as mean lower low water.
WDS	Acronym for ‘World Data Service’.

ANNEX II

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2	International Catalogue of Ocean Data Station. 1976. *(Out of stock)*
3 rev. 3	Guide to Operational Procedures for the Collection and Exchange of JCOMM Oceanographic Data. Third Revised Edition, 1999. 38 pp. (English, French, Spanish, Russian)
4	Guide to Oceanographic and Marine Meteorological Instruments and Observing Practices. 1975. 54 pp. (English)
5 rev. 2	Guide for Establishing a National Oceanographic Data Centre. Second Revised Edition, 2008. 27 pp. (English) *(Electronic only)*
6 rev.	Wave Reporting Procedures for Tide Observers in the Tsunami Warning System. 1968. 30 pp. (English)
7	Guide to Operational Procedures for the IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring. 1976. 50 pp. (French, Spanish)
8	*(Superseded by IOC Manuals and Guides No. 16)*
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10	*(Superseded by IOC Manuals and Guides No. 16)*
11	The Determination of Petroleum Hydrocarbons in Sediments. 1982. 38 pp. (French, Spanish, Russian)
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14	Manual on Sea-Level Measurements and Interpretation. (English, French, Spanish, Russian)
	Vol. I: Basic Procedure. 1985. 83 pp. (English)
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	Vol. III: Reappraisals and Recommendations as of the year 2000. 2002. 55 pp. (English)
	Vol. IV: An Update to 2006. 2006. 78 pp. (English, Arab)
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16	Marine Environmental Data Information Referral Catalogue. Third Edition. 1993. 157 pp. (Composite English/French/Spanish/Russian)
17	GF3: A General Formatting System for Geo-referenced Data
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	Vol. 3: Standard Subsets of GF3. 1996. 67 pp. (English)
	Vol. 4: User Guide to the GF3-Proc Software. 1989. 23 pp. (English, French, Spanish, Russian)

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	Vol. 6: Quick Reference Sheets for GF3 and GF3-Proc. 1989. 22 pp. (English, French, Spanish, Russian)
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20	Guide to Drifting Data Buoys. 1988. 71 pp. (English, French, Spanish, Russian)
21	*(Superseded by IOC Manuals and Guides No. 25)*
22 rev.	GTSPP Real-time Quality Control Manual, First revised edition. 2010. 145 pp. (English)
23	Marine Information Centre Development: An Introductory Manual. 1991. 32 pp. (English, French, Spanish, Russian)
24	Guide to Satellite Remote Sensing of the Marine Environment. 1992. 178 pp. (English)
25	Standard and Reference Materials for Marine Science. Revised Edition. 1993. 577 pp. (English)
26	Manual of Quality Control Procedures for Validation of Oceanographic Data. 1993. 436 pp. (English)
27	Chlorinated Biphenyls in Open Ocean Waters: Sampling, Extraction, Clean-up and Instrumental Determination. 1993. 36 pp. (English)
28	Nutrient Analysis in Tropical Marine Waters. 1993. 24 pp. (English)
29	Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. 1994. 178 pp . (English)
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36	Methodological Guide to Integrated Coastal Zone Management. 1997. 47 pp. (French, English)
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38	Guidelines for Vulnerability Mapping of Coastal Zones in the Indian Ocean. 2000. 40 pp. (French, English)
39	Manual on Aquatic Cyanobacteria – A photo guide and a synopsis of their toxicology. 2006. 106 pp. (English)
40	Guidelines for the Study of Shoreline Change in the Western Indian Ocean Region. 2000. 73 pp. (English)

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44	Submarine Groundwater Discharge in Coastal Areas – Management implications, measurements and effects. 2004. 35 pp. (English)
45	A Reference Guide on the Use of Indicators for Integrated Coastal Management. 2003. 127 pp. (English). *ICAM Dossier No. 1*
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47	TsunamiTeacher – An information and resource toolkit building capacity to respond to tsunamis and mitigate their effects. 2006. DVD (English, Bahasa Indonesia, Bangladesh Bangla, French, Spanish, and Thai)
48	Visions for a Sea Change. Report of the first international workshop on marine spatial planning. 2007. 83 pp. (English). *ICAM Dossier No. 4*
49	Tsunami preparedness. Information guide for disaster planners. 2008. (English, French, Spanish)
50	Hazard Awareness and Risk Mitigation in Integrated Coastal Area Management. 2009. 141 pp. (English). *ICAM Dossier No. 5*
51	IOC Strategic Plan for Oceanographic Data and Information Management (2008–2011). 2008. 46 pp. (English)
52	Tsunami risk assessment and mitigation for the Indian Ocean; knowing your tsunami risk – and what to do about it. 2009. 82 pp. (English)
53	Marine Spatial Planning. A Step-by-step Approach. 2009. 96 pp. (English; Spanish). *ICAM Dossier No. 6*
54	Ocean Data Standards Series:
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	Vol. 2: Recommendation to adopt ISO 8601:2004 as the standard for the representation of date and time in oceanographic data exchange. 2011. 17 pp. (English)
	Vol.3: Recommendation for a Quality Flag Scheme for the Exchange of Oceanographic and Marine Meteorological Data. 2013. 12 pp. (English)
	Vol. 4: SeaDataNet Controlled Vocabularies for describing Marine and Oceanographic Datasets – A joint Proposal by SeaDataNet and ODIP projects. 2019. 31 pp (English)
55	Microscopic and Molecular Methods for Quantitative Phytoplankton Analysis. 2010. 114 pp. (English)
56	The International Thermodynamic Equation of Seawater—2010: Calculation and Use of Thermodynamic Properties. 2010. 190 pp. (English)
57	Reducing and managing the risk of tsunamis. Guidance for National Civil Protection Agencies and Disaster Management Offices as Part of the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas Region – NEAMTWS. 2011. 74 pp. (English)
58	How to Plan, Conduct, and Evaluate Tsunami Exercises / Directrices para planificar, realizar y evaluar ejercicios sobre tsunamis. 2012. 88 pp. *(*English, Spanish*)*
59	Guide for designing and implementing a plan to monitor toxin-producing microalgae. Second Edition. 2016. 63 pp. (English, Spanish)
60	Global Temperature and Salinity Profile Programme (GTSPP) — Data user's manual, 1st Edition 2012. 2011. 48 pp. (English)

No.	Title
61	Coastal Management Approaches for Sea-level related Hazards: Case-studies and Good Practices. 2012. 45 pp. (English)
62	Guide sur les options d'adaptation en zone côtières à l'attention des décideurs locaux – Aide à la prise de décision pour faire face aux changements côtiers en Afrique de l'Ouest / A Guide on adaptation options for local decision-makers: guidance for decision making to cope with coastal changes in West Africa / Guia de opções de adaptação a atenção dos decisores locais: guia para tomada de decisões de forma a lidar com as mudanças costeiras na Africa Ocidental. 2012. 52 pp. (French, English, Portuguese). *ICAM Dossier No. 7*.
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70	A guide to evaluating marine spatial plans. 2014. 96 pp. (English)
71	IOC Communication Strategy for Marine Information Management (2015-2017). 2015
72	How to reduce coastal hazard risk in your community – A step-by-step approach. 2016
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75	ICAN (International Coastal Atlas Network) - best practice guide to engage your CWA (Coastal Web Atlas) user community. 2016
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Commission

Intergovernmental Oceanographic Commission
Manuals and Guides 82

PREPARING FOR COMMUNITY TSUNAMI EVACUATIONS

From Inundation to Evacuation Maps, Response Plans, and Exercises

SUPPLEMENT 2

Intergovernmental Oceanographic Commission
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82

PREPARING FOR COMMUNITY TSUNAMI EVACUATIONS

From Inundation to Evacuation Maps, Response Plans, and Exercises

SUPPLEMENT 2

How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS: Manual and Tutorial

UNESCO 2020

IOC Manuals and Guides, 82 Supplement 2
Paris, February 2020
English

For bibliographic purposes, this document should be cited as follows:

UNESCO/IOC. 2020. *Preparing for Community Tsunami Evacuations: from inundation to evacuation maps, response plans and exercises. Supplement 2: How to Create Evacuation Maps from Inundation Maps.* Paris, UNESCO. (Manuals and Guides, 82)

Guide prepared by: International Tsunami Information Center (ITIC)
New Zealand Ministry of Civil Defence & Emergency Management,
US NOAA Pacific Environmental Laboratory / NOAA Center for Tsunami Research (PMEL/NCTR), Caribbean Tsunami Warning Program (CTWP)
Intergovernmental Coordination Group for the Pacific Tsunami Warning and Mitigation System (ICG/PTWS) Working Group on Disaster Management, Preparedness, and Risk Reduction

This IOC Manuals and Guides publication consists of a guide (IOC/2020/MG/82) and two supplements. The guide presents a high-level summary of each programme module and the rational behind them. Supplements contain additional detailed information, templates, reference to specialized documents, tutorials and best practice examples.

Supplement 1: Programme Modules and Specialized Documents

Supplement 2: How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS: Manual and Tutorial

Published in 2020
by United Nations Educational, Scientific
and Cultural Organization
7, Place de Fontenoy, 75352 Paris 07 SP

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ANNEXES

Preface

The IOC Manuals and Guides N° 82 consists of a guide (IOC/2020/MG/82) and two supplements. The present document corresponds to *Specialised Document* n° III entitled *How to Create Evacuation Maps from Inundation Maps – from ComMIT to QGIS: Manual and Tutorial*. This manual and tutorial is used in Module 2: Developing tsunami evacuation maps.

IOC Manuals and Guides N° 82 focuses on actions that communities can take to build resilience to the next tsunami. It effects actions with the end goal of saving lives and reducing tsunami impact by focusing on coordinated Stakeholder Response Planning and Preparedness, accompanied by continuous Awareness on the End-to-End Warning System to sustain Advocacy. The actions and products of this guide—tsunami hazard assessments, inundation and evacuation maps, response plans and procedures, awareness, and exercises—assist communities in making themselves more prepared. The guide, formatted to support the training of people who are responsible for these deliverables, can be used as part of the process to become UNESCO/IOC Tsunami Ready, or simply to enhance preparedness.

It provides a summary on tsunami disaster risk reduction, evacuation, and the UNESCO/IOC Tsunami Ready community preparedness recognition pilot. It is followed by four evacuation planning modules (Modules 1 to 4) describing the how-to-steps, objectives, target participants, requirements, methodology, tools, templates, expected results, module references and examples, and finally a general bibliography and annexes on the Tsunami Evacuation Maps, Plans, and Procedures (TEMPP) Pilot course.

1. INTRODUCTION AND USE OF QGIS

1.1 INTRODUCTION

This manual and practical tutorial describes the process of creating tsunami evacuation and inundation maps using graphical information software (GIS), specifically QGIS. For this case, tsunami inundation model results were produced by the MOST numerical model (ComMIT interface).

The original version of the manual (Spanish and English) was prepared by Eng. Carlos Rodriguez in Spanish as part of TEMPP – Honduras, Central America Pilot (2015-17). In 2017 and 2018, TEMPP training was conducted in the Indian Ocean, organized by the Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System (ICG/IOTWMS) and the Indian Ocean Tsunami Information Center (IOTIC), and the English manual was updated. In 2018 and 2019, the manual was used as an evacuation mapping learning activity within the ITIC Training Program (ITP) in Chile (2018) and in Hawaii (2019), and further updates made to account for the new tools from Version 3.8.2 “Zanzibar”.

It is likely that depending on the version of QGIS used, that the descriptions and instructions in this manual may not be exact. This is especially true as newer versions of QGIS with additional tools and features are released.

Please note that many of the shape files may already be available from running the inundation models or local GIS/land use planning departments. These files should all be gathered in a directory. Test files are available for Grenada and Chile.

This section introduces the QGIS software, including the installation, addition of base map layers, and raster and vector images.

1.2 INTRODUCTION TO QGIS

Quantum GIS (QGIS for short) is a free and open-source cross-platform desktop geographic information system application that supports viewing, editing, and analysis of geospatial data.

It was initially released in July 2002. The initial objective of the project was to provide a GIS data viewer. QGIS has reached a point in its evolution where it is being used by many, both individuals and corporations to meet their daily needs for viewing, analysis and management of GIS data. QGIS provides a growing range of skills through basic and complementary roles. You can view, manage, edit, analyse data and design maps, which can be printed in different formats. It is written in C++, Python and Qt. It runs on Microsoft Windows, Linux, macOS and Android (beta) platforms.

New versions of QGIS are released regularly. Most of this document was based on the on the 2.18.20, some sections have been updated to reflect features of 3.8.2 "Zanzibar" (August 16, 2019).

1.3 SYSTEM/HARDWARE REQUIREMENTS (IT)

	Minimum	**Recommended**
Processor - CPU	Core i3 2.7Ghz	Core i7 3.5Ghz
Memory RAM	2Gb	8Gb or more
Hard Disk	500 Gb SATA	SSD de 128Gb or 500Gb SATA
Graphic card	1Gb RAM	2Gb RAM (NVIDIA Geforce)
Operating System	Windows 7-10 Mac Linux (Various) Android (beta)	Windows 7-10 Mac Linux (Various) Android (beta)

Table S2.1. System/hardware requirements

1.4 INSTALLATION OF QGIS

Step 1. To install the software QGIS must choose the web browser of your choice on your computer (for demonstration we are using Google Chrome) and select the installer, note that this software is free and open source. The web address where the installer is as follows: www.qgis.org, after selecting the executable file downloaded the application.

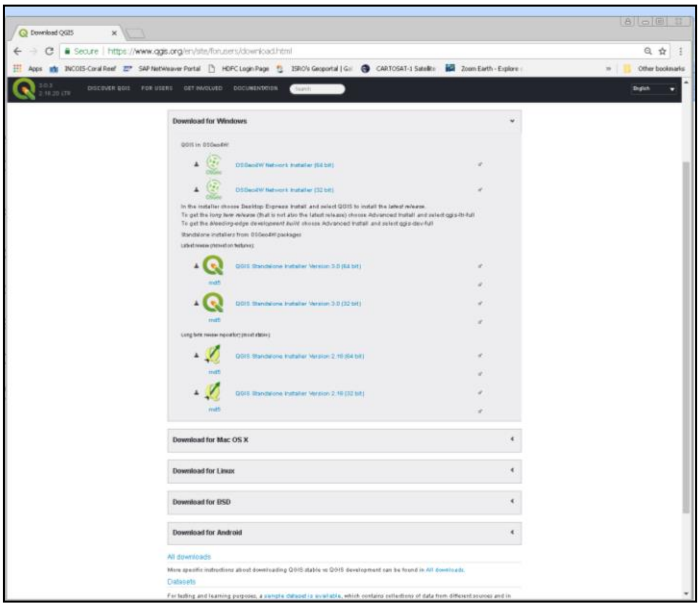


Figure S2.1. Software QGIS installation

Step 2. After the download proceed with terminal select the installer (.exe) and follow step by step installation the instructions below. This is the welcome interface software that appears when you start the installation, in this step click on "Next".

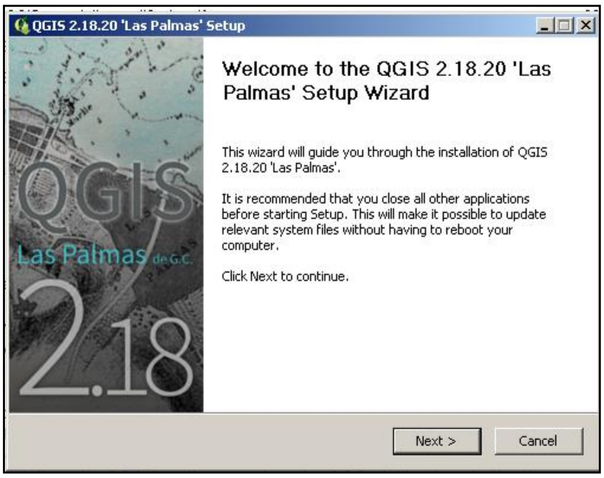


Figure S2.2. Welcome message window

Step 3. The following illustration shows the license information and the terms, if we agree click "I Agree".

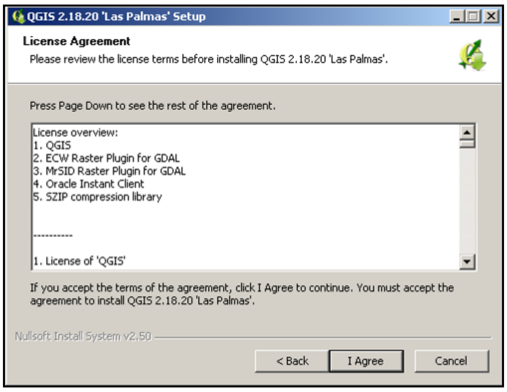


Figure S2.3. Licence information window

Step 4. The following illustration shows the recommended destination which can be changed to our preference, we just press the Browse button and select where we would like to install and then we press the button "Next".

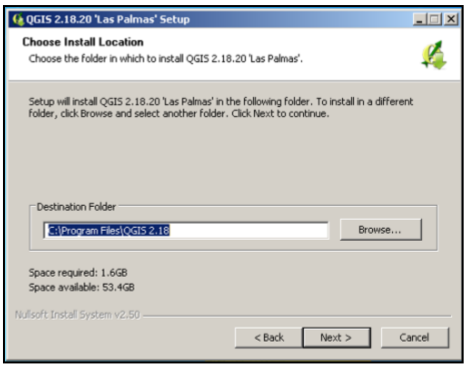


Figure S2.4. Choose install location

Note: we must note that the program requires a minimum of 1.5 GB of hard disk space to be installed; otherwise, it cannot be made the installation disk.

Step 5. The following illustration shows and asked to select the components, usually just leave it and press the button "Install".

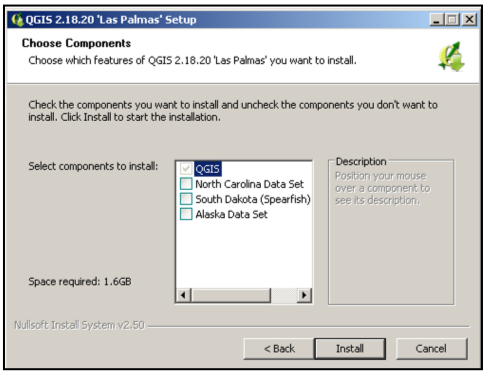


Figure S2.5. Choose components

Step 6. The following illustration shows the process of installing the software, just wait.

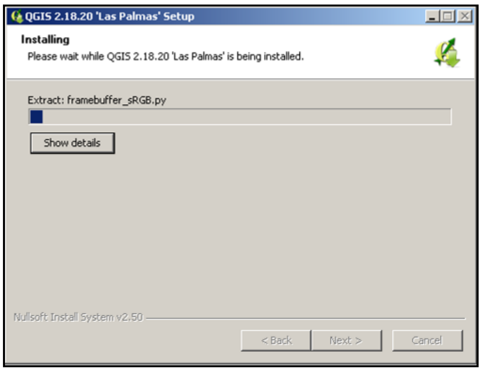


Figure S2.6. Installing process

Step 7. After the installation process finished we click the button "Finish" and we will have the software installed on your computer and can proceed to work on.

Figure S2.7. Installation process completed

1.5 ADDING IMAGE (RASTER) TO QGIS VIEWER

Step 1. Go to layer menu select Add layer-Add raster layer.

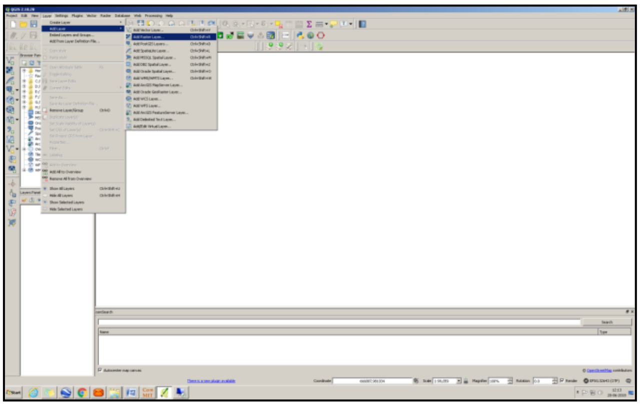


Figure S2.8. Interface view

Browse the raster file to be added to viewer and clock OK. The raster layer will be displayed in the viewer as shown below.

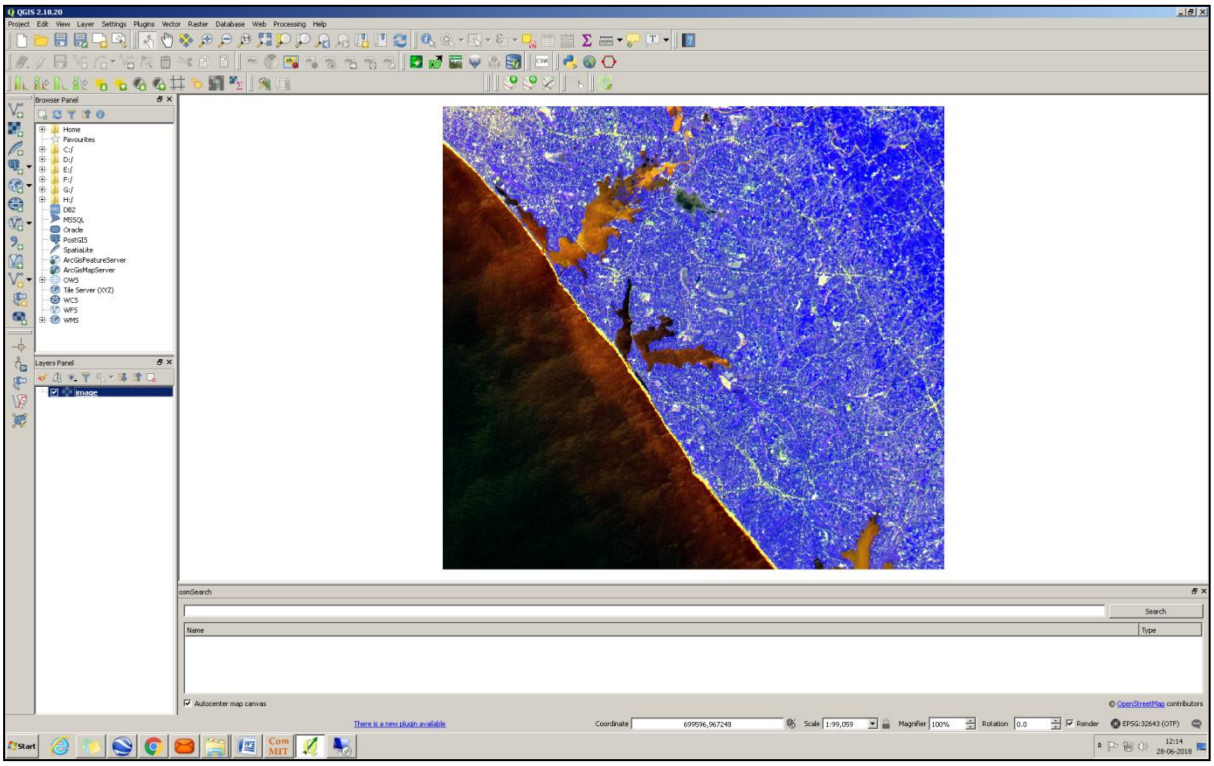


Figure S2.9. Raster layer displayed

The Zanzibar version (2019) allows the easy importation of georeferenced areal or satellite image, in the layer tab, choose XYZ tiles. To add the Google Maps map service in QGIS 3 simply, go to XYZ Tiles in the Browser panel. Now click on a New Connection, right-click on XYZ Tiles.

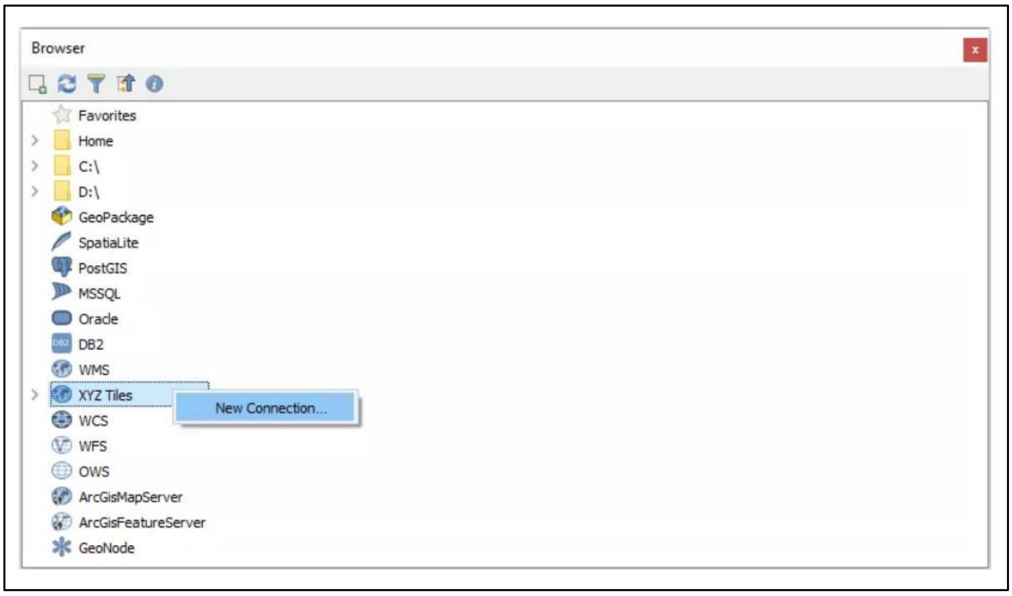


Figure S2.10. New connection window

Enter the name, for example: Google Satellite. Copy and paste one of the Google links listed below into the URL.

- Google Maps: https://mt1.google.com/vt/lyrs=r&x={x}&y={y}&z={z}
- Google Satellite: http://www.google.cn/maps/vt?lyrs=s@189&gl=cn&x={x}&y={y}&z={z}
- Google Satellite Hybrid: https://mt1.google.com/vt/lyrs=y&x={x}&y={y}&z={z}
- Google Terrain: https://mt1.google.com/vt/lyrs=t&x={x}&y={y}&z={z}
- Google Roads: https://mt1.google.com/vt/lyrs=h&x={x}&y={y}&z={z}

Adjust the maximum zoom level (19). Accept all changes.

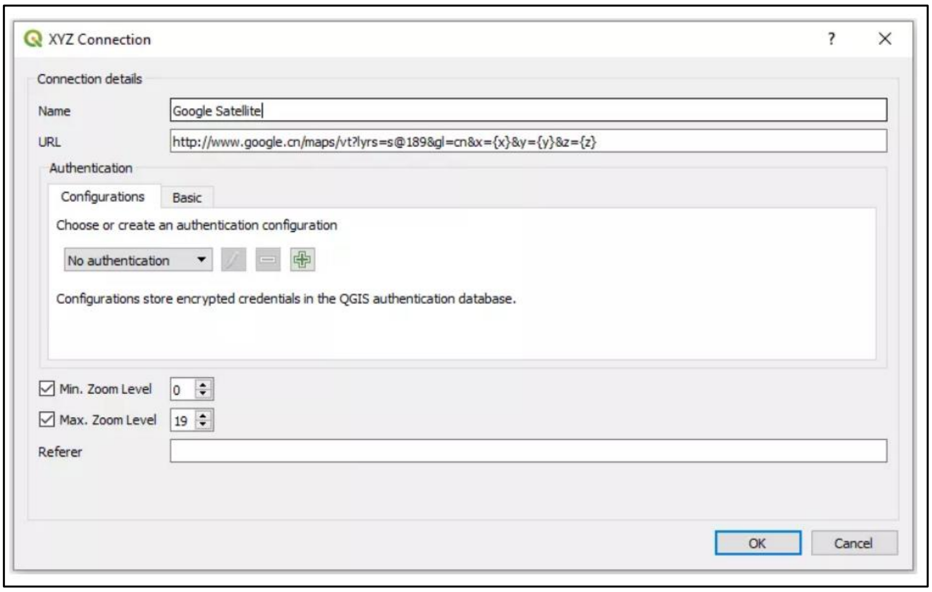


Figure S2.11. Window showing the connection
to Google Satellite established by XYZ Tile in QGIS 3

This way, a connection to Google Satellite is established by XYZ Tile in QGIS 3. To view inside QGIS simply double-click or drag the XYZ Tile service to the layers panel.

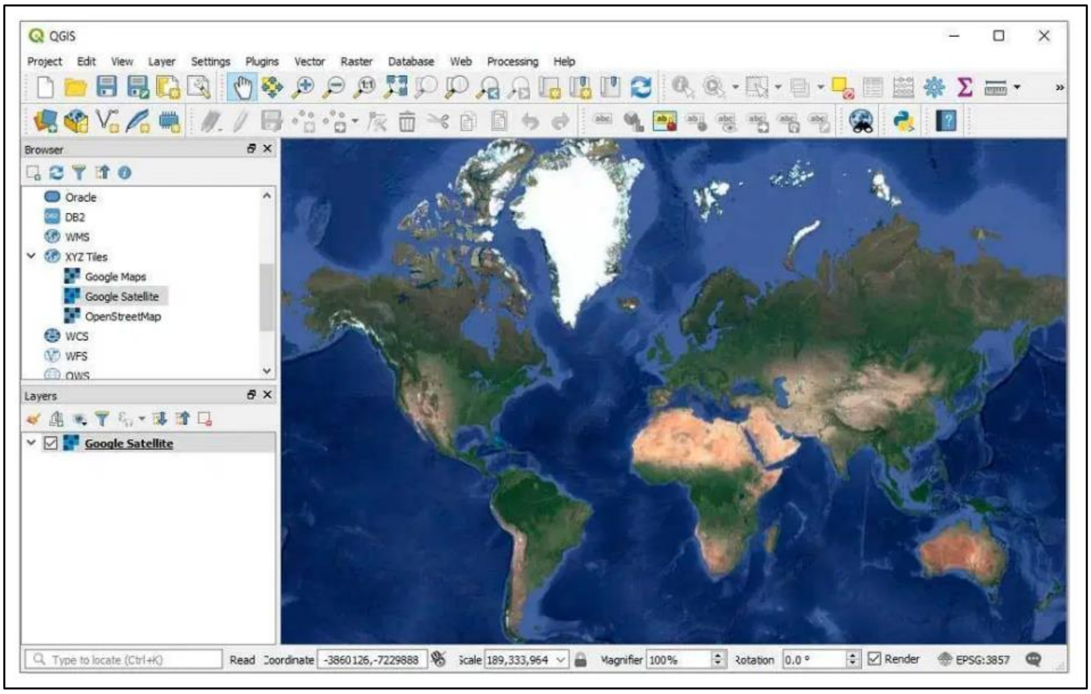
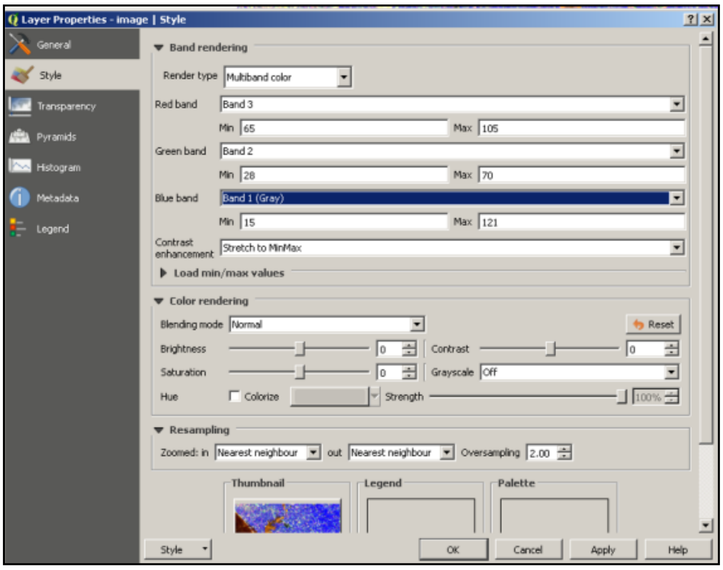


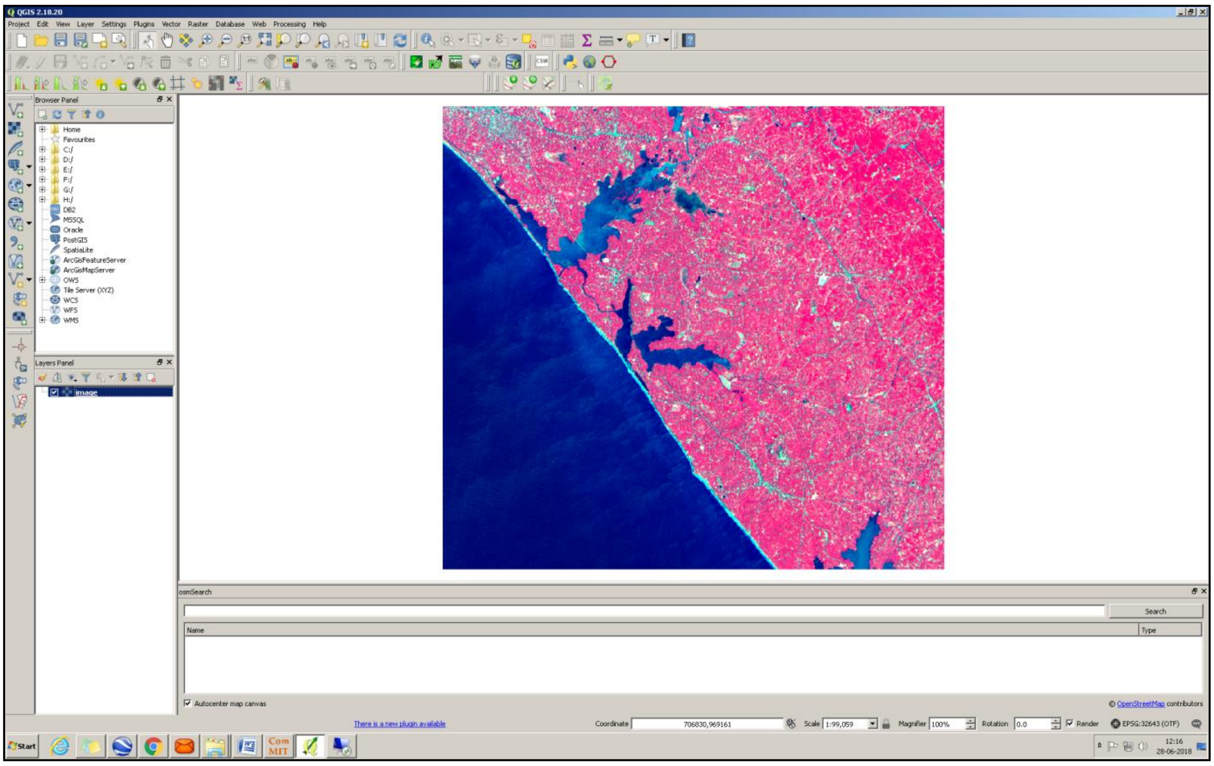
Figure S2.12. QGIS view

You can also add in this way Google Maps, Google Streets. For more help in adding google satellite (or map) layer, check geogeek at https://geogeek.xyz/how-to-add-google-maps-layers-in-qgis-3.html

Step 2. Change band combinations: Double click on image in layers panes the following dialog will open select style assign red band to band3, green band to band2 and blue band to band1press OK

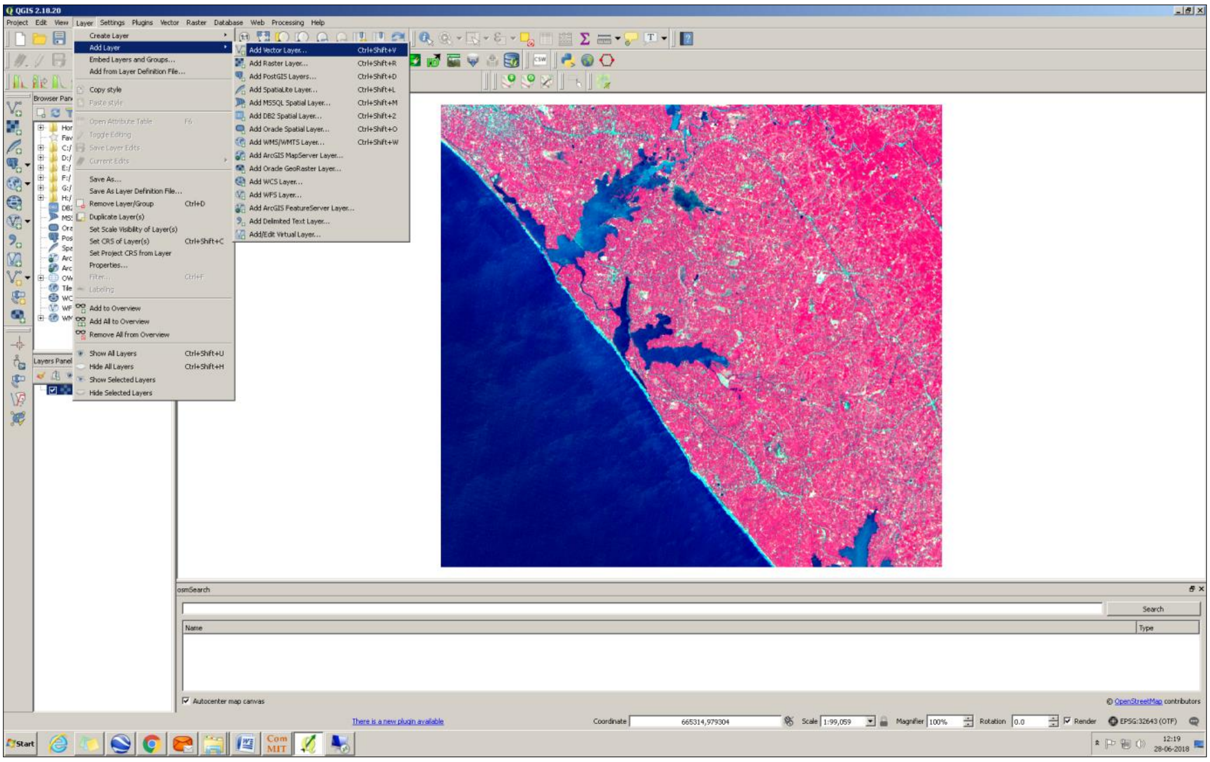


The image will display in FCC as shown below

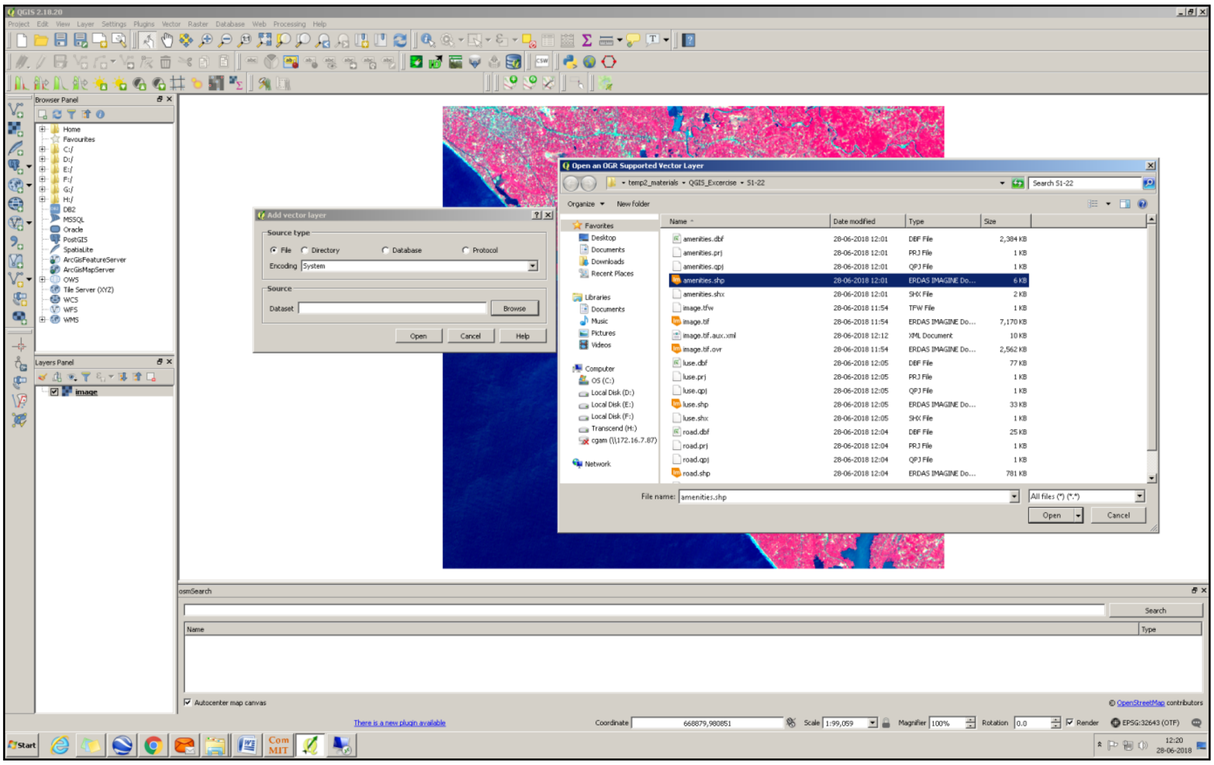


1.6 ADDING VECTOR LAYER

Go to layer menu select Add layer-Add vector layer.

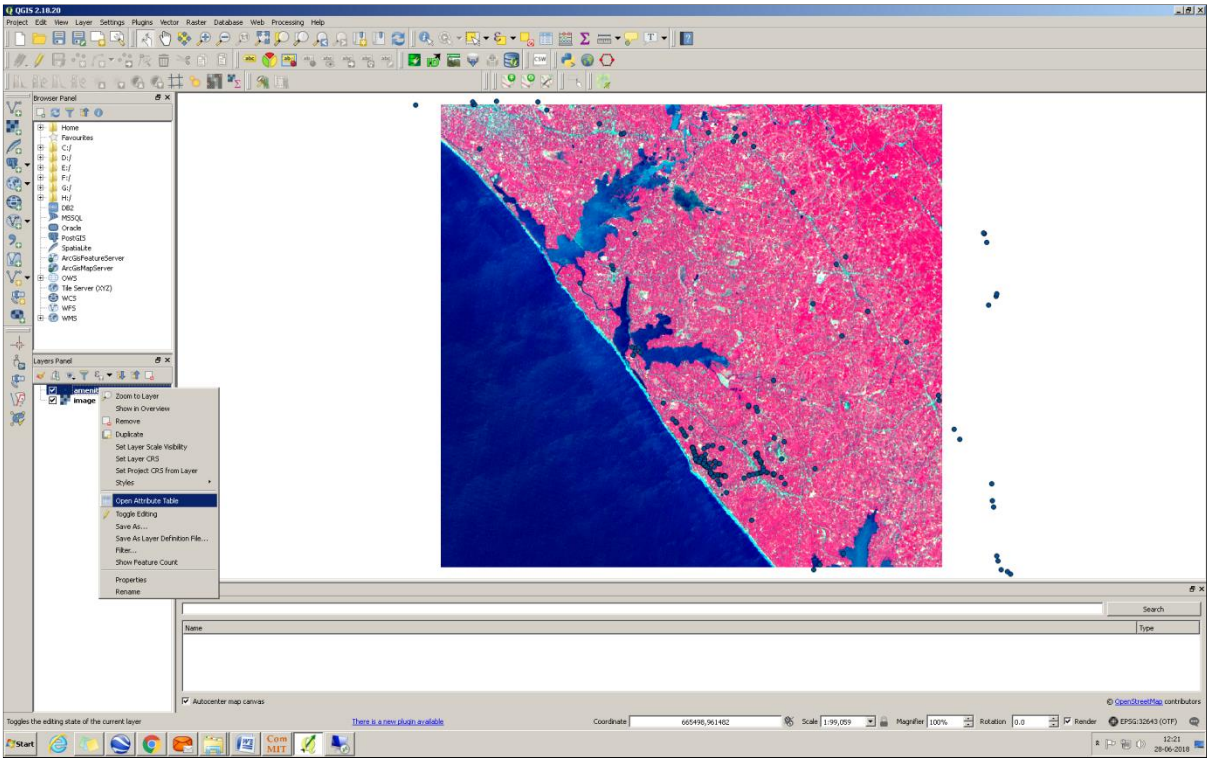


Browse the vector file amenities.shp to be added to viewer and click OK.

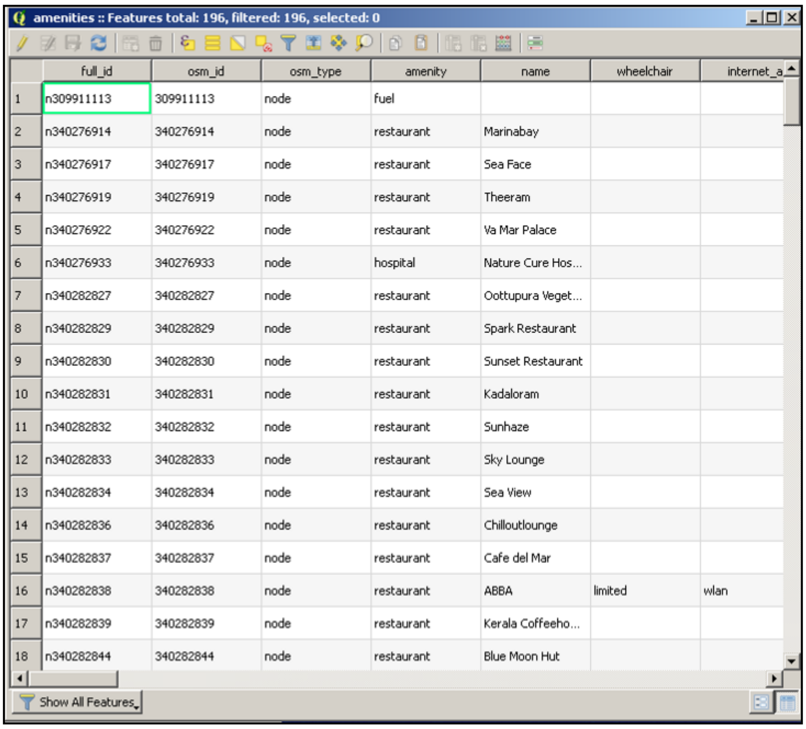


1.7 VIEWING ATTRIBUTE DATA

Right click on vector layer in layer panel and select open attribute table.



The following attribute table opens with the fields (column) and records (rows).



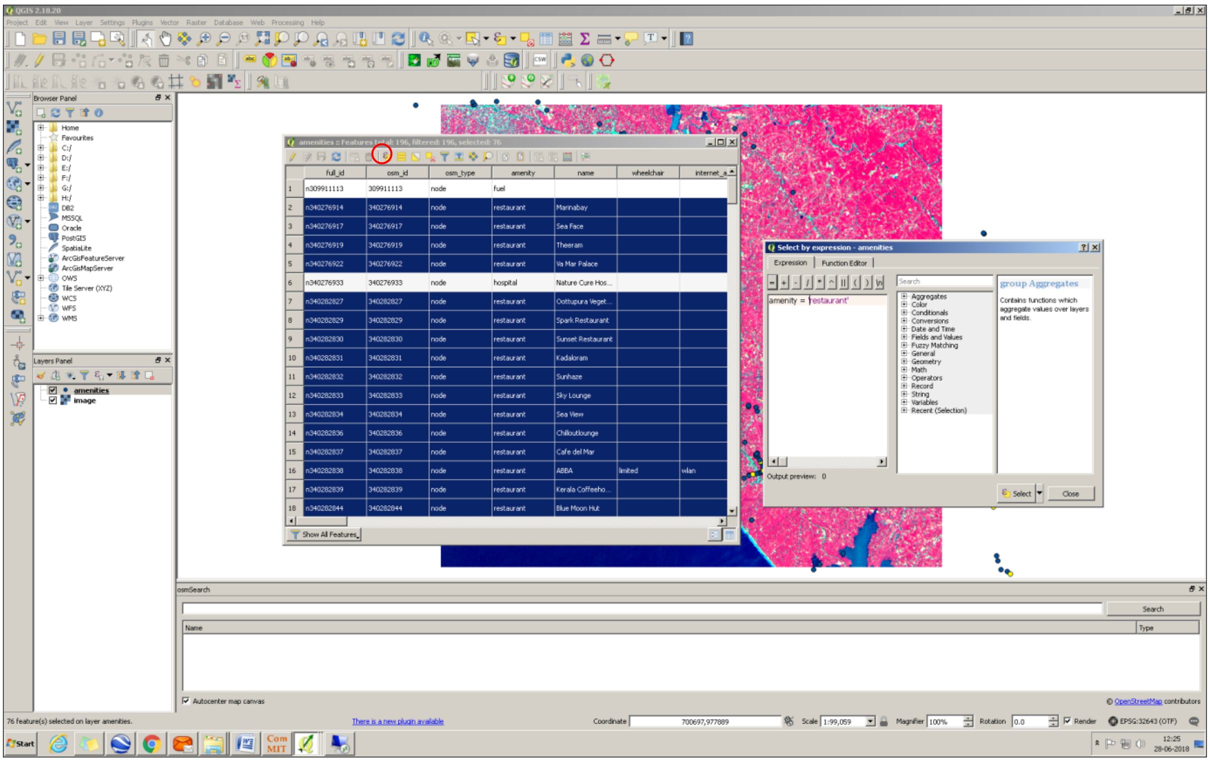
amenities :: Features total: 196, filtered: 196, selected: 0

	full_id	osm_id	osm_type	amenity	name	wheelchair	internet_a
1	n309911113	309911113	node	fuel			
2	n340276914	340276914	node	restaurant	Marinabay		
3	n340276917	340276917	node	restaurant	Sea Face		
4	n340276919	340276919	node	restaurant	Theeram		
5	n340276922	340276922	node	restaurant	Va Mar Palace		
6	n340276933	340276933	node	hospital	Nature Cure Hos...		
7	n340282827	340282827	node	restaurant	Oottupura Veget...		
8	n340282829	340282829	node	restaurant	Spark Restaurant		
9	n340282830	340282830	node	restaurant	Sunset Restaurant		
10	n340282831	340282831	node	restaurant	Kadaloram		
11	n340282832	340282832	node	restaurant	Sunhaze		
12	n340282833	340282833	node	restaurant	Sky Lounge		
13	n340282834	340282834	node	restaurant	Sea View		
14	n340282836	340282836	node	restaurant	Chilloutlounge		
15	n340282837	340282837	node	restaurant	Cafe del Mar		
16	n340282838	340282838	node	restaurant	ABBA	limited	wlan
17	n340282839	340282839	node	restaurant	Kerala Coffeeho...		
18	n340282844	340282844	node	restaurant	Blue Moon Hut		

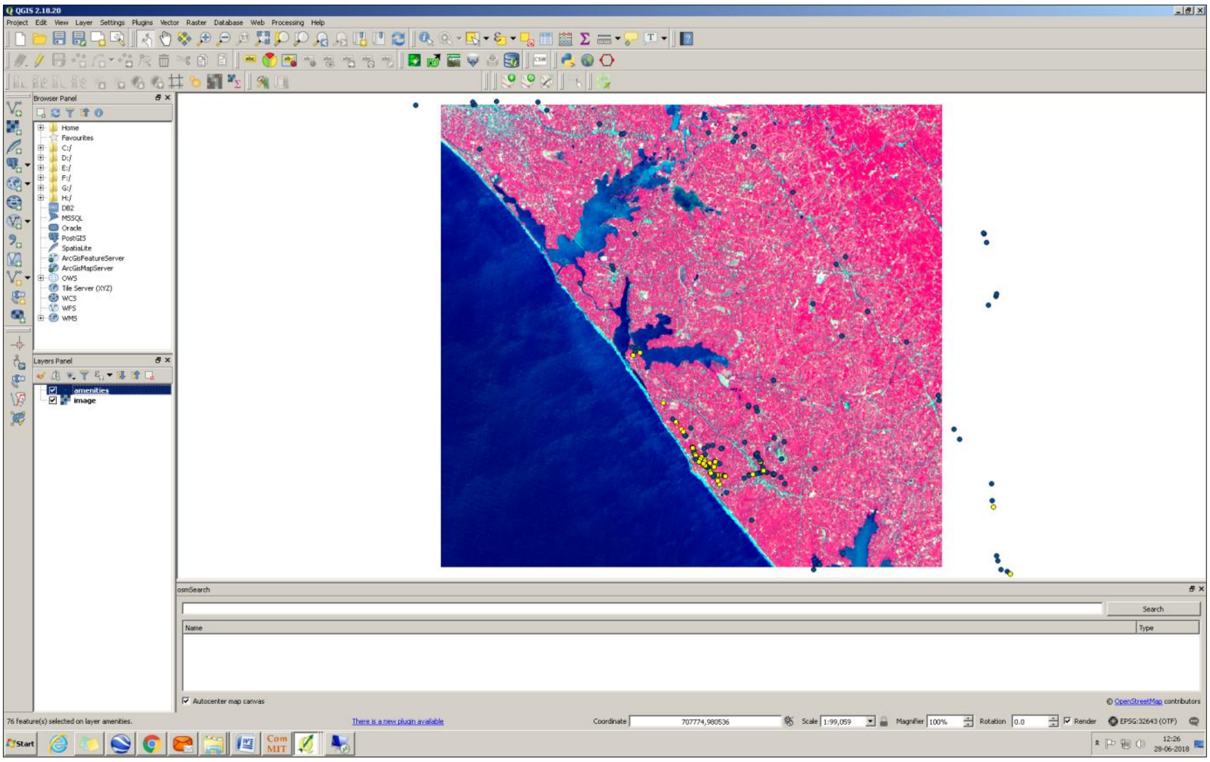
Show All Features

1.8 ATTRIBUTE QUERY

Click on the select feature using an expression tool (red circle marked). To select particular features based on the field type, you need to enter an expression. For example enter expression amenity = 'restaurant' to select all the restaurants in the amenity layer.



The selected features (restaurants) are shown in yellow colour.



2. FINALIZING INUNDATION MAP USING QGIS SOFTWARE

This section covers the use of the QGIS software to finalize the Inundation Map. For this case, the inundation model results from the ComMIT/MOST numerical model are used. The section gives instructions on exporting model runs from ComMIT, importing these into QGIS, and creating the inundation or 'flooding' layer atop the base map.

2.1 HOW TO COMBINE THE RESULTS OF COMMIT MODELLING WITH OTHER DATA LAYERS IN QGIS?

Computer software for modelling tsunami events called Community Model Interface for Tsunami (ComMIT) has the ability to export data in various formats, which can be used in QGIS. The format selection will depend on whether they are going to be used for other purposes besides the map to develop. Formats to be integrated into GIS are:

1. KMZ that can be displayed on the Google Earth platform free and then be imported into QGIS.

2. Netted - binary file format for (typically) gridded output, with associated metadata included with the file. ComMIT (and MOST) uses this format internally, but QGIS can read it directly.

3. Asia Raster File - image file information attached to pixel. This file shows an ideal balance between attributes and display layer. It is commonly used in large topographies areas layers.

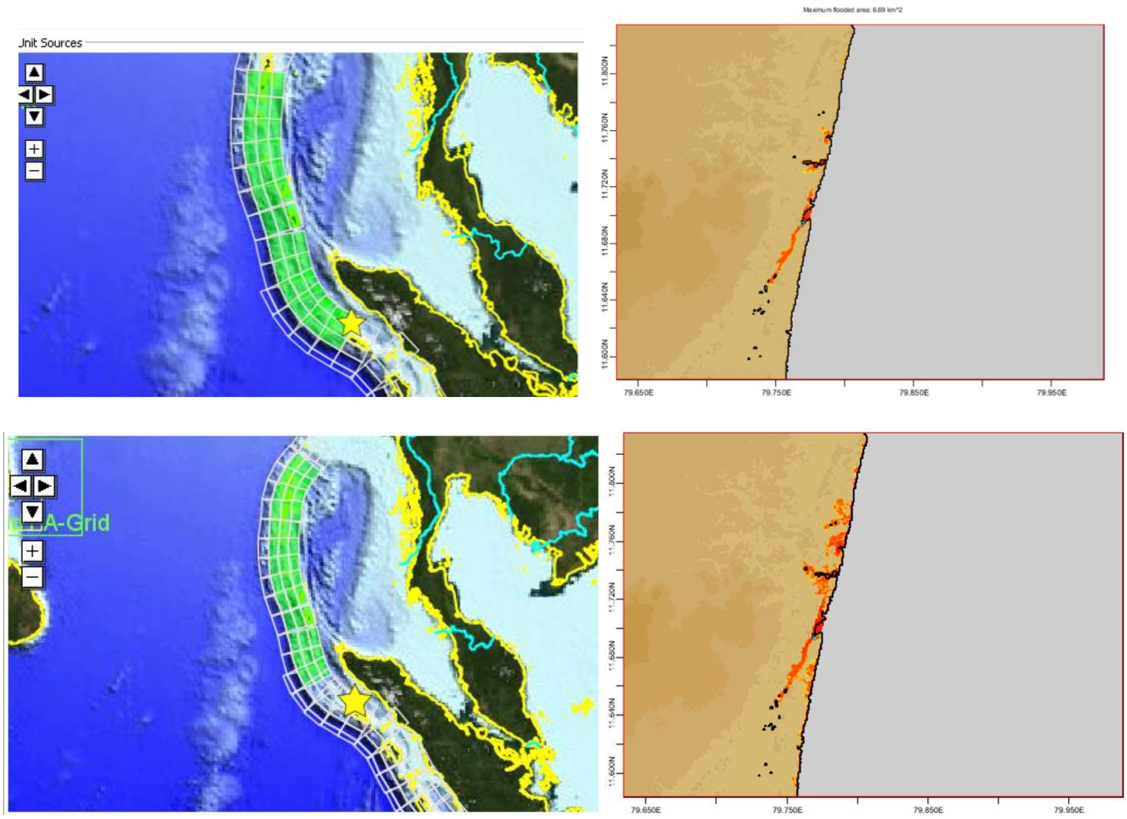
4. GeoTIFF Raster File - georeferenced image, which can be viewed and converted to vector in QGIS for further analysis. This format is one of the easiest to handle, and can support different resolutions in the latitude- and longitude-directions.

The recommended procedure for saving output for use in creating an inundation map depends on whether the hazard assessment run was using just the Worst Case Scenario, or if several earthquake scenarios were used. In the case of several (or many) scenarios run, a Composite Maximum inundation can be exported, and is perhaps the most used option, but a single scenario can be exported in the same way.

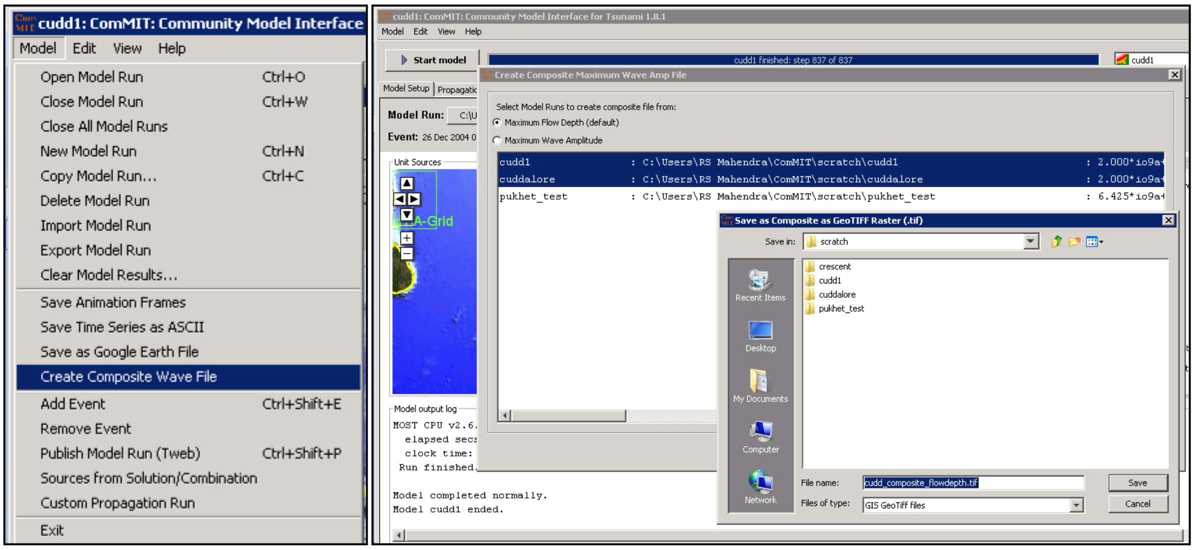
It is recommended that for an evacuation map, the inundation is saved as Flow Depth as opposed to Wave Amplitude using the Composite Maximum Wave feature.

Flow Depth is the water depth flowing over land, and is measured as wave amplitude minus altitude. Wave amplitude itself is measured from the reference water level (often Mean Sea Level or Mean High Water). These directions will assume the reader is saving Flow Depth.

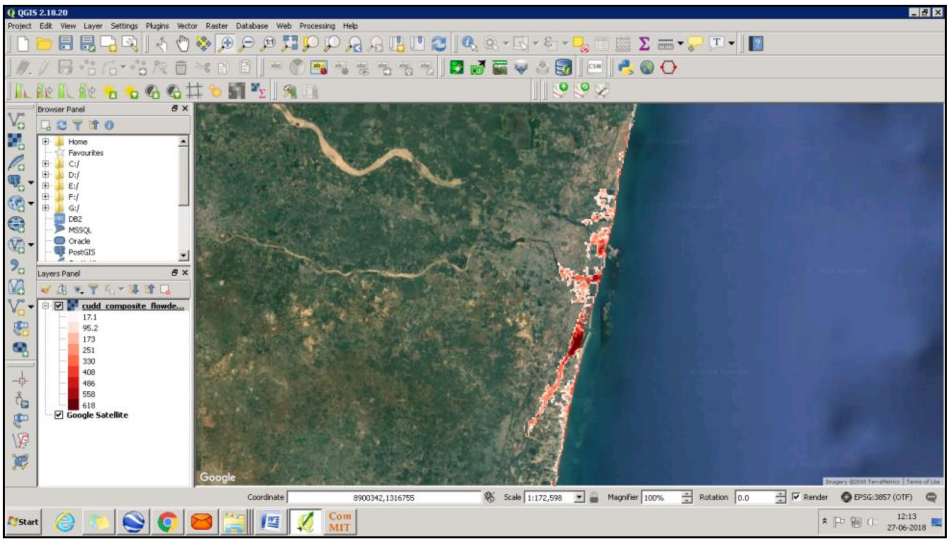
As an example, consider a hazard assessment consisting of two sources around Cuddalore, southeast coast of India each slightly different, with different maximum flow depth:



Step 1. To export Inundation (Maximum Flow Depth) after running the scenarios in a hazard assessment, the ComMIT user selects "Model->Create Composite Wave file": The following dialog (right side) then allows the user to select which Model Runs to use in the composite (or to simply use one, for a Worst Case Scenario):



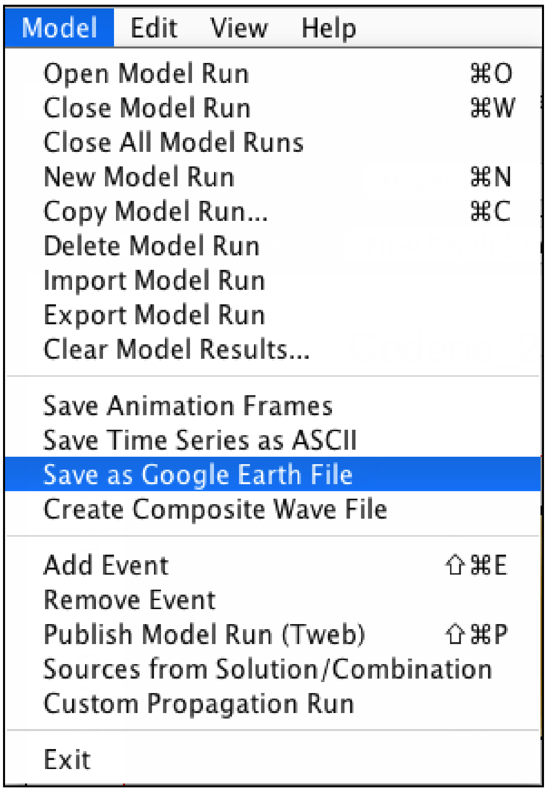
Step 2. The resulting GeoTIFF file "cudd_composite_flowdepth.tif" is saved (by default) in the "ComMIT/scratch" folder, and can be directly imported into QGIS for processing:



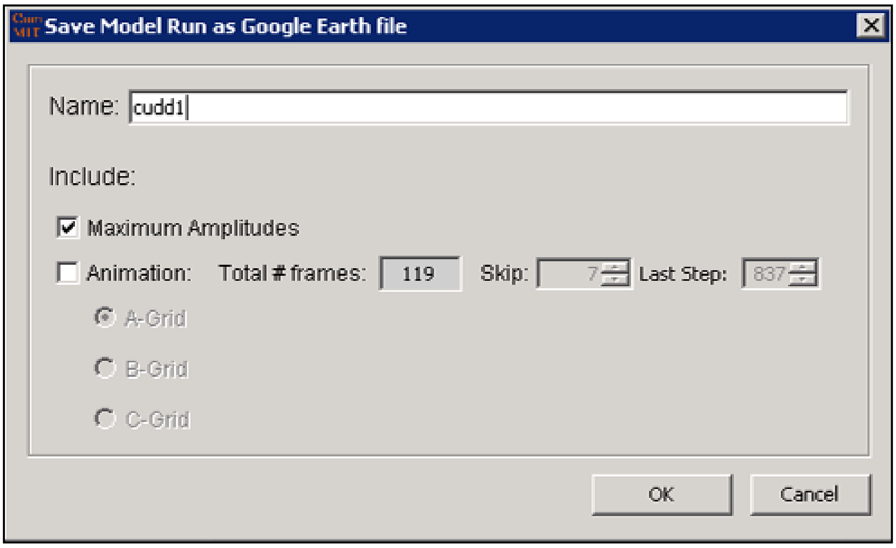
The other method for exporting data from ComMIT that might be useful is saving Google Earth output. To export the Tsunami Inundation modelling format (*.kmz) should take the following steps:

Step 1. Open ComMIT and select the Model Run of interest.

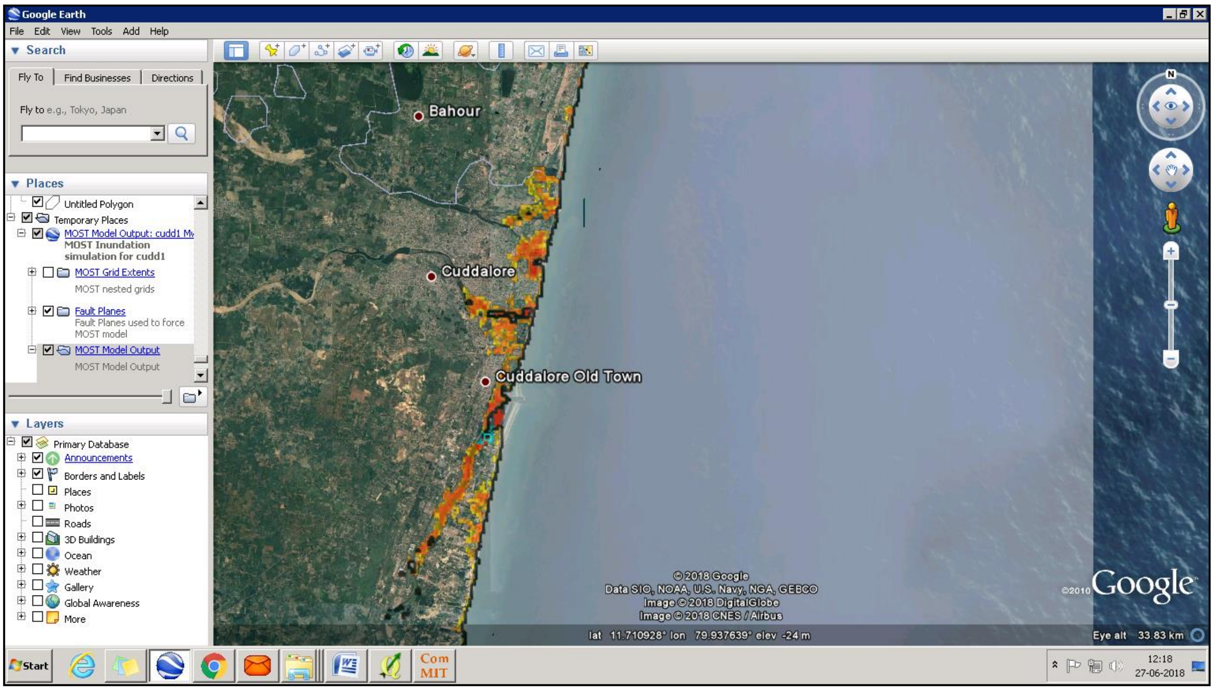
Step 2. Select the menu item Model and Save as Google Earth File



Step 3. Choose the desired name for the file to be saved by selecting the maximum amplitudes and other information required:



Step 4. Select the exported file and open it in Google Earth to check modelling and the impact of it:

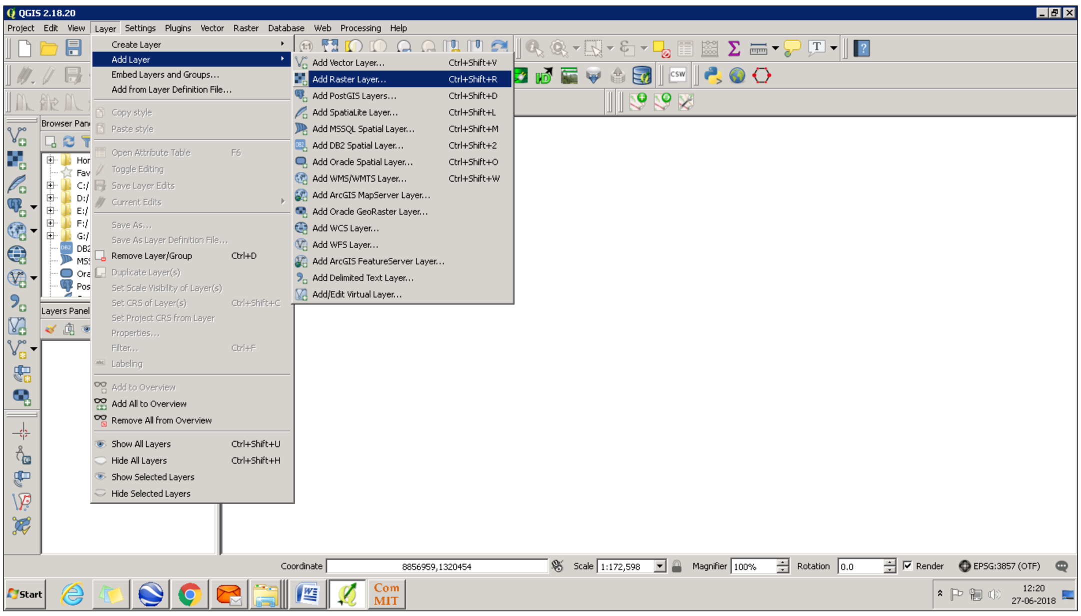


2.2 HOW CAN I CREATE AND CLEAN QGIS DATA FLOOD TSUNAMI MODEL?

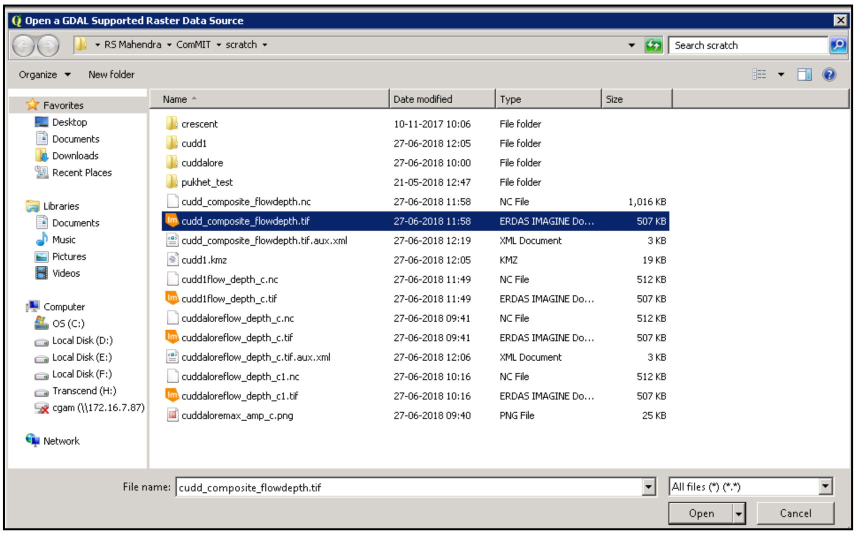
The integration model of Tsunami inundation exported by the Tsunami Modelling software ComMIT is relatively simple. To make this fundamental step in this development guide use export format Raster File Format (*.tif). Here are the steps to follow up the development of the flood zone.

Step 1. Open QGIS

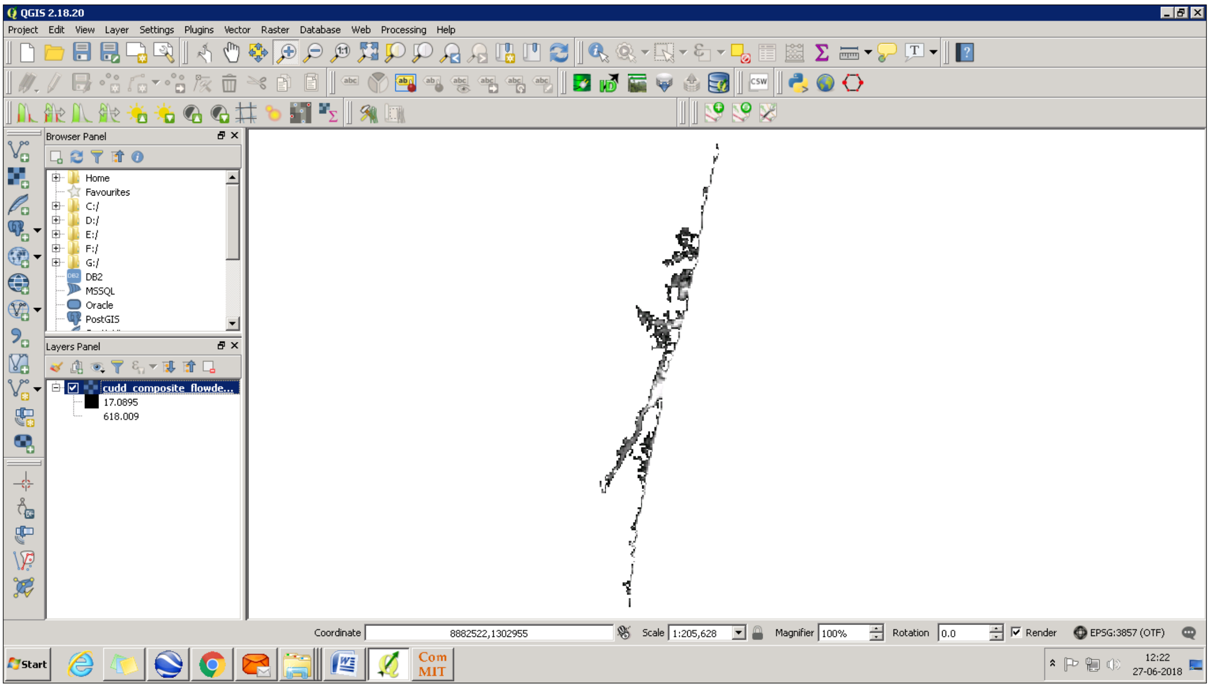
Step 2. Choose the option "Layer, Add Layer, Add Raster Layer"



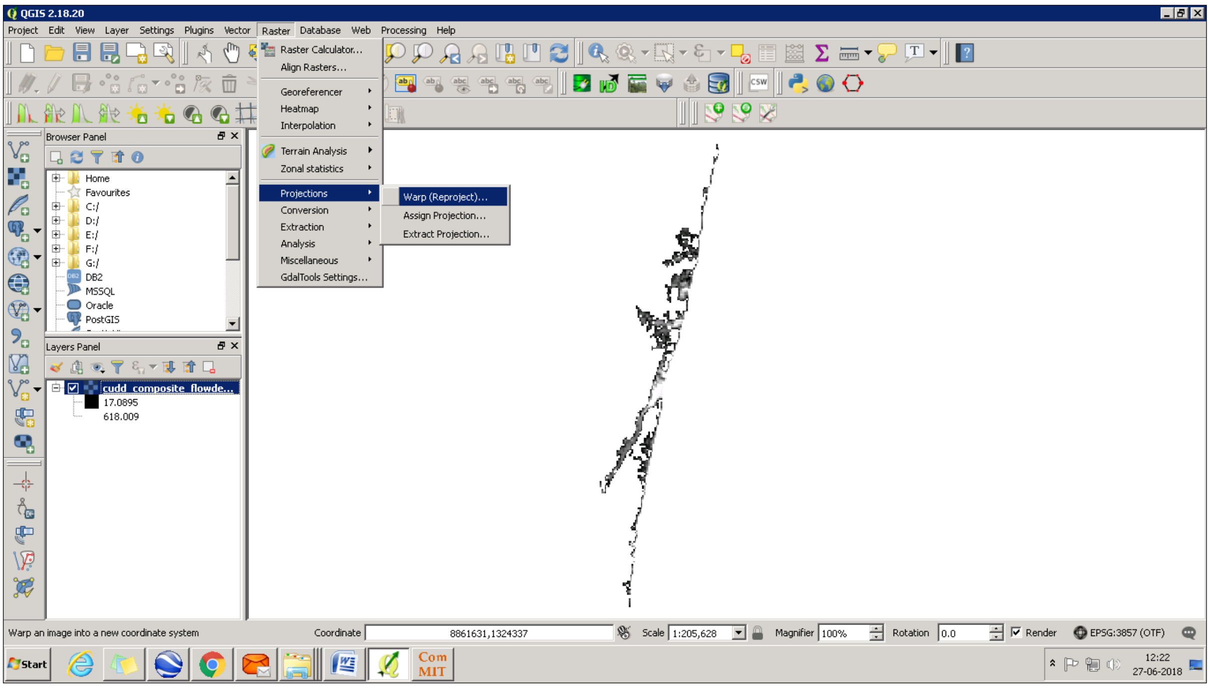
Step 3. Choose the file format (*.tif) for the modelling performed.

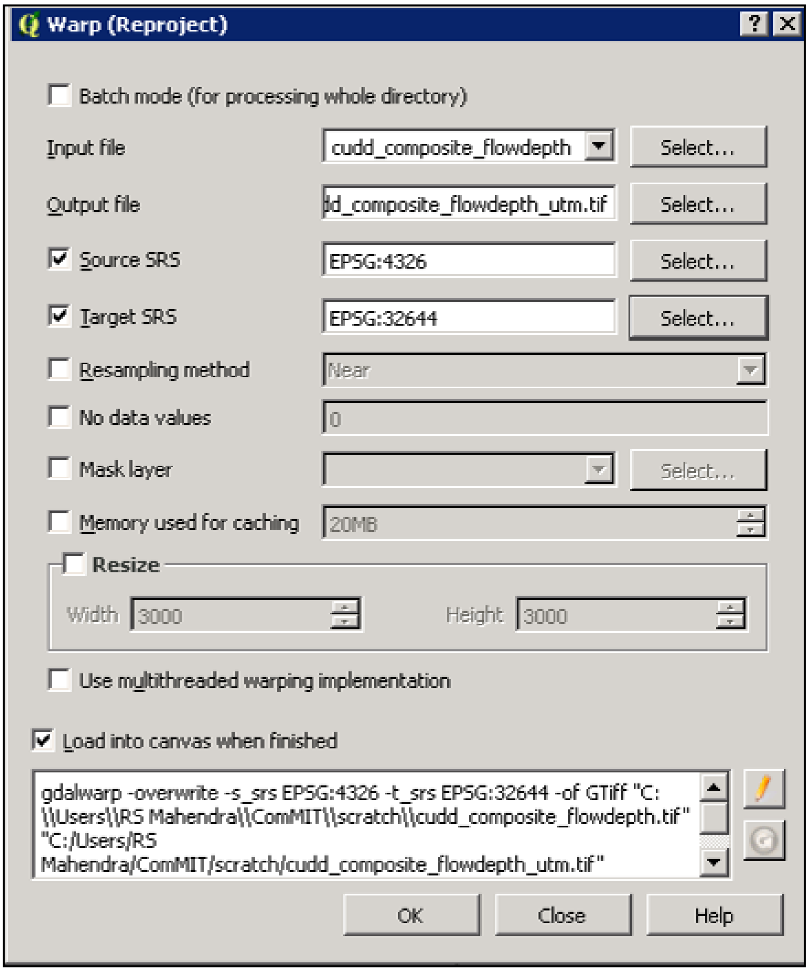


Step 4. Flood display area in the viewer QGIS.

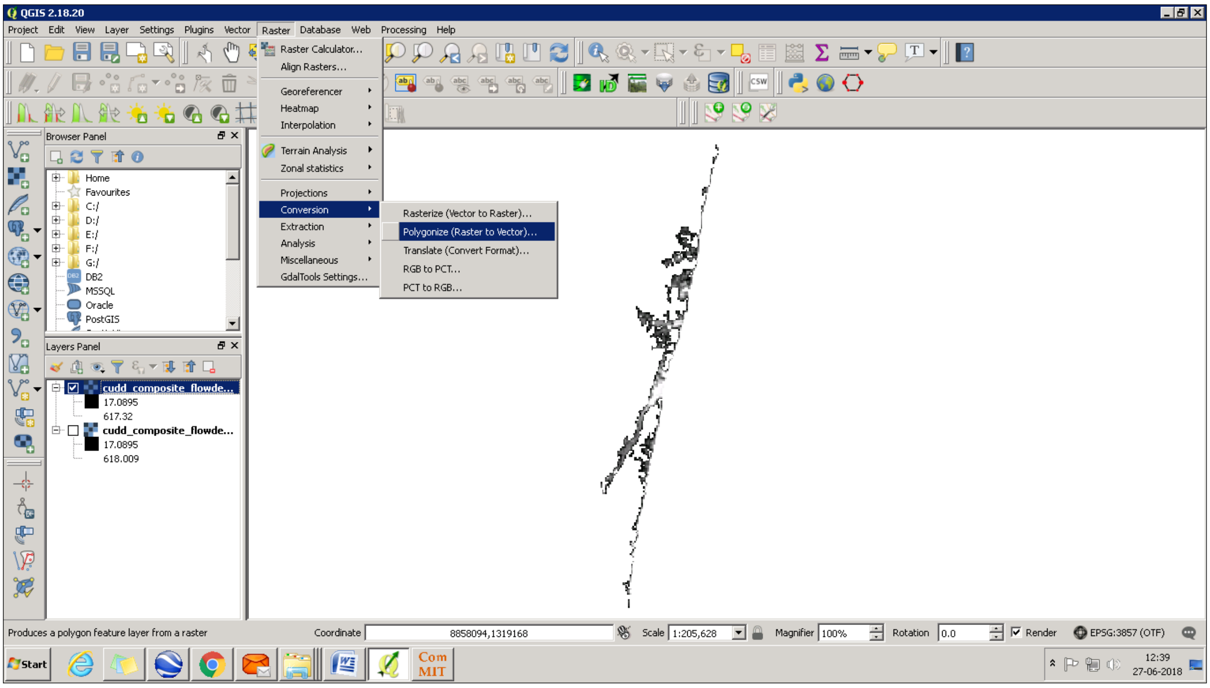


Step 5. We reproject the image to the coordinate system in which the map is being developed and worked. This step is very important because ComMIT contains the WGS -84 projection in this direction and many applications may experience problems when making projections with automatic coordinates.

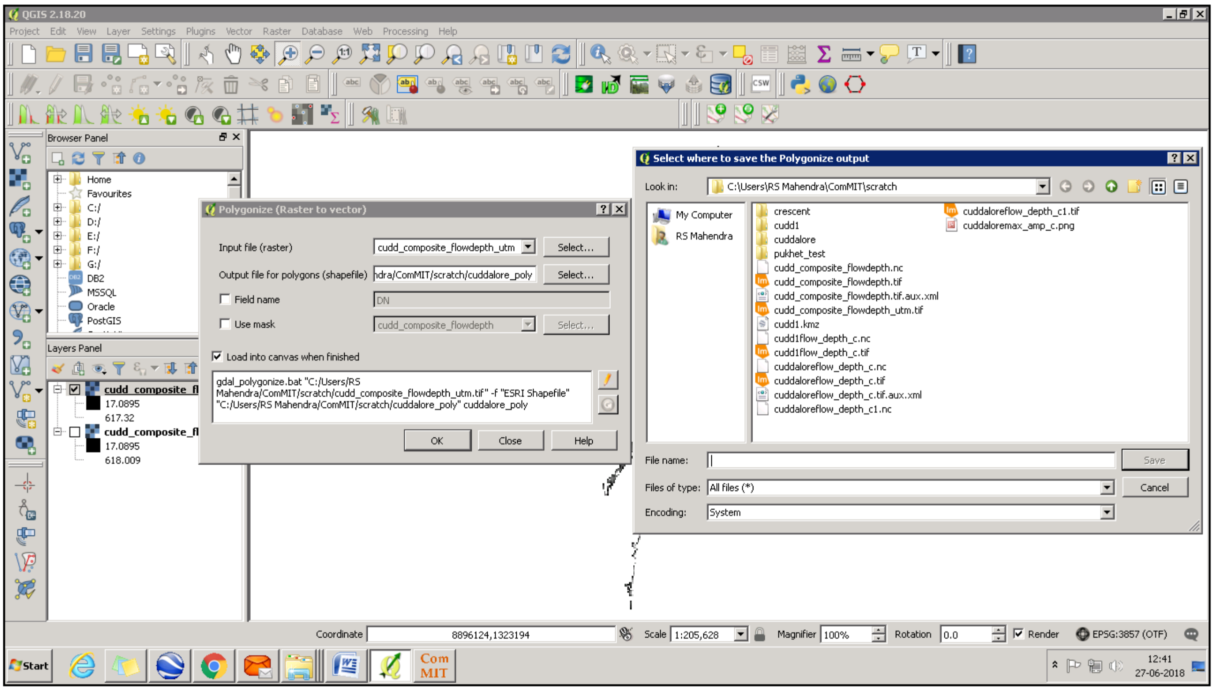




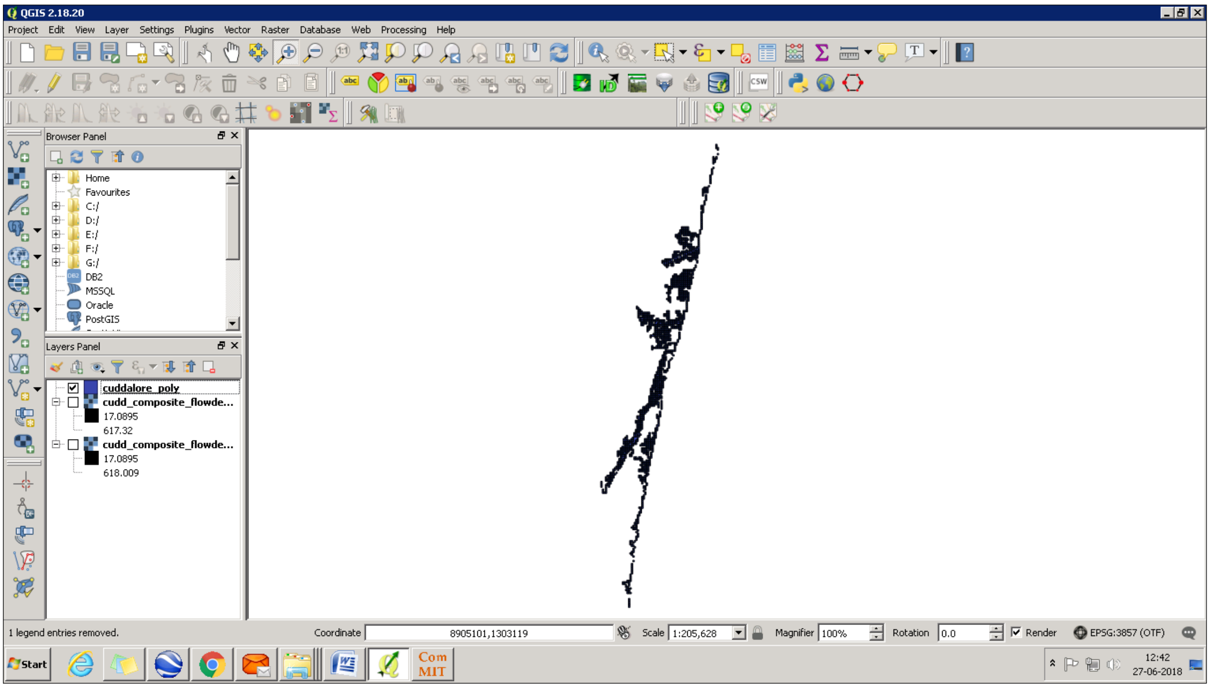
Step 6. Select the new file Raster re-designed to start with the information development. Select the option "Raster, Conversion, Polygonize (Raster to Vector)".



Step 7. Save the file to the desired place with the corresponding name.

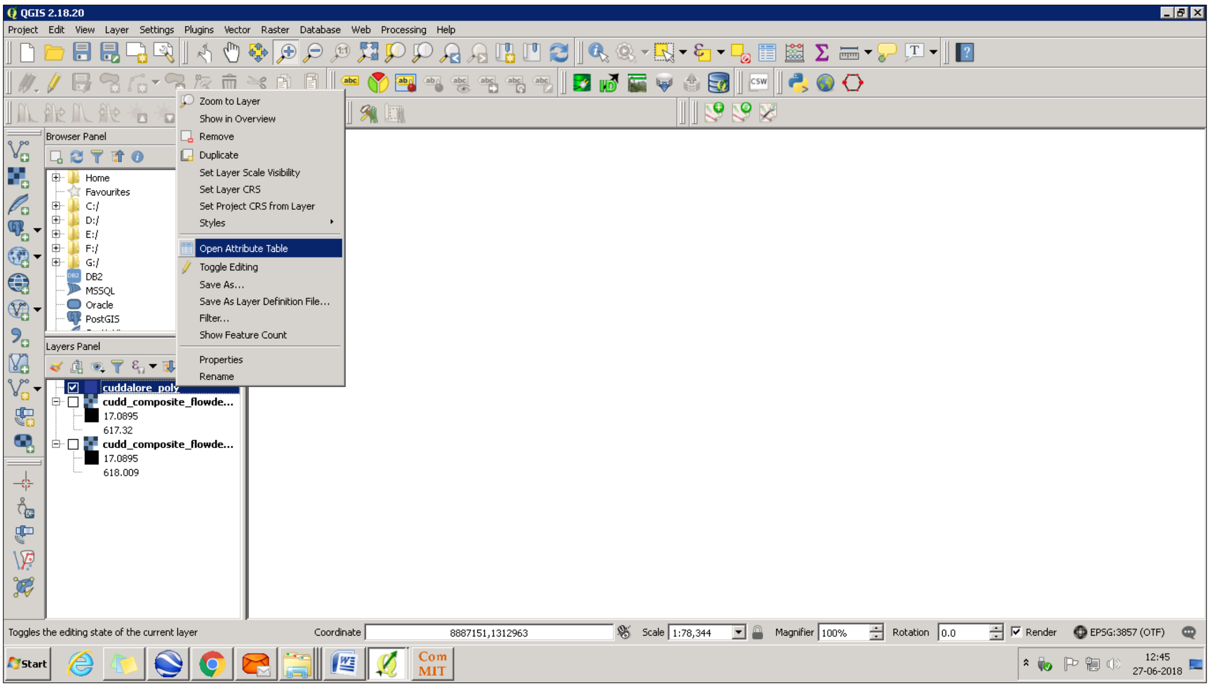


Step 8. Then we open the vector file that is generated by the vectorization.

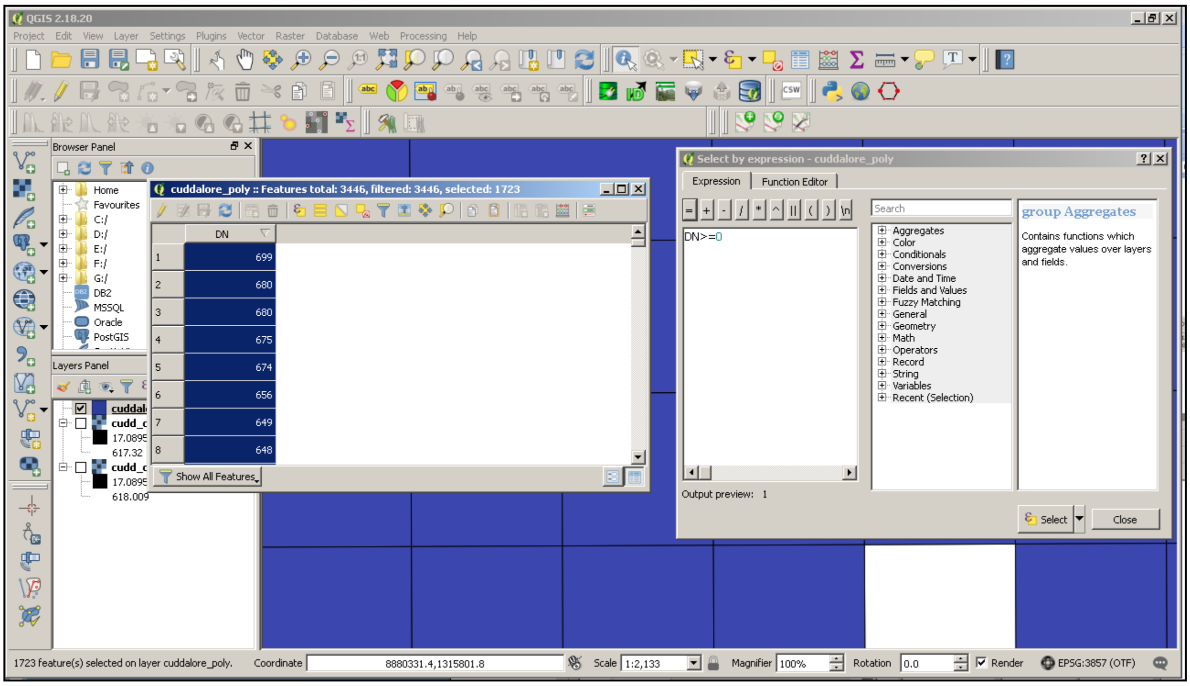


Step 9. We must choose the value of the polygons where we indicated that the tsunami generated flood to choose this mathematical operation in attribute tables DN>= 0. After QGIS in another colour shows the selected polygons proceed to export the selected polygons to a new layer of information in the coordinate system chosen to develop the map

Open attribute table by right clicking on vector layer in layer panel.

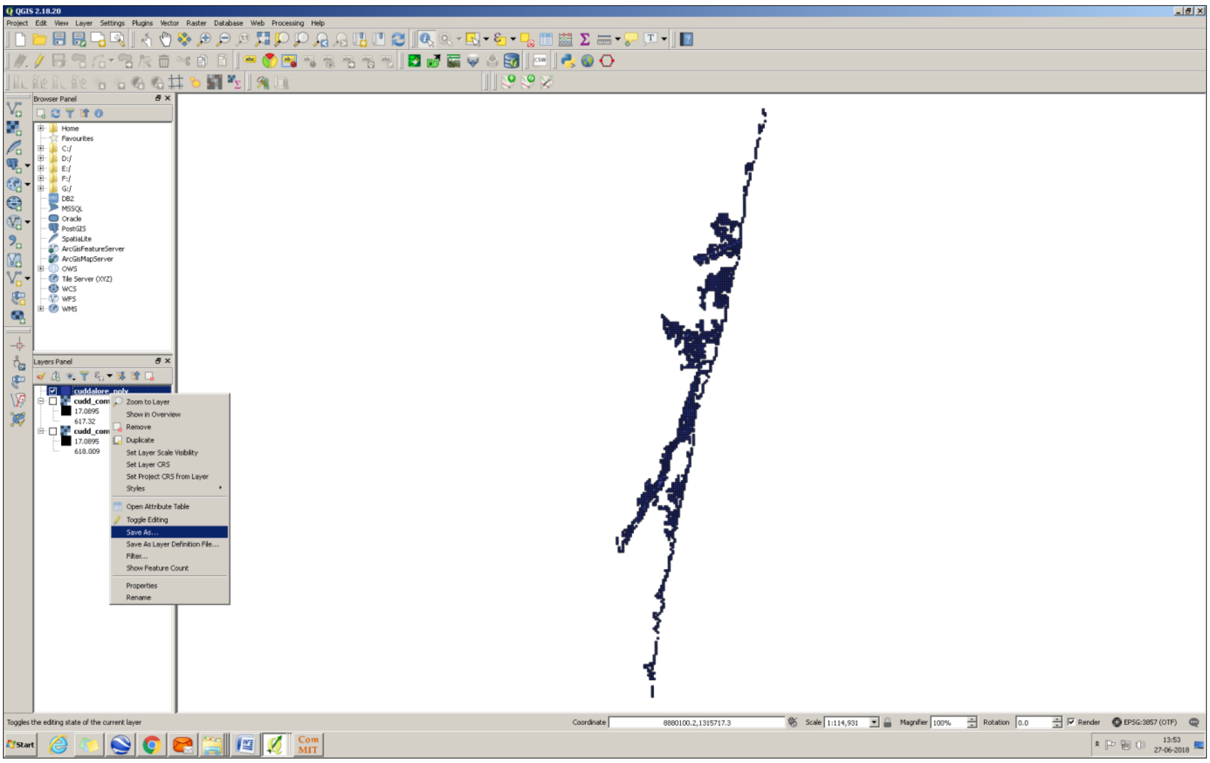


Select the tool "Select feature by expression" ( ) and type DN >= 0 and select.

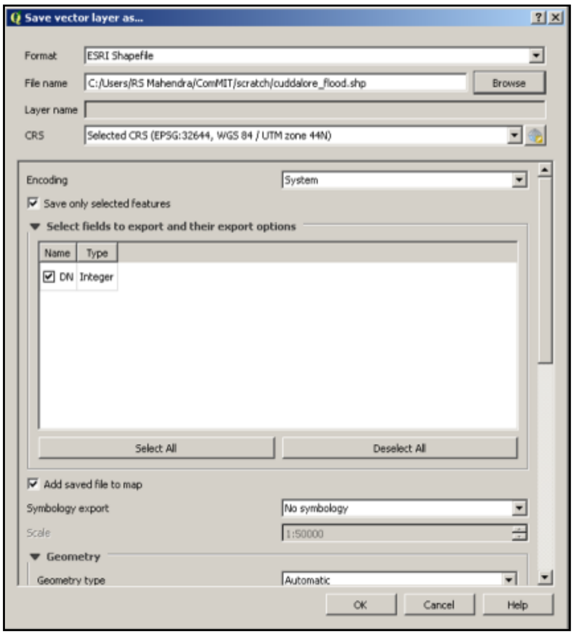


All the features having DN value greater than or equal to zero will be sleeted.

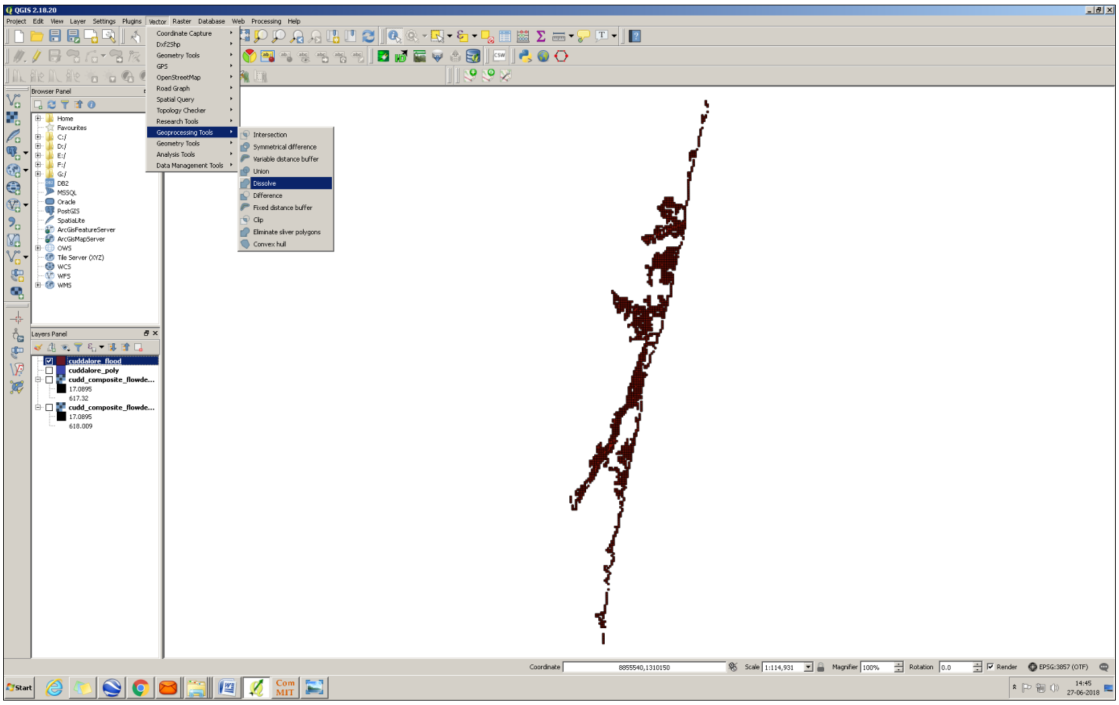
Step 10. Save the selected features into new shape file by right clicking on desired layer in layer file and then save as option

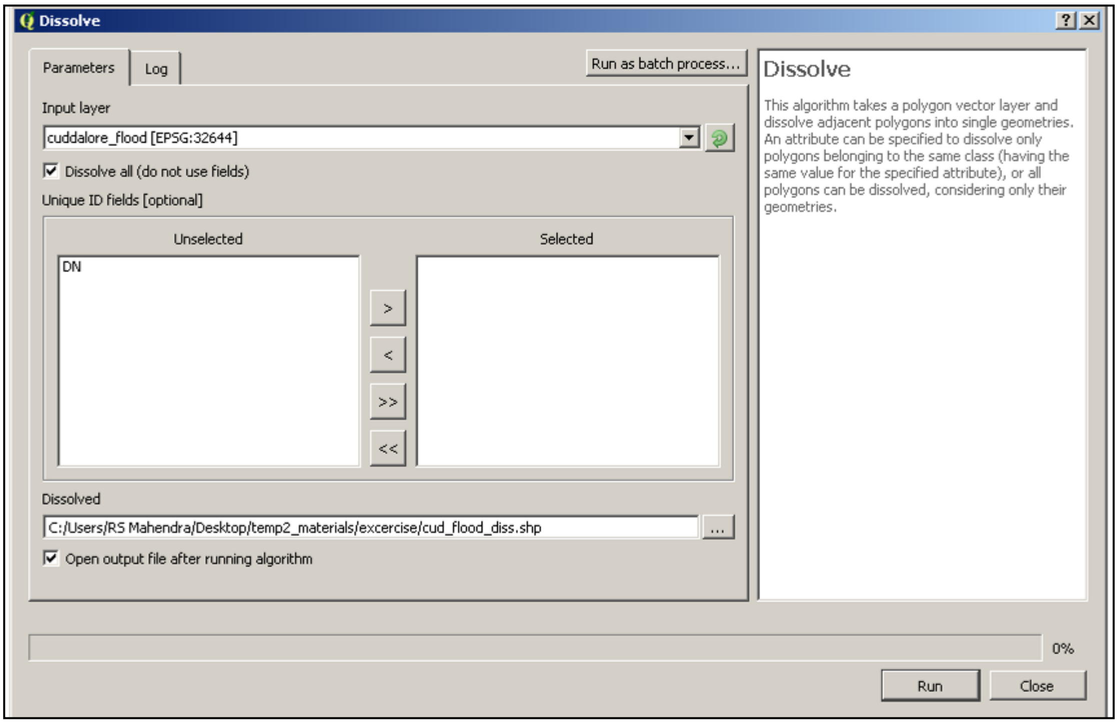


Following dialog will open and enter new file name and do not forget to select "Save only selected features"

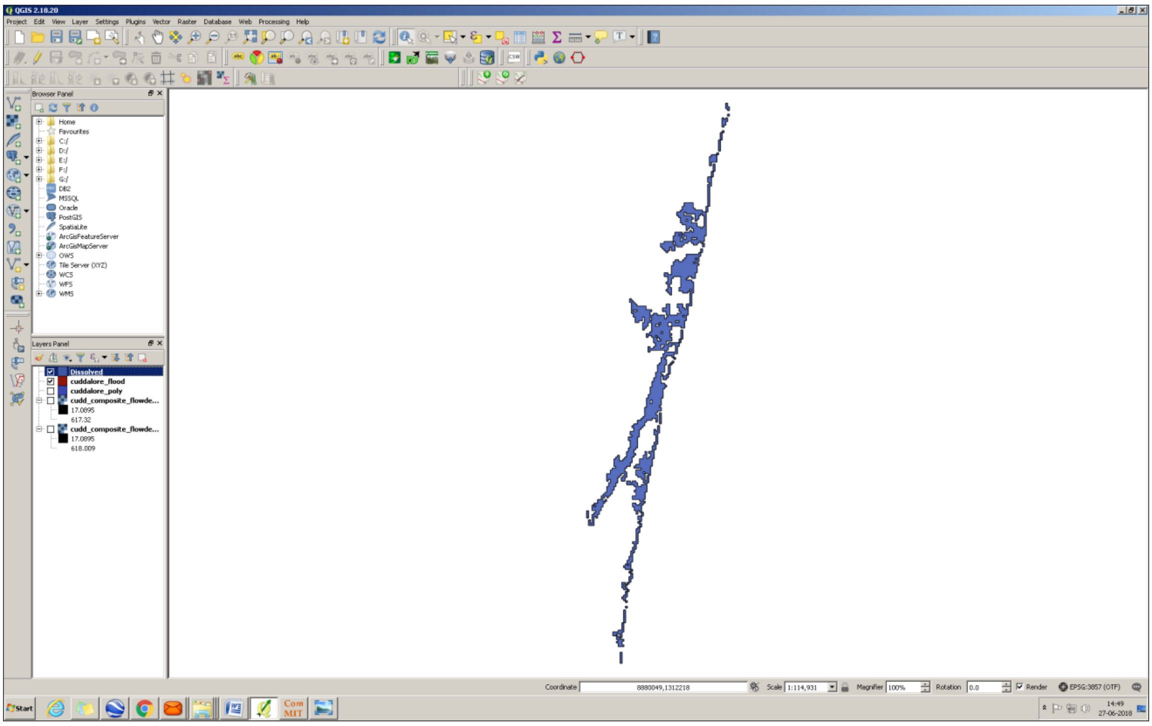


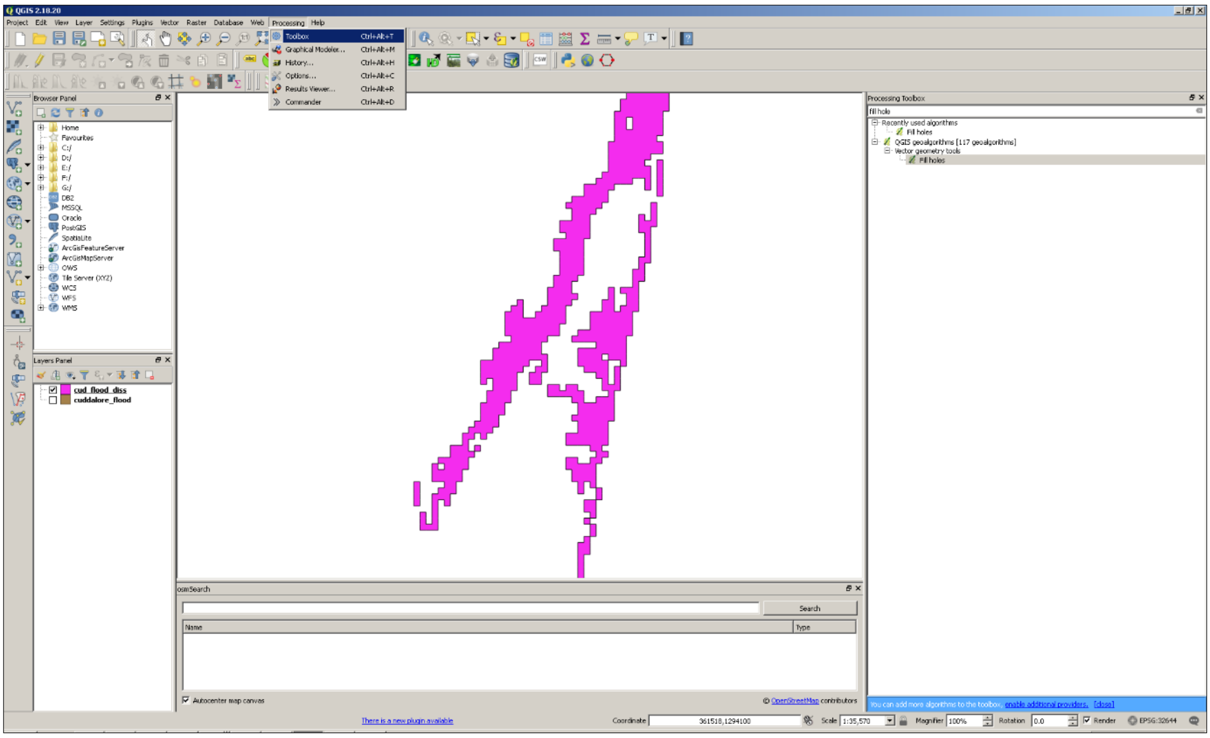
Step 11. The vectorized polygons floodplain proceed to perform the bonding process polygons known as "Dissolve" Then choose. In this process, there will only be clean polygons that indicates to the limits of involvement of the flood zone. This is a rather complicated process and depending on the type, computers or computer can take up to hours depending on the extent of the area to develop the map.

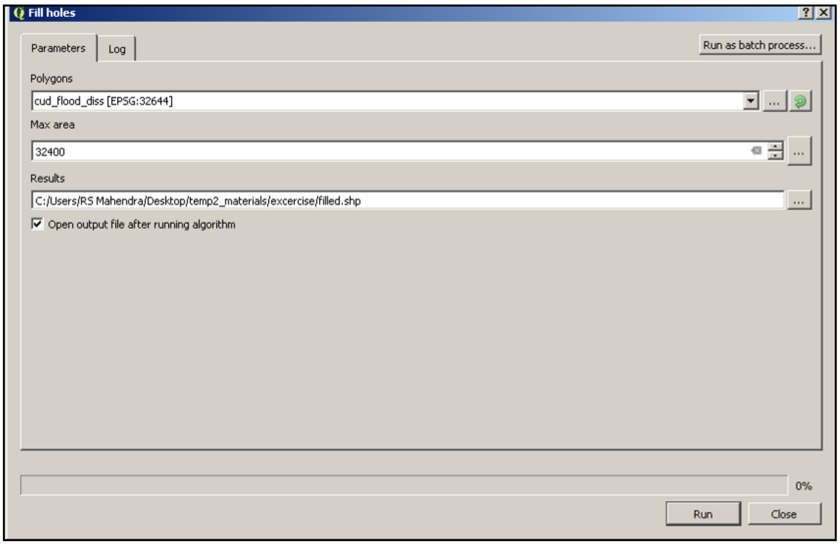


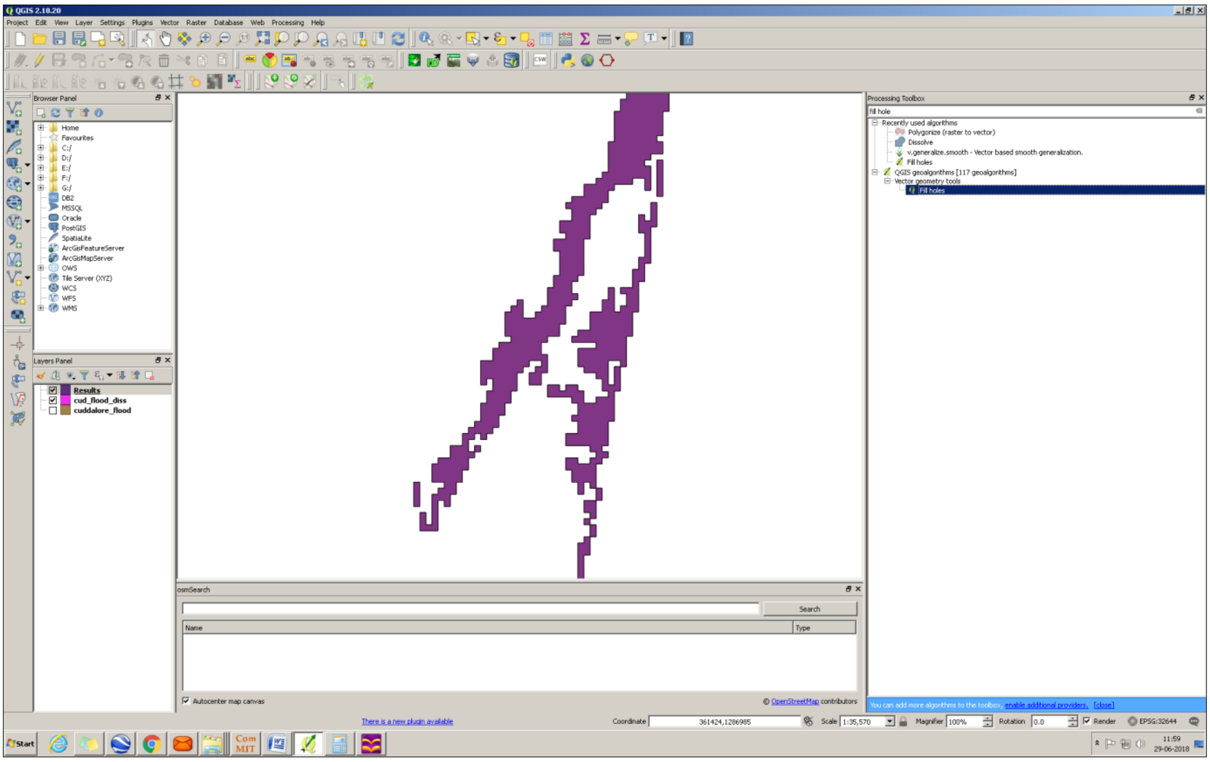


Step 12. The shape file after dissolving may have open place within inundation area this is because that grid might not become wet. The minimum mappable unit is 3X3 grids hence we will fill areas lesser than this (2X2 grids equivalent to 180 X180 m= 32400m) value.

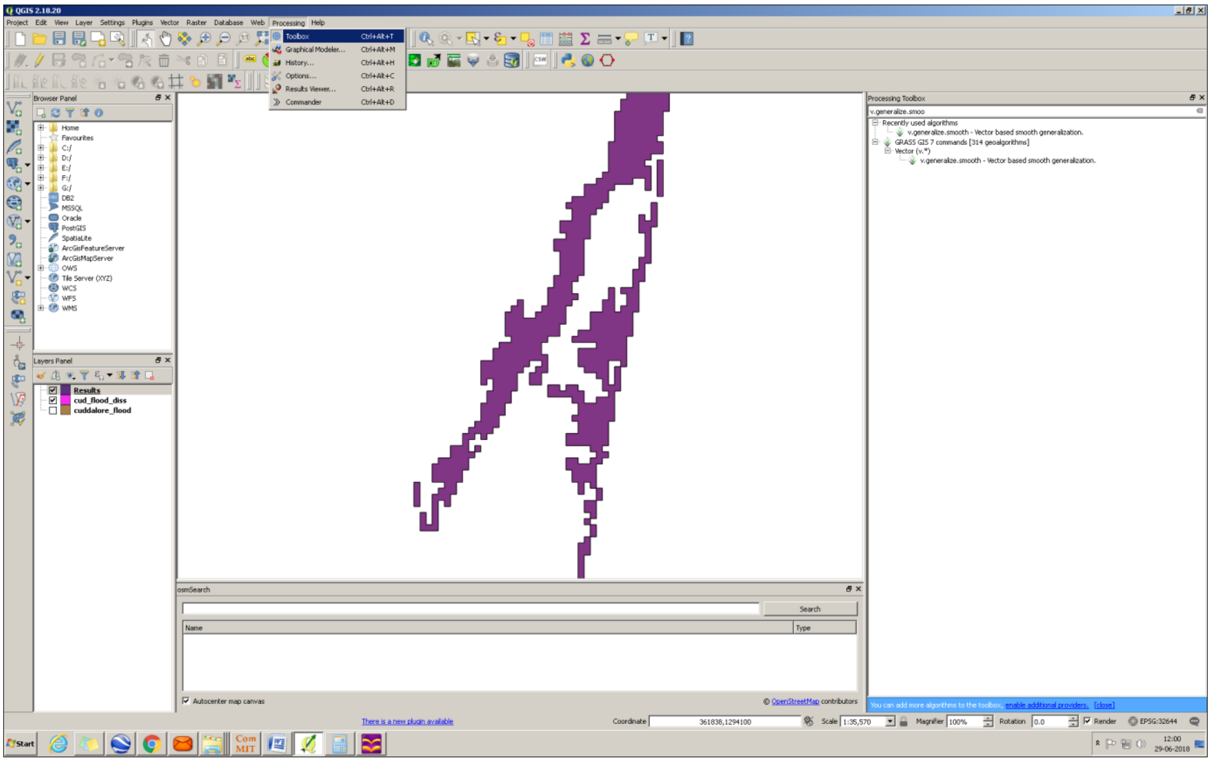



Processing Toolbox
Fill holes
cud_flood_diss
cuddalore_flood

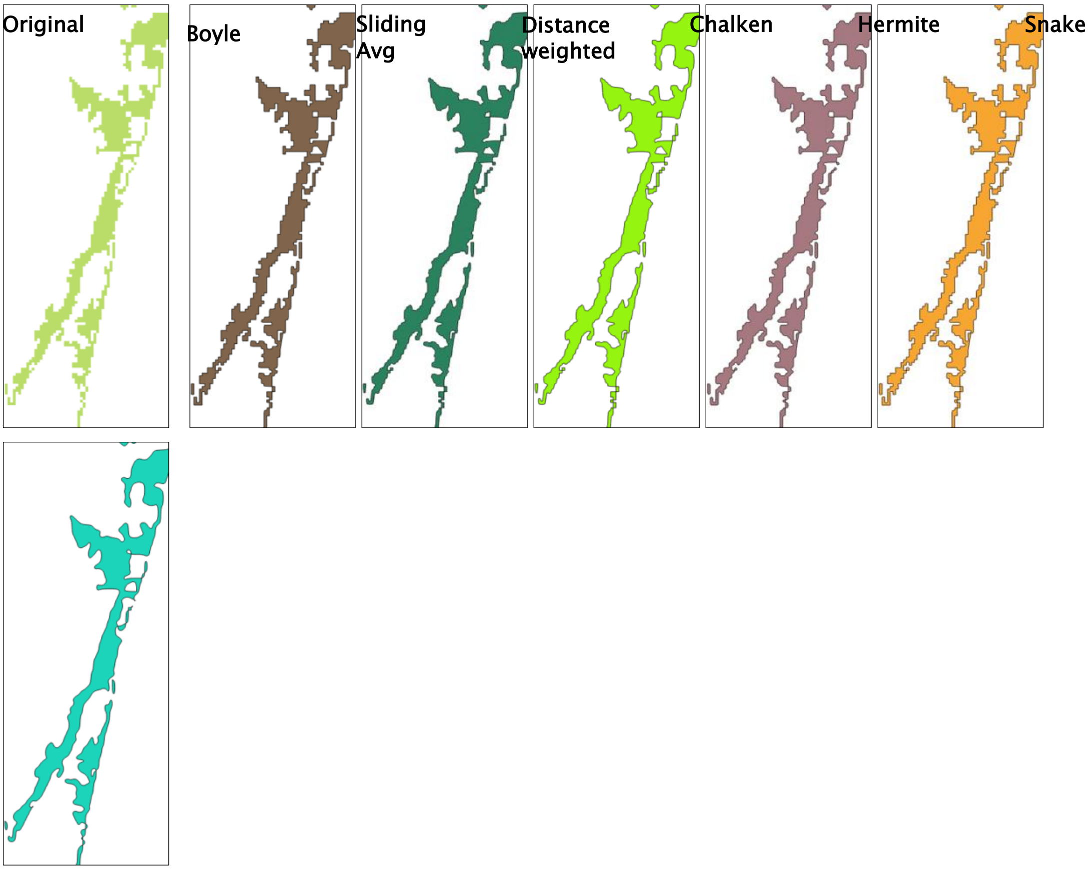

Fill holes
Parameters
Log
Run as batch process...
Polygons
cud_flood_diss [EPSG:32644]
Max area
32400
Results
C:/Users/RS Mahendra/Desktop/temp2_materials/excercise/filled.shp
Open output file after running algorithm
0%
Run
Close

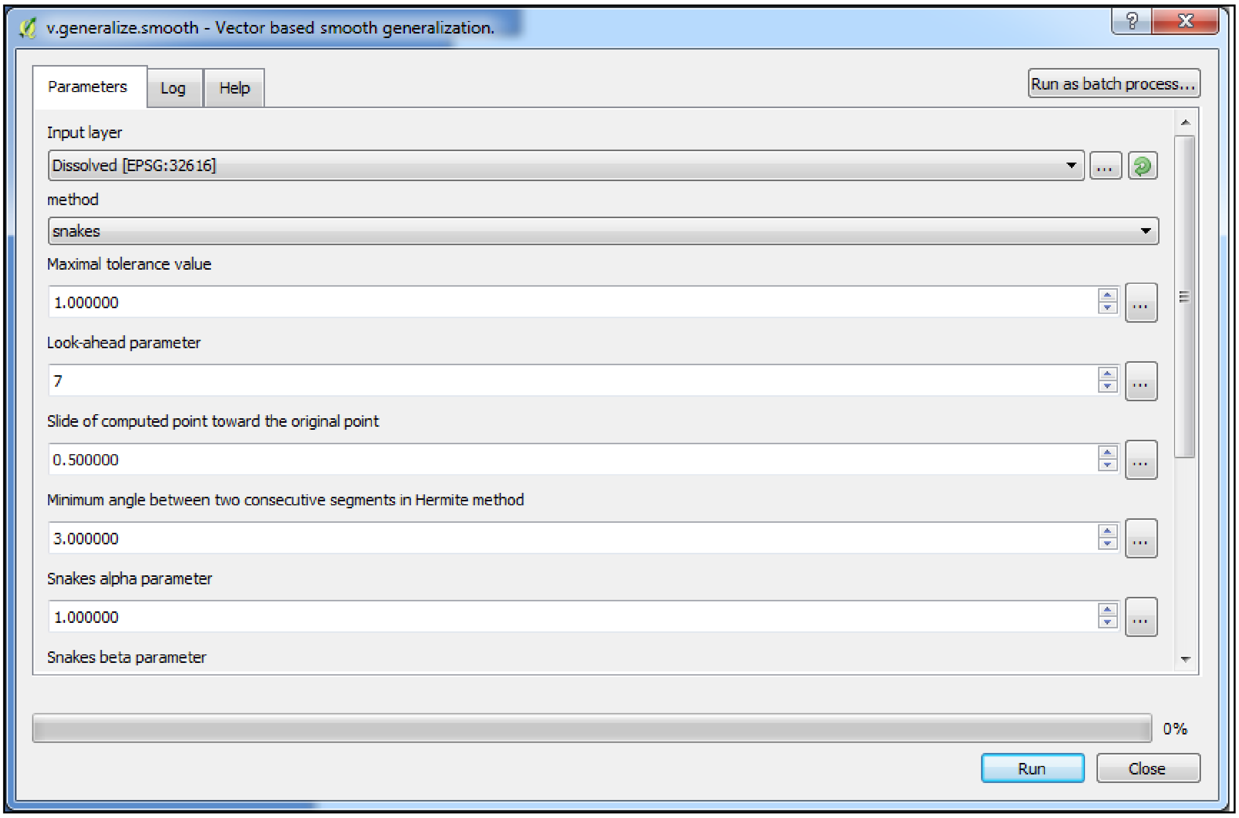


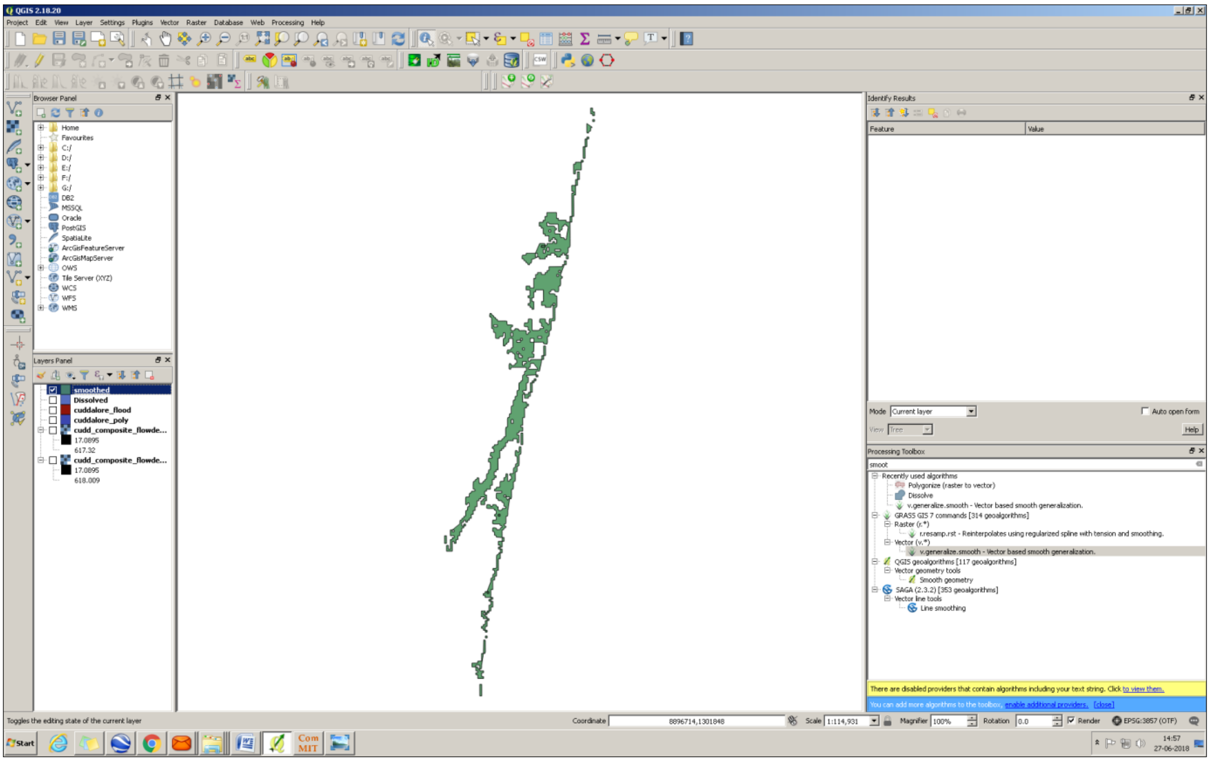
Step 13. Depending on the resolution of the data for each region, often we can experience pixelated results in automatic vectorization of data. That is why we need to make a vector smoothing to the results obtained from the previous process. The main benefit of this generalization or smoothing of the vector layer is that it will be presented in a more consistent and friendly to be presented on the development of the Evacuation map or Tsunami Evacuation. For smoothing vector work to perform we must use components Grass 7.04.



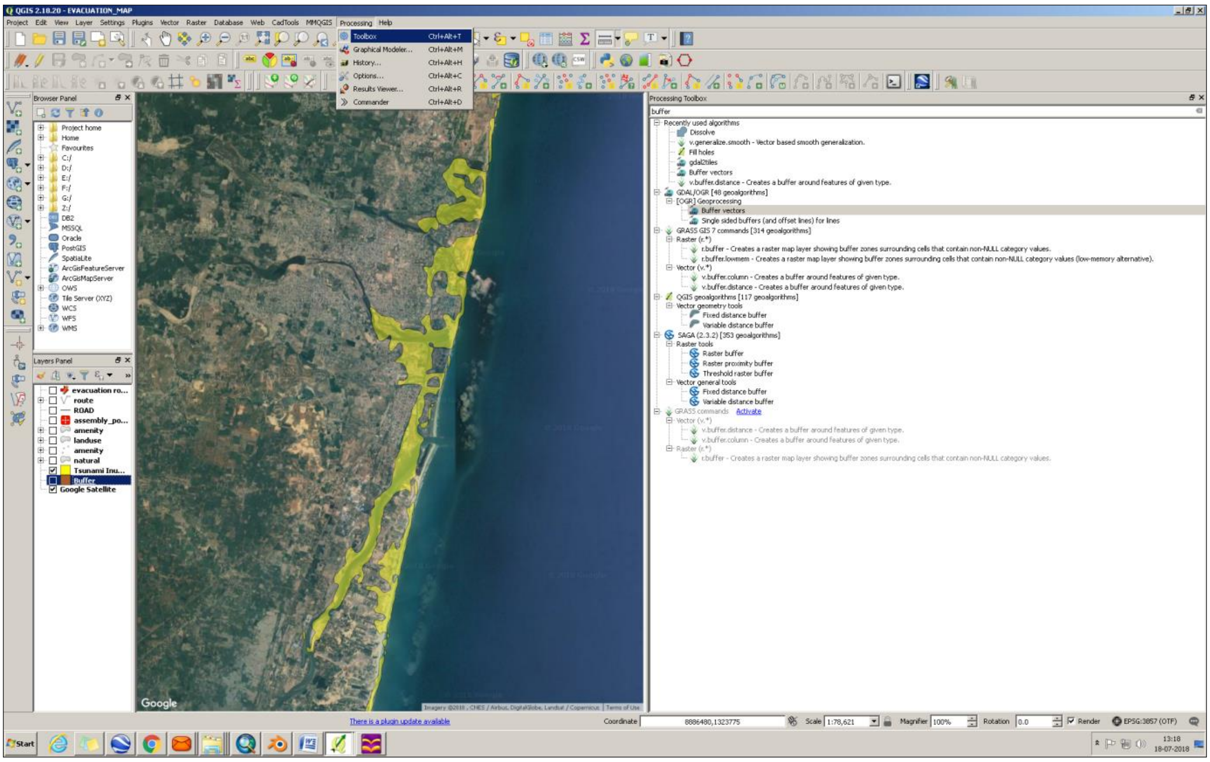
Comparison of different Smoothing Methods:



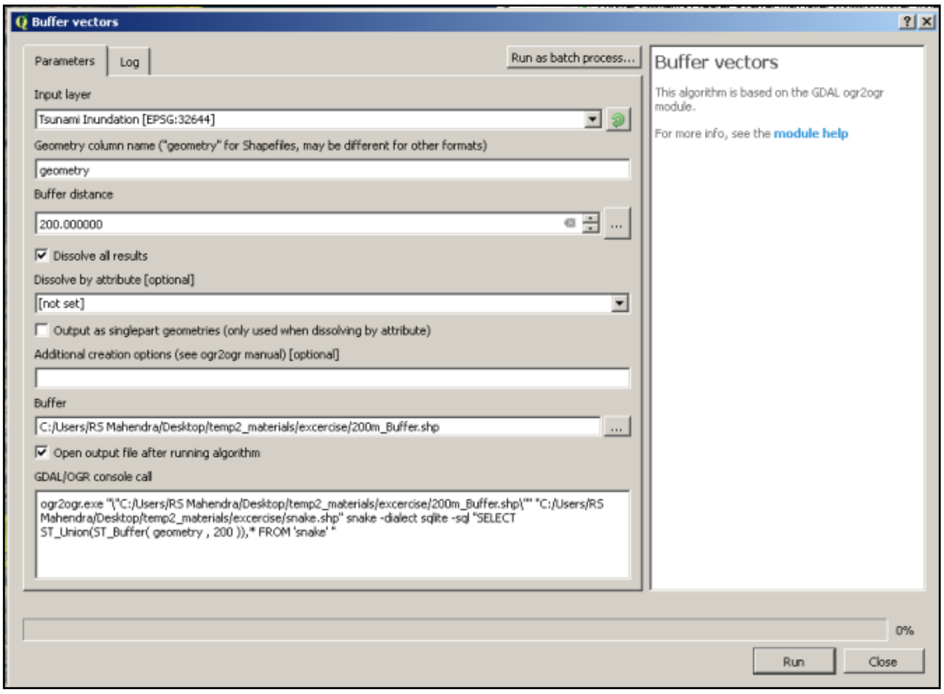




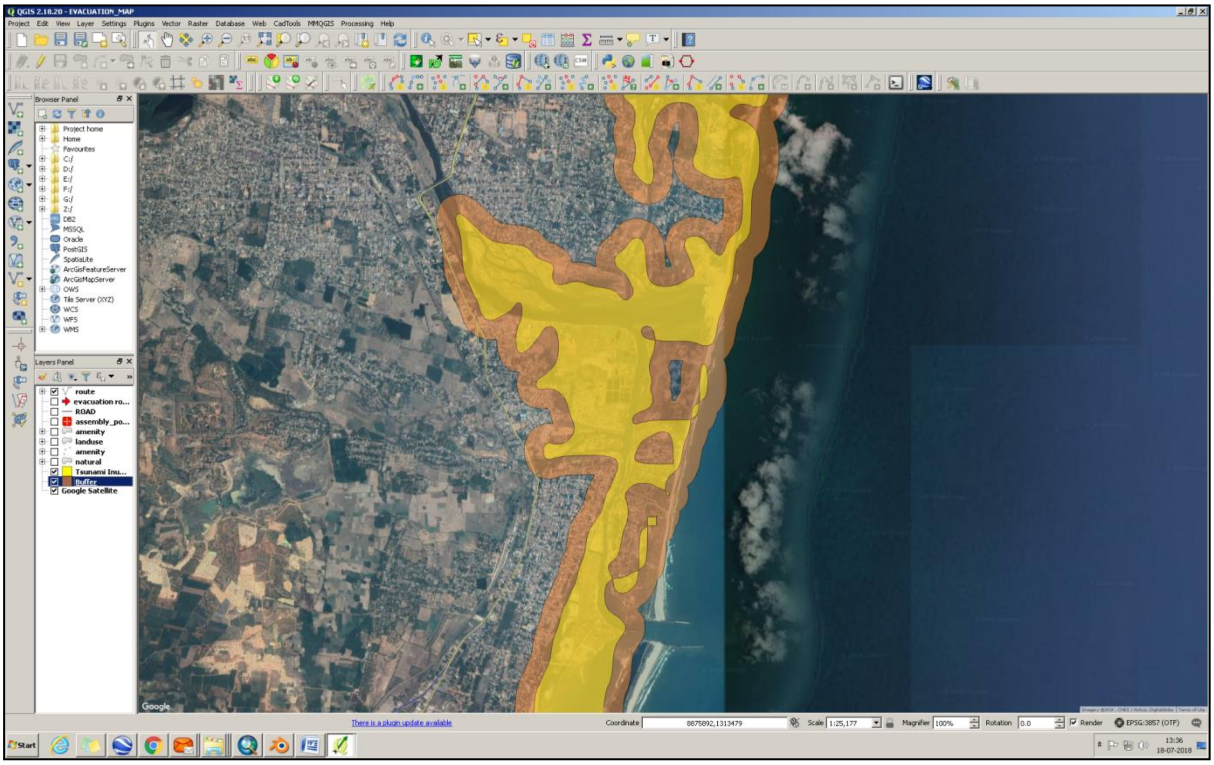
Step 14. It is necessary to add buffer to the tsunami hazard zone as transition zone to consider the uncertainties of the tsunami modelling. Hence, add 200 m buffer to tsunami hazard zone. Go to Processing menu select Toolbox and type buffer in processing tool box right side. Select "Buffer vectors" tools under "[OGR] Geoprocessing".



The following dialog will appear. Select the input layer to create buffer (tsunami inundation zone), enter buffer distance 200, check "dissolve all results" and enter output file name and then run



The created buffer will appear in viewer as shown below. Give appropriate symbology for buffer layer and add this in the map legend in the map composer.



It is also possible to add the inundation layers (outputs from for example ComMIT) as a Vector file and edit accordingly.

3. INSTALLATION OF QGIS PLUG-INS AND OCHA ICONS

This section covers the QGIS requirements for creating the tsunami evacuation map from the inundation map. QGIS plug-ins and OCHA symbology are recommended.

3.1 REQUIRED PLUG-INS

The following plug-ins are needed to develop Tsunami Evacuation Maps:

CADtools - Allows utilities of CAD drawing as a system within the QGIS platform.

Elevation - Gets and displays the elevation of points using a Google Maps API.

GEarthView- Displays selected elements and attributes QGIS Google Earth platform (also compatible with Pro version). It is enabled and tested to work on Windows, Mac OS X operating systems and some Linux systems. Google Earth platform must already be installed on the same device that QGIS is installed.

OpenLayers plug-in- Download the databases: Google Maps, Bing Maps, OpenStreetMap and others.

QuickMapServices: This facilitate users to add the web map services from OSM, NASA, etc.

QuickOSM - Executes QGIS specific queries for information from Open Street Maps (OSM Data).

3.2 HOW DO YOU INSTALL THE QGIS PLUG-INS?

Step 1. After opening, the QGIS application should select the top button that says Plugins and select "Manage and Install Plug-in". A screen will appear as shown below:

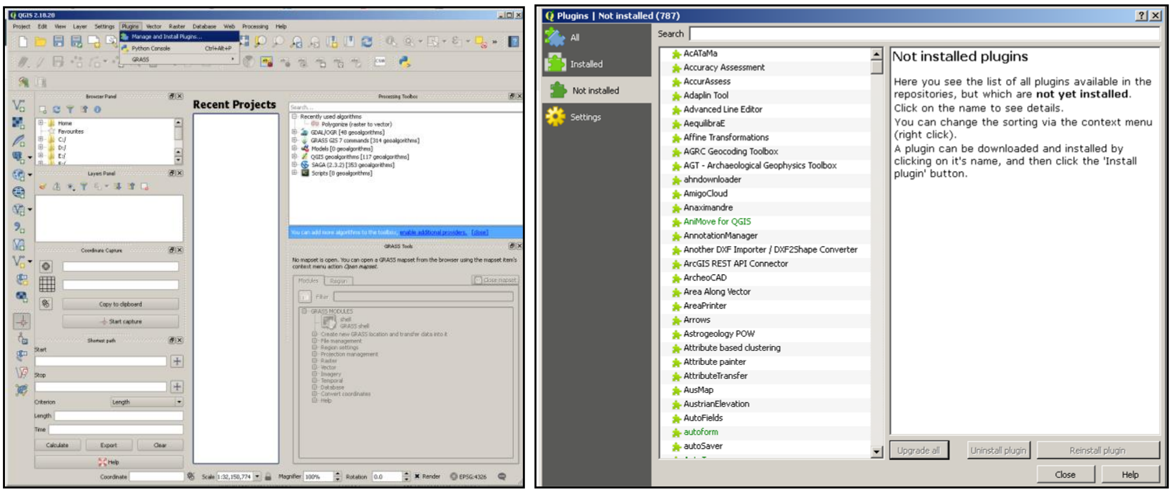


Figure S2. 13.Window Showing the Plugins

Step 2. Select the required plug-in to be installed and select the lower right button that says "Install Plug-in" as shown in the image below plug-in:

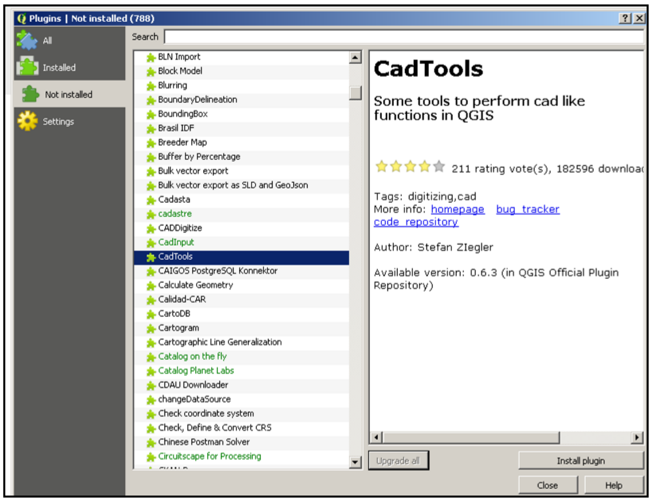


Figure S2.14. This Window Shows the Plug-in Options

Similarly install other plugging Elevation, GEarthView, OpenLayers plug-in, QuickOSMand QuickMapServices

3.3 HOW TO INSTALL LIBRARY SYMBOLOGY QGIS?

Step 1

- Download the OCHA symbols library, at the following link https://mapaction.org/resources/ocha-humanitarian-icons/
- Click on "OCHA_Humanitarian_Icons_For_GIS_v2.0.zip"
- Extract the zip file
- Copy the extracted "OCHA_Humanitarian_Icons_For_GIS_v2.0" folder and save into your working folder.

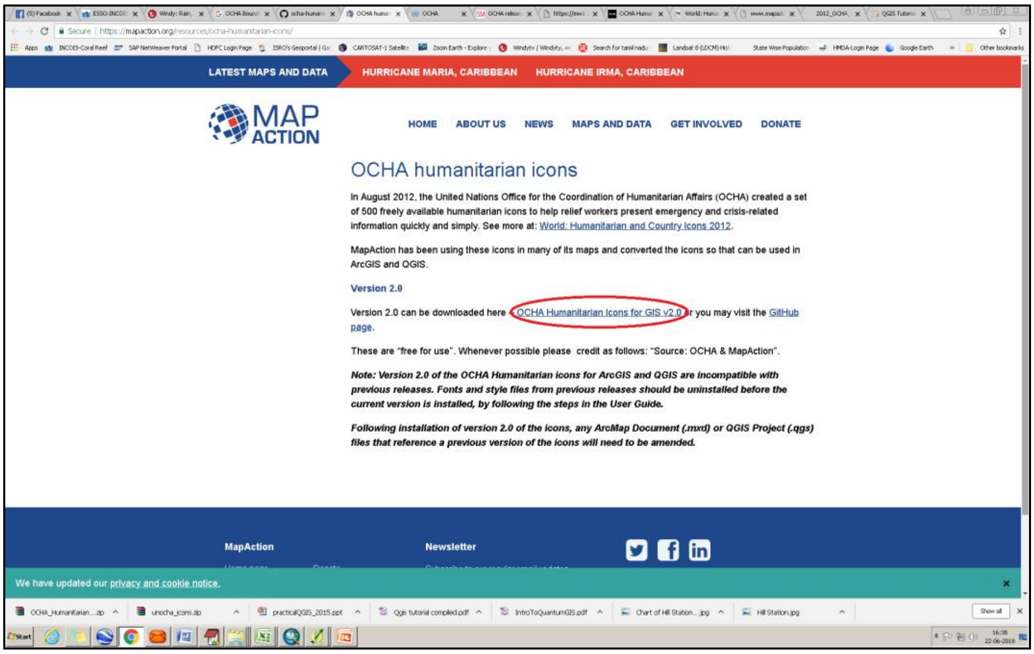


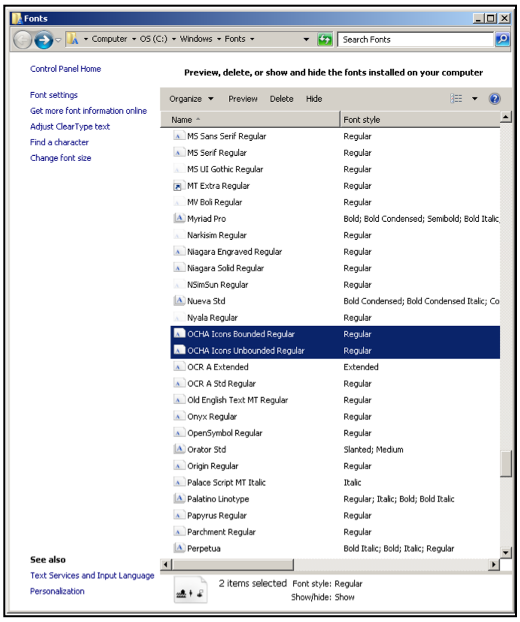
Figure S2.15. Web Page Showing OCHA Available Symbols

To establish a standard Evacuation or Tsunami Evacuation Maps symbology it must be a unify symbology, that is simple and common in all maps. For this reason, we use the symbols provided by OCHA (Office for the Coordination of Humanitarian Affairs) and then show the next step for installation:

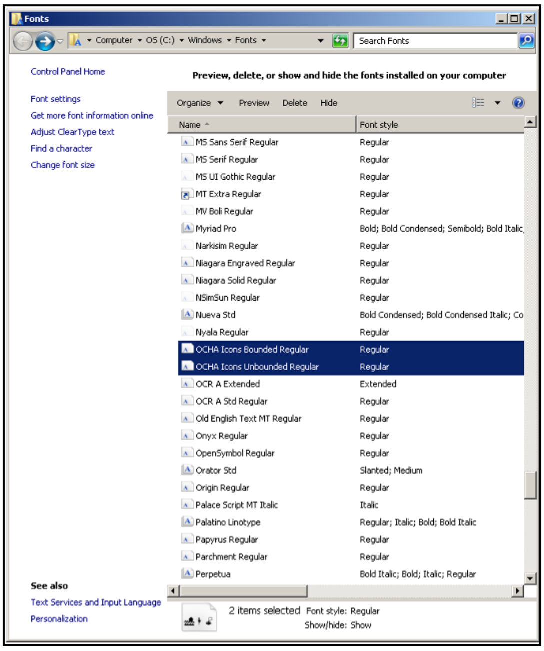
Step 2.

We must remove all previous versions OCHA on Windows first (if you are not going to, go to point 2 of step2.)

To Remove: Access the disk C:\Windows \ Fonts and removed the Fonts "OCHA Bounded Icons" and "OCHA Icons Unbounded".

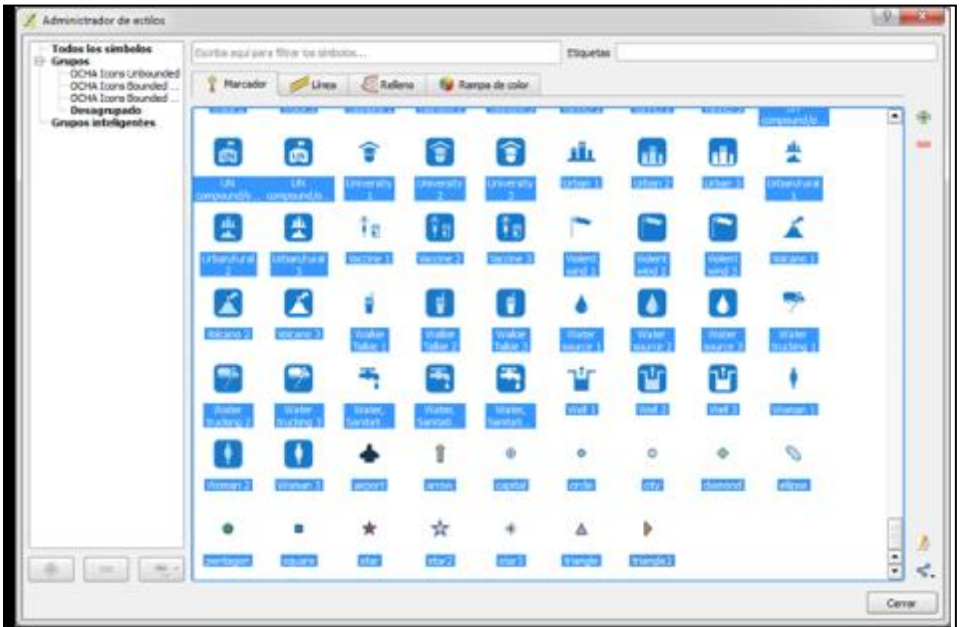


Add the current version of OCHA icons fonts: Go to the extracted folder (previously saved into your working folder). Go to the "01_Fonts" folder and copy the files "OCHA - Icons-Bounded.ttf" and "OCHA - Icons- Unbounded.ttf" in the Windows Fonts folder (C:/Windows/Fonts)



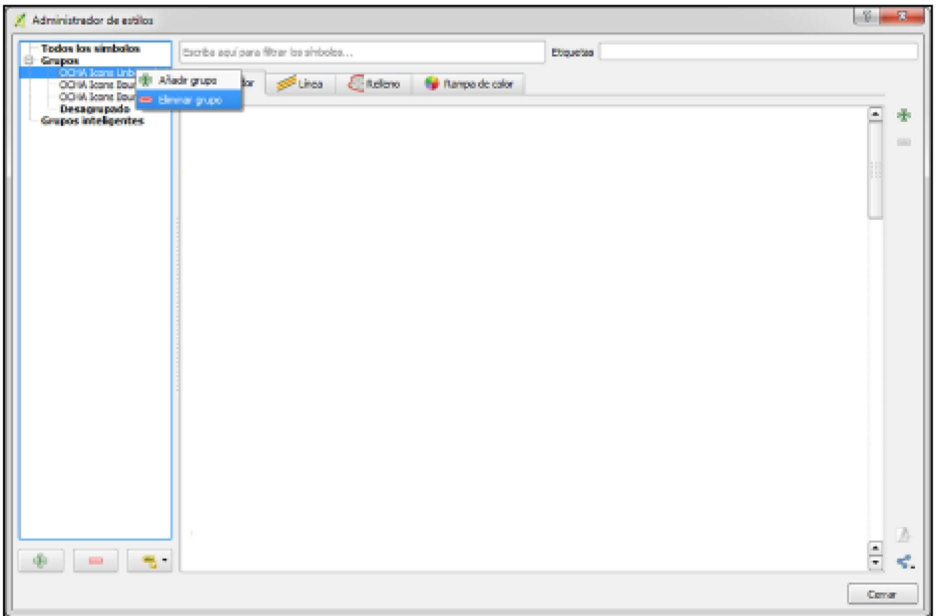
Step 3. Remove previous versions of the styles OCHA Humanitarian Icons on QGIS.

- Open QGIS.
- Go to Settings---Select Style Manager and selections OCHA Unbounded which is on your left hand side. (If it is not installed, go to step 4.).
- Select the first icon and press Ctl+A and right click remove items.



Window Showing The OCHA Symbols that are Going to be Replaced

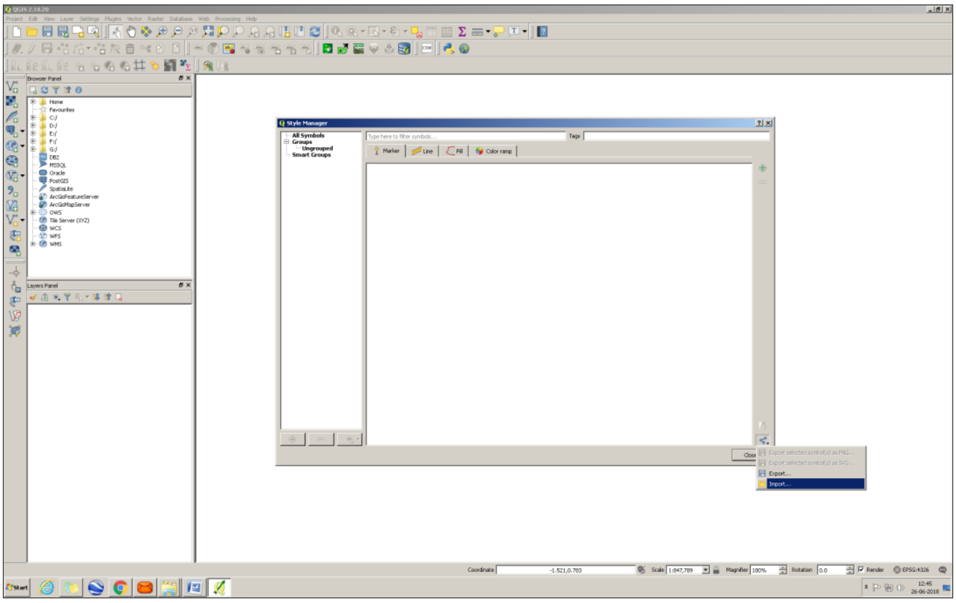
- We select icon delete item(s).
- Otherwise "Click" Unbounded right to OCHA Icons located on the left side and make "Click" Delete Group.
- We do the same in OCHA Icons Bounded White and OCHA Icons Bounded Transparent.



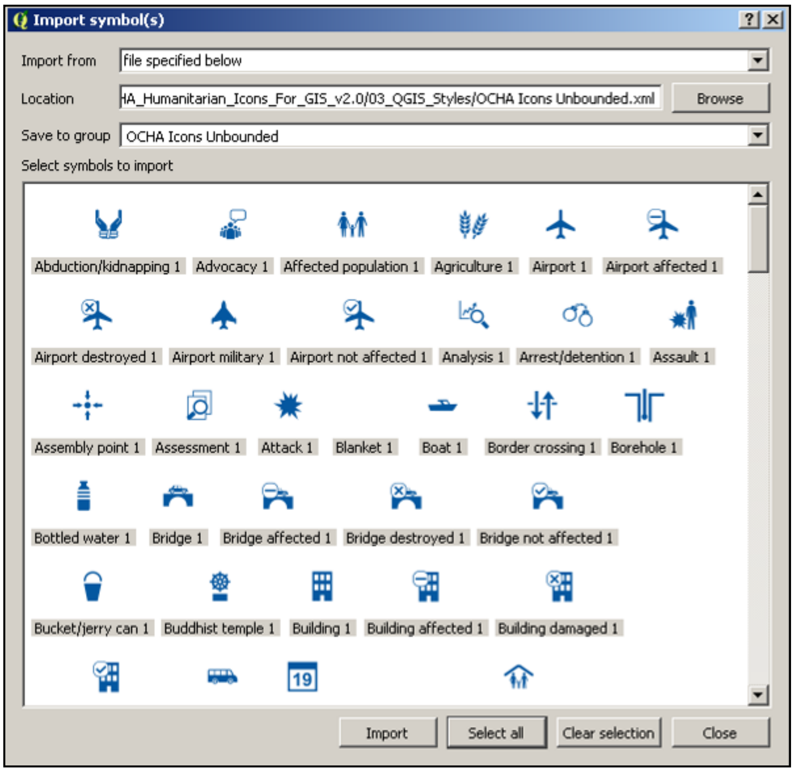
Window Showing How The Groups are Eliminated

Step 4. Adding the files of the new version of OCHA Humanitarian style Icons on QGIS:

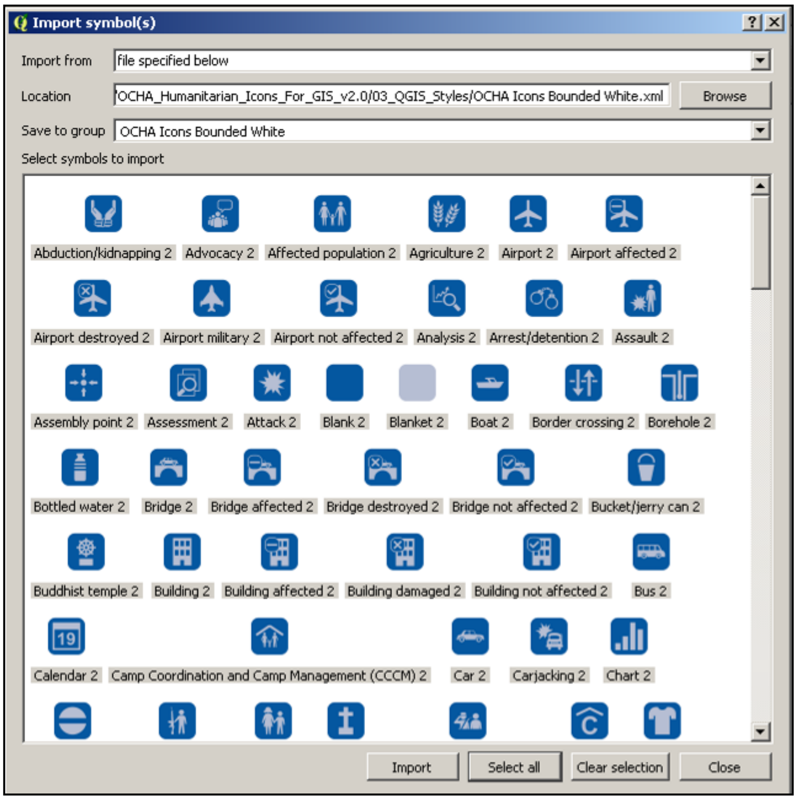
- Open QGIS.
- Go to Settings---Select Style Manager.
- We click on Share (import/export on newer QGIS versions). ---Select Import.



- In the Search window or "Browse" (on newer versions of QGIS an import window pops up, select the points of ellipsis at the end of the file row).
- Go to the extracted folder (previously saved into your working folder). Go to the "03_QGIS_Styles" folder select the "OCHA Icons Unbounded.xml file". On the select symbols to import window, click on select all and then click on import.



- Repeat Step 4 for OCHA Icons Bounded Transparent.xml and OCHA Icons Bounded White.xml. After this step, the icons should appear in the Style Manager window.



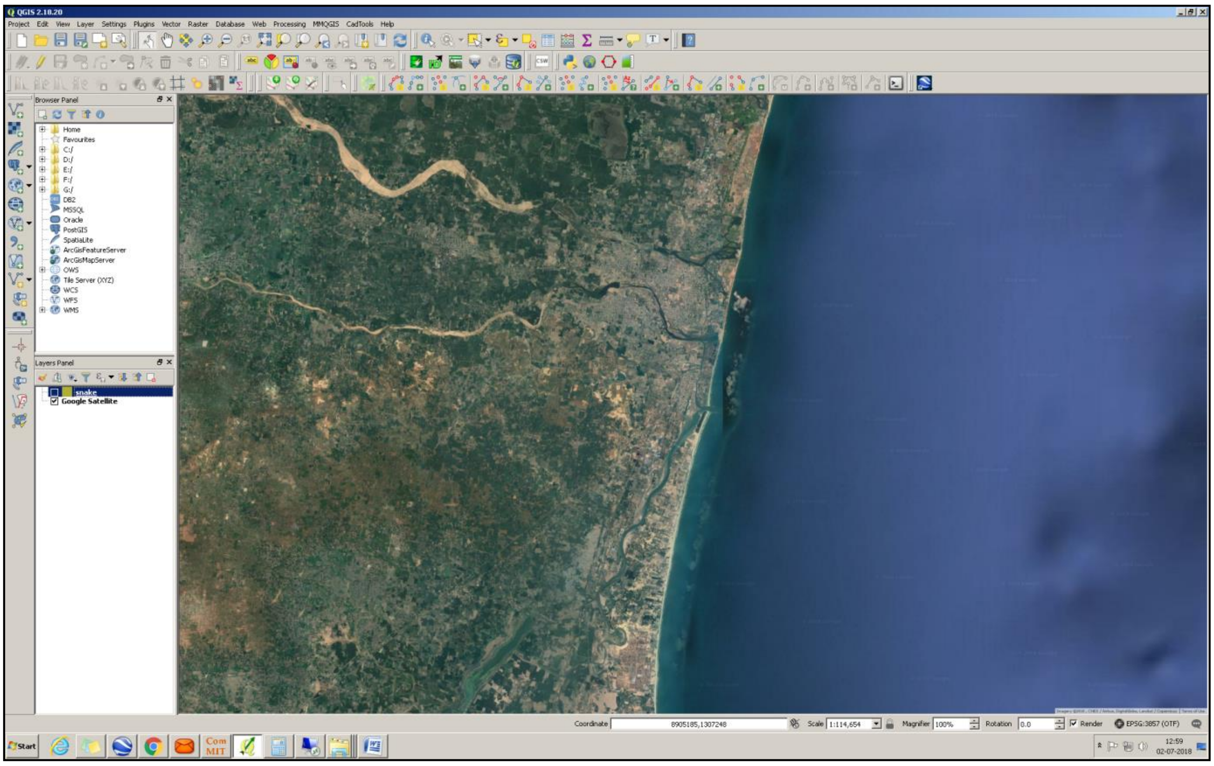
4. DEVELOPING TSUNAMI EVACUATION MAPS USING QGIS

4.1 REQUIRED DATA DEVELOPMENT TSUNAMI EVACUATION MAPS

The data needed to develop Tsunami Evacuation maps are different and will depend on the complexity of the coastal community development. Communities with greater coastal development have typically denser infrastructure and therefore results in many more dense mapping information. The density of information presents new challenges, as they often have to decide what kind of crucial information is the most effective to be added in the development of a map. For the development of a Tsunami Evacuation map, the following data layers or data are required:

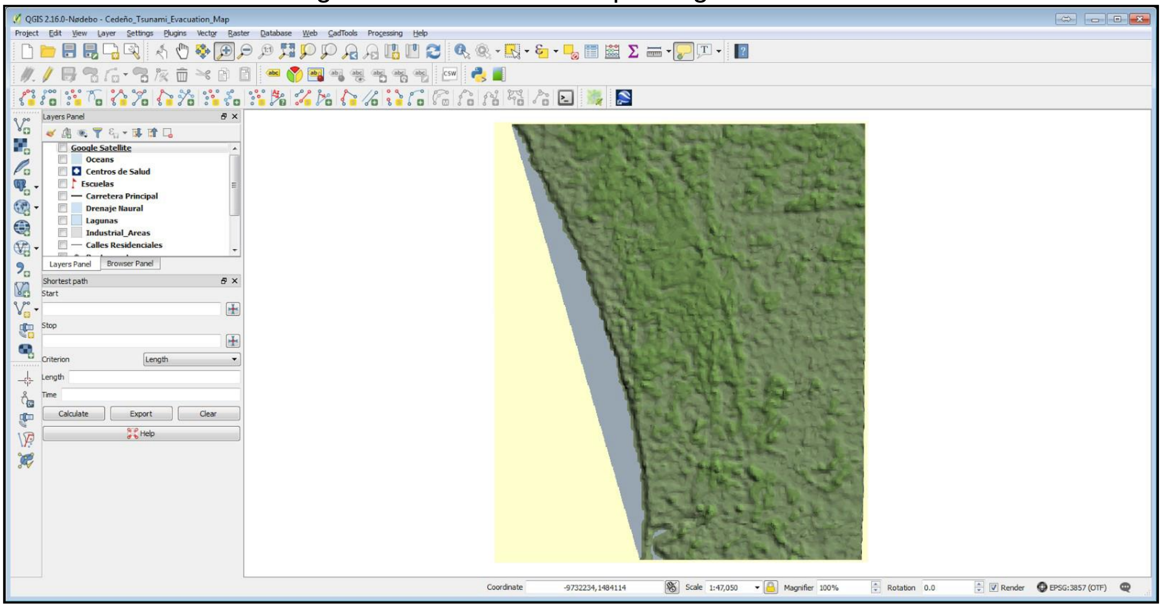
A. Aerial Images or satellite Area (Georeferenced)

The aerial or satellite images are georeferenced key element for the development of the map. This information must be as recent as possible because in them it may corroborate much of the information that is displayed on the map. It will also serve as a basis for better decision making when making complex editing or highly sensitive or more vulnerable and human fragile areas. (Please refer to note in Adding Layers in the Section 1.6 about adding Google imagery with the Zanzibar QGIS version).



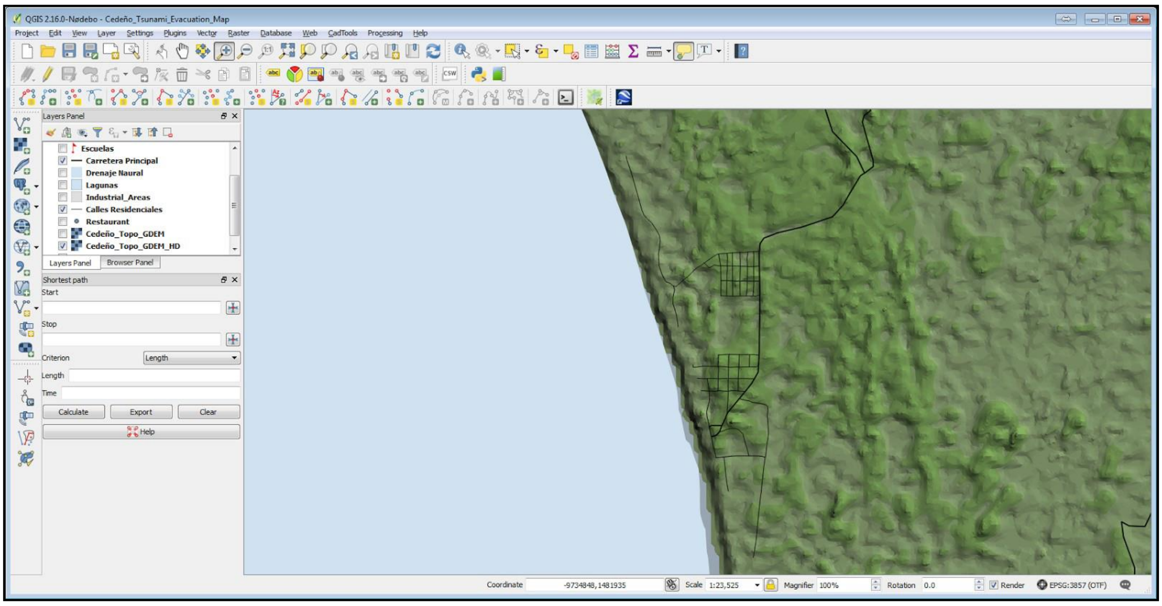
B. Digital Terrain Model

It can be a grid text as an image with elevation attributes. This layer attributes elevation information allows adding a suitable colour ramp along the vulnerable coastal area.



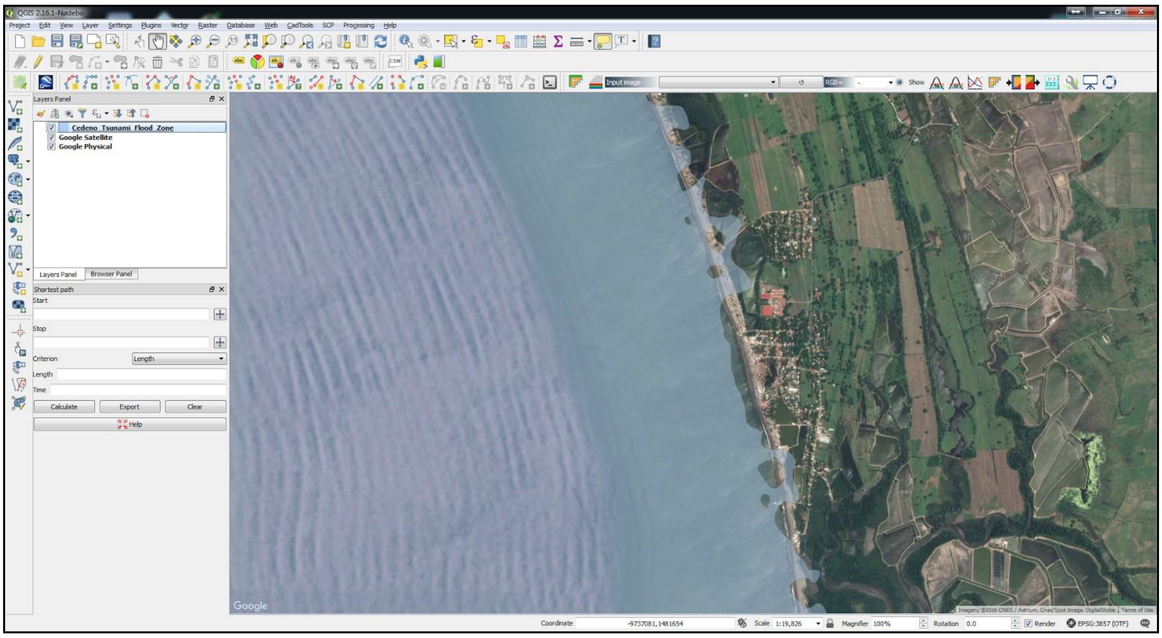
C. Vector Layer Road Infrastructure (Streets - drawn - Roads) -

The vector information is the backbone of the Tsunami Evacuation map because it is one of the layers in which the population is easily identified. Most communities effectively knows the road network in the area and often can recommend better evacuation routes using public roads or other routes. Please refer to Section 1.6 for adding vector files.



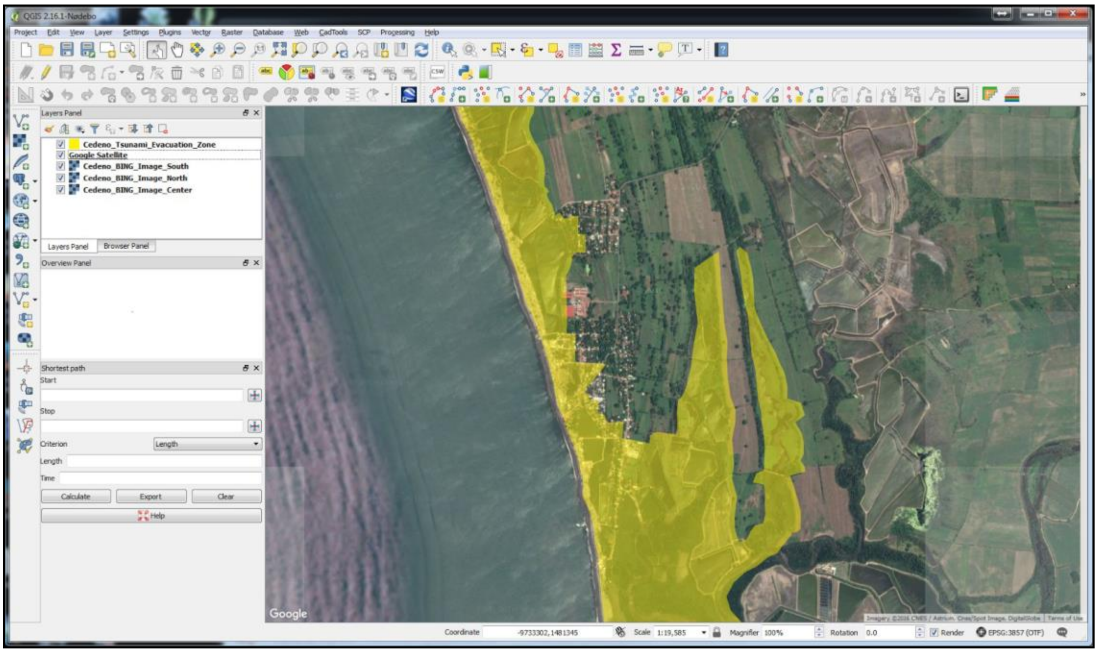
D. Tsunami Inundation Area Vector Layer (Polygon)

This layer of information is vital to the development of the Evacuation area. Based on the information gathered the vector layer we can improve the flood zone and gather topographic elements and road networks as well as some other natural elements easily recognized by the community to design and refine the evacuation zone or Tsunami Evacuation. Typically, the Evacuation zone is usually not wider than the Flood Zone +/- 30% of limits.



E. Tsunami Evacuation Area Vector Layer (Polygon)

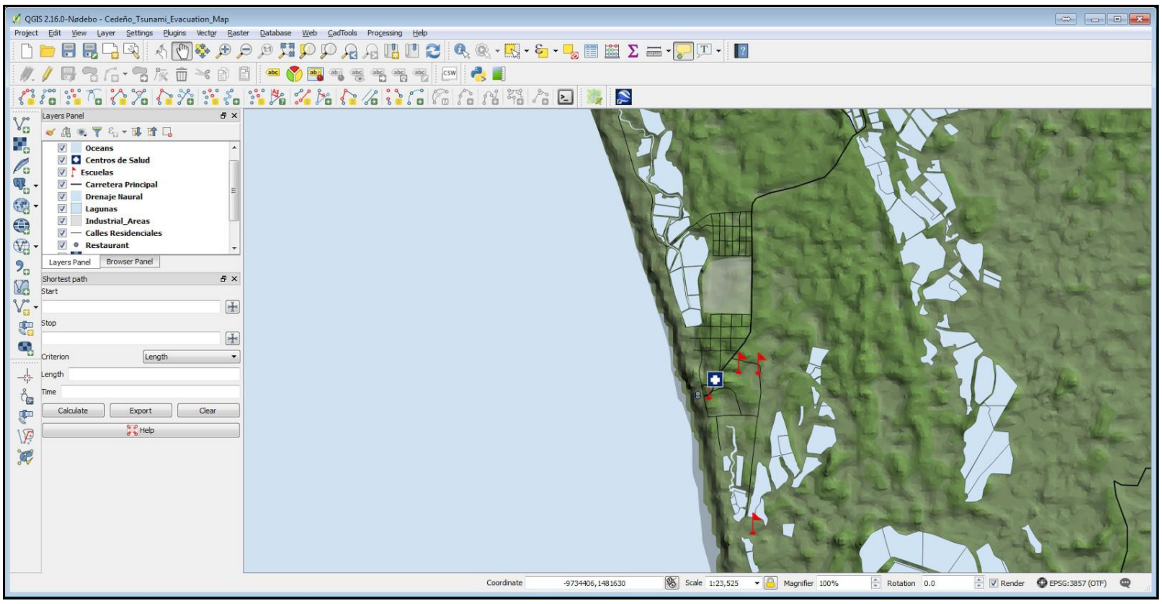
The yellow area is the recommended evacuation area of the coastal community and vulnerable area in a Tsunami event. Typically, this zone is designed by the developer of the map and is openly discussed with the community.



F. Water Ponds affluent Vector layer attribute

Lakes and Mangrove Areas (Lines and Polygons) - Important information when recommending escape routes. Typically, on water affluent there are built bridges that should be reviewed or inspected to determine if they are at risk to collapse or critical structural failure. Lakes or ponds are another critical factor because they contain a determined volume of water. If passing the limits can result from severe flooding to a structural collapse of the dam aggravating the situation in the area.

G. **Infrastructure Detailed layer** (May contain but is not limited to airports, schools, University and Educational Centres, Hospitals – Primary Health Care Centres, Springs – Seaports – Marinas – Anchoring Areas , Beaches and Resorts, Bridges , Police and Fire department offices, Assembly points, Camping site, Tourist points of great interest, etc.) The specific elements on the map shows known as landmarks or "Bench Marks", which can be easily recognized by the population. There's no doubt that some of these elements that can be seen or recognized by any person or close friend must be recognized to provide effective location awareness and essential elements to make a favourable decision in a relatively short period of time.



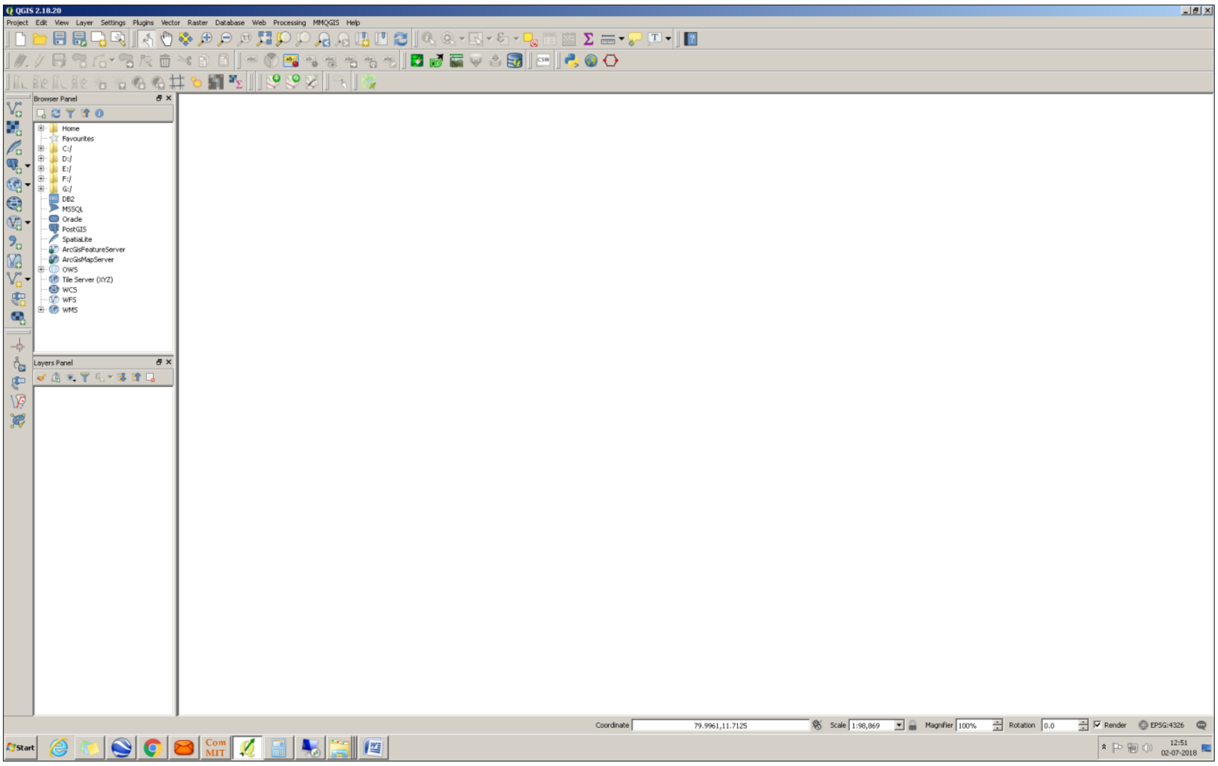
H. <u>**Entities Logos involved in development of the map**</u>

Dissemination of information and Entity responsible for providing Community Education. This information is much more relevant in the preparations of educational campaigns before a Tsunami event. Logos or information on the agencies in charge of publishing and carry out the message to the community are very important because they will know where to go when you want to use the information developed.

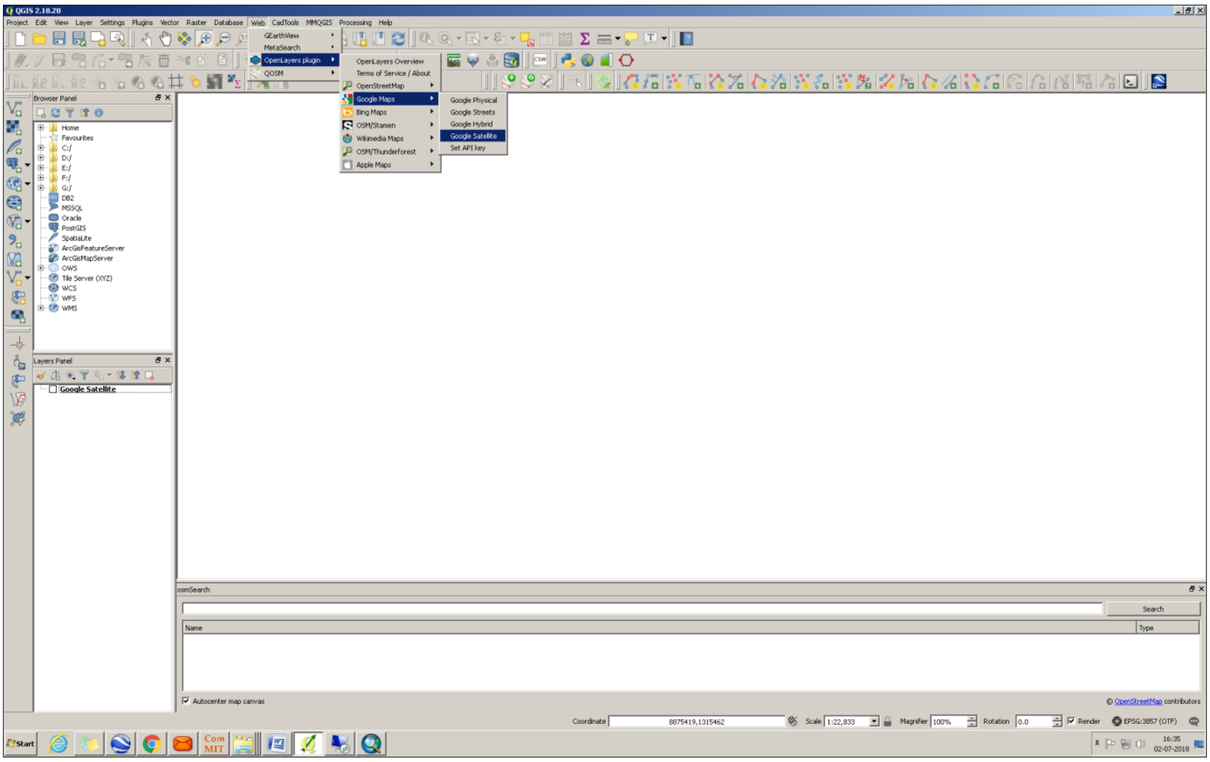
4.2 HOW TO USE QGIS TO CREATE A MAP WITH SYMBOLOGY, COLOUR AND STANDARD LEGEND?

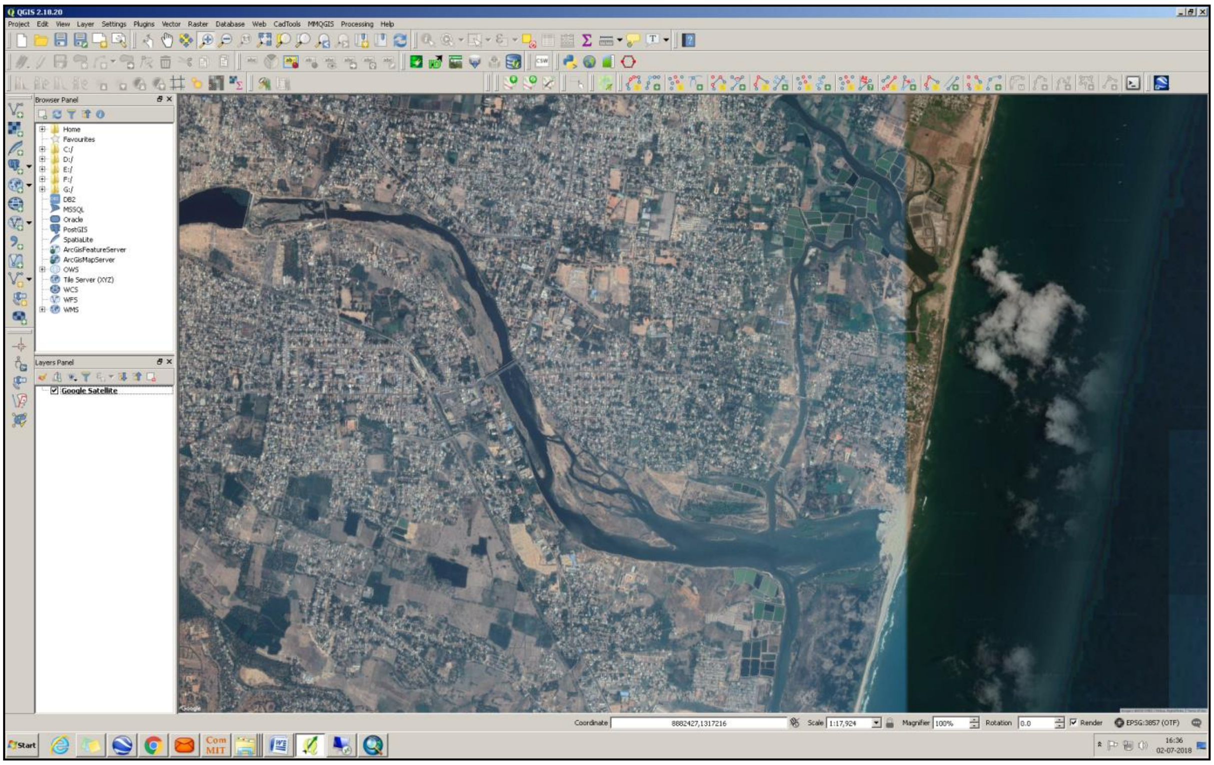
The use of Geographic Information Systems (GIS) expedite the development process of maps. This largely allows to develop better maps with rich data and more effective presentations that address the needs of the population. Below we present the basic guidelines step by step in the development of a Tsunami Evacuation map.

Step 1. Select and run QGIS application installed in your computer.

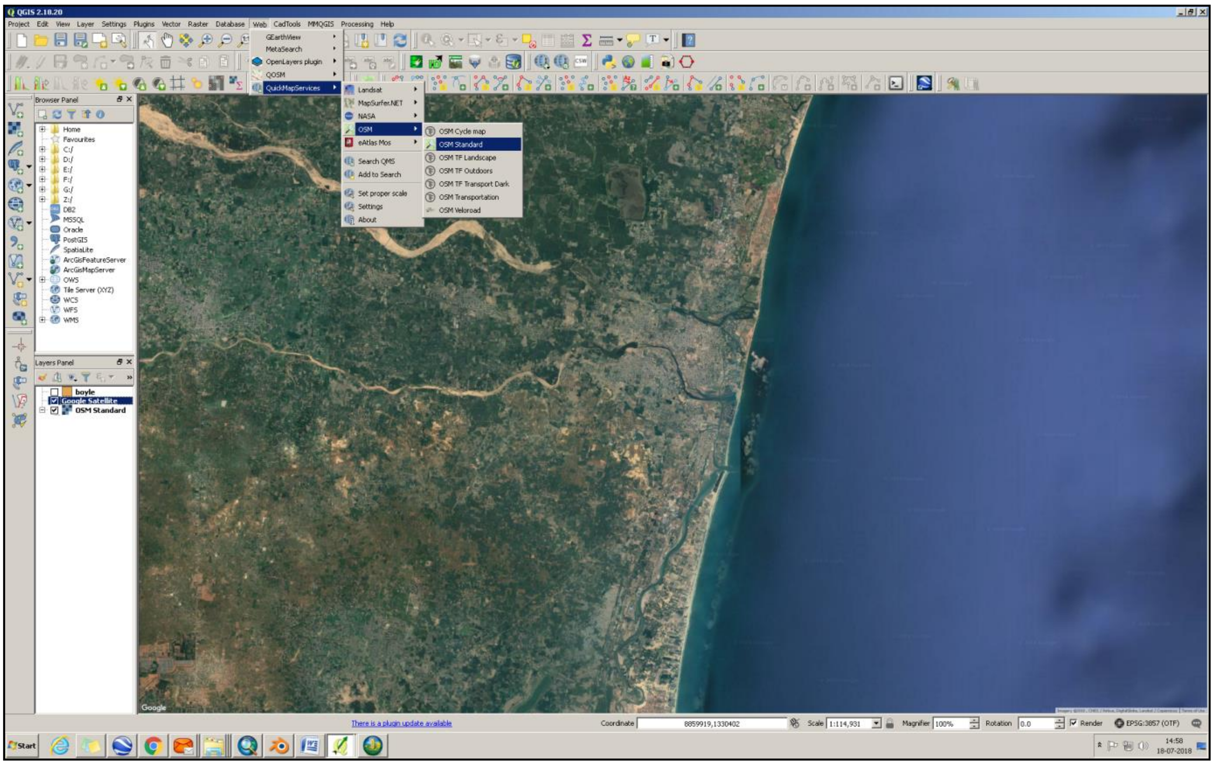


Step 2. Add the image layer or aerial or satellite images of the area to be analysed, verify any additional elements to be settle on the map. In absence of your own data you can add images from Web Map Services (WMS). Go to web menu select. In Zanzibar use the XYZ tile option as explained in section 1.4.

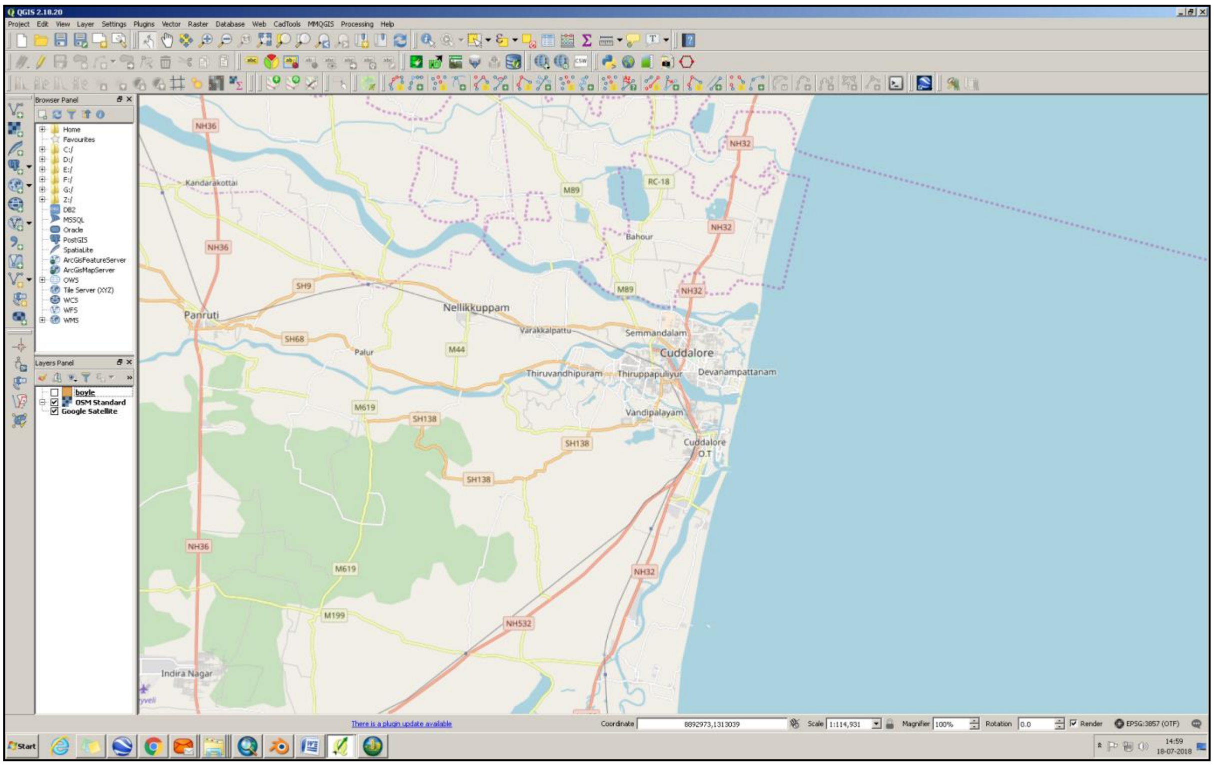




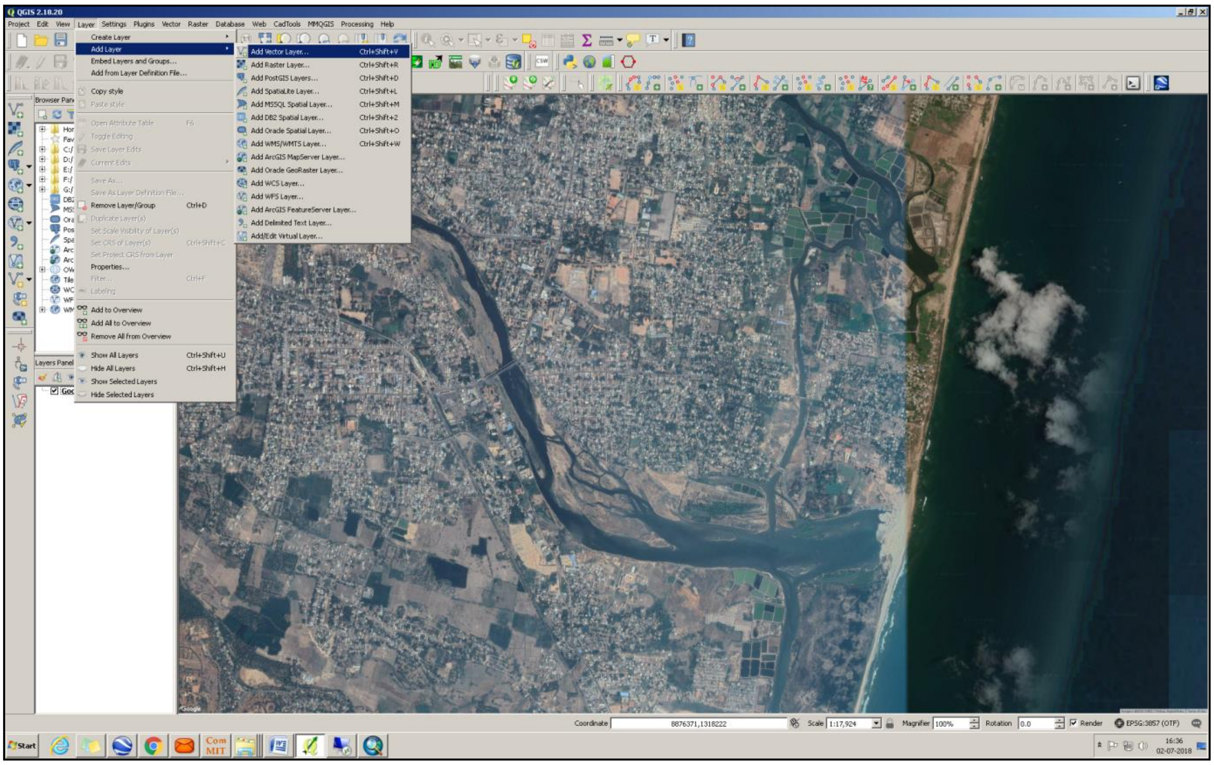
You can also add web-quick map service-OSM-OSM standard layer as well. For Zanzibar, use the XYZ option, which has the Open Street Map.

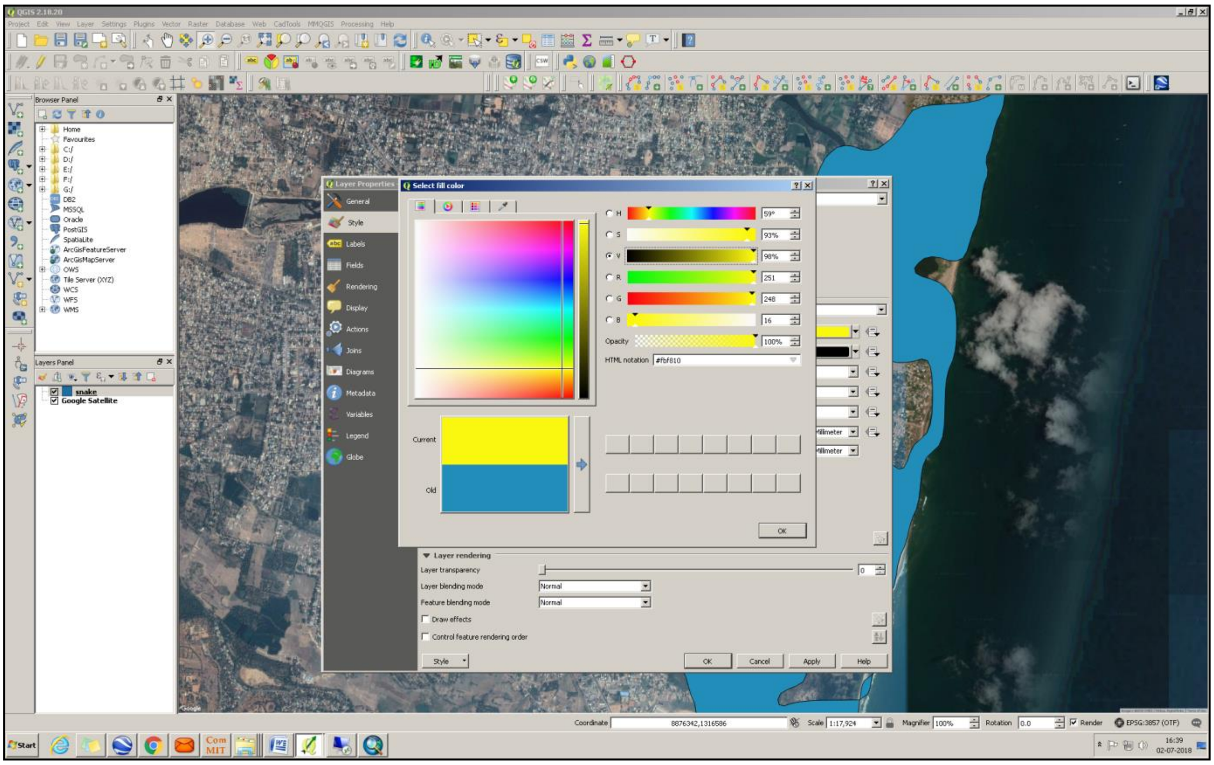


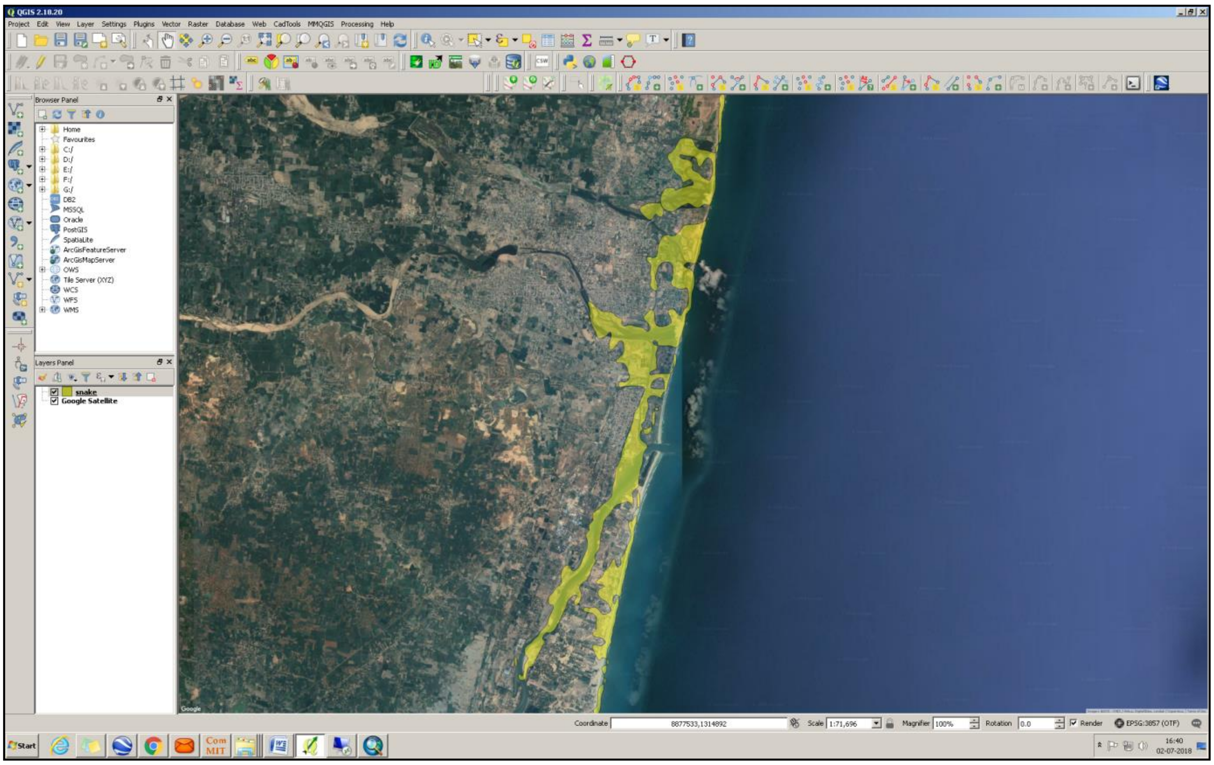
OSM map is displayed in the viewer as shown in the below figure.



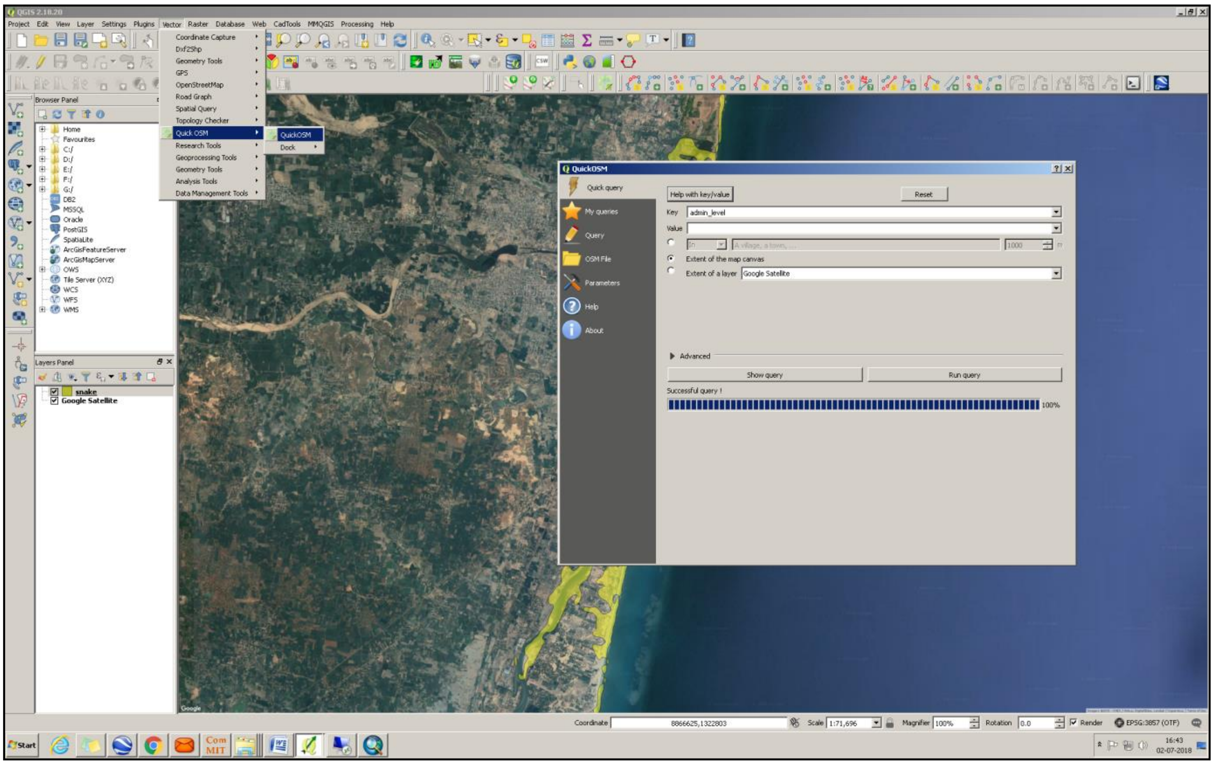
Step 3**.** Add the corresponding vector layer to the tsunami inundation zone or develop the area on the basis of the vector layer of tsunami inundation zone.



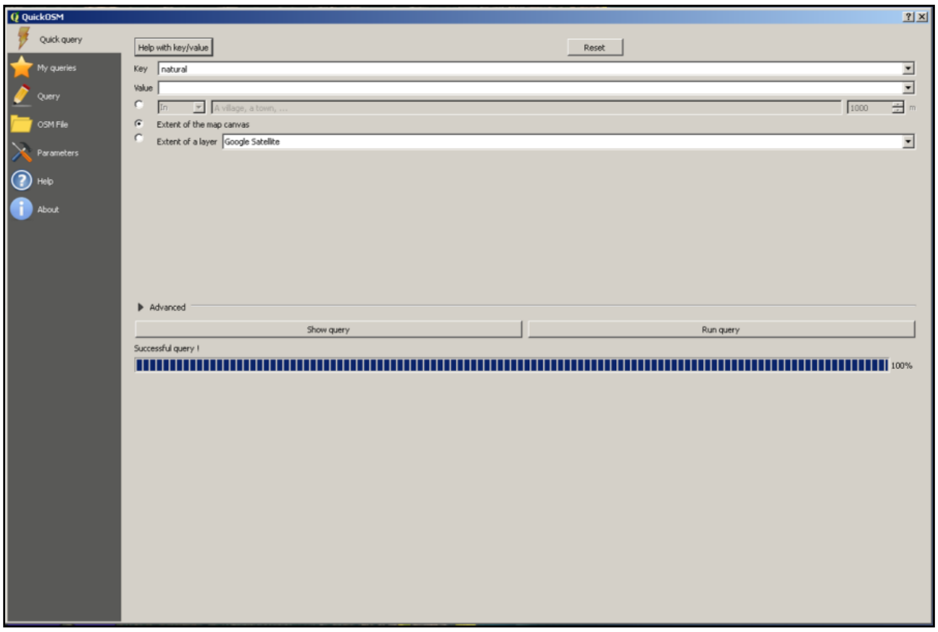




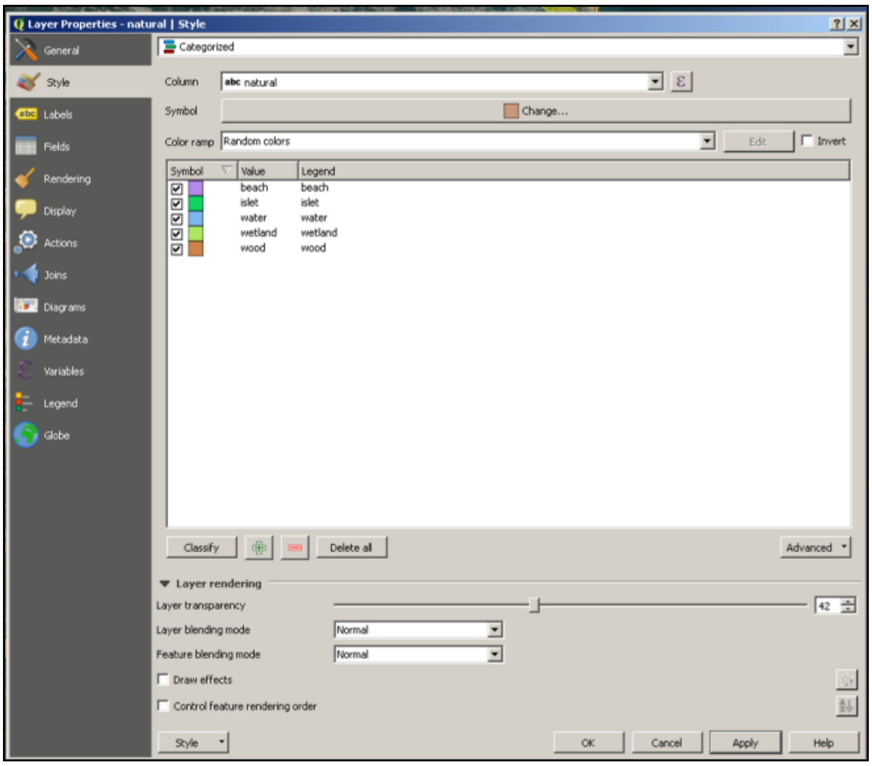
Step 4. Add the corresponding road system to the vector layer area. It is very important to differentiate the main streets layer to the layer of secondary streets. This can be done using different colours or line width. You can open your own vectors available with you. If not you can download open street data from QuickOSM plug-in as follows. Go to Vector-Quick OSM-QuickOSM, a QuickOSM dialog will open select "natural" in key option pull down menu and click on "Run Query". Natural layer will open in the viewer.

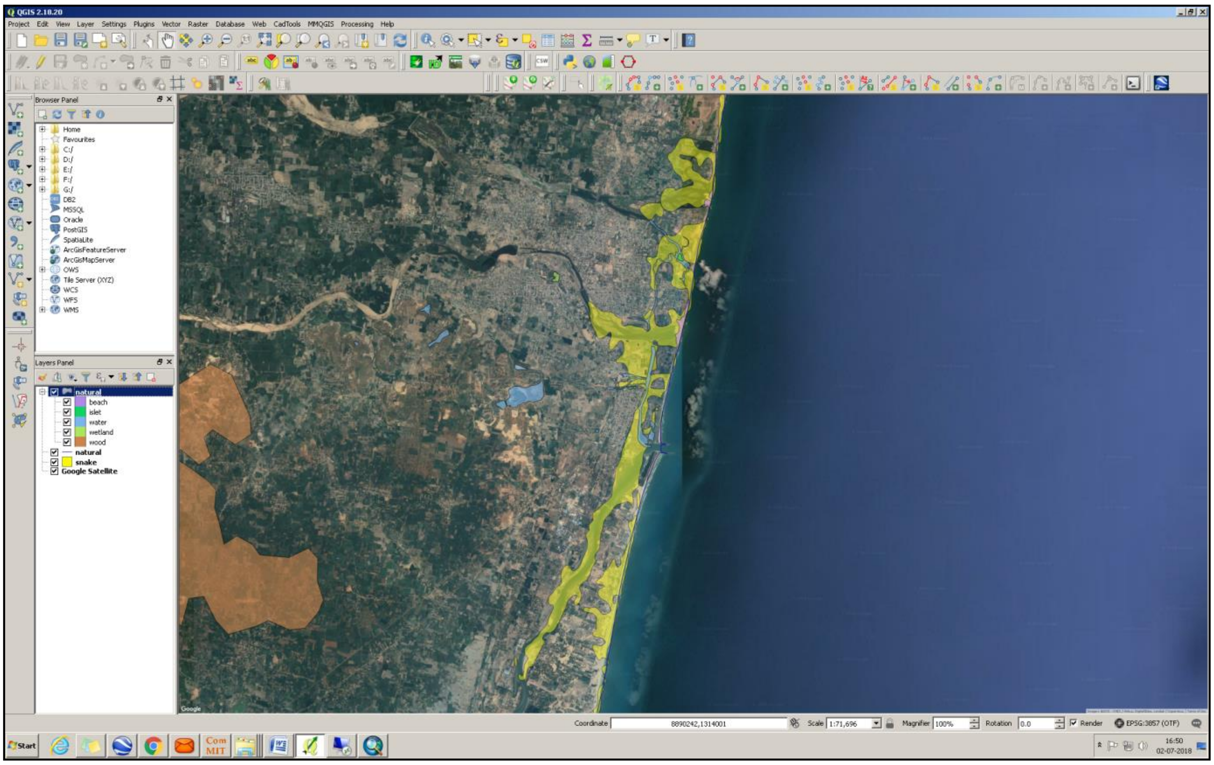


Step 5. Add the vector layer corresponding to oceans, lakes, ponds, swamps, rivers, etc. corresponding to the area with their characteristic features.

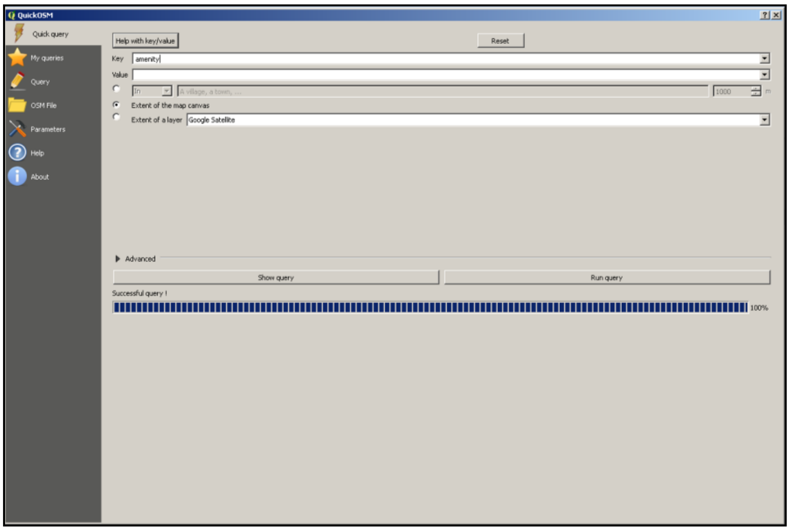


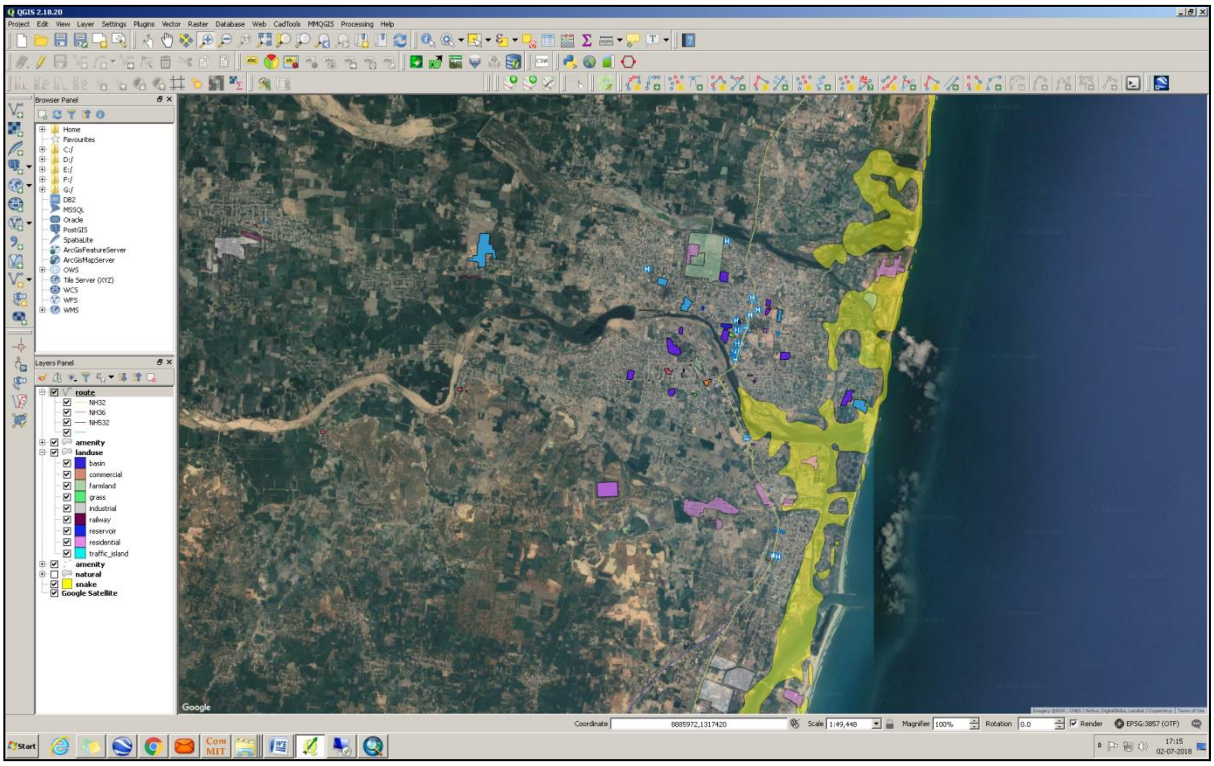
Give appropriate symbology and apply.





Step 6. Add in an orderly manner corresponding specific infrastructure information vector layers. This layer must contain information such as Schools, Police stations, Fire stations, Hotels, Hospitals, Health Centres. Go to Vector-Quick OSM-QuickOSM and select "amenity" in key option pull down menu and run query. Repeat query for "route", "building", "landuse" and other necessary layers.

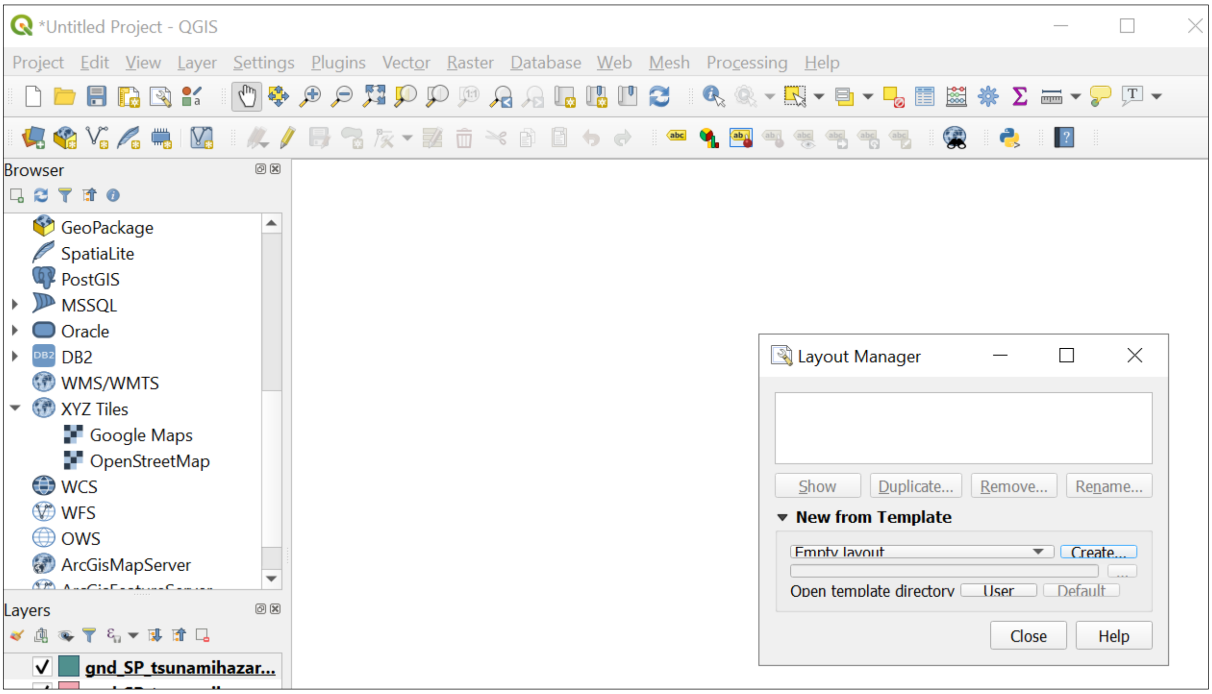


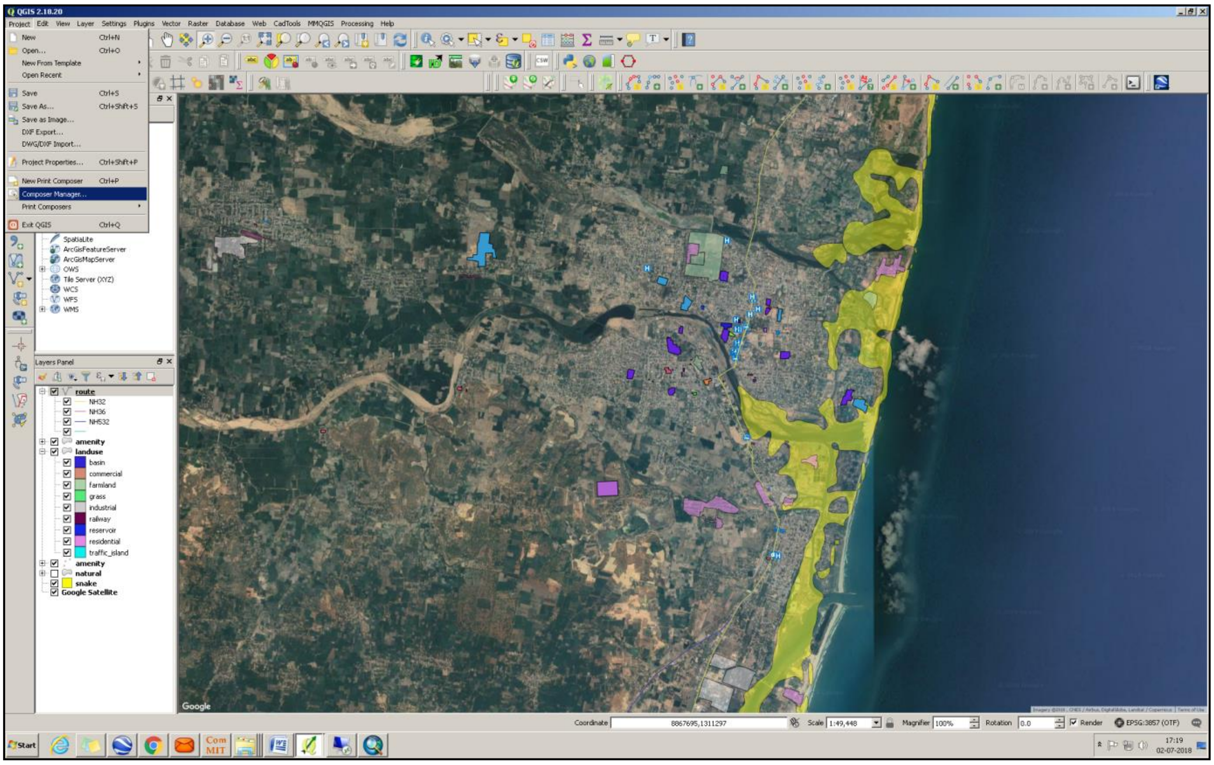


5. FINALIZING TSUNAMI EVACUATION MAP FOR PRINTING

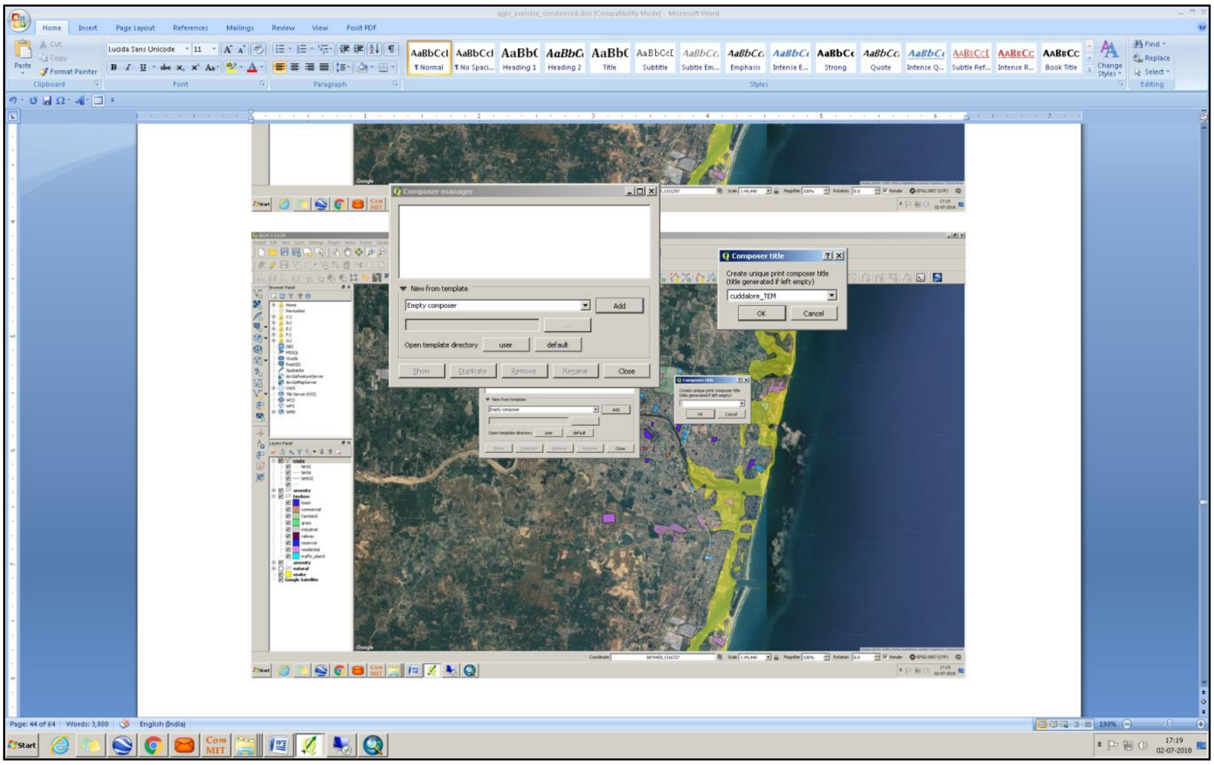
The following describe steps to create the final map for printing. It includes the setting of the paper size, insert of the map, and addition of a legend and pertinent contact information and logos. Typically, explanatory text is also included, but this is not covered in this tutorial.

Step 1. Once we have all the clean databases lists then proceed to the development of the structure of a printable map. The creation of a printable map is known as "Composer Manager". Go to Project-Composer Manager. In Zanzibar, QGIS 3.82, it is called Layout Manager.

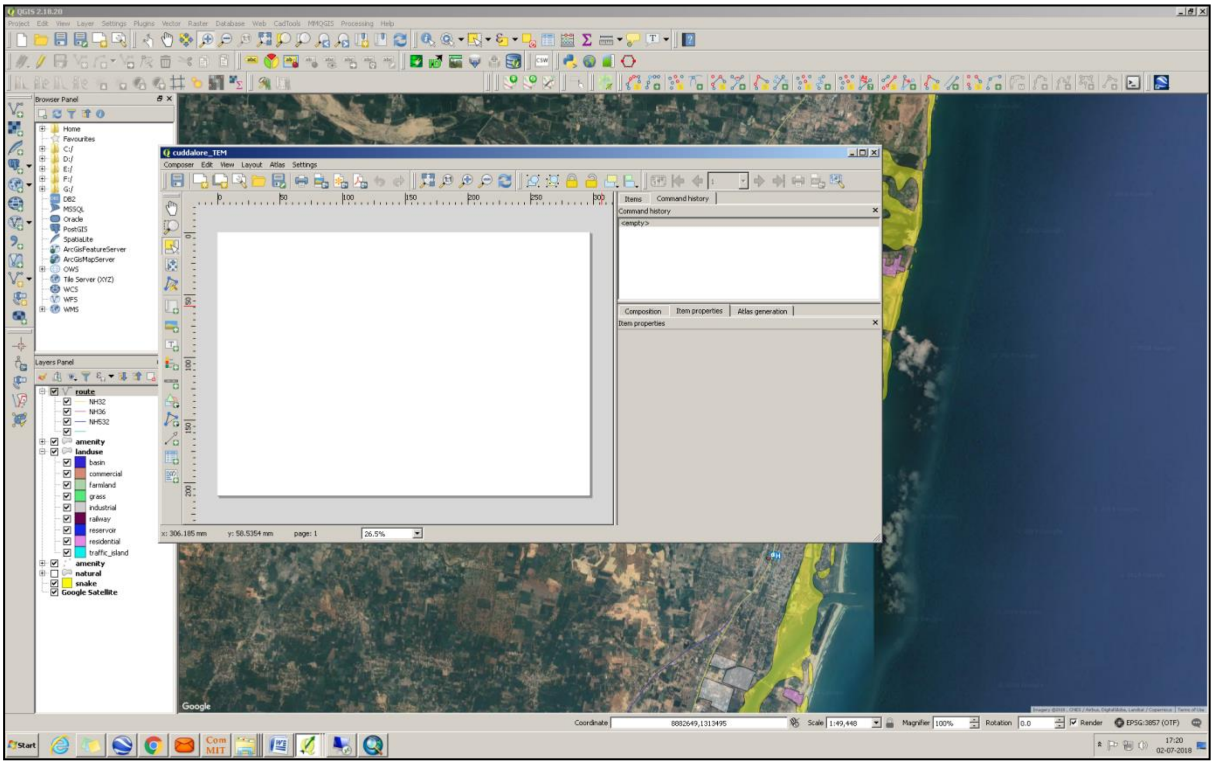




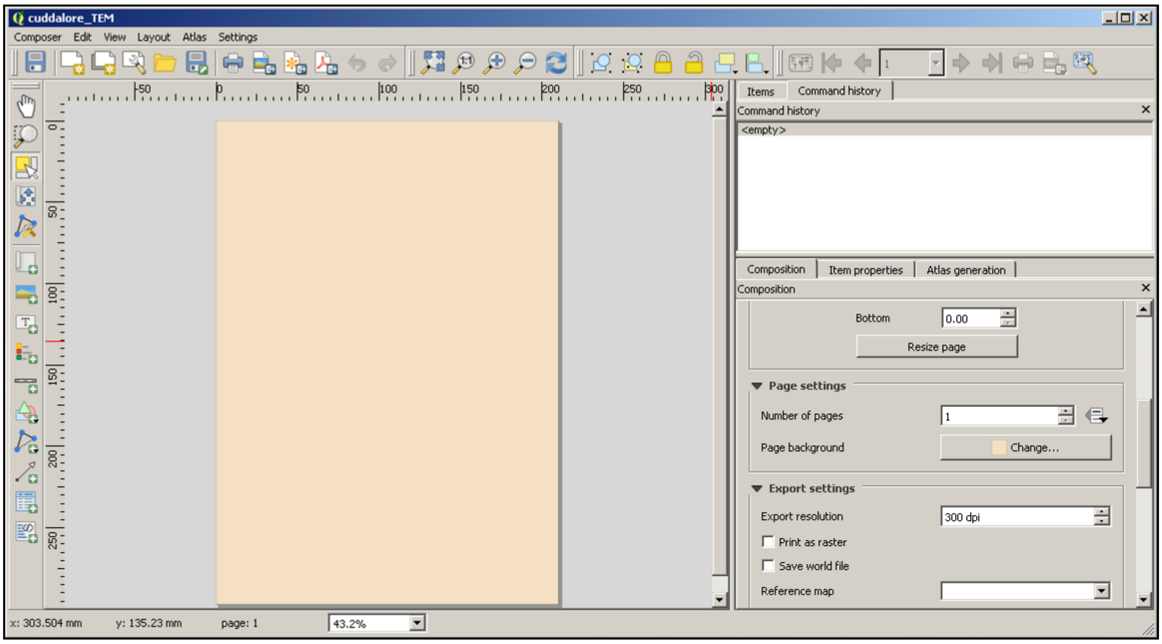
Step 2. Click "Add" option and type a name of new composer "cuddalore_TEM" in the composer/layout title dialog then press OK.



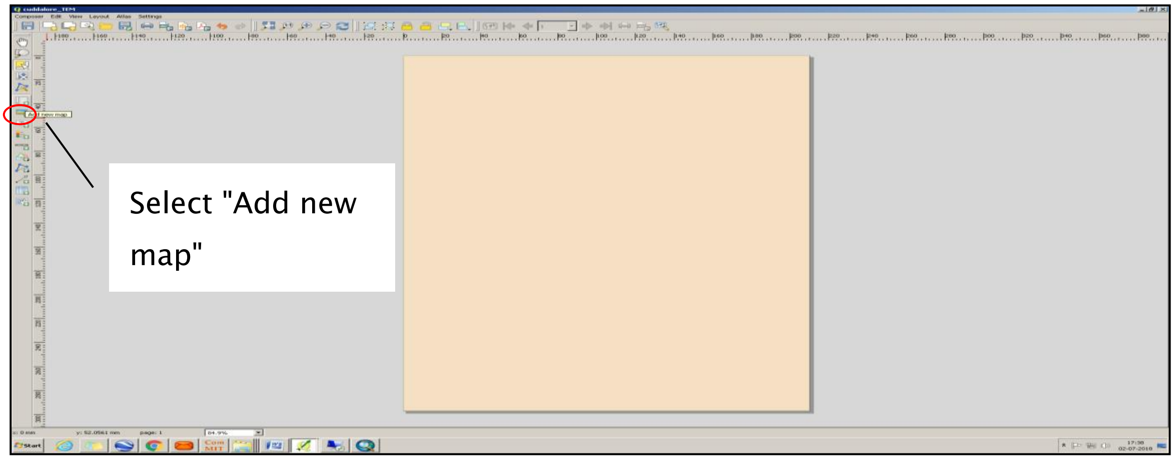
Following empty map composer layout opens.



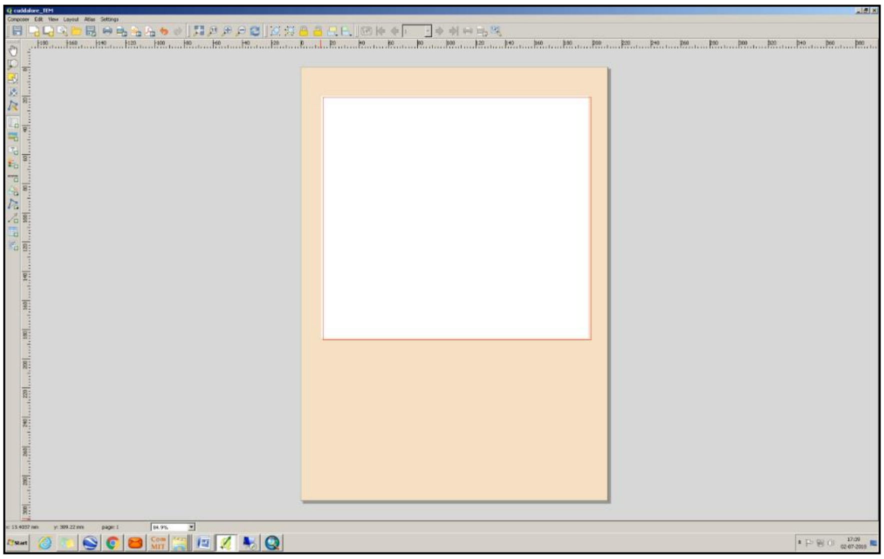
Step 3**.** Then select composition tab in right side panel and select appropriate size of your map layout (A4 portrait is selected for this exercise), you can change the page background colour of this layout in the composition tab. Now, following map composer layout is ready to transfer your map data.



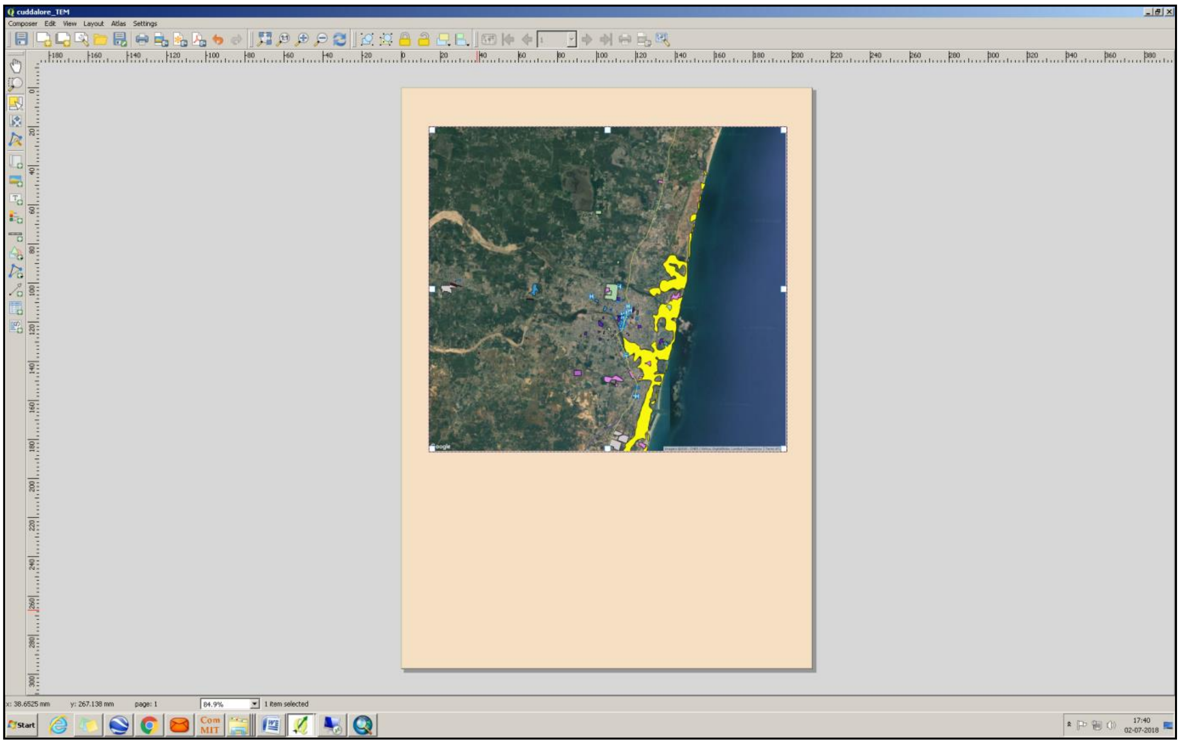
Step 4. Add a map in the map layout select **"**Add new map**"** tool from left side.



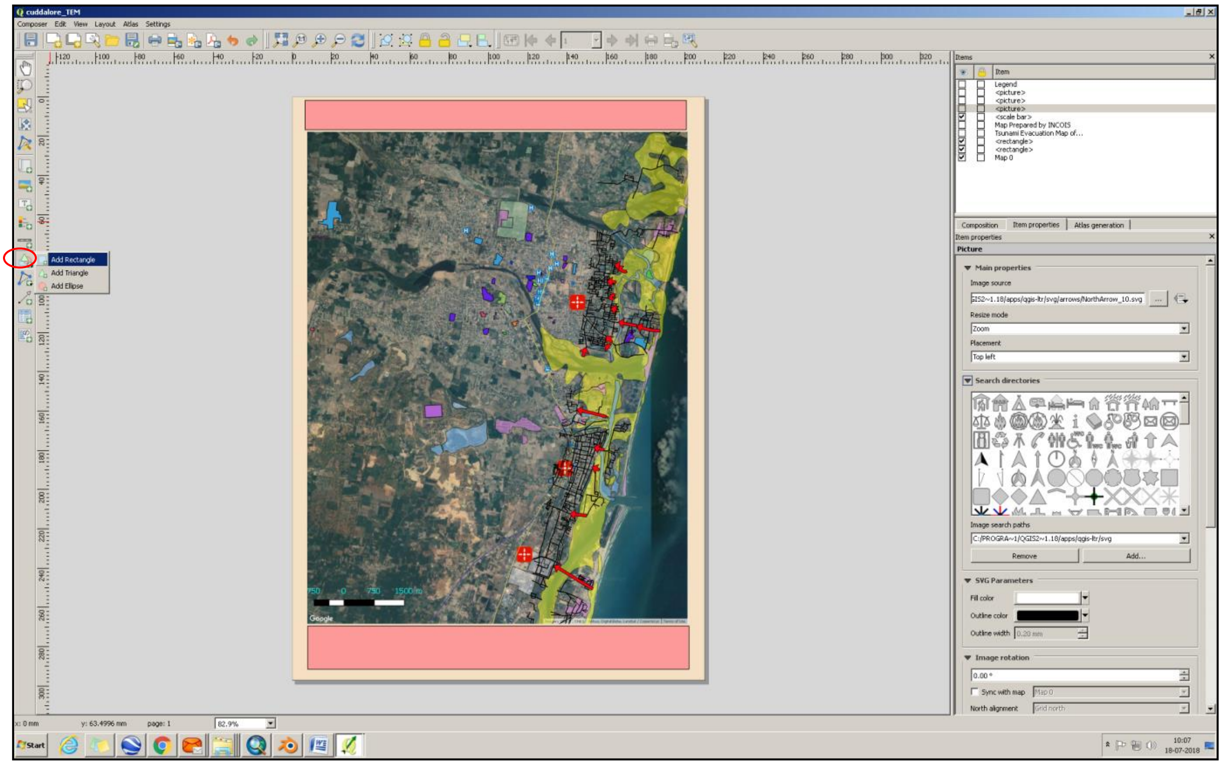
Draw desired dimensions on map layout as shown below.



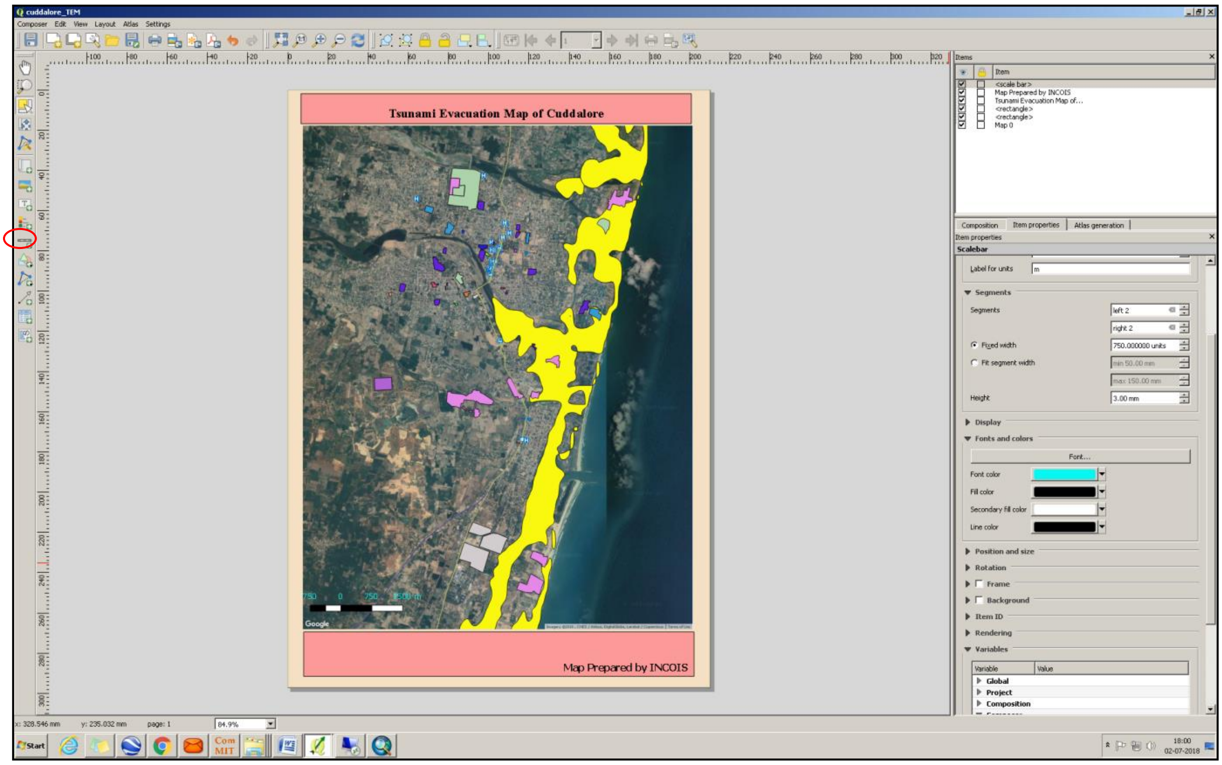
The following map will be fetched from the active viewer of the QGIS.



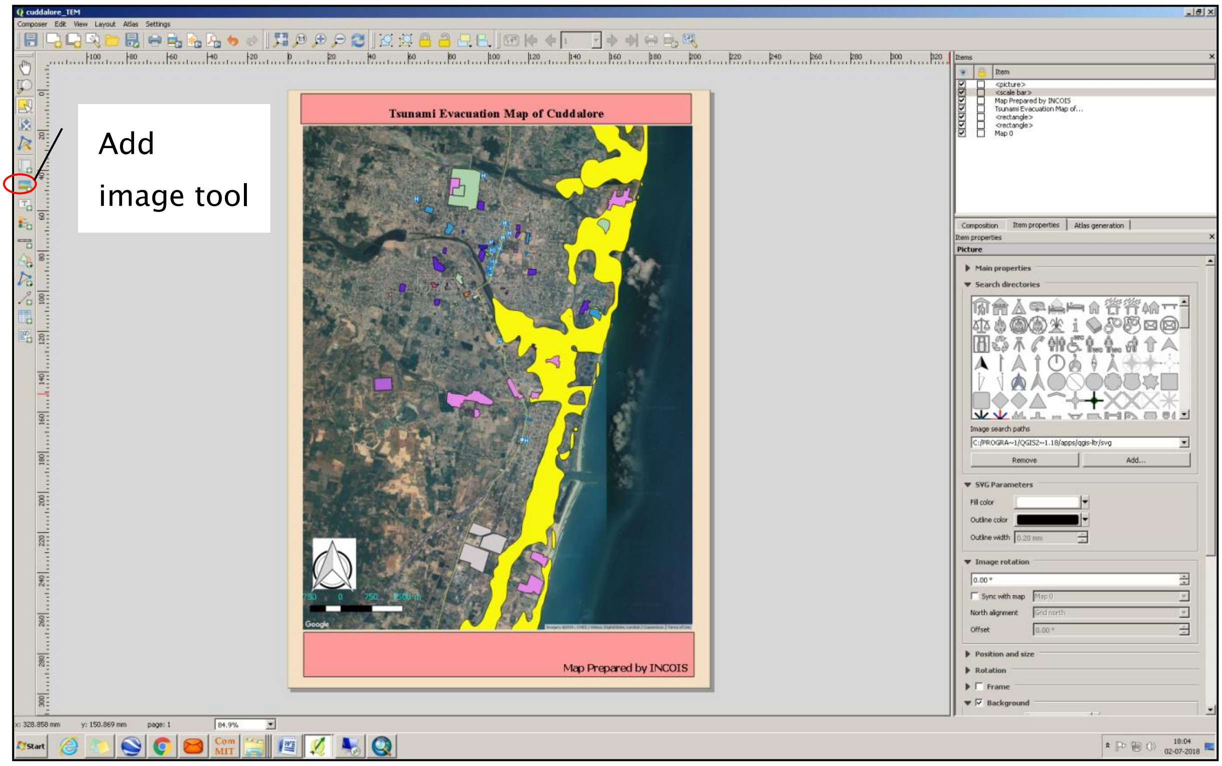
Step 5. Once we have the desired view of the map area and it is displayed on our design we begin to add the necessary information boxes to display the information to be entered into the final map. Select Add Rectangle for Add shape tool from left side and draw boxes in a place on layout you wish to add information.



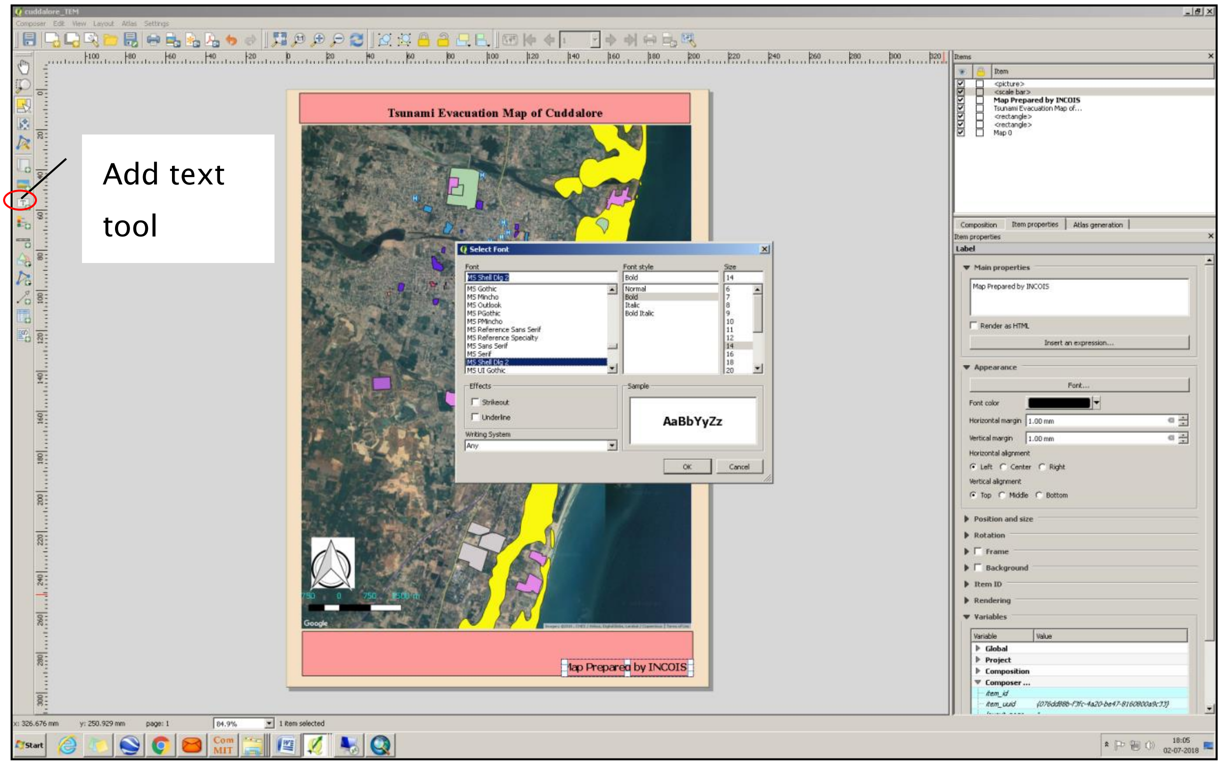
Step 6. After entering the information areas, we introduce the graphic scale. This will make computing distances graphically effectively to all users.



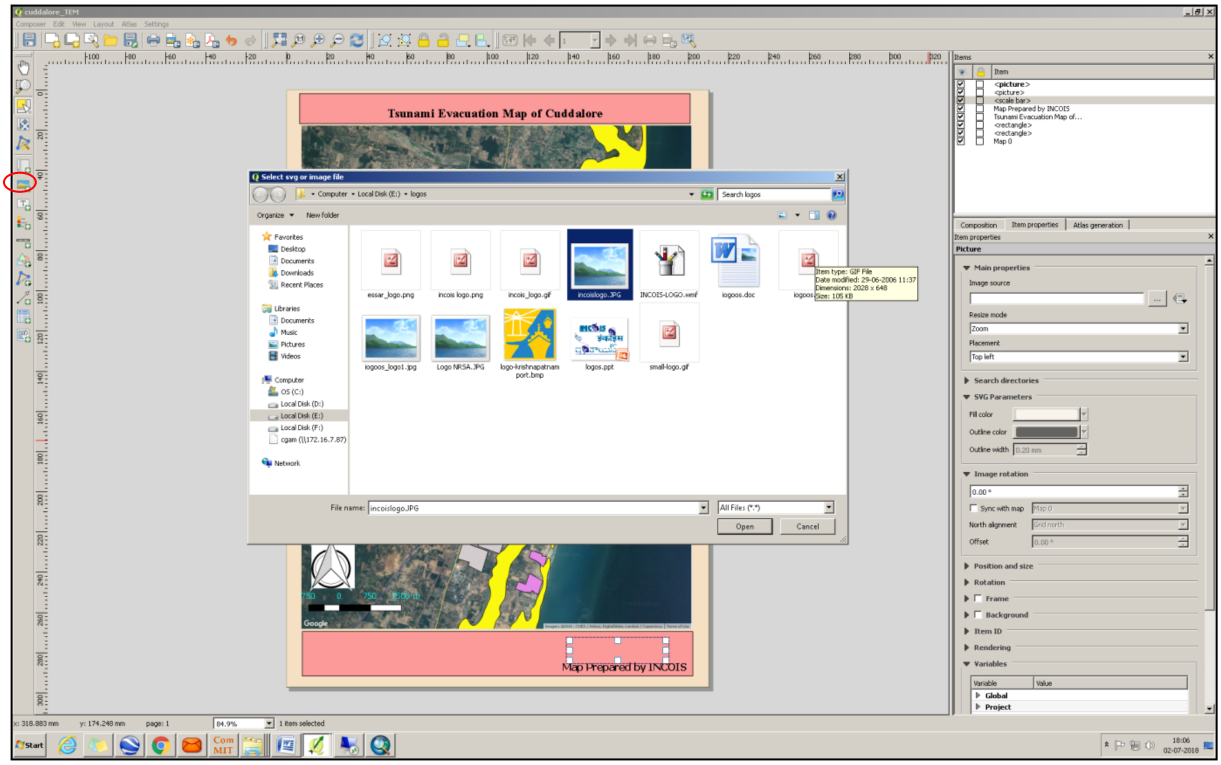
Step 7. To add the north on the map we must introduce an image and choose in the northern symbology of your preference from item properties tab-search directories. Then we can move and locate the most appropriate place of the map.



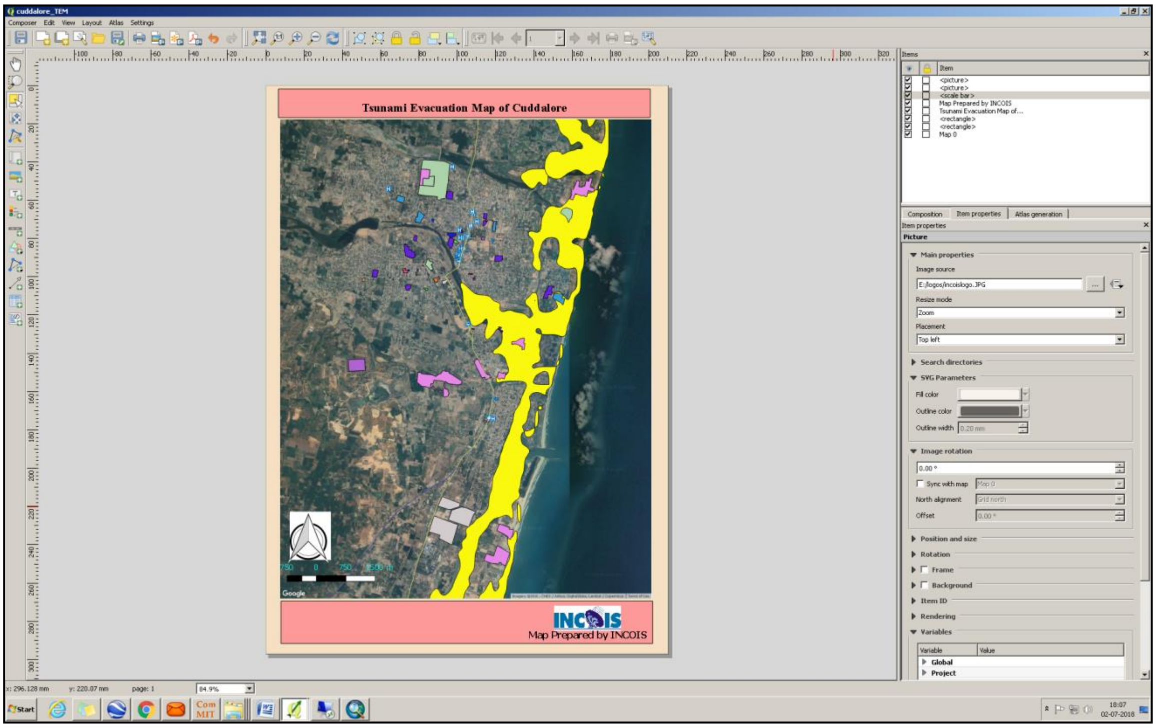
Step 8. We started to add text to the information boxes. Here we can choose the size and letter type for the map development.



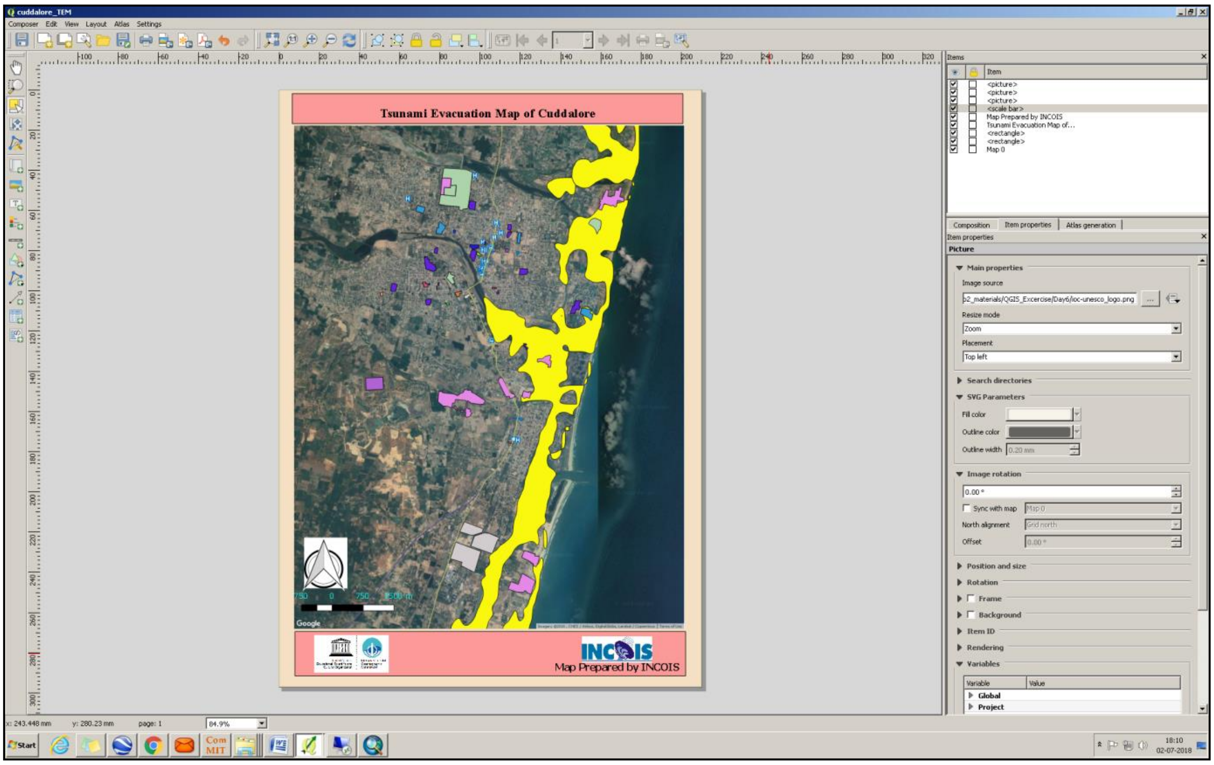
Step 9. Add logos of the participating entities using the option insert images and browse the image source from the item properties tab right side.



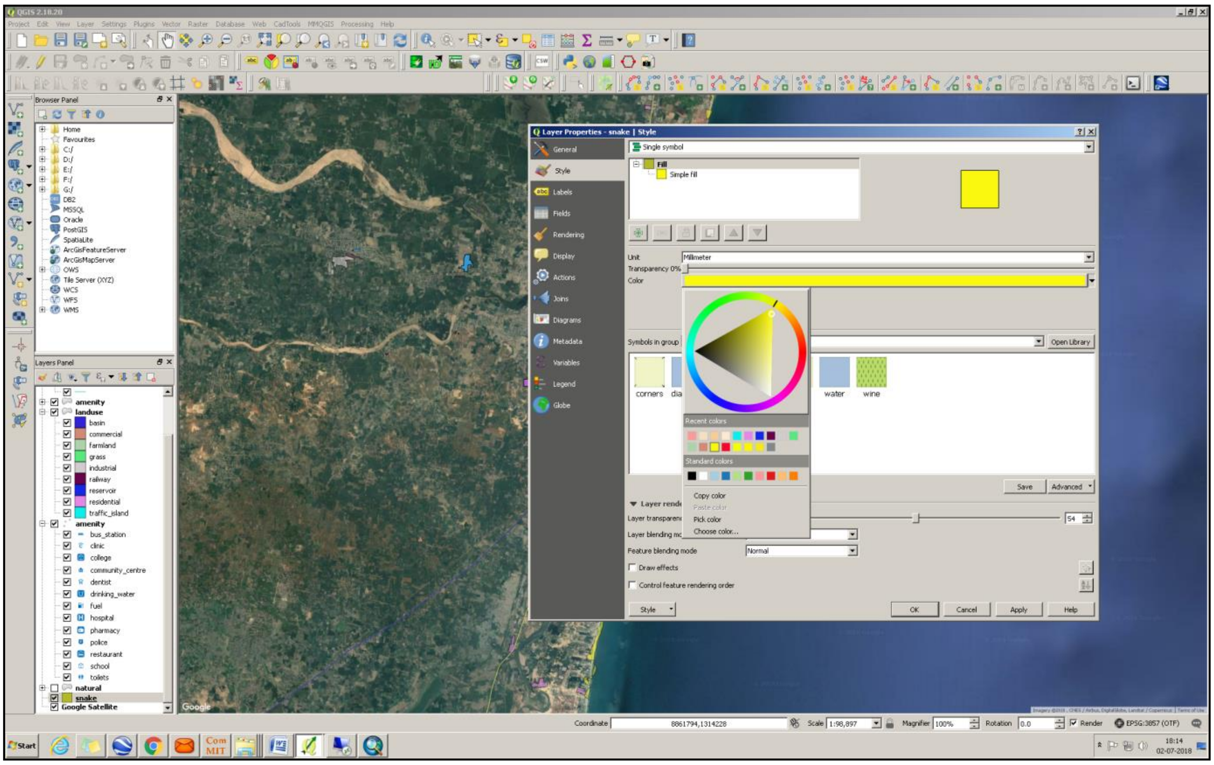
Your organization logo appears on map layout (INCOIS logo added in the layout).



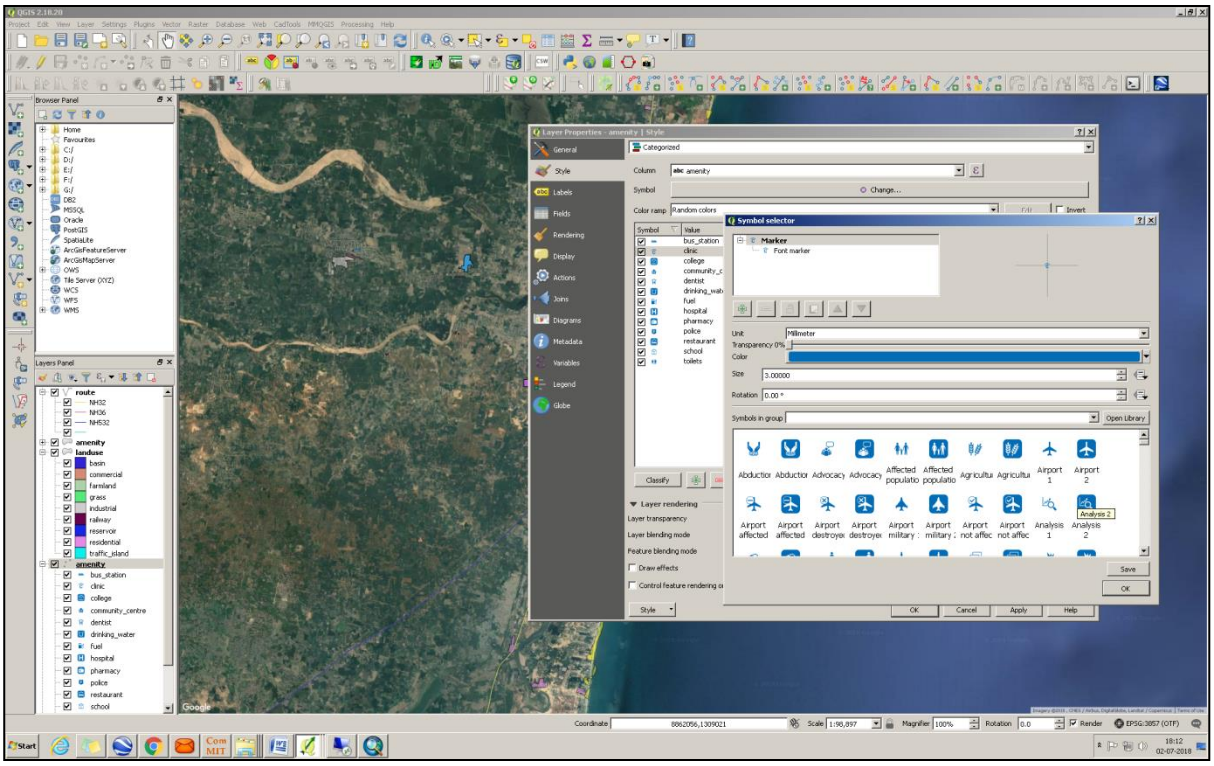
You can also add additional logos (collaboration/coordination agency) if necessary, UNESCO/IOC logo added in the below layout.



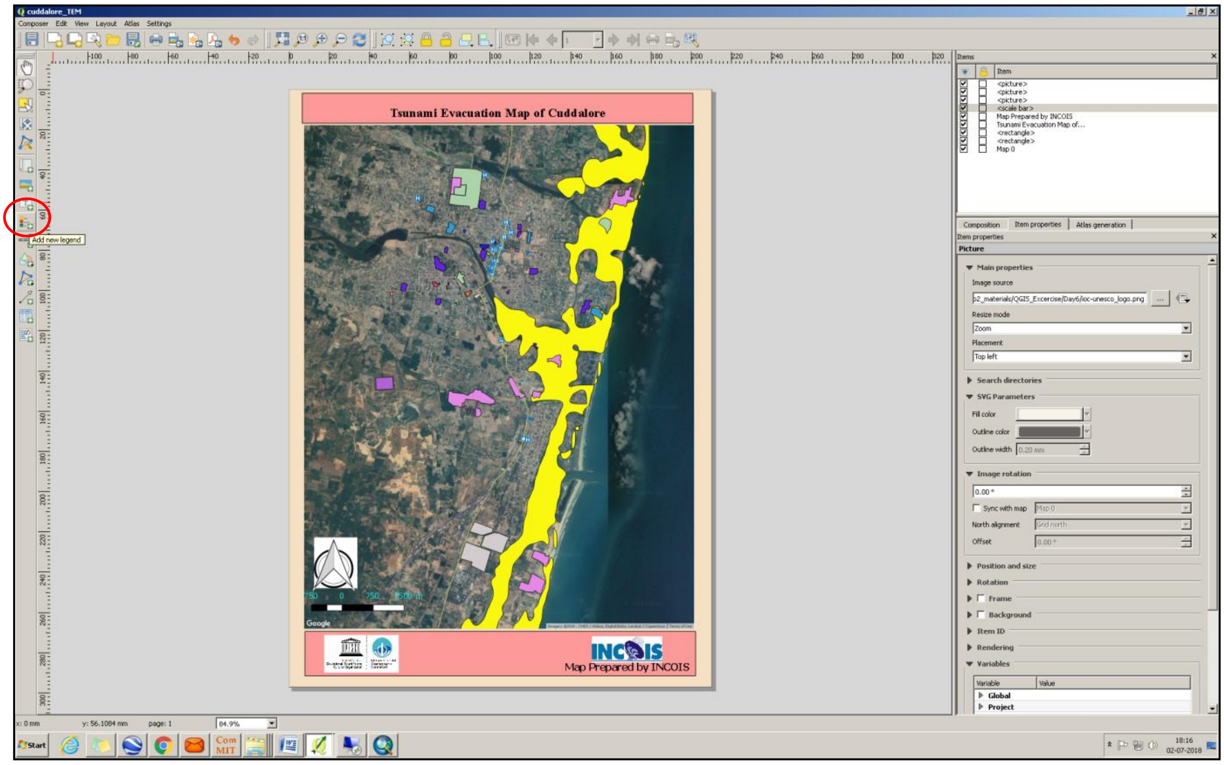
Step 10. Refine symbology: Here we can choose the required symbols to display in the map in a friendly way. The polygons can be colour with translucent layers (by changing layer transparency) and the point features should be symbolized using the OCHA icons installed earlier.

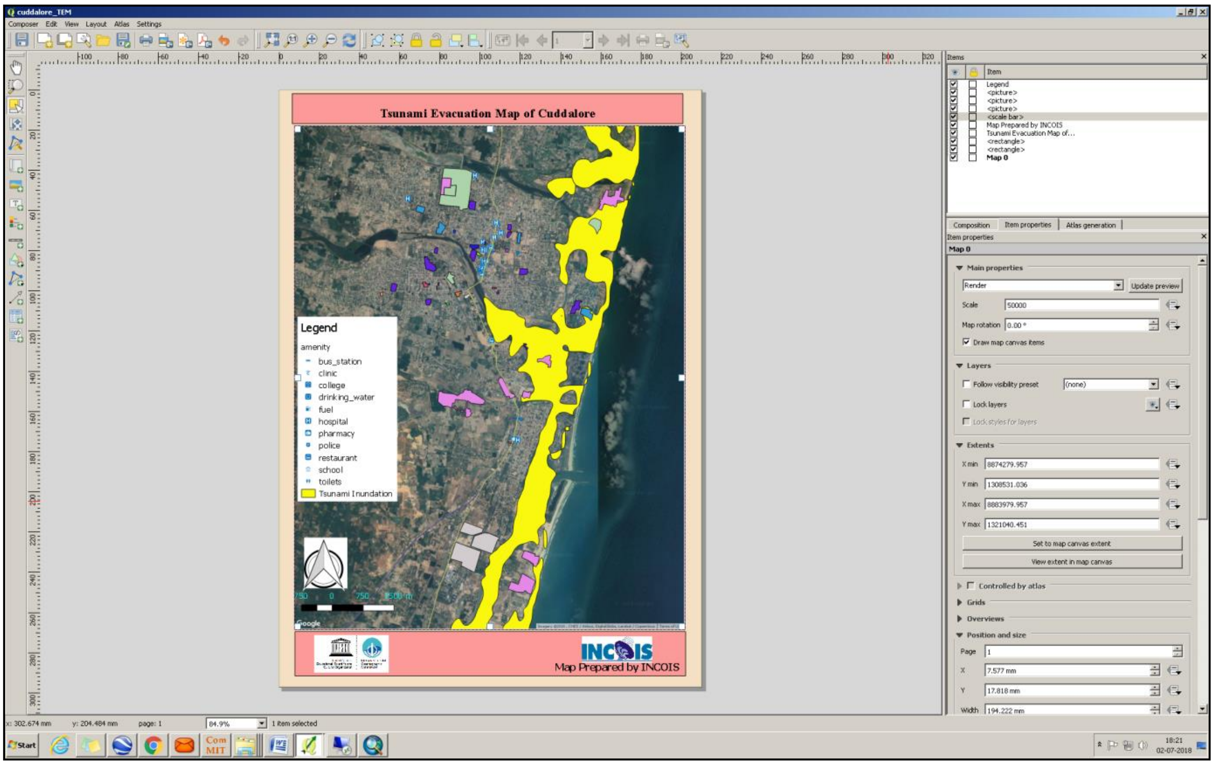


Use appropriate OCHA icons for amenities layer in layer properties style based on category.

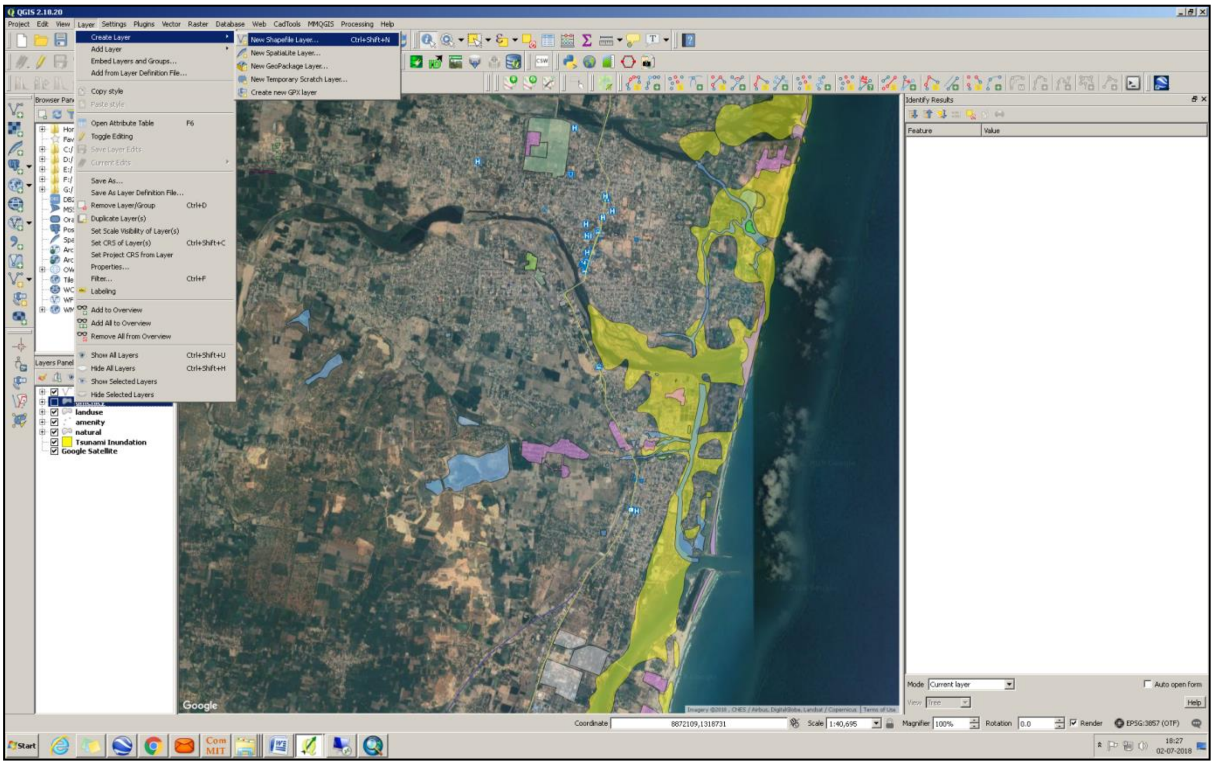


Step 11**.** Add the legend: When we have all the vectors layers symbolized, then we start with the process of adding the legend on the map in development.

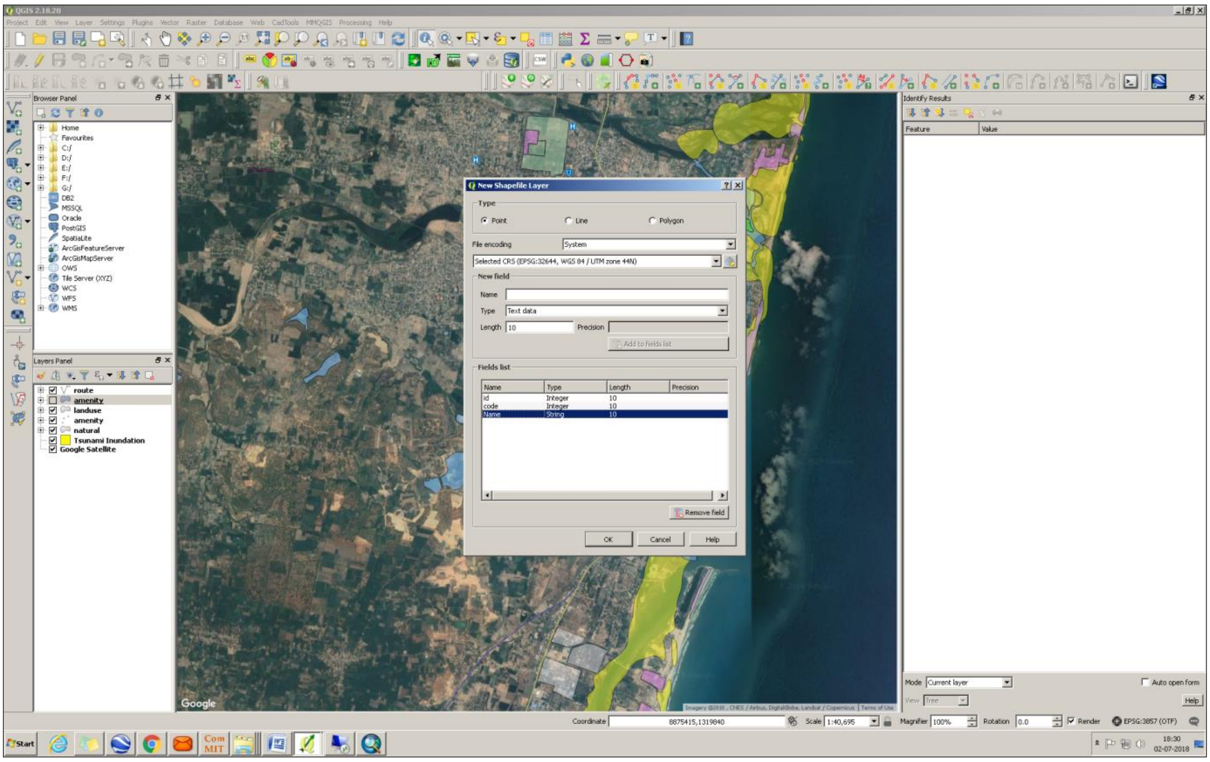




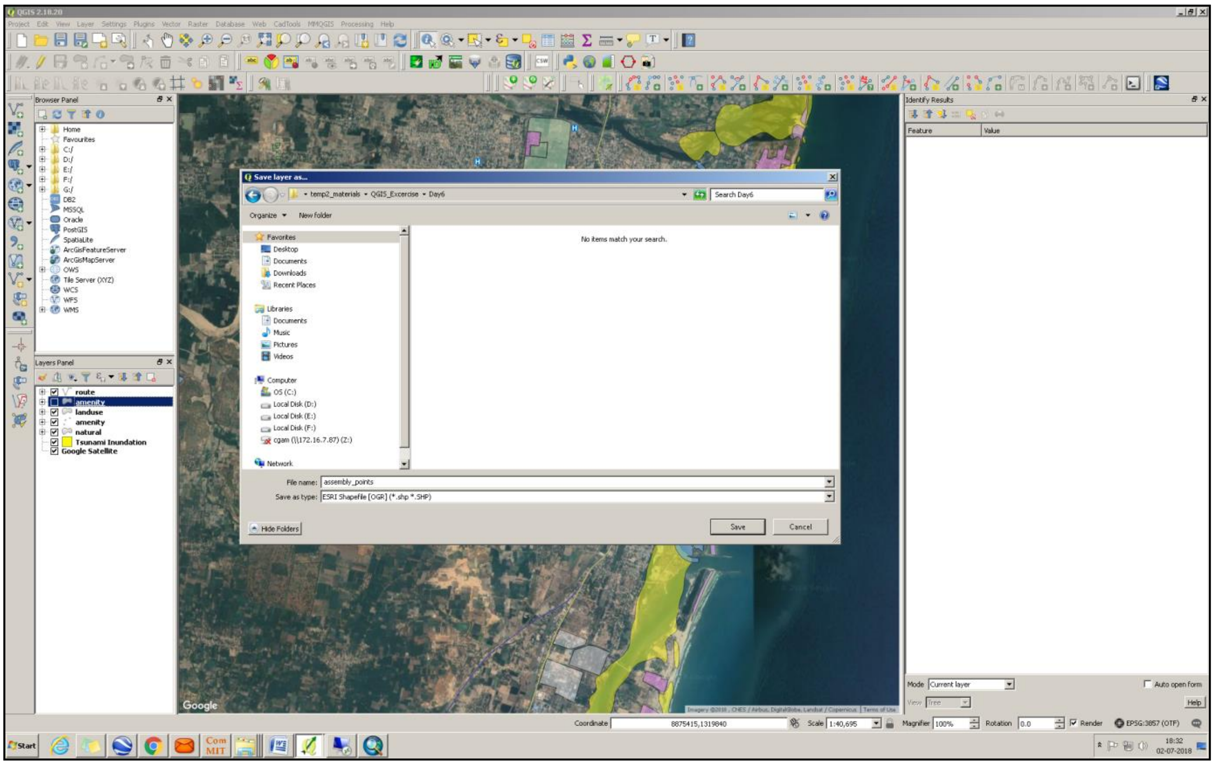
Step 12. Determination of assembly places or meeting points. Open new vector layer by following procedure (If you have these as a Vector File, not necessary).



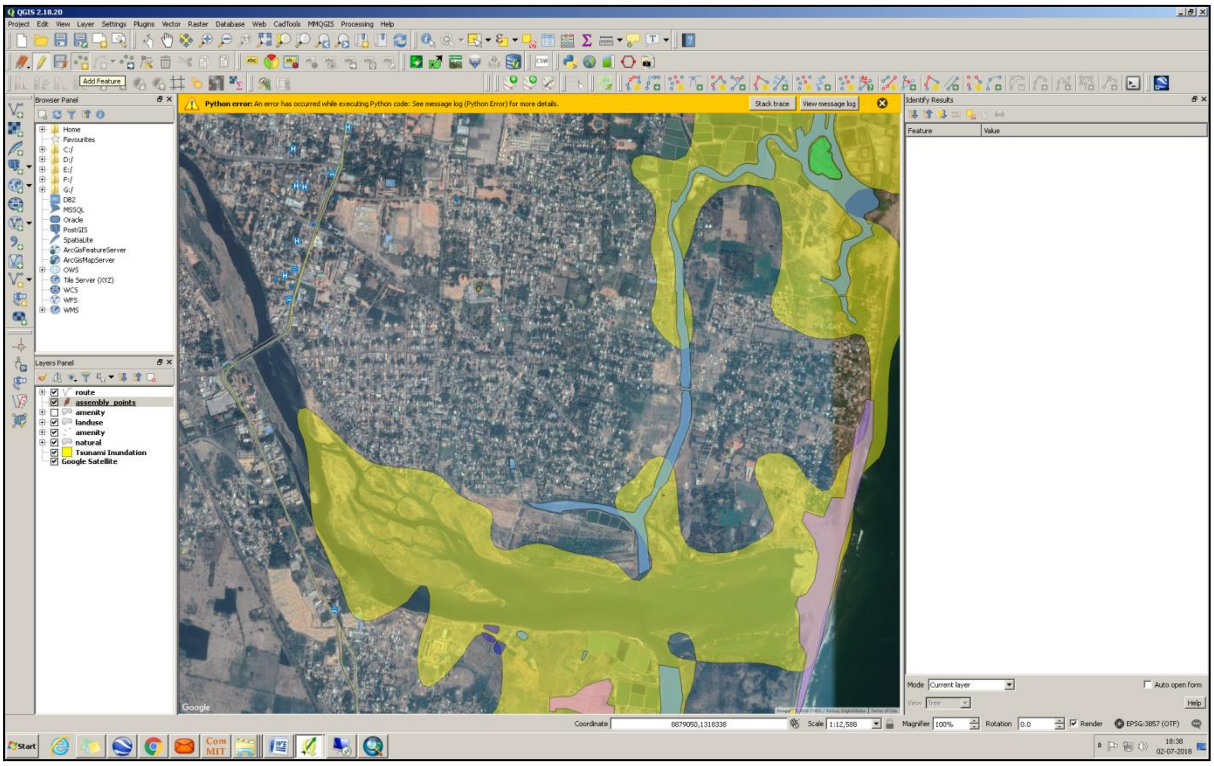
Select the type as "point" (it is a point feature for the location), select the desired projection and add "code" (whole number) and "name" (string) new fields to the new shape file and click OK.



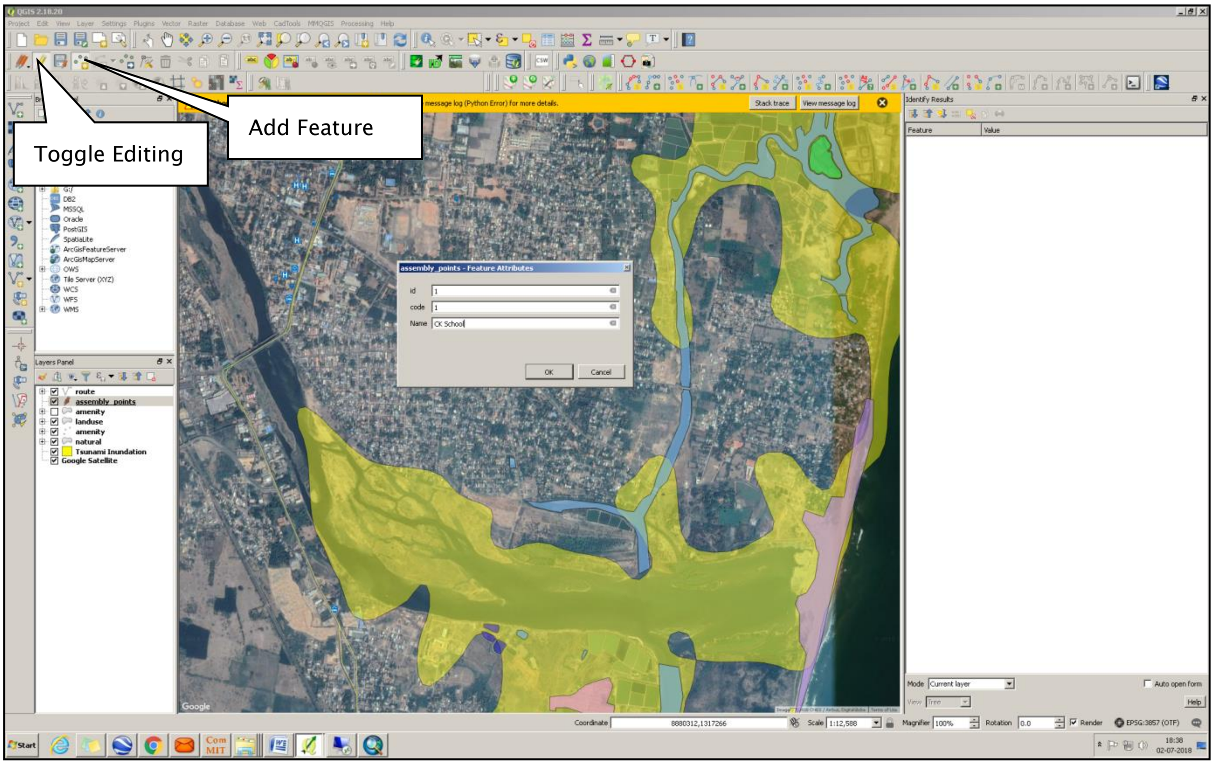
Then it will prompt for the new file name and navigate to your working folder and give file name (assembly_points) and click Save.



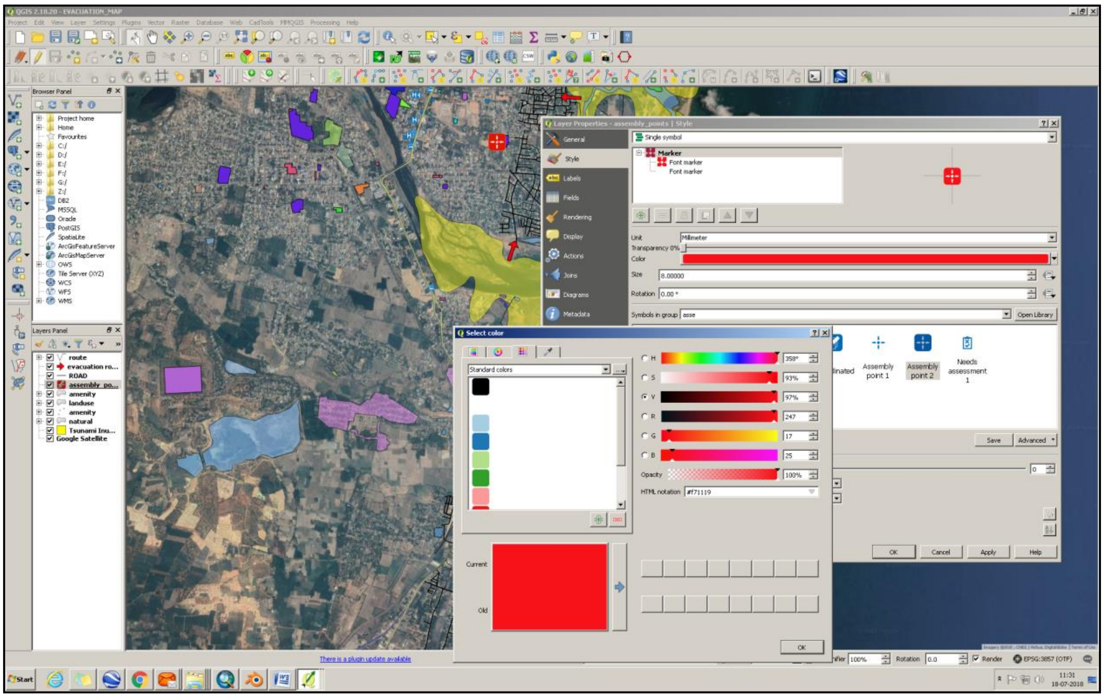
The new empty shape file opens in viewer



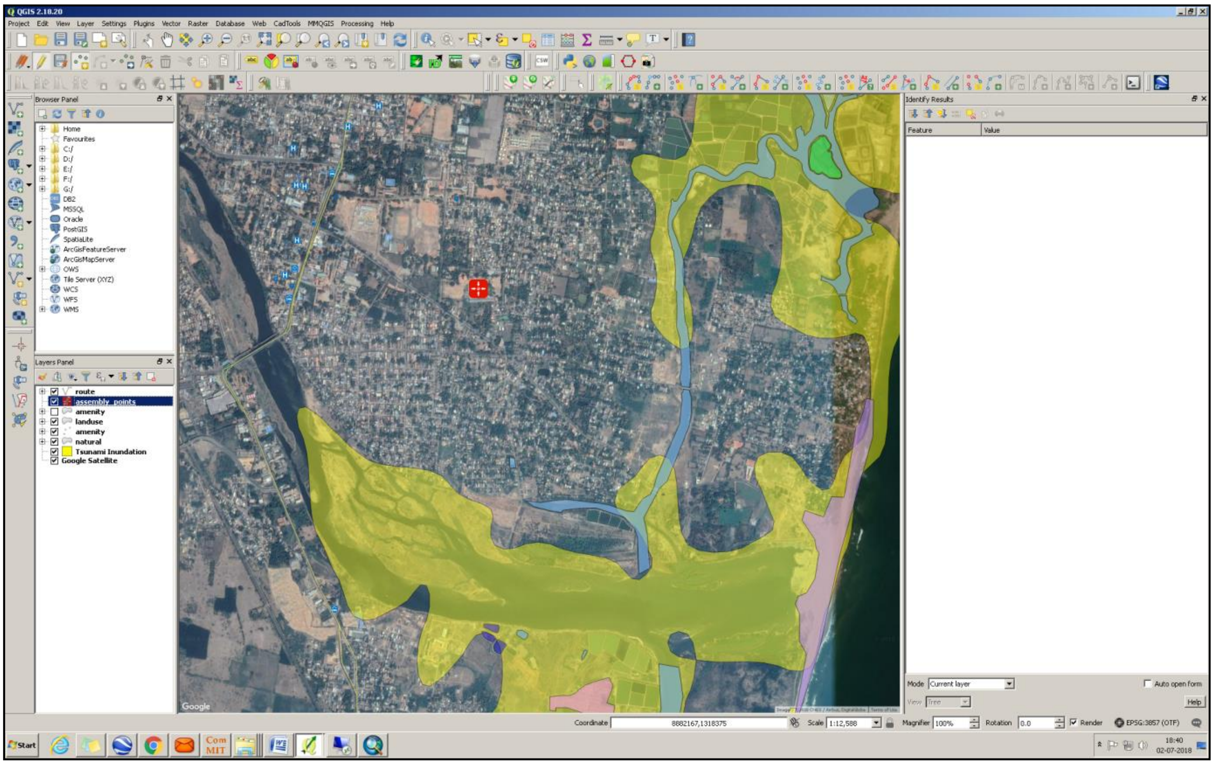
To add features into this new shape file select assembly_points and click on **"**Toggle Editing**"** this will enable the shape file to edit. Select "Add Feature" tool from top left tool panel as shown figure below. Then click in the viewer at the actual location of the assemble point identified for your area and enter the code and name of the assembly.



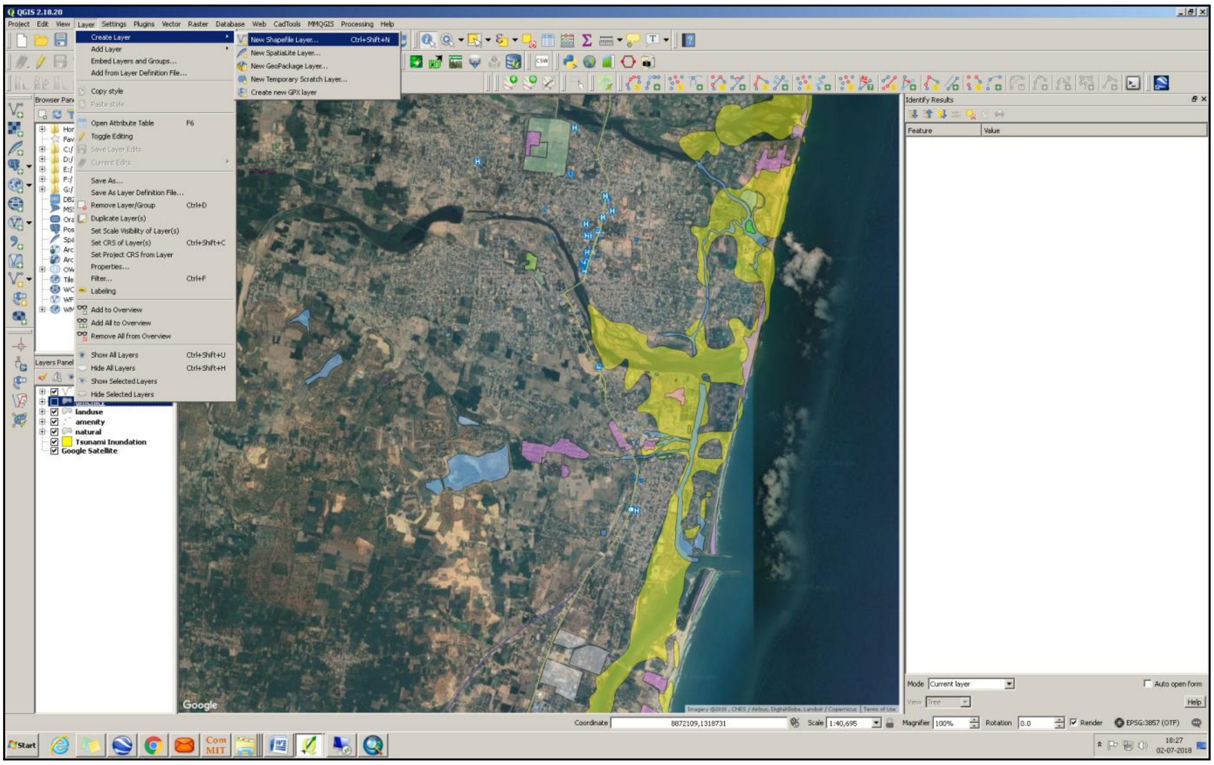
Select appropriate symbology for assembly point from layer properties-style option as shown below.



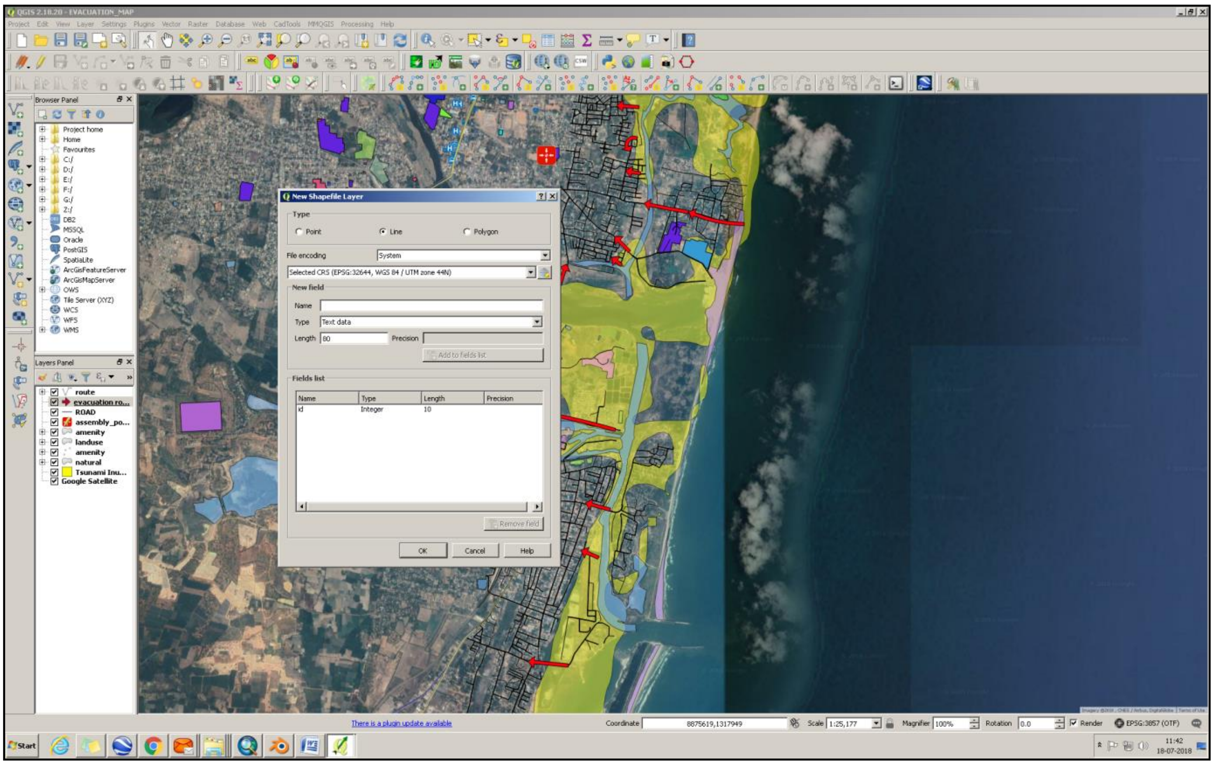
Now the symbol of your assembly point identified changed to the style you selected.



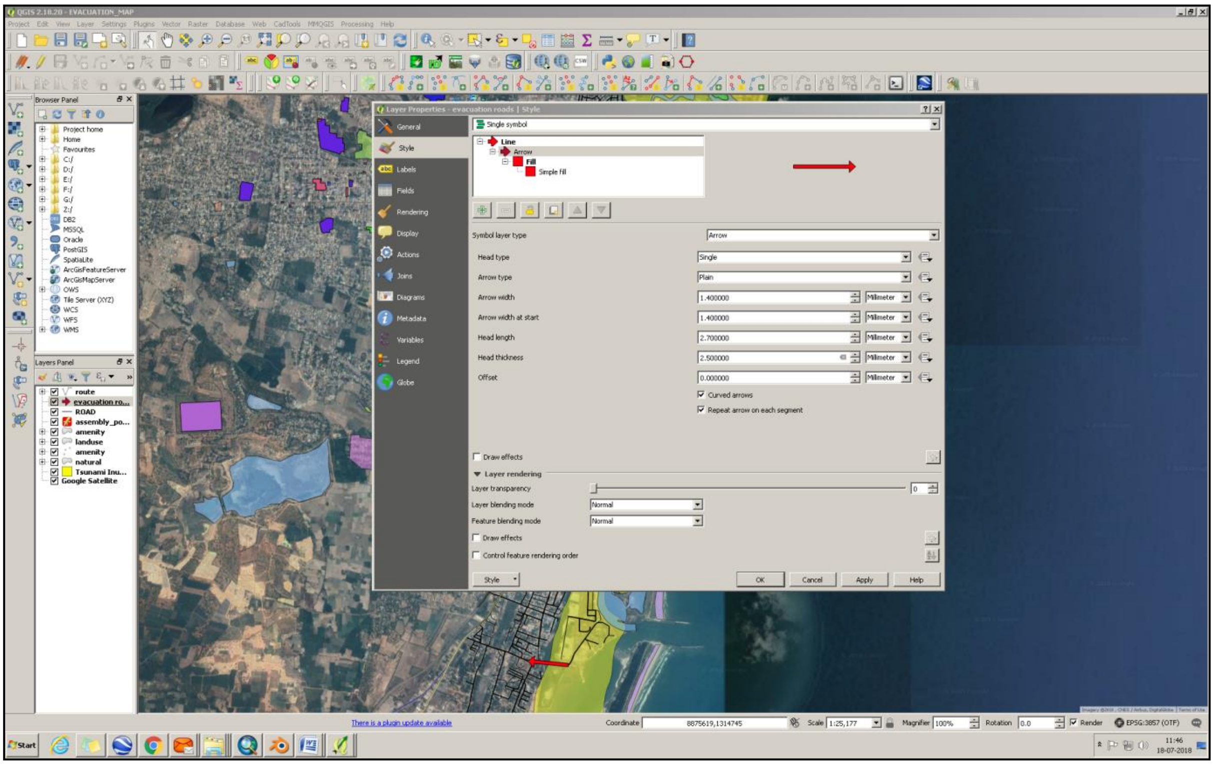
Step 13**.** Development of Tsunami evacuation routes on the map with their proper symbology. Create new shape file (line feature) by Layer-Create Layer-New Shape File option.



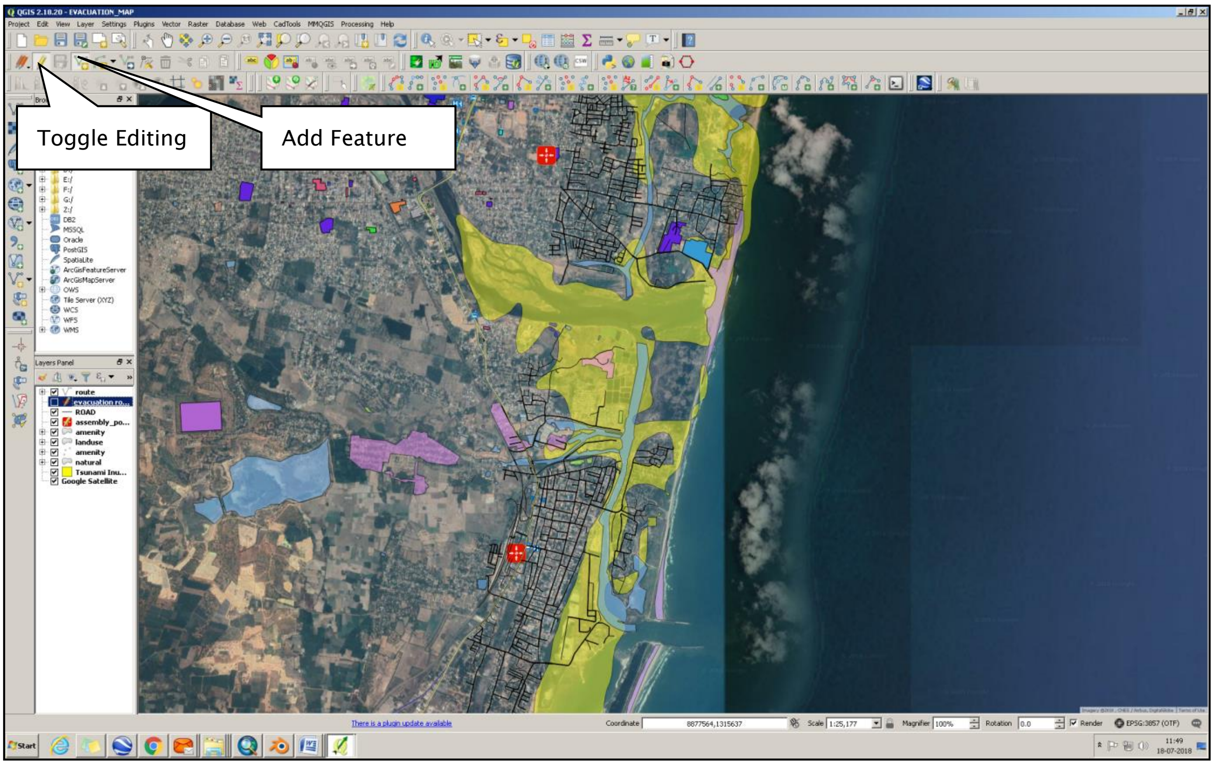
Then New Shapefile Layer dialog will appear. Select type line and appropriate projection and click OK. Then save as dialog will appear, enter the name "evacuation_route" then click Save.



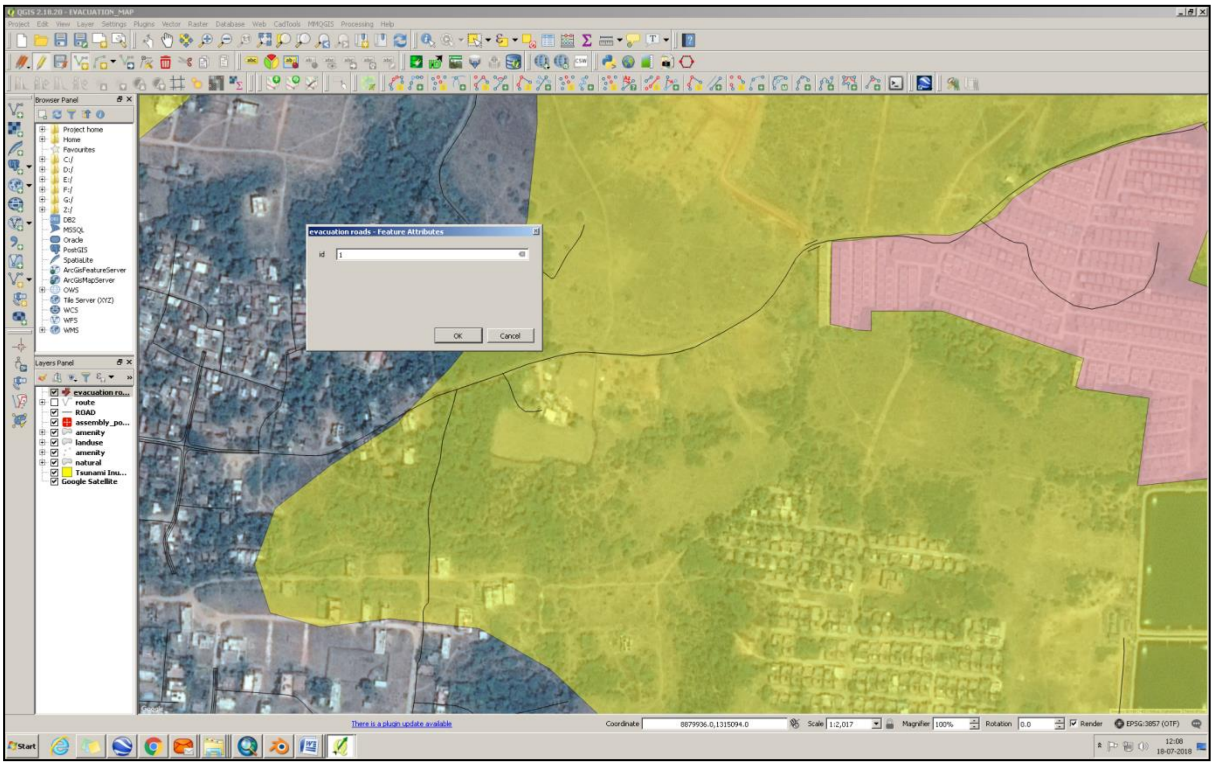
Then you right click on evacuation_route layer and select layer properties, select style table in the left and select line type is arrow as shown below.



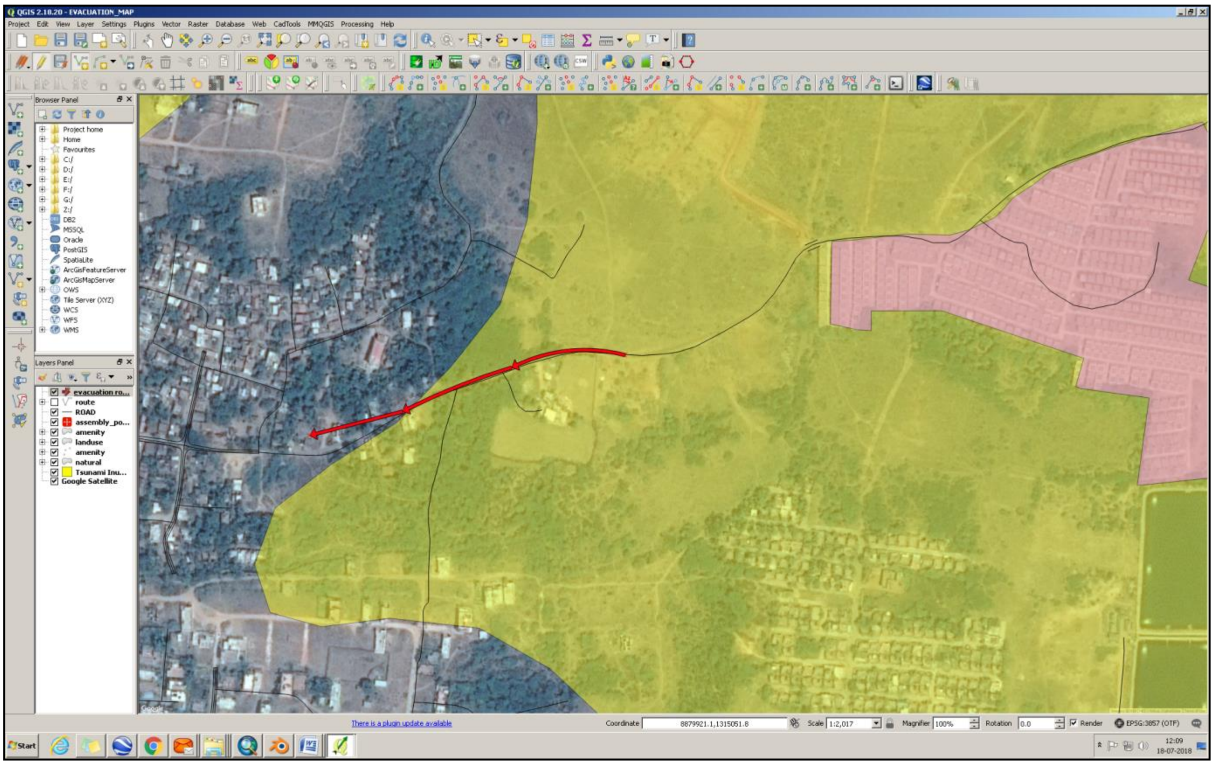
Select evacuation_route layer in layers panel and click Toggle Editing and select Add Feature tool from tool panel as shown below.



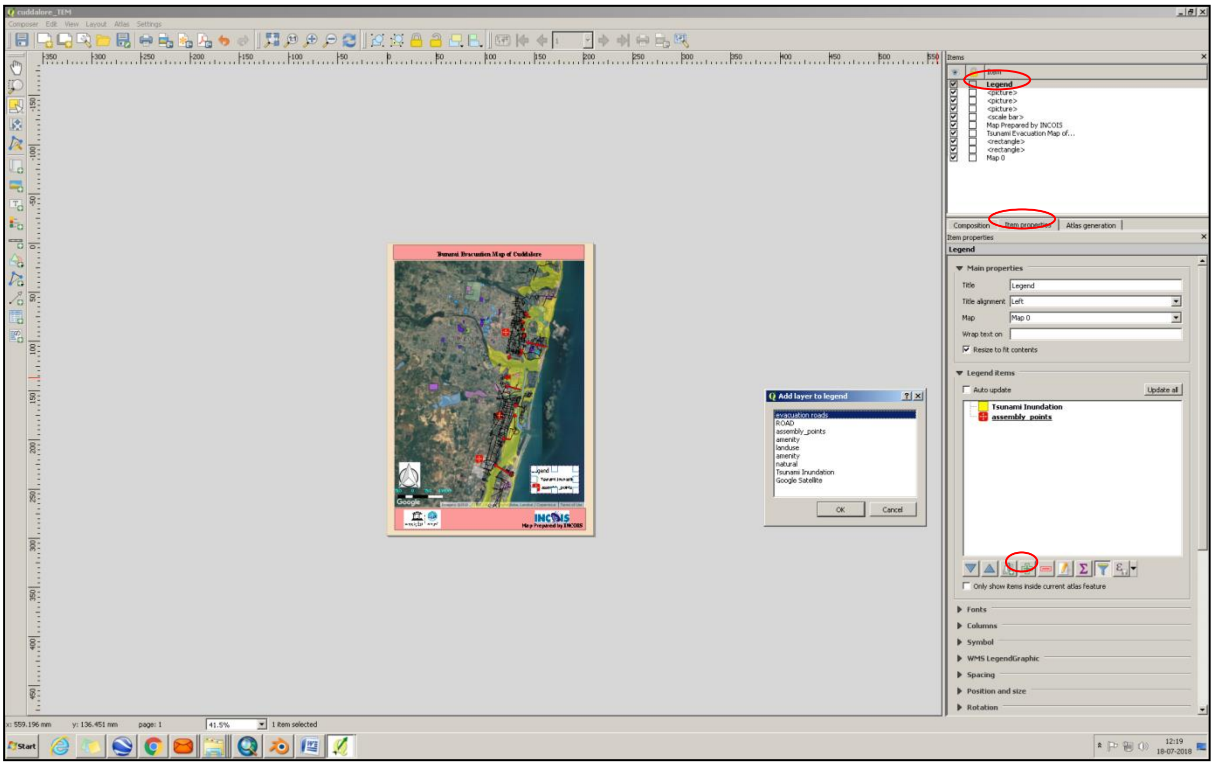
After selecting the add tool digitize a line on the roads to mark evacuation marks (arrows) as shown below and to end digitization of line right click and enter the feature attribute id and click OK.



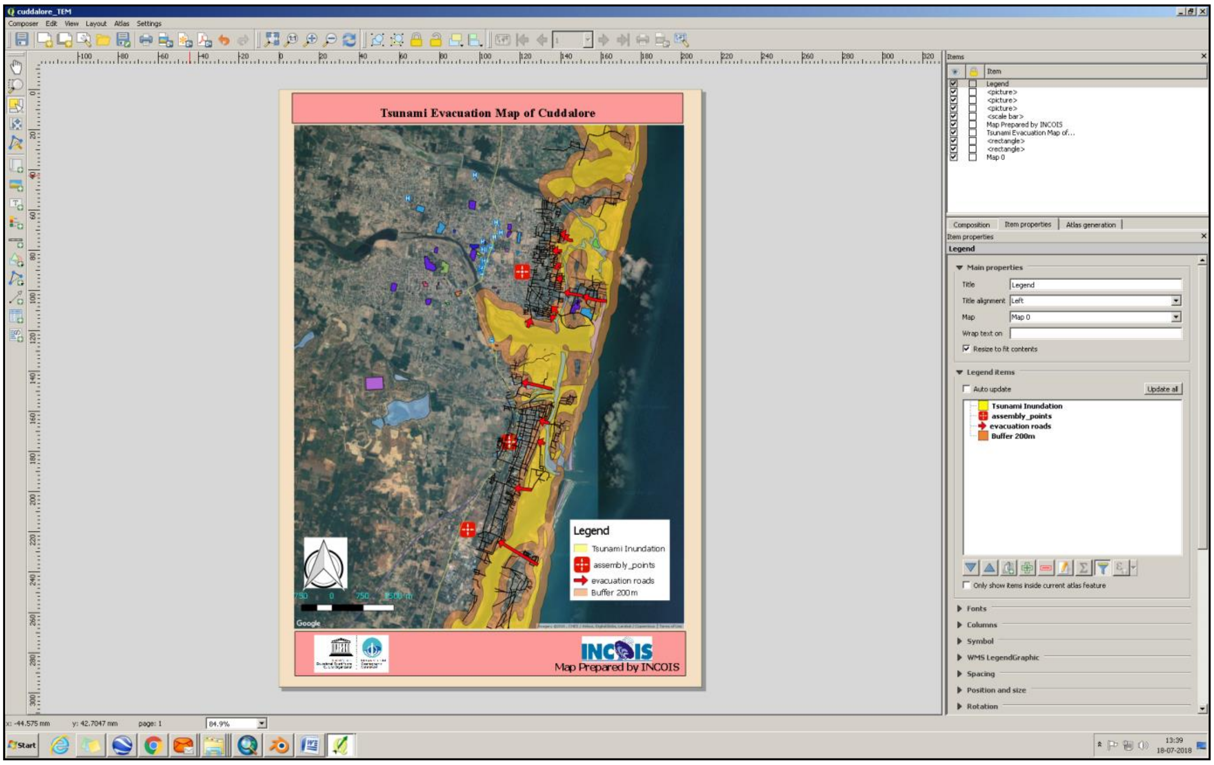
The line representing the evacuation arrow will be created as shown in the below figure.



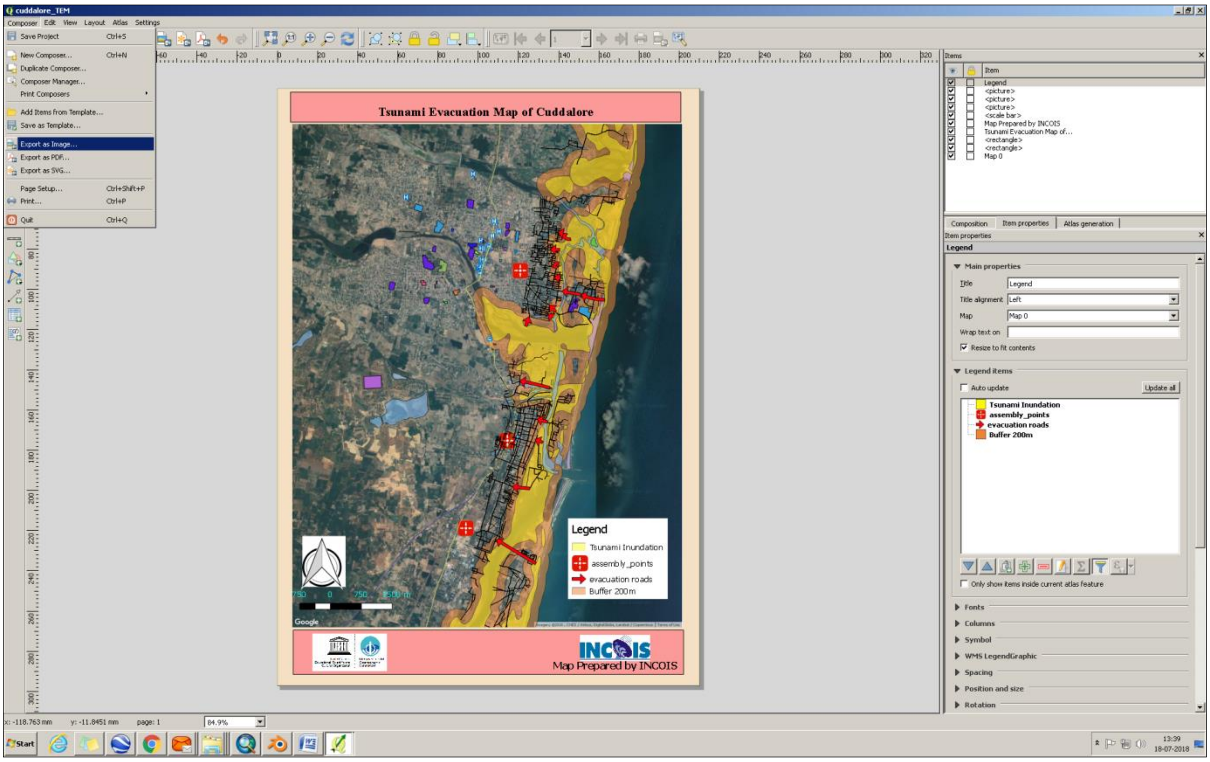
Step 14. After completion of the layer you add the evacuation route in the legend item properties tab selecting the add item tool (+ mark) select evacuation route and click ok. (Options to be selected is marked in red ellipses).



Cleaning and completing all the missing details to complete the development of the tsunami evacuation map labelling.



Step 15**.** Exporting Map: Your final map can be exported to various generic image formats by Composer (Layout) - Export as Image**.** You can also save as PDF and you can directly print to get your final Tsunami Evacuation Map.



ANNEX I

LIST OF ACRONYMS

ComMIT	Community Model Interface for Tsunami
FCC	False color composite
GIS	Geographic Information Systems
ICG/IOTWMS	Intergovernmental Coordination Group for the Indian Ocean Tsunami Warning and Mitigation System
INCOIS	Indian National Centre for Ocean Information Services
IOC	Intergovernmental Oceanographic Commission
IOTIC	Indian Ocean Tsunami Information Center
ITIC	International Tsunami Information Center
ITP	ITIC Training Program
KMZ	Keyhole Markup Language
MOST	Method of Splitting Tsunami)
OCHA	United Nations Office for the Coordination of Humanitarian Affairs
QGIS	Quantum GIS
TEMPP	Tsunami Evacuation Maps, Plans, and Procedures
UNESCO	United Nations Educational, Scientific and Cultural Organization
WMS	Web Map Services

ANNEX II

LIST OF TABLES AND FIGURES

IOC Manuals and Guides

No.	Title
1 rev. 2	Guide to IGOSS Data Archives and Exchange (BATHY and TESAC). 1993. 27 pp. (English, French, Spanish, Russian)
2	International Catalogue of Ocean Data Station. 1976. *(Out of stock)*
3 rev. 3	Guide to Operational Procedures for the Collection and Exchange of JCOMM Oceanographic Data. Third Revised Edition, 1999. 38 pp. (English, French, Spanish, Russian)
4	Guide to Oceanographic and Marine Meteorological Instruments and Observing Practices. 1975. 54 pp. (English)
5 rev. 2	Guide for Establishing a National Oceanographic Data Centre. Second Revised Edition, 2008. 27 pp. (English) *(Electronic only)*
6 rev.	Wave Reporting Procedures for Tide Observers in the Tsunami Warning System. 1968. 30 pp. (English)
7	Guide to Operational Procedures for the IGOSS Pilot Project on Marine Pollution (Petroleum) Monitoring. 1976. 50 pp. (French, Spanish)
8	*(Superseded by IOC Manuals and Guides No. 16)*
9 rev.	Manual on International Oceanographic Data Exchange. (Fifth Edition). 1991. 82 pp. (French, Spanish, Russian)
9 Annex I	*(Superseded by IOC Manuals and Guides No. 17)*
9 Annex II	Guide for Responsible National Oceanographic Data Centres. 1982. 29 pp. (English, French, Spanish, Russian)
10	*(Superseded by IOC Manuals and Guides No. 16)*
11	The Determination of Petroleum Hydrocarbons in Sediments. 1982. 38 pp. (French, Spanish, Russian)
12	Chemical Methods for Use in Marine Environment Monitoring. 1983. 53 pp. (English)
13	Manual for Monitoring Oil and Dissolved/Dispersed Petroleum Hydrocarbons in Marine Waters and on Beaches. 1984. 35 pp. (English, French, Spanish, Russian)
14	Manual on Sea-Level Measurements and Interpretation. (English, French, Spanish, Russian)
	Vol. I: Basic Procedure. 1985. 83 pp. (English)
	Vol. II: Emerging Technologies. 1994. 72 pp. (English)
	Vol. III: Reappraisals and Recommendations as of the year 2000. 2002. 55 pp. (English)
	Vol. IV: An Update to 2006. 2006. 78 pp. (English, Arab)
	Vol. V: Radar Gauges. 2016. 100 pp. and Supplement: Practical Experiences. 100 pp. (English, French, Russian, Spanish)
15	Operational Procedures for Sampling the Sea-Surface Microlayer. 1985. 15 pp. (English)
16	Marine Environmental Data Information Referral Catalogue. Third Edition. 1993. 157 pp. (Composite English/French/Spanish/Russian)
17	GF3: A General Formatting System for Geo-referenced Data
	Vol. 1: Introductory Guide to the GF3 Formatting System. 1993. 35 pp. (English, French, Spanish, Russian)
	Vol. 2: Technical Description of the GF3 Format and Code Tables. 1987. 111 pp. (English, French, Spanish, Russian)
	Vol. 3: Standard Subsets of GF3. 1996. 67 pp. (English)
	Vol. 4: User Guide to the GF3-Proc Software. 1989. 23 pp. (English, French, Spanish, Russian)

No.	Title
	Vol. 5: Reference Manual for the GF3-Proc Software. 1992. 67 pp. (English, French, Spanish, Russian)
	Vol. 6: Quick Reference Sheets for GF3 and GF3-Proc. 1989. 22 pp. (English, French, Spanish, Russian)
18	User Guide for the Exchange of Measured Wave Data. 1987. 81 pp. (English, French, Spanish, Russian)
19	Guide to IGOSS Specialized Oceanographic Centres (SOCs). 1988. 17 pp. (English, French, Spanish, Russian)
20	Guide to Drifting Data Buoys. 1988. 71 pp. (English, French, Spanish, Russian)
21	*(Superseded by IOC Manuals and Guides No. 25)*
22 rev.	GTSPP Real-time Quality Control Manual, First revised edition. 2010. 145 pp. (English)
23	Marine Information Centre Development: An Introductory Manual. 1991. 32 pp. (English, French, Spanish, Russian)
24	Guide to Satellite Remote Sensing of the Marine Environment. 1992. 178 pp. (English)
25	Standard and Reference Materials for Marine Science. Revised Edition. 1993. 577 pp. (English)
26	Manual of Quality Control Procedures for Validation of Oceanographic Data. 1993. 436 pp. (English)
27	Chlorinated Biphenyls in Open Ocean Waters: Sampling, Extraction, Clean-up and Instrumental Determination. 1993. 36 pp. (English)
28	Nutrient Analysis in Tropical Marine Waters. 1993. 24 pp. (English)
29	Protocols for the Joint Global Ocean Flux Study (JGOFS) Core Measurements. 1994. 178 pp . (English)
30	MIM Publication Series:
	Vol. 1: Report on Diagnostic Procedures and a Definition of Minimum Requirements for Providing Information Services on a National and/or Regional Level. 1994. 6 pp. (English)
	Vol. 2: Information Networking: The Development of National or Regional Scientific Information Exchange. 1994. 22 pp. (English)
	Vol. 3: Standard Directory Record Structure for Organizations, Individuals and their Research Interests. 1994. 33 pp. (English)
31	HAB Publication Series:
	Vol. 1: Amnesic Shellfish Poisoning. 1995. 18 pp. (English)
32	Oceanographic Survey Techniques and Living Resources Assessment Methods. 1996. 34 pp. (English)
33	Manual on Harmful Marine Microalgae. 1995. (English) [superseded by a sale publication in 2003, 92-3-103871-0. UNESCO Publishing]
34	Environmental Design and Analysis in Marine Environmental Sampling. 1996. 86 pp. (English)
35	IUGG/IOC Time Project. Numerical Method of Tsunami Simulation with the Leap-Frog Scheme. 1997. 122 pp. (English)
36	Methodological Guide to Integrated Coastal Zone Management. 1997. 47 pp. (French, English)
37	International Tsunami Survey Team (ITST) Post-Tsunami Survey Field Guide. 2nd Edition. 2014. 120 pp. (English)
38	Guidelines for Vulnerability Mapping of Coastal Zones in the Indian Ocean. 2000. 40 pp. (French, English)
39	Manual on Aquatic Cyanobacteria – A photo guide and a synopsis of their toxicology. 2006. 106 pp. (English)
40	Guidelines for the Study of Shoreline Change in the Western Indian Ocean Region. 2000. 73 pp. (English)

No.	Title
41	Potentially Harmful Marine Microalgae of the Western Indian Ocean Microalgues potentiellement nuisibles de l'océan Indien occidental. 2001. 104 pp. (English/French)
42	Des outils et des hommes pour une gestion intégrée des zones côtières - Guide méthodologique, vol.II/ Steps and Tools Towards Integrated Coastal Area Management – Methodological Guide, Vol. II. 2001. 64 pp. (French, English; Spanish)
43	Black Sea Data Management Guide *(Cancelled)*
44	Submarine Groundwater Discharge in Coastal Areas – Management implications, measurements and effects. 2004. 35 pp. (English)
45	A Reference Guide on the Use of Indicators for Integrated Coastal Management. 2003. 127 pp. (English). *ICAM Dossier No. 1*
46	A Handbook for Measuring the Progress and Outcomes of Integrated Coastal and Ocean Management. 2006. iv + 215 pp. (English). *ICAM Dossier No. 2*
47	TsunamiTeacher – An information and resource toolkit building capacity to respond to tsunamis and mitigate their effects. 2006. DVD (English, Bahasa Indonesia, Bangladesh Bangla, French, Spanish, and Thai)
48	Visions for a Sea Change. Report of the first international workshop on marine spatial planning. 2007. 83 pp. (English). *ICAM Dossier No. 4*
49	Tsunami preparedness. Information guide for disaster planners. 2008. (English, French, Spanish)
50	Hazard Awareness and Risk Mitigation in Integrated Coastal Area Management. 2009. 141 pp. (English). *ICAM Dossier No. 5*
51	IOC Strategic Plan for Oceanographic Data and Information Management (2008–2011). 2008. 46 pp. (English)
52	Tsunami risk assessment and mitigation for the Indian Ocean; knowing your tsunami risk – and what to do about it. 2009. 82 pp. (English)
53	Marine Spatial Planning. A Step-by-step Approach. 2009. 96 pp. (English; Spanish). *ICAM Dossier No. 6*
54	Ocean Data Standards Series:
	Vol. 1: Recommendation to Adopt ISO 3166-1 and 3166-3 Country Codes as the Standard for Identifying Countries in Oceanographic Data Exchange. 2010. 13 pp. (English)
	Vol. 2: Recommendation to adopt ISO 8601:2004 as the standard for the representation of date and time in oceanographic data exchange. 2011. 17 pp. (English)
	Vol.3: Recommendation for a Quality Flag Scheme for the Exchange of Oceanographic and Marine Meteorological Data. 2013. 12 pp. (English)
	Vol. 4: SeaDataNet Controlled Vocabularies for describing Marine and Oceanographic Datasets – A joint Proposal by SeaDataNet and ODIP projects. 2019. 31 pp (English)
55	Microscopic and Molecular Methods for Quantitative Phytoplankton Analysis. 2010. 114 pp. (English)
56	The International Thermodynamic Equation of Seawater—2010: Calculation and Use of Thermodynamic Properties. 2010. 190 pp. (English)
57	Reducing and managing the risk of tsunamis. Guidance for National Civil Protection Agencies and Disaster Management Offices as Part of the Tsunami Early Warning and Mitigation System in the North-eastern Atlantic, the Mediterranean and Connected Seas Region – NEAMTWS. 2011. 74 pp. (English)
58	How to Plan, Conduct, and Evaluate Tsunami Exercises / Directrices para planificar, realizar y evaluar ejercicios sobre tsunamis. 2012. 88 pp. (English, Spanish)
59	Guide for designing and implementing a plan to monitor toxin-producing microalgae. Second Edition. 2016. 63 pp. (English, Spanish)
60	Global Temperature and Salinity Profile Programme (GTSPP) — Data user's manual, 1st Edition 2012. 2011. 48 pp. (English)

No.	Title
61	Coastal Management Approaches for Sea-level related Hazards: Case-studies and Good Practices. 2012. 45 pp. (English)
62	Guide sur les options d'adaptation en zone côtières à l'attention des décideurs locaux – Aide à la prise de décision pour faire face aux changements côtiers en Afrique de l'Ouest / A Guide on adaptation options for local decision-makers: guidance for decision making to cope with coastal changes in West Africa / Guia de opções de adaptação a atenção dos decisores locais: guia para tomada de decisões de forma a lidar com as mudanças costeiras na Africa Ocidental. 2012. 52 pp. (French, English, Portuguese). *ICAM Dossier No. 7*.
63	The IHO-IOC General Bathymetric Chart of the Oceans (GEBCO) Cook Book. 2012. 221 pp. (English). *Also IHO Publication B-11*
64	Ocean Data Publication Cookbook. 2013. 41 pp. (English)
65	Tsunami Preparedness Civil Protection: Good Practices Guide. 2013. 57 pp. (English)
66	IOC Strategic Plan for Oceanographic data and Information Management (2013-2016). 2013. 54 pp. (English/French/Spanish/Russian)
67	IODE Quality Management Framework for National Oceanographic Data Centres. 2014; revised edition 2019 (English)
68	An Inventory of Toxic and Harmful Microalgae of the World Ocean (in preparation)
69	A Guide to Tsunamis for Hotels: Tsunami Evacuation Procedures (North-eastern Atlantic and the Mediterranean Seas). 2016 (English)
70	A guide to evaluating marine spatial plans. 2014. 96 pp. (English)
71	IOC Communication Strategy for Marine Information Management (2015-2017). 2015
72	How to reduce coastal hazard risk in your community – A step-by-step approach. 2016
73	Guidelines for a Data Management Plan. 2016
74	*Standard Guidelines for the Tsunami Ready Recognition Program*. (in preparation)
75	ICAN (International Coastal Atlas Network) - best practice guide to engage your CWA (Coastal Web Atlas) user community. 2016
76	Plans and Procedures for Tsunami Warning and Emergency Management – Guidance for countries in strengthening tsunami warning and emergency response through the development of Plans and Standard Operating Procedures for their warning and emergency management authorities. 2017
77	IOC Strategic Plan for Data and Information Management (2017-2021). 2017
78	Harmful Algal Blooms (HABs) and Desalination: A Guide to Impacts, Monitoring and Management. 2017
79	IOC Communication and Outreach Strategy for Data and Information Management (2017-2019). 2017
80	Ocean Literacy for All – A toolkit. 2017
81	Procedures for Proposing and Evaluating IODE Projects and Activities. 2018
82	Preparing for community tsunami evacuations: From Inundation to Evacuation Maps, Response Plans, and Exercises (English and Spanish) and Supplement 1 and 2 (English only), 2020.