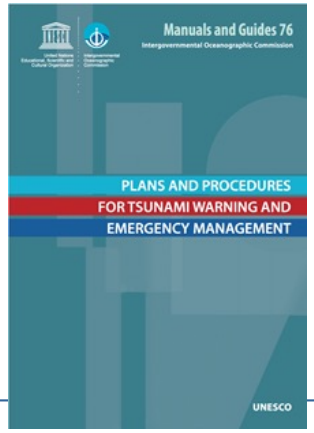
UNESCO/IOC – NOAA ITIC Training Program in Hawaii (ITP-TEWS Hawaii)
TSUNAMI EARLY WARNING SYSTEMS
AND THE PACIFIC TSUNAMI WARNING CENTER (PTWC) ENHANCED PRODUCTS
TSUNAMI EVACUATION PLANNING AND UNESCO IOC TSUNAMI READY PROGRAMME
15-26 September 2025, Honolulu, Hawaii

unesco
Intergovernmental Oceanographic Commission

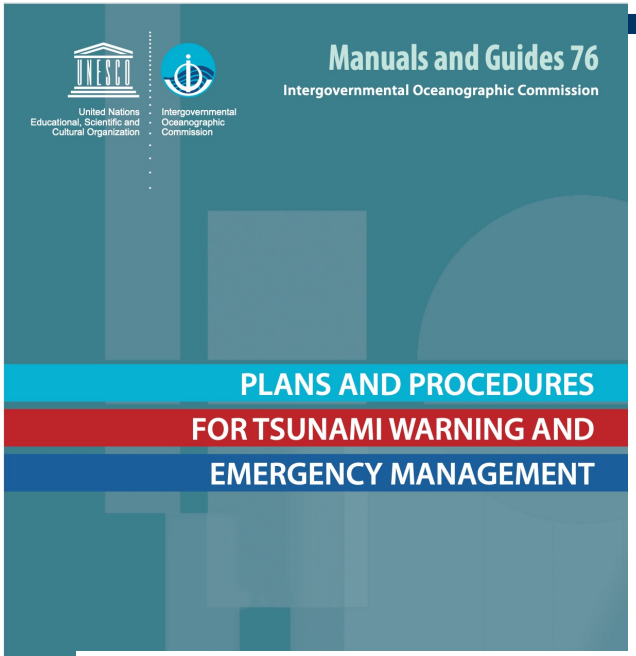
IOC Manual and Guides 76
TWC Standard Operating Procedures



Christa von Hillebrandt-Andrade
Deputy Director, ITIC
Dr. Laura Kong
Director, ITIC

Pacific Community
Communauté du Pacifique

TWC and TER Standard Operating Procedures



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

2. END-TO-END TSUNAMI WARNING SYSTEM
2.1 What is a Tsunami Warning System (TWS)?
2.2 Understanding the end-to-end system
2.3 Tsunami Coordination Committees
2.4 Documents supporting a TWS

3. TSUNAMI WARNING
3.1 Introduction
3.2 Roles and Responsibilities of a TSP
3.3 Roles and Responsibilities of a NTWC
3.4 NTWC Operations Manual
3.5 NTWC SOPs
3.6 NTWC SOP Development
3.7 Core activities of a NTWC – event response operations
3.8 Core activities of a NTWC – post and non-event operations

4. TSUNAMI EMERGENCY RESPONSE
4.1 Introduction
4.2 The Roles and Responsibilities of a EMA
4.3 Tsunami emergency response plans
4.4 Tsunami emergency response SOPs
4.5 Development of TER plans and SOPs

A. GUIDELINES FOR NTWC SOPs
B. GUIDELINES FOR EMA TSUNAMI EMERGENCY RESPONSE PLANS AND SOPs

Definition: Standard Operating Procedure (SOP)

A SOP is a written document that describes the **actions to be taken in a system** or **process**. A SOP describes each individual activity in a sequence of activities, documenting **who does what, when, where, and how** for each activity.

Source: IOC Manuals and Guides, 76

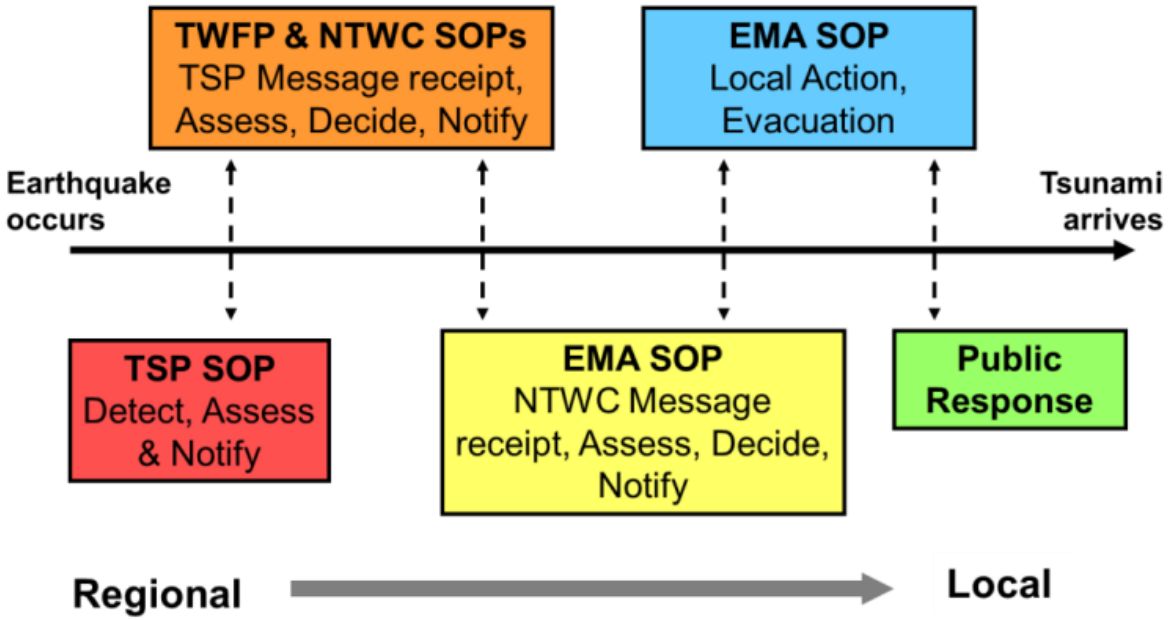
What are SOPs?

- Set of written instructions for routine/repetitive organization activities. Procedures followed in an emergency.
- Detail work processes conducted/followed within organization.
- Document way activities are performed for consistent conformance to system requirements and organization's mission.

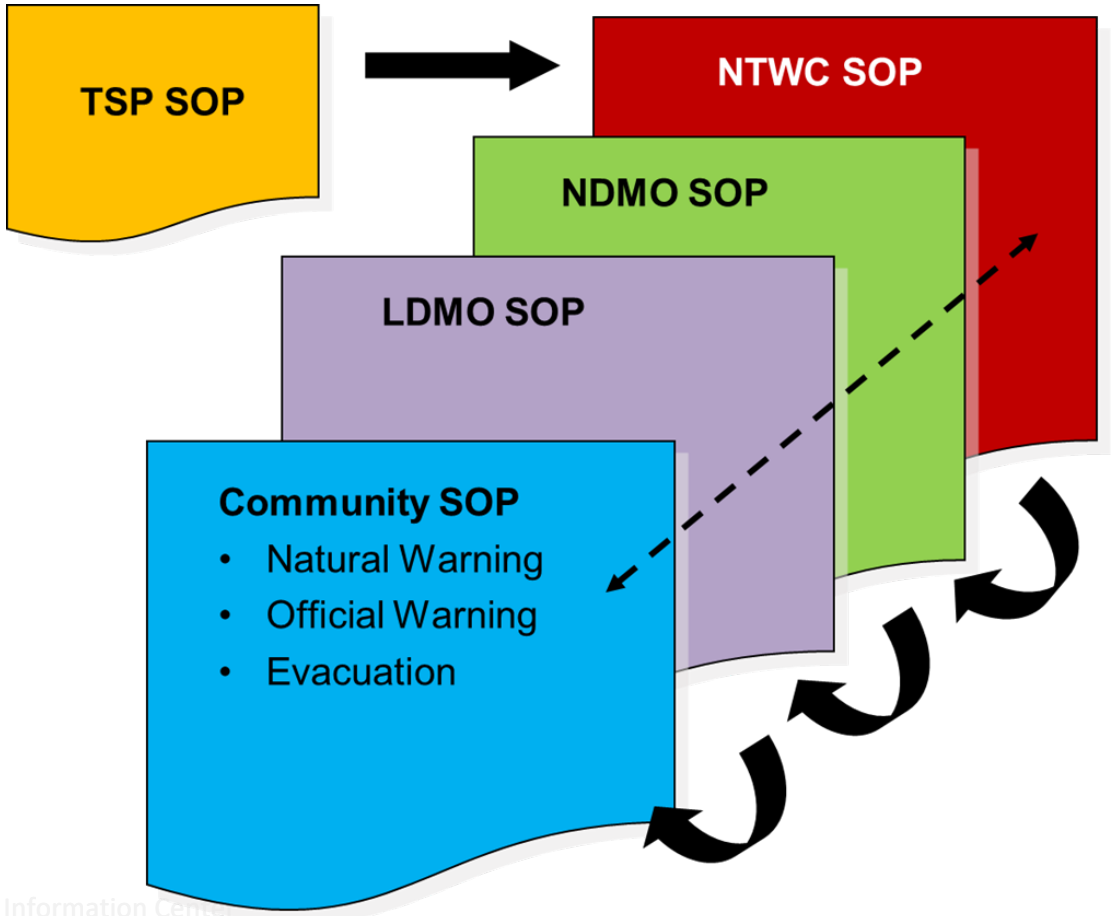
Based on US Environmental Protection Agency Manual

End to End Warning Response SOPs

IOC Manuals and Guides, 76
page 4



SOPs Need to be Integrated



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Considerations for SOPs – Min vs Adv TWC

- Minimum SOPs
  - Use information from TSPs or other national/regional sources
- Advanced SOPs
  - Independent capacity to monitory seismicity and/or
  - Tsunami numerical modeling capability

Considerations for SOPs – Local vs Distant

- Local Tsunami
  - Feel an earthquake
- Regional or Distant Tsunami
  - Seismic Alarm
  - Bulletin from TSP or other agency

Why are SOPs important?

- Foundation of effective, reliable warning system to protect assets and save lives
- All warning systems require SOPs, but for tsunami, essential for rapid response (evaluation / warning / messaging / response)
- In an end-to-end system, communications links between stakeholders must be robust or warning chain will be broken
- SOPs developed, practiced and modified as necessary – a "living document"

Different Types of SOP Documents

1. Official SOP documents for management purposes
2. Comprehensive TW operations SOP documents with many details for study and reference during non-crisis
3. Quick-Reference SOP documents for reference during crisis
4. Systems SOP documents so recipients understand TWC/TER SOP and what to expect (Users Guide)

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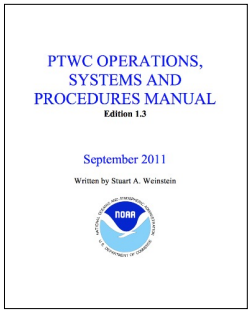
Official SOPs for Management

- **Directives**
  - TWC Performance Expectations
  - Roles & Responsibilities / Concept of Operations
  - Maintained by Parent Organization
  - Formal Review / Change Process with Organizational Stakeholders



- **Station Duty Manual**
  - Duty Staff Performance Expectations
  - Maintained by TWC Management
  - Includes Tasks outside Crisis Operations
  - Formal Review / Change Process with Staff

Concept of Operations - Roles and Responsibilities
Transmission / Dissemination of Warning

JMA…

- ✓ Issues tsunami warning
- ✓ Disseminates warning to public with media cooperation

Local governments…

- ✓ Disseminate warning to residents
- ✓ Warn residents and relevant organizations to take actions against expected

Concept of Operations - Operation 24 hrs/day, 7 days/week …

Succession of Operation

- ✓ Morning/Evening Briefings -
  overlap in in shifts to brief next shift
- ✓ Daily Report -
  issued EQ info, seismic activity,
  system status during shift
- ✓ Daily Schedule Sheet -
  checklist of daily tasks
  logged as completed

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TWC Operations Manual: (Refer to during non-crisis)

- **Most Detailed**
- **Steps to Carry Out**
  - How ? Why ?
- **Logical Flow**
  - Flow Charts, Timelines
- **Background Information**
  - Scientific Basis
  - Organizational Basis
  - Definitions
- **Format**
  - Paper, Electronic (Web Based)

For Warning Centers, SOPs are not just on what to do in an Earthquake.

They should also be geared to maintaining:

100% Operational Reliability

1. Data availability monitoring
2. Data quality monitoring
3. Maintenance and repair priorities
4. System Alteration Procedures
5. System Failure Procedures

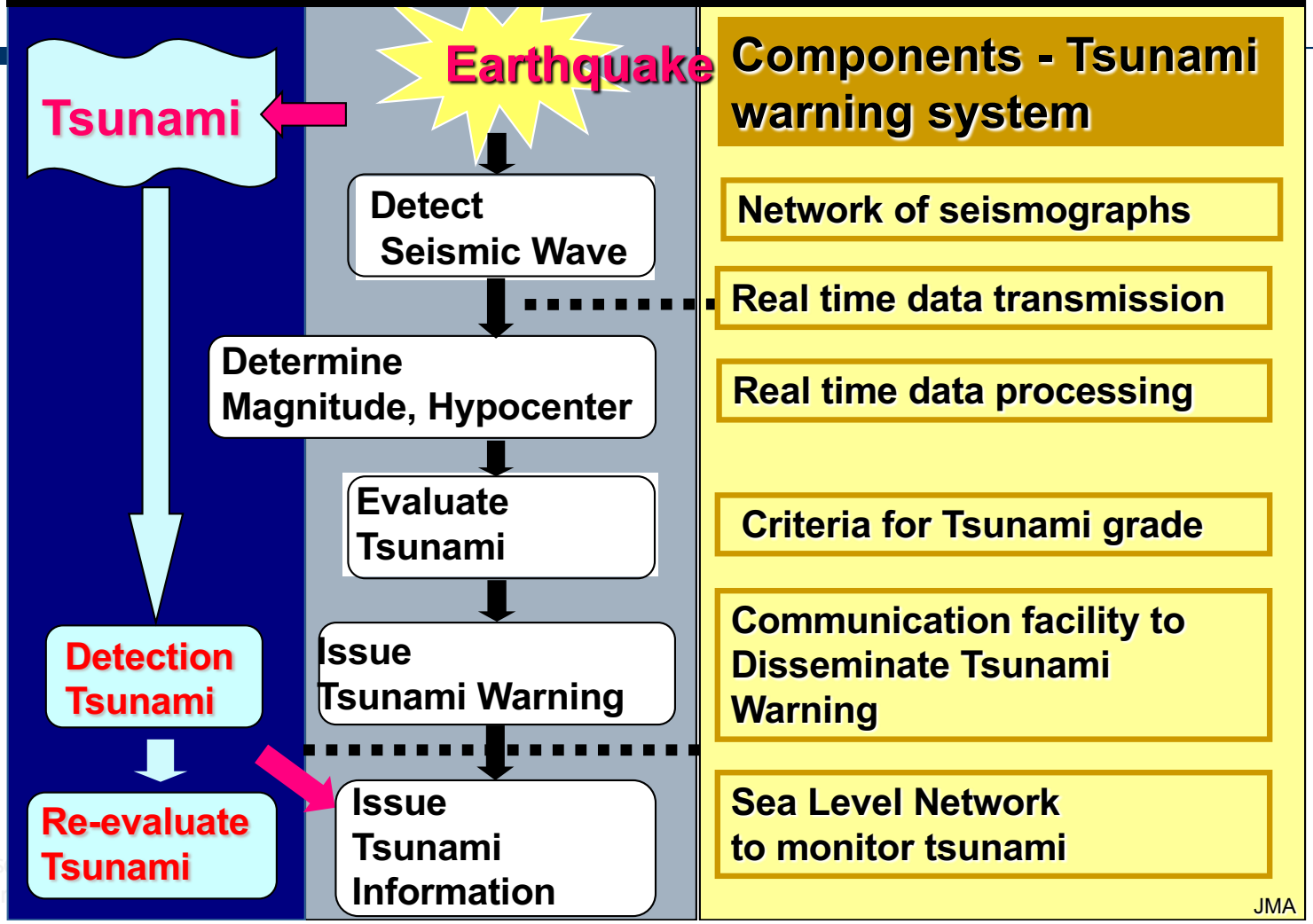
Long Term Readiness:

1. Communication Tests
2. Table-top Exercises

TWC Operations
What should SOPs cover:

- **SOPs are Living Documents**
- **Main TWC Characteristics**
  - Fast
  - Accurate
  - Reliable
  - Effective
- **Main TWC Activities**
  - Seismic Data Collection and Analysis
  - Sea Level Data Collection and Analysis
  - Decision-Making Tools and Procedures
  - Message Creation and Dissemination

Tsunami Warning - REQUIREMENTS



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Quick Reference SOPs (Crisis mode)

- **Timeline-driven activities**
  - Need to act rapidly (minutes)
    >> there is no time to read detailed manual !
  - E.g., How much time do you have?
    What information is wanted?
  - Flow Charts describe overall flow, but Checklists allow faster response

- **Criteria Tables & Checklists**
  - What to use / What to look at
  - What is the action required
  - When is the action needed by
  - What are the steps/procedures not to forget
  - Who to notify (with ph nbrs, etc)

General TWC SOP during an Event

0. EQ!!! - Digital Alarm - Duty Staff paged
1. Detect and Analyze Large Earthquake
2. Determine Tsunami Hazard based on Pre-Determined Criteria
3. Issue Initial Message
4. Further Seismic Analyses
5. Create Forecast if needed, issue 2nd Mess.
6. Detect and Analyze Tsunami Signals
7. Re-evaluate Tsunami Hazard
8. Issue Additional Message
9. Repeat Steps 6-8 until Threat Passed
10. Cancellation or Final Message

Event Operations - Local Event - TIMELINE-DRIVEN

IOC Manuals and Guides, 76
Annex A – page 34

Example of NTWC SOP Timeline Template for a Local/Regional Earthquake and Tsunami. Minimum NTWC (TSP-dependent, in blue and black). Advanced NTWC (TSP-independent, Seismic Processing and Tsunami Forecasting, in red and black)

STEP	TIME since EQ*	ACTIVITY	ACTION AND PROCEDURES
1	1 min	Seismic Alarm Trigger	• Alarm sounds from automated seismic processing system • Feel earthquake and respond, receive phone call or other • For a strongly felt earthquake (greater than Modified Mercalli Intensity Scale VI), alert should be issued immediately to the public and EMA EOC advising to clear the beach
2	2 min	Earthquake Monitoring and Analysis	• Monitor RTED/CISN and other information tools • Receive Information provided by TSP/other Centres • Review/update automatic phase picks and solution. Perform Interactive analysis if required. Highest priority for review is earthquake magnitude and focal depth

3	3 min	Tsunami Threat Assessment	• Obtain ETA by look up in TSP Message
			• Obtain threat by look up in TSP Message
			• Calculate tsunami travel times/ETA to nearest coasts or refer to pre-calculated reverse tsunami travel time map ('bullseye' with country as centre
			• Estimate Threat by
			  ○ Tsunami Scenario Database look up
			  ○ Earthquake location, depth, magnitude as proxy for tsunami threat height and area

4	5 min	Issuance of warning and related information	• Use Country Criteria Table to decide on Alert Level. If warning thresholds (for earthquake magnitude or expected tsunami amplitude) are exceeded, issue warning to tsunami-threatened areas immediately. For warning, issue ETAs at forecast points.

5	7 min	Re-analysis, Tsunami monitoring	• Monitor for updates to earthquake parameters by TSP/other Centres
			• Obtain tsunami observations by loop up in TSP Message
			• Monitor sea level stations near the epicentre
			• Re-evaluation of focal parameters obtained using additional data.
			• Estimate Threat by
			  ○ Tsunami Scenario Database look up
			  ○ Real-time Tsunami Forecast modeling
			  ○ Earthquake location, depth, magnitude as proxy for tsunami threat height and area.

6	10 min	Re-assessment and issuance of new information	• Upgrade warning if observed tsunami higher than expected at Step 3 • Issue tsunami arrival and height observations (Downgrade or Cancel if tsunami is smaller or no tsunami is observed.)
7	10 min to hours	Information	• If tsunami is generated, tsunami information regularly issued until no tsunami threat exists. Neighboring and TSP information should be considered in evaluation.
8	Hours	Cancellation	• If tsunami threat no longer exists, tsunami warning cancellation is issued.
9	Days to weeks	Tsunami science survey	• Survey of tsunami run-up, inundation, and eyewitness observation along coastal area. • Survey of tsunami disaster on people, structures, geology, and social impact and early warning response
10	Week to months	Summary report	• Analysis of the warning centre and emergency response operational procedures • Revision and update of SOP as required

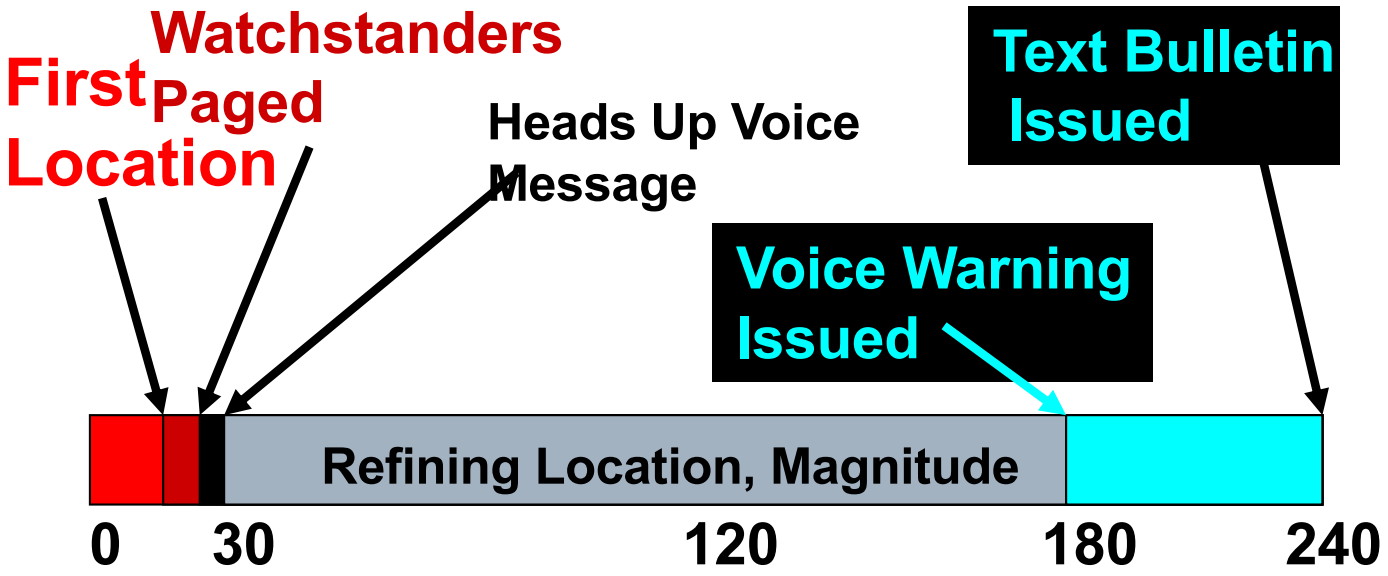
** times elapsed since earthquake are approximate and under ideal circumstances*

Event Operations - Local Event - TIMELINE-DRIVEN - PTWC

STEP	TIME since EQ*	ACTIVITY	ACTION AND PROCEDURES
1	1 min	Seismic Alarm Trigger	• Feel earthquake / respond, receive phone call • Alarm sounds from automated seismic processing system • For a strongly felt earthquake (greater than Modified Mercalli Intensity Scale VI), alert should be issued immediately to the public and national disaster management or emergency operations centers advising to clear the beach.
2	2 min	Earthquake Review	• Review/update automatic phase picks and solution • Perform Interactive analysis if required • Highest priority for review is earthquake magnitude & focal depth
3	3 min	Tsunami Threat Decision Making	• If tsunami simulation database is operational, expected tsunami threat area and heights are determined. • If no tsunami simulation database, earthquake magnitude and depth criteria are used as proxy for tsunami threat height and area. • Tsunami Threat threshold criteria should be pre-decided using historical and other science data.
4	5 min	Issuance of warning and related tsunami information	• If warning thresholds (for earthquake magnitude or expected tsunami height) are exceeded, issue warning to tsunami-threatened areas immediately • Calculate tsunami travel times and issue expected tsunami arrival time at forecast points
5	7 min	Re-analysis	• Monitor sea level data (coastal run-up, coastal sea-level, deep-ocean gauges) • Re-evaluation of focal parameter from Step 2 with additional data. • Comparison to focal parameters and tsunami forecasts provided by international/regional centers
6	10 min	Re-evaluation and issuance of new information	• Upgrading of warning if observed tsunami are higher than the expected at Step 3 • Issuance of tsunami arrival and height observations • (Downgrade or Cancel if tsunami is smaller or no tsunami is observed.)
7	10 min to hours	Information	• If tsunami is generated, tsunami information is regularly issued until no tsunami threat exists. Neighboring and international tsunami center information should be considered in evaluation.
8	Hours	Cancellation	• If tsunami threat no longer exists, tsunami warning cancellation is issued.
9	Days to weeks	Tsunami site survey	• Survey of tsunami run-up, inundation, and eyewitness observation along coastal area. • Survey of tsunami disaster on people, structures, geology, and social impact and early warning response
10	Week to months	Summary report	• Analysis of the warning center and emergency response operational procedures • Revision and update of SOP as required

Earthquake in Hawaii Region

Timeline to Issue Initial Warning Bulletin



Time in Seconds

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International Tsunami Information Center

Event Operations - Distant Event - TIMELINE-DRIVEN

Example of NTWC SOP Timeline Template for a Distant Earthquake and Tsunami. Minimum NTWC (TSP-dependent, in blue and black). Advanced NTWC (TSP-independent, Seismic Processing and Tsunami Forecasting, in red and black)

STEP	TIME since EQ*	ACTIVITY	ACTION AND PROCEDURES
1	3 min	Seismic Alarm Trigger	• Alarm sound from an automatic seismic processing system • Monitor RTED/CISN and other information tools • Receive Information provided by TSP/other Centres
2	10 min	Earthquake Monitoring and Analysis, Tsunami monitoring	• Obtain ETA by look up in TSP Message • Review/update automatic phase picks and solution. Perform Interactive analysis if required. Highest priority for review is earthquake magnitude and focal depth • Calculate tsunami travel times/ETA to nearest international sea level stations and country • If ETA to country is within the predefined time, go to step 3. • Monitor sea level stations near the epicentre • If there is enough time, NTWC shall issue Information that event is under assessment for tsunami threat to the country. (If no tsunami is observed in the near source region, Information is issued that there is no tsunami threat.)
3	13 min	Tsunami Threat Assessment	• Obtain threat by look up in TSP Message • Estimate Threat by ○ Tsunami Scenario Database look up ○ Real-time Tsunami Forecast modeling ○ Earthquake location, depth, magnitude as proxy for tsunami threat height and area.
4	15 min to hours	Issuance of warning and related information	• Use Country Criteria Table to decide on Alert Level. If warning thresholds (for earthquake magnitude or expected tsunami amplitude) are exceeded, issue warning to tsunami-threatened areas immediately. For warning, issue ETAs at forecast points. • If very distant, advise and wait until threat closer for warning.
5	20 min to hours	Re-analysis, Tsunami monitoring	• Monitor for updates to earthquake parameters by TSP/other Centres • Obtain tsunami observations by look up in TSP Message • Monitor sea level stations across the ocean • Re-evaluation of focal parameters using additional data, calculate CMT • Re-estimate Threat by ○ Tsunami Scenario Database look up ○ Real-time Tsunami Forecast modeling
6	30 min to hours	Re-assessment and issuance of new information	• Upgrade warning if observed tsunami higher than expected at Step 3 • Issue tsunami arrival and height observations (Downgrade or Cancel if tsunami is smaller or no tsunami is observed.)
7	30 min to hours	Information	• If tsunami is generated, tsunami information regularly issued until no tsunami threat exists. Neighboring and TSP information should be considered in evaluation.
8	Hours-days	Cancellation	• If tsunami threat no longer exists, tsunami warning cancellation is issued.
9	Days to weeks	Tsunami science survey	• Survey of tsunami run-up, inundation, and eyewitness observation along coastal area. • Survey of tsunami disaster on people, structures, geology, and social impact and early warning response
10	Week to months	Summary report	• Analysis of the warning centre and emergency response operational procedures • Revision and update of SOP as required

** times elapsed since earthquake are approximate and under ideal circumstances*

Event Operations - Distant Event - TIMELINE-DRIVEN - PTWC

STEP	TIME since EQ*	ACTIVITY	ACTION AND PROCEDURES
1	3 min	Seismic Alarm Trigger	• Alarm sounds from an automatic seismic processing system • Information provided by international centers; PTWC, WC/ATWC, JMA, WDC-Seismology-NEIC, GFZ??
2	10 min	Earthquake Review and Sea Level monitoring for tsunami generation	• Review/update automatic phase picks and solution, including addition of other international seismic stations • Calculation to tsunami travel times to nearest international sea level stations and national territory • If tsunami travel time to the national territory is within the predefined time, GO to STEP 3. • Continue to monitor sea level data located at near epicenter. • If there is enough time, NTWC shall issue Information that event is under evaluation for the tsunami threat to the national territory. • (If no tsunami is observed in the near source region, Information is issued that there is no tsunami threat.)
3	13 min	Tsunami Threat Decision Making	• Decide on tsunami threat (height and area) based on pre-decided criteria, depending on whether tsunami simulation database exists or not; estimated tsunami • If tsunami is observed at nearby sea level stations, evaluate a tsunami magnitude based on distance and observed tsunami height.
4	15 min to hours	Issue warning and related information	• If warning thresholds (for earthquake magnitude or expected tsunami height) are exceeded, issue warning to tsunami-threatened areas immediately. • If very distant, advise and wait until threat closer for warning.
5	30 min to hours	Re-analysis	• Monitor sea level data (coastal run-up, coastal sea-level, deep-ocean gauges) • Re-evaluation of focal parameter (Step 2) using additional data • Comparison to focal parameters and tsunami forecasts provided by international/regional centers (PTWC, JMA, NEIC)
6	30 min to hours	Re-evaluation and issuance of new information	• Upgrading of warning if observed tsunami are higher than the expected at Step 3 • Issuance of tsunami arrival and height observations • (Downgrade or Cancel if tsunami is smaller or no tsunami observed.)
7	30 min to hours	Information	• If tsunami is generated, tsunami information is regularly issued until no tsunami threat exists. Neighboring and international tsunami center information should be considered in evaluation.
8	Hours	Cancellation	• If tsunami threat no longer exists, tsunami warning cancellation is issued.
9	Days to weeks	Tsunami site survey	• Survey of tsunami run-up, inundation, and eyewitness observation along coastal area. • Survey of tsunami disaster on people, structures, geology, and social impact and early warning response
10	Week to months	Summary report	• Analysis of the warning center and emergency response operational procedures • Revision and update of SOP as required

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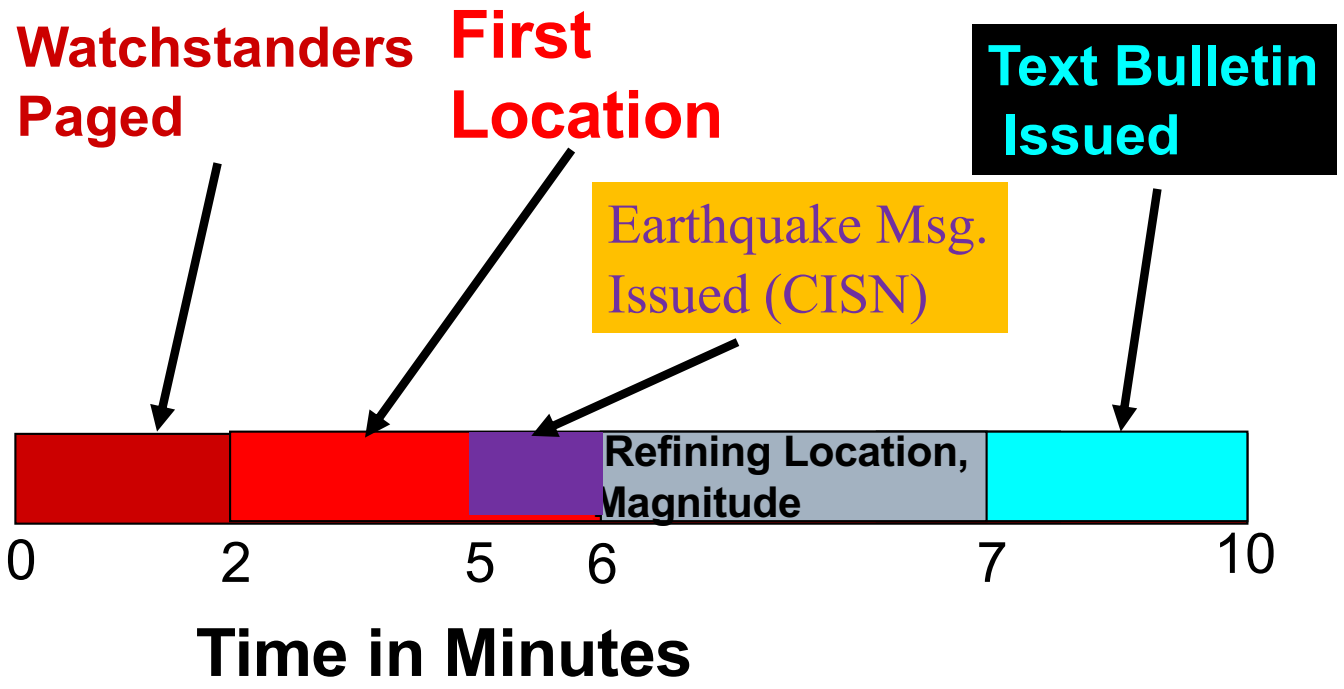
Earthquake Outside Hawaii Region

Timeline to Issue Initial Bulletin



Criteria Tables – PTWC for Puerto Rico and Caribbean

- Earthquake Criteria – Distant Event

Earthquake					
Sea	**Land**	**Depth**	**Magnitude**	**ETA**	**Product/Alert Level**
Yes	Yes	< 62 mi (100 km)	6.5 - 7.8	> 3 hr	TIS – No Threat
Yes	Yes	≥ 62 mi (100 km)	≥ 6.5	> 3 hr	TIS – No Threat
Yes	Near Sea	< 62 mi (100 km)	≥ 7.9	> 6 hr	TIS – Potential Threat
Yes	Near Sea	< 62 mi (100 km)	≥ 7.9	3 - 6 hr	Tsunami Watch

- Sea Level Criteria

Alert Level	Maximum Expected Rise of Sea Level above the Tide
None	0 to 1 ft (0 to 0.3 m)
Advisory	1 to 3.3 ft (0.3 to 1 m)
Warning	> 3.3 ft (> 1 m)

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CRITERIA TABLES – ACTIONS
(depends on PTWC Products - Location, Magnitude)

PTWC Product Type	PTWC EQ Magnitude	Country's Alert Level	Estimated Time of Wave Arrival (ETA) at Country's Coast	Emergency Response Action
THREAT MESSAGE	H > 1 m	WARNING	ETA < 3 hrs. (*)	EVACUATE TSUNAMI EVACTUATION ZONES
THREAT MESSAGE	H > 1 m	WATCH	3 (*) < ETA < 6 hrs.	Prepare to evacuate
INFORMATION STATEMENT	H > 1 m	INFORMATION	ETA > 6 hrs.	Monitor event alert EM stakeholders
INFORMATION STATEMENT	H < 1 m			NO ACTION
MESSAGE	H > 1 m at distant coastline	To be determined from a disaster tsunami threat: PTWC message number 1	ETA > 3 hrs. (*)	Monitor event, alert EM stakeholders

Flow Charts

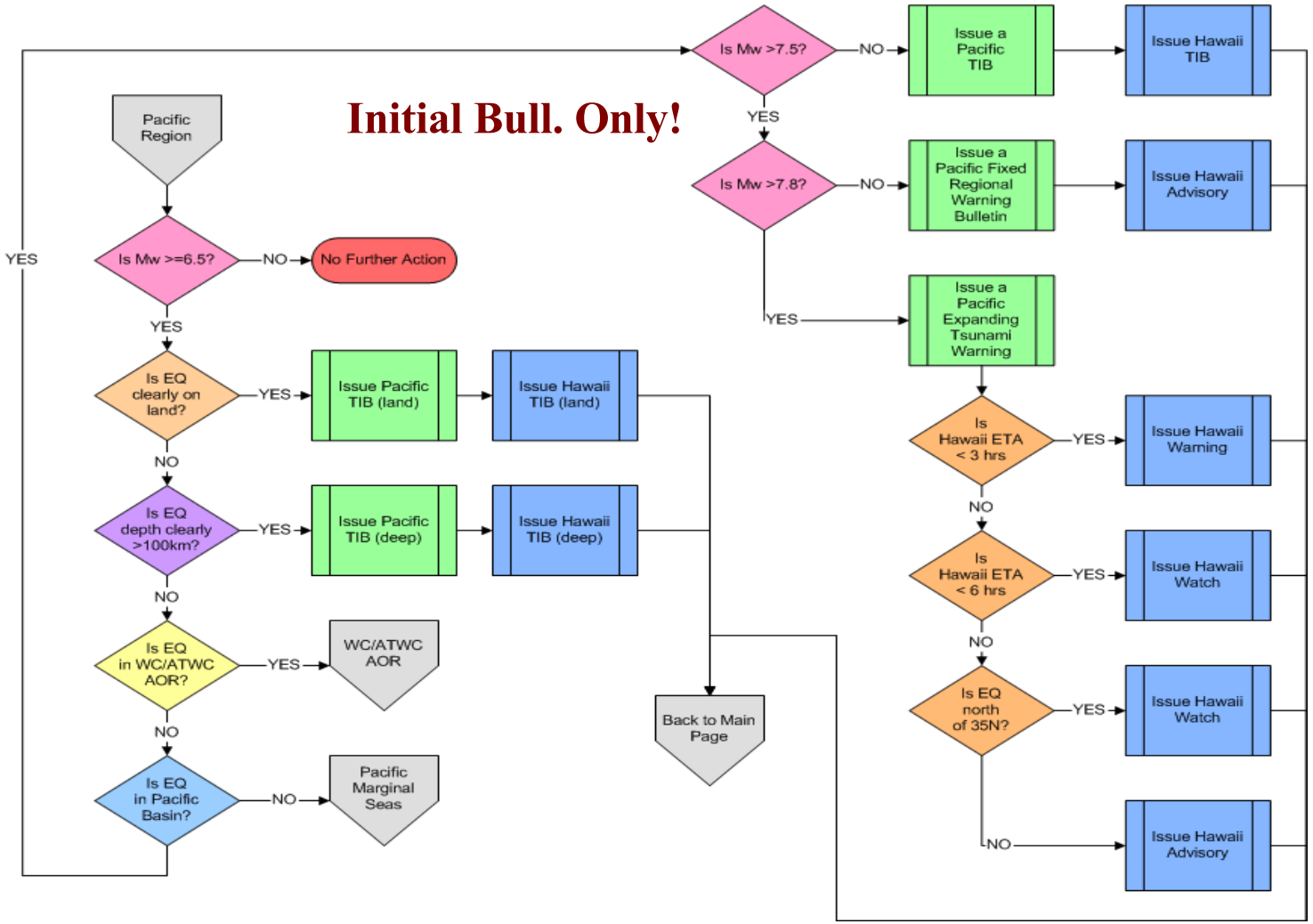
Effective Way of Presenting SOPs

Flow Charts Indicate:

- **Steps to be followed**
- **Decision Tree**
- **Systems or subsystems involved**

- **Flow Charts can be nested**
- **BUT, often not useful in real event (cannot give answer when there is uncertainty or data lacking) (experience is most important)**

PTWC SOP - Pacific Basin EQ



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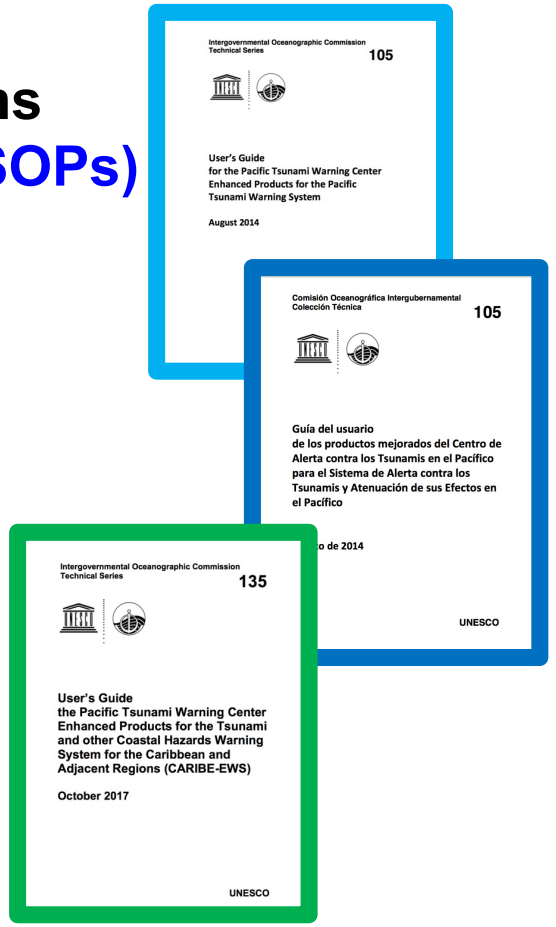
For TWC Customers – Users Guide

- System overview / history
- Arrangements / Organizations
- TWC Procedures / Criteria (SOPs)
- Products and their Meaning, includes Example Products
- Technical Background and Interpretation Guidance
  - *Tsunami science and hazard*
  - *EQ source characterization*
  - *Message interpretation for emergency response*
  - *Sea level measurement*
  - *Travel time calculation*
  - *Wave forecasting*
  - *Glossary*



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SUMMARY - MOVING FORWARD

- Develop SOPs
- Use SOPs (Real Event or Exercise)
- Did they work?

  If not, revise them IMMEDIATELY
- KEEP IT CLEAR, CONCISE, SIMPLE
- FOLLOW YOUR PROCEDURES
- It becomes your basis for action, and is defendable post-event

Thank You

Christa von Hillebrandt-Andrade
Deputy Director, ITIC