1.

# Procedures

## SOP Guidance

### SOPs For Each Event Type

There are separate SOPS for each type of event triggering activation of the JATWC, listed in Table 2.1.3 below. The SOPs follow in section 2.2. Further elaboration and guidance is incorporated in **Section 3 Referenced Concepts and Guidance**, and in the **Appendices**.

|  |  |  |  |
| --- | --- | --- | --- |
| **Event Type** | **Description** | **Summary of NP Response** | **SOPs to Use** |
| **GA Manual Solution** | GA Duty Seismologist presses the "Red Button" to send a "Manual Solution" for an undersea or coastal earthquake with magnitude of 6.5 or above – the criteria for an earthquake to be deemed "potentially tsunamigenic". Or GA Duty Seismologist sends a Manual Solution on request from NP. | Threat assessment, product issue and monitoring. | **2.2.1 Seismic - GA Manual Solution or International Bulletin** |
| **International Bulletin (no Manual Solution)** | NP receives an international tsunami statement/message from PTWC or bulletin from JMA, but no GA Manual Solution has been received. | Threat assessment, product issue and monitoring. | **2.2.1 Seismic - GA Manual Solution or International Bulletin** |
| **Felt Earthquake** | NP receives multiple reports of a "felt earthquake", either from GA, a State/Territory Office or directly from the public. | Issue National No Threat Bulletin – Felt Earthquake. | **2.2.2 Seismic – Felt Earthquake** |
| **Volcanic Activity** | NP receives advice from the Darwin VAAC of significant volcanic activity under the sea or at the coast. | Threat assessment, product issue and monitoring. | **2.2.3 Non-Seismic** |
| **Celestial Impact** | NP receives advice from the CCC of imminent or actual celestial impact. | Threat assessment, product issue and monitoring. | **2.2.3 Non-Seismic** |
| **Landslide** | NP receives advice of submarine or coastal landslide.  | Threat assessment, product issue and monitoring. | **2.2.3 Non-Seismic** |
| **Oceanic -Unknown Sea Level Change** | NP receives anecdotal advice of tsunami or notices unexplained sea-level changes. | Threat assessment, product issue and monitoring. | **2.2.3 Non-Seismic** |

**Table 2.1.3 SOPs by Event Type**

## SOPs

* + 1.

### Non-Seismic Events

|  |  |  |  |
| --- | --- | --- | --- |
| **Comms Officer** | **Tsunami Warning Lead** | **Science Officer** | **Type** |
| **PHASE 1 DETECT** |  |
| **1. INFORM TSUNAMI WARNING LEAD:**1.1 If a report has been received of a tsunami or unexplained sea-level change or of a volcanic event or landslide with the potential to cause a tsunami, inform **Tsunami Warning Lead**. Log the report (written or verbal) in a Cherwell ticket. 1.2 If NP staff noticed an unexplained sea-level change (e.g. during the daily monitoring of the ASLOS and tsunameter network), inform **Tsunami Warning Lead** and log the event in the Cherwell ticket. | **1. DISCUSS WITH GA, VACC, AND CCC:**1.1 Communicate with **GA Duty Seismologist** by videolink or phone to discuss the event and help determine the severity of the threat1.2 If the event is volcanic or of unknown source communicate with **Darwin VAAC** to discuss the event and help determine the severity of the threat 1.3 If the event is a celestial impact or of unknown source communicate with **CCC** by phone to discuss the event and help determine the severity of the threat1.4 Based on the reports received and/or the sea-level changes observed, in consultation with other agencies determine if bulletins should be issued for this event.Refer to **Section 3.1.2 Non-Seismic Events** for guidance.1.5 Commence **Event Log** (refer Appendix E Section 7) and ensure all key information and decision-making points are logged. If present, instruct the **Science Officer** to assist with updating the **Event Log**.   | **DEPUTISE FOR TSUNAMI WARNING LEAD IF ABSENT:**If the **Tsunami Warning Lead** is unavailable at the start of an event (e.g. on a meal break), the **Science Officer** should carry out **Tsunami Warning Lead** duties during **PHASE 1 DETECT** and **PHASE 2 INITIAL ASSESSMENT** until the **Tsunami Warning Lead** returns. | **N****O****N****S****E****I****S****M****I****C** |
| **2. FORWARD EVENT DETAILS TO STATES/TERRITORIES:**2.1 Using CMSS Prepared Message 156 compose a notice to the Regions informing them of the event, and including a copy of the written report if one was received. Send to States/Territories via address GSEI with priority A 2.2 Log the sent message.2.3 Acknowledgement of receipt of messages by State/Territory Offices is no longer required. It is the responsibility of the **Tsunami Warning Lead** to ensure appropriate HPR officers are aware of a tsunami threat to their regions. | **2. CHECK AGAINST EVENT SOURCE ZONE:**2.1Confirm the event is located within the ATWS area of service using the ATWS Source Zone map (Figure 1.5.1).2.2If event is within any of the source zones (Pacific, Indian Ocean, South Atlantic),continue to **PHASE 2 INITIAL ASSESSMENT**.2.3Otherwise, **take no further action.** Finalise **Event Log**. | **ASSIST WITH EVENT LOG:**As directed by the **Tsunami Warning Lead**, assist with updating the **Event Log**, recording all key information and decision-making points. |  |
| **PHASE 2 INITIAL ASSESSMENT** |  |
|  | **3.** **SELECT GUIDANCE:**3.1Start Decision Support Tool (DST) on Tsunami Warning Lead PC and choose **Manually Enter Event>Non Seismic**. Choose event type (Volcano, Landslide, Celestial Impact, or Unknown),fill in details including, severity, location, and time,and then Trigger TTT. Load the event from the **Non Seismic** event list after it has been processed by the TTT (~30 seconds). Refer to **Section 3.1.2 Non-Seismic Events** for guidance.3.2. If an event has occurred but a location is not known and observations have confirmed a tsunami has been generated, then use the lat/lon of the observation location and select Unknown (Location unknown) as the event type. |  | **N****O****N****S****E****I****S****M****I****C** |
|  | **4. IOTWMS THREAT ASSESSMENT AND INITIAL BULLETINS:**4.1 Perform IOTWMS Assessment and issue IOTWMS Threat Bulletin as soon as possible:* Issue an **IOTWMS No Threat Bulletin** if the assessment shows **no** Indian Ocean zones are above threat threshold. Then **issue no further IOTWMS bulletins unless the assessment changes.**
* Issue an **IOTWMS Potential Threat Bulletin** if the assessment shows **any** Indian Ocean coastal zones above threat threshold.
* After performing the ATWS assessment use the NTWC Status Reporting Form (located on the TSP Australia Password-Protected webpage) to report Australia's current warning status.

NOTE: If you suspect that any Australian locations may be under imminent threat then **carry out ATWS Steps 5-8 before performing IOTWMS Step 4.1** or have the **Science Officer** complete step 4.1 concurrently if available. |  | **N****O****N****S****E****I****S****M****I****C** |
|  | **5. ATWS ASSESSMENT:**5.1 Perform ATWS Assessment.NOTE 1: For non-seismic events the DST will always use the **TTT Threat Assessment** mechanism. Refer **to Sections 3.1.2 and 3.13** for guidanceNOTE 2: If any zones are shown as being at a lower threat level than both adjacent zones (e.g. Marine-No Threat-Marine), consider manually upgrading the threat levels of these "orphan" zones to that of the adjacent zones. Refer to **Section 3.9 Coastal Threat Adjustments** for more details. |  | **N****O****N****S****E****I****S****M****I****C** |
| **3. CHECK JATWC PRODUCTS AND WEBSITES:**3.1 For all ATWS products issued by the JATWC, check that the products have been delivered and have been updated on the JATWC Public webpage. | **6. BELOW THREAT LEVEL – ISSUE ATWS NO THREAT BULLETIN:**6.1 If **no** Australian zones are assessed at Marine Threat level or above:* Issue an **ATWS National No Threat Bulletin** within a target time of 30 minutes, then
* **Issue no further ATWS bulletins unless the threat assessment changes.**
* **Go to 9.2**
 |  | **N****O****N****S****E****I****S****M****I****C** |
|  | **7. ABOVE THREAT LEVEL - NOTIFY STATE/TERRITORY OFFICES:**7.1 If **any** Australian zones are assessed at Marine Threat:* Call the **HPR Leads** of the HPR teams responsible for those zones and invite them to join the tsunami video conference(refer Appendix E Section 4).
* Advise the **HPR Leads** of the following:
	+ An **ATWS National Watch Bulletin** affecting their State/Territory is about to be issued
	+ Event type and location
	+ Predicted threat levels (Marine or Land) for their State/Territory
	+ Predicted earliest wave arrival times for their State/Territory

NOTE 1: If waves are predicted to arrive in less than 105 minutes at any zones, call the responsible States/Territories for those areas first and let them know of the impending threat, then invite them to join the video conference before inviting other affected States/Territories.NOTE 2: If the only Australian zones above threat level are the Antarctic (Casey, Mawson, Davis) or Willis Island zones, an **ATWS National No Threat Bulletin** will be issued instead – advise the States/Territories accordingly. |  | **N****O****N****S****E****I****S****M****I****C** |
| **4. NOTIFY CCC AND SENIOR BUREAU MANAGERS:**4.1 If an **ATWS National Watch Bulletin** has been issued, notify CCC and key senior Bureau managers in accordance with the **JATWC Notification Protocol** (web link on JATWC Operations page). Inform them of the following:(a) That the JATWC has issued an **ATWS National Watch Bulletin** (or National No Threat Bulletin in the case of the Antarctic or Willis Island zones being the only zones above threat level) and:(b) Which Australian coastal zones are assessed as being above the threat threshold.Refer to **Appendix E Section 11** for further information on the JATWC Notification Protocol. | **8. ABOVE THREAT LEVEL – ISSUE ATWS NATIONAL WATCH BULLETIN:**8.1 If **any** Australian zones other than the **Antarctic (Casey, Mawson, Davis)** or **Willis Island** are assessed at Marine Threat, issue an **ATWS National Watch Bulletin** (target time: within 30 minutes of the event).8.2 **Tweet** the National Watch Bulletin (see Section 3.14 Tweeting of Tsunami Bulletins and Warnings).8.3If the **only** Australian zones assessed at Marine Threat or above are the **Antarctic (Casey, Mawson, Davis)** or **Willis Island**, issue an **ATWS National No Threat Bulletin** instead of a National Watch.NOTE: Although Willis Island’s threat level is assessed by the DST and shown on the DST assessment map, Willis Island is not listed in any ATWS Watches or Warnings because it is staffed only by Bureau officers. If Willis Island is assessed as above threshold, notify Queensland State/Territory. |  | **N****O****N****S****E****I****S****M****I****C** |
|  | **9. JATWC ACTIVATION DECISION:**9.1 If an ATWS National Watch Bulletin has been issued, or an ATWS National No Threat Bulletin has been issued but Antarctic or Macquarie Island zones are above threat level, proceed to **PHASE 3 ACTIVATE** of the **Section 2.2.1 Seismic – GA Manual Solution or International Bulletin SOPs.**9.2 Otherwise **no further action is required**. Finalise **Event Log**. |  | **N****O****N****S****E****I****S****M****I****C** |

# Referenced concepts and guidance

This Section presents concepts and guidance that are not unique to a given phase (particularly where they are relevant to multiple phases) or that require significant explanation (hence would have added complexity to the core procedures themselves).

The following concepts and guidance are generally presented in order of referencing within the procedures. Hence the order aligns to the phase in which it is first relevant to the overall tsunami warning process.

## Tsunamigenic Events and the Activation of JATWC

Events which potentially cause a tsunami are categorised as seismic (undersea earthquakes) and non-seismic. More specifically, non-seismic tsunamigenic events are volcanic events, undersea landslides, and celestial impacts. These events result in different types of information which trigger the JATWC into operational status. These triggers are discussed below. It is JATWC procedure that the JATWC Tsunami Decision Support Tool (DST) is used for threat assessment.

### Seismic Events

Geoscience Australia (GA) will trigger the JATWC into activation of a threat assessment by issuing a Manual Solution. If PTWC tsunami statements/messages are received before the GA Manual Solution is received, then cross-check with GA. GA will usually issue a Manual Solution based on PTWC data if the GA system is unable to create one.

If GA is unable for technical reasons to generate a manual seismic solution then manually enter the event details provided by GA using the DST's BOM manual entry capability. If contact with GA cannot be established but PTWC has issued a tsunami statement/message, then JATWC shall undertake the threat assessment based on the PTWC data and issue appropriate JATWC bulletins. If GA does not estimate that the earthquake meets their criteria for a manual solution, but PTWC does issue a tsunami Information Statement (for Pacific no threat events) or Threat Message (for Pacific threat events), then JATWC must issue a No Threat bulletin – in that case request GA to issue a Manual Solution. For a "Felt Earthquake" situation request GA to issue a Manual Solution and issue a No Threat – Felt Earthquake bulletin.

The DST assesses tsunami threat based on MOST T2 model scenarios except where the earthquake is too distant from the nearest scenario – in that case the DST uses the TTT Threat Assessment method. Table 3.1.1 below shows the likely threatened regions for various seismic sources and is only intended as an overview.

| **Magnitude (Mwp)**(if < 100km deep) | **Indicative Threat Potential** | **Potential Earthquake Sources and Affected Australian Territory** |
| --- | --- | --- |
| 6.5 to 7.5 | Potential for a *Locally* destructive tsunami (< 100km) | **Sunda Trench:** Christmas, Cocos Is **Timor Trench:** NW Reefs **Hjort Trench:** Macquarie Is |
| 7.6 to 7.8 | Potential for a *Regionally* destructive tsunami (< 1000km) | **Sunda Trench:** Christmas/Cocos Is, NW WA **Timor Trench/Banda Sea:** NW reefs/ NT/ NW WA **San Cristobal/New Hebrides Trench:** Willis Is**South New Hebrides Trench:** Norfolk Is & Lord Howe Is **Kermadec Trench:** Norfolk Is/NZ**Puysegur Trench/Fjordlands:** Macquarie Is, SE Australia **Hjort Trench:** Macquarie Is. |
| 7.9 and above | Potential for an *Ocean Wide* destructive tsunami | **Sunda Trench & Other Indian Ocean Trenches**: WA/NT then rest of Australia (including Heard Is, Mawson, Davis & Casey)**Timor Trench/Banda Sea:** NW Reefs/NT/NW WA then rest of Australia**South Solomon/San Cristobal/New Hebrides/South New Hebrides /Tonga/Kermadec Trenches:** Willis, Qld/ Norfolk, Lord Howe, NSW then rest of Australia**Puysegur/Fjordlands & Hjort Trenches:** SE Australia, Macquarie Is (Tas/Vic/NSW less than 2 hours) then the rest of Australia**Chile & Other Pacific Ocean Trenches:** Macquarie /Norfolk Is then rest (including Casey, Davis, Mawson) |

**Table 3.1.1 Indicative Threat Potential to Australia and Territories**

### Non-Seismic Events

Tsunamis are predominantly caused by undersea earthquakes (~85%). However, landslides (~5-10%), and volcanic eruptions (~5%) are also significant causes of tsunamis. In this section processes are given for (A) Volcanic Tsunamis, (B) Celestial Impact Tsunamis, (C) Submarine or Coastal Landslide Tsunamis, and (D) Unknown-Cause Tsunamis. Table 3.1.2 below gives some guidance as to the tsunamigenic potential and affected Australian territories due to potential non-seismic sources in the Australian region.

Unlike tsunamis generated from subductive undersea earthquakes, which can be well modelled from seismic observations combined with a knowledge of the underlying seismicity, it is not yet possible to accurately model non-seismic tsunamis in a similar manner. If a tsunami source location can be identified the tsunami threat assessment will use the TTT Threat Assessment method and severity levels detailed in **Section 3.13 Events without a corresponding MOST scenario**. Otherwise the service will rely on sea level observations or coastal impacts being reported to the JATWC. It is possible in this circumstance that the first warnings will be issued after communities on the Australian coast have been impacted. Therefore, the JATWC will not always be able to provide early warning for tsunami generated from non-seismic sources.

In all cases the JATWC should continue to monitor nearby gauges and DARTs for a minimum of the expected arrival time + 2h at the closest 2 locations.

| **Indicative Threat Potential** | **Potential Sources and Affected Australian Territory** |
| --- | --- |
| Potential for a *Locally* destructive tsunami (< 100km) | **Volcano Eastern Indonesian region\*:** Christmas Is**Landslide - Australian Continental shelf or local coastal Landslide:** Any Australian locations (limited area) **Celestial Object (radius ~10 – 30 m) impacting near Australian coast:** Any Australian locations (limited area) |
| Potential for a *Regionally* destructive tsunami (< 1000km) | **Volcano Eastern Indonesian region\*:** Christmas/Cocos Is, NT**Volcano Papua New Guinea region\*:** Willis Is, QLD**Volcano Kermadec Island region:** Norfolk/Lord Howe Is, TAS**Volcano South Fiji Basin region:** Norfolk Is**Landslide - Australian Continental shelf, Major coastal landslide (Australia and neighbouring countries):** Any Australian locations (moderate area)**Celestial Object (radius ~30 – 60 m) impacting in Australian waters:** Any Australian locations (moderate area) |
| Potential for an *Ocean Wide* destructive tsunami | **Volcano Eastern Indonesian region\*:** Christmas/Cocos Is, WA**Volcano Papua New Guinea region\*:** Willis Island/Norfolk/Lord Howe, NT, QLD**Volcano Kermadec Island region:** Norfolk/Lord Howe Is, NSW, QLD, VIC, TAS**Volcano Tonga-Samoa volcanic arc:** Norfolk/Lord Howe Is, NSW, QLD**Volcano South Fiji Basin region:** Norfolk/Lord Howe Is, NSW, QLD**Volcano Heard and McDonald Islands:** Antarctic Stations, WA**Volcano Antarctica region:** Antarctic Stations, Macquarie Island**Landslide – Catastrophic land collapse into the Indian or Pacific Oceans:** Any Australian locations (wide spread area)**Celestial Object (radius 60+ m) impacting in the Indian or Pacific Oceans:** Any Australian locations (wide spread area) |

**Table 3.1.2 Indicative Threat Potential to Australia and Territories**

Volcanoes marked with (\*) are routinely monitored by Darwin VAAC.

#### (A) ***Volcanic Tsunamis***

A volcanic eruption could potentially cause a tsunami by volcanic explosion, caldera collapse, flank collapse, and/or pyroclastic flows. Although a larger eruption generally increases the risk of a larger tsunami, there are many factors that may complicate this relationship. The Darwin VAAC's primary means of monitoring volcanic activity is from detection of a volcanic ash plume from satellite observations. Darwin VAAC can provide information about the height and coverage of the plume, which is linked to the size of the eruption. While clouds can obscure volcanic ash, large eruptions (VEI > 4) will extend into the stratosphere and will be visible above the clouds (see Table 3.1.3). However, the Darwin VAAC does not have complete ground coverage to monitor for other features of a volcanic eruption that may cause a tsunami and these may occur from smaller eruptions. Additionally, undersea volcanic eruptions may cause tsunamis but may not be detected.



**Table 3.1.3 Summary of Volcanic Explosivity Index (VEI)**

The Darwin VAAC is responsible for identifying potentially tsunamagenic volcanic eruptions and then informing the JATWC. However, in the event of a large eruption (VEI > 4) in the Darwin VAAC area of responsibility the Darwin VAAC's primary focus will be on issuing volcanic ash advisories. For all high impact eruptions, both the Tsunami Warning Lead and VAAC duty officer should independently check the list of potentially tsunamigenic volcanoes listed in Appendix L. The Tsunami Warning Lead should seek advice from the Darwin VAAC as to the extent of stratospheric injection and if there are any ground observations. Then do one of the following:

(1) *Issue no products and monitor for any potential tsunami*: This action should be taken if there is little to no stratospheric injection and there is no evidence a tsunami has been generated.

(2) *Create the event in the DST with a Severity of 1 hour*: This action should be taken if there is little to no stratospheric injection and there is evidence that a small tsunami has been generated and the impacts are consistent with a low-level Marine Threat.

(3) *Create the event in the DST with a Severity of 3 hours*: This action should be taken if there is obvious stratospheric injection consistent with a VEI of 4 and/or there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a high-level Marine Threat or low-level Land Threat.

(4) *Create the event in the DST with a Severity of 6 hours*: This action should be taken if there is significant stratospheric injection consistent with a VEI of 5+ and/or there are reliable observations or reports that indicate a catastrophic tsunami has been generated.

#### (B) ***Celestial Impact Tsunamis***

There are no recorded tsunamis from celestial impacts in the NGDC database that dates back to 2000 BC. However, impacts from objects of 200m radius have an approximately 100,000-year recurrence rate with smaller objects more common. The location of the majority of large objects is well known and the size of the object and location of the impact may be known well in advance. However, this is not necessarily the case.

The energy in large impactor is roughly equivalent to the energy released by a large earthquake; see Table 3.1.4 for some approximate equivalents. However, the impactor will lose kinetic energy as it passes through the atmosphere and may break up depending on its size and composition. If it impacts the ocean, the initial wave height may be extremely high but will attenuate more rapidly than an earthquake-generated wave would. Additionally, because it has a shorter wavelength less shoaling would be expected.

|  |  |
| --- | --- |
| Approximate impactor radius | Approximate equivalent earthquake magnitude |
| 10m | M6.5 |
| 20m | M7.0 |
| 30m | M7.5 |
| 60m | M8.0 |
| 110m | M8.5 |
| 200m | M9.0 |

**Table 3.1.4 Earthquake and Impactor Energy comparison**

The CCC is the most likely source of notification for an imminent or actual celestial impact. Notification would be in the form of a CCC briefing email. This may contain the location, time of impact, and the size of the impactor. For any large celestial body that is about to or has just impacted in the ocean, JATWC should be activated. In consultation with the CCC and GA, the Tsunami Warning Lead should do one of the following:

(1) *Create the event in the DST with a Severity of 3 hours*: This action should be taken if the celestial body is known to have a radius of between 10 and 60m and/or there are reliable observations or reports that indicate a tsunami has been generated.

(2) *Create the event in the DST with a Severity of 6 hours*: This action should be taken if the celestial body is known to have a radius of greater than 60m or the radius in unknown, and/or there are reliable observations or reports that indicate a catastrophic tsunami has been generated.

#### (C) ***Submarine or Coastal Landslide Tsunamis***

A tsunami may be generated by a landslide originating on the coast into the ocean or from a landslide on the ocean floor. Landslides can occur from a structural instability such as the accumulation of sediment or may be triggered by an earthquake or volcanic eruption. In either case it is unlikely that a tsunami will be noticed immediately. The main area of risk for Australia is a landslide on the continental shelf, which could cause a local tsunami with little to no warning.

There is no authority that will advise the JATWC if a landslide has occurred. It is most likely, except in the most extreme circumstances, that a landslide event will be treated as an unknown-cause tsunami until the source can be identified. However, the CCC and GA should be contacted if the Bureau becomes aware of an event. If a landslide is identified then the Tsunami Warning Lead should do one of the following:

(1) *Create the event in the DST with a Severity of 1 hour*: This action should be taken if there are reliable observations or reports that indicate a small tsunami has been generated.

(2) *Create the event in the DST with a Severity of 3 hours*: This action should be taken if there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a low-level Marine Threat.

(3) *Create the event in the DST with a Severity of 6 hours*: This action should be taken if there are reliable observations or reports that indicate a catastrophic tsunami has been generated and the impacts are consistent with a high-level Marine Threat or low-level Land Threat.

In the event of a landslide triggered from a volcano or an earthquake, the warnings are covered by the procedures for those events, but higher than usual sea level observations may result, leading to an upgrade of the tsunami warning.

#### (D) ***Unknown-Cause Tsunamis***

#### The JATWC can be activated from observations of tsunami waves at sea level gauges (coastal gauges or tsunameter buoys) without any known source event.

Preliminary assessment should consider the quality of the reported data. All operational tsunameter and coastal stations can be used to trigger JATWC activation.

The JATWC can also be activated from anecdotal reports of a tsunami, or tsunami impacts in coastal areas, without any known source event. A general assessment is made based on:

**Certainty:** Largely driven by the credibility of reports. Reports from authoritative sources and those reports that have been corroborated should be viewed as having higher credibility than “someone saw something”.

**Impact:** A report of land inundation and significant damage should be treated with higher attention than marine effects.

**Urgency:** If the reports are of impacts distant to Australia and territories, there is some time available to seek confirmation from other sources (anecdotal or direct sea-level observations from coastal stations and tsunameter stations).

Once the JATWC has been activated for a credible tsunami with no known source, GA, the Darwin VAAC, and the CCC should be contacted to try and find a possible cause for the tsunami. At the same time the Tsunami Warning Lead, treating the observation location as the source location and the observation time as the event time, should do one of the following:

(1) *Create the event in the DST with a Severity of 1 hour*: This action should be taken if there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a low-level Marine Threat

(2) *Create the event in the DST with a Severity of 3 hours*: This action should be taken if there are reliable observations or reports that indicate a tsunami has been generated and the impacts are consistent with a high-level Marine Threat or low-level Land Threat.

(3) *Create the event in the DST with a Severity of 6 hours*: This action should be taken if there are reliable observations or reports that indicate a catastrophic tsunami has been generated.

If subsequent observations are detected that are not consistent with the travel times to sea level stations then open another instance of the DST, create a new event (using the location and time of the new observation), and perform an ATWS threat assessment. Then using the instance of the DST that has the original event, manually upgrade any zones that are assessed at an increased threat level in the new event. While the source location is unknown the arrival times listed for any zone under threat will be the same as the observation time (i.e. any time from now).

If during the event a source can be identified, or the location can be triangulated, then the origin location, origin time, and source type if known should be entered into the DST. If any warning had been issued then new warnings with the updated source information should be issued. The new warnings should contain a manually entered line linking them to the previous warnings. Any observations or Impact reports will need to be re-entered into the DST as it will treat it as a "new event".

* 1.

## Tsunami Coastal Observations Greater Than Predicted

Whilst every effort has been made to model tsunami threats as accurately as possible, there are still circumstances under which observed tsunami waves may be higher than those predicted. Additionally, it can be difficult to judge what anecdotal tsunami wave observations correspond to a marine or land warning within a coastal forecast zone. However, in the cases where reliable observations (e.g. from reliable tide gauges) have been received of waves that are greater than predicted, please do the following:

ATWS:

If tsunami waves corresponding to a **Marine Threat** have been observed in a zone that was assessed as **No Threat,** then that zone should be manually upgraded to **Marine Threat** and a new ATWS warning should be issued immediately for the affected State/Territory, in consultation with the relevant State/Territory Office.

If tsunami waves corresponding to a **Land Threat** have been observed in a zone that was assessed as **No Threat** or as **Marine Threat,** then that zone should be manually upgraded to **Land Threat** and a new ATWS warning should be issued immediately for the affected State/Territory, in consultation with the relevant State/Territory Office.

IOTWMS:

If tsunami waves corresponding to an **IOTWMS Threat-Level** have been observed (i.e. above 50cm wave amplitude at a tide gauge) in a zone that was assessed as **No Threat** then a new IOTWMS bulletin containing that observation should be issued immediately.

## Tsunami Threat Cancellation

Tsunami threat cancellation can occur based on changed input data, usually a downgrade of GA earthquake magnitude, or through consideration of observations. In terms of observations, two cancellation situations exist, and each should be based on observations from at least two sea-level sites which were expected to be significantly affected, taking into account the MOST guidance.

### Cancelling a Watch/Warning when no tsunami at or above Marine Threat level

The first situation is when a Watch or Warning has been issued, but observations subsequently confirm that no tsunami was generated, or that a tsunami was generated but it was below the marine threshold and therefore of no threat:

* If no wave was observed at the expected time, cancellation needs to be based on assurance that no wave eventuated (‘absence of evidence is not evidence of absence’). This is done by allowing for inaccuracy in estimated travel time. Accordingly, if no tsunami waves above the threat threshold are observed for 2 hours past the predicted TTT arrival times for at least two tsunameters or coastal sea-level stations, it can be inferred that no above-threshold tsunami was generated and cancellation can be considered. It is important to recognise that the TTT times are rounded down to the nearest 15 minutes.
* If a wave was observed at a tsunameter buoy, use the procedure in Appendix F to scale the observed tsunami waves as a guide to cancellation

### Cancelling a Warning after a Marine or Land Threat is over

The second situation is where a tsunami was observed and it impacted the land and/or marine environment, but the threat has now reduced below marine threat levels.

* Tsunamis arrive in a series of waves. The estimated time of arrival of the last wave above the marine threat threshold should be used as a decision point. A ‘tolerance’ time can be applied from the actual impact time of the last wave above the marine threat threshold, based on quantitative sea-level observations or reliable qualitative impact reports.
* The ‘tolerance’ time is defined in Table 3.11.1. Local effects such as seiches and coastal convergence can cause extended periods of even larger waves and these should be considered and discussed with the emergency management authorities prior to issuing Tsunami Threat Cancellations.

|  |  |  |
| --- | --- | --- |
| Severity (non-seismic events) | Magnitude | Tolerance time in hours |
| ≥ 6 | > 8.5 | 6 |
| 3 | 7.5 – 8.5 | 4 |
| 1 | < 7.5 | 2 |

**Table 3.11.1 Cancellation tolerance time in hours - time since last tsunameter/ASLOS quantitative observation, or reliable qualitative impact report, above Marine Threat level**

Upon cancellation of a confirmed tsunami, States/Territories should include a statement in their *next two* public weather and coastal waters forecasts. The statement should read:

*“A tsunami warning for [state] has been cancelled. Unusual tides and currents may persist for many hours.”*

##

## Earthquake Events without a Corresponding MOST Scenario

All potentially tsunamigenic earthquakes that have no corresponding MOST scenario, and potentially tsunamigenic non-seismic events (i.e. volcanic, celestial impact, landslide, unknown), will be assessed by the DST using the TTT Threat Assessment method.

**For Earthquakes**:

Earthquakes deeper than 100km are not considered tsunamigenic and only a National No Threat Bulletin is to be issued without need for further assessment.

Earthquakes are considered to have no corresponding MOST scenario if the distance between the observed epicentre and the nearest scenario is GREATER THAN the following limits:

Mwp <= 7.7: 200 km

7.8 <= Mwp <= 8.2: 300 km

8.3 <= Mwp <= 8.7: 400 km

>= 8.8 500 km

If the earthquake is outside the above limits the DST will report **"TTT Threat Assessment Being Used"** on the Assessment tab when the event is loaded, rather than reporting the MOST scenario number being used. In that case advise the **GA Duty Seismologist** that the event is too distant from a scenario for a MOST-based threat assessment, and that an assessment based on tsunami travel time and earthquake magnitude is being used instead, for all ATWS and IOTWMS products issued.

The **TTT** **Threat Assessment** mechanism assesses zones as under **Marine Threat** based on the following criteria:

|  |  |
| --- | --- |
| **Mag** | **Action** |
| 6.5 to 7.5 | The threat area is defined to be within the 1 hour travel time isochrone |
| 7.6 to 7.8 | The threat area is defined to be within the 3 hour travel time isochrone |
| 7.9 and above | The threat area is defined to be within the 6 hour travel time isochrone |

If sea level data indicates a land inundation threat is possible, upgrade the warnings to Land Threat for areas in a direct beaming direction based on the orthogonal direction to the fault.

**For Non-Seismic Events**:

As the potential tsunami risk and severity from non-seismic events are very difficult to determine in near real time, the **TTT Threat Assessment** method is also used for these events. As a general guide, the following levels of threat severity should be used to assess zones as under threat:

|  |  |
| --- | --- |
| **Severity** | **Action** |
| Level 1 | The threat area is defined to be within the 1 hour travel time isochrone |
| Level 3 | The threat area is defined to be within the 3 hour travel time isochrone |
| Level 6 | The expanding threat area is defined by the elapsed time since event + 6 hour travel time isochrone |

**Section 3.1.2 Non-Seismic Events** gives guidance for the choice of severity level for each type of event. Performing an ATWS Threat Assessment will place all zones that have a significant location within the travel time isochrones under **Marine Threat**. If there is a major event that warrants using a severity level of 6 hours then warning area should be expanded by 1 hour each hour until observations indicate that coastal impacts are below **Marine Threat** level at the leading edge of the tsunami. To do this the 'Severity' field on the assessment tab should be manually increased by 1 each hour into the event and a new ATWS threat assessment performed. Existing threat areas should then be maintained until they meet the criteria for cancellation detailed in **Section 3.11 Tsunami Threat Cancellation**.

The Tsunami Warning Lead and Science Officer should be constantly assessing observations and reports to determine if any zones should be upgraded to **Land Threat**. In general this will be a highly subjective process. However, if higher than expected impacts are observed for Australian locations there are clear procedures given in **Section 3.10 Tsunami Coastal Impacts Greater Than Predicted**. Furthermore, for celestial impacts, at a bare minimum, zones within 1 hour for a severity level 3 event and zones within 3 hours for a severity level 6 event should be upgraded to **Land Threat**.

Notes on Non-Seismic Event Threat Levels:

1. The scaling of threat levels based on tsunameter data, as detailed in Appendix F is **NOT** appropriate if the **TTT Threat Assessment** mechanism is being used. Instead, if the **Tsunami Warning Lead** believes that, based on sea level observations, there is a reasonable chance that an Australian coastal zone will be under **Land Threat** then it should be manually upgraded to **Land Threat**.
2. The travel times calculated by the TTT assume the wave speed is limited by the water depth and this assumption is only accurate if the wavelength is very large. Tsunamis generated by non-seismic sources may not have a large enough wavelength for this for this assumption to be accurate and therefore may travel slower than predicted, particularly in very deep water.
3. If a re-assessment is performed when expanding the threat area by 1 hour, any zones previously manually upgraded to **Land Threat** will revert to **Marine Threat** and will need to manually upgraded again. Zones with an evacuation order will persist after a re-assessment.

Due to the extra level of uncertainty relating to non-seismic events, sea level observations should be monitored for at least 2 hours past the expected arrival time at the first observation location for confirmation of a tsunami.

# APPENDIX L: List of KNOWN Potentially Tsunamigenic Volcanoes

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Volcano** | **Region** | **Latitude** | **Longitude** | **Date** | **Fatalities** | **% attributed to tsunami** | **Notes** | **Reference** |
| Awu | Sangihe | 3.67 N | 125.50 E | 2 Mar. 1856 | 2806 | ? |   | 2 |
| 18 Nov. 1892 | 1532 | ? |   | 2 |
| Banda Api | Banda Sea | 4.525 S | 129.871 E |   |   |   | tsunamigenic potential | 2 |
| Banua Wuhu | Sangihe | 3.138 N | 125.491 E | 1889, 1918 |   |   | submarine volcano | 2 |
| Emperor of China | Banda Sea | 6.62 S | 124.22 E |   |   |   | submarine volcano, tsunamigenic potential | 2 |
| Gamalama (Ternate) | Halmahera | 0.80 N | 127.325 E | 1 Sept. 1763 |   |   | 9m tsunami observed | 2 |
| Gamkonora | Halmahera | 1.375 N | 127.52 E | 20 May 1673 | Many | 100 | Tsunami inundated villages | 3 |
| Iliwerung | Lesser Sunda Is. | 8.540 S | 123.590 E | 1973 | 2 | 100 | Tsunami from submarine eruptions (Hobal vent) and landslide; tsunami 9m amsl | 3 |
| 1979 | 539 | 100 |
| 1983 | ? | 100? |
| Jolo (Bud Dajo) | Philippines | 5.95 N | 121.07 E | 1897 |   |   | possible submarine eruption | 3 |
| Kavachi | Solomon Islands | 9.02 S | 157.95 E |   |   |   | active submarine volcano, tsunamigenic potential | 3 |
| Krakatau | Sunda Strait | 6.102 S  | 105.423 E | 27 Aug. 1883  | 36,417 | <95 | Tsunami to 40 m a.m.s.l.; 6m tsunami on NW Australian coast | 1, 3 |
| Long Island | NE of PNG | 5.358 S | 147.12 E | Circa 1660 | 2,000? | 5? | Pyroclastic flows, tsunami. | 3 |
| Nieuwerkerk | Banda Sea | 6.60 S | 124.675 E |   |   |   | submarine volcano, tsunamigenic potential | 2 |
| Paluweh (Rokatenda) | Lesser Sunda Is. | 8.32 S | 121.708 E | 4 Aug.1928 | 226 | 30 | 5-10 metre tsunami generated by landslides during eruption. | 3 |
| Rabaul | New Britain, PNG | 4.271 S | 152.203 E | 29-May-37 | 507 | 5? | Most killed by pyroclastic flows | 3 |
| Ritter Island | NE of PNG | 5.52 S | 148.121 E | 13 Mar. 1888 | 3,000? | 100 | Tsunami 12-15 m a.m.s.l. | 3 |
| Ruang | Sangihe | 2.28 N | 125.425 E | 3 Mar. 1871 | 400 | 100 | Killed on neighbouring Tagulandung island by tsunami | 3 |
| Taal\* | Philippines | 14.002 N | 120.993 E |   |   |   | tsunamigenic potential | 2 |
| Tambora | Lesser Sunda Is. | 8.25 S | 118.00 E | 1815 | 10,000 | 10? | 82,000 also killed from starvation | 3 |
| Teon | Banda Sea | 6.92 S | 129.125 E | 1659 |   |   |   | 2 |
| Tidore | Halmahera | 0.65 N | 127.40 E | 1608 |   |   |   | 2 |
| Yersey | Banda Sea | 7.53 S | 123.95 E |   |   |   | submarine volcano, tsunamigenic potential | 2 |
| Submarine volcanoes in the following regions have been identified as having potential to cause tsunami in Australia: |   | 4 |
| Eastern Indonesia (including Krakatoa)  |  |  |  |  |  |  |   |
| Papua New Guinea (New Britain - New Ireland) |   |   |   |   |   |   |
| Kermadec Is region\* |  |  |  |  |  |  |  |   |
| Tonga-Samoa volcanic arc\* |   |   |   |   |   |   |   |
| South Fiji Basin region\* |  |  |  |  |  |  |  |   |
|   |   |   |   |   |   |   |   |   |
| \* indicates outside Darwin VAAC area of responsibility |   |   |   |   |   |   |
| [1] Geoscience Australia Tsunami fact sheet: http://www.ga.gov.au/urban/factsheets/tsunami.jsp |   |   |   |
| [2] J. Rynn, 2002, *A preliminary assessment of tsunami hazard and risk in the Indonesian Region*, Science of Tsunami Hazards, 193-205  |   |
| [3] Summarised from Simkin & Siebert, Volcanoes of the World (1994). |   |   |   |   |   |
| [4] Rynn. J. and Davidson, J.. 1999, *Contemporary Assessment of Tsunami Risk and Implications for Early Warning for Australia and Its Island Territories*, Science of Tsunami Hazards, 107-125 |   |