Research on
Navigation Safety Measures
in the Event of
Major Earthquake/Tsunami Strikes

Final Report (Excerpt)

February, 2015

The Japan Association of Marine Safety
Japan Maritime Center

Preface

This report was prepared for foreign seafarers by the Japan Association of Marine Safety in collaboration with Japan Maritime Center as an English version excerpted from "Research on Navigation Safety Measures in the Event of Major Earthquake/Tsunami Strikes," published in FY2012 to FY2013 after the joint research project: the Marine Accident Prevention Project.

This report is consisted of three key chapters entitled "Guidance for Tsunami Safety Measures in a port", "Safety/Disaster Prevention Measures for Large Vessels Carrying Dangerous Cargo", and "Conclusion".

Note that descriptions concerning small boats or pleasure boats, which are not necessary for foreign seafarers, were skipped.

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I. Guidance for Tsunami Safety Measures in a port

Chapter 1. Purpose of the Guidance for Tsunami Safety Measures in a port

1. Purpose of the Guidance

The purpose of the Guidance is to promote the preparation of tsunami measures for individual ports or port areas by providing basic ideas for tsunami measures that vessels should take for the safety of vessel traffic in port areas, as well as by presenting points to be considered in preparing tsunami measures.

"Research Report on the Preservation of Vessel Safety under a Tsunami Alert" (FY2003) summarized tsunami's characteristics and impacts on vessels and presented guidance concerning important points to be considered in preparing tsunami measures in port areas with a view to promoting deliberation on such measures.

This guidance has been prepared by reviewing the conventional guidance, based on the lessons of the Great East Japan Earthquake that occurred on March 11, 2011, as well as the results of the discussions of the Committee for the Navigation Safety Measures on the Occasion of Tsunami held in FY2012 and FY2013.

2. Needs for Tsunami Safety Measures

It is necessary for individual ports (or regions) to have specific tsunami measures in advance, since little time is allowed from the occurrence of an earthquake to the arrival of a tsunami. In addition, tsunami behaviors and impacts on vessels vary according to the port-specific conditions such as geographical conditions and usage.

It is generally very difficult to prevent tsunami damage unless prompt decisions are made and swift actions are taken, since little time is allowed before tsunami arrival once a tsunami-accompanied earthquake occurs. Therefore, it is necessary to fully study in advance the actions vessels should take as well as Tsunami Safety Measures in a Port (hereinafter referred to as "Tsunami Safety Measures").

Chapter 2. Establishing Tsunami Safety Measures

1. Studies on Tsunami Safety Measures

1-1. Conference for Establishing Tsunami Safety Measures

In preparing and implementing Tsunami Safety Measures, individual relevant organizations should be assigned with clearly-defined roles and implement such measures in a concerted way. Therefore, those organizations should have meetings, discussions and mutual consultations on a regular basis to promote understanding on the measures and to ensure their smooth execution.

In order to establish port/region-specific tsunami measures based on an understanding of detailed conditions of the port or region, cooperation among different relevant organizations is indispensable. Furthermore, in some cases, tsunami arrives in a short time from the occurrence of an earthquake, so it is important for relevant organizations to discuss and agree how to respond in the case of tsunami in advance. Unfortunately, in the Great East Japan Earthquake disaster, there were many cases where the relevant organizations had difficulty in taking action as they could not communicate with each other due to a power outage and communication failure. Those cases serve as lessons in the importance of establishing mutual agreements on Tsunami Safety Measures.

To this end, it is necessary to ensure discussion and coordinated consideration on issues concerning tsunami measures on a regular basis at conferences (Tsunami Safety Measures Conference) to ensure compliance with tsunami measures and the smooth execution of those steps. In addition, regular tsunami drills should be conducted.

1-2. Consistency in Regional Disaster Prevention Plans

(Skipped)

1-3. Preparation Procedures for Tsunami Safety Measures

As for the preparation of port/region-specific tsunami measures, each specific measures must be established based on the understanding of region-specific tsunami characteristics and their impacts on vessels.

Below are the standard procedures for establishing Tsunami Safety Measures at the Tsunami Safety Measures Conference, etc.

Study Flow of Tsunami Safety Measures

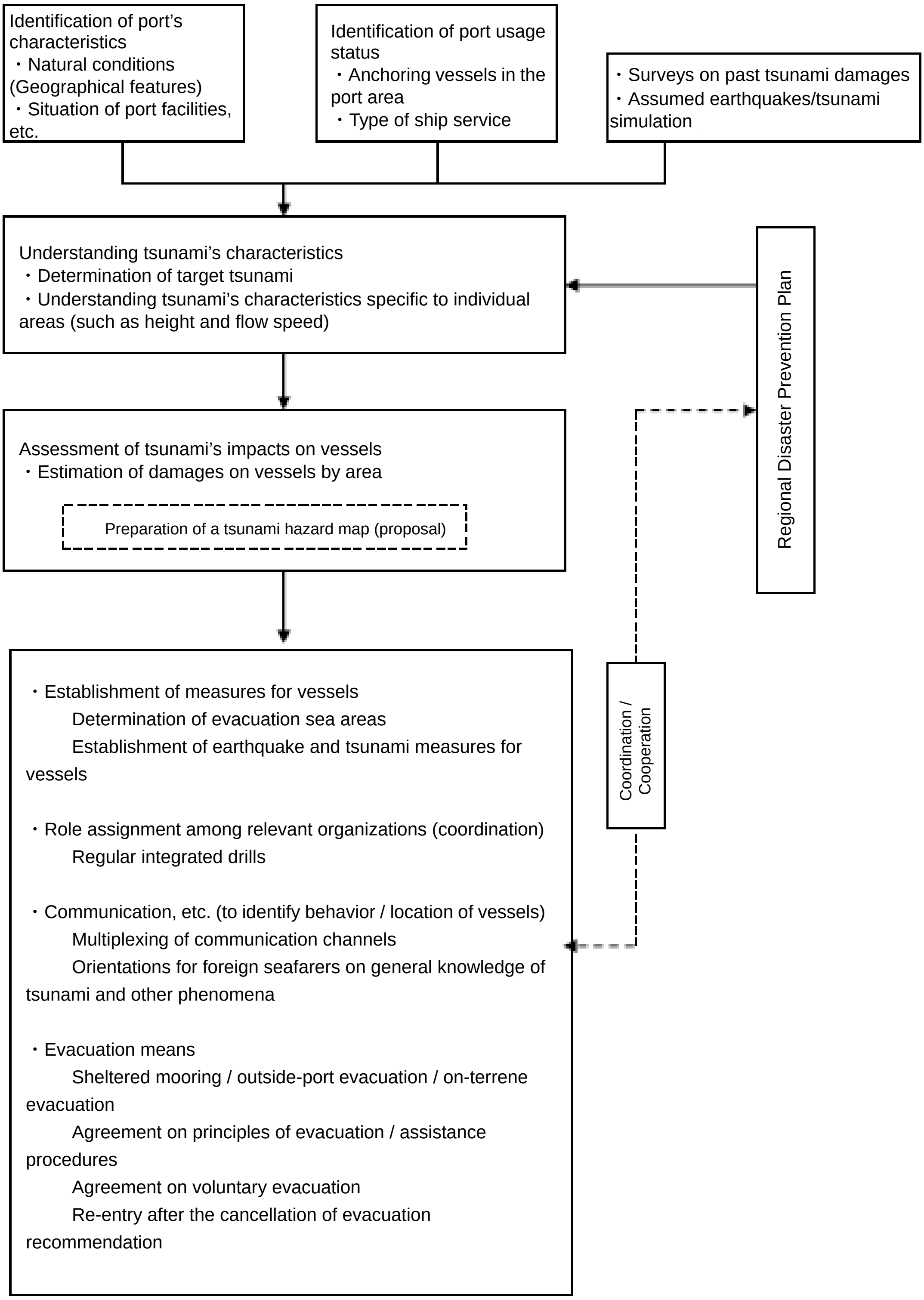


Figure 2-1: Flow of Tsunami Safety Measures

1-4. Assessment of Tsunami Impact in a Port

(1) Identification of port-specific features

Information on port-specific features is indispensable for the establishment of Tsunami Safety Measures. Therefore, a full investigation must be conducted on natural characteristics and situation of facilities that affect tsunami behaviors, such as terrain, water depth, and port facilities.

In addition to surveys on natural characteristics, such as seabed topography and slope, water depth, coastal topography, and hydrographic conditions, surveys must be conducted on the locations of port facilities, including breakwaters and quays, hazardous material facilities and docks. In particular attention must be paid to hazardous material facilities, timber basins, and aquaculture facilities as those facilities could, due to driftage, cause a secondary disaster or disturbance of navigation route, etc.

Port facilities and areas (and their functions/features/specifications) that should be identified are as follows:

(Major port facilities, etc.)

[1] The locations and functions of breakwaters and levees

[2] Quays, boat-lift yards, and cargo unloading yards (water depth, crown height, and usage)

[3] Anchorage areas, navigation route, ship basins, and harbor

[4] Timber basins and basins for small boats including pleasure boats

[5] Hazardous material facilities and passenger facilities

[6] Ship yards and docks

[7] Rivers and canals, etc.

[8] Other facilities

Check if the following items can be used in case of emergency: the location of anti-seismic quays, outdoor lighting equipment, facilities with fire-fighting equipment, facilities with disaster-prevention materials and equipment.

(Other facilities that require attention)

[1] Places with a large number of visitors, such as beaches, fishing spots, and recreational areas

[2] Culturing rafts, fixed fishing nets, and other surface structures

[3] Places where tsunami is likely to run-up, such as slopes and inclined ground

[4] Spots of low crown height

(2) Gathering information on port usage

In order to prepare safety measures including evacuation of vessels in advance, when a tsunami is expected the congestion status of vessels in the port and their types of services must be identified.

Tsunami Safety Measures must be developed on realistic assumptions based on an understanding of the conditions such as the congestion status of vessels in the port, type of vessels' services, status of offshore construction, etc. Though swift gathering of precise information on vessel situations cannot be expected in emergent situation, it is useful grasp the information about the berthing situation from daily-based survey when tsunami happened.

Such regular surveys should include the following items:

[1] Vessels' arrival/departure patterns; distribution of anchoring/mooring vessels by time zone, day of week, and area; the maximum number of cargo-handling vessels; and the maximum number of entering vessels

[2] Areas of vessel traffic congestion such as navigation route; the severity of congestion

[3] Usage of anchorages

[4] Situation of vessels that could require special assistance in the event of emergency: e.g. vessels carrying dangerous cargo; timber carriers; offshore cargo handling vessels; vessels not under command (mooring/ repairing, dredging boats, etc.); pleasure boats; fishing boats; barges; etc.

[5] Situation of vessels supporting entry/departure operations: e.g. tugboats, pilot boats, or ferry boats

[6] Situation of surface construction works

[7] Regular events at port area

(3) Understanding of tsunami dynamics and behaviors in a port

Assumptions of tsunami dynamics in port/port area must be made through referencing tsunami hazard maps for disaster prevention (based on tsunami simulation outputs), tsunami flood risk maps, past tsunami damages, and estimated tsunami height based on tsunami damage in past earthquakes. Moreover, tsunami dynamics in port/port area must be supposed and identified as possible.

Determining tsunami impact in conjunction with Tsunami Safety Measures must be properly conducted while preserving consistency with regional disaster prevention plans and taking past tsunami damage into consideration.

The characteristics/behaviors of tsunami in a port (specifically, height, flow speed, etc.) must be estimated for each zones in a port and calculated based on port features and usage (as mentioned above), paying attention to the following areas.

[1] Areas where tsunami are likely to rise higher

[2] Areas where tsunami flows are likely to go faster

[3] Areas where eddy currents are likely to occur

[4] Areas where geographical conditions could cause surge waves

[5] Positions where crown height is so low that small boats could easily be carried onto the ground

[6] Areas of rivers, etc. where tsunami are likely to run up

[7] Areas where water depth decreases to an extreme when undertow

[8] Areas where tsunami impact is likely relatively low

The following items are recommended as a reference in understanding tsunami dynamics/behavior in a port:

(a) Tsunami risk maps

Japan Cost Guard has prepared such maps based on tsunami risk information obtained through conducting tsunami simulations using the fault models for the following major earthquakes feared to occur in future: a Tokai earthquake, a Tonankai/Nankai earthquake, and a Nankai Trough earthquake. The information includes estimated tsunami behavior in specific sea areas.

The results of simulations by Japan Coast Guard were made available on the following web site in the form of a "Tsunami Risk Map," a "Tsunami Time-Variation Diagram," and a "Tsunami Animation": http://www1.kaiho.mlit.go.jp/KAIYO/tsunami/.

Note: In actual situations, hypocenter positions, earthquake magnitudes, and details of geographical conditions will affect tsunami behaviors. Therefore, actual tsunami scale or height may differ (larger or smaller) from the simulation results.

(b) Tsunami Flood Risk Map

Tsunami flood risk maps were prepared as base materials for the preparation of municipality-specific tsunami evacuation plans or tsunami hazard maps. At the same time, tsunami flood risk maps are supposed to be used in studying physical measures for the enhancement of tsunami measures. Tsunami flood risk maps, although primarily prepared for the establishment disaster prevention on terrene, will be helpful for the estimation of general tsunami behaviors.

Note: Tsunami hazard maps for separate municipalities are publicly open on the hazard map portal site (http://disapotal.gsi.go.jp) prepared by the Ministry of Land, Infrastructure, Transport and Tourism

(c) Damage caused by past tsunami

Unfortunately, almost all of the tsunami damage information found in historical documents is tsunami damage on terrene. Therefore, for the study of tsunami damage on the sea, in addition to surveys of local historical records, it is necessary to collect information from local residents.

(d) Other materials

Impact of tsunami in a specific port must be estimated by using following materials: "Survey Report on the Methods of Tsunami Estimation for Pacific Ocean Earthquakes" (prepared in FY1996 jointly by the Ministry of Construction, the Ministry of Agriculture, Forestry and Fisheries, the Fisheries Agency, and the Ministry of Transport); "Tsunami Inverse-Spread Diagram" (estimate time of tsunami arrival by using the tsunami diagram, port/port area as hypocenter, then inverse); and general tsunami dynamics/behaviors.

1-5. Tsunami Impact Assessment on Vessels

Based on the tsunami characteristics in a port estimated through surveys or the previously described investigations, area-by-area estimations are made on the severity of tsunami impacts on vessels at sea where impacts are expected and studies are made on sheltering sites/routes, evacuation orders/priorities.

As previously shown, tsunami characteristics (height, flow speed, etc.) are numerically estimated through simulations and other methods. On the other hand at present, tsunami impact on vessels is yet to be estimated; and numerical assessments will be difficult. However, while the establishment of evaluation methods for tsunami impact on vessels has to be left to future research, it is possible to estimate such impact somewhat accurately using the results of tsunami simulations or mooring criteria simulations on specific ports/port areas. It is likely realistic to make comparisons of relative risk degree according to estimations on the impact on vessels using the methods described above.

It is recommended that studies are conducted and that sheltering sites/routes, and evacuation priorities and orders are established based on the relative estimated risk degree calculated via the methods described above. In addition to the usefulness of such graphical presentations of port areas' risk degrees (for example, tsunami hazard maps for a port) for promoting studies on Tsunami Safety Measures, such graphical representations of risk degree, when delivered to the persons responsible for the vessels, will aid in the promotion of their awareness of disaster prevention and of the appropriate actions, such as smooth evacuation, in the event of a tsunami strike.

The following items should be shown on such hazard maps: tsunami height estimation; tidal stream; and risk-degree estimation for vessels. These items are expected to set up by circumstances of each ports/port areas.

The "Guide to Tsunami/High Tide Hazard Map*" (compiled by the administration office of "Tsunami/High Tide Hazard Map Study Group, in March 2004) is recommended as a consultation tool for such studies.

* At present, the guide is available from the Coastal Development Institute of Technology (a general incorporated foundation)

1-6. Vessel Actions in the Event of Tsunami

(1) Tsunami Information Delivery Flow and Vessel Actions in general

Figure 2-2 shows the general flow of tsunami information delivery and the actions that vessels are supposed to take on receipt of information

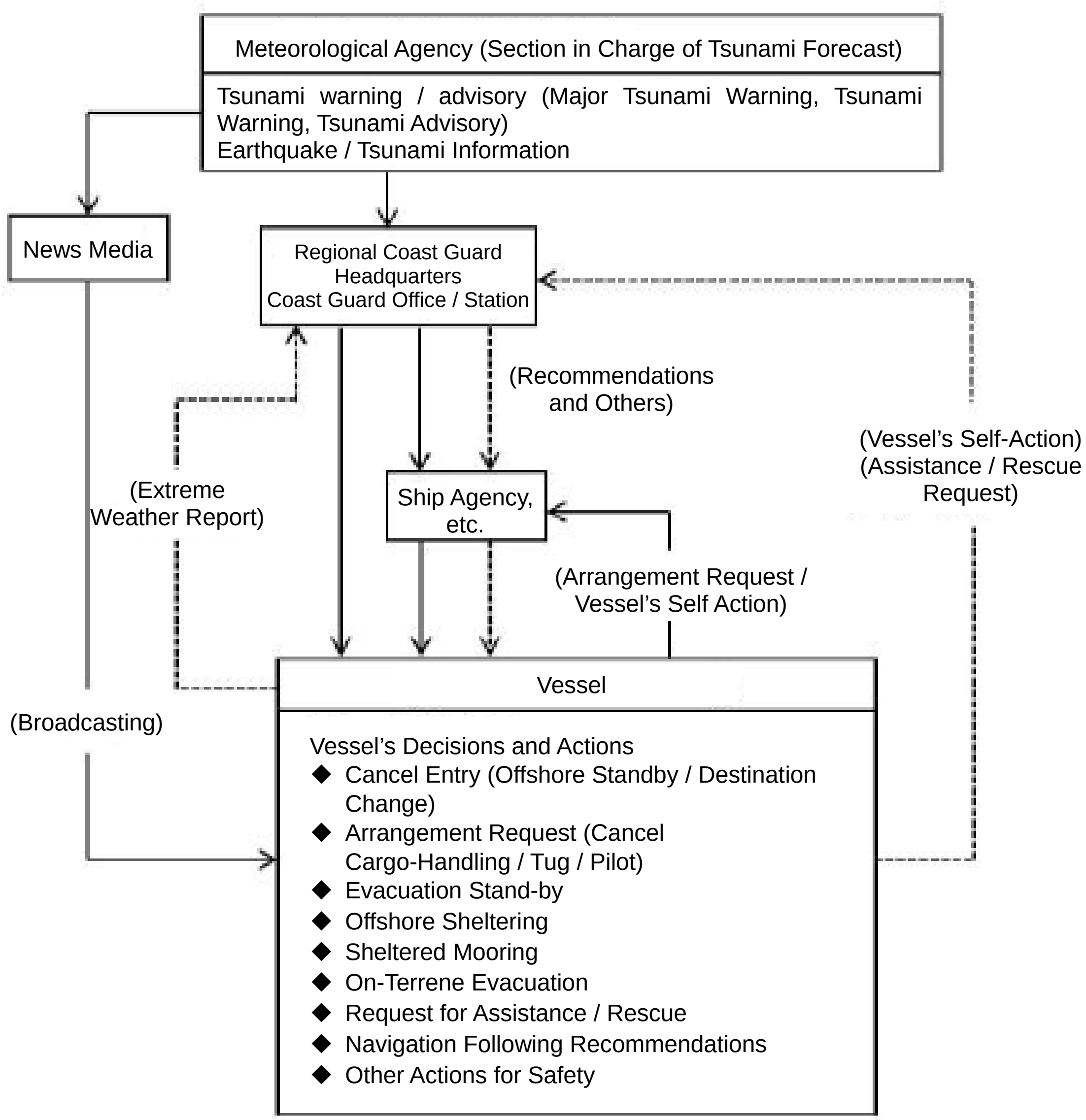


Figure 2-2: General Flow of Tsunami Information Delivery and the Action that vessels are supposed to take on receipt of information

(2) Evacuation

(A) Decisions on Evacuation

When getting informed of tsunami strikes through tsunami warnings/advisories, vessels have to make decisions on their actions such as offshore sheltering, staying at their mooring sites and taking tsunami measures, or ordering crews to evacuate on-terrene. In making such decisions, it is necessary to take the following factors into consideration:

(a) External factors (information or instructions)

- Recommendations, etc. on evacuation by the Chief of Coast Guard Office/Station (Captain of the port)
- Instructions on evacuation by the port administrator, fishing port administrator, fishing port administrators (fisheries cooperative administration, etc.), or marina operators.
- Measures vessels are to take against tsunami strikes in consideration of the following: Navigation Safety Measures for Large Vessels Carrying Dangerous Cargo; Administrative Provisions on Cargo Handling; Conference on Port Construction Works; Conference of Dangerous Cargo Handling Operators; and manuals for emergency operations prepared by operators.

(b) Port conditions/situations

- Tide level projection at the estimated time of tsunami arrival, crown height of quays, and vessel draft
- Tsunami behaviors in port areas estimated from past tsunami records or tsunami simulation results
- Port capacity for vessels (mooring, in-port anchorage, , cradling, landing)
- Situations of port and nearby vessels
- Situation of vessel traffic congestion on routes and other areas
- Situation of earthquake damage on port facilities
- Navigational warnings

(c) Situation of own vessel

- Time required to complete "evacuation standby"
  (Time required for the following: engine standby; passenger /vehicle offloading and retract gangway/lamp; cargo handling suspension and housing onboard/land cargo handling equipment; suspension of working and housing equipment; housing fishing gear, etc.; picking up workers/divers; getting landing/cradling)
- Time required for reaching safe offing from mooring point/anchorage, or operation/work site
- Evacuation method and safety of each method (offshore evacuation, shift to and mooring/anchoring in smaller port less susceptible to tsunami impact, landing/cradling)
- Time required for each evacuation method
- Time and measures required for surviving tsunami by staying at quay, anchorage, or working sea area

- The number of crew members required for completing evacuation and the time required for assembling this number
- Time required for returning to vessel from home, work site, or other place
- Land shelter locations and required time for crew members, passengers, and workers—placing the highest priority on safety
- Availability of self unberthing (arrangement or availability of pilot or tugboat)
- Availability of arrangement of carriage/landing and facilities and required time
- Allowance of sufficient time margin (evacuation time, tsunami arrival time, tsunami height)

(B) Time required for completing offshore evacuation

Offshore evacuation cannot succeed unless sufficient time for moving to safe sea areas is afforded before estimated tsunami arrival time. Therefore, it is important for a ship master to have confirmed the time required to accomplish offshore evacuation.

Time required for offshore evacuation consists of the following two factors: (1) time for standing-by evacuation; and (2) time required to move the vessel to safe sea areas. However, it is difficult to estimate such time in advance, because (1) the time depends on the situation of the vessel and the quay where the vessel stays, and (2) it depends on the port situation. Therefore, it is necessary for a ship master to confirm times (1) and (2) every time they enter port.

In addition, quay masters are required to consider the following in ensuring smooth offshore evacuation:

- Facility improvement, such as preparing multiple power source for cargo handling equipment and mooring equipment
- Applicability of berthing/unberthing methods (head-out) to ensure large vessels are able to achieve this smoothly
- For the case of large vessels carrying dangerous cargo:
  - ○ Installation of equipment such as quick release hooks
  - ○ Arrangements for smoothly putting oil fences back
  - ○ Preparation of manuals and drills for cargo handling suspensions and emergency unberthing

With regard to time required in entering evacuation standby status, two questionnaire surveys have been conducted as follows:

(a) The Japan Association of Marine Safety conducted surveys in 1997 on targeting general vessels that were regularly using nine ports located in the prefectures which are facing the Sea of Japan between Aomori and Ishikawa. The survey results are shown in Table 2-1.

The table indicates that two thirds of the vessels replying were able to enter evacuation standby in less than 30 minutes; one third, in less than 15 minutes; and another third, in more than 30 minutes.

(b) Tokyo-wan Association for Marine Safety conducted similar surveys in 1984 on vessels entering Tokyo Port. The results of the survey are shown in Table 2-2 for quay-moored vessels, and in Table 2-3 for buoy-moored vessels.

Recent large LNG tanker berths have emergency unberthing equipment such as quick release hooks installed and the time to standby un-berth is reportedly around 40 minutes. ("Symposium Proceedings on Vessel Tsunami Measures," the 3rd Conference on the Great East Japan Earthquake, November 20, 2013, Japan Institute of Navigation)

(C) In the case of insufficient time allowed for offshore evacuation

Many large vessels are unable to un-berth without tugboats, particularly when gales are pushing the hull onto the quay. Almost all vessels under the command of non-Japanese masters who have less experience of Japanese ports, in particular, will not be able to un-berth without pilotage and tugboat assistance.

Furthermore, only limited port/port area provides 24/7 tugboat services, in addition, at the time of tsunami strikes, tugboats themselves must evacuate. Also, pilotage service will not be available at night as pilots and tugboat crews are generally off-duty.

It is considered as a "best available procedures" for the following vessels to stay berthing using more mooring lines: there is difficulty to unberth without assistance by tugboat, in spite of this might be the only way to evacuate; there is no sufficient time to evacuate from the port, regardless of availability of evacuating from the port.

Furthermore, it is recommended for small boats such as fishing boats, work boats, or pleasure boats that enhanced berthing measures are taken before crews proceed to evacuate via land.

Table 2-1: Time Required to Complete Evacuation Standby (General Vessels)

Number of ships (%)

Gross Tonnage	Anytime Ready	Less than 15 min	15 to 29 min	30 to 44 min	45 to 59 min	60 to 89 min	90 to 119 min	Over 120 min	Total
Less than 5	**8**(22)	**15**(43)	**6**(17)	**3**(9)	**3**(9)				**35**
5 to 19	**7**(15)	**13**(28)	**17**(37)	**4**(9)	**5**(11)				**46**
20 to 49		**1**(10)	**7**(70)		**2**(20)				**10**
50 to 99	**3**(43)	**2**(28)			**2**(28)				**7**
100 to 499	**5**(6)	**35**(41)	**25**(29)	**9**(11)	**6**(7)	**3**(3)	**2**(2)		**85**
500 to 999	**7**(5)	**38**(27)	**59**(42)	**27**(19)	**4**(3)	**3**(2)	**1**(1)	**1**(1)	**140**
1,000 to 2,999	**6**(5)	**31**(27)	**45**(39)	**22**(19)	**8**(7)	**1**(1)	**1**(1)	**1**(1)	**115**
3,000 to 5,999	**4**(4)	**15**(16)	**21**(23)	**24**(26)	**14**(15)	**7**(8)	**2**(2)	**4**(4)	**91**
6,000 to 9,999		**3**(25)	**4**(33)	**5**(42)					**12**
10,000 to 49,999		**6**(10)	**21**(34)	**8**(13)	**9**(15)	**12**(19)	**3**(5)	**3**(5)	**62**
50,000 or more		**1**(25)	**1**(25)		**1**(25)	**1**(25)			**4**
Total	**40**(6.6)	**160**(26.4)	**206**(33.9)	**102**(16.8)	**54**(8.9)	**27**(4.4)	**9**(1.5)	**9**(1.5)	**607**

Table 2-2: Time Required to Complete Evacuation Standby (Vessels Berthed at Quay)

Number of ships (%)

Gross tonnage	Less than 30 min	40 to 59 min	60 to 89 min	90 to 119 min	120 to 149 min	Over 150 min	Total
Less than 1,000	**63**(85)	**10**(14)		**1**(1)			**74**
1,000 to 2,999	**38**(72)	**15**(28)					**53**
3,000 to 4,999	**13**(43)	**13**(43)		**2**(7)		**2**(7)	**30**
5,000 to 9,999	**15**(39)	**13**(34)	**3**(8)	**2**(5)		**5**(13)	**38**
10,000 to 49,999	**24**(19)	**68**(54)	**7**(6)	**24**(19)		**3**(2)	**126**
50,000 to 99,999	**10**(19)	**30**(56)	**6**(11)	**4**(7)		**4**(7)	**54**
100,000 to 149,999	**5**(20)	**15**(60)	**1**(4)	**4**(16)			**25**
150,000 or more		**2**(67)		**1**(33)			**3**
Total	**168**(42)	**166**(42)	**17**(4)	**38**(9)		**14**(3)	**403**

Table 2-3: Time Required to Complete Evacuation Standby (Vessels on Buoy-Mooring)

Number of ships (%)

Gross tonnage	Less than 30 min	30 to 59 min	60 to 89 min	90 to 119 min	120 to 149 min	Over 150 min	Total
Less than 1,000	**44**(94)	**3**(6)					**47**
1,000 to 2,999	**33**(87)	**5**(13)					**38**
3,000 to 4,999	**12**(55)	**6**(27)	**2**(9)	**2**(9)			**22**
5,000 to 9,999	**12**(41)	**14**(48)		**1**(3)		**2**(7)	**29**
10,000 to 49,999	**42**(37)	**51**(45)	**5**(4)	**12**(10)		**4**(4)	**114**
50,000 to 99,999	**21**(41)	**24**(47)	**1**(2)	**4**(8)		**1**(2)	**51**
100,000 to 149,999	**7**(29)	**12**(50)	**2**(8)	**2**(8)		**1**(4)	**24**
150,000 or more	**2**(67)					**1**(33)	**3**
Total	**173**(53)	**115**(35)	**10**(3)	**21**(6)		**9**(3)	**185**

2. Preparation of Tsunami Safety Measures for vessels

2-1. Designation of Tsunami-Sheltering Areas

As a matter of procedure, areas for tsunami sheltering and the navigation route to those areas when a tsunami risk is expected must be designated in advance. The features of the port region and the assessment of tsunami-impact on vessels must be considered in preparing such procedures.

Sheltering areas must be determined taking care of the following:

(a) Areas must be determined in full consideration of tsunami impact on surrounding areas.

(b) Areas must be chosen among areas relatively close to the port that are projected to receive less tsunami impact.

(c) Area sheltering capacity must match the number of vessels under normal situations. Note that it is necessary to designate more than one area and assign prioritized order to those areas.

(d) Areas should be separated for large or mid-size vessels from those for small vessels.

(e) Time for moving from each of the quays to the sheltering areas for each category of vessel must be estimated and kept available during emergencies.

(f) Areas inside the port that are expected to have relatively lower tsunami should be designated as emergency-evacuation areas for vessels that have no time to make offshore evacuations due to delays in evacuation actions.

(g) In assigning sheltering areas, it must be ascertained whether safe sea evacuation routes exist. In doing so it is important to pay attention to the fact that tsunami impact may increase near breakwaters etc.

(h) Additional measures should be prepared in advance, particularly for small vessels, in consideration of bad weather or sea conditions that might interfere with vessel evacuation in tsunami risk situations.

(i) All concerned port organizations and vessels should be kept well informed of sheltering areas and evacuation routes.

(j) With regard to vessel-traffic congested areas (for instance, Tokyo or Osaka Bay) where sheltering areas may overlap with those of neighboring ports, adjustments and agreements in regard to evacuation areas should be made in advance with such ports.

2-2. Recommended Vessel Actions

It is necessary to conduct studies on recommended vessel actions for each vessel category and situation based on an assessment of earthquake/tsunami impacts for vessel.

For the preparation of a port-specific vessel-action manual for the cases where a strong earthquake has occurred or there is a tsunami risk, it is necessary to have completed, in advance, studies on what actions are desirable for individual vessels to take.

In this sub-section, tsunami impacts on vessels of different types and in different situations are summarized, and then recommended standard actions are introduced.

Table 2-4 shows what impact on what types of vessels tsunami will give, and what actions vessels are recommended to take.

Table 2-5 shows what type of vessels and in what situations the type of tsunami information (warning or advisory) is issued.

Figure 2-3 shows the procedural flow of actions to be taken by large/mid-sized vessels.

When taking the above mentioned actions, attention should be paid to the following:

(a) Those tables show the standard actions that vessels are recommended to take for vessels of various types in different situations. However, as previously mentioned, tsunami impact on vessels is heavily dependent on the characteristics or situations of individual ports/port areas, it is recommended to prepare port/port area specific tsunami measures based on considerations of specific conditions or situations.

(b) The measures shown in the tables were originally established based on surveys and research conducted in FY2003, and then reviewed to reflect lessons from the Great East Japan Earthquake on March 11, 2011.

(c) In the tables, vessels are classified into the two categories—large/mid-sized vessels and small vessels. Note that the classification of vessels cannot be made simply by tonnage; one reason for classifying large vessels and mid-sized vessels into the single category of "large/mid-sized vessel" is that, although large vessels and mid-sized vessels will be impacted differently—for instance, mooring line break conditions or situations for large vessels are different from those for mid-sized vessels—there is no significant difference in terms of recommended measures for those two sizes.

However, large vessels are required to prepare additional measures to cope with situations where they are unable to leave port by themselves as most large vessels require tugboat assistance or pilotage services to do this. On the other hand, the category "Small Vessels" designates vessels that, judging from port-facility conditions, can be considered small enough for measures such as being carried onto land and tied down. Small boats such as pleasure boats or small fishing boats fit this category.

(1) Large/mid-sized vessels (including fishing vessels)

(A) vessel berthing in a port

Tsunami impact for vessels berthing in a port and recommended measures or actions for those vessels is shown below:

(Expected Tsunami Impacts on Vessels)

[1] Earthquake movement causes hull motion (simultaneously in hull and beam directions) that increases tension on vessels' mooring lines, which engenders a risk of mooring line breakage/elongation.

[2] Power loss due to earthquake damage will in some cases interfere with the separation off the vessel or housing of cargo handling equipment.

[3] Hull lifts due to a rise in water level or movement caused by flow pressures of strong tsunami currents will elongate mooring lines, increasing tension on those lines.

[4] In extreme cases, hull lift or movement may cause mooring line breaks and set vessels drifting off quay; and, in the worst case, lead to collisions or groundings.

[5] There is a risk that a vessel will be lifted and carried onto the quay by overflowing tsunami water.

[6] There is a risk that a vessel dragged down by back-drawing tsunami water will touch the seabed with the bottom of its hull.

[7] There is a risk that tsunami pressure flow will press a vessel onto the quay, preventing it from unberthing.

[8] There is a risk that a vessel will fail to house the oil-fence it has erected.

(Recommended Vessel Actions)

<General Vessels (including working vessels)>

[1] Vessels are required, on receipt of a major tsunami warning, a tsunami warning, or a tsunami advisory issued by the Meteorological Agency, to Suspend their cargo handling operations and other work, even if in the middle of operations and make efforts to collect earthquake/tsunami information.

Note: In the case where an earthquake occurs in an area close to the coast, there is a risk that vessels will be trapped in a situation where a tsunami arrives before the Meteorological Agency is able to issue a tsunami warning or other report. Therefore, vessels are recommended to make efforts to collect tsunami information immediately after sensing a strong earthquake (of intensity 4 or

over) or sensing an earthquake, even if not strong, with a slow but long-lasting movement.

[2] In a situation where a major tsunami warning or tsunami warning has been issued, vessels are recommended to make offshore evacuation as their first choice if they have sufficient time to reach evacuation sheltering areas before the tsunami is expected to arrive. Note that tsunami with a height of more than 1 to 2 meters can cause damage. However, in the case where a no more severe warning than a (general) tsunami warning has been issued, vessels can choose moored sheltering, judging from the comparison of their hull-size to the expected tsunami height.

[3] Vessels in a situation where, although a major tsunami warning or tsunami warning has been issued, they cannot afford the time to execute an offshore evacuation are recommended to choose, as a second best counter-measure, moored sheltering with enhancing mooring by way of adding or tightening mooring lines. However, in the case where a major tsunami warning has been issued and it is likely dangerous to stay onboard, vessels are recommended to let their crew members leave to evacuate by terrene if sufficient time is available to reach high ground.

[4] Vessels, in the case where a tsunami advisory has been issued, are recommended to choose moored sheltering or offshore evacuation, judging from the scale of the expected tsunami height and the vessel's hull size.

[5] Vessels are recommended to take, judging from the vessel size and conditions, following maneuvering or ship-securing measures:

(a) Enhanced supervision on water-level variations, water-flow situations, or objects drifting on surface.

(b) Standby main engines and anchor.

(c) Anchor before the completion of berthing: this will make emergency unberthing maneuvering easier.

(d) Berthing with head-out will drastically reduce the time required for emergency unberthing and turning.

(e) In emergency self-unberthing, let-go or cutting all of the mooring lines will be effective.

(f) Aft-swing maneuvering using forward spring-line will be effective in the case where tsunami pressure flow is blocking the vessel from unberthing.

(g) Having long spring/breast mooring lines will be effective in adding mooring forces.

(h) Enhanced arrangements for securing mooring lines: take measures for the enhancement of mooring by adding/tightening mooring lines, and other appropriate measures.

<Vessels Carrying Dangerous Cargo>

[1] Vessels carrying dangerous cargo are recommended to consider offshore evacuation as the first choice if they have sufficient time to reach the sheltering area in order to prevent secondary disasters that might be caused by dangerous cargo onboard.

[2] Vessels carrying dangerous cargo are recommended, in addition to the action shown in [1], to take the same measures/actions recommended for general vessels (including working vessels).

[3] Vessels carrying dangerous cargo are recommended to promptly take the following emergency actions, as well as action [5] for general vessels (including working vessels):

(a) Promptly clear off water and house any oil fences that have been erected.

(b) Membrane-type LNG carriers must execute protection measures to avoid sloshing that might occur after emergency unberthing.

(B) Anchoring/buoy-mooring vessels (including working vessels)

With regard to anchoring/buoy-mooring vessels, tsunami impacts and other phenomena are shown below as well as recommended vessel actions.

(Expected tsunami impacts on vessels)

[1] Bays, coves, or ports that are used for anchoring are, in general, almost fully closed in except for a narrow entrance where a tsunami will increase flow speed. Therefore, anchoring vessels will face a high risk of dragging anchor.

[2] Buoy-moored vessels will be put in a similar situation to that of anchoring vessels. In addition, when receiving abeam or diagonal tsunami flows they will face a high risk of suffering drag forces exceeding the mooring force given by the buoy if forward-aft moored.

[3] Reversing of tsunami-flow direction accompanying the pushes and pulls of tsunami-flow will, in some cases, cause a loss of holding power by anchor chain.

[4] Vessels will face the risk of grounding in shallow water or colliding with quay when pushed by a tsunami's pressing flows.

[5] Vessels will face the risk of touching ground with hull bottom in tsunami

backflows.

[6] Vessel radars will be at risk of losing reflections due to tsunami water covering quay surfaces or other structures.

[7] Vessel radars, according to the situation, may be able to detect tsunami coming from the offing.

(Recommended Vessel Actions)

[1] Vessels are required, where the Meteorological Agency has issued a tsunami warning/advisory, to suspend operations and make efforts to collect tsunami information.

Note: in the case where an earthquake has occurred in a point close to coast, a tsunami might arrive earlier than the Meteorological Agency issues warnings/advisories. Therefore, vessels, when having sensed strong earthquake motions (of intensity 4 or over) or slow but long-lasting earthquake motions, even if the earthquake is not so strong, are recommended to promptly take action in collecting information.

[2] Vessels are recommended, where major tsunami warnings/tsunami warnings have been issued, to heave up anchor or let-go their mooring lines and go offshore sheltering areas if there is sufficient time to evacuate.

[3] Vessels are recommended, where a major tsunami warning/tsunami warning has been issued, to choose sheltering in a port if there is insufficient time to execute offshore evacuation.

[4] Vessels are recommended, where tsunami advisories have been issued, to choose sheltering in a port; however, they can choose offshore evacuation according to their situation.

[5] Vessels are recommended to prepare, considering vessel-size and conditions, for the following vessel maneuvering and ship-securing measures:

(a) Enhance vessel's tsunami resistance by using main engines, rudders, and thrusters, as well as enhancing holding power by extending anchor cables or applying double anchors. Note: when applying double anchors, make sure to constantly supervise vessel's turning conditions to prepare for clearing fouled anchor.

(b) Turning ship's heading by dredging in the direction of oncoming tsunami will aid in resisting the tsunami's force.

(c) Standby slipping anchor for emergency break-away.

(d) Maintain high-level supervision on the transit of land markers to detect

anchor dragging.

(e) Enhance supervision on changes in tsunami water level, water flow situations, and drifting objects on surface.

(C) Proceeding Vessel

Tsunami impacts on proceeding vessels and recommended vessel actions are shown below.

(Expected tsunami impacts on vessels)

[1] Vessels proceeding inside bay or port will face a high risk of suffering navigational maneuvering problems such as fluctuation of ship's position/heading, less steerage (if ship's draft is not enough) by tsunami flow.

[2] Vessels proceeding in a port will face the risk of being pressed by strong tsunami flows and will be unable to proceed due to strong currents, even if they use full-ahead.

[3] Vessels proceeding in a port at the time of tsunami strike will face a very high risk of grounding or collision, because tsunami flows have different directions or speeds at different points. Particularly around the port entrance tsunami will form eddy currents.

[4] Large vessels will face the risk of being trapped in uncontrollable situations even with tugboat assistance or using thrusters due to tsunami flow pressures.

[5] When overriding the tsunami crest, vessels will face the risk of suffering rapid reduction of speed because the engine limiter works to prevent the main engine from rotating too fast while propeller racing.

[6] When receiving tsunami on aft, vessels will face the risk of being trapped in a surf-riding situation on the front slope of the tsunami.

[7] Vessels proceeding in tsunami situations will face the risk that their radars lose quay reflections due to floods on quay surfaces.

[8] Vessels proceeding in tsunami situations have the chance of identifying tsunami coming from the offing via radar reflections.

(Recommended Vessel Actions)

[1] Vessels are required, where the Meteorological Agency has issued major tsunami warnings/tsunami warnings/tsunami advisories, to make efforts in collecting earthquake/tsunami information.

Note: in the situation where an earthquake has occurred at a point close to the coast, tsunami may arrive earlier than the issuance of tsunami warning or other

information by the Meteorological Agency. Therefore, vessels are recommended, when having sensed strong earthquake motions (of intensity 4 or over) or a slow and long-lasting movement, even if the earthquake was not so strong, to immediately start collecting information.

[2] Proceeding vessels are recommended to immediately evacuate to offshore, if they have sufficient time to proceed offshore sheltering areas.

[3] Proceeding vessels are recommended to choose sheltering in a port, if they have insufficient time to make offshore evacuation.

[4] Proceeding vessels are recommended to choose offshore evacuation in a situation where tsunami advisories have been issued.

[5] Proceeding vessels are recommended to take into account following maneuvering actions or equivalents, according to their hull size or situations:

(a) Keep steerage by setting the engine at maximum power when passing port entrances during tsunami strikes.

(b) When proceeding nearby port entrances at the timing of tsunami back-drawing, vessels may be able to proceed with better course stability than when there is tsunami incoming or eddy-currents. This is because there is less tsunami pressure flow interfering with navigation by causing speed reduction or oblique vessel movement, etc.

(c) When trapped in tsunami, proceeding vessels are recommended to turn the bow to the direction of the oncoming tsunami and adjust main-engine rotation to avoid impact on the hull and rapid speed-reduction due to propeller racing.

(d) Proceeding vessels are recommended to standby anchor to avoid collision with levees or other vessels.

(e) Proceeding vessels are recommended to enhance supervision on changes in tsunami water-level, the situation of tsunami flow, and drifting objects on the surface.

(2) Small Boats (Pleasure Boats or Small Fishing Boats)

(Skipped)

Table 2-4: Tsunami Impact on Vessels and Recommended Vessel Actions

	Large/Mid-sized Vessels (Including Fishing Vessels)				Small Boats (Pleasure Boats/Small Fishing Boats)	
	In a port Berthing		Anchoring/Buoy Mooring (Including Working Vessels)	Proceeding	In a port Berthing	Proceeding/Anchoring
	General (Including Working Vessels)	Vessels Carrying Dangerous Cargo				
Tsunami Impacts	[1] Risk of mooring-line elongation/break due to vessel motions (hull-direction/beam-direction) caused by earthquake motions. [2] Risk of failures in separation/housing of cargo-handling equipment due to power-loss caused by earthquake damage. [3] Elongation of mooring lines and rise in mooring-line tensions due to hull lift by tsunami water level rises or hull movement caused by the flow pressure of strong tsunami. [4] Risk of collision or grounding of drifting vessels off quays as a result of mooring-line breaks due to excessive lift/movement by tsunami. [5] Risk of vessel overriding on quay due to tsunami flowing over quays. [6] Risk of vessels touching ground with hull bottoms by back-drawing tsunami water. [7] Risk of failure in unberthing due to tsunami pressure-flow. [8] Risk of failure in housing oil-fences.		[1] Risk of anchor-dragging for anchoring vessels: bays, coves, or ports generally used for anchoring, different from open areas, are almost fully closed in except at their narrow entrances, where tsunami flows increase speed. [2] Risk on buoy-mooring vessels is basically similar to that of anchoring vessels, however high risk of having tsunami force exceeding buoy-resistance force for forward-aft buoy-mooring vessels when receiving abeam or diagonal tsunami flow. [3] Risk of losing holding power by anchor chain due to changes in flow direction caused by forwarding and back-drawing of tsunami. [4] Risk of grounding in shallow areas or colliding with quays when carried by tsunami pressure flow. [5] Risk of touching ground with hull bottom when dragged by tsunami back-drawing flows. [6] Risk of losing radar reflections from quays flooded by tsunami water. [7] Chance of detecting tsunami coming from offing by radar reflections.	[1] High risk of suffering navigation maneuvering problems such as fluctuation of ship's position/heading, less steerage (if ship's draft is not enough) by tsunami flow. [2] Risk that vessels proceeding in a port might be unable to go forward even if they use full-ahead, being pushed back by strong tsunami-pressure flow. [3] High risk of grounding or collision for vessels proceeding in a port in tsunami situations because the direction and strength, etc. of tsunami flow in a port are so complex. Particularly near the port entrance, tsunami flow might generate severe eddy currents. [4] Risk of inability to control hull using tugboats or thrusters due to tsunami flow, in cases of large vessels. [5] Risk of rapid speed-reduction due to main engine limiter activated for suppressing engine excessive rotation as a result of engine racing that might occur when the vessel is overriding tsunami. [6] Risk of a vessel's being trapped in a surf-riding situation on the front slope of tsunami when receiving waves on aft. [7] Risk of radar-reflection loss from quays when quays are flooded with tsunami water. [8] Tsunami from the offshore may be determined using radar reflections.	(Skipped)	(Skipped)
Recommended Actions	[1] Required to suspend cargo-handling/operations and make efforts in collecting information, in situations where the Meteorological Agency has issued a major tsunami warning, tsunami warning or tsunami advisory. Note, vessels are highly recommended to promptly start collecting information in a situation where they have sensed a strong (intensity of 4 or over) earthquake or slow but long-lasting earthquake movement, even if the earthquake was not so strong, because, in the case where an earthquake occurs at a point close to the coast, tsunami might arrive earlier than Meteorological Agency issues warnings. [2] Recommended to consider offshore evacuation as the first choice if the vessel has sufficient time, in a situation where a major tsunami warning or tsunami warning has been issued, —tsunami of a height of 1 to 2 meters or over are said to cause damages. Note, in the case of tsunami warning, vessels can choose sheltered mooring, according to a comparison of their hull-size to the expected tsunami height. [3] Recommended to choose sheltered mooring with enhancing mooring force by adding/tightening mooring lines. Note, in a situation where a major tsunami warning has been issued, staying in the vessel is considered risky, and if there is sufficient time, choose on-terrene evacuation. [4] Recommended to choose sheltered mooring or offshore evacuation according to the comparison of the hull-size to the expected tsunami height, in a situation where a tsunami advisory has been issued,. [5] Recommended to take the following vessel-maneuvering and vessel-securing measures, considering the vessel size: (a) Enhance the supervision of changes in tsunami height, flow situations, and drifting objects on surface. (b) Standby main engines and anchor (c) Anchor before the completion of berthing: it will likely make unberthing maneuvers easier for emergency unberthing. (d) Berth the vessel with head-out: it will likely drastically reduce the time for unberthing and turning. (e) Let-go or cutting all the mooring lines will be effective for emergency self unberthing. (f) Aft-swing maneuvering using forward spring lines will likely be effective in a situation where tsunami pressure flow is blocking the vessel from unberthing. (g) Taking spring/breast lines long will be effective for enhancing mooring forces. (h) Enhance mooring forces by adding lines or tightening, and also enhance the arrangement for securing mooring lines.	[1] Recommended to take offshore evacuation as the first choice if the vessel has sufficient time in a situation where major tsunami warnings or tsunami warnings have been issued. This is for the purpose of preventing secondary damages due to dangerous cargo carried by the vessel. [2] Recommended to take the same actions that general vessels (including working vessels) except the action recommended in [1]. [3] Recommended to promptly prepare for the operations shown below, in addition to the actions shown in [5] for general vessels (including working vessels): (a) Prompt recovery of oil-fences the vessel has erected. (b) Measures for preventing the sloshing that could occur after emergency unberthing in a membrane-type large LNG tanker.	[1] Required to Suspend operations and make efforts to collect earthquake/tsunami information when the Meteorological Agency has issued major tsunami warnings, tsunami warnings, or tsunami advisories. Note: in the situation where an earthquake occurred close to the coast, there is a risk that a tsunami will arrive before the Meteorological Agency issues tsunami warnings or advisories. Therefore, vessels are recommended, when having sensed strong earthquake motions or slow but long-lasting earthquake motions, even if the earthquake is not so strong, to promptly collecting information. [2] Recommended, in a situation where a major tsunami warning or tsunami warning has been issued, to evacuate offshore if the vessel can afford sufficient time. [3] Recommended, in a situation where a major tsunami warning or tsunami warning has been issued, to choose in a port sheltering if the vessel cannot afford sufficient time to make offshore evacuation. [4] Recommended, in a situation where a tsunami advisory has been issued, to takes in a port sheltering as a first choice; however, judging from their own situations, vessels can opt for offshore evacuation. [5] Recommended to consider applying the following vessel maneuvering and vessel securing-measures according to the vessel size and situations: (a) Resisting against tsunami forces by enhancing holding power by applying double-anchors or keeping anchor cables long-stretched, and using thrusters as well as the main engine. Note: in a case where double-anchor is applied, it is necessary to maintain supervision on vessel-turning situations in order to clearing fouled anchor. (b) Dredging anchor to face the vessel's bow head-on to the oncoming tsunami can be effective in resisting tsunami forces. (c) Standby slipping anchor for emergency escape. (d) Maintaining supervision on land-marker transit to detect anchor dragging. (e) Enhancing supervision on changes in tsunami-water level, flow situations, and drifting objects on surface.	[1] Required to make efforts to collect earthquake/tsunami information in the situation where the Meteorological Agency has issued a major tsunami warning, tsunami warning, or tsunami advisory. Note: when having sensed strong earthquake motions (intensity of 4 or over) or slow but long-lasting earthquake motions even if the earthquake is not so strong, vessels are recommended to immediately start information collection, because in a case where an earthquake has occurred at a position close to coast tsunami may arrive earlier than a Meteorological Agency warning or other. [2] Recommended to immediately evacuate offshore if the vessels have sufficient time, in a situation where a major tsunami warning or a tsunami warning has been issued. [3] Recommended to take in a port sheltering if the vessel lacks sufficient time, in a situation where a major tsunami warning or a tsunami warning has been issued,. [4] Recommended to take in a port sheltering. However, the vessel can evacuate offshore based on the vessel's individual situation, in a situation where a tsunami advisory has been issued,. [5] Recommended to consider applying the following vessel maneuvering and vessel securing-measures according to the vessel size and situation: (a) In a situation where tsunami has arrived when passing a port entrance, etc. set the engines at its maximum power to keep steerage. (b) In a situation where tsunami is back-drawing, vessels, when passing a port entrance will have the chance to suffer less interference such as speed reduction or oblique shifting caused by tsunami pressure flow, and to more easily keep the heading than in a situation where tsunami is incoming or generating eddies. (c) In the situation where a tsunami has arrived, face the bow into the oncoming tsunami, and adjust engine-rotation to avoid tsunami impact on the hull and rapid speed-reduction due to propeller racing. (d) Standby anchors to avoid collisions with levees or other vessels. (e) Enhance supervision on changes in tsunami-water level, flow situations, and drifting objects on surface.	(Skipped)	(Skipped)

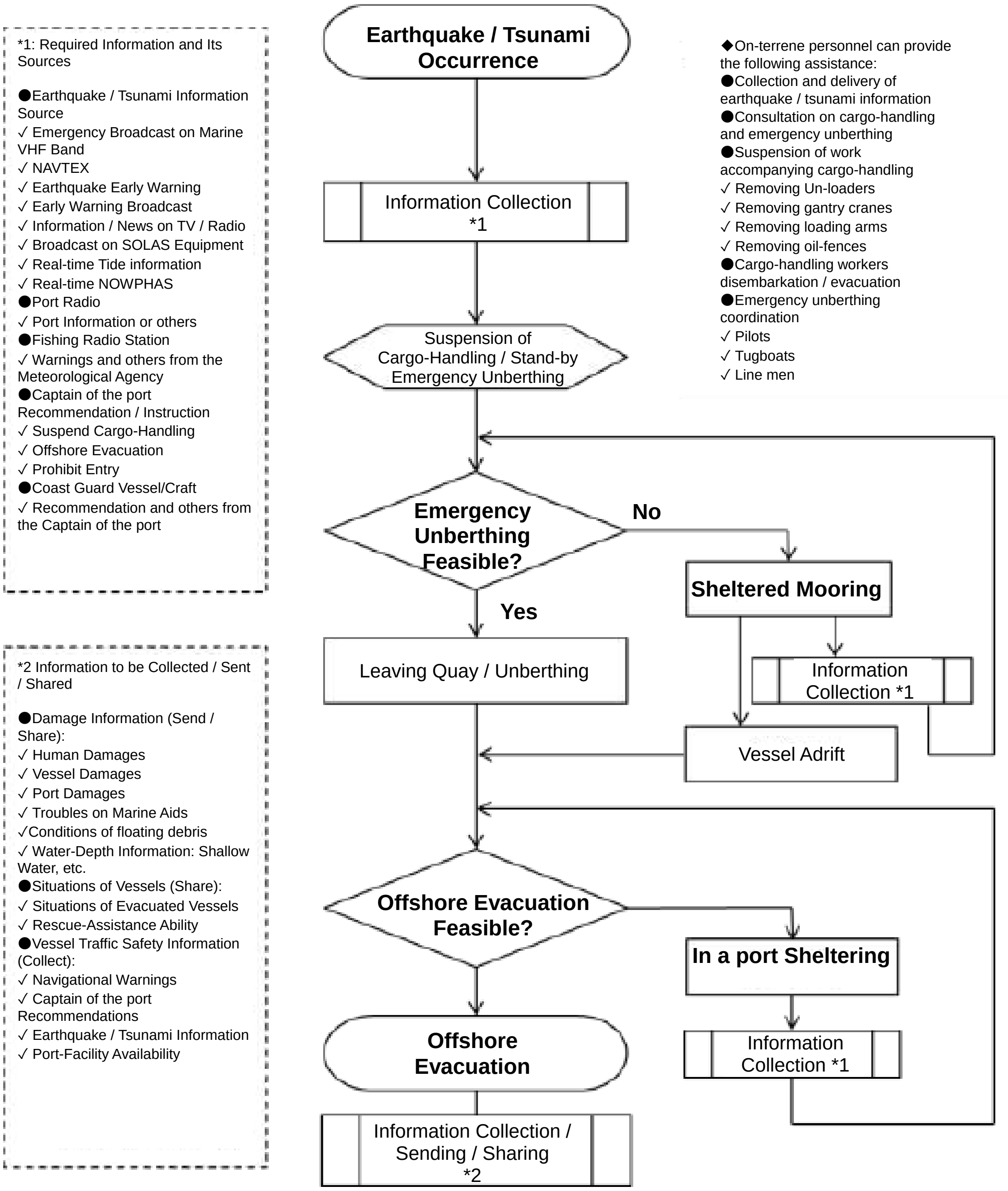


Figure 2-3: Procedural Flow of Large/Mid-Sized Vessels' Evacuation

2-3. In-Table Summarized Tsunami Response Actions by Vessel Type and Situation

Table 2-5: Tsunami Warning/Advisory, Vessel Types, and Recommended Actions

Tsunami Warning/Advisory (PH: Predicted Height)		Time Allowance to Tsunami Strike	Large/Mid-Sized Vessels (Including Fishing Vessels)				Small Vessels (Pleasure Boats, Fishing Boats, etc.)
			In a port Berthing Vessels		Anchoring Vessels/Buoy-mooring Vessels (including Working Vessels)	Proceeding Vessels	
			General Vessels (Including Working Vessels)	Vessels Carrying Dangerous Cargo			
Major Tsunami Warning	Over 10 meters (10 m < PH) 10 meters (5m< PH≦10 m) 5 meters (3m<PH≦5m)	No	Suspend Loading/Unloading or Operations Berthing Sheltering or Evacuation on Terrene	Suspend Loading/Unloading or Operations Berthing Sheltering or On-terrene Evacuation	Suspend Operations In a port Sheltering	In a port Sheltering	(Skipped)
		Yes	Suspend Loading/Unloading or Operations Offshore Evacuation	Suspend Loading/Unloading or Operations Offshore Evacuation	Suspend Operations Offshore Evacuation	Offshore Evacuation	
Tsunami Warning	3 meters (1m<PH≦3m)	No	Suspend Loading/Unloading or Operations Sheltering at Berth	Suspend Loading/Unloading or Operations Sheltering at Berth	Suspend Operations In a port Sheltering	In a port Sheltering	
		Yes	Suspend Loading/Unloading or Operations Offshore Evacuation or Berthing Sheltering	Suspend Loading/Unloading or Operations Offshore Evacuation	Suspend Operations Offshore Evacuation	Offshore Evacuation	
Tsunami Advisory	1 meter (0.2m<PH≦1m)		Suspend Loading/Unloading or Operations Berthing Sheltering or Offshore Evacuation	Suspend Loading/Unloading or Operations Berthing Sheltering or Offshore Evacuation	Suspend Operations In a port Sheltering (Offshore Sheltering, if necessary)	Offshore Evacuation	
Remarks				Business operators are required to prepare action manuals	Survey usual anchorage in advance for identifying the areas where water is likely to flow fast at the time of tsunami strike		

Time Allowance to Tsunami Strike:
Yes: Vessels may have sufficient time to evacuate (to put the vessel in a safe state by offshore evacuation or landing and binding) following the release of a major tsunami warning/tsunami warning
No: Vessels will not have sufficient time to make evacuation (to put the vessel in a safe state by offshore evacuation or landing and binding) following the release of a major tsunami warning/tsunami warning
Large-sized Vessels: Vessels unable to make self-leaving off the port without the assistance of support boasts (tugboats, etc.) and/or pilot service
Mid-sized Vessels: Other Vessels than Large Vessels or Small Vessels
Small Vessels: pleasure/fishing boats: They are small enough to be carried onto land and sheltered (excluding docking)
On-Terrene Evacuation: Crew members take refuge on terrene in high places, as high risk is predicted for in-vessel sheltering. Before leaving the vessel, complete securing-vessel-measures where possible, such as securing dangerous cargo and ensuring protection from vessel being swept away
Offshore Evacuation: Choose a wide area where water is deep and away from the coast (if face a difficulties in evacuation, re-choose in a port sheltering.)
In a port Sheltering: Sheltering in the emergency sheltering areas inside the port and resisting tsunami water power by means of anchors or using engines/thrusters
Mooring Sheltering: Resisting tsunami power while berthing by means of enhancement of berthing force or through the use of engines. (Acceptance of land workers seeking emergency shelters onboard should be considered)

Note: Procedures in table above should be understood as general measures. Specific measures should reflect the characteristics of the area (port) and tsunami action-manuals reflecting measures based on-studies of the port in question should be recommended to vessels. Furthermore, it is recommended for vessels to prepare tsunami action manuals in advance, which reflect the measures mentioned above.

3. Preparation of Tsunami Safety Measures

3-1. Information Delivery Means

In general, the time from an earthquake occurrence to the arrival of a tsunami is short. Thus, the key to the successful execution of Tsunami Safety Measures will be the prompt and proper delivery of correct information to the parties concerned. Therefore, the means, channels, and routes of information delivery must be prepared based on extensive studies; and the parties concerned must be fully informed.

In addition, the parties concerned must always have up to date information on individual vessels' behaviors or situations and must have prepared systems for keeping communication channels with vessels open in order to promptly and properly deliver accurate information.

Japan Coast Guard, in their disaster prevention action plans, outlines the following disaster-information delivery protocol:

[1] For anchoring vessels in areas close to tsunami-risk areas, send patrol boats or aircraft to visit and give guidance, or use other means such as loud-speakers or banners to inform them of the tsunami risk.

[2] For proceeding vessels, deliver disaster information via navigational warning/safety notice.

[3] For local residents or beach visitors in coastal areas at tsunami risk, send patrol boats or aircraft and inform them of tsunami risks via loud speakers or banners.

The prompt and proper delivery of correct information is the key to disaster prevention; therefore, the channels, routes, and effective means of delivering information must be set via the Tsunami Measures Conference.

Information delivery channels must be duplicated to protect against situations where communication infrastructures become unavailable. At the same time, it is important to keep non-Japanese seafarers informed of how tsunami behaves and how to prepare for tsunami.

Business operators, such as ship agents or fisheries cooperative associations, must always keep updated with information on their ships' behaviors and arrange secured means of communication effective under tsunami risk.

3-2. Evacuation Methods

(1) Agreement on prioritized evacuation order and assistance arrangement

Prioritized evacuation order, for the purpose of ensuring that vessels around the port evacuate promptly and safely, must be established. In addition, the arrangement of evacuation assistance—particularly required for large vessels (pilots, tugboats, mooring-line release workers, or others)—must have been established and agreed upon.

Prioritized Evacuation Order: the order of vessels' evacuation (offshore evacuation) in the event of expected tsunami strike must be prepared. Such orders must be determined considering the following:

- Port conditions or characteristics: what impact is expected on each of the quays in the port, which quay is expected to suffer the most severe damage, and what impacts are estimated on vessel-navigation areas and others.
- The severity of impact in the vicinity if the vessel is damaged.
- Kinds and extent of assistance vessels will require.
- The extent of difficulty vessels will have in navigation or maneuvering.

Because the risk of secondary disasters must be considered first, except in the case where the port-parties themselves are concerned, agreement must be made on the order in which evacuation will be carried out. The priority of evacuation should, in general, be ordered as below (but also considering port-specific conditions and follow the agreement if any).

[1] Vessels loaded with dangerous cargo (LNG tankers, large LPG tankers, or crude-oil tankers)

[2] Vessels carrying passengers on board

[3] Large vessels such as mega-ships

[4] Other vessels; they should evacuate in order of largest to smallest.

Fishing boats, working boats, or pleasure boats are allowed to un-berth for offshore evacuation by first-ready-first-go basis (boats can un-berth whenever they are ready to move), as they are operated with different conventions from those for general vessels; however, they are required not to interfere with large vessels maneuvering to unberth, or other vessels that are proceeding.

With regard to fishing ports, parties responsible for port management, such as Captain of the ports or fisheries cooperative associations or other organizations, are recommended to prepare plans for evacuation procedures or mooring enhancement, and to keep the skippers, crew members, and others that use the port well-informed of all plans.

Furthermore, with regard to evacuation assistance—e.g. by pilotage services, tugboats, mooring lines release workers—for large vessels for unberthing or other maneuvers, agreement on the emergency operations of that assistance must be agreed upon for the purpose of ensuring smooth evacuation of large vessels in accordance with evacuation prioritization.

In addition, measures applicable to situations where sufficient assistance cannot be expected must be prepared because through assistance—by even a single tugboat, or, if vessels are equipped, with thrusters—the likelihood of successful unberthing is increased.

Furthermore, the head of Coast Guard Office/Station (Captain of the port) must provide guidance for securing maritime safety when necessary.

(2) Agreements on voluntary evacuation measures, etc.

Agreements must be made in advance for the purpose of ensuring that vessels voluntarily take the Tsunami Safety Measures shown in the table even without having received recommendation of evacuation from the head of Coast Guard Office/Station (Captain of the port).

Although vessels, in general, will take actions following the evacuation-recommendation from the head of Coast Guard Office/Station (Captain of the port), there is still a risk that time will be taken for vessels to receive the recommendation because the Captain of the port, in principle, issues its recommendation after receiving tsunami information. There is also a risk that a vessel will fail to receive the recommendation due to trouble of communication infrastructure.

Therefore, vessels desirably should promptly take action following the Tsunami Safety Measures table even if they have not received recommendation of Captain of the port—not waiting for it—when getting tsunami information from TV broadcasts or other sources. For successful voluntary evacuation, agreement on vessels' voluntary evacuation must be made for individual ports. Port authorities, organizations, and other parties concerned must routinely have meetings or consult with one another to share information on what the tsunami measures table requires in the case of their specific port.

(3) Port re-entry after the cancelation of a recommendation

Vessels, when re-entering a port following the cancelation of an evacuation recommendation or other some such should pay attention to what damage port facilities may have suffered and note whether fairways have been cleared. In addition, if the chief of Coast Guard Office/Station (Captain of the port) has issued guidance or other statement, vessels must obey.

In general, evacuation or other recommendations are cancelled when tsunami warnings/advisories are cancelled. Vessels must pay as much attention as possible to the information on what if any damage the port facilities have suffered, whether the fairways have been cleared, what changes in water depth have occurred, and follow any traffic guidance given by the chief of

Coast Guard Office/Station (Captain of the port). In order to prevent traffic congestion caused by vessels heading to the entrance to re-enter, vessel should obey the traffic guidance which the Captain of the port may issue.

<<Appendix>>

These materials will be useful in exploring Tsunami Safety Measures in a port.

1. Characteristics of Tsunami

1-1. What is a tsunami?

Tsunami is induced by earthquakes that occur under the ocean bed. The ocean bed, rising/sinking/sliding, causes the upward/downward motion of the water around the location of the earthquake outbreak; and, such water motion generates tsunami waves. The amplitude of water-surface motion (up and down) becomes larger as the tsunami waves come closer to coast. The Japanese word "tsunami" is composed of "tsu" (meaning "port") and the word "nami" (meaning "wave"), combining to mean "extraordinary waves striking a port."

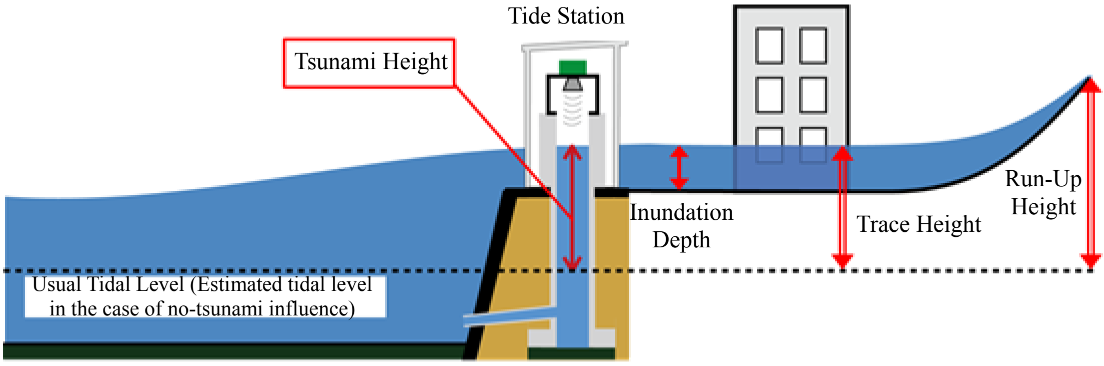
Tsunami generated at a distant coast (generally belonging to foreign countries), called "Far-field Tsunami," take a long time to arrive at the coast of Japan. On the other hand, tsunami generated near the coast of Japan, called "Near-field Tsunami", take a relatively shorter time to arrive.

(1) Tsunami height

Tsunami height is defined as the difference between the sea-level elevated by tsunami and the usual tidal level. Table 1 shows the definition for terms that characterize a tsunami/tsunami incident. Figure 1 shows an illustration representing the relations between those terms. Figure 2 shows how the sea level varies due to a tsunami; and at the same time the tsunami period and tsunami height.

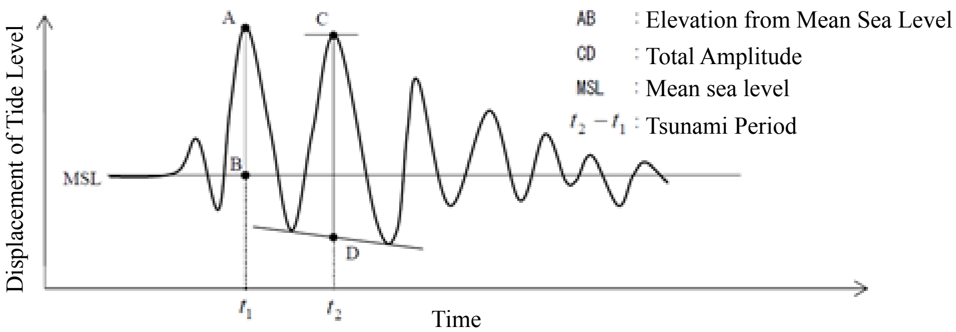
Table 1: Tsunami Terminology

Usual Tidal Level	Predicted tide level, based on an analysis of past observations of tide level (Astronomical Tide Level). This corresponds to the tide level that is expected if a tsunami does not strike.
Tsunami Height	Elevation of the sea level raised by tsunami measured from the usual tidal level.
Inundation Height	Water depth in tsunami flooded area: water surface elevation measured from the ground
Tsunami Trace Height (Run-up Height plus Inundation Height)	Elevation of tsunami trace measured from usual tidal level: it consists of the run-up height and the inundation height of tsunami
Wave Height	The difference in the elevations of the consecutive water-level rise (crest) and fall (bottom): total amplitude



Source: Meteorological Agency Web Pages

Figure 1: Illustrated Relation of the Terms Related to Tsunami Flood



Source: Japan Weather Association Web Pages

Figure 2: Height and Period of Tsunami

(2) Magnitude of Tsunami

Table 2 shows the "Imamura-Iida Tsunami Magnitude"—tsunami magnitude ("m") class—determined through consideration of tsunami height at coastal regions and the length of the coast where tsunami damages have been observed.

Table 2: Tsunami Magnitude Scale (Imamura-Iida Scale)

Magnitude Scale	Tsunami Height	Total Energy (10^{22} erg)	Damage Severity
− 1	Lower than 0.5 m	0.06	No damage
0	Approx. 1 m	0.25	Very limited
1	Approx. 2 m	1	Coastal areas and ships
2	Approx. 4 to 6 m	4	Limited damage on inland areas; casualties
3	Approx. 10 to 20 m	16	Significant damages along the coast line: total length of 400 km or more
4	Higher than 30 m	64	Significant damages along the coast line: total length of 500 km or more

Hatori has proposed a tsunami-magnitude formula as shown below that produces a tsunami magnitude consistent with Imamura-Iida scale: the formula, using both tsunami run-up height at the coast close to tsunami-wave origin and tide level records obtained over a wide area.

$$m = 2.7\log H + 2.7\log\Delta - 4.3 \qquad (1.1)$$

where

Δ(km): ocean-surface direct distance from epicenter to observation point on the ocean surface. Note: the formula is effective for the distance range of 20 to 2,000 km.

H(cm): the maximum total-amplitude of the variations in tide-levels and tsunami trace height observed at the distance of Δ.

On the other hand, Abe has introduced another scale, “Mt” which is represented by the formula shown below; Mt is also referred to as “tsunami magnitude.”

$$Mt = \log H + \log\Delta + 5.55 \qquad (1.2)$$

where

Δ(km): ocean-surface direct distance from epicenter to observation point on the ocean surface,

H(m): the maximum tide level observed at the point of distance Δ. It correlates with tsunami magnitude at wave origin and the magnitude of fault motions that caused the earthquake.

Those two magnitudes, “Mt” and “m,” can be converted to each other through the following equation:

$$Mt = 0.37m + 7.1 \qquad (1.3)$$

1-2. Conditions of Tsunami Generation

(1) Generation mechanism

Tsunami is generated by earthquakes; an earthquake occurs when the rock ground breaks apart to form faults. Faults are categorized as shown in Figure 3.

Note the following remarks when considering tsunami generation:

・Tsunami are likely to break-out when a dip-slip fault, reaching the ocean bed, causes ocean-bed displacement

・There are many dip-slip faults found in the ocean around Japan; therefore, it is recommended to consider tsunami risk when an earthquake occurs in the ocean area.

・Note that an earthquake, even if its magnitude is small, can cause a big tsunami—this is often called a "tsunami earthquake."

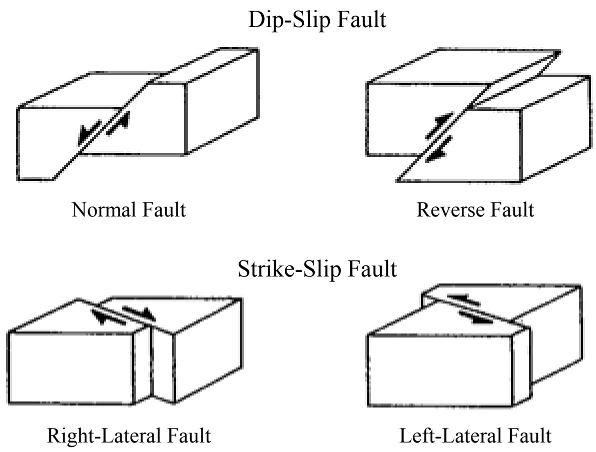


Figure 3: Types of Fault

In addition, tsunami can occur due to a vast amount of sediment falling into water, a volcanic eruption, or a meteor strike.

(2) Focal depth of an earthquake

Tsunami are induced by the movements of an ocean-bed rock ground with a vast amount of energy sufficient to shake the entire block of water from the bottom to the surface; therefore, an earthquake with a deeper focal point is less likely to cause a tsunami.

As a matter of fact, the analysis of historical earthquake records led to the following conclusions: an earthquake with a focal depth deeper than 80 km rarely causes a tsunami; an earthquake with a focal depth of 50 to 80 km causes a relatively small tsunami; and, an earthquake with a focal depth of 50 km or shallower causes a large tsunami. A Tokai earthquake or To-Nankai/Nankai earthquake, which is predicted to occur in near future, unfortunately, is expected to occur at a relatively shallow point under the ocean bed.

1-3. Tsunami Dynamics

1-3-1. Propagation

Tsunami waves, because they go through water, travel much more slowly than earthquake ground-motions; therefore, tsunami arrives later than the earthquake in the case the epicenter occurs far away.

In addition, because of their long wavelengths tsunami travel far with almost no dissipation, conversely earthquake attenuate by distance.

Tsunami propagation velocity (wave velocity) is represented by the equation below:

$$V = \sqrt{gH} \quad (1.4)$$

where

V: Wave Velocity (m /sec)

g: Gravitational Acceleration (9.8 m/sec^2)

H: Water Depth (m)

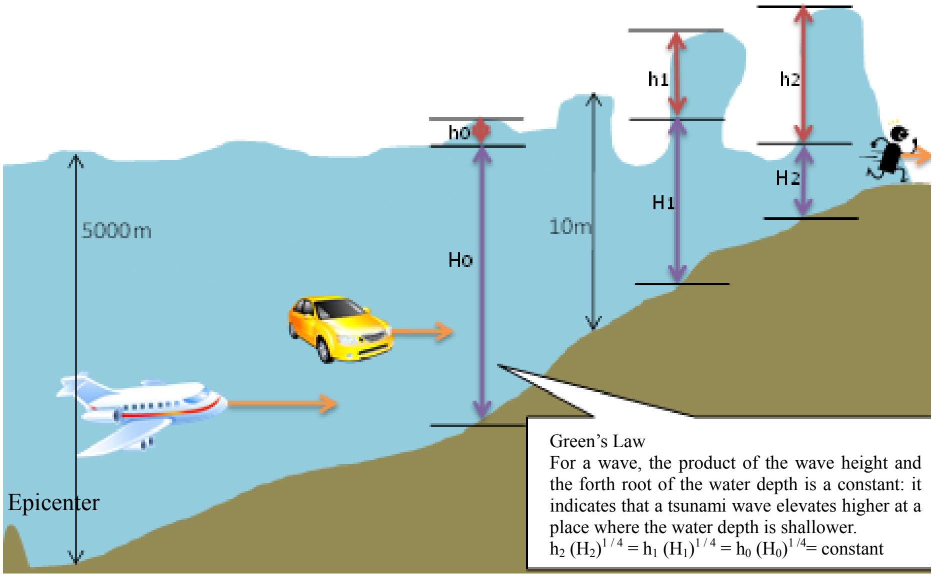
Tsunami waves, as they are reaching shallow areas, increase in elevation, which is represented by the equation below; it is called “Green’s Law.” Refer Figure 4.

$$h \propto 1/\sqrt[4]{H} \quad (1.5)$$

where

H: Water Depth (m)

h: Wave Height (m)

Water Depth	5,000 m	500 m	50 m	10 m	1 m
Wave Height	1.0 m	1.7 m	3.2 m	4.7 m	8.4 m
Propagation Velocity (Wave Celerity)	800 km/hour	250 km/hour	80 km/hour	36 km/hour ≒ 19knot	11 km/hour≒ 5 knot
Illustrated Relations of Parameters					

* A wave which has experienced a rise in its elevation of 1.0 m at a place where the water depth was 5,000 m elevates to the level of 8.4 m at a place where the water depth is 1 m.

Figure 4: Relation of Water Depth to Tsunami Wave Height/Velocity

1-3-2. Flow speed of Tsunami Water

Flow speed of tsunami water (water particle velocity) while the tsunami is proceeding is represented by the equation shown below.

$$U = \eta \cdot \sqrt{g/H}$$

where

U: Flow Speed of Tsunami Water (m/sec)

η : Elevation measured from Still-Water Level (m)

g : Gravitational Acceleration (9.8 m/sec^2)

H: Water Depth (m)

Tsunami water, for example in the instance of a 2 m high tsunami at a water depth of 10 m, flows approximately at a speed of 2 m/sec. It flows faster in places where the water depth is shallower, if the wave height is assumed to be constant.

1-3-3. Period of Tsunami Wave

The period of a tsunami wave varies depending on the following: the geographical conditions of the area where the tsunami was caused, such as the dimensions of the area or water depth; conditions of tsunami wave propagation, such as the distance from tsunami origin area; and, geography of the place struck by the tsunami, such as the topology of the bay.

The wave length of a tsunami is represented by the product of the wave velocity and period, as shown in the equation below.

$$L = T \cdot V \qquad (1.6)$$

where,

L: Wave Length (m)

T: Period (sec)

V: Wave Velocity (m/sec)

Note:

・Tsunami period, in general, tends to be shorter at points where it is closer to the epicenter and longer at points where it is further.

・Tsunami period, in general, is in the range of a few minutes to a few tens of minutes.

・The specific periods of the bays often seen in Japan are also in the range of a few minutes to a few tens of minutes; therefore, there is a risk that tsunami waves, resonating with the bay, will elevate higher than predicted.

・With regard to a Tokai earthquake, its tsunami periods are estimated to be approximately 5 to 15 minutes.

1-3-4. Deformation of Tsunami

In general, ground displacement and initial tide-level displacement caused by an earthquake, being correlated with each other, share values of similar magnitude. On the other hand, tsunami heights at coast, being uncorrelated with initial ground displacement, can have values that differ in the extreme from area to area.

(1) Influence of water-channel width

The wave-elevation of a tsunami that is proceeding in a bay with a geographical configuration where the width becomes progressively narrower along its length from the entrance to the far end will get higher according to the equation shown below.

$$h \propto 1/\sqrt{W} \qquad (1.7)$$

where,

h: Wave Elevation

W: Bay Width (assumed that the water depth is constant)

(2) Seiche (resonance effect)

Tsunami-wave amplitude grows at an accelerated pace when the period of tsunami-wave is close to the periods of the tide-level oscillations that are likely to happen in port areas or bay: this is referred to as "seiche" (resonance effect).

Long bays—with a relatively long depth compared with its width—are prone to resonate with far-field tsunami such as Chilean Tsunami. On the other hand, short bays are prone to resonate with near-field tsunami.

(3) Bore (staircase wave)

Staircase waves that resemble bores which are often seen at a large-river mouth caused by the rising tide at spring tide have been observed as being caused by tsunami. Such staircase tsunami-waves are known for having fierce destructive power.

(4) Tsunami-wave refraction

Tsunami waves reduce their velocity in shallow waters and change their direction in such a way as to encircle the area of shallow waters. Thus, those tsunami waves can increase in elevation after passing such shallow waters.

(5) Tsunami-wave diffraction

A tsunami wave that is proceeding in shallow waters propagates slower than when proceeding in deep waters. Hence, tsunami waves, after passing shallow waters, change their course in such a way as to encircle the shallow waters, in a manner similar to a light ray being diffracted by a convex lens. Thus, tsunami waves can increase in elevation after passing shallow waters.

1-3-5. Forwarding/Back-drawing of Tsunami

A tsunami is referred to as "forwarding" when the sea level is rising and as "back-drawing" when the sea-level is falling, at the time of the tsunami's arrival (the first tsunami strike). In general, in the event of an earthquake, the ocean-bed, rising in some places and falling in others, raises or pulls-down the ocean surface. Whether a tsunami initially hits the coast while forwarding or drawing back depends on the distribution of ridges and troughs at the source and the relative distance to the shore.

A tsunami, after striking a coast, goes back toward offing with their offing-end portion going first, due to the slope of the water surface.

While the tsunami goes back toward offing, because the ground elevation is lower along the tsunami retreating direction, the surface of the out-bound water is allowed to go down further and make the front slope of out-bound tsunami steeper. Hence, the water flow of the tsunami gains flow speed when the tsunami is retreating.

In addition, it must be noted that tsunami back-drawing lasts a relatively long time.

2. Past Tsunami-Damages

2-1. Tsunami Incidents

Details of major tsunami and damages occurred in the past along the coast or in the vicinity of Japan are listed in Table 3.

Table 3: Major Tsunami of Japan

Date of Occurrence	Area of Tsunami Origin	Magnitude		Damaged Areas	Casualties (Number of Deaths)
		Earthquake	Tsunami Scale		
Nov. 29, 684	Tokai/Nankaido Offing	8.4	3	Tokai to Nankaido	
Jul. 13, 869	Sanriku Offing	8.6	4	Sanriku	1,000
Aug. 26. 887	Kii Offing	8.6	3	Shikoku/Kii/Osaka	
Dec. 17, 1096	Tokai Offing	8.4	3	Suruga/Ise	
Feb. 22, 1099	Nankaido Offing	8	3?	Nankaido	
Aug.3, 1361	Kii Offing	8.4	3	Shikoku/Osaka	
Sep.20, 1498	Tokai Offing	8.6	3	Tokai/Ise/Kanto	5,000
Feb. 3, 1605	Boso/Nankaido Offing	8	3	Tokai/Nankaido/Boso	3,800
Dec. 2, 1611	Sanriku Offing	8.1	4	Sanriku/Hokkaido	6,800
Nov.3, 1677	Boso Offing	8	3	Miyagi to Boso	500
Dec.31, 1703	Near Boso	8.2	3	Southern Area of Kanto	5,233
Oct. 28, 1707	Tokai/Nankaido Offing	8.4	4	Tokai/Nankaido/Osaka	4,900
Aug. 29, 1741	South East Offing of Hokkaido	7.5?	3	Oshima/Tsugaru/Sado	1,467
Apr. 24, 1771	Ishigakijima Offing, Okinawa	7.4	4	Ishigakijima/Miyakojima	11,861
Dec. 23, 1854	Tokai Offing	8.4	3	Tokai/Ise/Kumano	900
Dec 24, 1854	Nankaido Offing	8.4	3	Nankaido/Osaka	3,000
Jun. 15, 1896	Sanriku Offing	7.6	3 to 4	Sanriku/Hokkaido	27,172
Mar. 3, 1933	Sanriku Offing	8.3	3	Sanriku/Hokkaido	3,008
Dec. 7, 1944	Kumano-Nada	8	2.5	Mie	998
Dec. 21, 1946	Kii Offing	8.1	2.5	Shikoku/Wakayama	1,330
May 24, 1960	South Offing of Chile	9.4	4	Whole of Pacific Coast of Japan	142
May 26, 1983	Akita/Aomori Offing	7.7	3	Tohoku/Hokkaido	100
Jul. 12, 1993	South West Offing of Hokkaido	7.8	3	Okushiri-Island/Hokkaido	230
Mar. 11, 2011	Tohoku/Kanto Offing	9	4	Aomori to Ibaraki	Approx. 20,000

Source: "Natures and Disasters of the Sea," by Sanae Unoki

2-2. Tohoku Pacific-Offing Earthquake

The following is the summary of the Tohoku Pacific-Offing Earthquake (Widely known as "the Great East Japan Earthquake"), based on releases by the Meteorological Agency:

1. Summary of the Earthquake (by the Meteorological Agency)

2011 Tohoku Pacific Offing Earthquake

(1) Date of Occurrence: Around 14:46 , March 11, 2011

(2) Source and Magnitude (estimated)

Location: Sanriku Offing (38.1 degrees N, 142 degrees E, at around 130 km ESE of Oshika-Peninsula), approx. 24 km deep

Magnitude: Mw 9.0 (Moment Magnitude)

Fault Dimensions: Approx, 450 km long and 200 km wide

Fault Slip-Distance: Approx. 20 to 30 m (maximum)

Ocean-Bed Displacement (directly above the earthquake source):

Approx. 24 m to ESE, Approx. 3m Lift (Japan Coast Guard's Releases: April 6, 2011)

(3) Seismic Intensity Observations

The intensity observations of more than upper-5 are listed below:

Intensity 7	: Northern Miyagi
Intensity 6 upper	: Southern/Middle Miyagi; Naka-dori/Hama-dori, Fukushima; Northern/Southern Ibaraki; Northern/Southern Tochigi
Intensity 6 lower	: South Coast/Northern Inland/Southern Inland, Iwate; Aizu, Fukushima; Southern Gunma: Southern Saitama; North-West Part of Chiba
Intensity 5 upper	: Sanpachi-Kamikita, Aomori; Northern Coast, Iwate; Southern Coast/Inland, Akita; Murayama/Okitama, Yamagata; Northern Gunma; Northern Saitama; North-East Part/South Part of Chiba; Tokyo's 23 Wards; Niijima-Island, Tokyo; Eastern Kanagawa;

Middle/West Part of Yamanashi;
Eastern/Fuji-Five-Lake Area, Yamanashi

(4) Tsunami

- 1449 hrs, March 11: Major Tsunami Warning Issued
- 1758 hrs, March 13: All warnings/advisories, Cancelled

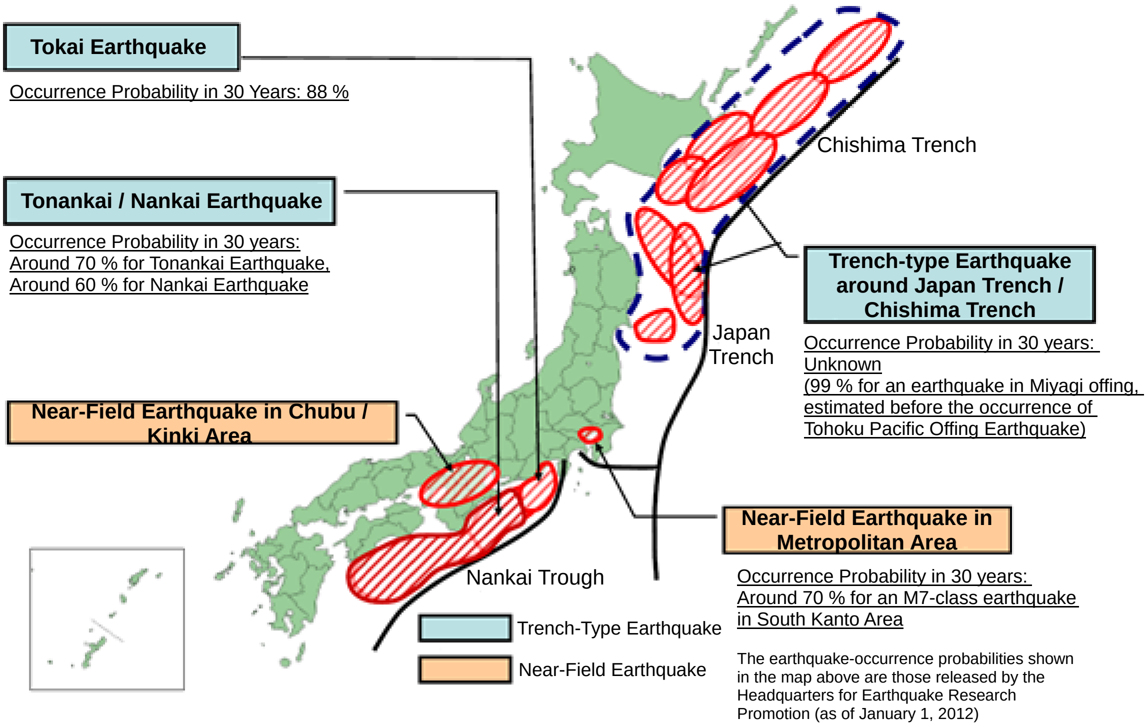
Tsunami Observations (at Tide Stations)

Shoya, Erimo:	3.5 m Maximum, at 1544 hrs
Miyako:	8.5 m or over Maximum, at 1526 hrs
Ofunato:	8.0 m or over Maximum, at 1518 hrs
Kamaishi:	4.1 m or over Maximum, at 1521 hrs
Ayukawa, Ishinomaki:	7.6 m or over Maximum, at 1525 hrs
Soma:	9.3 m or over Maximum, at 1551hrs
Oarai:	4.2 m Maximum at 1652

Source: Compiled from "Handout 1 at the May 28, 2011, 1st Expert Panel on Earthquake/Tsunami Measures Reflecting the Lessons of Tohoku Pacific Offing Earthquake"

3. Earthquakes Predicted in Future

Figure 5 shows the earthquakes that have been subjected to discussion at the Central Disaster Prevention Council. Their future occurrence in the vicinity of Japan has been predicted.



Source: Cabinet Office Webpages

Figure 5: Large-Scale Earthquakes Subjected to Discussion at the Central Disaster Prevention Council

4. Understanding of Mooring Criteria (Critical Conditions)

Table 4 shows the mooring criteria presented at the "Research Committee of Navigation safety Measures at the time of tsunami strike" (held in FY2012 and 2013). The criteria were derived from the output of simulations on quay models and vessels (large vessels carrying dangerous cargo (VLCCs and LNG tankers) and general vessels (10,000 DWT-class and 3,000 DWT-class) moored at the quays) for the various values of tsunami height or flow speed.

Summary:

The simulations were conducted for determining mooring criteria on a port model (Shimizu Port was used as the model) applying hypothetical waves of tsunami wave-form or sine waves. The derived mooring criteria of tsunami height are approximately 1 to 3 meters for VLCCs or large LNG tankers, and approximately 3 to 6 meters for 10,000 or 3,000 DWT-class vessels.

The findings of these tsunami simulations, where various tsunami waves—hypothetical tsunami-waves or sine waves (period of 5, 10, and 15 minutes)—of different combinations of wave-height and flow speed were applied to the Shimizu-Port model. The findings were as follows:

(a) Mooring criteria for tsunami height goes down when the effect of flow speed, in addition to that of tsunami height, is not negligible;

(b) Mooring criteria gets lower for a shorter tsunami period; it indicates that the rapid rate of water-level rise, as well as the tsunami height, influences the mooring criteria.

With regard to the conditions—sea-level lift or the form (tsunami wave or sine wave)/amplitude/ period of tsunami—where the mooring force of model ships reaches its critical values, the results of the simulations are summarized as follows:

For VLCCs or large LNG tankers, in the case where waves of tsunami wave-form were applied, the mooring force reaches its critical value for the sea-level lift of 3 meters in the direction of ship center-line, and for the sea-level lift of 1 meter in ship-beam direction. In the case where sine waves are applied, the mooring force reached its critical value for waves of amplitude of 1 meter and a period of 5 minutes; for waves of amplitude of 2 meters and a period of 10 minutes; and, for a wave of amplitude of 3meters and a period of 15 minutes.

For 10,000 DWT or 3,000 DWT-class vessels, in the case where waves of tsunami wave-form are applied, the mooring force reached its critical value for sea-level lift of 6 meters in ship center-line direction; and in the case where sine waves were applied, the mooring force reached its critical value for waves of amplitude of 3 meters and a period of 10 minutes and for the waves of amplitude of 6 meters and a period of 10 or 15 minutes.

When the mooring criteria are applied to practical situations, the following should be noted:

In general, the period of tsunami wave is within the range of several minutes to several tens of minutes, and tends to become shorter as the observation point comes closer to the wave source—meaning that the rate of water level rise is larger, and longer as the observation point gets further away— meaning that the rate of water level rise is smaller.

Take the Nankai Trough Earthquake as an example: the three major bays, Tokyo Bay, Ise Bay, and Osaka Bay, are far enough away from the possible earthquake source so that the periods of tsunami will be longer. This means that the rate of water-level rise will be small. Consequently, mooring criteria are expected to be larger than the values shown above.

In addition, it should be noted that the mooring criteria introduced above were derived from simulation output based on the assumptions that vessels are moored by regular mooring methods. Therefore, in actual situations, the measures for enhancing mooring forces, such as the addition of mooring lines, particularly breast lines/spring lines, and tightening of the mooring-drum brakes, are expected to raise the mooring criteria (critical values).

Figure 6 shows "Critical Conditions Causing Spring-Line Break-Downs," presented in the "Research Report on the Measures for Securing Vessels in a Situation of Tsunami Risks" released in FY2003; the diagram shows the critical water-level lift and the critical tsunami-water flow-speed, for different types of vessels that are moored by usual mooring methods and suffering water-level lift and flow pressure at the same time, due to a tsunami of a period of 10 minutes.

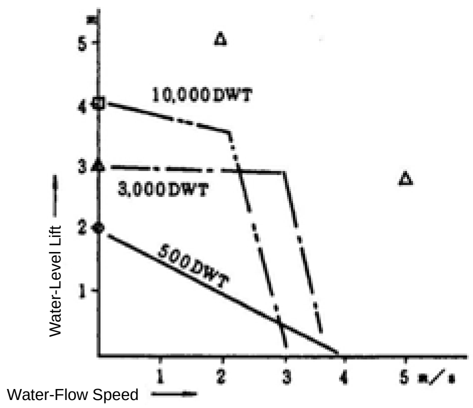
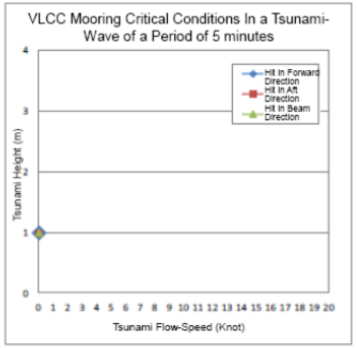
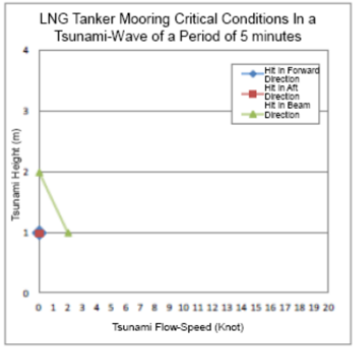
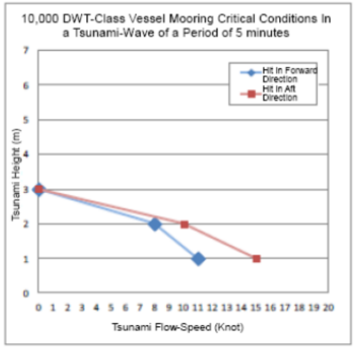
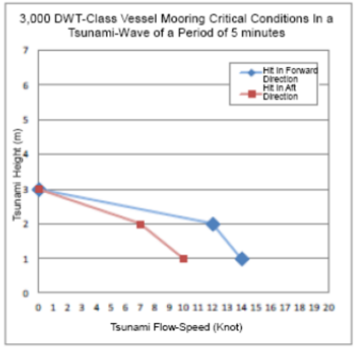
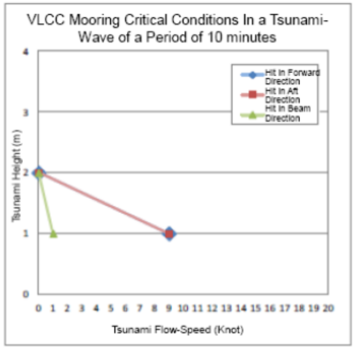
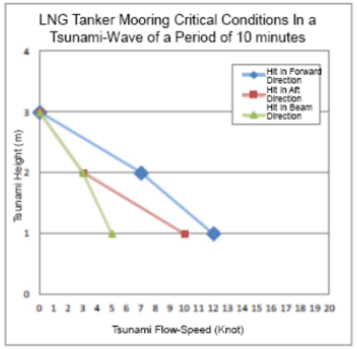
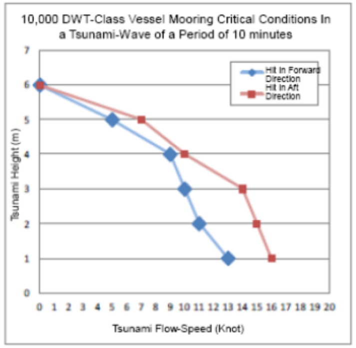
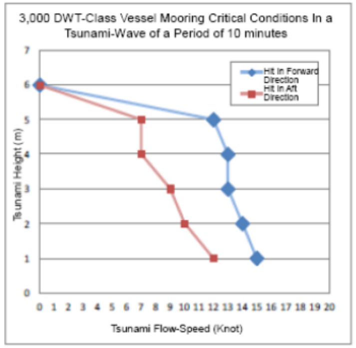
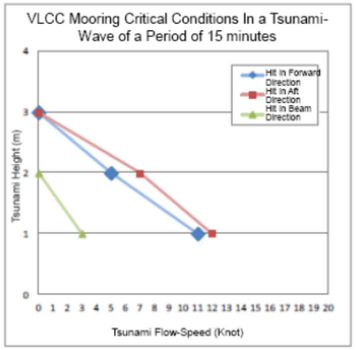
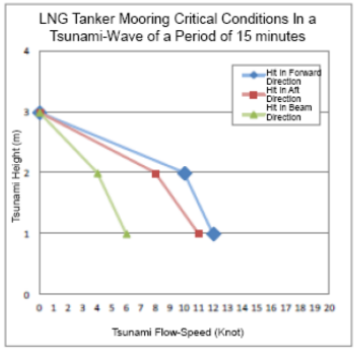
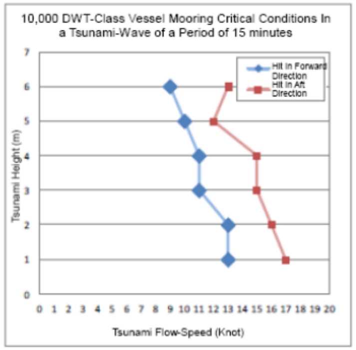
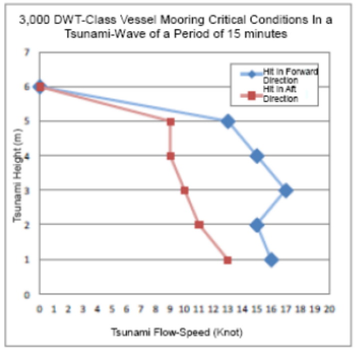


Figure 6: Critical Conditions for Causing Spring-Line Break-Down

Table 4: Mooring Critical Conditions of Vessels Caused by Hypothetical Sine-Wave Tsunami

	VLCC	Large LNG Tankers	10000DWT	3000DWT
Tsunami Period: 5 minutes				
Tsunami Period: 10 minutes				
Tsunami Period: 15 minutes				

5. Understanding of Anchoring Criteria (Critical Conditions)

In addition to the mooring criteria previously described, the "Research Committee of Navigation safety Measures at the time of tsunami strike" held in FY2012 and 2013 presented the "Anchoring Criteria" (critical conditions for anchoring). The criteria were derived from calculations of critical tsunami-flow speed, at which the external force that the tsunami places on the vessel overcomes the anchor force and the vessel begins to move dragging its anchors. The criteria (critical conditions) are presented below and summarized in Table 5 and Table 6. Equation 2-1 and Equation 2-2 are the equations that were applied to the calculations of such critical conditions; the parameters that were set for the calculations are summarized in Table 7.

Conclusions:

In the case where an anchoring vessel is hit by tsunami, the critical conditions for anchoring are the following: tsunami-water flow speed is approximately 3 to 6 knots, and approximately 2 to 4 knots on the assumption that swinging angle is supposed to 15 degrees.

Table 5: Anchoring Criteria for Tsunami-Water Flow Speed

Unit: knots

			500DWT	3,000DWT	10,000DWT	30,000DWT	60,000DWT	200,000DWT	100,000DWT	300,000DWT
			General Vessel	General Vessel	General Vessel	General Vessel	General Vessel	General Vessel	Vessels Carrying Dangerous Cargo (LNG Tanker)	Vessels Carrying Dangerous Cargo (VLCC)
Tsunami Height: 0 meters	Anchor: JIS-Type	Mud	4.62	4.02	3.60	3.38	3.15	3.17	3.28	3.28
		Sand	4.83	4.21	3.77	3.54	3.29	3.32	3.45	3.43
	Anchor: AC14-Type	Mud	(6.70)	5.87	5.24	4.91	4.53	4.57	4.75	4.73
		Sand	(5.72)	5.00	4.47	4.20	3.89	3.92	4.08	4.06
Tsunami Height: 5 meters	Anchor: JIS-Type	Mud	4.51	3.93	3.53	3.31	3.10	3.12	3.23	3.23
		Sand	4.74	4.14	3.72	3.49	3.25	3.28	3.41	3.39
	Anchor: AC14-Type	Mud	(6.59)	5.77	5.16	4.84	4.48	4.51	4.70	4.67
		Sand	(5.63)	4.93	4.41	4.14	3.85	3.88	4.04	4.02

Table 6: Anchoring Criteria for Swinging Situation

Unit: knots

			500DWT General Vessel	3,000DWT General Vessel	10,000DWT General Vessel	30,000DWT General Vessel	60,000DWT General Vessel	200,000DWT General Vessel	100,000DWT Vessels Carrying Dangerous Cargo (LNG Tanker)	300,000DWT Vessels Carrying Dangerous Cargo (VLCC)
Swing: 0 deg	Anchor: JIS-Type	Mud	4.51	3.93	3.53	3.31	3.10	3.12	3.23	3.23
		Sand	4.74	4.14	3.72	3.49	3.25	3.28	3.41	3.39
	Anchor: AC14-Type	Mud	(6.59)	5.77	5.16	4.84	4.48	4.51	4.70	4.67
		Sand	(5.63)	4.93	4.41	4.14	3.85	3.88	4.04	4.02
Swing: 5 deg	Anchor: JIS-Type	Mud	4.20	3.66	3.29	3.08	2.88	2.90	3.01	3.00
		Sand	4.41	3.85	3.46	3.25	3.03	3.05	3.17	3.16
	Anchor: AC14-Type	Mud	(6.14)	5.37	4.81	4.51	4.17	4.21	4.38	4.35
		Sand	(5.25)	4.59	4.11	3.86	3.58	3.61	3.76	3.74
Swing: 10 deg	Anchor: JIS-Type	Mud	3.54	3.08	2.77	2.60	2.43	2.45	2.53	2.53
		Sand	3.72	3.25	2.91	2.73	2.55	2.57	2.67	2.66
	Anchor: AC14-Type	Mud	(5.17)	4.52	4.05	3.80	3.51	3.54	3.69	3.67
		Sand	(4.42)	3.86	3.46	3.25	3.02	3.04	3.17	3.15
Swing: 15 deg	Anchor: JIS-Type	Mud	2.98	2.60	2.34	2.19	2.05	2.06	2.14	2.14
		Sand	3.14	2.74	2.46	2.31	2.15	2.17	2.26	2.25
	Anchor: AC14-Type	Mud	(4.36)	3.82	3.42	3.20	2.97	2.99	3.11	3.09
		Sand	(3.73)	3.26	2.92	2.74	2.55	2.57	2.68	2.66

Note: In the table above, the parenthesized values are shown for a 500 DWT-class vessel with AC14-type anchors, only for the purpose of comparing them to those of other combinations of vessel-class and anchor-type; however, it is rare for a 500 DWT-class vessel to have AC14-type anchors.

[Equation for Vessel Holding Power]

$$P = \omega_a \cdot \lambda_a + \omega_c \cdot \lambda_c \cdot l \qquad \text{(Eq. 2-1)}$$

where

P (tons): Vessel Holding Power

(calculate Tsunami Flow Speed (V) assuming P as Fx)

ωa(tons)：Anchor Weight

λa：Anchor Holding Power Coefficient

ωc（tons /m）：Unit Anchor-Cable-Weight (tons/m)

λc：Anchor-Cable's Frictional Resistance Coefficient

l(m): Anchor-Cable's Contact Length to the Bottom

Source: "Navigation Handbook" by Keinosuke Honda

[Equation for Fluid Pressure]

$$F_x = C_{xc} \cdot (\rho_c / 7600) \cdot Lpp \cdot D \cdot V^2 \qquad \text{(Eq. 2-2)}$$

where

Fx(tons)：Tsunami Fluid Pressure on the Hull Front-Surface

C_{xc}：Longitudinal Fluid Pressure Coefficient

ρ_c（$kg \cdot sec^2/m^4$）：Water Density（=0.1248）

Lpp（m）：Length Between Perpendiculars

D（m）：Draft

V（m/sec）：Tsunami Flow Speed

Source：Prediction of Wind and Current Loads On VLCCs（by OCIMF）

With regard to the behaviors and characteristics of an anchor while the vessel is anchoring, the research so far has reported the following:

(a) JIS-type ship anchors, after moving on the bottom for a distance of 10 to 20 times longer than its fluke length, are prone to tumble upside-down with its flukes up off the bottom. Here the anchor's holding power coefficient is drastically decreased and the vessel is likely to move dragging its anchors. (see Ref. (1))

(b) Ship anchors, for example AC14-type anchors, that have stabilizers with proper areas, after moving for a distance approximately 6 times longer than its fluke length with any attitude on the bottom, easily cut into the bottom to gain stability and the state of maximum holding power is secured. (see Ref. (2))

(c) Anchor holding power depends on characteristics and strength of the sea bottom. Sand bottom will, as easily predictable, lends very low holding power to an anchor. On the other hand, mud bottom, because its dynamic characteristics heavily depend on the stiffness of mud, gives an extremely strong grip to an anchor in some cases, and insufficient grip in other cases. (see Ref. (3))

<<References>>

(1): URA, Tamaki; and YAMAMOTO, Yoshiyuki: "A Basic Study on the Stability of Anchors": Journal of the Society of Naval Architects of Japan; Vol. 140, 1976; pp. 279-285

(2): URA, Tamaki; and YAMAMOTO, Yoshiyuki: "A Basic Study on the Stability of Anchors (3 rd Report)": Journal of the Society of Naval Architects of Japan; Vol. 146, 1978; pp. 196-200

(3): URA, Tamaki: "How can we rely on anchors? (1st)": Kaigi-to-Juken (Maritime Technology and Ship Officer's Certification Test Preparation): No.1, 1981; pp. 34-39

Table 7: Parameter Settings for Calculating Vessel Holding Power

Vessel Class (DWT)	500	3,000	10,000	30,000	60,000	200,000	100,000	300,000
Vessel Type	General Vessel	General Vessel	General Vessel	General Vessel	General Vessel	General Vessel	Vessel Carrying Dangerous Cargo (LNG Tanker)	Vessel Carrying Dangerous Cargo (VLCC)
Length (m)	50	80	113	170	200	300	315	333
Length Between Perpendiculars (m)	45	75	107	164	190	292	302	324
Molded Breadth (m)	11	13	19	27	32	50	50	60
Molded Depth (m)	5	6	10	14	18	24	27	29
Bell-Mouth Height (m) *1	1	0.5	1	2	2.5	3	7.5	4.3
Full-Load Draft (m)	3	5	8	10	13	18	12	20.5
Gross Tonnage (GT)	460	1,600	6,000	18,000	35,000	102,000	135,000	160,000
Full Load Displacement (MT)	1,100	3,700	13,500	36,800	51,700	235,600	143,400	342,000
Longitudinal Fluid Pressure Coefficient *2	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Weight of JIS-type Anchor (kg) *3	900	1,920	3,540	6,000	7,800	16,900	12,900	23,000
Weight of AC14-type Anchor (kg) *3	675	1,440	2,655	4,500	5,850	12,675	9,675	17,250
Unit Anchor Cable Weight (kg/m)	12.6	25.3	46.3	78.8	101.3	219.0	165.8	299.8
Holding Power Coefficient of JIS-type Anchor (Sand/Mud) *5	3.5/3.0	3.5/3.0	3.5/3.0	3.5/3.0	3.5/3.0	3.5/3.0	3.5/3.0	3.5/3.0
Holding Power Coefficient of AC14-type Anchor (Sand/Mud) *5	7/10	7/10	7/10	7/10	7/10	7/10	7/10	7/10
Frictional Resistance Coefficient (Sand/Mud) *6	0.75/1.0	0.75/1.0	0.75/1.0	0.75/1.0	0.75/1.0	0.75/1.0	0.75/1.0	0.75/1.0
Length of Anchor Cable (m) *7	135	135	150	150	180	180	180	180
Water Depth (m)	15	15	20	20	30	30	30	30
Draft to Water-depth Ratio (Full-Load Draft/Water Depth)	5.0	3.0	2.5	2.0	2.3	1.7	2.5	1.5

Notes:
*1: Calculated on the assumption that the bell-mouth height is (molded depth – full load draft)/2.
*2: Referencing the OCIMF-proposed longitudinal fluid-pressure coefficient at the relative flow direction (bearing angle from ship bow) of 0 degrees
*3: Referencing the anchor weight designated in C27.1 of Class NK. The weight of an AC14 type anchor is assumed (as a high holding-power anchor) to be 75 % of a JIS-type anchor.
*4: Calculated by applying the value of a cable diameter derived through referencing the nominal diameter “d_c” specified in C27.1 of Class NK to the anchor-cable unit weight (kg/m) formula specified in JIS F 3303 (chain specification), $W = 0.0219\ d_c^2$, where W is the anchor-cable unit weight (kg/m), and d_c is the nominal diameter of anchor cable.
*5: Using, as a reference, the nominal value of holding-power coefficient for an anchor of different type shown in the “Navigation Handbook.”
*6: Using, as a reference, the frictional resistance coefficients of sand or mud against a vessel in a holding state, which are shown in the “Navigation Handbook”
*7: Calculated by using an equation for the determination of anchor cable length for a vessel to anchor—S = 3D + 90, where “S” is the anchor-cable length in meters and “D” is the water depth in meters; the formula is shown in the “Navigation Handbook.”

6. Guide to the Estimation of Critical Maneuvering Conditions

When a vessel is caught in a situation where it is hit by tsunami waves, it is important to be able to judge whether it can afford to make a sheltering in the offing. Thus it is important to know the impact tsunami waves will have on a vessel proceeding in relatively shallow waters inside/outside port toward the offing to evacuate. For instance, the vessel may risk touching bottom because the occurrence of touching bottom depends on the height of back-drawing tsunami, the vessel's draft, or water depth. Alternatively, the vessel may lose control or be put into a situation where it has to override breaking waves.

(1) Rough estimation on the critical conditions for course keeping

Figure 7 shows the results of calculations on critical tsunami-wave relative direction and flow speed within the range marked-out by the line showing the relation between the critical tsunami relative direction-angle and the flow speed. A vessel trapped in tsunami in this way may be able to maintain its course, given the following assumptions:

The vessel is an general cargo vessel;

The tsunami, coming diagonal onto the vessel's bow, causes a rotational moment on the vessel;

The vessel, using its rudder, tries to keep its course;

The vessel uses its usual rudder angle of 15 degrees, because it has to leave room for rudder angle so that it is able to change, as well as to keep, its course;

Tsunami flow speed is represented by its ratio to the vessel speed, because, against a tsunami wave of the same flow speed, a vessel proceeding at a faster speed is able to easily keep its course.

Note: A tsunami wave with a height of 2 meters, when travelling in water of a depth of 10 meters, will flow at a speed of 1.98 m/s (approx. 3.85 knots). The diagram indicates that a vessel proceeding at 11.55 knots—3 times faster than that of tsunami flow speed—will be unable to keep its course by a steering of a rudder angle of 15 degrees, against a tsunami coming from the direction angle of 78 degrees. An angle of 7 to 8 degrees is similar to the heading fluctuation, even in a normal situation, that vessels, when proceeding straight with an attitude of receiving waves from a diagonal direction, are likely to experience. Therefore, vessels in tsunami waves are recommended to proceed at a faster speed and as parallel as possible to the tsunami wave flowing direction.

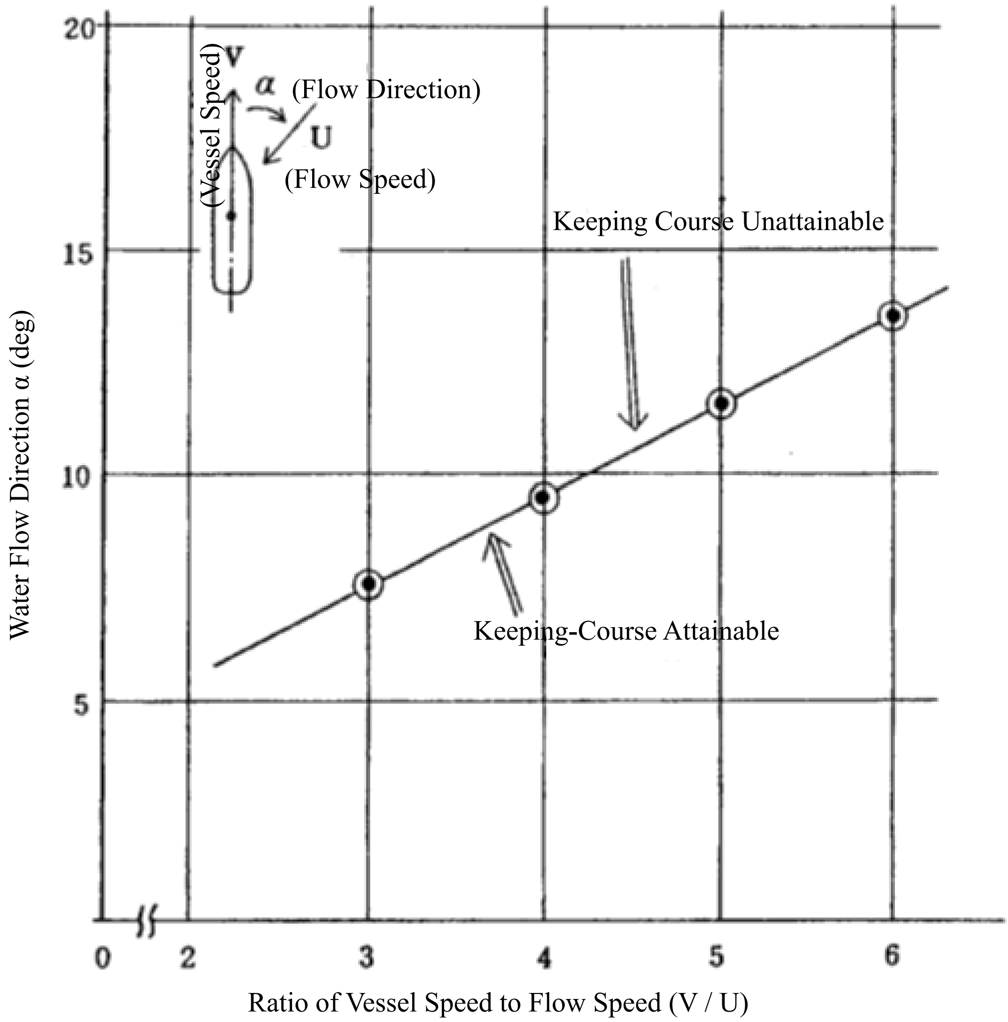


Figure 7: Critical Conditions for Vessel Course Keeping

where

$$U = \eta \cdot \sqrt{g/H}$$

U: Tsunami water flow speed (m /sec)

η: Wave-surface elevation above still-water level,

g: gravitational acceleration (9.8 m/sec^2),

H: Water depth (m)

With regard to small vessels, it can be said that, while fishing boats or pleasure boats have good maneuverability, working boats or boats towing others lack maneuverability or speed so that they are likely to get trapped in critical situations and be unable to keep their course in much less severe conditions of tsunami flow direction or speed than general cargo vessels.

In addition, low-speed vessels, in particular, when encountering unbroken tsunami waves may lose ground speed being carried back by flowing tsunami, even if they, intending to override tsunami waves, try to proceed in a direction perpendicular to the tsunami wave-lines; and as a result get trapped in a dangerous situation.

(2) Guide to the estimation of critical conditions for small vessels in broken waves

(Skipped)

7. Tsunami Information

7-1. Information released by the Meteorological Agency

The Meteorological Agency, when an earthquake occurs in Japan or in the vicinity of Japan, immediately analyzes the seismometer data that is transmitted to the agency on a real time basis, and then promptly releases an earthquake early-warning, a tsunami warning/advisory, earthquake information, or other. Such information is delivered to the authorities or organizations that are in charge of disaster prevention through ground-based commercial communication lines that on-line connect the agency to those organizations or the EM-Net. Then, local residents or vessels get informed of such tsunami information through such organizations or by news media.

With regard to a tsunami induced by an earthquake occurring in a foreign country, the agency, closely communicating with the Pacific Tsunami Warning Center (PTWC) in Honolulu, releases a tsunami warning/advisory. In addition, with regard to a tsunami induced by an earthquake that occurs in the Japan Sea, the agency provides foreign organizations or governments with tsunami information including its predicted height and arrival time.

Because earthquake early-warnings or tsunami warnings/advisories need to be released as early as possible the agency has installed the Earthquake Phenomena Observation System (EPOS) at its headquarter (Tokyo) and Osaka District Meteorological Observatory for the purpose of enabling the start of analyses and identification of earthquake-source location and magnitude automatically immediately after earthquake occurrence.

7-1-1. Tsunami Forecast System

(1) Tsunami forecast release scheme

As early as in 1952, the tsunami forecast scheme was established by law for the purpose of "tsunami judgment" (identification or prediction of tsunami magnitude or risk) and the delivery of tsunami forecasts.

By 1986, the development of a data-communications network for the delivery of tsunami information was completed.

In 1987, the Meteorological Agency installed the Earthquake Phenomenon Observation System (EPOS). In the system computers fully-automatically conduct a full sequence from earthquake detection to the identification of source.

In 1999, the system was enhanced through the employment of tsunami numerical simulation technologies. The enhanced system enabled the agency to release tsunami information including specific numerical vales on tsunami height and to release highly accurate quantized tsunami information to the 66 forecast-areas nationwide, which were determined based on prefecture. The previous 18 forecast areas were more finely segmented into these 66 areas.

Moreover, in 2009, the whole tsunami-forecast operation scheme was transformed so that the two headquarters, Tokyo and Osaka, were responsible for tsunami forecast operations. Previously, six forecast units, located in Sapporo, Sendai, Tokyo (Headquarter), Osaka, Fukuoka, and Okinawa, had been in charge of the forecasts for the regions assigned to them.

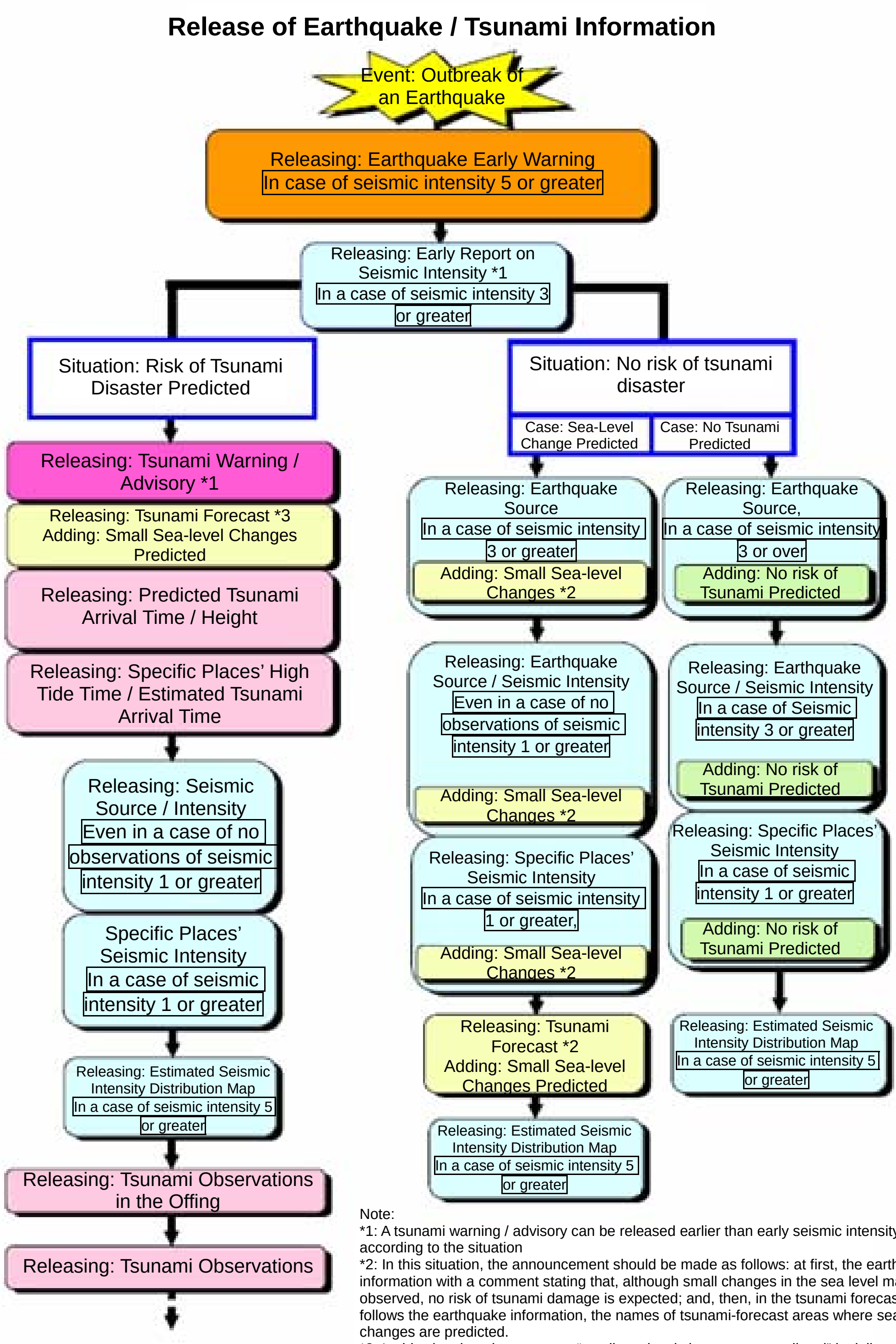
Generally, tsunami forecasts are released according to the following sequence: in the first preliminary stage, tsunami databases are created identifying faults that are likely to cause tsunami; numerical simulations are applied to those fault examples and the results are stored in a database; when an earthquake occurs, the database is consulted to immediately retrieve instances of tsunami behaviors (simulation results) sharing similarities with the actual earthquake in terms of source and magnitude. In such a way, prompt releases of tsunami warnings/advisories to coastal areas facing tsunami risk are enabled.

(2) Tsunami forecast area and Tsunami Forecast Center, the section in charge of tsunami forecast

The Meteorological Agency, at the same time when releasing a tsunami warning/advisory, makes a notice on the predicted tsunami height and arrival time at each of the 66 tsunami-forecast areas nationwide—covering Japan's entire coast line. Those tsunami forecast areas are set based on studies on the areas' specific tsunami behaviors that are significantly affected by the geographical conditions of coast areas. Then, considerations are made on what actions the local authorities and organizations in charge of disaster prevention should take.

7-1-2. Tsunami forecast and tsunami information

[1] Types, timing, and content of tsunami information



Note:
*1: A tsunami warning / advisory can be released earlier than early seismic intensity reports according to the situation
*2: In this situation, the announcement should be made as follows: at first, the earthquake information with a comment stating that, although small changes in the sea level may be observed, no risk of tsunami damage is expected; and, then, in the tsunami forecast that follows the earthquake information, the names of tsunami-forecast areas where sea-level changes are predicted.
*3: In this situation, the comment "small sea level changes are predicted" is delivered even to the tsunami forecast areas that are not the targets of tsunami warning / advisory.

Source: Meteorological Agency's web pages

Figure 8: Information on tsunami and earthquakes

[1] Tsunami warning/advisory

Tsunami warnings (major tsunami warning/tsunami warning) or tsunami advisories are released in a situation of tsunami-disaster risk predicted, within a rough target range of approximately 3 minutes (according to the situations of earthquake, within 2 minutes).

Table 8: Standards for Tsunami Warnings/Advisories: Release Criteria, Contents, and Announcement Phrase

Type of Information	Release Criteria	Tsunami Height		Announce Phrases for Predicted Damage and Recommended Actions
		Numerical Expression (Class of Predicted Tsunami Height)	Verbal Expression for Major Earthquakes	
Major Tsunami Warning*	Tsunami-height of over 3 meters at the highest, predicted	"Over 10 meters" (10 m < P.H.) P.H.: Predicted Height	"Major"	" Wooden houses will be completely destroyed or swept away. Humans will be caught in tsunami-water flow. People in coastal areas or on river banks, immediately evacuate in safe places. Hurry to high land or a tsunami-shelter building."
		"10 meters" (5 m < PH ≦10 m)		
		"5 m" (3 m < P.H. ≦5 m)		
Tsunami Warning	Predicted maximum tsunami height is more than 1 m and less than or equal to 3 m	"3 m" (1 m < P.H. ≦3 m)	"High"	"Low elevation areas will be flooded by tsunami water and suffer inundation damage. Humans will be caught up in tsunami-water flows. People in coastal areas or on river banks, immediately evacuate in safe places. Hurry to high land or a tsunami-shelter building."
Tsunami Advisory	Predicted maximum tsunami-height is more than 0.2 m and less than or equal to 1m; and risk of tsunami damage is expected	"1 m" (0.2 ≦P. H. ,≦ 1 m)	(Not Applied)	"People at sea may be caught up in fast flowing tsunami water; farming rafts may be washed away; small vessels may be capsized. People at sea, immediately return to land, and go away from the coast."

* A Major Tsunami Warning is designated as "special warning." The Meteorological Agency, on Friday August 30, 2013, initiated the operation of "special warning"; the agency releases a special warning for an extraordinary natural phenomenon that the usual waning release criterion is unable to cover. The release criteria of a special warning are determined through consultation with governors, and municipal mayors who are in charge of disaster prevention in local areas.

Source: Meteorological Agency's web pages

[2] Tsunami advisory

A tsunami advisory is released where a risk of tsunami disaster is no longer expected following the earthquake occurrence; a tsunami advisory includes the information shown in Table 15.

Table 9: Tsunami Advisory

Situation of Release	Announce Phrase
No tsunami risks are expected.	“Earthquake information is released as follows, including the statement that no tsunami risk is expected.”
A sea-level change of less than 0.2 m is predicted.	“No special care against tsunami disaster is required; sea-level change is predicted less than 0.2 m at the highest.”
Sea-level changes have lasted even after the tsunami advisory was canceled.	“Sea-level changes due to tsunami have been observed, and are predicted to last; people working at sea, fishing, or bathing are recommended to pay sufficient attention.”

Source: Meteorological Agency’s web pages

(2) Types and announcement of tsunami information

Tsunami warnings/advisories, when released, must be followed by tsunami information that includes the predicted arrival time, tsunami height, and other information.

Table 10: Types and Announcement of Tsunami Information

Information Category	Announce Phrase
Information on predicted tsunami arrival time/height	“Predicted arrival time and height at the individual tsunami-forecast areas, is released as follows.” (Note: the items of announcement are specified in Table 8) “The predicted tsunami arrival time is the earliest for the tsunami-forecast areas. Tsunami may arrive more than one hour later to some areas.”
Time of high tide and predicted tsunami arrived time at specific places	“Time of high tide and predicted tsunami arrival time at representative points is released as follows.”
Tsunami observations (*1)	“Tsunami height observations and time at coasts are released as follows.”
Tsunami observations in the offing (*2)	“Tsunami height observations and time in the offing, and estimated tsunami arrival time and height from such observations is released as follows for the individual tsunami-forecast areas.”

Note:

*1: The tsunami-observation information includes the following: the arrival time and behavior (forwarding or back-drawing) of the tsunami first strike, and the maximum height and time of tsunami observations by the time of the information release.

*2: The information on tsunami observations in the offing includes the following: the observation time of the tsunami first strike observed in the offing and its behavior (forwarding or back-drawing), and the observation time and height of the maximum tsunami-wave observed in the offing at each observation point by the time of the information release. In addition, the arrival time of the first strike on coast/the arrival time and height of the maximum wave estimated from the observations in the offing is released for the individual tsunami-forecast area.

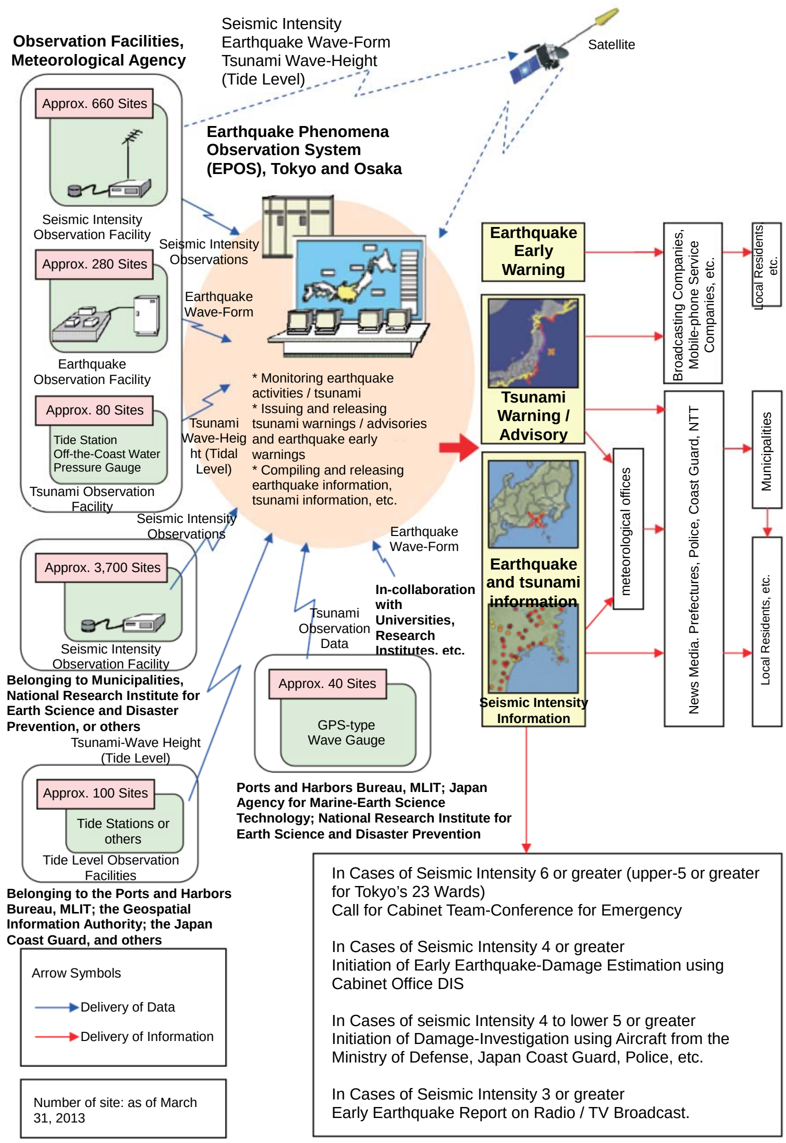
Source: Meteorological Agency’s web pages

7-1-3. Distribution of Tsunami Forecast/Information and Channels

The Meteorological Agency, for the purpose of alleviating the impact of earthquake disasters, monitors earthquakes and tsunami on an around-the-clock basis, releases information promptly on the occurrence of earthquakes or tsunami, and releases predictions for and observations of the earthquake or tsunami. Such early information immediately after the occurrence of an earthquake ensures the authorities or organizations in charge of disaster prevention can take action.

In addition, the agency, following the Basic Act on Disaster Control Measures and the Meteorological Service Act, promptly distributes such information to the organizations concerned and news media to local residents and vessels for their information.

Creation Flow and Distribution Channels of Earthquake/Tsunami Information



Source: Meteorological Agency's Web Pages

Figure 9: Creation/Delivery Flow of Earthquake/Tsunami Information by the Meteorological Agency

(1) Gathering of earthquake data

[1] Earthquake monitoring

The Meteorological Agency monitors earthquake activities on a 24-hour basis by compiling the observations obtained from the 280 seismometers located nationwide that belong to the agency and the observations obtained by the seismometer belonging to the National Research Institute for Earth science and Disaster Prevention, etc.

In addition, the agency, at the time of an earthquake occurrence, integrates the data obtained by their own seismometers with a function of measuring ground motions installed at 660 locations nationwide and the data from the seismometers that belong to local authorities, the National Research Institute for Earth Science and Disaster Prevention, etc. The number of available observation facilities installed nationwide is approx. 4,700 in total.

[2] Earthquake early warning

The agency, immediately after an earthquake occurrence, analyzing the observation data from the seismometers located in the vicinity of the epicenter, estimating the location of the earthquake source and its magnitude, predicting the arrival time of the earthquake principal motions to places around Japan based on the results of such analyses, releases an earthquake early warning as promptly as possible.

(2) Gathering of tidal data

The agency, using the tidal data from the 80 tsunami observation facilities nationwide that the agency has built, and the data from observation equipment belonging to other organizations such as GPS-type wave gauges deployed by the Ports and Harbors Bureau MLIT and so on, monitors tsunami phenomena at approx. 220 locations nationwide.

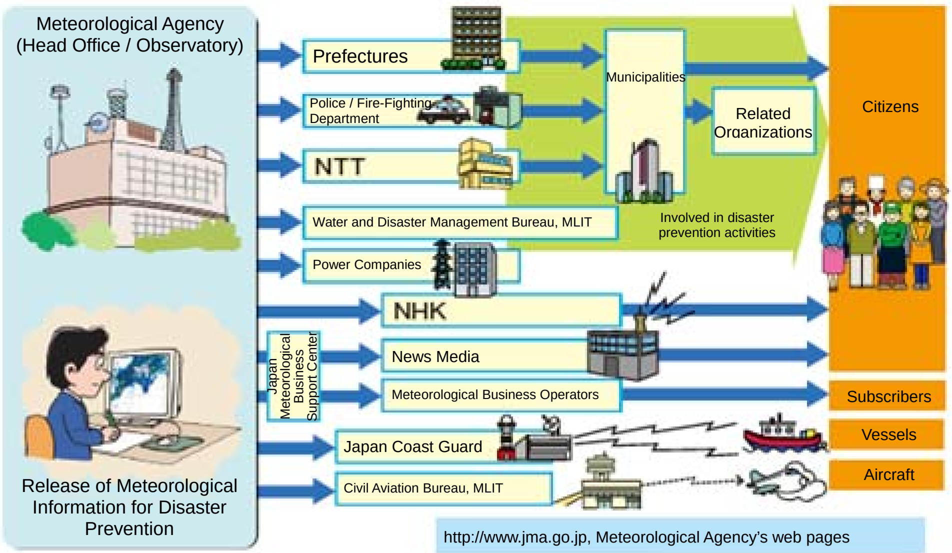
(3) Release of tsunami forecasts or earthquake/seismic-intensity information

On the occurrence of an earthquake, the agency, using data from seismometers and tsunami monitoring data, identifying the earthquake source location and estimating its magnitude and tsunami scale, creates and releases tsunami forecast statements.

(4) Distribution of meteorological information for disaster prevention

Meteorological information such as tsunami warnings/advisories released by the agency is distributed to local residents via mass-media such as TV/radio broadcasts, as well as through the national organizations in charge of disaster prevention or the local authorities. This has contributed to the prevention /alleviation of the impact of disasters.

Such information is directly delivered in a secure way through administrative authorities such as prefectures or NTT primarily to the municipalities, which are directly involved in disaster prevention activities on the frontline. In addition, such information is distributed by multiple means, for instance delivered via the Internet or the Nationwide Warning System (J-ALERT) administered by the Fire and Disaster Management Agency.



Source: Meteorological Agency Brochures

Figure 10: Distribution Flow of Meteorological Information for Disaster Prevention

7-2. Distribution of Tsunami Information by Japan Coast Guard

Japan Coast Guard, basing procedures on the Disaster Prevention Basic Act and the Act on Special Measures concerning Countermeasures against Large-scale Earthquake for the purpose of conducting their anti-disaster operations in an integrated way and following well-prepared plans, has prepared the "Japan Coast Guard Disaster Prevention Operation Plan" that stipulates the appropriate actions for them in a time of disaster-risk. Tsunami information is distributed following the plan and the Meteorological Service Act.

In addition, Japan Coast Guard delivers to vessels, as a navigational warning, information on abnormalities in navigation aids due to earthquakes or tsunami and information on obstacles drifting on the surface.

Note: because, while the Meteorological Agency classifies their tsunami information into "Tsunami Forecast" and "Earthquake/Tsunami Information," the modes of information delivery are not specified. Those two types of information are, hereinafter, uniformly referred to as "Tsunami Information," except in the case where differentiation is necessary.

Information delivery measures to vessels and others in different situations are shown below.

(1) Proceeding vessels

- International Marine VHF Radio Channels: Tsunami information is broadcast on VHF Channel 16 as emergency information
- NAVTEX Navigational Warning
- Japan Navigational Warning
- NAVAREA Navigational Warning
- AIS's (Automatic Identification System) information
- MICS's (Maritime Information and Communication System) information

(2) Anchoring vessels

- Sending patrol vessels/crafts or aircraft to cover anchorage area and inform by means of loud speakers or banners
- Sending Coast Guard Office/Station staff to visit vessels or use ship telephones

(3) Local residents in coast areas or sea-bathing visitors, etc.

Sending patrol vessels/crafts or aircraft to cover coastal areas and inform by means of loud speakers or banners.

(4) Information delivery by parties concerned with vessels

Significant port business operators such as ship agents, major fisheries cooperative associations (marine radio stations), marinas, marine clubs, port construction-work safety associations, and others are supposed to relay tsunami information that is delivered to them by Coast Guard Office/Station to the vessels, fisheries cooperative associations, port construction-work companies (construction work vessels), or pleasure boats that belong to them via telephone, FAX, mobile phone, marine band, or construction-workers' radio, or by direct visit to vessel.

(5) Delivery of earthquake information to vessels

Reports on earthquakes that occurred in the vicinity of Japan including the coasts of Japan, of a seismic intensity lower 5 or greater, are distributed by the Meteorological Agency to vessels as a NAVTEX Navigational Warning, a Regional Navigational Warning (for which the Coast Guard regional headquarters are responsible), and a Japan Navigational Warning.

(6) Delivery of information on abnormalities in navigation aids or surface obstacles

Information on abnormalities in navigation aids or surface obstacles is distributed as a NAVARIA XI Navigational Warning, a NAVTEX Navigational Warning, a Regional Navigational Warning, and a Japan Navigational Warning. In addition, the graphically mapped information is available on the Internet.

7-3. Tsunami Information Delivery by Regional Tsunami Disaster Management Organizations

While the tsunami information released by the Meteorological Agency is delivered to the regional organizations involved in tsunami disaster management, such as prefectures, Cost Guard Offices, police offices, fire departments, regional development bureaus, news media, JR, and NTT, responsibility for delivering such information to local residents rests on municipalities and news media.

However, while the Meteorological Service Act stipulates in Article 23 that others than the Meteorological Agency are not permitted to make warnings on weather, tsunami, high tides, waves, or floods, according to the Disaster Management Basic Act Article 56 and the Meteorological Service Act Enforcement Order No.10, municipal mayors are permitted to independently release their own tsunami warnings in remote areas where the prompt recipient of the Meteorological Agency's tsunami information is difficult or where the receipt of such tsunami warnings is no longer possible.

7-3-1. Information delivery through municipalities

Municipalities, by broadcasting on municipal emergency radio, blasting sirens, ringing fire bells and loudspeaker vans, inform the local coast-area residents, people staying on the coast, and the maritime organizations of the earthquake/tsunami information delivered by prefectures, police stations, NTT, and news media.

7-3-2. Information delivery by news media

(1) Emergency warning broadcast

Major news media companies, on the release of large-scale earthquake warning or tsunami warning, or at the request of local authorities for broadcasting evacuation orders, broadcast emergency warnings. Television-sets/radios with emergency broadcast receiving function, even if their power switched off, but connected to a power receptacle, are able to receive such emergency broadcast on NHK's ordinary TV channel and NHK radio No.1 and on the channels/frequencies of the private broadcast companies participating in the Emergency Broadcasting Network System.

(2) News-media's position in the regional disaster prevention plans prepared by prefectures

Prefectural regional disaster prevention plans stipulate the actions that news media are supposed to take as follows: "News media should voluntarily raise audience attention, on radio by inserting the announcement of an emergency warning in program intervals or by interrupting programs, or on TV by displaying tickers on screen or interrupting programs. In addition, when a tsunami warning is released news media must, at the request of local authorities and broadcasting evacuation orders, etc. based on the Basic Act on Disaster Control Measures, broadcast their emergency programs."

8. Laws and Regulations on Measures against Tsunami Disaster

The laws and regulations concerning measures against tsunami disasters are summarized below.

8-1. Basic Act on Disaster Control Measures

(1) Basic Act on Disaster Control Measures

"Disaster Countermeasure Basic Act" (hereinafter referred to as "Disaster Control Act") was enacted in 1961 in the wake of the disaster caused by a typhoon that hit Ise-wan area (Ise-wan Typhoon) in 1959. The act represents the general law for rules and regulations concerning disasters.

The Act stipulates in its Article 60 as follows:

When a disaster has occurred or is expected to occur, the mayor of a municipality may make an evacuation recommendation to the residents or others or make an instruction of evacuation eviction if urgently necessary.

In Article 61, the Act stipulates as follows:

When the mayor is unable to make a request or instruction of evacuation, a Police or Coast Guard officer may make such an instruction towards persons the officer considers as needing to evacuate.

In Article 63, the Act stipulates as follows:

The mayor, when he/she considers it necessary, may establish a warning zone, restrict or prohibit access to the zone by persons except those who have permission, and make instructions of evacuation.

Furthermore, in its Article 63 Item 2, the Act stipulates as follows:

When the mayor of a municipality, etc. is not present on-site or on the request of the mayor, etc., a Police/Coast Guard officer may exercise the mayor's authority.

(2) Basic Plan for Emergency Preparedness

The Basic Plan for Emergency Preparedness is the government basic plan that the Central Disaster Management Council prepares pursuant to the Disaster Countermeasure Act.

The Central Disaster Management Council amended the Basic Plan for Emergency Preparedness on December 27, 2011, based on the final report of the "Expert Group on the Earthquake/Tsunami Countermeasures in the light of the lessons of Tohoku Pacific Coast Earthquake," dated September 28 2011, for the purpose of realizing what the Expert Group proposed in the report.

The main points of the amendment are the addition of a new chapter "Tsunami Disaster Management" and the improvement of the description for the purpose of enhancing earthquake/tsunami countermeasures, as follows:

[1] For the purpose of managing all possible situations, assume maximum-scale earthquake and tsunami.

[2] Setting two levels of target tsunami and corresponding measures

・Against a maximum-scale tsunami, preparing comprehensive measures focusing on evacuation of residents;

・Against a relatively often-occurring tsunami, improving coast-guarding facilities, etc.

[3] Building highly tsunami resistant towns

・Promotion of land utilization so that low-inundation risk areas are used for residency, and according-to-plan development of evacuation spaces or evacuation buildings, etc.

[4] Properly equipping citizens with disaster prevention knowledge

・Familiarizing citizens with disaster prevention actions, such as "when sensing a strong earthquake motion, evacuate without hesitation, immediately and independently;

・Executing disaster prevention education programs and developing education programs concerning tsunami;

・Development of tsunami hazard maps and familiarizing residents with the plans.

[5] Improvement of research and observation systems for earthquakes/tsunami

[6] Establishing or securing systems for delivering information of tsunami warnings and evacuation execution

(3) Regional Disaster Prevention Plan

Each of the heads of local authorities, pursuant to the Disaster Countermeasure Act, prepares its own Regional Disaster Prevention Plan through consultation with its regional disaster management council. Such plans stipulate specific actions or operations of disaster management.

The ministries concerned, for the purpose of supporting the local government's activities for preparing such plans, prepared the "Guides to the Enhancement of Tsunami Measures in Regional Disaster Prevention Plan" in 1998 and the "About promoting the activities for preparing against tsunami in coast areas" (note of consent of the ministries concerned) in 1999, and notified local governments of those documents. The points of those documents are as follows:

[1] Guides to the Enhancement of Tsunami Measures in Regional Disaster Prevention Plan

In March, 1998, the ministries concerned (National Land Agency, Ministry of Agriculture, Forestry and Fisheries, Fisheries Agency, Ministry of Transport, Meteorological Agency, Ministry of Construction, and Fire and Disaster Management Agency) presented the Guide to the Enhancement of Tsunami Measures in Regional Disaster Prevention Plan, introducing the basic concepts and procedures for prefectures or municipalities in preparing their Regional Disaster Prevention Plans.

The document shows the following as the basic ideas for tsunami measures involving vessels:

・ Measures for securing the safety of vessels in ports, harbors, and fishing ports

While Coast Guards, in cases where they, on a recipient of tsunami warning, judge whether the water areas are facing risks, take actions such as delivering tsunami warnings to vessels, making recommendations, controlling the area, and making restrictions, port administrators are recommended to request concerned parties on vessels to take appropriate actions to secure vessels' safety in cases where they deem it necessary.

Note: with regard to ports, harbors, or fishing ports that are not subject to the Act on Port Regulations, the administrators should have meetings in advance with ship owners and fisheries cooperative associations and request them to prepare appropriate measures for securing vessels' safety.

・Measures for fishing boats

In a situation with a risk of tsunami strike, measures for fishing boats should be executed within a range where such execution will not risk human life.

[2] About the enhancement of awareness of tsunami in coastal areas

The Liaison Conference of Ministries and Agencies on Tsunami measures in July 1999 (participated in by the Cabinet Secretariat, Cabinet Office, Police Agency, Ministry of Defense, Ministry of Internal Affairs and Communications, Fire and Disaster Management Agency, Ministry of Agriculture, Forestry and Fisheries, Ministry of Land, Infrastructure and Transport, Meteorological Agency, and Japan Coast Guard), recognizing the importance of advance preparation for tsunami measures and evacuation/rescue operation arrangements, agreed on comprehensively promoting tsunami measures.

The conference agreed on vessels' tsunami measures as follows:

・The enhancement of awareness of tsunami

The awareness of the necessity of being precautious against tsunami should be enhanced as stated in the following attachment, where the instruction is: "When having sensed a strong earthquake motion, residents must evacuate to safe places away from the coast; vessels evacuate offshore."

・"Instructions for preparing against tsunami" (an attachment to the announcement)

<Instructions for Vessels>

1. When having sensed a strong earthquake motion (intensity 4 or greater) or long lasting slow motions, even if the earthquake was small, vessels must immediately leave the port to evacuate offshore.*
2. Even if not having sensed earthquake motions, when a tsunami warning/advisory is released, vessels must leave the port to evacuate offshore.*
3. Vessels must try to receive correct information via TV/radio broadcasts or radio communications.
4. Small boats unable to evacuate offshore,* must be pulled up out of water to a high place and be firmly tied down if possible.
5. Vessels must be on-alert until the tsunami warning/advisory is cancelled, as tsunami can strike repeatedly.

* Note: choose wide-open and deep areas for offshore evacuation; pulling-up of a small boat must be executed only in the case where sufficient time is available.

(4) Japan Coast Guard Disaster Management Action Plan

The Japan Coast Guard (hereinafter referred to as "Coast Guard") Disaster Management Action Plan, pursuant to the Disaster Control Act, stipulates as follows the operations that the Coast Guard should execute at the time of disaster.

[1] Delivery of disaster information: conducted toward the residents and vessels in the vicinity of the tsunami risk area, the Coast Guard sends patrol vessels/crafts or aircrafts to patrol the area and inform by means of loud speakers and banners, in addition to visiting vessels; toward proceeding vessels, the Coast Guard informs them by means of navigational warnings or safety messages; toward the residents or visitors sea-bathing in the tsunami-risk coastal areas, the Coast Guard sends patrol vessels/crafts or aircrafts to inform them by means of loud speakers or banners.

[2] Delivery of warning to vessels, etc.: when receiving warnings on weather, tsunami, high tide, or waves, or information on disasters, the Coast Guard immediately informs the vessels of the warning/information by means of navigational warning, safety message, signage, and/or visit by patrol vessels/boats/aircrafts, and at the same time informs business operators concerned if necessary; when detecting navigation hazardous debris or abnormalities in navigation aids that could severely risk of navigation safety, or to set restrictions/prohibitions on vessel traffic, the Coast Guard promptly raises navigational warnings or sends message on navigation safety, or informs by means of Notice to Mariners if necessary.

[3] Evacuation recommendation: toward the ports in the tsunami risk areas or vessels close to the coast, the Coast Guard makes recommendations of evacuation to safe waters such as in

the offing, and, if necessary, restricts port-entry or impose controls to the vessels in the port to move.

[4] Actions to vessels carrying dangerous cargo: the Coast Guard, if necessary, instructs to leave or restricts/prohibits their navigation, and with regard to vessels in the middle of loading/unloading dangerous cargo, makes necessary guidance, such as suspension of loading/unloading, for the prevention of accidents.

[5] Setting up warning zones: the Coast Guard, if necessary, pursuant to Article 63 of the Disaster Control Act, makes instructions for leaving the warning zone and restricts/prohibits entry to the zone.

8-2. Act on the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities, and others

(1) Act on the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities

The Act on the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities (hereinafter referred to as Petroleum Disaster Act) was effected in 1975 for the purpose of protecting citizens' life/physical integrity and property from disasters in specially designated disaster prevention zones such as petroleum industrial complexes (hereinafter referred to as special disaster prevention zone) through promoting comprehensive policies concerning the prevention of disaster occurrence or expansion related to special disaster prevention zones in combination with the Fire Service Act, High Pressure Gas Safety Act, Disaster Countermeasure Act, and other laws concerning disaster prevention.

(2) Disaster prevention plan for Petroleum Industrial Complexes and Other Petroleum Facilities

In the prefectures that have special disaster prevention zones—as of April 1, 2011, 85 zones in 33 prefectures and 104 municipalities are designated special disaster prevention zones, pursuant to the Petroleum Disaster Act. The prefectural headquarter for the prevention of petroleum disasters, playing the central role in collaboration with organizations concerned, promotes, in a comprehensive way and following the plans for activities for the establishment of disaster management systems. The headquarters conducts the following as their responsibility: the preparation of Plans for the Prevention of Disaster in Petroleum Industrial Complexes and Other Petroleum Facilities (hereinafter referred to as disaster prevention plan); coordination between organizations in time of disaster; and the promotion of research and study.

Disaster prevention plans, required by the Article 31 Item 2 of the Petroleum Disaster Act, must include the items on "the execution of emergency measures against disasters caused by extraordinary natural phenomena including earthquakes or tsunami," and "the control and management of evacuation, traffic, and setting-up warning zones." Hence, such plans stipulate emergency measures for vessels including the giving of instructions/recommendation of suspension of loading/unloading work and controlling/restricting vessels' evacuation/traffic.

8-3. Meteorological Service Act and others

The Meteorological Service Act stipulates in Article 15 as follows: the agency, when releasing warnings of tsunami or other, must notify designated administrative organization such as Coast Guard, prefectures, etc. Coast Guard that received such a notification from the Meteorological Agency must endeavor to inform the relevant vessels proceeding/anchoring in ports.

8-4. Maritime Transportation Act and others

The Maritime Transportation Act, in Article 10-3, obligates all passenger transport business operators to prepare their own "Safety Management Rules" describing the items that the operator and its employees must follow for securing transport safety.

In addition, the act obligates business operators (the transport business operators permitted to operate in the designated areas) designated by the "Act on Special Measures for Large-scale Earthquakes," "Act on Special Measures for Tonankai/Nankai Earthquake" or the "Act on Special Measures for Promotion of Earthquake Disaster Prevention Measures against Trench-type Earthquake in Japan Trench or Trenches in the Vicinity of Chishima Trench" to prepare/observe their "standards for earthquake disaster prevention."

8-5. Act on Port Regulations

The Act on Port Regulations stipulates, in Article 37 Item 4, that the Captain of the port of the specific port, when expecting a risk to vessel traffic safety due to tsunami and other phenomena, may recommend the vessels in the port to take necessary measures.

And, the act, in Article 37 Item 3, stipulates that the Captain of the port, within the range of necessity for preventing risks to vessel traffic or alleviating traffic congestions, may control/restrict or prohibit the navigation of vessels entering specific areas, or make an instruction on where to anchor, restrict a vessel's shift, or make an instruction for vessels to leave outside from the port.

Furthermore, such stipulations on the port are subject to legal enforcement, even when not designated as a special port. In such a case, the head of the Coast Guard Office/Station may exercise the authority of the Captain of the port.

II Safety/Disaster Prevention Measures for Large Vessels Carrying Dangerous Cargo

1.1. Objectives

With regard to the safety/disaster prevention measures for large vessels carrying dangerous cargo, while such safety measures as emergency unberthing have been proposed, the studies have been conducted for the purpose of reflecting the lessons from the Great East Japan Earthquake; in this section, the reviews of the conventional safety/disaster prevention measures are introduced as shown below.

Note that, in light of the severe damages on petroleum industrial complexes, etc. experienced in the Great East Japan Earthquake, studies and reviews on earthquake/tsunami countermeasures with regard to on-land facilities have so progressed that new standards for tsunami-countermeasures compliant with the Fire Service Act have been proposed.

1.2. Safety/Disaster Prevention Measures for Large Vessels Carrying Dangerous Cargo

1.2.1. Current Status of Earthquake/Tsunami Safety Measures for Large Vessels Carrying Dangerous Cargo

Currently, large-sized oil carriers with dimensions larger than a designated size, and the berths used for loading/unloading by such carriers, are subject to the regulations for safety/disaster prevention measures for loading/unloading operations, according to the “Standards for the Preparation of Safety/Disaster Prevention Measures for Large-sized Oil Carriers and Berths used by such Carriers (Coast Guard Administrative Guide Line, dated January 17, 2011)”; furthermore, LNG berths, of liquefied-gas berths, have been equipped with emergency shut-down systems, etc. that have proactively employed the recommendations by the Marine Disaster Prevention Center.

1.2.1.1. Standards for Safety/Disaster Prevention Measures for Large-Sized Oil Carriers and Berths

(1) Target vessels or berths

[1] An oil carrier of 50,000 DWT or over, or a berth used by such a vessel for loading/unloading.

[2] A liquefied-gas (petroleum/natural) carrier of 25,000 gross tonnages or over, or a berth used by such a vessel for loading/unloading

(2) Safety/disaster prevention measures concerning emergency unberthing

The standards for the safety/disaster prevention measures have been prepared as the technical standards concerning the port entering/leaving or loading/unloading of a large vessels carrying dangerous cargo; the standards include the requirements covering a wide range from facility to operation. Of the standards, the following are the requirements with regard to emergency unberthing at the time of earthquake or tsunami.

[1] Requirements for facilities

Quays are required, for the purpose of ensuring that a vessel can make safe emergency unberthing, to be equipped with sufficiently strong quick release hooks if possible.

[2] Requirements for the preparation and strictly carrying out of the manuals for berthing/unberthing and loading/unloading operations

Manuals for berthing/unberthing or loading/unloading, and the checklists for individual operations must be prepared and strictly observed.

[3] Pre-arrangement concerning the means of the suspension of loading/unloading operations at the time of emergency

Berth operators and tanker operators must, in advance, mutually confirm the procedures for safely stopping their operations of loading/unloading or the release of arms or hoses at the time of an emergency situation.

[4] Countermeasures for extraordinary weather or sea-conditions

When a tsunami warning or a major earthquake alert is issued, loading/unloading operations must be suspended immediately, and, as a general rule, the vessel must be evacuated to a safe water-area off the port. Note: in a case where the procedures for an individual vessel to follow have been pre-agreed in the tsunami countermeasures conference, etc., the vessel should follow such procedures.

1.2.1.2. Safety/disaster prevention measures for LNG berths

With regard to LNG berths, the individual berths have employed not only safety/disaster prevention measures for general oil carrier berth, but also the following safety measures for emergency unberthing, through proactively applying the recommendations by the Maritime Disaster Prevention Center:

[1] Employment of Emergency Shut Down System (ESDS)

The system has such functions as automatically or manually stopping the loading/unloading pump promptly in an emergency situation and closing the emergency shut-down valves.

[2] Employment of Emergency Release System (ERS)

The system has such functions as remotely releasing the loading arms promptly in an emergency situation even in the middle of loading/unloading operations.

[3] Employment of arm angle irregularity detection and alarm system

The system monitors the loading arm angle, and activates ESDS and ERS, when detecting irregularity in the angle.

[4] Employment of mooring-line load monitoring equipment

The equipment, using the outputs of the sensors attached to the quick release hook, monitors the load on mooring lines.

1.2.2. Earthquake/Tsunami Countermeasures for Large Vessels Carrying Dangerous Cargo: Improvement through Reflecting the Lessons from the Great East Japan Earthquake

1.2.2.1. Damage Situations of Large Vessels Carrying Dangerous Cargo in the Great East Japan Earthquake

(1) Sendai-Shiogama Port

VLCC (150,000 DWT: in the middle of unloading)

The vessel, while executing emergency unberthing operations, received tsunami-flow pressure that caused its mooring lines to be cut off; the vessel, although executing an emergency dropping anchor but being swept around by tsunami waves, made offshore evacuation by self-maneuvering and navigation, after having collided with other vessels

In addition, the vessel, during executing the required emergency shut down operations for dangerous cargo facilities, suffered 4 casualties: the casualties were induced by the delay of the delivery of retreat instructions to the staffs working on the unberthing operation on the quay; the delay of instruction delivery was induced by the unavailability of the vessel's PA system due to the insufficient capacity of the emergency batteries.

Note 1: The Fire and Disaster Management Agency, Ministry of Internal Affairs and Communications, considering such risks during emergency operations, has revised the laws and regulations on fire and disaster management, so that, with regard to the facilities having the risk of inundation due to tsunami flooding, such stipulations were added regarding the actions for emergency stop taking into account the time allowance for tsunami arrival, and the security of employees' safety. (Notice No.197 "Sho-bou-ki" dated August 21, 2012)

Note 2: Tsunami observation at Sendai-Shiogama Port (Sendai Port-Area) (Brochure released by the Ports and Harbors Bureau, Ministry of Land, Infrastructure, Transport and Tourism)

Maximum Wave: + 7.7 meters

(2) Onahama Port

VLCC (100,000 DWT: in the middle of unloading)

The vessel, although suffering tsunami waves with the loading/unloading facilities including "Chikusan Arm" connected, survived the tsunami while moored at the crude oil berth.

The staff working on mooring or unloading operations, although on a sea-berth off the land, made evacuation into the vessel following the berth master's timely and proper advice: none of them suffered damages.

Note: Tsunami observation at Onahama (release by the Meteorological Agency)

First Wave : + 2.6meters, 1508 hrs

Maximum Wave : + 3.3 meters, 1539 hrs

(3) Kashima Port

VLCC (160,000 DWT, in the middle of unloading)

The vessel was pushed by tsunami-water flow and its mooring line was cut-off; however, the vessel, by self-maneuvering and navigation, made offshore evacuation.

LPG Carrier (47,000 GT, during preparation for unloading)

The vessel had its mooring line cut-off by the tsunami; however, the vessel, by self-maneuvering and navigation, made offshore evacuation.

Note: Tsunami observation at Kashima Port (Brochure released by the Ports and Harbors Bureau, Ministry of Land, Infrastructure, Transport and Tourism)

Maximum Wave:+ 5.7 meters

1.2.2.2. Lessons from the Great East Japan Earthquake

Following the Great East Japan Earthquake, in FY2012, the Japan Association of Marine Safety determined the items that require the revision in the current tsunami measures, based on the past reports and interviews with people engaged in maritime affairs, and outlined approaches for such items in Table 2.

Out of the table, dos and don’ts that large vessels carrying dangerous cargo should follow are shown in a form of lesson, as follows.

- ✓ Make sure to equip berth facilities with auxiliary/emergency power supplies for berth facilities, and equip operable communication means for emergency situations with vessels.
- ✓ Make pre-agreements on how and what decisions to make for evacuation with parties concerned, in the situation of a tsunami strike.
- ✓ Keep in mind that vessels are forced to unberth by themselves in a situation where no assistance (land nor offshore) is available.
- ✓ Share the information on the safe areas on the water that will experience less tsunami impact.
- ✓ Evacuation of vessels carrying dangerous cargo
  - ・Take it into consideration that a secondary disaster, breaking-out in port areas, will have tremendous impacts. Such vessels should choose offshore evacuation as an emergency measure, if allowed by the time allowance for tsunami arrival and the required time to reach a safe area.
  - ・ Generally speaking, head-out berthing is desirable for a vessel to berth,

1.2.2.3. Safety/disaster-prevention measures for large vessels carrying dangerous cargo, reflecting the lessons from the Great East Japan Earthquake

The evacuation methods of large vessels carrying dangerous cargo should be reviewed and revised based on simulation-assessment on vessel maneuvering and navigation from the standpoint of safety preservation, putting emphasis on the following:

- ✓ There is a risk of the break-out of severe secondary disasters induced by the vast amount of inflammable dangerous cargo on-board of such vessels;
- ✓ Such vessels should evacuate outside the port, except for cases when they are in some special situations;
- ✓ Facilities, methods, procedures and systems for emergency unberthing must be developed.

If a large carrier loaded with vast amount of crude-oil or liquefied gas collides with or goes aground, it may induce the loss of port functions due to the closing of water areas, as well as large-scale disasters such as run-off of the load and fires caused by ignition of the load.

From the stand point of the prevention of such secondary disasters and the limitation of damages, large vessels carrying dangerous cargo are required to take prompt actions and evacuate to safe areas as swiftly as possible.

As described earlier, the safety measures of emergency unberthing have been employed as a part of the safety measures for large vessels carrying dangerous cargo. However, studies are required on the following for reflecting the lessons from the Great East Japan Earthquake:

(1) Action items for berth master

[1] Studies on berthing methods for large vessels carrying dangerous cargo

With regard to the berthing method, berth masters should consider a berthing method that is suitable for the berth's situation, taking into account the effectiveness of head-out berthing.

On the other hand, in some specific berth situations, head-in berthing may lead to safer and quicker unberthing.

Therefore, berth masters must determine how a vessel should berth, through comprehensive and systematic consideration on the time required for unberthing, whether safety will be preserved at the time of berthing/unberthing, and how easy the maneuvering will be, etc., in addition to considering the following matters:

- How the port facilities are located around the berth;
- In which direction from the berth, the port exit is located;
- How wide and deep, and in what shape, the available water route and the vicinities are;
- How many towing boats are available and their performance;
- Whether pilots are available;
- Whether the vessel is equipped with thrusters:
- How loading/unloading facilities are arranged on the berth or on the vessel;
- What are the characteristics of weather or sea conditions around the berth or port;
- How much vessel traffic is around the berth.

What is stated above must be considered when berths are to be newly constructed; and in addition, with regard to the existing berths, these factors must be considered when such berths are undergoing large-scale re-construction or when, along with such reconstruction, alteration to the operations are to be made.

However, it should be noted that tug-boat arrangements or thruster facilities are effective for ensuring safe and prompt unberthing, regardless of berthing methods—head-in or head-out.

[2] Facilities on quay

a) Quick release hook

As a lesson from the Great East Japan Earthquake, it is desirable to duplicate, if allowed, the power sources by means of installing emergency generators, and install, if allowed, remote-controllable facilities. The staffs working on unberthing operations for an oil-carrier at an oil-refinery's berth suffered damages by tsunami; in some cases, staffs for unberthing operations were not available.

b) ESDS and ERS

ESDS and ERS, effective for ensuring that a vessel can make its emergency unberthing promptly and with less difficulty, should be employed; and for them, the power system should be duplexed, such as installing emergency generators.

With regard to the application of ERS to VLCC, the possibility of oil run-off at the time of releasing has been feared; however, if an equipment which is able to purge nitrogen is added, such oil run-off will be suppressed when the ERS is manually operated.

Note that there is a risk of oil run-off of a certain amount when the ERS is automatically activated when the vessel hull is displaced due to the mooring-line break-down, although this depends on the rate of hull movement off the berth.

Photo 1: ERS

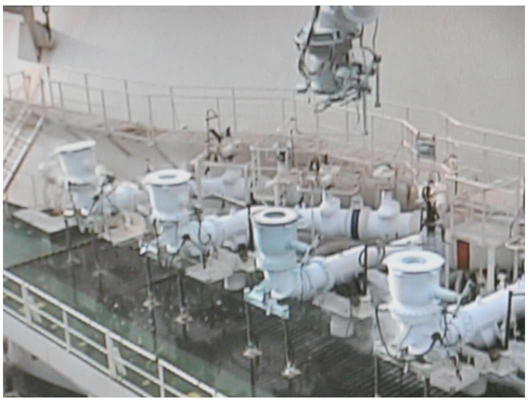


Photo 2: Actually Activated ERS

Photo 3: Actually Activated ERS (On-board Equipment) on March 11

*Source of Photo 1 to 3: CHUBU Electric Power Co., Inc.

c) Emergency PA system

As the lessons from the Great East Japan Earthquake show, the power supply for emergency PA systems must be duplexed with emergency power generators, etc.

[3] Suspension of loading/unloading

Loading/unloading operations must be suspended when the information on a major tsunami warning, a tsunami warning, or a tsunami advisory released by the Meteorological Agency is obtained.

Furthermore, there is a risk that, in a case where the earthquake occurred at a close-to-coast point, a tsunami will arrive before the agency releases a tsunami warning, etc.: therefore, the parties engaging in the loading/unloading operation must make efforts to gather information when sensing a strong earthquake (intensity 4 or greater) or slow but long-lasting motions even if the earthquake itself is not strong.

[4] Oil fence

In some cases in the Great East Japan Earthquake, many difficulties were experienced when works to remove oil fences for emergency unberthing of oil carriers were operated from the land side as working boats could not approach the location.

Therefore, it is necessary to establish a system for prompt collection of oil fences so that they do not obstruct works for emergency unberthing.

In addition, measures should be taken to keep the oil fences from floating away so that they do not interfere with vessel traffic.

[5] Emergency manuals

Emergency manuals for the procedures of emergency suspension of loading/unloading or emergency unberthing should be prepared; in addition, training or drills should be executed periodically on such operations.

Such drills should be executed focusing on the following items and the order listed below:

a) (On the outbreak of earthquake/tsunami) Gathering information/investigation on damage situations

b) Distributing information

c) Discussing with parties concerned

d) Distributing the result of such discussions

e) Suspending loading/unloading operations, and standing-by main engine

f) Releasing loading arm (using ERS)

g) Unberthing

h) Arriving at safe water

For the purpose of preparing the cases where the vessel-to-land or land-to-vessel communications are blocked due to power losses or communication traffic congestions as were often seen in the Great East Japan Earthquake, the training on the items from a) to d), should be executed following the "pre-arrangement" for the cases of communication shut-down, based on the scenario where such power is lost.

(2) Actions taken by vessels

[1] Moored sheltering

There will be a risk that a vessel cannot afford to make its emergency unberthing due to physical obstacles or difficulties in securing safety; vessels must prepare the procedures for enhancing mooring force and other measures for making moored sheltering.

[2] Emergency unberthing of a membrane-type LNG vessel

A membrane-type LNG carrier has a risk of suffering damages on the tank due to sloshing, although the occurrence of such phenomenon depends on the LNG level in the tank; on the other hand, a MOSS-type LNG carrier rarely suffer such damages.

A membrane-type LNG carrier, in a case where having the sufficient time allowance for measures such as taking countermeasures against a typhoon that is coming closer, can adjust its tank level by transferring the cargo from one tank to another to prevent the tank level from reaching its critical range. However, the following actions would be practical for such vessel to take in the situation where it is being forced to unberth due to the occurrence of an emergency situation such as being struck by a tsunami or having a fire during its loading/unloading operations: the vessel should at first leave the berth; then make such maneuvering that could alleviate as much as possible the vessel's motion caused by tsunami waves, winds, wind-waves or heaves; and then, shift its cargo with the tank level being kept within the allowance range of loading.

(Reference 1)

Sloshing is a phenomenon where, due to the vessel's hull motions during navigation, its cargo (LNG) in the tank moves synchronously with the vessel motions to strike hard against the tank walls.

(Reference 2)

The tank structure of a LNG carrier is designed according to the International Gas Carrier Code (IGC Code: International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk); therefore, a vessel with such tank structure is required to execute cargo handling operations that satisfy the IGC Code requirements.

The International Safety Management Code (ISM Code) requires the preparation of manuals to ensure operations that meet the IGC Code requirements.

Gaztransport & Technigaz SAS (GTT), the licenser, specifies the inhibited range of load-level during navigation (for instance, the range of 10 to 70 percent of the tank's height) in order to prevent sloshing damages.

Vessel management companies prepare a manual, referring to such materials as technical documents concerning cargo storing facilities issued by the licensor, the Classification Society Guidance, technical specifications issued by the ship builders; and the navigation guidance issued by the vessel operators. An ISM certificate is issued by the maritime authorities of the flag state (in Japan, Inspector Ministry of Land Infrastructure, Transport and Tourism (JG), and Nippon Kaiji Kyokai (NK) are in charge). A procedural manual should be prepared taking into account the limitations in the event of tsunami arrival, such as low vessel speed.

(3) Arrangement of assistance

[1] Pilot arrangement

The following are considered effective:

Agreeing on pilot-arrangement in emergency situations with pilot associations;

Studying the procedures for emergency unberthing in a situation where pilotage services are unavailable.

Requiring berth masters to fully discuss and share information with vessel masters.

[2] Tub-boat arrangement

Tug boats are required to maintain the same capability as that is obtainable under normal conditions, if at all possible. To this end, it is effective to coordinate with the ships and make pre-arrangements with the vessel's operator.

If such arrangements are made case-by-case according to conditions, such as the amounts of time before tsunami arrival and the expected height of the tsunami, they will allow for practical actions that fit the actual situations.

(Example of pre-arrangement, note: "X" means time, "Y" means length, and "Z" means number of vessel)

・ Time allowance is X minutes or longer: Z tug-boats will be available.

・Time allowance is X minutes or shorter, and the predicted tsunami height is Y meters or lower: Z tug-boats will be available.

・Time allowance is X minutes or shorter, and the predicted tsunami height is Y meters or higher: No tug-boats will be available.

With regard to the cases where the situation is predicted to prevent the arrangement of sufficient number of tug-boats from being available as prearranged, it is necessary to specifically study in advance, by using the assumptions (ex. “X number of tag-boats are available”; or “No tug-boats are available”), the details of the actions to take (such as how to unberth or how long will it take to make the unberthing); for such studies, making reference of the investigation reports on the past incidents will be effective, or conducting simulations on the individual berth will be desirable.

If the patrol boats or fire boats deployed at the loading/unloading site of a large vessel carrying dangerous cargo have towing capability, those boats will be used for assisting the vessel’s emergency unberthing.

Table 1 Overview of the safety measures for large-scale tanker berth (skipped)

Table 2: Conventional Tsunami Countermeasures or Navigation Safety Measures and Points of Revision, Part 1

Item	Challenge	Experienced Incidents and Necessity of Revision	Basic Ideas of Solution
1. Securing Power and Communication Means	(1) Securing the power for berth facilities	✓ Loading/unloading facilities lost functions due to power loss, not released, prevented the vessel from unberthing. ✓ A vessel, even having approx. 40 minutes allowance for unberthing if the unloader is released, was unable to do anything due to power shut-down, and failed to unberth.	✓ Keeping auxiliary power supplies or effective communication means available is indispensable, for emergency situations.
	(2) Securing communication means with ships	✓ Very limited number of business operators had prepared tsunami countermeasures on the assumption of power loss. ✓ On-board generators or others might be used for supplying power, when technically possible. ✓ Communications between the vessel and land was interfered with by power-loss or telephone line congestions that blocked the use of telephone or facsimile. ✓ VHF radio systems were working well to secure vessel-to-vessel communication. ✓ CB-Radio equipment (transceivers) were useful for vessel-to-land communications. ✓ MCA Radio systems were effectively working. ✓ Battery-powered radios were helpful for information gathering. ✓ TV sets, rarely able to receive digital TV broadcasting on board in the off-coast areas, were not available for getting the information on the tsunami or damage situations. ✓ Some of the business operators, in the wake of the earthquake disaster, equipped their unloaders with emergency power supplies, relocated such unloaders onto higher places, or installed satellite telephone systems, for preparing the tsunamis in future.	✓ Preparing manuals specifically for the individual business operators on the assumption that there is a risk of the shut-down of power or communication means, and periodically executing drills, is indispensable. ✓ Multiplexing the communication means is indispensable for preparing against the shut-down of information infrastructures, for the purpose of securing the distribution means of recommendations or other information as an alternative to the telephone or facsimile. ✓ Improving of on-board reception and transmission equipment is necessary; and along with that, requesting broadcasting business operators to expand their broadcast areas is necessary. Also employing BS receivers on board will be effective.
2. Voluntary evacuation at the time of tsunami strike	(1) Pre-arrangements for the case where the secure delivery of a tsunami warning or evacuation recommendation is not be expected	✓ The Regional Coast Guard Office, responsible for the issuance of evacuation recommendation, suffered damages (loss of power, inundation , or others), and the ship agents lost their communication means (VHF, telephone, or facsimile) due to power shut-down; as a result, the tsunami-information or evacuation-recommendations were not delivered.	✓ Pre-arrangements should be established on the actions when a tsunami warning is released—for example, take the same actions as those for the case where an evacuation recommendation is issued.
	(2) Pre-arrangements with regard to decision-making on evacuation	✓ Vessels were not able to communicate with cargo owners or ship-agents, due to the power shut-down that the land facilities suffered.	✓ Pre-arrangements should be established between the cargo owner, the ship-agent, and the vessel, too—for example, vessels may evacuate without making announcements. ✓ The issue of the evacuation of on-quay staffs and vessel crew-members should be treated as one of the voluntary safety-measures for the tsunami-measures conference, etc. to discuss. The issue of the evacuation method of on-quay staffs, in particular, should be discussed so that their evacuation into the vessel is considered one of the options.
	(3) Smooth evacuation of a large number of vessels	✓ A large number of vessels rushed to the area around the entrances to evacuate off the port; as a result, such areas got congested; in some cases, on the other hand, vessels approaching a point where navigation route meet, communicating on VHF radio with the vessels coming-down on the other channel, made the arrangement on the passing order, formed a line and made the merge in safety.	✓ Because, in a case where the time allowance of the tsunami arrival is short, if taking offshore evacuation without a particular reason, a vessel may have an accident, the evacuation methods for small vessels at berth in port areas should be discussed so that such small vessels may be excluded from the targets of evacuation. ✓ Pre-arrangements on evacuation methods and others should be discussed by the parties concerned, because ports are often congested by the vessels that conducted their emergency unberthing and going offshore.
	(4)Let non-Japanese speaking crew know what to do when tsunami warnings have issued	✓ Some ports have arrangements on evacuation orders for the situation where an earthquake or tsunami is predicted to occur. ✓ Non-Japanese speaking crew members did not understand what happened and what they were supposed to do.	✓ The education and information delivery of the general knowledge on tsunami and the countermeasures to non-Japanese speaking crew members is important and indispensable.

Table 2: Conventional Tsunami Countermeasures or Navigation Safety Measures and Points of Revision, Part 2

Item	Challenge	Experienced Incidents and Necessity of Revision	Basic Ideas of Solution
3. Evacuation assistance from the land and on the sea	Evacuation in the situation where tug-boat or pilot assistance are not expected	✓ The arrangement of pilots, tug-boats, or mooring line workers was difficult during tsunami situation. ✓ There was seen a case where several tug-boats tried in vain to assist a large vessels carrying dangerous cargo that was drifting due to being pushed by the tsunami wave during its offshore evacuation.	✓ Conventionally, on the assumption that pilots, tug boats, and mooring-line workers are arranged, the studies have been conducted on offshore evacuation; however, the actions or measures should be made for a situation where no arrangement is made. ✓ It is indispensable to have knowledge on the number and performance of the tugs that can be arranged in an emergency situation, and to have conducted the studies on the unberthing method by which their assistance works effectively. ✓ It is desirable to agree on the pre-arrangements with regard to the actions and communication arrangement in an emergency situation with tug-boat operators and pilots.
4. Identifying the locations of safe evacuation water-area	Information sharing on safe offshore evacuation water-areas	✓ With regard to offshore evacuation, there was no information available on how far off the port to evacuate for securing safety.	✓ Clarifying and sharing information on the safe evacuations areas where tsunami impacts would be less for individual vessel types, is indispensable.
5. Evacuation of vessels carrying dangerous cargo	(1) Criteria of the suspension of loading/unloading	✓ Conventionally, a tsunami forecast is released within approx., 3 minutes ✓ Laws and regulations, targeting some kinds of operation sites, specify the earthquake intensities for which pumps must be stopped and emergency-shut-down valves must be closed.	✓ Studies on the timing of the suspension of loading/unloading are required, including it as one of the options that loading/unloading must be suspended, not waiting for the release of tsunami forecast, and the actions must be initiated for the preparation against the coming tsunami. ✓ Between-land-and-vessel pre arrangement is necessary on the criteria for the suspension of loading/unloading at the time of earthquake occurrence.
	(2) Evacuation methods (offshore, anchored sheltering, mooring enhancement, or on-terrene evacuation)	✓ Evacuation methods must be decided according to the time allowance to tsunami arrival, the time required to choose between the evacuation to a safe water area, offshore evacuation, anchored sheltering, mooring enhancement, and on-land evacuation. ✓ A vessel carrying dangerous cargo, if causing a secondary disaster in port areas, will give exert severe impact on vessel-traffic safety. ✓ No assistance by pilots, tug-boats, or mooring line workers is expected, or the power required to un-berth will be lost due to the power shut-down that occurred on terrene, in the situation where a vessel is forced to unberth. ✓ Looking into the situations of the vessels that chose anchored sheltering, it is clear that the vessels that have completed anchoring before the tsunami arrival suffered relatively less damages. ✓ A vessel that chose moored sheltering should keep its main engines ready as well as enhancing the mooring force by adding mooring lines. ✓ The oil fences had to be removed for a vessel to unberth; however, working boats failed to come close; although oil fence releasing was tried from the land, such work was difficult due to strong tension at the connecting section; finally, the connecting section was cut-off with knives.	✓ With regard to enhanced mooring, hull motions simulations should be conducted to estimate the mooring critical conditions (mooring limit), and then the studies should be conducted on what actions should be taken, based on such estimations of critical mooring conditions. ✓ With regard to anchored sheltering and offshore evacuation, what actions should be taken should be figured out with the assessment of the impact on the vessel by the tsunami., ✓ It is necessary to establish a system for prompt collection of oil fences so that they do not obstruct emergency unberthing works. ✓ As regards emergency response such as stoppage of cargo handling and unberthing, it is necessary to develop a manual for such operations and to conduct regular training exercises.

Table 2: Conventional Tsunami Countermeasures or Navigation Safety Measures and Points of Revision, Part 3

Item	Challenge	Experienced Incidents and Necessity of Revision	Basic Ideas of Solution
5. Evacuation of vessels carrying dangerous cargo	(3) Moorage method for large vessels carrying dangerous cargo	✓ Time required for offshore evacuation must be reduced. ✓ Emergency self unberthing must be taken into consideration. ✓ In the middle of an emergency shut-down operation in an oil refinery, a casualty case occurred induced by the tsunami.	✓ In general, vessels should be berthed with head-out that the difficulty of emergency self unberthing is reduced, and the time required for making an offshore evacuation is shortened; however, whether to berth head-in or head-out must be decided case by case according to the conditions or situations of the berth or the vessel—how deep and wide is the water area surrounding the berth, how heavy is the vessel traffic around the berth, what kind of loading/unloading facilities are available on the berth, what kind of singularity the weather or sea conditions around the berth have, and what condition the vessel is in. If the vessel decided to berth head-in, the measures for reducing the time required for unberthing must be prepared if necessary, such as arranging tug-boats for unberthing assist, or applying the equipment (must be remote-controllable) with the capability of quick release. ESDS or ERS is equipment that ensures that a vessel can make its emergency unberthing even in the middle of loading/unloading. ✓ Assessment using simulations on vessel navigation or maneuvering is required.
6. Evacuation methods for other vessels than vessels carrying dangerous cargo	(1) Criteria for the suspension of loading/unloading (except for passenger vessels and pleasure boats)	✓ Same as the backgrounds with regard to vessels carrying dangerous cargo	✓ Studies and discussions should be conducted through referencing the cases of vessels carrying dangerous cargo.
	(2) Evacuation methods (offshore evacuation, anchored sheltering, mooring enhancement, or on-terrene evacuation)	✓ Same as the backgrounds with regard to vessels carrying dangerous cargo	✓ Studies and discussions on the appropriate evacuation methods, by the type and ✓ Size of vessel must be conducted, in addition to those for vessels carrying dangerous cargo.
	(3) Mooring methods for large vessels	✓ Same as the backgrounds with regard to vessels carrying dangerous cargo	✓ Studies and discussions should be conducted through referencing the cases of vessels carrying dangerous cargo.
7. Post-tsunami information-delivery to vessels	(1) Necessary information to damaged vessels or vessels in evacuation	✓ Ship agents and other suffered damage or lost power; no information on the situations of the ports including the availability of port infrastructures or water route in the ports were available; those vessels were trapped in a situation where they had no way to make decisions. ✓ The information was also unavailable on obstacles drifting on the surface in the ports or in the coast offing. ✓ The navigation safety information that was issued by the Coast Guard Office represented positions by latitude and longitude; however, such representation was not easy to understand; such position representation as "X degrees Y miles from Z" will be easier to understand.	✓ With regard to the availability of port infrastructures, situations in the port such as water depth or channel availability, and the obstacles drifting around the offing of the coast, easy to understand information should be delivered.
	(2) Means for information provision	✓ Although the ministries or agencies concerned posted the information related to the earthquake on the Internet, such information was not delivered to the damaged vessels or sheltering/evacuated vessels ✓ Hydrographic and Oceanographic Department posted on their web pages their graphical information that represents on a map the navigational warnings with regard to the situations of the obstacles drifting in the offing of the coasts damaged by the tsunami. ✓ General vessels having the capability of Internet connection are rare; almost all the general vessels staying in the offing had no other way of information gathering than getting information via their ship agent, etc. using facsimile and others.	✓ It would be reasonable to assume that, as the information delivery means to the vessels staying in the offing for evacuation, the navigational warning or the Internet will be playing a central role; however, the delivery of information should desirably be done in an easy-to-understand way. ✓ Foreign vessels, in particular, must be given such information in an easy-to understand way.

III. Conclusion

In this part, the summary of the following is introduced: the “Questionnaire/Interview Survey on the Great East Japan Earthquake” conducted by the Japan Association of Marine Safety in FY2011; and the “Research and Study on Navigation Safety Measures at the time of Major Earthquake and Major Tsunami” conducted by the same association in FY2012 and 2013.

The survey in FY2011 was conducted mainly by means of questionnaire or interview of the crew members who were on-board the vessels that stayed in the ports that were affected by the Tohoku Pacific Offing Great Earthquake on March 11, 2011, and also to the organizations and their members having involvement to such ports

On the other hand, the research conducted in FY2012, through compiling and analyzing the lessons and problems that were found during the survey by the Central Disaster Management Council and the previous fiscal year’s survey, presented a general view of the damages due to the Great East Japan Earthquake; furthermore, the research, through compiling and analyzing of the incidents related to the current tsunami measures/navigation safety measures, extracted the problems to review and study concerning such measures; finally, the research showed basic ideas for the improvement and enhancement of such measures.

Moreover, the association, picking up Shimizu Port as a model, conducted the surveys on the current Tsunami Safety Measures for the port; in addition, the association executed tsunami simulations applying the Nankai Trough Major Earthquake Fault Model and made the assessment of the impacts that the port is expected to suffer; then, the association conducted the studies on the measures applicable to the port. In addition, the association, for the purpose of determining the critical mooring conditions for large vessels carrying dangerous cargo (VLCCs or LNG tankers), made assessments on tsunami impacts by executing hull-motion simulations.

In FY2013, the association studied the critical mooring/anchoring conditions for large vessels carrying dangerous cargo and general vessels (3,000 DWT class and 10,000 DWT class). At the same time, the association conducted simulations for the following: the studies on the behaviors of large vessels carrying dangerous cargo during their emergency unberthing maneuvering, by applying a hypothetical quay; a large cargo vessel’s emergency unberthing under tsunami forces, by applying simulated tsunami forces in the model port; the maneuvering of cargo vessels (of 3,000 gross tonnage, and of 500 gross tonnage) from their outgoing berthing. In addition, the association, based on the findings from such simulations and others, studied the safety/disaster prevention measures for large vessels carrying dangerous cargo.

The association has reflected the outputs of the studies/discussions at the research committee, the basic concepts, and the experiences or findings in the “Appendix: Guides to the

Preparation of Tsunami Safety Measure in a port," which is believed to contribute to the preparation or review of tsunami measures for individual ports.

With regard to the assignment of roles to the individual parties concerned, the parties concerned are required to discuss and agree on pre-arrangements, at the conference of Tsunami Safety Measures for vessels, along with the discussions or review of Tsunami Safety Measures.

(1) Securing electric powers and communication means

Summary: It is required to keep the emergency power sources prepared for loading/un-loading facilities or mooring so that they work well in emergency situations caused by power shut-downs.

In the Great East Japan Earthquake, power loss caused by the earthquake made loading/unloading facilities go down and prevented them from being cut off from the vessel, and as a result the vessel failed to conduct emergency unberthing. For instance, a vessel, although having a time allowance of about 40 minutes until the tsunami strike, was unable to do anything because of power loss.

In addition, with regard to emergency power supplies, it is recommended to take tsunami countermeasure such as relocating the emergency power supplies on the upper floors because if installed on the ground floor, they may face a risk of function loss due to the inundation caused by tsunami water.

Summary: Emergency communication system should have a multiplexed configuration where means other than telephones or facsimiles, so that the system is able to function even in a case where the communication infrastructures have lost their functions due to damages.

With regard to the multiplexing of communication means, the utilization of the satellite telephone systems or MCA Radio system* which have been used by some business operators will be the candidates for the alternative communication channel; furthermore, the utilization of port radios for relaying instructions of the Captain of the port, such as evacuation recommendation, is feasible, and it will be another form of multiplexing of communication means.

* Note: MCA Radio system is a business-user oriented mobile communication system where a number of users share multiple channels; MCA has been permitted as an alternative communication system to the emergency municipal radio communication system. Some vessels use MCA Radio system because it covers coastal areas.

(2) Pre-arrangement

[1] Pre-arrangement for a case where the evacuation recommendation is not delivered

Summary: Parties concerned should agree on the actions for disaster prevention, such as “In a case where a tsunami warning, etc. is released, by taking the same actions as agreed for the case of an evacuation recommendation.

In the case of the Great East Japan Earthquake, situations were seen as follows: Coast Guard Offices/Stations, which was responsible for issuing orders, lost such functions due to power loss or inundation, and also the ship agents were not able to use communication means such as VHF, telephone or facsimile due to power shut down. As a result tsunami information or evacuation recommendations were not delivered; hence, prompt and proper actions were not taken.

[2] Pre-arrangement on vessel's decision of evacuation

Summary: Pre-arrangement should desirably be done in advance on the decision making procedure of vessel evacuation method; and available assistance, etc., so that, in the situation where a tsunami warning has been released. The vessel master, making proper judgments on the vessel actions in the tsunami-strike situation, prompts speedy and proper actions under the pre-arrangement described.

In the cases of the Great East Japan Earthquake, such incidents described in the following were often seen: the vessel master solely by his judgment has to decide every action because communications to cargo-owners, vessel operators, or ship agencies had been blocked due to the power-loss and communication congestions that occurred in the land facilities.

[3] Pre-arrangement on vessel-evacuation support scheme

Summary: On the vessel master's evacuation decision including an emergency unberthing, the availability of the assistance by pilot, tug-boat, or mooring-line worker will have a significant impact; therefore, it is desirable for parties concerned to agree on pre-arrangement on such matters.

The following should be remembered: in the cases of the Great East Japan Earthquake, around the ports that suffered severe damages, the vessels rarely received assistance from pilots, tug-boats or mooring-line workers.

[4] Pre-arrangement by parties concerned on offshore evacuation

Summary: Because, vessel traffic in the port is expected to be congested by the vessels on their way to the offing, it is recommended for the parties concerned to agree on pre-arrangement on emergency evacuation.

In the cases of the Great East Japan Earthquake, severe vessel traffic congestions occurred around the levees at the port entrance by many vessels rushing to the entrance.

On the other hand, there was an instance that vessels approaching a channel meeting point on one of the passage, having VHF radio contact to the vessels coming on another passage, determined the order of passing the cross-point, formed lines according to the passing order made successful evacuations

(3) Keeping non-Japanese speaking crew members informed of tsunami general knowledge and delivering tsunami information to them

Summary: Non-Japanese speaking crew members must be kept informed of tsunami general knowledge and countermeasures.

In the case of the Great East Japan Earthquake, non-Japanese speaking crew members, at the time of the earthquake occurrence did not understand what happened or did not know what they were supposed to do

Therefore, it is essential to keep non-Japanese speaking vessel-masters informed of the following items by means of distributing brochures or leaflets so that they properly execute the first-hand actions or the countermeasures in the situation of tsunami strikes:

- General knowledge of earthquake (likelihood of occurrence, expected scale, etc.) that are expected in the vicinity of their way ports;
- How to collect information at the time when an earthquake or an tsunami breaks out;
- Hazard map
- The pre-arranged emergency countermeasures in the port; such as first-hand actions, Tsunami Safety Measures and safe offing areas to evacuate;
- Recommendation of the Captain of the port's and others.

(4) Sharing information on the evacuation areas where vessel safety is secured

Summary: Information on the safe areas that will receive less tsunami impacts must be shared in advance.

It is recommended, through executing tsunami simulations, that knowledge on tsunami impacts on the areas that are used for offshore evacuation/stand-by; is shared by the parties concerned including vessels.

The tsunami simulations executed on the Shimizu-Port model shows the following:

In the offing areas with a water-depth of deeper than approx. 200 meters, although the sea-level changes may be observed there, the tsunami-water flow-speed is less than 0.5 meters (approx. 1 knot); it indicates that in such areas, tsunami impacts are expected to be relatively small.

(5) Critical mooring conditions and critical anchoring conditions

Summary: The mooring hull-motion simulations in the model port (Shimizu-Port) by applying waves of tsunami-wave form or sine wave form revealed that the critical mooring condition of tsunami-height is approx. 1 to 3 meters for VLCCs or large LNG vessels, and is approx. 3 to 6 meters for10,000 DWT class or 3,000 DWT class vessels.

The magnitude of moored vessels' motion, under different combinations of tsunami height and tsunami flow speed, was obtained through executing tsunami simulations on the Shimizu-Port model for the waves of tsunami wave-form or sine-wave (with a period of 5/10/15 minutes); the findings are shown as follows:

(a) Critical mooring condition of tsunami height becomes lower when both the impact of tsunami height and the impact of tsunami-water flow are exerted at the same time.
(b) Critical mooring conditions become lower (meaning more severe) as the tsunami period gets shorter; it indicates that not only a tsunami height but also a rapid rise in water level affects critical mooring conditions.

In addition, the following findings were obtained:

With regard to VLCCs and large LNG tankers, when waves of tsunami-wave-form are applied to the mooring vessel, the mooring reaches its critical situation at the tsunami-wave height of 3 meters if the tsunami wave is hitting the vessel from the direction along the ship center line, and at the height of 1 meters if the tsunami wave is hitting from the beam direction; and for the waves of sine-wave form, the mooring reaches its critical situation at the tsunami-wave height of 1 meters for a period of 5 minutes, 2 meters as for a period of 10 minutes, and 3 meters for a period of 15 minutes.

With regard to the vessels of 10,000 DWT class or 3,000 DWT class. the mooring reaches its critical situation for a wave of tsunami-wave-form at the height of 6 meters if the tsunami is hitting the vessel from the direction along the ship center line; and for a sine-wave tsunami, the mooring reaches its critical situation at the tsunami height of 3 meters for a period of 5 minutes, and 6 meters for a period of 10/15 minutes.

Generally, a tsunami period is in the range of several minutes to several tens of minutes, and the period becomes shorter— it means the water level rises rapidly—at the point closer to the earthquake source, and longer —it means the water level rises relatively slowly—at the point farer away from the earthquake source.

For instance, with regard to the tsunami-waves that would be caused by the Nankai Trough, at one of the three major bays (Tokyo-wan, Ise-wan, and Osaka wan), because it's far away from the expected earthquake source, the tsunami-wave period is relatively long (meaning that the water level rises slowly); therefore the critical mooring conditions are expected to be larger (meaning more moderate) than the values shown above.

It should be noted that, because the simulations mentioned above assumed that vessels are moored with usual mooring methods, the proposed mooring conditions should be applied to the case where vessels are moored with usual mooring methods; therefore, the mooring-force improvement method such as the addition of mooring lines, in particular breast lines and spring lines or the retorquing of mooring-drum brakes is expected to raise (meaning alleviate) the critical mooring conditions.

Summary: With regard to the vessels in anchored sheltering, the critical mooring condition of tsunami-water flow speed when the vessel is hit by tsunami waves is approx. 3 to 6 knots; when assuming swing angle is 15 degrees, the critical condition is approx. 2 to 4 knots.

Note that the critical tsunami-water flow speed shown above was obtained when the following conditions were assumes:

Type of anchors: JIS or AC14;

Anchoring method: single anchor;

Vessel type: 500 DWT class to 300,000 DWT class

Water depth: 15 meters for 500 DWT class and 3,000 DWT class; 20 meters for 10,000 DWT class and 30,000 DWT class; 30 meters for 60,000 DWT class, 200,000 DWT class and 300,000 DWT class;

Anchor cable extension length: obtained from the equation,S (m) = 3D + 90 (where, D is the depth of water)

(6) Feasibility of the emergency unberthing of a large vessels carrying dangerous cargo

Simulations were conducted with regard to the situations where large vessel carrying dangerous cargo is trying to make an emergency unberthing off a hypothetical quay, on the different assumptions as follows:

Berthing head-in or head-out;

Assisted by a tugboat or not;

Equipped with thrusters or not..

The outputs of the simulation indicate the following:

Summary: A single tug-boat is able to assist a vessel to make an emergency unberthing under on-shore wind of 5 m/sec.

(a) Assumption: the vessel is using stern-kick maneuvering; wind is on-shore of 5 m /sec; the vessel is not using a thruster; the vessel is not assisted by a tug-boat.

The vessel does not make an emergency self unberthing, because of provability of damage on quay and/or hull.

(b) Assumption: the vessel is assisted by a single tug-boat; the vessel is using stern kick; the tug-boat is pulling the bow.

The vessel makes a transfer with a low risk of damages to the hull or the fenders. Furthermore, during the vessel's turning, the tug-boast makes an effective assist

Summary: A large LNG tanker, if equipped with a thruster, makes an emergency unberthing under on-shore wind of 5 m/sec.

(a) Assumption: the vessel is a LNG tanker equipped with a thruster; stern-kick is applied on the stern, and the bow thruster is used.

The vessel is able to make a transfer off the quay. The risk of damages to the hull and fenders is low. The vessel makes an emergency unberthing.

(b) Assumption: assistance by a tug-boat is available; the vessel is using thrusters:

Such method makes vessels maneuvering easier during the vessel's unberthing: furthermore, while the vessel is turning, it helps the vessel accomplish a relatively large turning angular speed in a short time.

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(7) Suspension of loading/un-loading

Summary: Loading/unloading must be suspended when tsunami information such as a Major Tsunami Warning/Tsunami warning, or Tsunami Advisory is delivered.

In some cases where an earthquake breaks out in a close-to-coast area, there is a chance of a tsunami arriving before the Meteorological Agency releases the tsunami warning or other warnings.

Vessels must make efforts to collect information when sensing a strong (intensity 4 or greater) earthquake, or even in the case of a small earthquake when sensing slow but long-lasting motions.

(8) Evacuation: how to choose and execute evacuation method (offshore evacuation, in a port sheltering, moored sheltering, or on-terrene evacuation).

Summary: Vessels, according to the length of time allowance for the arrival of the tsunami and the time required to make an evacuation to safe water, must choose most appropriate evacuation method—offshore evacuation, in a port sheltering, moored sheltering, on-land evacuation, or others.

Among the vessels that were sheltered inside a port using an anchor in the Great East Japan Earthquake, those that were already anchored before the tsunami arrival suffered less damage.

When strengthening the mooring and sheltering the ship at the port, use extra mooring lines and/or apply additional tightening to the brakes of a mooring drum. At the same time, be ready for starting the main engine and anchorage.

Large vessels may face a risk of damages to quay or their hull, in a situation where tugboat assistance or thrusters are unavailable.

(9) Safety measures for large vessels carrying dangerous cargo

[1] Requirements to quay masters

Summary: Quay masters, with regard to the berthing method of large vessels carrying dangerous cargo, are required to make decisions on the berthing method, while considering the superiority of berthing with head-out, through comprehensive considerations including the current berth utilization or situations.

Although, in general situations, berthing with head-out is considered better to make a safe and prompt emergency unberthing, quay masters should decide the berthing method at individual quays through comprehensive study, as well as the time required for unberthing, safety and convenience of berthing/unberthing in normal situations.

Note: tugboat arrangement and thruster facilities will be effective for a safe and prompt unberthing, regardless of berthing direction.

Summary: Quays should desirably be equipped with remote-controllable quick release hooks, ESDSs, and ERSs

(a) Quick release hook: In light of the lessons of the Great East Japan Earthquake that the worker, while engaging in the unberthing operation of a tanker, suffered damages by tsunami, and in addition when considering the case where worker are unavailable, quays should desirably be equipped with remote-controllable hooks if allowed.

(b) ESDS or ERS: they are so effective that the execution of emergency unberthing will be completed with less difficulty and in less time, and should be installed with emergency powers.

Summary: with regard to oil tankers, etc., the preparation of such arrangement of housing oil-fences, which have been expanded prior to loading/unloading, so that such fences will not interfere with emergency unberthing, is required. In addition, oil fences, etc. should be expanded in such a way that they will not, due to run-off by tsunami, interfere with vessel traffic.

In a case of the Great East Japan Earthquake, such oil fence removing, which was necessary for a tanker to unberth, was not executable because the working-boat had no chance of coming close to the fence; hence, the operation, done by the work from the land, involved considerable difficulty.

Summary: with regard to the emergency procedures of loading/unloading suspension or unberthing, quay masters are required to prepare manuals and periodically execute drills.

With regard to training, the involvement of vessels will improve the training effectiveness; quay masters should not miss any chance of training—table top exercises, dry-run drills or drill-execution at the time of usual unberthing will be effective.

[2] Vessel-side arrangement

Summary: Though there is a possibility of difficulty in unberthing caused by physical obstacles or problems of safety, vessels are required to prepare, in collaboration with quay masters, the procedures such as mooring-force enhancement which is required for moored sheltering.

Summary: Membrane-type tankers, during their emergency unberthing, must at first make efforts to leave the quay regardless of tank load level, and then start maneuvering so that vessel motions due to tsunami-waves, winds, or heaves will be alleviated to be as small as possible; and in addition, such tankers are required to consider, as one of the practical measures, shifting cargo within the allowable range of loading criteria.

Membrane-type LNG tankers have a risk of tank damage due to sloshing depending on the LNG quantity in the tank— sloshing is a phenomenon where the LNG loaded in tank moves in a synchronous way with the hull motions, and as a result strongly hits the tank walls.

[3] Assistance arrangement

Summary: Pre-arrangement with the pilot associations on the pilotage in emergency situations will be effective. Quay masters are required, for the emergency unberthing where pilots are unavailable, to conduct preliminary studies on such procedures, and in addition, to have meetings with vessel masters.

Summary: Tug-boasts should aim to show equivalent performances to those in their usual operations as much as possible; therefore, it will be helpful for vessels to have pre-arrangement with vessels.

Such pre-arrangement should be made for individual cases classified with the situations—for example, how much time is allowed before the tsunami arrival, or how high the expected tsunami height is; making such case-by-case pre-arrangement will ensure practical actions.

(Classification of situations: example)

・If the time allowance is longer than X minutes, Z tug-boats will be available.

・If the time allowance is shorter than X minutes, and the expected tsunami height is lower than Y meters, Z tug-boats will be available.

・If the time allowance is shorter than X minutes, and the expected tsunami height is higher than Y meters, no tug-boats will be available.

Summary: In a case where the escort boats/fire boats deployed at the site of loading/unloading of a large vessel carrying dangerous cargo have towing capability, they will be used for emergency unberthing.

(10) Emergency unberthing on the model port (Shimizu Port)

Summary: The tsunami simulations on the model port (Shimizu Port) revealed that, during the tsunami strike, it was difficult to surely make a series of manoeuvers from emergency unberthing/turning to leaving port.

The studies on the emergency unberthing feasibility of a large container vessel and maneuvering methods, on the assumption that the vessel is trapped in a tsunami based on the simulation outputs on the model port (Shimizu Port), revealed the following:

(a) The hypothetical vessel did not make unberthing in onshore tsunami flows; on the other hand for offshore flows, the vessel made unberthing.

(b) In the situation where the vessel speed had not yet been increased to a fast level, it was likely for the vessel to lose control against a tsunami flow of a speed of more than approx. 2 knots; furthermore, once the vessel lost control, there was a risk of grounding in shallow water or a risk of collision with a quay or levee.

(c) Once the vessel had managed to move to the area where the flow situation was relatively moderate, several cases were seen where the vessel, recovering its turning ability, secured the steerage by increasing the engine output almost to its maximum and made a safe evacuation off the port.

(d) Once the vessel managed to make unberthing, the vessel was able to anchor in port areas; therefore, it was necessary to pre-determine the area for making anchored sheltering, and to stand by for dropping anchors.

Summary: A cargo vessel of gross tonnage of 3,000/500 tons, passing through the port entry, made offshore evacuation, during the tsunami strike.

Vessel-maneuvering simulations were conducted for the purpose of studying the feasibility for a cargo vessel of gross tonnage of 3,000/500 tons to proceed from the far end of the port along the navigation route, pass the port entrance, and make offshore evacuation, in the situation of forwarding/back-lashing waves and large eddy currents. The results are shown as follows:

(a) The vessel made its evacuation off the port if the vessel succeeded in securing its steerage by raising its engine output to almost its maximum.

(b) The vessel, while passing the port entrance with its maximum engine output at the timing when the tsunami water was back-lashing, was able to keep its course relatively stable compared with the cases of forwarding flows or large eddy currents, in addition, the vessel's drifting was small; hence, the vessel made s stable navigation.

(11) Post tsunami-strike information provision

Summary: To the anchored-sheltering vessels in the offing, easy-to-understand and useful information on the availability of port infrastructures, the situations in port areas including navigation route and their water depths, and navigation obstacles drifting on the water surface must be delivered.

In the case of the Great East Japan Earthquake, such vessels were totally unable to get information on the situations in the port including the availability of port facilities, whether navigation route were available or not, and the information about navigational obstacles drifting on the surface in port areas or in the near-by coast areas, because their ship-agents suffered damages or lost powers; such information shut-down interfered with such vessels' making decisions on go/no-go of port re-entry. In addition, there were many cases observed where, unfortunately due to the shift of ground TV broadcast to the digital broadcast system, the vessels staying in the offing were unable to collect the information on tsunami information or damage situations via television broadcasts.

Therefore, as well as the improvement of broadcast reception equipment on vessels, it will be effective to request the broadcast business operators to expand their broadcast range; in addition, the improvement of satellite-broadcast (called BS) reception environments will be effective.

With regard, in particular, to the information delivery to the vessels anchored sheltering in the offing, because the Navigational Warning System or the Internet plays the central role for information gathering, the preparation of systems to enable foreign vessels to understand the information delivered via such means will be necessary.

At the same time, vessels sheltering in the offing are recommended to try to inform the parties concerned of the situations of the nearby areas, and, in addition, to try to exchange information with other vessels staying in the offing.

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