The lessons of the Great East Japan Earthquake 2011 and the countermeasures against earthquakes and tsunami in future- Fundamental Concepts behind Future Tsunami Disaster Prevention –

by

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ABSTRUCT

At 14:46 on March 11, 2011, a massive moment magnitude 9.0 earthquake occurred off the Sanriku coast. The Great East Japan Earthquake vastly exceeded expectations in all aspects, such as the scale of the earthquake, the height of the tsunami, the extent of flooding, the broad extent of subsidence, and the scale of human and material loss; the enormity of loss centered on Iwate, Miyagi and Fukushima prefectures is the greatest since World War II. It is necessary to seriously accept the fact that enormous damages clearly exceeding prior and existing predictions occurred recently, improve past concepts, reexamine everything from prediction of earthquakes and tsunamis to disaster prevention measures, and rebuild a disaster prevention plan for the future. Based on the occurrence of the recent colossal tsunami and the damages that it caused, it was revealed that there are problems with disaster prevention measures that overly depend on shore protection facilities. As a result, it is necessary to combine land usage, evacuation facilities, disaster prevention facilities, etc., focusing on resident evacuation, and to establish comprehensive tsunami measures that incorporate every possible measure, both hard and soft.

KEYWORDS: Evacuation behavior, Predictions of earthquakes and tsunamis, The Great East Japan Earthquake, Tsunamis of two levels,

1. INNTRODUCTION

Due to geographical, topographical, geological and meteorological conditions, Japan has experienced numerous kinds of natural disasters, including earthquakes, tsunami, volcanic eruptions, typhoon, torrential rain and heavy snowfall. This is particularly the case with regard to earthquakes; despite Japan only making up a minuscule 0.25% of the earth's land surface, roughly 20% of all magnitude 6.0 or higher earthquakes worldwide between 2000 and 2009 have occurred within or in the vicinity of Japan's islands. While many lives and much property have been lost to natural disasters, advances such as the development and strengthening of disaster prevention systems, the promotion of national land conservation and the improvement of meteorological forecasting have improved Japan's capacity to respond, and lessened its vulnerability to, natural disasters. This has resulted in a downward trend in damage due to natural disasters since the middle of the 20th century. (Fig.1)

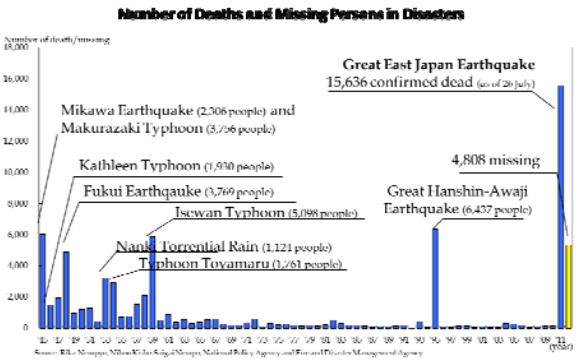

Fig.1 Number of deaths and missing persons in disasters[1]

However, the Great Hanshin-Awaji Earthquake in 1995 smashed the morning calm and reinstilled in

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the Japanese a sense of the danger of earthquakes. And then the Great East Japan Earthquake that struck on March 11, 2011 brought another terrible reminder to the Japanese that, when living in a country prone to earthquakes, no amount of contingency planning can completely protect against natural disasters.The Japanese islands are located at the point where four of the earth's tectonic plates meet - the Eurasian and North American continental plates and the Pacific and Philippine Sea oceanic plates. This is one of the reasons why earthquakes are so frequent in Japan. At the point where the continental and oceanic plates meet, the oceanic plates are sliding under the continental plates, and this subduction pulls the continental plates downward; when the limit of how far the continental plates can be pulled downward is reached, they snap back upwards, creating powerful ocean trench earthquakes. Classic examples of such massive ocean trench earthquakes are the Tokai, Tonankai and Nankai megathrust earthquakes occurring at the Suruga and Nankai troughs; and the 2005 Miyagi Earthquake and the recent Great East Japan Earthquake occurring at the Japan Trench. Also, there are numerous active faults within Japan, with the specific number being put at around 2000. Even a magnitude 7 earthquake will cause extensive damage if it occurs directly beneath a city; the Great Hanshin-Awaji Earthquake of 1995 is a case in point, as the epicenter of the earthquake was an active fault.

Turning our attention to tsunamis, we find that there have been eight tsunamis, including the tsunami resulting from the Great East Japan Earthquake, since the Meiji Era (1868) with death tolls of 100 or more people. All of these tsunamis followed magnitude 7.5 or greater earthquakes, and using the number of dead or missing as an index, we see that the top three tsunamis (which accompanied the Great East Japan Earthquake, 1896 Meiji-Sanriku Earthquake and the 1933 Sanriku Earthquake, respectively) all struck the Sanriku coastline; this suggests that the Sanriku area has long been prone to sustaining significant damage from tsunamis. Also, since 1980 there have been 13 earthquakes producing tsunamis at least 50cm high, which is an average of one such tsunami every two to three years. And of these 13 tsunamis, those that followed the 1983 Central Japan Sea Earthquake, the 1993 Hokkaido-Nansei-Oki Earthquake, the 2010 Chile Earthquake and the 2011 Great East Japan Earthquake were large enough to trigger the warning system for giant tsunamis. With the exception of the tsunami produced by the far off Chile Earthquake, each of these tsunamis resulted in at least 100 people killed or missing.

In this paper, we discuss the lessons learned from, and earthquake and tsunami countermeasures resulting from, the Great East Japan Earthquake of March 11, 2011, focusing on the interim report of the Central Disaster Prevention Council's "Expert Panel on Applying the Lessons of the Great East Japan Earthquake to Japan's Earthquake and Tsunami Countermeasures" (hereafter, "Expert Panel") released on June 26, 2011. Chapter 2 will provide a general overview of the Great East Japan Earthquake, including the distribution of seismic intensity, distribution of fault slippage and vestiges of the tsunami. Chapter 3 will look at the damage and other results of the seismic ground motion and the tsunami. Chapter 4 introduces the thinking that has underscored earthquake and tsunami countermeasures prior to the Great East Japan Earthquake. Reflections on the disconnect between expected and actual damage will be touched upon. Chapter 5 will take those reflections and apply them to the thinking for future disaster-prevention countermeasures targeted at earthquakes and tsunamis. Chapter 6 will touch on the future direction of earthquake and tsunami countermeasures, and Chapter 7 will summarize the outlook for the future. The content of chapters 4 through 6 will largely reflect the content of the Expert Panel's interim report.

2. OVERVIEW OF THE 2011 THE GREAT EAST JAPAN EARTHQUAKE

At 14:46 on March 11, 2011, a massive moment magnitude 9 earthquake occurred off the Sanriku coast. The depth of the earthquake was 24km and, on the moment magnitude scale, it was the fourth largest earthquake in the world since the start of the 20th century [2]. The ground motion from the earthquake were picked up by seismic intensity meter in the Tohoku and Kanto regions and everywhere else in Japan from Hokkaido to Kyushu; the strongest measurement was JMA seismic intensity scale 7 in Kurihara City, Miyagi

Prefecture, and from Iwate Prefecture all the way to Chiba Prefecture, the earthquake measured at least JMA seismic intensity scale 5-. The size of the area registering at least JMA seismic intensity scale 5+, which is capable of causing severe damage to buildings and other structures, was 35,000km2, or roughly 10% of Japan's entire land area. The source region of the main shock stretches 450km north to south and 200km east to west, and the area around the epicenter moved at least 30m [3]. Because of the incredibly broad extent of asperity collapse, it took time to measure the collapse from start to finish. As a result, the reported magnitude of the earthquake announced by Japan Meteorological Agency was revised four times. Specifically, three minutes after the start of the earthquake, JMA reported it as magnitude 7.9; one hour and fifteen minutes later it was reported as magnitude 8.4; one and a half hours later it was reported as magnitude 8.8; and two days later it was reported as having a moment magnitude of 9.0.

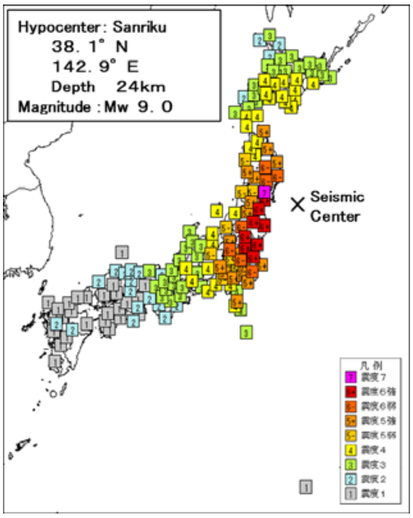

Fig.2 Observed Intensity [4]

Also, the graph of the seismic source time function, which represents the seismic energy released, shows that a significant amount of energy was released over a span of more than three minutes.

Not only was this earthquake powerful, it was also extremely long in duration. Fig.3 plots, at ten second intervals, the values obtained from waveform data produced by seismic intensity meters in various regions and are based on JMA seismic intensity scale. We can see that the earthquake registered intensity scale 4 or higher in Otemachi in Tokyo's Chiyoda Ward for roughly 130 seconds. In Gorin in Sendai City's Miyagino Ward, the earthquake registered intensity scale 4 or higher for roughly three minutes and at least intensity scale 5- for roughly two minutes.

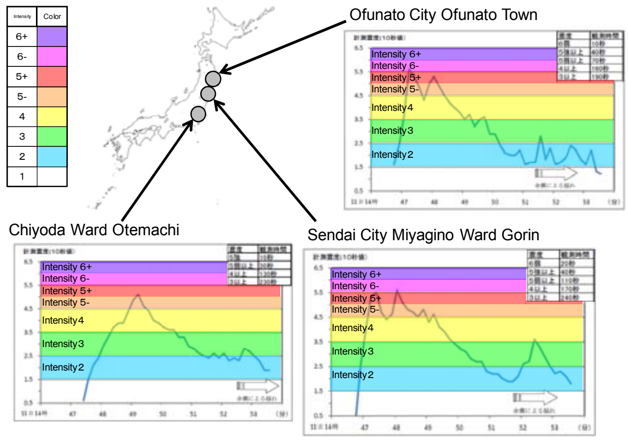

Fig.3: seismic intensity meters in various regions [4]

More damaging than seismic ground motion, however, was the massive tsunami that resulted from it, striking Japan's Pacific coast from Aomori Prefecture down to Chiba. JMA's records show that some tide level measuring facilities were themselves swept up in the tsunami, indicating that the tsunami far exceeded the tide level measurement range and making it impossible to obtain data from those spots. Thus, JMA worked together with various universities to look for vestiges of the tsunami to determine how far inland it went along the Pacific coast. (Fig.4)

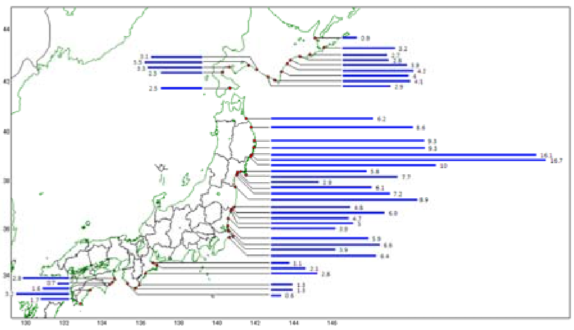
Fig.4: The height of tsunamis estimated from traces of tsunamis at the principal investigation points （unit：m） [4]

This is not the height of the tsunami but rather the height of the vestiges found. According to JMA's records, the largest value was 16.7 at Ofunato City, Iwate Prefecture; however, research by other scientific groups and research institutions record a height of more than 30m for the tsunami.

3. DAMAGE CHARACTERISTICS

3.1 Overview of Damage

The Great East Japan Earthquake vastly exceeded expectations in all aspects, such as the scale of the earthquake, the height of the tsunami, the extent of flooding, the broad extent of subsidence, and the scale of human and material loss; the enormity of loss centered on Iwate, Miyagi and Fukushima prefectures is the greatest since World War II. (Table 1)

Table 1:Earthquake and tsunami caused the tremendous degree and extent damage; as 12 prefectures. [5]

Human Loss	death：15,687, missing：4,757 （as at August 9,2011）
Building Damage	Collapsed ：112,703 buildings, Partially ：143,760buildings （as at August 9,2011）
Applicable Disaster Relief Act	241cities （10 prefectures ） （※）including 4 cities applied on the northern Nagano earthquake

The damage is characterized by its tremendous degree and extent, which made it difficult to gather information and transport supplies, disrupted not only the supply chain in the affected regions but the socio-economic activity of all of Japan, resulted in disaster in sparsely populated and aged areas, and produced compounded damage from the combination of earthquake, tsunami and nuclear power plant accident.

This disaster has resulted in more than 20,000 dead or missing, with the majority being along the Tohoku coast, as well as caused 110,703 buildings to completely collapse and 143,760 to partially collapse.

In terms of transportation infrastructure, expressways, like the Tohoku Expressway, national roads and other roads were closed, with those along the Pacific coast being broken to pieces; in addition, harbor facilities and airport facilities stopped functioning. In terms of lifeline facilities, roughly 8.91 million homes lost power, roughly 480,000 homes had their gas stop and roughly 2.2 million homes temporarily had their water service stop. The cost of the damage to this stock of infrastructure (buildings, lifeline facilities, social infrastructural facilities, etc.) is estimated to total approximately 16.9 trillion yen. (This figure does not include other types of damage, such as the damage to nuclear power plants, the damage caused by harmful rumors, and the damage to Japan's economy.)

Despite the fact that about 80% of these facilities as well as banks, post offices and other public institutions have been restored to working order, roughly half of the harbors and other such infrastructure remain unusable. (Table 2)

Table 2: Recovery level of infrastructures [5]

Lifeline as at July 14	
Electricity	About 96 %
City gas	About 86 %
Liquefied Petroleum Gas	About 95 %
Aqueduct	About 98 %
Gas station	About 85 %
Bank	About 80 %
Post office	About 84 %
Mail delivery	About 80 %
Fixed-line phone	About 99 %
Mobile phone	About 98 %
Traffic as at July 14	
Road (National Control)	About 99 %
Railway	About 96 %
Port	About 46 %

3.2 Tsunami Damage

The damage from the tsunami was particularly extensive and severe. This was particularly true along the Pacific coast from the Tohoku region, which was close to the source region, down to the Kanto region. The Tohoku region has a saw-tooth coastline along the Pacific Ocean, and some areas were hit with a tsunami wave over 20m tall, and in some plains areas, the tsunami reached 5km or more inland. Flooding covered 561km2 of the affected regions and is believed to have extended up to 650km in a straight line along the coastline. (Fig.5)

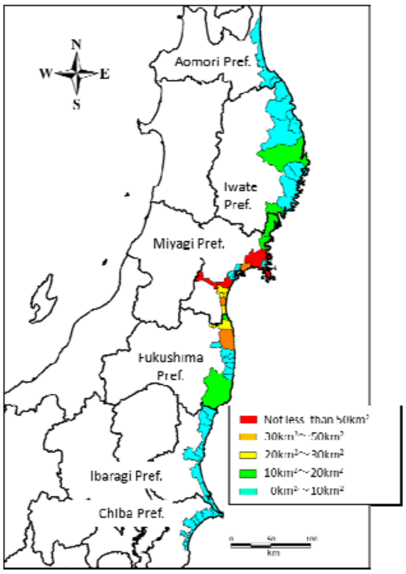

Fig.5 Flooded Area[4]

The extent of flood damage in a majority of these areas goes far beyond what is anticipated by tsunami hazard maps; in addition, the height of the tsunami in most of the flooded areas greatly exceeded the height anticipated by tsunami hazard maps. (Fig.6) (Fig.7)

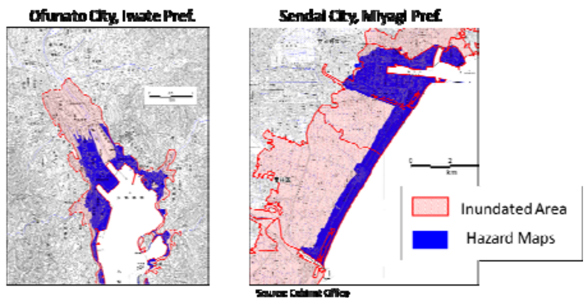

Fig.6: Comparison between flooded area and tsunami hazard map [4]

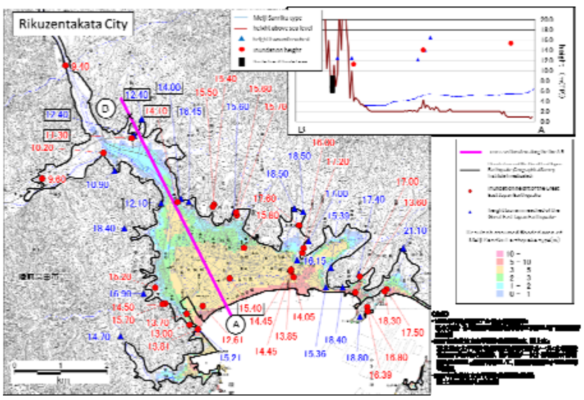

Fig.7: Flooded Area in Rikuzentakata City [4]

This giant tsunami generally devastated the entirety of the areas it affected, not only destroying houses and economic infrastructure but also knocking out municipalities' ability to respond to disasters. This is not just a serious blow to rescue and relief efforts but also to recovery and rebuilding efforts.

Over 92% of those who perished in the Great East Japan Earthquake drowned as a result of the tsunami. Furthermore, 65% of those who died were aged 65 or older. (Fig.8)

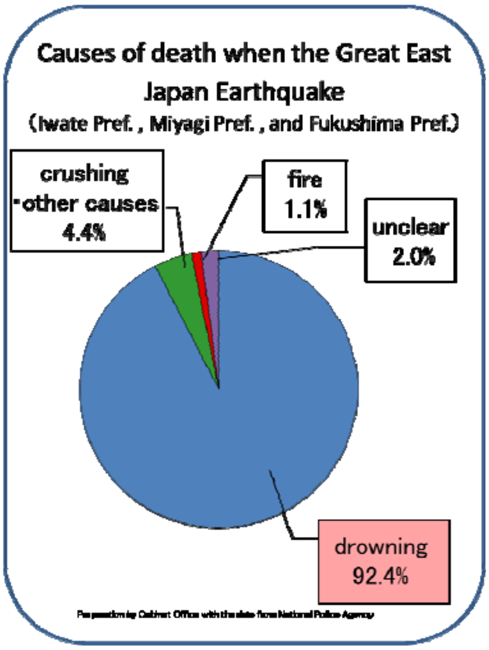

Fig.8: Causes of death when the Great East Japan Earthquake [1]

3.3 Earthquake Damage

Compared with the tremendous damage wreaked by the tsunami, the scale of the damage caused directly by the earthquake, such as building damage, was comparatively lower than the extensive damage one would assume for a M9.0 earthquake. This can largely be attributed to such factors as the relatively small amount of long-period ground motion (one to two second vibration cycles that cause wooden homes to collapse and several second or longer vibration cycles that cause high-rise buildings to sway) and improved seismic capacity and other countermeasures incorporated in response to past earthquakes like

the Great Hanshin-Awaji Earthquake.
We must not only investigate, analyze and verify those phenomena, like the tsunami, that exceeded expectations but also those phenomena, like the earthquake damage, which were far below expectations, and we must incorporate what is learned from both into future disaster-prevention countermeasures.

3.4 Other Damage: Land Subsidence, Liquefaction Phenomena, Stranded Persons, etc.
The earthquake caused land subsidence to occur over a large area. The amount of land on the plains of Sendai at or below sea level prior to the earthquake was 3km2; however, after the earthquake it had grown roughly 530% to 16km2. (Fig.9)

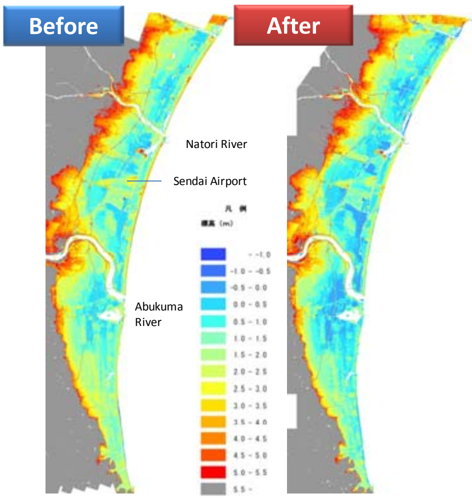

Fig.9: Subsidence in Sendai Plain [4]

Also, damage in the Kanto region due to liquefaction phenomena was significant; approximately 19,000 homes in Ibaraki, Chiba, Saitama, Kanagawa and other prefectures reported damage due to liquefaction. (Fig.10)

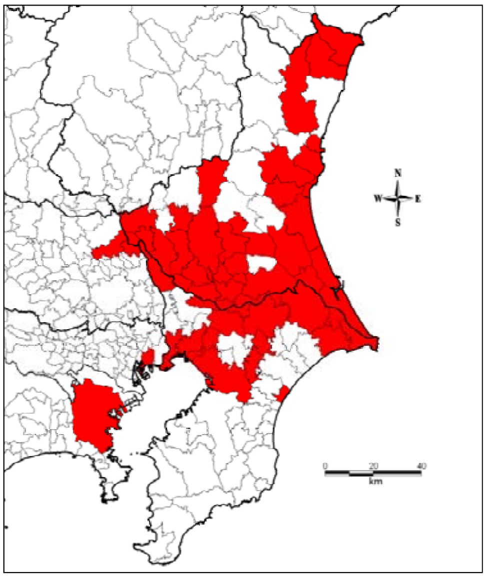
Fig.10: Liquefaction Phenomena in Kanto Area [4]

Meanwhile in the Tokyo metropolitan area, in the immediate aftermath of the earthquake all of the railway lines stopped running, large-scale traffic congestion resulted and roughly 100,000 people were stranded in Tokyo, unable to get home. (Pic.1)


Pic.1: The situation of the Tokyo Metropolitan Government Building (2011/03/11) [4]

In addition to all of this, there was a nuclear accident at the Fukushima No.1 nuclear power plant as a result of the earthquake. In response to this accident, the government has mobilized every resource at its disposal to assess the situation and bring it under control as soon as possible.

3.5 The effects of various disaster prevention countermeasures
The government has thus far implemented a

variety of disaster-prevention countermeasures. While this has produced some definite results in the case of the present disaster, new challenges have also appeared which must be addressed.

(Earthquake Early Warning System/Seismic Warning System)

JMA operates an "Earthquake Early Warning System" that analyses measurement data from seismographs close to an earthquakes epicenter, immediately predicts the estimated time when main ground motion will hit and what intensity scale will be, and then sends out a notification. Bullet trains running at the time of the earthquake were equipped with seismic warning systems that enabled them to stop moving before the main force of the earthquake hit, thus preventing any injuries or deaths.

(Effectiveness of Storm Surge Barriers)

Despite the fact that the storm surge barriers did not stop the tsunami, research reports show that they did reduce its height by roughly 40% and delayed its landfall by around six minutes. Nevertheless, it is clear that there is a limit to how much shore protection facilities, etc., can be relied upon as part of disaster-prevention measures [6].

4. APPROACH THUS FAR TO ANTICIPATING EARTHQUAKES AND TSUNAMIS[7]

4.1 Earthquakes and Tsunamis Anticipated by the Central Disaster Prevention Council

Expert panels convened in the past by the Central Disaster Prevention Council have anticipated ocean trench earthquakes, such as those originating in the Japan trench (where the recent Great East Japan Earthquake was located) and the Kuril-Kamchatka Trench and its environs; Tokai, Tonankai and Nankai megathrust earthquakes; and Tokyo metropolitan area epicentral and Chubu and Kinki region epicentral earthquakes. These panels have estimated damage, outlined scenarios, created strategies and examined countermeasures.

The panel establishes models for these anticipated epicentral areas and earthquakes; estimates strong ground motion; estimates casualty numbers, number of buildings damaged, etc., from the estimated size of the vibrations and height of the tsunami; and then, based on the damage estimate results, creates a master plan for lessening the damage caused by an anticipated earthquake and tsunami. Also, an earthquake disaster prevention strategy containing quantitative disaster reduction targets and specific implementation policies is developed as a preventive measure, and an emergency measure action guide and detailed plan which lay out the role of each government agency, etc., in the event of an earthquake are developed as emergency measures. (Fig.11) (Fig.12)

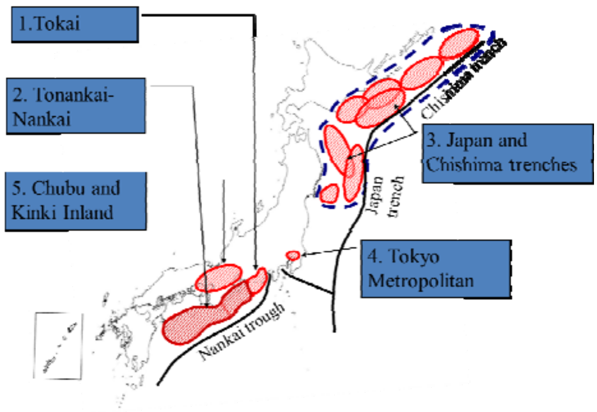

Fig.11: Countermeasures on large earthquakes [8]

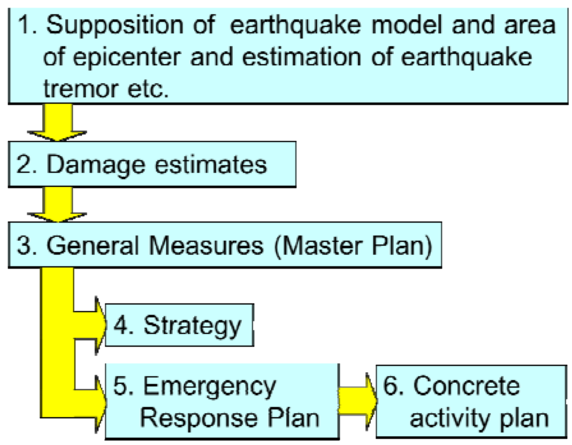

Fig.12 Flow of Countermeasures against Large-scale Earthquake [9]

When envisioning target earthquakes and tsunamis, the expert panel relies on re-creations of earthquakes over the past several hundred years in different areas; they look to see if there are repeating patterns and whether such patterns suggest a high likelihood of an earthquake in the near future in a given area; they then make these anticipated earthquakes and tsunamis the target of their examinations.

The recent earthquake was a magnitude 9.0 earthquake with multiple source regions extending all the way to the southern half of the Japan

Trench, making it one for which it was not possible to confirm data for the past several hundred years. An earthquake like the recent one shows the limits of traditional prediction methods, given that predictions assume that earthquakes and tsunamis will come from areas where they have occurred over the past several hundred years; thus, the expectation was that the epicentral area would be the northern half of the Japan Trench.

4.2 Self-reflection on discrepancies between the recent damages and expectations

The number of the dead or missing is 7 times and of the collapsed houses is about 11 times as much as one of the damage assessments done in 2006 assumed a similar earthquake to the Meiji-Sanriku Earthquake (in 1896). (Table 3) It is necessary to respond seriously to the fact that the results of past predictions of earthquakes and tsunamis differed greatly from the actual earthquake and tsunami that occurred, and to fundamentally reexamine the concepts behind anticipating earthquakes and tsunamis in the future.

Table 3: Disaster Prevention [10]

	Magnitude	Inundation Area	Number of death or missing	Number of collapsed houses
Great East Japan Earthquake	9.0	561 sq km	20,444	112,703
Damage assessment done in 2006 *	8.6	270 sq km	2,700	9,400

* Assumed a similar earthquake to the Meiji-Sanriku Earthquake (in 1896)Source: Cabinet Office

Up until now, consideration was given to a seismic source model where seismic movements and tsunamis that have been recorded up until now could be reproduced, for earthquakes with high incontinence from among the largest earthquakes that Japan has experience over the past few hundred years. This model served to predict the largest earthquake that would occur next. As a result, even for earthquakes that presumably occurred in the past, those for which seismic movements and tsunamis could not be reproduced were deemed as having low accuracy of occurrence, and were not subject to expectation. In terms of the recent damages, it is necessary to fully self-reflect on the fact that the 869 Jogan Sanriku earthquake, 1611 Keicho Sanriku earthquake, and 1677 Empo Boso-oki earthquake that were thought to have occurred in the past were taken out of consideration.

In such a way, one of the reasons why these earthquakes were not applicable to expectations in initial findings, while being aware that they occurred in the past, is that it is difficult to reproduce an image of the earthquake as a whole. Even if, for example, the entire image of an earthquake is not completely understood, it is necessary in the future to make full use of such information as an applicable earthquake. Even if accuracy is low, it is necessary to give sufficient consideration to historical earthquakes and tsunamis that resulted in overwhelmingly large damages.

Since earthquake and tsunami predictions differed from the actual circumstances, strong ground motion, tsunami height, tsunami range, and submergence area ended up being amplified as compared to prior predictions. In particular, although the estimated submergence area is based on disaster prevention measure materials, such as hazard maps, it cannot be denied that the fact that the recent tsunami was of a tsunami height and submergence area that exceeded predictions was linked to amplification of damages. The hazard maps based on prior predictions served as materials resulting in a sense of security, and as it is possible that this caused damages to be amplified by the recent tsunami that exceeded such predictions, it is necessary to conduct surveys on the inadequacy of hazard maps.

At the same time, when looking at the development of shore facilities, etc., results were exhibited up to the tsunami height subject to design, but when taking into consideration the recent, massive earthquake and the damages caused by the enormous tsunami, it was revealed that there are limitations to disaster prevention measures overly dependent on shore protection facilities, etc.

Expected for tsunami height and earthquake magnitude that were presented by the Japan

Meteorological Agency largely fell below the actual earthquake and tsunami height. After a certain amount of time, the earthquake magnitude and tsunami warning was revised to a level several notches higher. In particular, it can be thought that the impact by the initial tsunami expectation is large. It is possible that the evacuation behavior of residents and evacuation supporters were sluggish due to the original tsunami warning, possibly causing expansion of damages.

With regard to the reason why an earthquake scale and tsunami warning that differed greatly from the actual earthquake and tsunami were issued, in addition to thoroughly determining the cause, it is necessary to conduct detailed survey analysis regarding the kinds of impacts that the announcement of the tsunami warning had on actual evacuation behavior, etc., and to explain this to the public. At the same time, it is also necessary to review recurrence prevention measures based on improving warning systems in anticipation of massive earthquakes as well as policies that make use of offshore tsunami observation data in tsunami warnings, and to promote improvements as quickly as possible.

It is necessary to seriously accept the fact that enormous damages clearly exceeding prior and existing predictions occurred recently, improve past concepts, reexamine everything from prediction of earthquakes and tsunamis to disaster prevention measures, and rebuild a disaster prevention plan for the future.

5. CONCEPT BEHIND EARTHQUAKES AND TSUNAMIS SUBJECT TO DISASTER-PREVENTION MEASURES

5.1 Significance of expected earthquakes and tsunamis

Since the past, for earthquake and tsunami measures, the national and local governments had anticipating earthquakes that are subject to review beforehand, and planned and promoted various disaster-prevention measures in relation to the estimated results of ground motion and tsunamis based on such anticipating earthquake. The recent earthquake and tsunami clearly exceeded prior and existing predictions, but this does not mean that there is no significance in the actual expectations of earthquakes and tsunamis. It is desirable to conduct sufficient survey analysis on the factors as to why an event that clearly exceeded expectations occurred, continue to carry out necessary expectation of earthquakes and tsunamis, review damage expectations once again, and continue moving forward with disaster prevention measures.

At the same time, natural phenomena are associated with a great deal of uncertainty and thus, it is necessary to make sufficiently known that there are certain limitations to expectations.

5.2 Future concepts behind applicable earthquakes and tsunamis based on the recent earthquake disaster

In order to expect applicable earthquakes and tsunamis, it is necessary to conduct further accurate surveys on the occurrence of earthquakes and tsunamis, etc. by going back as much into the past as possible, analyze historical materials such as ancient documents, carry out surveys on tsunami deposits, and move forward with surveys based on scientific findings, such as surveys on costal topography.

When doing so, it is necessary to consider conceivable possibilities while also taking into consideration the fact that it is difficult to predict earthquakes and that there is uncertainty in long-term assessment, and to review expected earthquakes and tsunamis by also sufficiently bringing into view the possibility that damages could be amplified.

In addition, when reviewing the necessary disaster prevention measures based on predicted earthquakes and tsunamis, even in cases where measures for such earthquakes and tsunamis are expected to be difficult, it is necessary to establish expected earthquakes and tsunamis without hesitation.

Investigative research such as clarification, etc. of mechanisms behind the occurrence of earthquakes and tsunamis become further necessary. Above all, in order to confirm the large-scale tsunamis that occurred sequentially over the course of several thousand years, the enrichment of comprehensive research based not only on seismology but geology, archaeology, and history as well, such as surveys on tsunami deposits, geological surveys on sea terraces, surveys on biological fossilization, etc., is important.

Also, in order to accurately comprehend the state of areas near ocean trenches, which are thought to be the cause behind the occurrence of the recent massive tsunami, it is necessary to make further efforts toward promoting research to increase accuracy of expected earthquakes and tsunamis based on seismology, such as by directly observing crustal movement on the ocean floor, conducting surveys on the state of fixation of plates, etc.

The colossal tsunami caused by the recent M9.0 earthquake may possibly have been caused by a so-called “linkage of ordinary earthquakes” and “tsunami earthquake” occurring at the same time. Future progress with the occurrence mechanism behind tsunami earthquakes, survey analysis of linkage between ordinary earthquakes and tsunami earthquakes, and sufficient clarification of the occurrence mechanism behind this are important in expecting future tsunamis associated with trench-type earthquakes.

In particular, in a case where a tsunami earthquake occurs independently, it is possible that there is no large shaking, and a sudden tsunami arises in a state where residents are not alerted to awareness regarding evacuation. As large damages have repeatedly occurred in the past, such as with the 1869 Meiji-Sanriku earthquake and the 1605 Keicho earthquake, particular measures related to warnings and evacuation in anticipation of tsunami earthquakes are necessary.

In regions with nuclear power plants, the impact on such nuclear power plants is extremely large when damages are incurred. Thus, in reviewing predicted earthquakes and tsunamis, it is necessary to conduct further detailed survey analysis regarding the focal area of the earthquakes and wave source area of the tsunamis.

6. CONCEPT BEHIND THESE ANTICIPATED TSUNAMIS IN CONSTRUCTING TSUNAMI MEASURES

6.1 Fundamental concept

In constructing tsunami measures in the future, it is necessary to fundamentally anticipate tsunamis of two levels. The first is tsunamis that are anticipated upon constructing comprehensive disaster-prevention measures that center on resident evacuation. Such tsunamis are anticipated based on ultralong-term surveys on tsunami deposits and observations of crustal movements, etc., and are tsunamis of the largest class that yield enormous damages if they occur, even though the frequency of occurrence is extremely low. The recent Great Tohoku Earthquake is thought to correspond to this category.

The second is tsunamis that are expected upon constructing shore protection facilities, etc. that prevent tsunamis from penetrating inland based on structures such as breakwaters. Compared to tsunamis of the largest class, these tsunamis have a higher frequency of occurrence, and are tsunamis that yield large damages despite being of a low tsunami height.

6.2 Concept behind measures for tsunami heights of the largest class

Based on the occurrence of the recent colossal tsunami and the damages that it caused, it was revealed that there are problems with disaster prevention measures that overly depend on shore protection facilities. It is necessary to construct tsunami measures that anticipate tsunamis of the largest class and the Great Tohoku Earthquake, make protection of residents’ lives the top priority, and to maintain the minimum socioeconomic functions necessary, such as administrative functions, hospitals, etc., regardless of what kind of disaster occurs. As a result, it is necessary to combine land usage, evacuation facilities, disaster prevention facilities, etc., focusing on resident evacuation, and to establish comprehensive tsunami measures that incorporate every possible measure, both hard and soft.

In order for various measures to be diversified/integrated and exhibit effects as tsunami measures, it is necessary to establish a mechanism where an organic linkage among various related plans, such as a regional disaster prevention plan and city plan, can be secured.

In addition, since it is not known what kind of a tsunami will actually hit when it does come, it is necessary to develop the required structure and establish measures so that residents can adopt appropriate evacuation behavior. As a result, with regard to observation and monitoring of tsunamis, presentation of tsunami warnings, communication of tsunami warnings, etc., evacuation guidance, development of evacuation routes and evacuation centers, as well as what kind of information residents received, the type of judgments they made, and how they took action, it is necessary to conduct survey analyses on topics in the recent tsunami and establish sufficient measures in the future. As the recent damages exceeded "damage deterrence measures," it is necessary to strive towards increasing disaster prevention awareness such as through disaster prevention education and disaster prevention training for residents and public administration based on the necessity of "damage abatement measures" that do not broaden damages as much as possible.

In particular, it is important to conduct reviews on what kinds of information can be helpful in residents' evacuation behavior, how communication means should be thought of, such as the enhancement of the government's disaster prevention radio and use of mobile phones, and establish the necessary measures in conjunction with relevant agencies.

Furthermore, in the case that nuclear power plants, municipal government buildings, which serve as a base during disasters, and disaster prevention bases such as police stations and fire departments become damaged, the impact of such damages is enormous. As a result, it is particularly important to consider all possible measures to ensure tsunami measures for these important facilities.

6.3 Tsunami measures based on shore protection facilities for tsunamis of high frequencies

Shore protection facilities, etc., which have been developed since the past, are based on anticipation of tsunamis of relatively high frequency, and they have exhibited results for damage deterrence of tsunami heights up to a certain level. However, due to the recent occurrence of a tsunami largely exceeding the designed tsunami height, although certain effects were seen such as reduction of water level, delay in the tsunami arrival time, etc., many shore protection facilities, etc. were damaged, and enormous tsunami damages were incurred in hinterlands.

Significantly increasing the tsunami height applicable to development of shore protection facilities, etc. is not realistic in terms of the necessary costs for facility development and the impacts on the shore environment and usage. However, from the perspectives of protection of human life, protection of residents' property, stabilization of local economic activities, and securing efficient industrial bases, it is desired for development of shore protection facilities, etc. for tsunamis of a relatively high frequency and certain height to continue progressing.

With regard to shore protection facilities, it is necessary to promote technological development of structures where facilities can exhibit effects tenaciously even in cases where the tsunami height exceeds the designed height, and to maintain such facilities.

7. SUMMARY

In Japan, the possibility of a large-scale earthquake and tsunami is constant and everywhere; this is an inescapable fact that has been and will always remain true.

In order to prepare for these earthquakes and tsunamis, Japan is comprehensively and systematically advancing disaster-prevention countermeasures based on the "Disaster Countermeasure Basic Act" as well as upgrading earthquake disaster prevention facilities in accordance with a five year plan based on the "Act on Special Measures concerning Earthquake Disaster Management."

Also, in June of this year, Japan established the "Tsunami Countermeasures Promotion Act" in order to take all possible measures against tsunamis so as to avoid repeating the experience of the Great East Japan Earthquake. To protect the lives, health and property of Japan's residents from the harm of tsunamis, Japan is working to raise basic awareness about tsunamis and is working comprehensively and effectively on tsunami countermeasures geared towards recovery and rebuilding.

Soft infrastructural measures, such as strengthening tsunami observation systems, promoting study and research, forecasting damage resulting from tsunamis, implementing disaster-prevention education and training, and creating evacuation plans, as well as hard infrastructural measures, such as upgrading shore protection facilities, promoting urban development focused on tsunami countermeasures, and ensuring the security of facilities handling hazardous materials are being established. Other efforts include promoting international cooperation in tsunami countermeasures and establishing a "Tsunami Disaster Prevention" day.

Furthermore, the "Basic Policy on Great East Japan Earthquake Reconstruction," based on the Great East Japan Earthquake Reconstruction Basic Act, was adopted in July of this year. In order to rejuvenate the society and economy of the affected areas, help residents rebuild their lives and revitalize the country, Japan must devote itself completely to recovering from the Great East Japan Earthquake and push ahead with forward-looking initiatives; because the full scope of Japan's task in overcoming the national hardships created by the Great East Japan Earthquake is now clear. It is incumbent on every member of society that we work together and do our utmost to overcome this challenge.

This paper has focused on the Expert Panel's interim report concerning the lessons learned from the Great East Japan Earthquake and the future direction of earthquake and tsunami countermeasures. The final report of the Expert Panel is expected in the fall of this year, and based on its recommendations, fundamental revisions will be made in the Basic Disaster Prevention Plan, which is the document laying out Japan's essential policies and initiatives on disaster-prevention countermeasures. Also, study will continue on ocean trench, ultra-wide and super-massive earthquakes comprised of interlinking Tokai, Tonankai and Nankai megathrust earthquakes in the Nankai trough, where concern exists about future earthquakes.

Finally, I want to offer my sincerest prayers for those who lost their lives in the disaster, and I resolve to work, with renewed determination, to advance the cause of disaster prevention.

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