

Chapter 2: Overview of Damage Caused by the Great East Japan Earthquake and Tsunami

The Great East Japan Earthquake and Tsunami, which measured 9.0 on the Richter scale with a maximum seismic intensity of 7 and a maximum tsunami run-up height of at least 40.1 meters, caused unprecedented damage. In Iwate Prefecture alone, over 6,200 people were killed or still missing (in 2010, Iwate's population was 1,330,147), over 26,000 houses were completely or partially destroyed, and industrial damage exceeded 820 billion yen.

Earthquake Overview

- Date of occurrence: 14:46:18, March 11, 2011
- On March 11, 2011, the Japan Meteorological Agency (JMA) named the earthquake the "2011 off the Pacific coast of Tohoku Earthquake." On April 1, 2011, the government named the disaster the "Great East Japan Earthquake." In Iwate Prefecture, the earthquake is referred to as the "Great East Japan Earthquake and Tsunami" .
- Epicenter: 130 km east-southeast of Oshika Peninsula, off the Sanriku coast (38.1° N / 142.9° E)
- Depth of epicenter: approx. 24 km
- Epicenter area: 450-500 km long and 200 km wide (off the Iwate - Ibaraki coasts)
- Moment magnitude scale: 9.0

Summary of the Earthquake

At 14:46 on March 11, 2011, a 9.0 earthquake on the moment magnitude scale (M) occurred, with its epicenter off the coast of Sanriku. A maximum seismic intensity of 7 on the JMA Seismic Intensity Scale was observed in Kurihara City, Miyagi Prefecture, and an seismic intensity of upper 6 was observed in Miyagi, Fukushima, Ibaraki and Tochigi Prefectures.

In Iwate Prefecture, Ofunato City, Hanamaki City, Ichinoseki City, Kamaishi City, Oshu City, Yahaba Town, Fujisawa Town (now merged into Ichinoseki City), and Takizawa Village (now Takizawa City) observed an seismic intensity of lower 6, with strong tremors also observed throughout other areas of the prefecture.



Rikuzentakata City [Before the Earthquake]



Rikuzentakata City [After the Earthquake]

Summary of the Earthquake

Name	The 2011 off the Pacific coast of Tohoku Earthquake
Time	March 11, 2011 2:46 p.m.
Epicenter	Off the Sanriku Coast (38° 06.2' N, 142° 51.6' E, 24 km depth)
Magnitude	9.0 (moment magnitude scale)
Maximum Seismic Intensity in the Prefecture	Lower 6 (Ichinoseki City, Yahaba Town, Kamaishi City, Ofunato City, Takizawa City, Fujisawa Town, Hanamaki City, Oshu City)
Height of Tsunami	Miyako: 8.5m (minimum) Ofunato: 8.0m (minimum) Kamaishi: 4.2m (minimum) Kuji Port: 8.6m (estimated)

(Data courtesy of the JMA)

■Earthquake Mechanism

This massive earthquake is thought to have been an "interplate earthquake", in which the Pacific Plate slid below the North American Plate where eastern Japan is located on. The tip of the North American Plate, which was also dragged down by the Pacific Plate, was unable to withstand the force and recoiled, causing a large earthquake and tsunami.

The epicenter of the earthquake was off the coast of Iwate and Ibaraki Prefectures, covering an extremely wide area of about 450–500 km vertically and 200 km horizontally, and is thought to have been the result of six epicenter blocks (Central Sanriku-oki, Miyagi-oki, near the Southern Sanriku-oki Trench, near the Sanriku-oki to Boso-oki Trench, Fukushima-oki, and Ibaraki-oki) interlocking to create a fault rupture. The six epicenter blocks had been observed and recognized as a potential subduction zone up until the disaster. The rupture of the fault began around 130 km east-southeast of the Oshika Peninsula in Miyagi Prefecture (near the southern Sanriku-oki Trench), causing a chain reaction which spread north to central Sanriku-oki and south off the shore of Ibaraki Prefecture.

■Post Earthquake Crustal Deformation

The Geospatial Information Authority of Japan (GSI) set up 1,240 GPS-based control stations at 20 km intervals, which are used as reference points for surveying, and monitors crustal deformation nationwide, publishing data on the amount of change in horizontal and vertical crustal deformation caused by the main shock of earthquakes.

The earthquake caused severe shaking in the Tohoku region, leading to unprecedented tsunami damage. As a result of the earthquake, the Oshika control station (Ishinomaki City, Miyagi Prefecture) moved approximately 5.3 meters to the east-southeast and sank 1.2 meters, with crustal deformation observed in a wide area from Hokkaido to the Kinki region.

In the prefecture, large movements were observed in coastal areas, with the Ofunato control station moving 4.19 m horizontally and -77 cm vertically, and the Kamaishi control station moving 3.32 m horizontally and -53 cm vertically. Large movements were also observed in the inland areas, with the Iwate Daito control station moving 3.30 m horizontally and -32 cm vertically.

■Liquefaction

The earthquake caused ground deformation over a wide area from Tohoku to Kanto, resulting in liquefaction, tilted buildings, land subsidence, and other damage. This was due to strong seismic motions over a wide area, with tremors that continued over a long period of time. Liquefaction was observed over an extremely wide area, even in the Kanto region far from the epicenter. In particular, damage was identified in the Tokyo Bay area, landfilled areas down the Tone River, as well as old river channels and ponds, having a major impact on building foundations, roads, and lifeline services which rely on underground connectivity.

■Aftershocks

After the main shock on March 11, 2011, aftershocks were frequent in the epicenter area.

According to statistics from the JMA, there were 115 earthquakes of seismic intensity 4 or higher from March 11 to March 31, 2011, 52 in April, and 16 in May. Since then, the frequency

has gradually decreased, but earthquakes of seismic intensity 4 or higher were recorded 262 times during a period of about one and a half years until August 31st 2012. Of these, a maximum seismic intensity of 6 or higher was recorded twice, a maximum seismic intensity of 6 or lower twice, a maximum seismic intensity of 5 or higher 12 times, a maximum seismic intensity of 5 or lower 40 times, and a maximum seismic intensity of 4 measured 206 times.

Tsunami Overview

- Maximum inundation height: 18.3 m (survey location: Ryouishi Bay, Kamaishi City, Iwate Prefecture)
- Maximum run-up height: 40.1 m (survey location: southern entrance of Ryori Bay, Sanriku-cho, Ofunato City, Iwate Prefecture)
- Distance upstream: 48.88 km (survey location: Kitakami River / Oizumi, Tome City, Miyagi Prefecture)
- Flooded area: 561 km²

Scale of Tsunami

The tsunami that followed the earthquake struck the Pacific coast region from Aomori to Chiba prefectures, devastating many coastal cities, towns, and villages.

Thirty to fifty minutes after the earthquake, one of the largest tsunamis ever recorded washed over the Pacific coast of eastern Japan. The GSI announced that, based on land-based GPS observations and sea floor crustal movement observation data from the Japan Coast Guard, there was horizontal fault movement (fault slip) of over 50 meters in the area near the Japan Trench (close to the epicenter), which is estimated to have caused the sea floor to rise by over 12 meters in the area. This crustal movement is believed to have caused the huge tsunami.

Tsunami heights (from sea level) observed at tsunami observation facilities in various areas were at least 8.5m in Miyako City, at least 8.0m in Ofunato City, at least 8.6m in Ayukawa, Ishinomaki City, Miyagi Prefecture, and at least 9.3m in Soma City, Fukushima Prefecture.

✂There was a period of time when data was unavailable because the observation facility was damaged by the tsunami. It is possible that subsequent waves may have been higher.

The tsunami was not only felt along the Sanriku coast near the epicenter, but throughout the Japanese archipelago, exceeding 3 meters in parts of Hokkaido, and 1 to 1.5 meters was recorded in the Tokyo Bay area.

Tsunami heights (inundation height) at points on land near the coast are measured from traces of flooding left on buildings. Most of the Sanriku coast from northern Iwate Prefecture to the Oshika Peninsula in Miyagi Prefecture reached 10 to 15 meters, and the Sendai Bay coast reached around 8 to 9 meters at its highest. The run-up height, which is the height a tsunami reaches on land, was 40.1 meters at Ryori Bay, Ofunato City and the highest in Japan's recorded history, measured by the 2011 Tohoku Earthquake Tsunami Joint Survey Group. In addition, tsunami propagation into rivers was observed in many locations, overtopping levees and causing extensive damage. A survey by the Tohoku Regional Development Bureau, a branch of the Ministry of Land, Infrastructure, Transport and Tourism confirmed that the tsunami had traveled 49km inland up the Kitakami River from the river entrance.

■Tsunami Warnings

The JMA estimated the magnitude of the earthquake to be 7.9 on the JMA magnitude scale, and at 14:49, three minutes after the earthquake, issued a major tsunami warning for Iwate, Miyagi, and Fukushima Prefectures, and a tsunami warning or advisory for the rest of the Pacific coast. The first report stated the expected tsunami height was 6 meters for Miyagi Prefecture and 3 meters for Iwate and Fukushima Prefectures. However, a sharp rise in tide levels was observed from GPS wave observation buoys in various areas at around 15:10, and a second tsunami warning was issued at 15:14, raising the expected tsunami height to more than 10 meters in Miyagi Prefecture and 6 meters in Iwate and Fukushima Prefectures.

This earthquake caused almost all broadband seismographs in Japan to reach their measurement limits, hence why it took time to calculate the magnitude in accordance to the moment magnitude scale, which estimates the size of massive earthquakes. Due to this delay, this information could not be used for tsunami warnings issued at the time. The JMA has since drastically revised its tsunami warning announcement method, mainly to promote prompt evacuation and warnings, because the first report's information that the tsunami was expected to reach a height of 3 meters led to delays in evacuation.

■Source Areas of the Tsunami

The Meteorological Research Institute estimated the tsunami source area (the area where a direct change in the height of the sea surface is observed due to topographic changes on the sea floor) by calculating backwards from the arrival time of the tsunami at 19 tsunami observation stations located along the Pacific coast and offshore from Hokkaido to the Kanto region. The source area was estimated to be approximately 550 km long and 200 km wide, extending from offshore Iwate Prefecture to Ibaraki Prefecture. (Monthly Report on Earthquakes and Volcanoes in Japan March 2014)

This expansive tsunami source area is the cause of the massive tsunami.

Summary of Damage

■Human Casualties, Residential Damage, Industrial Damage, Damage to Public Infrastructure, Damage to Lifelines

The Great East Japan Earthquake and Tsunami caused serious damage throughout the prefecture. The tsunami was larger than the 1896 Sanriku Earthquake and Tsunami, the 1933 Sanriku Earthquake and Tsunami, and the 1960 Chile Earthquake and Tsunami, and led to many casualties and extensive material damage in coastal areas. The damage in coastal areas varied greatly from municipality to municipality and region to region, with some areas suffering catastrophic damage and losing most of their ability to function as villages and cities, while other regions sustained extensive damage to coastal cities but had cities further inland which managed to survive. In inland areas, strong tremors also caused casualties and damage to houses. The socioeconomic impact was felt throughout the whole prefecture due to extensive damages to public infrastructure and the agriculture, forestry and fisheries industries. Logistical disruptions and reputational damage caused by unfounded rumors also contributed.

Even after the March 11, 2011 earthquake, numerous earthquakes, both large and small, occurred intermittently. In particular, on April 7, 2011, a strong earthquake with a magnitude of 7.1 struck

with its epicenter off the coast of Miyagi Prefecture, and strong tremors were observed throughout the prefecture, with Ofunato City, Kamaishi City, Yahaba Town, Ichinoseki City, Hiraizumi Town, and Oshu City all measuring just under 6 on the JMA seismic intensity scale.

■Human Casualties (Iwate Prefecture)

The Great East Japan Earthquake and Tsunami caused a total of 6,253 casualties, with 5,146 dead and 1,107 missing. The number of casualties, including those injured, accounted for 0.5% of the prefectural population and 2.3% of the coastal population (as of March 31, 2024).

■Residential Damage (Iwate Prefecture)

The number of houses totally or partially destroyed reached 26,079, most of which were damaged by the tsunami. The population of the areas submerged by the tsunami was approximately 88,000, accounting for about 30% of the total population of coastal municipalities (as of March 31, 2024).

■Evacuees (Iwate Prefecture)

The number of evacuees peaked at approximately 54,000 on March 13, 2011 (two days after the earthquake). However, even after the completion of emergency temporary housing, some evacuees were still waiting for home repairs to be completed. All evacuation centers were eventually closed by October 7, 2011 (approximately seven months after the earthquake).

Construction of emergency temporary housing began in Rikuzentakata City and Kamaishi City on March 19, 2011 (eight days after the earthquake), and all 13,984 units were completed on August 11, 2011 (five months after the earthquake).

■Industrial Damage (Iwate Prefecture)

Industrial damage totaled 829.4 billion yen. Of this amount, damage to fisheries and fishing ports accounted for the largest amount at 564.9 billion yen, followed by 133.5 billion yen for commercial industries, 98.4 billion yen for agriculture and forestry, and 32.6 billion yen for tourism (accommodation) as of November 25, 2011.

In addition to the aforementioned damage, the earthquake had a serious impact on all areas of the prefecture's commerce and economy, including travel cancellations and the cancellation of various events due to a mood of self-restraint.

■Damage to Public Infrastructure (Iwate Prefecture)

Damage to public infrastructure totaled 2,752 locations and 257.3 billion yen. Of these, damage to rivers, coasts, and road infrastructure accounted for the most damage at 172.3 billion yen, of which damage to coastal infrastructure such as seawalls and flood gates was particularly severe at 128.9 billion yen. Damage to road infrastructure specifically amounted to 25.2 billion yen, with coastal roads damaged by the tsunami and inland roads damaged by intermittent aftershocks. Damage to port-related infrastructure was 44.5 billion yen, and damage to park infrastructure was 40.5 billion yen (as of July 25, 2011).

In addition to the damage to many of the tsunami disaster management facilities, the tsunami also caused land subsidence in many areas, resulting in flooding every time the tide rose.

Damage Classification		Damage
Human Casualties	Number of Deaths	5,146 people
	(Deaths directly caused by the disaster)※	4,675 people
	(Deaths indirectly caused by the disaster)	471 people
	Number of Missing Persons	1,107 people
Residential Damage	Number of Houses Destroyed	26,079 properties

※ Includes the number of fatalities due to aftershocks after April 8, 2011 following the Great East Japan Earthquake Tsunami
(As of March 31, 2024)

Industrial Damage	(Billion yen)	Public Infrastructure Damage	(Billion yen)
Agriculture and Forestry Industry	984	Rivers, Coasts and Road Infrastructure	1,723
Fisheries Industry	5,649	Park Infrastructure	405
Commercial Industry	1,335	Port Infrastructure	445
Tourism Industry (Accommodation)	326	Total	2,573
Total	8,294		

(According to the Iwate Prefecture Disaster Countermeasures Headquarters as of November 25, 2011)

(According to the Iwate Prefecture Disaster Countermeasures Headquarters as of July 25, 2011)

■ Damage to Lifelines (Iwate Prefecture)

The maximum damage to lifelines, as determined by the prefectural disaster headquarters, is as follows: approximately 760,000 homes were left without power (restored on May 28, 2011), 9,400 homes had no access to gas (restored on April 26, 2011), 190,000 homes were left without access to running water (restored on July 12, 2011), and 66,000 telephone lines were out of service (restored on April 17, 2011).

■Characteristics of Damage in Iwate Prefecture

According to the estimated capital stock damage by the Development Bank of Japan Inc., the damage to Iwate Prefecture as a whole was approximately 4.276 trillion yen, which, when compared to the GDP of Iwate Prefecture at that time according to the Department of National Accounts, Economic and Social Research Institute, Cabinet Office, was equivalent to one year of GDP. For context, this is a higher ratio than the damage estimated for Miyagi (0.81 years' worth of GDP) and Fukushima (0.43 years' worth of GDP) Prefectures.

Although Miyagi Prefecture experienced the greatest amount of damage among the main prefectures affected, Iwate Prefecture had the highest percentage of estimated capital stock damage at 12.6% of total estimated capital stock, and percentage in the coastal areas of Iwate Prefecture was particularly prominent at 47.3% when compared to other areas.

This is because the coastal area of Iwate Prefecture is a rias coast, characterized by steep mountains rising close to the sea and a complex topography of narrow bays. With the steeply sloping mountains reaching the coast, residential and commercial infrastructure is only able to sit on the few flat areas in this unique terrain. This is the main reason why the tsunami caused extensive damage to the area.

Due to this geographical composition, the land utilization ratio of inundated areas was higher in Iwate Prefecture compared to the other prefectures, with 34% of land utilized for buildings, compared to 21% in Miyagi Prefecture and 12% in Fukushima Prefecture.

Estimated Capital Stock Damage and Percentages

(Unit: billion yen)

		Estimated Capital Stock	Estimated Capital Stock Damage					Percentage of Total Capital Stock	GDP	Damage as % of GDP
			Public Infrastructure	Residential	Manufacturing Industry	Other	Total			
Iwate Prefecture	Inland Areas	26,369	457	22	64	211	754	2.90%	4,255	1.0 years' worth
	Coastal Areas	7,449	1,943	607	191	781	3,522	47.30%		
	Total	33,818	2,400	629	255	992	4,276	12.60%		
Miyagi Prefecture	Inland Areas	31,443	856	40	148	551	1,595	5.10%	8,007	0.81 years' worth
	Coastal Areas	23,182	2,031	1,446	290	1,130	4,897	21.10%		
	Total	54,625	2,887	1,486	438	1,681	6,492	11.90%		
Fukushima Prefecture	Inland Areas	34,314	630	7	263	370	1,270	3.70%	7,228	0.43 years' worth
	Coastal Areas	15,941	1,244	145	151	319	1,859	11.70%		
	Total	50,254	1,874	152	414	689	3,129	6.20%		

※Capital stock and damage estimates made by the Development Bank of Japan Inc. (April 28, 2011).

※GDP figures are derived from "FY 2009 Prefectural Accounts" (February 29 2012, National Accounts of Japan, Economic and Social Research Institute, Cabinet Office).

Percentage of Land Utilization in Tsunami Inundation Areas

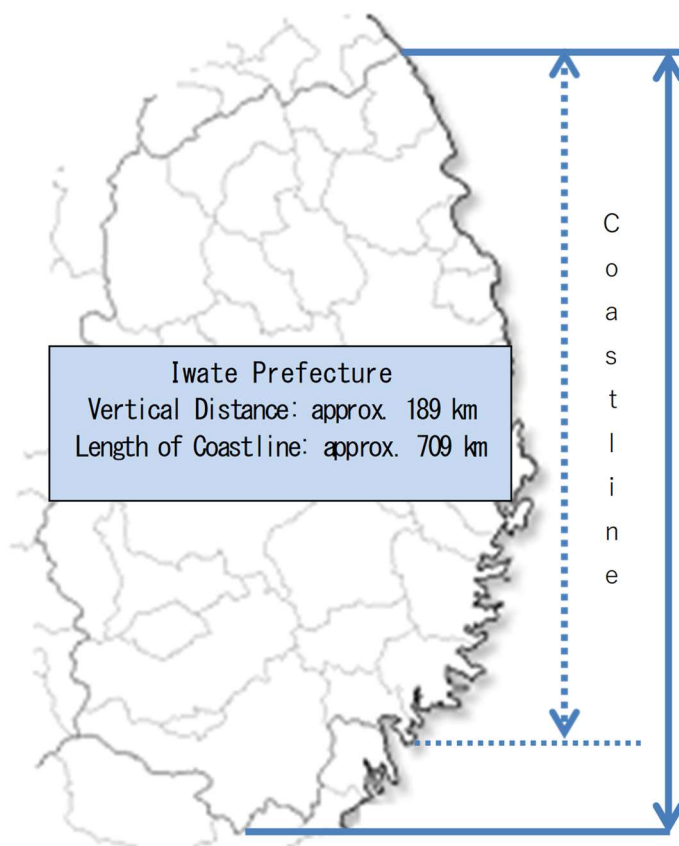
(%)

Land Utilization	Rice Fields	Other Agricultural Land	Forests	Buildings
Iwate Prefecture	17	4	9	<u>34</u>
Miyagi Prefecture	41	7	7	21
Fukushima Prefecture	53	3	4	12
Tohoku Region	37	5	7	20

Source: "Land Utilization in Tsunami Inundation Areas"
(April 18, 2011, Geospatial Information Authority of Japan)

Extent of Tsunami Damage

To protect ourselves from tsunami damage, measures must be taken along the whole Iwate coastline.



Coastline Length Calculations are based on "Coastline Lengths by Prefecture" published by the Fisheries Agency.