July 8, 2011

Tokyo Electric Power Company

Report on investigation results regarding tsunami generated by the Tohoku - Taiheiyou - Oki - Earthquake in Fukushima Daiichi and Daini Nuclear Power Stations (vol.2) [outline]

Regarding the tsunamis that stroke Fukushima Daiichi and Daini Nuclear Power Stations caused by the Tohoku-Chihou-Taiheiyo-Oki Earthquake on March 11, 2011, we surveyed them inside and outside of the sites and analyzed their characteristics and influences due to water immersion into the power stations based on the review flow as shown in Figure 1.

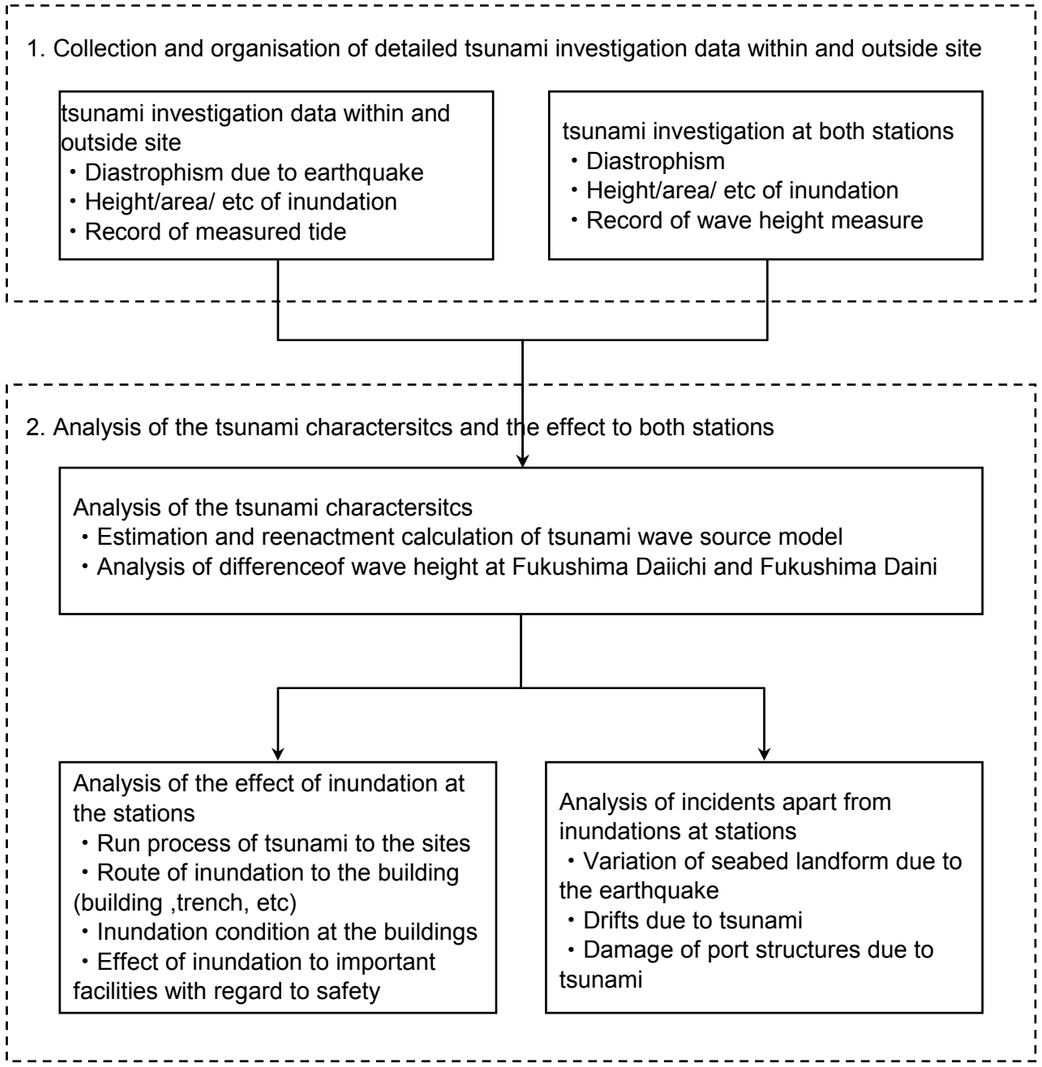


Figure 1: Main review items and review flow

1. Survey results of surveys on the tsunamis at Fukushima Daiichi and Daini Nuclear Power Stations (information reported on April 9 is partially updated)

We explored on site, measured inundation height, depth and area, obtained more data and enhanced their accuracy. Survey results are as follows. In addition, we measured ground displacement (approx. 0.5 to 0.65 meter of ground settlement), but they are not reflected in inundation height, as they are provisional values.

(1) Fukushima Daiichi Nuclear Power Station

Inundation height

- Areas where main building are located (Units 1 to 4, Site height O.P.+10m)

O.P. approx.+11.5-approx.+15.5 m* (inundation depth approx. +1.5-approx.5.5m)

* O.P.approx.16-approx.17m (inundation depth approx.6-approx.7m)

- Areas where main building are located (Units 5 and 6, Site height O.P.+13m)

O.P. approx.+13-approx.+14.5 m (inundation depth equal to or blow approx. +1.5-approx.

・O.P.approx.＋13～approx.＋14.5m（inundation depth approx. under 1.5m）

Inundated area ◇Almost all areas at seaside area and main building area

(2) Fukushima Daini Nuclear Power Station

Inundation height

◇Sea side area (site height O.P.＋4m)

・O.P.approx.＋7m※ (inundation depth approx. 3m) ※：There were limited areas of high area at Unit 1 heat exchanger building south side south surface, etc

◇Areas where main building are located (site height O.P.＋12m)

・O.P.approx.＋12～approx.＋14.5m※ (inundation depth approx. under 2.5m)

※: Between Unit 1 south of building to Main Anti-Earthquake Building, there were limited areas of O.P. approx.＋15～approx.＋16m (inundation depth approx.3～approx.4m)

Inundated area

◇all areas of seaside, however there are no evidence at main building area

◇Flood was concentrated at the road from south east of main building area to Main anti earthquake building, and areas around Unit 1/2, and south of Unit 3 building was flooded (No inundation at Unit 4)

2． Analysis of tsunami characteristics

(1) Estimation and reenactment calculation of tsunami wave source model (Figure 2、Figure 3)

Estimation of tsunami wave source model which explains diastrophism and records of inundation height, tsunami run height, inundated area and measured tide at broad area (Hokkaido ～ Chiba), was implemented using numerical simulations. The result is as follows:

◇Estimated wave source model is Magnitude(Mw)9.1
◇As a result of reenactment calculation, inundation height and inundated areas at both stations reenacted well.
◇Tsunami height※ at both station tide measure location are as follows:
- Fukushima Daiichi：Approx.+13m
- Fukushima Daini：Approx. + 9m

※：Due to measure damage、the actual tsunami height at measure location is unknown

(2) Analysis of difference of tsunami at Fukushima Daiichi and Fukushima Daini

◇ We analyzed reason to why the height of tsunami at Fukushima Daiichi was higher than that of Fukushima Daini.

As a result, it is considered that the difference of the overlap level of the peak of the tsunami from the large landslide area expected off the coast of Miyagi Prefecture and Fukushima Prefecture may have affected（Figure 4）.

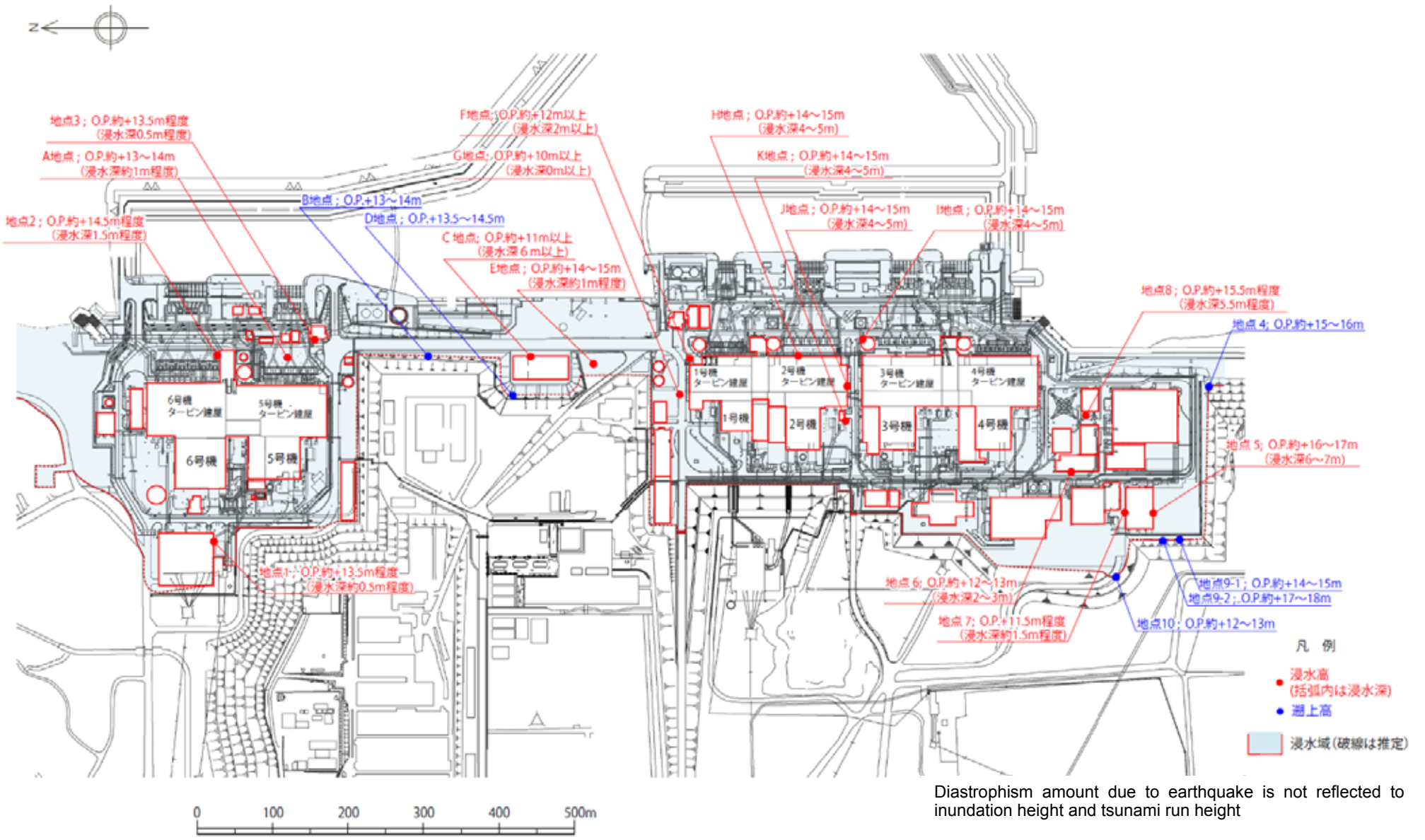


Figure 2（1） Investigation result of tsunami at Fukushima Daiichi(Inundation height, Inundation depth and inundated area）

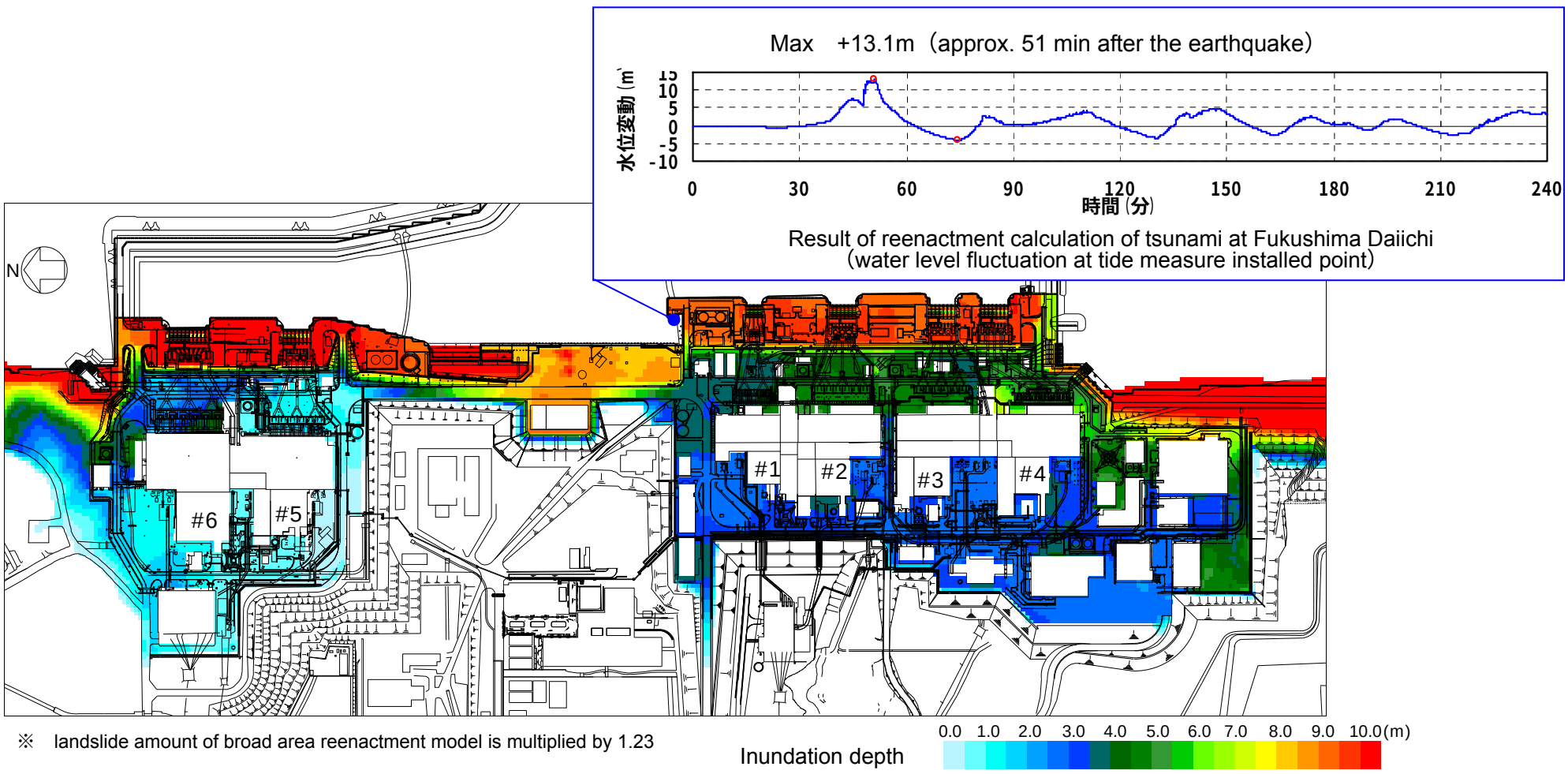
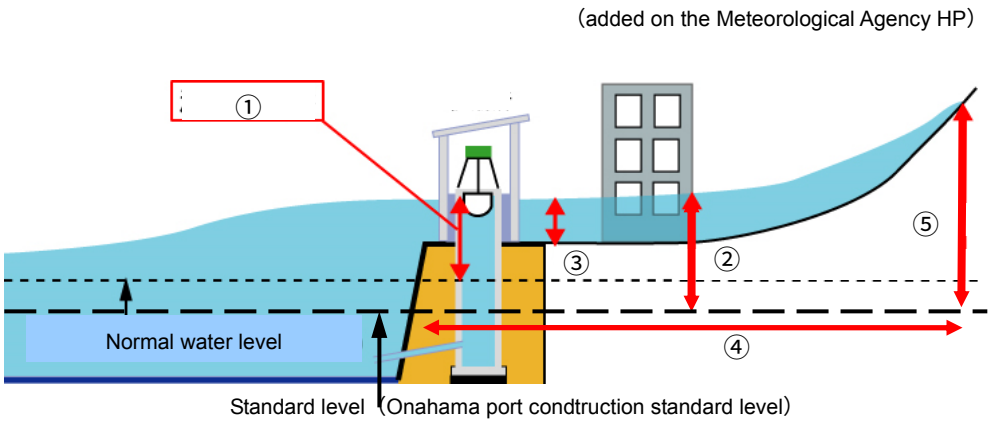


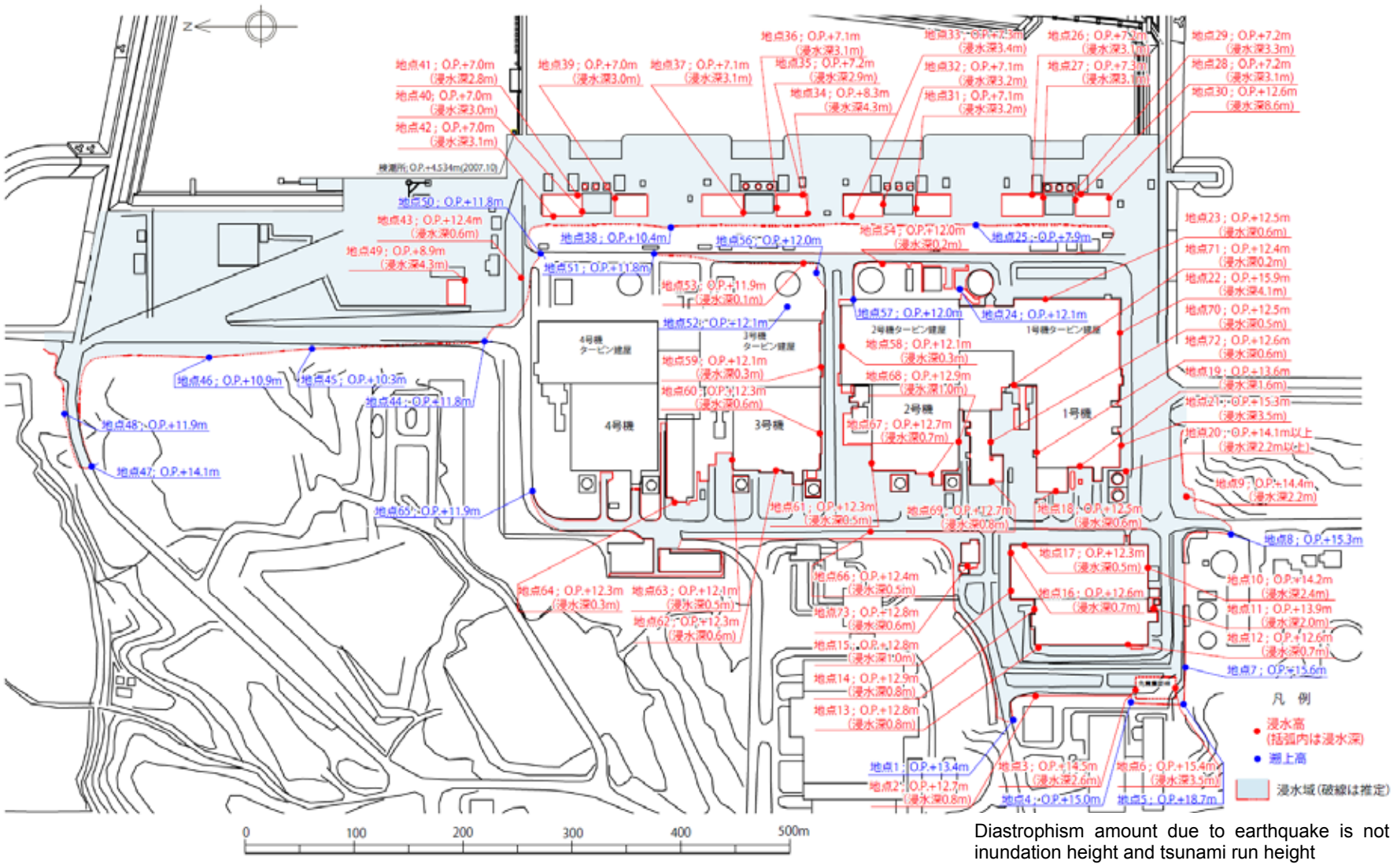
Figure 2（2） Reenactment calculation result of Fukushima Daiichi tsunami（Inundation depth and inundated area）

Definition

① Tsunami height：water level difference of normal tide level (tide level when there is no tsunami) and seawater level increase as a result of tsunami
② Inundation height；height from standard level to traces such as discoloration and drifts left on buildings and facilities (stated with O.P.)
③ Inundation depth；height from ground level to traces such as discoloration and drifts left on buildings and facilities.
④ Inundation area；area inundated by tsunami
⑤ Tsunami run height；height from standard level to traces such as discoloration and drifts left on slopes and road surfaces, as a result of tsunami running up inland (stated with O.P.*)

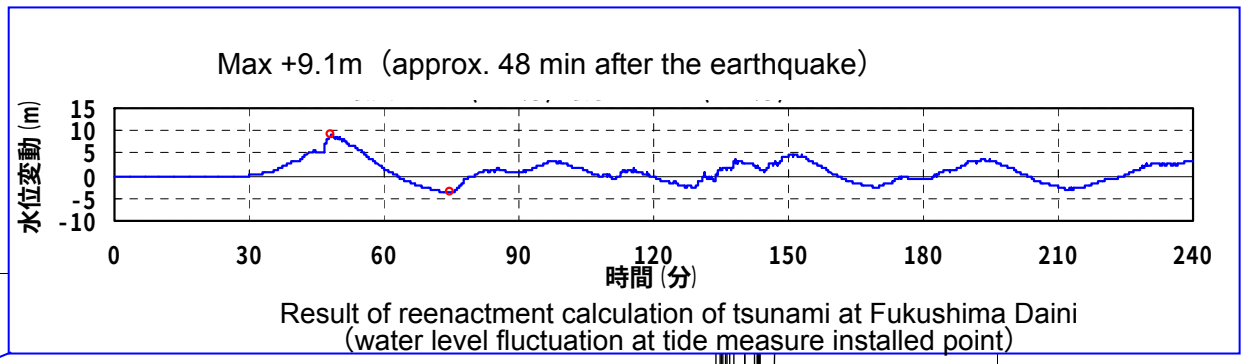
*Onahama port construction standard level(O.P) is 0.727m below Tokyo bay average seawater level (T.P)





Diastrophism amount due to earthquake is not reflected to inundation height and tsunami run height

Figure 3（1） Investigation result of tsunami at Fukushima Daini(Inundation height, Inundation depth and inundated area）



Result of reenactment calculation of tsunami at Fukushima Daini (water level fluctuation at tide measure installed point)

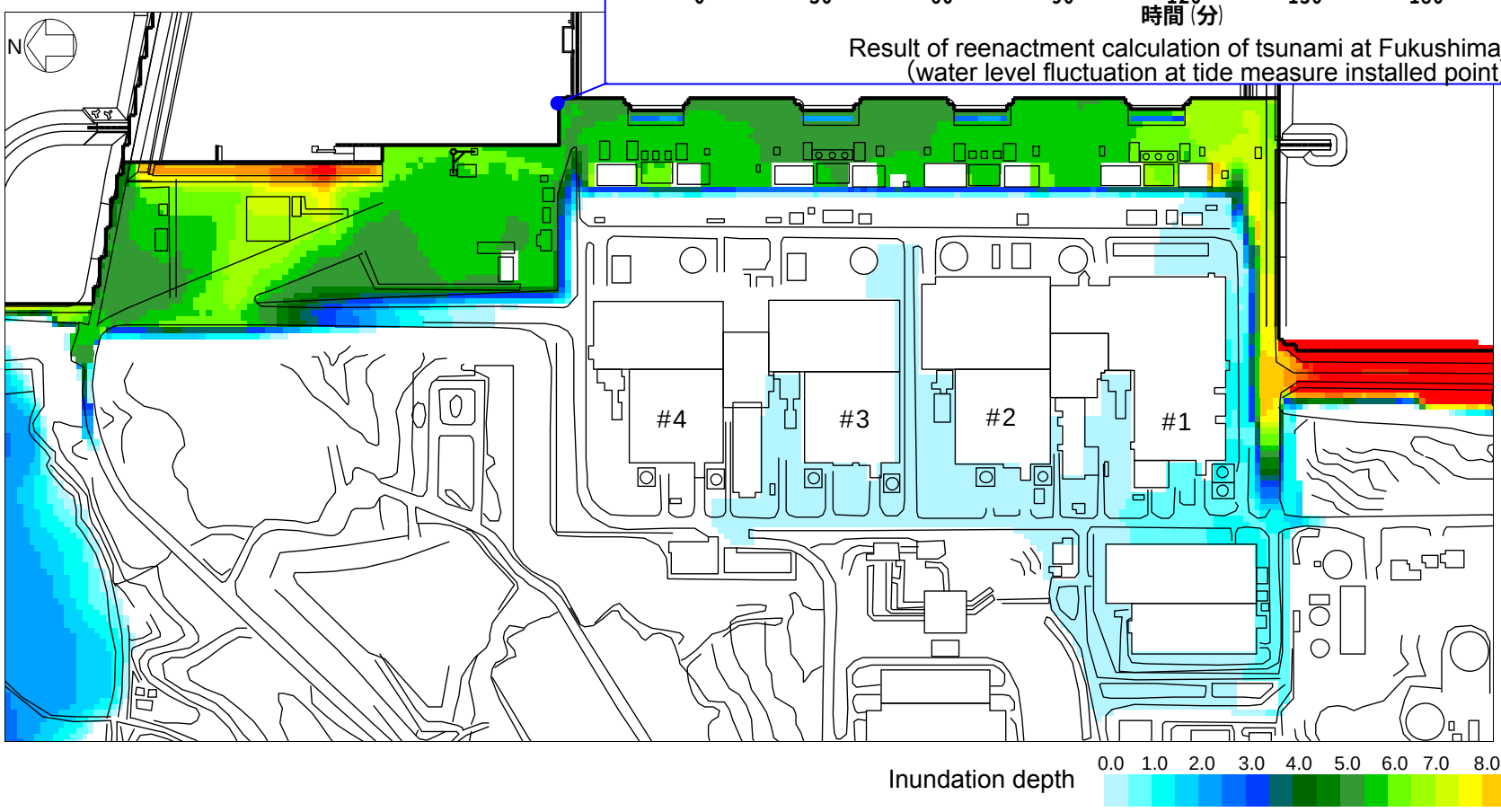


Figure 3（2） Reenactment calculation result of Fukushima Daini tsunami（Inundation depth and inundated area）

Definition

① Tsunami height：water level difference of normal tide level (tide level when there is no tsunami) and seawater level increase as a result of tsunami

② Inundation height；height from standard level to traces such as discoloration and drifts left on buildings and facilities (stated with O.P.)

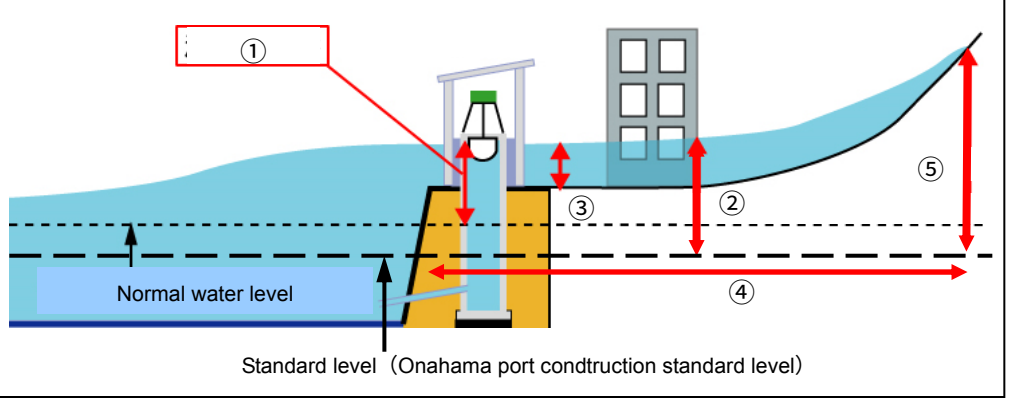
③ Inundation depth；height from ground level to traces such as discoloration and drifts left on buildings and facilities.

④ Inundation area；area inundated by tsunami

⑤ Tsunami run height；height from standard level to traces such as discoloration and drifts left on slopes and road surfaces, as a result of tsunami running up inland (stated with O.P.*)

*Onahama port construction standard level(O.P) is 0.727m below Tokyo bay average seawater level (T.P)

（added on the Meteorological Agency HP）

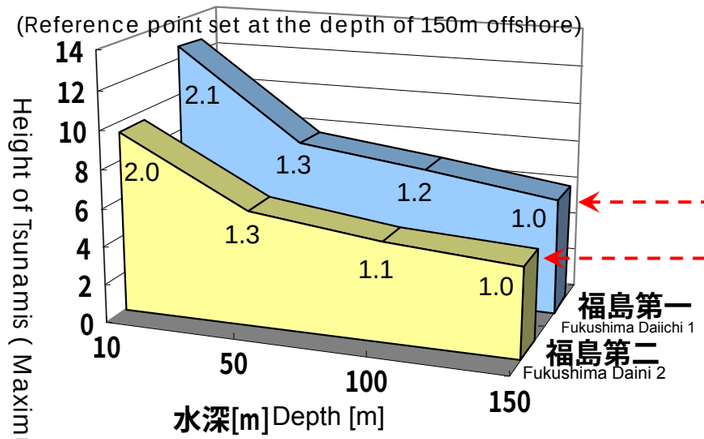


Time history of waveforms regarding water level at the depth of 150m offshore of Fukushima Daiichi Nuclear Power Station

- No significant difference in tsunami from each block at the depth of 150m was confirmed between 2 power stations.
- The height of tsunami increased as most of waveforms from each block overlap at its peak.
- No difference in amplification factors at the depth shallower than 150m was confirmed between 2 power stations.

Numbers in the figure show amplification factors

(Reference point set at the depth of 150m offshore)

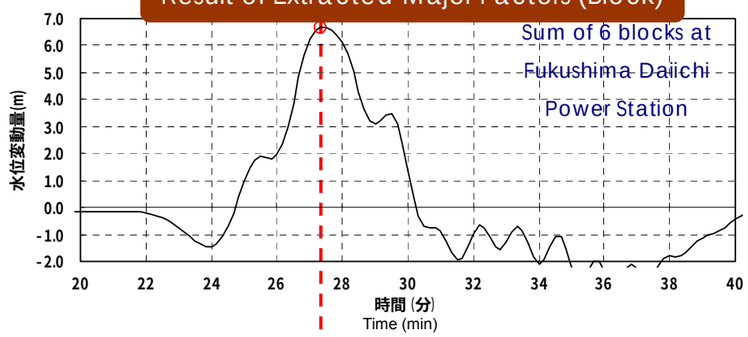


※ Result of extensive reappearance model

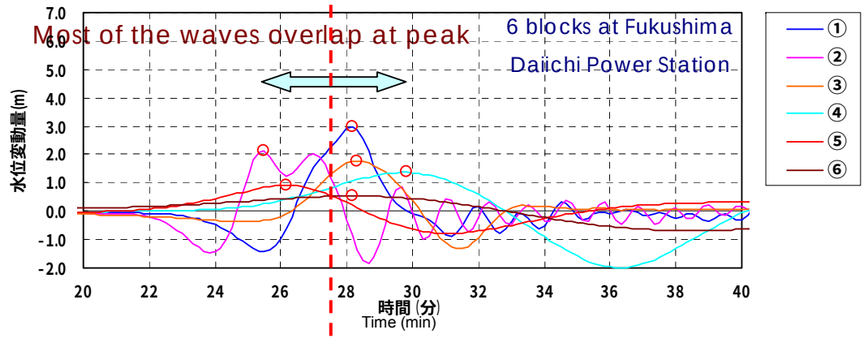
- No significant difference in tsunamis from each block at the depth of 150m was confirmed between 2 power stations.
- The height of tsunami was low as most of waveforms from each block did not overlap at its peak.
- No difference in amplification factors at the depth shallower than 150m was confirmed between 2 power stations.

Time history of waveforms regarding water level at the depth of 150m offshore of Fukushima Daini Nuclear Power Station

Result of Extracted Major Factors (Block)

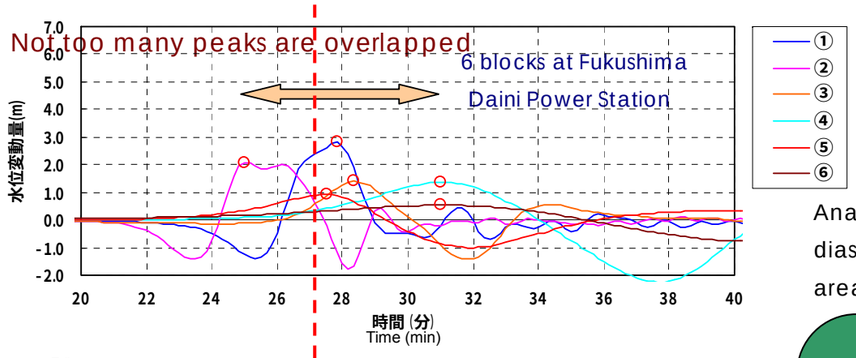


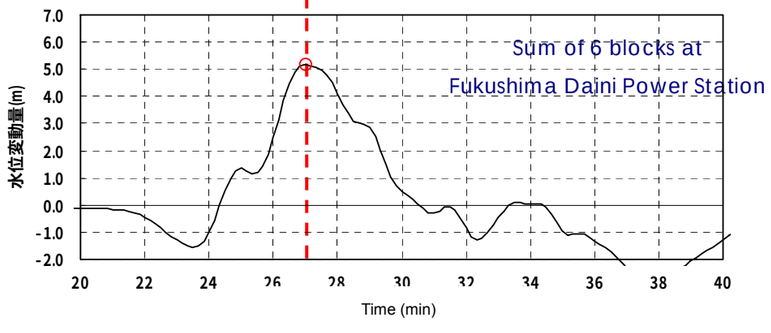
Most of the waves overlap at peak



Almost all the differences can be explained by the sum of 6 blocks

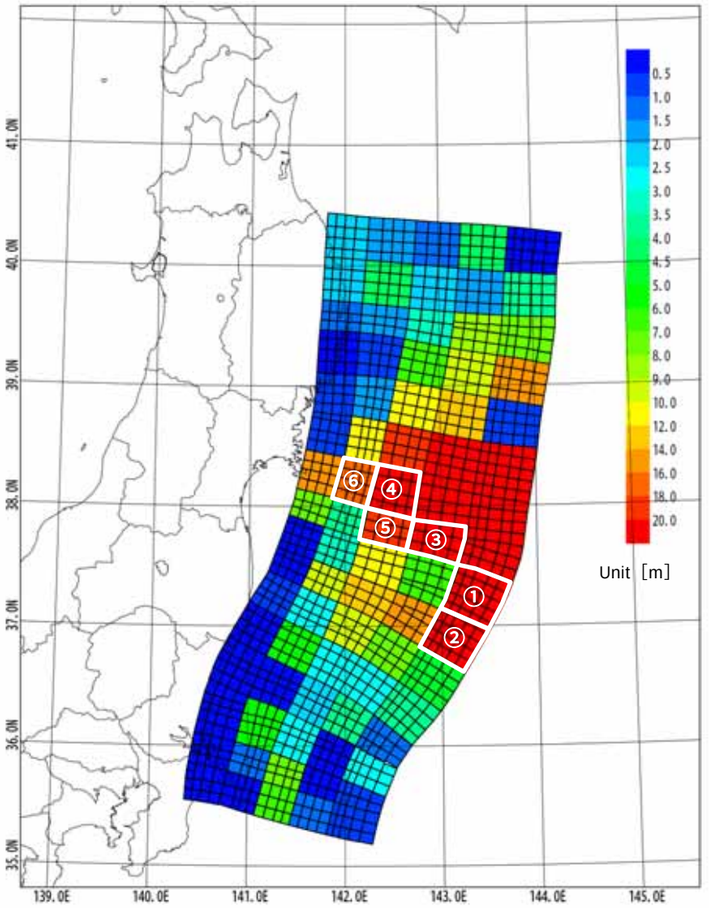
Not too many peaks are overlapped





※ Time: Time past from the occurrence of the earthquake

Among estimated wave source models, below figure shows the location of blocks that influenced the height of tsunamis at offshore of both power stations.



Analysis was conducted using tsunami wave source model which explains diastrophism and records of inundation height, tsunami run height, inundated area and measured tide at broad area (Hokkaido to Chiba) most effectively.

Summary

The main cause for the difference in tsunamis at Fukushima Daiichi and Daini Power Stations is that the peak of tsunamis generated at the area with large slippage estimated to be located at offshore of Fukushima and Miyagi was greater at Fukushima Daiichi and weaker at Fukushima Daini.

Fig4 Analysis for differences in tsunamis

３．Analysis of influence of tsunami at Fukushima Daiichi and Fukushima Daini

(1) Fukushima Daiichi Nuclear Power Station

【Inundation condition of the buildings】

Although around the main buildings located at O.P.+10m site, almost all areas were considered to be flooded, there have been no damage confirmed at the main buildings outer walls and pillars.

Due to inundation, main buildings' open parts (such as buildings entrance/exits and equipment bay doors (hatches), inlets/outlets (louvers), apertures connected to trenches and ducts buried underground of sites (pass-through slots for cables) is considered to have become the inundation route; we confirmed parts of Unit 1 to 4 east side of turbine building (sea side) doors and shutters have mainly been damaged by the tsunami. Within the building, broad area of the underground has been considered to be inundated by water running via passage and stair rooms, etc. Aperture points considered to have been the inundation route is shown on Figure 5.

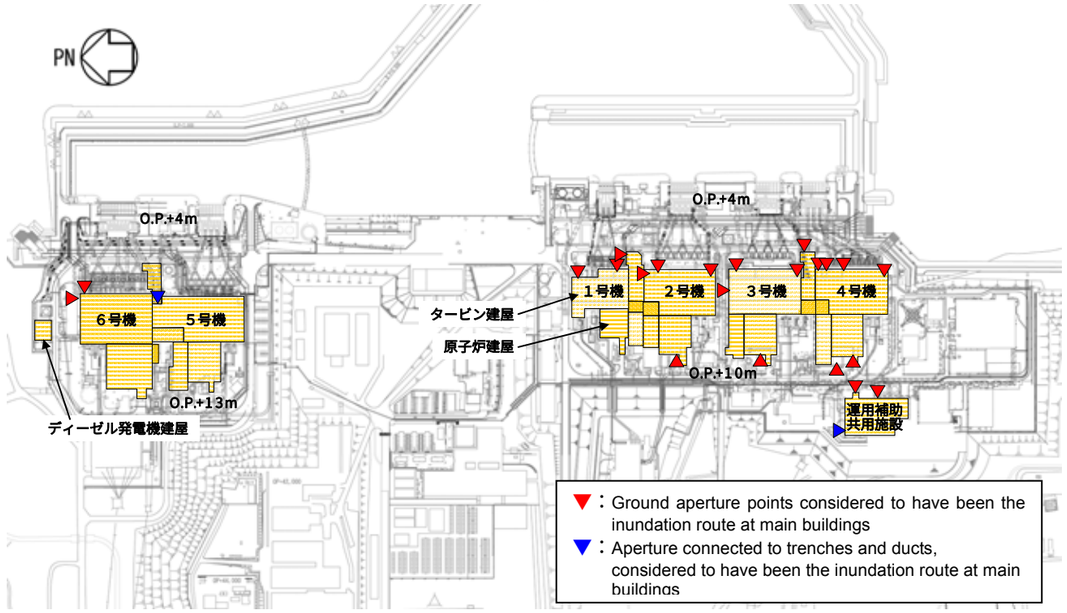


Figure 5　Aperture points considered to have been the inundation route at main buildings (Fukushima Daiichi Nuclear Power Station

【Influence to important facilities with regard to safety due to inundation】

Amongst important facilities with regard to safety, emergency power panels, emergency diesel power facilities (D/G) and DC main bus panel were subject to investigation on the extent and influence of inundation (to the extent possible for investigation). Summary is shown as follows (details shown on Table 1).

Emergency power panel：Apart from Unit 6 power panel, all power panels at Unit 1 to 5 were inundated.

D/G　：Apart from D/G(6B), D/G main or ancillary parts were inundated, and are unable to use

DC main bus panel： Unit 1,2,4 DC bus panel is inundated. No inundation at Unit 3,5,6 power panels.

Also with regard to emergency seawater cooling system facilities installed at outdoor yard area, apart from pumps removed due to inspection, all of them kept their position after the tsunami, and no pumps itself were flown out. Figure 6 shows the condition of Unit 6 emergency seawater system facility.

However, we also confirmed the collapse of cranes for facility inspection, damage to pumps and ancillaries by drifts, and infection of seawater to motor bearing lubricant oil.

With regard to D/G (6A) cooling system seawater pump, although it was inundated due to tsunami, we confirmed the intactness of cooling system seawater pump motor, and we confirmed the operation of D/G(6A) the next day on 19 March.

Table 1　Influence due to tsunami to emergency power panels（M/C, P/C）、emergency diesel generator facilities（D/G）、DC main bus panel (Fukushima Daiichi)

		Unit 1			Unit 2			Unit 3			Unit 4			Unit 5			Unit 6		
Facility	Line ※1	Inundation Yes/	Condition after tsunami	location	Inundation Yes/	Condition after tsunami	location	Inundation Yes/	Condition after tsunami	location	Inundation Yes/	Condition after tsunami	location	Inundation Yes/	Condition after tsunami	location	Inundation Yes/	Condition after tsunami	location
Emergency power panel (M/C)	C	YES	×	T/B 1FL O.P. +10.2m	YES	×	T/B B1FL O.P. +1.9m	YES	×	T/B B1FL O.P. -0.3m	YES	×※2	T/B B1FL O.P. +1.9m	YES	×	T/B B1FL O.P. +2.77m	NO	○	R/B B2FL O.P. +1m
	D	YES	×		YES	×		YES	×		YES	×		YES	×		NO	○	R/B B1FL O.P. +7m
	E(H)				YES	×	CmnB1FL O.P. +2.7m				YES	×	CmnB1FL O.P. +2.7m				NO	○	R/B 1FL O.P. +13.2m
Emergency power panel (P/C)	C	YES	×	C/B B1FL O.P. +4.9m	YES	○	T/B 1FL O.P. +9m	YES	×	T/B B1FL O.P. -0.3m	YES	—※2	T/B 1FL O.P. +9m	YES	×	T/B B1FL O.P. +2.77m	NO	○	R/B B2FL O.P. +1m
	D	YES	×		YES	○		YES	×		YES	○		YES	×		NO	○	R/B B1FL O.P. +7m
	E				YES	×	CmnB1FL O.P. +2.7m				YES	×	共用B1FL O.P. +2.7m				NO	○	DG B1FL O.P. +5.7m
emergency diesel power facility (D/G)	A	YES	×	T/B B1FL O.P. +4.9m	YES	×	T/B B1FL O.P. +1.9m	YES	×	T/B B1FL O.P. +1.9m	YES	×※2	T/B B1Fl O.P. +1.9m	NO	×	T/B B1FL O.P. +4.9m	NO	×	R/B B1FL O.P. +5.8m
	B	YES	×	T/B B1FL O.P. +2m	NO	×	CmnB1FL O.P. +10.2m	YES	×		NO	×	CmnB1FL O.P. +10.2m	NO	×		NO	○	DG 1FL O.P. +13.2m
	H																NO	×	R/B B1FL O.P. +5.8m
DC main bus panel	A	YES	×	C/B B1FL O.P. +4.9m	YES	×	C/B B1FL O.P. +1.9m	NO	○	T/B MB1L O.P. +6.5m	YES	×	C/B B1FL O.P. +1.9m	NO	○	T/B MB1F O.P. +9.5m	NO	○	T/B MB1F O.P. +9.5m
	B	YES	×		YES	×		NO	○		YES	×		NO	○		NO	○	

Note：○：Capable of use, ×：Unable to use

T/B：Turbine Building、R/B：Reactor Building、Cmn：Operation support common facility、DG：Diesel Generator building

※1：M/C of Unit 2/4 are Line E, M/C of Unit 6 is Line H.

※2：M/C(4C), D/G(4A) is under inspection / construction. P/C (4C) is under replacement.

：Inundated　：Facilities unable to use as its main/ancillary parts are inundated

：Unable to receive power as supplier part is unable to supply power. MC (6C/H) is unable to receive power as D/G(6A/6H) is unable to use.

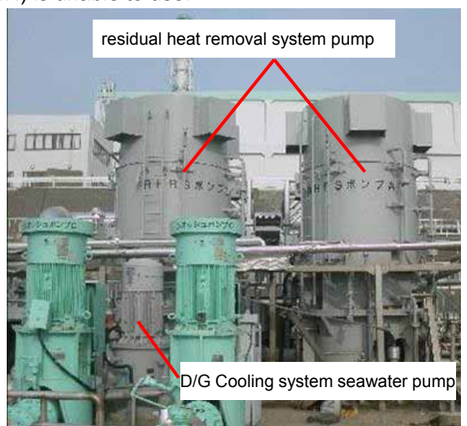


Figure 6 Condition of Unit 6 Emergency seawater cooling facility

(2) Fukushima Daini Nuclear Power Station

【Inundation condition of the buildings】

Although around the main buildings, areas at O.P.+4m at east side of the site (sea side), and O.P. +12m at south side of the site, were considered to be flooded, similar to Fukushima Daiichi, there have been no damage confirmed at the main buildings outer walls and pillars.

Due to inundation, main buildings' open parts (such as buildings entrance/exits and equipment bay doors (hatches), inlets/outlets (louvers), apertures connected to trenches and ducts buried underground of sites (pass-through slots for cables) is considered to have become the inundation route; we confirmed seawater heat exchanger buildings located at O.P. +4m, and at south of Unit 1 reactor building located at O.P. +12m, parts of doors and shutters have been damaged by the tsunami. Within the building, inundation area expanded via passage and stair rooms, etc, and we confirmed that basement floor of the main buildings at Unit 1, Unit 3 turbine building basement second floor, seawater heat exchanger at all units were inundated due to tsunami. . Aperture points considered to have been the inundation route is shown on Figure 7.

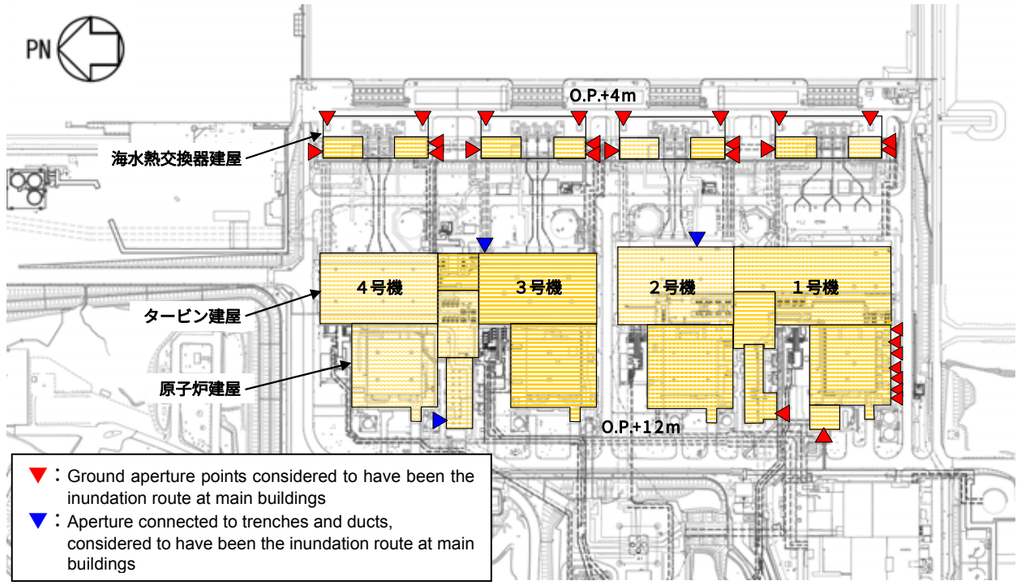


Figure 7　Aperture points considered to have been the inundation route at main buildings (Fukushima Daini Nuclear Power Station

【Influence to important facilities with regard to safety due to inundation】

Amongst important facilities with regard to safety, emergency power panels, emergency diesel power facilities (D/G) and DC main bus panel were subject to investigation on the extent and influence of inundation (to the extent possible for investigation). Summary is shown as follows (details shown on Table 2).

Emergency power panel：All emergency power panels installed at seawater heat exchanger buildings were inundated at all units, and apart from Unit 3 D-2 line power panel all panels lost its function. Emergency power panels installed at reactor buildings were inundated at Unit 1 C,H line, and Unit 3 H line.

D/G　：Apart from Unit 3 D/G(B)(H)、Unit 4 D/G(H), D/G main or ancillary parts were inundated, and are unable to use.

DC main bus panel：　Unit 1 DC main bus panel (H) is inundated

Also, power for both motors of residual heat removal cooling seawater system pump and residual heat removal cooling system pump of emergency cooling system facility installed at seawater heat exchanger buildings, are supplied from emergency power panel (C-2, D-2) of the seawater heat exchanger buildings. Apart from Unit 3 D-2 line power panel all panels lost its function. As emergency power panels installed at seawater heat exchanger buildings, have lost function apart from Unit 3 D-2 line, apart from Unit 3 residual heat removal cooling seawater system pump and residual heat removal cooling system pump, all the others stopped. After that inspection at Unit 1, 2, 4 residual heat removal cooling seawater system pumps and residual heat removal cooling system pumps were carried, and for those which intactness is confirmed, power supply origin was switched and commissioning operation was carried out.

Table 2　Influence due to tsunami to emergency power panels（M/C, P/C）、emergency diesel generator facilities（D/G）、DC main bus panel (Fukushima Daini)

Facilities	Line	Unit 1		Unit 2		Unit 3		Unit 4	
		Inundation Yes/ No	Condition after tsunami	Inundation Yes/ No	Condition after tsunami	Inundation Yes/ No	Condition after tsunami	Inundation Yes/ No	Condition after tsunami
Emergency power panel (M/C) (R/B B1F O.P.+6.0m)	C	YES	×	No	○	No	○	No	○
	D	No	○	No	○	No	○	No	○
	H	YES	×	No	○	YES	○	No	○
Emergency power panel (P/C) (R/B B1F O.P.+6.0m)	C-1	YES	×	No	○	No	○	No	○
	D-1	No	○	No	○	No	○	No	○
Emergency power panel※ (P/C) (Hx/B 1F O.P.+4.2m)	C-2	YES	×	YES	×	YES	×	YES	×
	D-2	YES	×	YES	×	YES	○	YES	×
Emergency diesel generator facility(D/G) (R/B B2F O.P.±0m)	A	YES	×	No	×	No	×	No	×
	B	YES	×	No	×	No	○	No	×
	H	YES	×	No	×	No	○	No	○
DC main bus panel (Unit 1,2A,B:C/B 2F O.P.+1.8m Unit 3,4A,B:C/B 1F O.P.+1.22m Unit 1～4 H:R/B B2F O.P.±0m)	A	No	○	No	○	No	○	No	○
	B	No	○	No	○	No	○	No	○
	H	YES	×	No	○	No	○	No	○

Note：○：Capable of use, ×：Unable to use

R/B：Reactor Building, Hx/B：Seawater heat exchanger building, 、C/B：Control Building

※: Emergency power panel (P/C C-2,D-2)is installed at Seawater heat exchanger building

：Inundated，　：Facilities unable to use as its main/ancillary parts are inundated

4．Analysis of incidents apart from inundations at stations

We grasped the variation of seabed landform within ports due to the earthquake, damage incurred by drifts due to tsunami, and damage of port structures due to tsunami. We confirmed that condition of drifts can be explained by flow of reenactment calculation of tsunami. Also, port structures partly lost function of cancelling waves, however, it was confirmed that dam body is mostly viable.