# The 2011 Off Pacific Coast of Tohoku Earthquake/Tsunami and Damage to the NPPs

Yuichi UCHIYAMA

June 2011 JNES Seismic Safety Div.



**Content**

## Content





## Content

# 1 General damage caused by the earthquake and tsunami

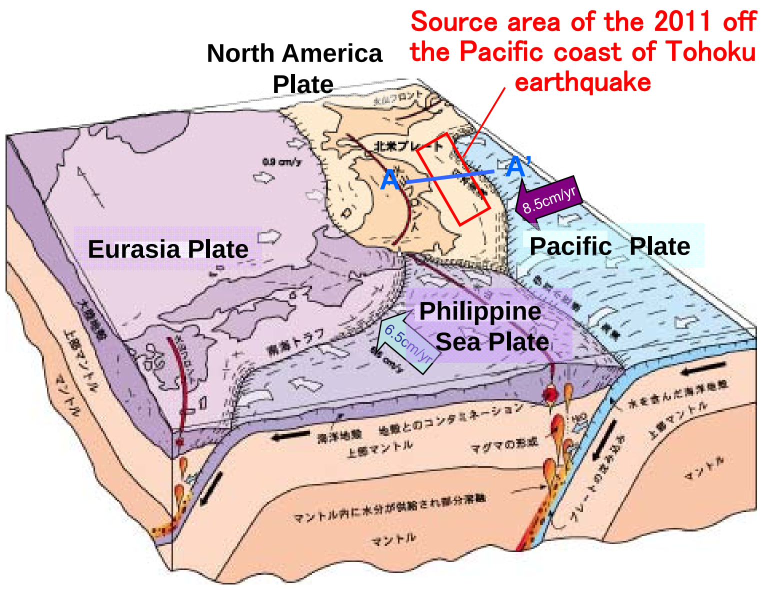


## 1-1 Outline of the 2011 off the Pacific coast of Tohoku earthquake

### (1) Earthquake Summary

#### ■ Tectonic setting & the source area

The four major plates, i.e., the North American, the Eurasian Continent, the Pacific, and the Philippine Sea plates, account for the evolution of Japan islands. The islands are strongly compressed in two directions due to subductions of the Pacific and the Philippine Sea plates.




**Plates structure around Japan**

- Pacific plate
- North America Plate
- Philippine Sea plate
- Eurasia Plate

**Plate Motion**

- Pacific plate subducting under North America plate of 8.5 cm/yr in west direction
- Phillipine sea plate subducting under Eurasia plate of 6.5 cm/yr in north-west direction

**Locations of principal interplate earthquakes**

- Along Japan trench：Plate boundary of pacific plate and north America one
- Along Nankai trough: Plate boundary of Philippine sea plate and Eurasia one

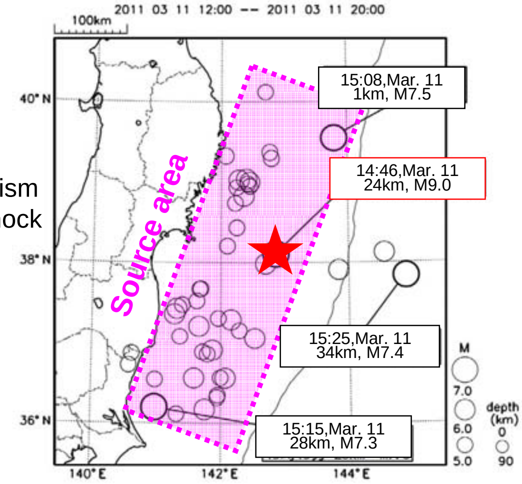
## ■ Earthquake summary

- At 14:46 on March 11, 2011, an Mw 9.0 earthquake occurred off the Pacific coast of Tohoku region, the boundary between the North American and the Pacific plates.
- According to Japan Meteorological Agency (JMA), the source area was estimated to rupture with a size of 450km long and 200km wide, covering the off Iwate Sanriku, off Miyagi, off Fukushima, and off Ibaraki area.
  (Consider consistence with Japanese literature, the sea areas off Sanriku/Miyagi/Fukushima/Ibaraki are briefly translated as Sanriku-Oki, Miyagi-Oki, Fukushima-Oki, Ibaraki-Oki, respectively).
- The hypocenter is estimated 24km deep and magnitude Mw 9. The mechanism solutions indicate a reverse faulting with the compressional axis in WNW-ESE direction.

Distribution of aftershocks occurring in about 8 hours after the main shock

ERI

Focal mechanism of the main shock



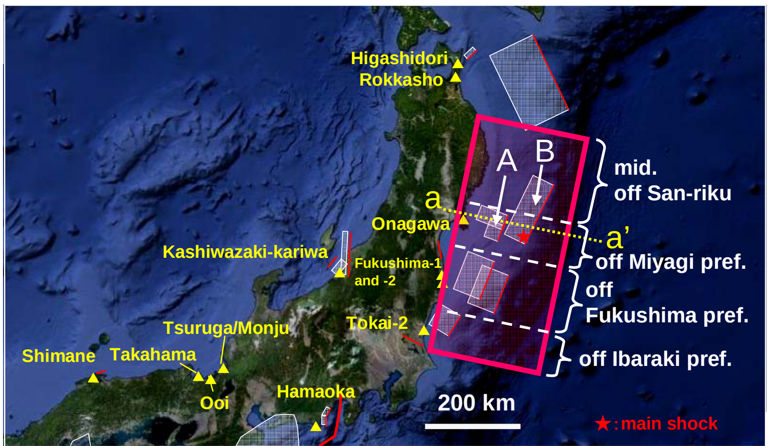

( JMA 5th report with modification by JNES)

| | |
|---|---|
| Origin time | March 11, 2011 at 14:46 (JST) |
| Magnitude | 9.0 (Japan Meteorological Agency) |
| Hypocenter | 38.103°, 142.861°<br>depth=24km |
| Focal Mechanism | Reverse fault with the WNW-ESE compressional axis (CMT solutions) |
| Seismic Intensity | 7: Kurihara city, Miyagi, 6+: 28 cities and villages at Miyagi, Fukushima, Ibaraki and Tochigi Prefectures. |
| Location | Sanriku offshore (130 km ESE of Ojika Peninsula) |
| Distance | 130km of Onagawa NPP, 180km of Fukushima NPP |

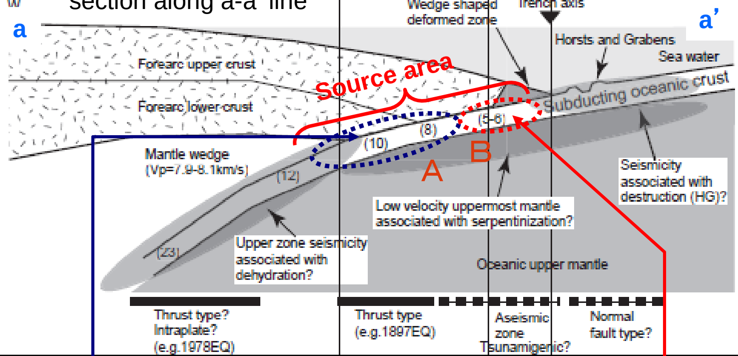


## ■ The source area & the multi-segment rupture

- The hypocenter was located in the Off Miyagi area. It is inferred that a multi-segment rupture started from the hypocenter, then propagated to the north (the sea area off Iwate Pref.), and to the south (the sea area off Fukushima Pref. and Ibaraki Pref.).
- Rupture around the hypocenter: this quake ruptured the shallow portion along Japan trench, close to the source area of the scenario earthquakes A and B.
- Multi-segment rupture: rupture propagated to the deep part (A) as well as the shallow part east to B. (The lower figure plots a cross-sectional view of the source area)
- Large slip was estimated to occur in the shallow part along Japan trench from the water area off the Northern Sanriku to the area off the Boso, with the largest value above 20m.




Schematic illustration of cross section along a-a' line

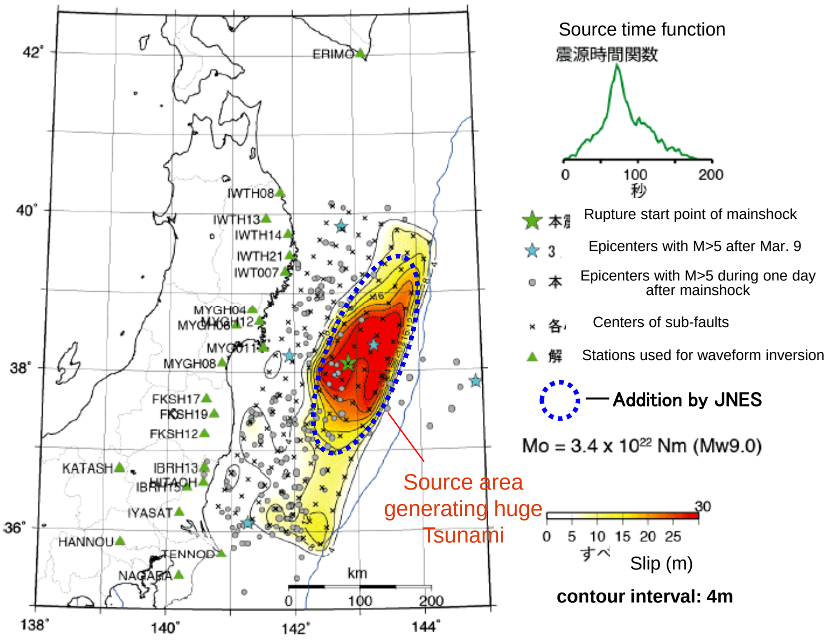



Deep potion of interplate: smaller slip than that at shallower potion and generating strong motion due to near land

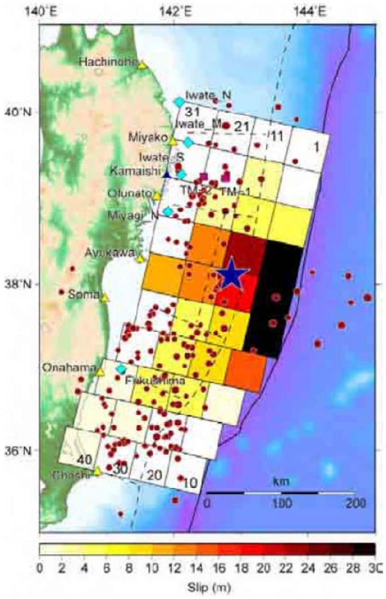
Shallow portion of interplate: Large and slow slip and generating great tsunami

## (2) Source process

- Analysis results suggest that the great tsunami was caused by the large slip (as large as 30m) in the shallow portion (east to the hypocenter) of the plate boundary.
- Source process inverted from strong motion data by JMA is consistent with the slip distribution inverted from Tsunami records.



Source model from seismic waveform inversion (JMA)



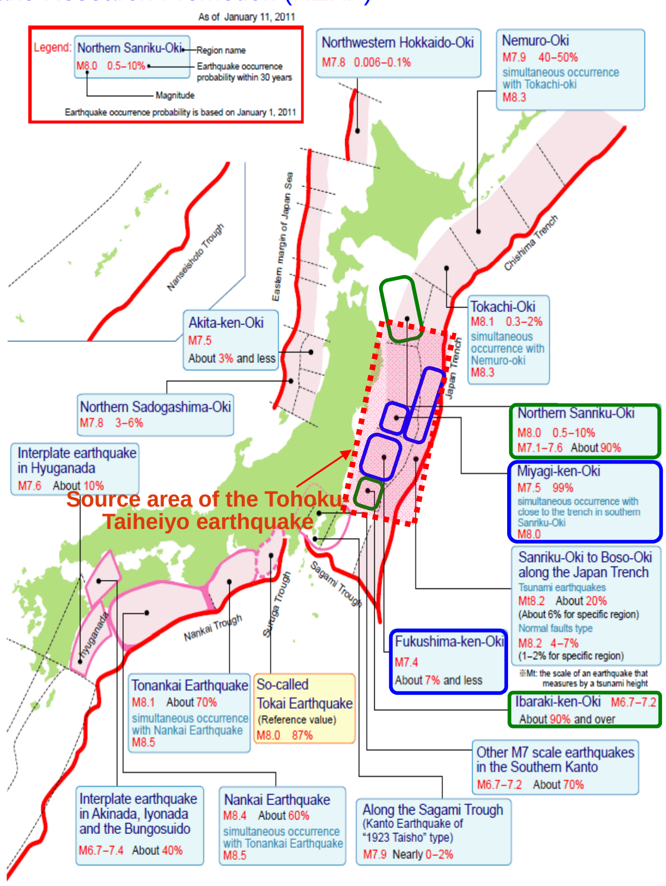
Source model from tsunami inversion (Fujii and Satake)



## (3) National Evaluation of Long-Term Seismicity

Long-Term Evaluation Subcommittee, Earthquake Research Committee
Headquarters for Earthquake Research Promotion (HERP)

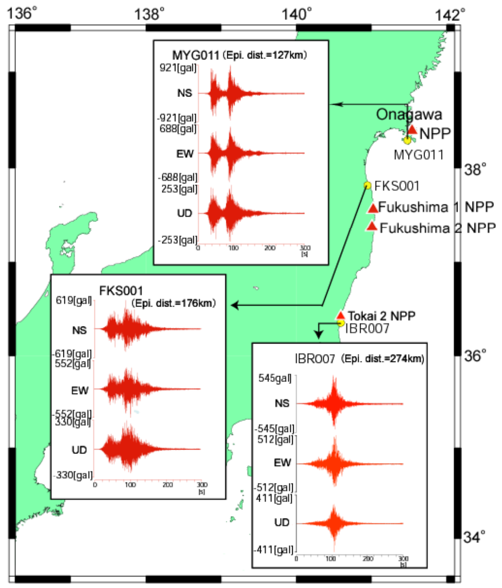
- HERP did warn against the M7.5 Miyagi-oki earthquake with an occurrence probability of 99% within 30 years.
- HERP also warned for simultaneous occurrence of rupture close to the trench in southern Sanriku-Oki with a probability about 40% within 10 years.
- The M9.0 earthquake, which ruptured to as south as Ibaraki-Oki area and recorded large slip of above 20m, is far beyond the long-term evaluation results.
  - The shallow portion along the trench had been known as a potential source area for tsunami earthquakes. A strong coupling in this area, however, had not been expected.
  - HERP estimated an occurrence probability of 20% within 30 years for a tsunami earthquake of Mt8.2 in some area along the trench from Sanriku-Oki to Boso-Oki.
  - The slip value as large as 20m suggests a very strong coupling in the past several hundred or even one thousand years.

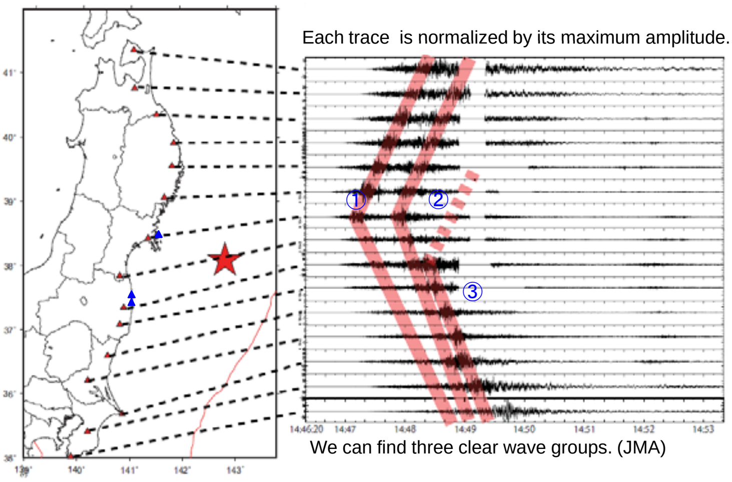


# 1-2 Seismic ground motion and tsunami observation

## ■ Seismic Observation: Ground Motion

- Seismic records at the observatory MYG011 near the Onagawa plant showed two large pulses with similar amplitudes, whereas the second pulse of records at FKS001 (near the Fukushima plant) is clearly larger than the first pulse. It suggests that two sub-events occurred, first in the deep portion, then the other in the shallow portion with larger slip.
- Seismic records at IBR007 showed a single large peak at about 120 seconds after the P wave arrives. It suggests that the rupture in the shallow portion propagates to south and ground motions observed in the southern stations are hence amplified due to directivity effects.



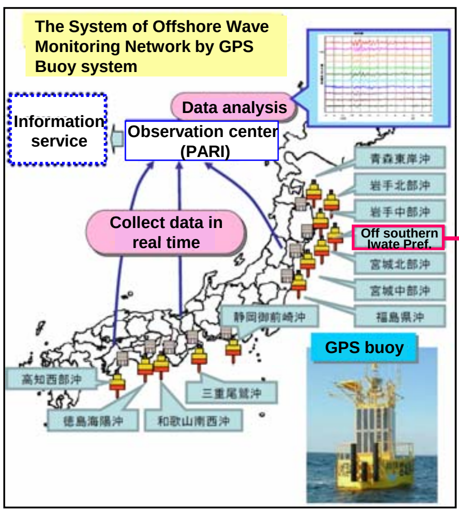

(Propagation of seismic motion / JMA report with modification by JNES)



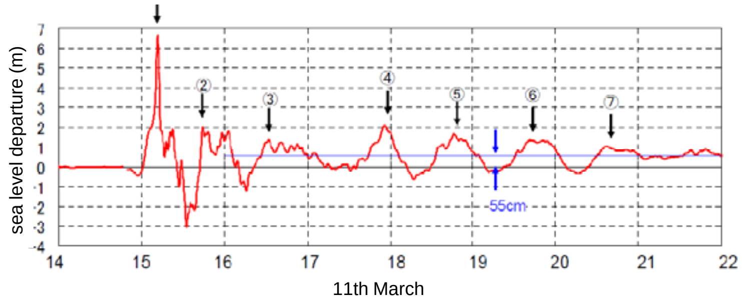
## ■ Tsunami Observation: Offshore Wave Monitoring System

Tsunami waveform:

- The GPS wave meter (known as GPS buoy) located at off Kamaishi City, Iwate Pref., records the largest wave height of 6.7m in 15 minutes after the original time (i.e., 14:46), the second to seventh peaks decreased slowly. The first three pulse phases were irregular, whereas the other four phases showed a similar duration of about 50 minutes.
- In detail, the first pulse phase showed a two-step rise: water level rose to 2m in 6 minutes, then dramatically rose 4m in 4 minutes.




**Tsunami waveform record from GPS buoy data off southern Iwate Pref. (204m off Kamaishi)**

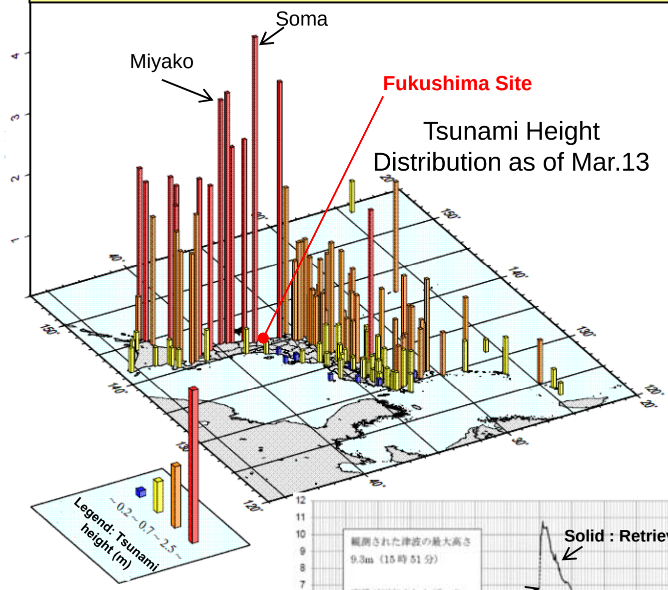



- The maximum wave height was 6.7 m (first wave) off southern Iwate Pref. at 15:12.
- First tsunami wave was extremely high.
- Wave period
  - First to third tsunami wave: irregular period
  - Fourth to seventh tsunami wave: about 50 minutes period
- Total amount of rose in average sea level were 55 cm after the earthquake.

Reference: Independent Administrative Institute Port and Airport Research Institute

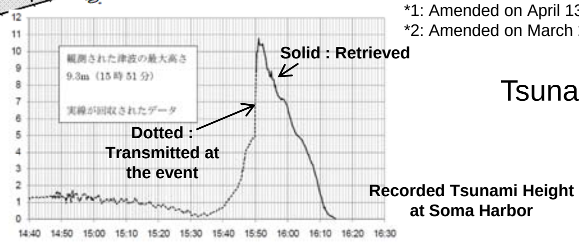
## ■ Tsunami Observation: Distribution of Tsunami Height

- Observed tsunami height at 2011 Tsunami in Japan:
  At coast (Tsunami height) : > 9.3m (Soma), >8.0m (Miyako)
  Run-up height : 40.5m (Aneyoshi, Miyako, 宮古市姉吉地区), 38.9m (Omoe Peni., Miyako 宮古市,重茂(おもえ)半島)
- Chilean Tsunami at Japan coast : up to 2m




| Tsunami height observed on Mar.11 (JST) | | | | | |
|---|---|---|---|---|---|
| | First tsunami wave | | | The maximum wave | |
| **Soma** | 14:55 | Up flow | 0.3 m | 15:50 | >7.3 m → **>9.3 m*1** |
| Ooarai | 15:15 | Up flow | 1.8 m | 16:52 | 4.2m |
| Kamaishi | 14:45. | Down flow | 0.1 m | 15:21 | > 4.1 m |
| Miyako | 14:48 | Up flow | 0.2 m | 15:21 | >4.0 m → **>8.5 m*2** |
| Ayukawa, Ishinomaki city | 14:46 | Up flow | 0.1 m | 15:20. | > 3.3 m |
| Oofunatoshi | 14:46 | Down flow | 0.2 m | 15:15 | >3.2 m → **>8.0m*2** |
| Sekinehama, Mutsu city | 15:20 | Down flow | 0.1 m | 18:16. | 2.9 m |
| Hanasaki, Nemuro city | 15:34 | Down flow | Weak ? | 15:57. | 2.8 m |
| Tokachi-ko | 15:26 | Down flow | 0.2 m | 15:57. | > 2.8 m |
| Uraga | 15:19 | Down flow | 0.2 m | 16:42 | 2.7 m |

*1: Amended on April 13 by retrieved data of pressure gauge type tsumamimeter
*2: Amended on March 23 by retrieved data of pressure gauge type tsumamimeter



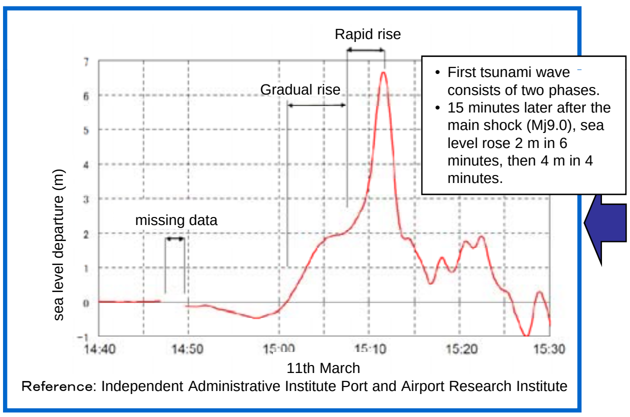

Recorded Tsunami Height at Soma Harbor

Tsunami Height by JMA 14th Report and its amendments

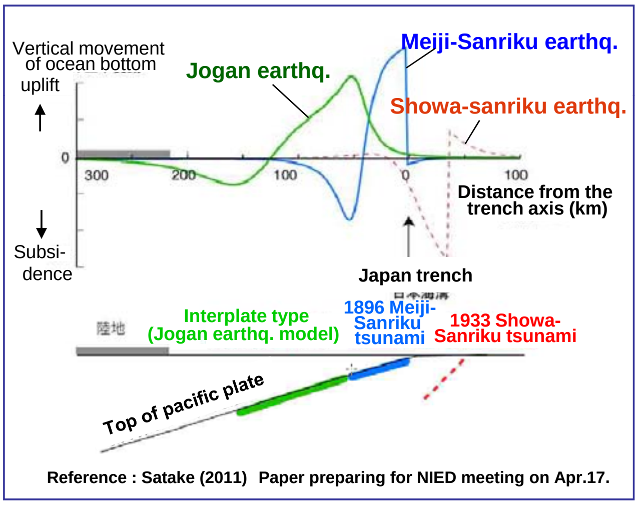


## ■ Tsunami Observation: Analysis and Inference

Using analytical investigation, Prof. Satake (ERI, University of Tokyo) infers that:
- This tsunami is featured with both the long-period dominant wave generated by rupture in the portion like the 869 Jogan EQ and the short-period wave generated by rupture in the shallow portion like 1896 Sanriku Oki EQ.
- Tsunami with big height arrived at the coast and run up subsequently. Meanwhile, tsunami with a long wave length further supplies running up energy in long duration such that tsunami run-up areas were widened.




Record of GPS Tsunamimeter of Off -Kamaishi



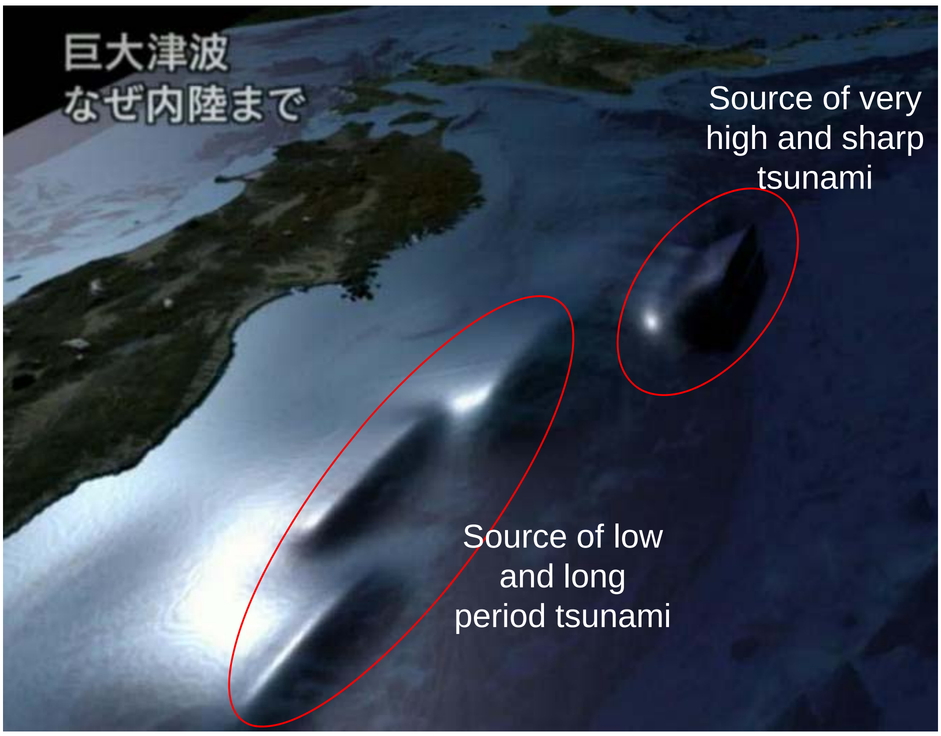
**Hypothesis by Prof. Furumura (Tokyo Univ.) and Prof. Ito (Tohoku Univ.) on the cause of very high sharp peak of the tsunami**

(From NHK TV)


From NHK TV on May 10



Tsunami Model by Dr.Fujii (Fuji Tokoha Univ.)




From NHK TV on May 10

# 1-3 General Damage

## ■ Damage Outline

- Inundation: Miyagi Pref. 327km$^2$; Fukushima Pref. 112km$^2$, Iwate Pref. 58km$^2$. Total area :461km$^2$.
- House/building: 368,000 houses damaged (total/semi/partial destruction or inundation). 17,000 public buildings damaged.
- Infrastructure: road damage at 4,000 places, railroad damage at 7,280 places (of 1,680 places damaged by tsunami), gas supply shutdown for 460,000 households (at its peak), power supply cutoff at 4,000,000 households, telephone disconnection of 800,000 lines.

Inundation area

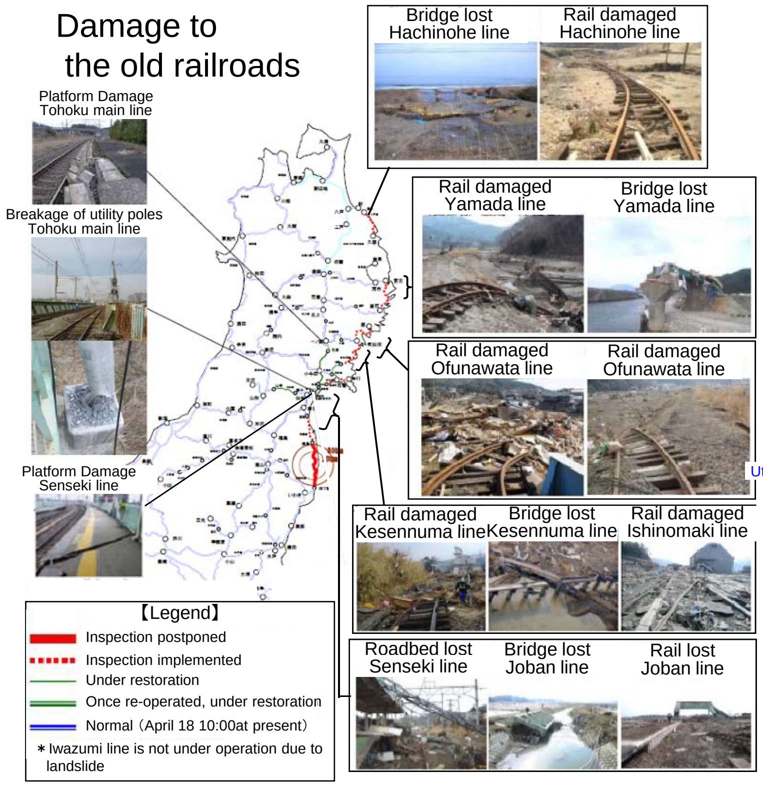
| Prefecture | Inundated area * (km$^2$) | Administration Area facing sea** (km$^2$) | Rate of inundated area (%) | Remarks (Administrative coastal cities and villages counted) |
|---|---|---|---|---|
| | A | B | A÷B×100 | |
| Aomori | 24 | 844 | 2.8 | 5 city/town/village (Hachinohe, Misawa, Rokkasho, Oirase, Hashikami) |
| Iwate | 58 | 4946 | 1.2 | 12 city/town/village (Miyako, Ofuna etc.) |
| Miyagi | 327 | 2003 | 16.3 | 17 city/town/village |
| Fukushima | 112 | 2456 | 4.6 | 10 city/town/village |
| Ibaraki | 23 | 1444 | 1.6 | 10 city/town/village |
| Chiba | 17 | 689 | 2.5 | 10 city/town/village |
| Total | 561 | 12382 | 4.5 | – |


*Identified from air-photos. **Only those listed in the Remarks column are counted.

The 5th Release on Tsunami Inundation by Geospatial Information Authority of Japan.

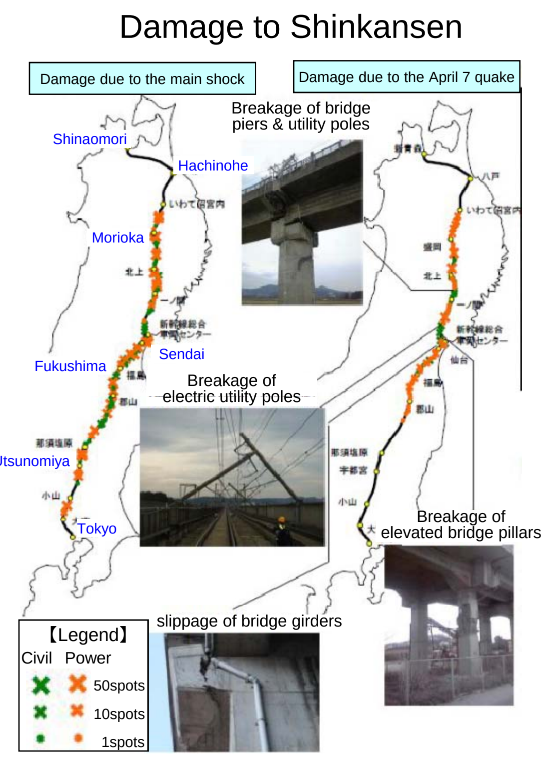


## ■ Railroad Damage




Release by Eastern JR (April 17)

Eastern JR Release (April 4)



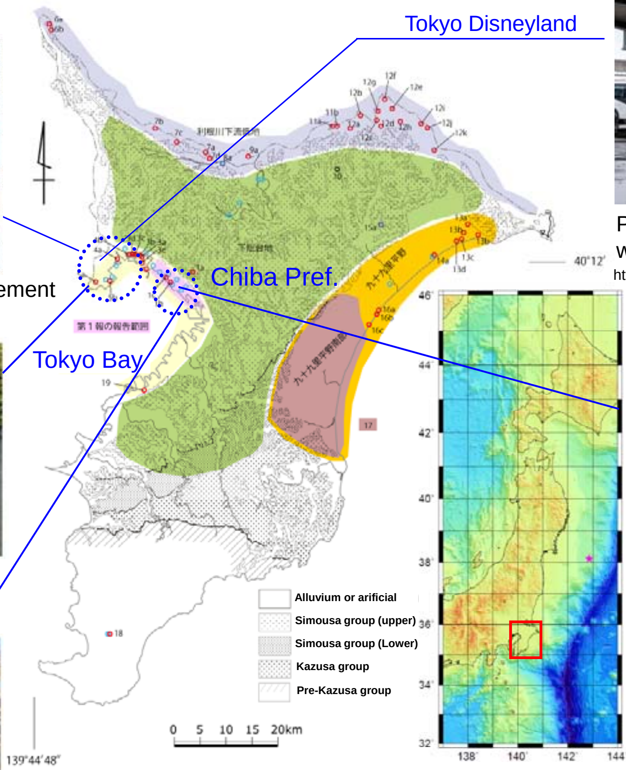

Eastern JR Release (April 17)

## ■ Civil Damage(2) : Liquefaction

Urayasu city：Lifting of building basement due to liquefaction and subsidence

Urayasu city：liquefaction and floating of a manhole

Around Chiba port：Subsidence of a electric pole and large volume of sand boil




○ Liquefaction due to the Tohoku-Taiheiyo earthq. (confirmed)
○ Damaged except liquefaction due to the Tohoku-Taiheiyo earthq.
○ Liquefaction due to the Chiba-ken Toho-oki earthq., but not Tohoku Taiheiyo one.
○ Liquefaction due to the Tohoku-Taiheiyo earthq. (reported)

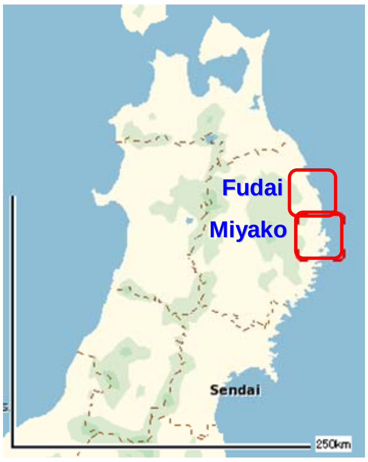
CERC: Investigation report on liquefaction damage caused by the 2011 of the Pacific coast of Tohoku earthquake
http://www.wit.pref.chiba.lg.jp/_sui_chi/chishitu/touhoku/ekijouka20110318b.pdf

Parking spot at Tokyo Disneyland was inundated due to liquefaction
http://www.nippon-sekai.com/main/articles/other/liquefaction-affects-tokyo-disneyland/

Inage Kaihin (lawn) park：wide area of sandboil and subsidence



## ■ Damage to Breakwaters & Tide Embankments

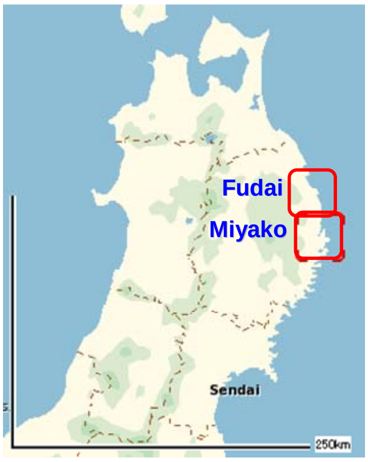



- Taro district, Miyako case : 10m-high sea wall with a local nickname of "the Great Wall of China", was destroyed by the 15m-high tsunami.
- Otabe district, Fudai Village case : 15.5m-high sea wall was constructed according to the village chief's strong willing, and it blocked the 15 m high tsunami and successfully protected the houses in this district. As a lesson learnt from great damages caused by the Meiji Sanriku tsunami and the Showa Sanriku tsunami, local wisdom of preparedness against a15m high tsunami has been widely disseminated in this area.
- These two examples give some suggestion when we examine to prepare for violent natural phenomena.


The 10m-high tide embankment was destroyed in Tao district, Miyako city, Iwate pref.


The 15.5m-high tide embankment is sound in Otabe district, Fudai village, Iwate pref.

## ■ Ancient instruction and observance



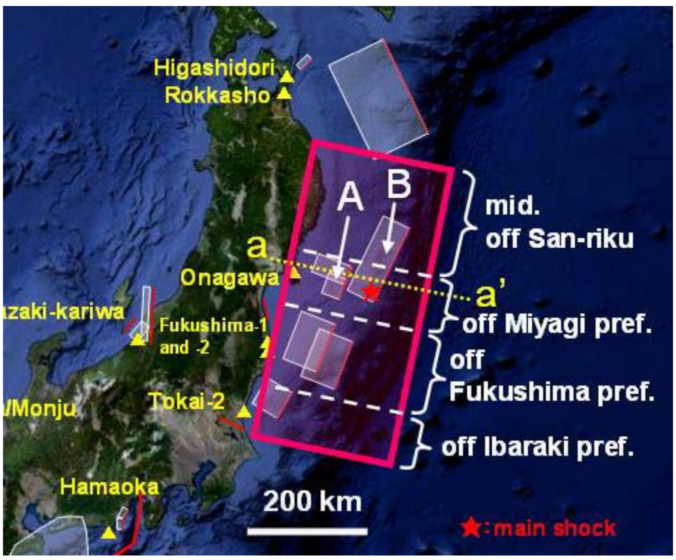

- The left bottom photo show a stone monument standing at the entrance to Aneyoshi district in Miyako City. As an instruction from previous generations and also lessons learnt from their experience of the 1896 Meiji Sanriku tsunami, the inscription reads: "Do not build any house below this stone," Thanks to having followed this ancient instruction, the 2011 tsunami did not claim a single casualty in this district.
- It is seen that the fate depended on whether this kind of previous tsunami lessons had been reflected in tsunami design or not.

A photo from the village's point of view (i.e. facing the coast)

A photo at the spot slightly below the stone monument



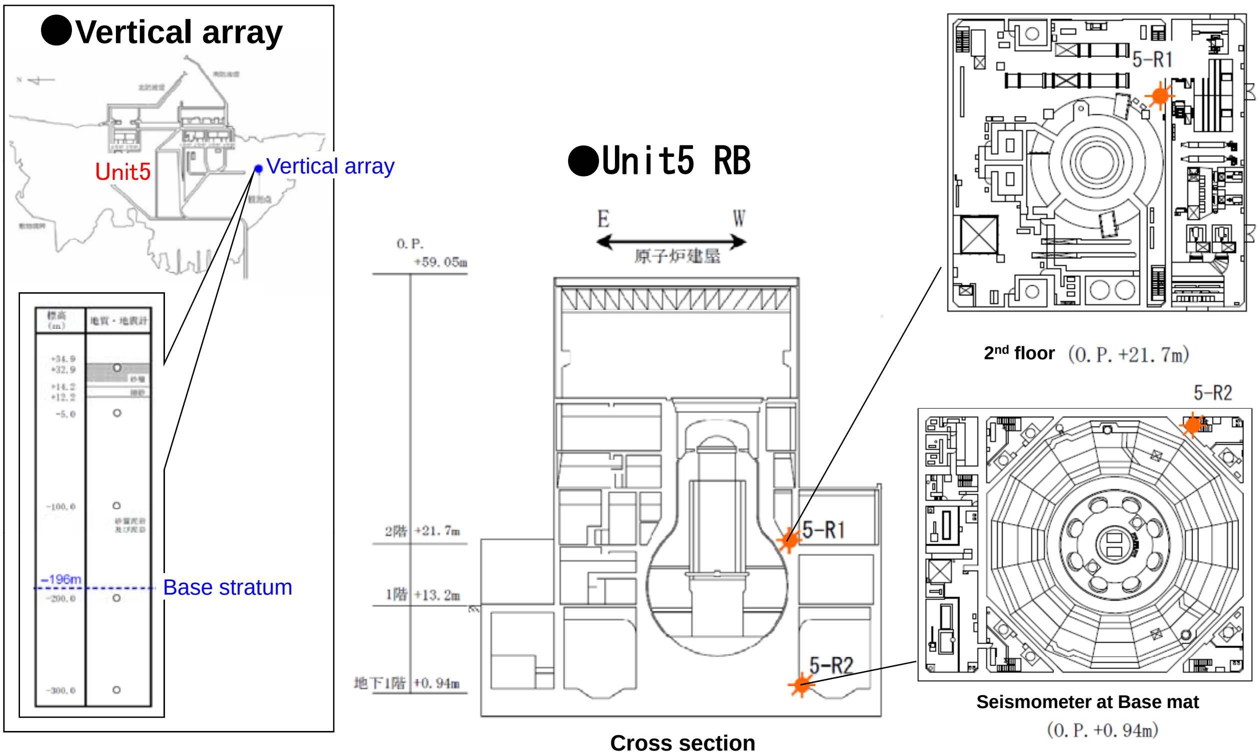
# 2 Damage of Fukushima Daiichi and Daini NPP site




| Site | Unit | Ele. Output | OPC at EQ | OPC after EQ | OPC after Tsunami |
|---|---|---|---|---|---|
| 1F | #1 | 460 | OP | ASD | All external powers (4 lines): Lost by EQ<br>All EDGs (8) : Lost ny Tsunami |
| | #2 | 784 | OP | ASD | |
| | #3 | 784 | OP | ASD | |
| | #4 | 784 | AI | – | |
| | #5 | 784 | AI | – | All external powers(2 lines): Lost by EQ<br>4 EDGs out of 5 :Lost by Tsunami |
| | #6 | 1,100 | AI | – | |
| 2F | #1 | 1,100 | OP | ASD | 1 line out of 4 : Servived<br>9 EDGs out of 12: Lost by Tsunami |
| | #2 | 1,100 | OP | ASD | |
| | #3 | 1,100 | OP | ASD | |
| | #4 | 1,100 | OP | ASD | |

# 2.1 Fukushima Daiichi NPP site

① Seismic observation system in Fukushima No1 site
- ･Seismometer : inside RB＋vertical seismometer array＋recorder
  Horizontal(2 components) and Vertical Acc. Time history
- ･Recorder：Overwrite protection reflecting lesson learned from NCO EQ






## Observed ground motion

- ･Record was cut due to long time vibration( around 170 sec)
- ･Table Ⅱ-2-1：Max.acc. of 3 components at RB basemat
  Horizontal Max. acc.： 550Gal at Unit2（EW）

### Table 2-1

Max. accelerations on base mat in reactor buildings

| Loc. of observation (bottom floor of reactor bld.) | | Obs. Value※1 Max. value (gal) | | | Max. response acc. for backcheck Ss (gal) | | |
|---|---|---|---|---|---|---|---|
| | | NS | EW | UD | NS | EW | UD |
| Fukushima Dai-ichi | Unit 1 | 460※2 | 447※2 | 258※2 | 487 | 489 | 412 |
| | Unit 2 | 348※2 | 550※2 | 302※2 | 441 | 438 | 420 |
| | Unit 3 | 322※2 | 507※2 | 231※2 | 449 | 441 | 429 |
| | Unit 4 | 281※2 | 319※2 | 200※2 | 447 | 445 | 422 |
| | Unit 5 | 311※2 | 548※2 | 256※2 | 452 | 452 | 427 |
| | Unit 6 | 298※2 | 444※2 | 244 | 445 | 448 | 415 |

※1 These are temporal values, and may be corrected later.
※2 Each recording stopped at about 130-150 s from recording start time.

## ② Comparison between design basis ground motion(DBGM)Ss and Observed motion（1/2)

■ **Outline of DBGM Ss**

- ●Seismic back-check : Review of DBGM Ss based on Revised Seismic Reviewing Gide
- ●Earthquakes to define DBGM :
  - ⅰ Interplate earthquake of Off-Fukushima,
  - ⅱ Intraplate earthquake just beneath the site,
  - ⅲ Earthquake due to active faults around the site
  - ⅳ Diffused earthquake around the site
- ● DBGM Ss :
  - ・Procedure : Should envelope ⅰ～ⅳ
  - ・Ss-1, Ss-2, Ss-3

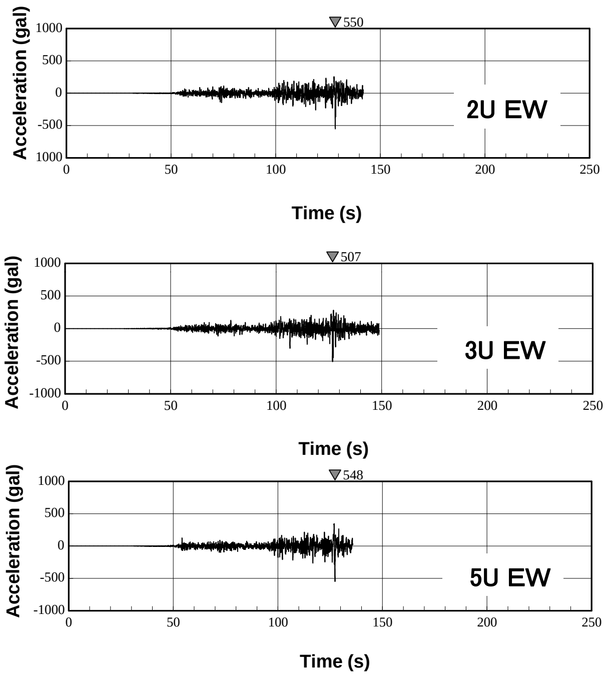
■ **Characteristics of response spectrum (ORS) of observed motions**

- ・Observed ORS lower than Ss spectra (DBS) in the almost period
- ・Observed ORS overshoot max. 30 % Ss spectra (DBS) in the period between 0.2 to 0.3 second
- ・Tokyo Electric Co. : No safety related facilities in this band of period

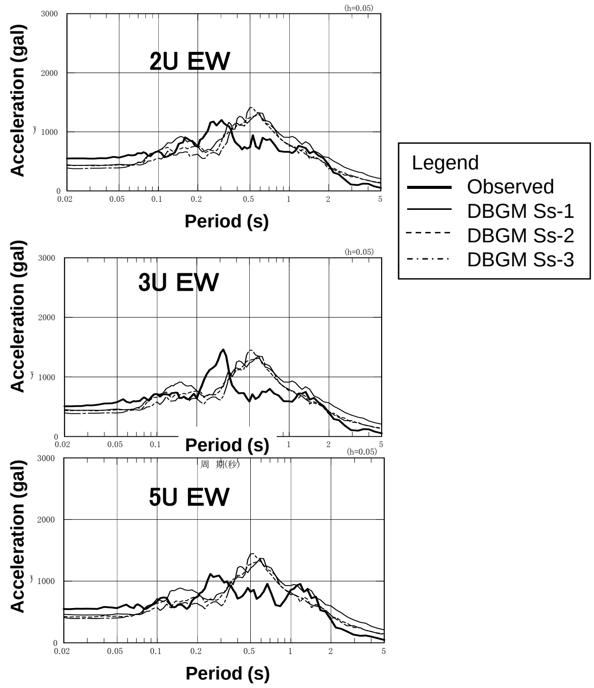


## ② Comparison between design basis ground motion(DBGM)Ss and Observed motion（2/2)

●Acc.time history at RB basemat




● Ors of observed motion and Ss



## ③ Exceedance Probability of DBGM Ss and Probabilistic Seismic Hazard Evaluation

■ **Exceedance Probability of DBGM Ss**

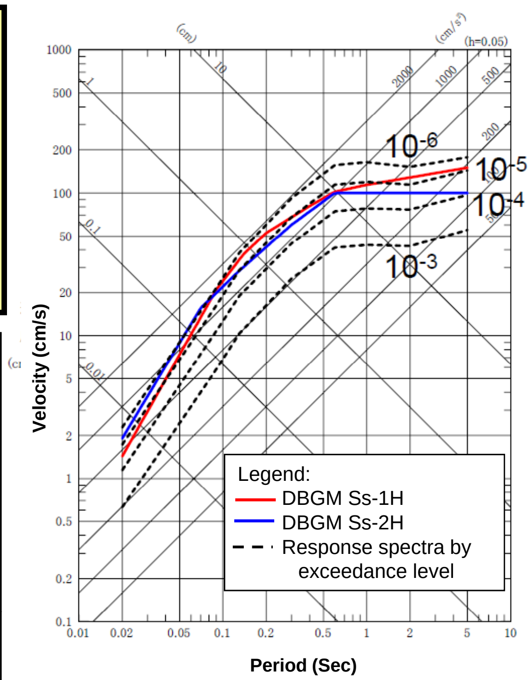
- **Revised Seismic design review guide recognize undeniable possibility of ground motion over Ss**
- **It require referring exceedance probability of Ss**

■ **NISA direction to utilities**

● **NISA: Based on revised guide, request all utilities to define Ss and seismic safety evaluation of facilities**

● **Utilities:Evaluate exceedance probability of Ss according to JNEA Seismic PSA standard**

- **Annual exceedance probability (AEP) of Fukushima No1（Right side fig.）**
  **AEP of Ss：10−4～10−5**

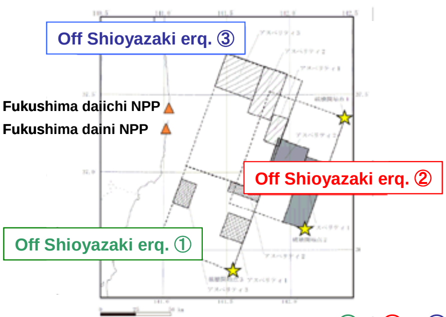
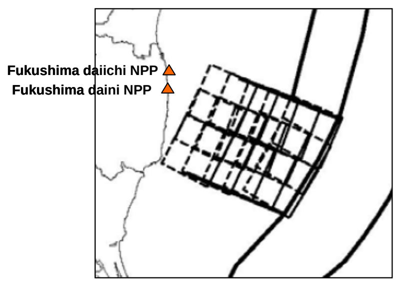
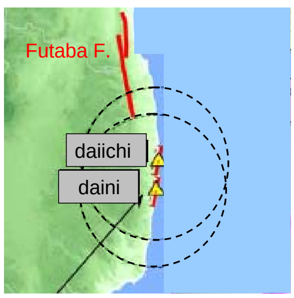
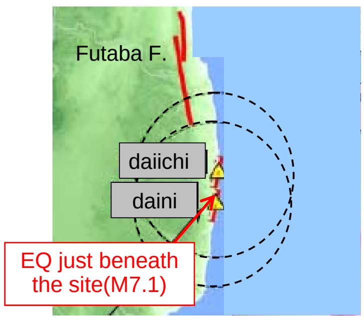



**Annual exceedance probability of DBGM Ss of Fukushima No1 site**



## Example of seismic hazard evaluation

(Case for Fukushima daiichi & daini NPPs)

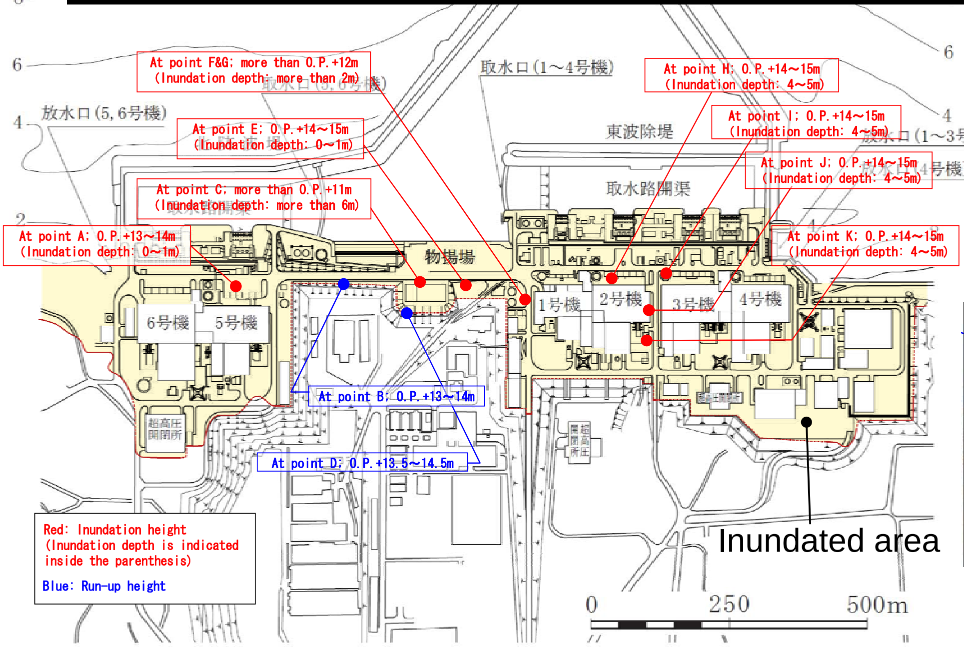
| | Source model with identified active faults | Diffuse seismicity |
|---|---|---|
| Interplate type |   Source = ①+②+③ |   Source : interplate type at off Fukushima pref. |
| Inland active F. type |   Source = Futaba fault |   Source = 想定敷地下方の地震 |

※In addtion above, intra slab type earthquakes is considered only for diffuse seismicity.

## (2) Tsunami

### ① inundated area and height

| Unit | Height（m） | Site elevation（m） |
|---|---|---|
| Around #1 – #4 | 14～15 | Around 10 |
| Around #5,#6 | 13～14 | Around 12～13 |
| ･Average subsidence of Tohoku-Kanto coastal area: around – 0.8m | | |





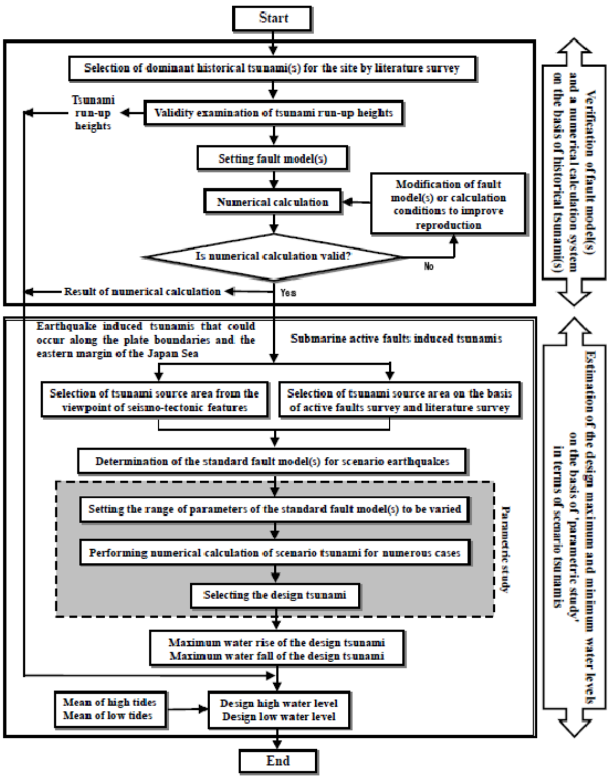
TEPCOプレスリリース4月9日

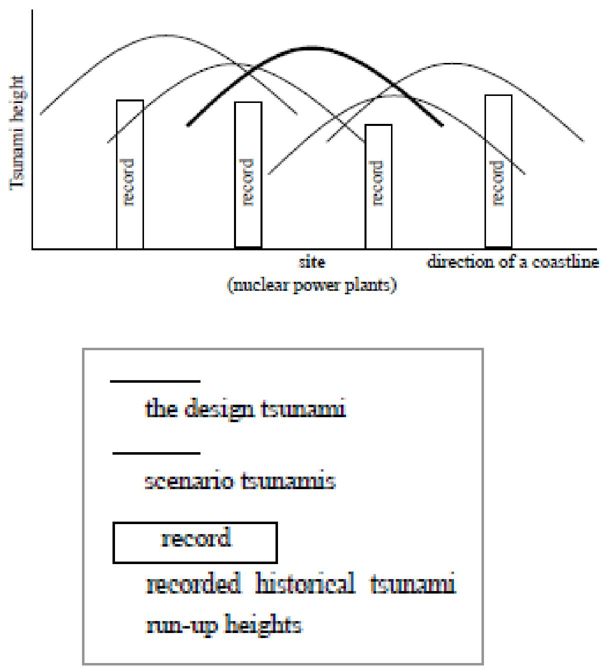


### ② Comparison between design tsunami height and observed

## ■ Evaluation standard for design tsunami

**･Evaluation guide：JSCE｢Tsunami evaluation technology for NPP（2002）｣**
**Above guide is incorporated into IAEA tsunami guide DS417 (Ⅱ2-3)**

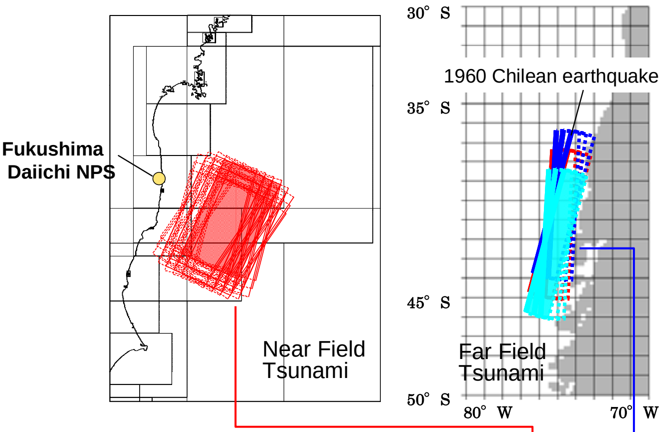


## ■ Tsunami source model at Fukushima Daiichi site

**・Earthquake : The off Shioyazaki earthquake（M7.9、1938）**
**・Design height: See Fig below**

Re-evaluation study based on JSCE methodology

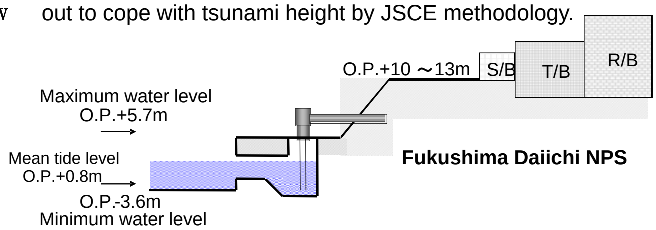



Maximum water level = 4.4m + O.P.＋1.3m = O.P.+5.7m
Minimum water level = -3.6m – O.P.±0.0m = O.P.-3.6m

History of design basis tsunami evaluation

| | Evaluation and timing | | |
|---|---|---|---|
| | Constraction permit（1966 ～1972） | Based on JSCE guide（2002） | Seismic back-check |
| Design Max. height | O.P. 3.1 m （Chile EQ：M9.0, 1960） | O.P.5.7 m （Shioyazaki EQ：M7.9、1938） | Not yet reported |
| Obser-ved （trace） | ・#1-#4：14～15m<br>・#5,6：13～14m | | |

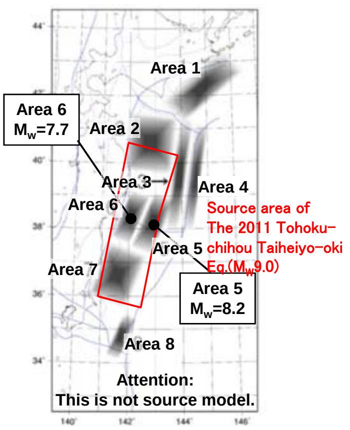
Modification around sea water pumps had been carried out to cope with tsunami height by JSCE methodology.






## ■Tsunami source

### JSCE 2002



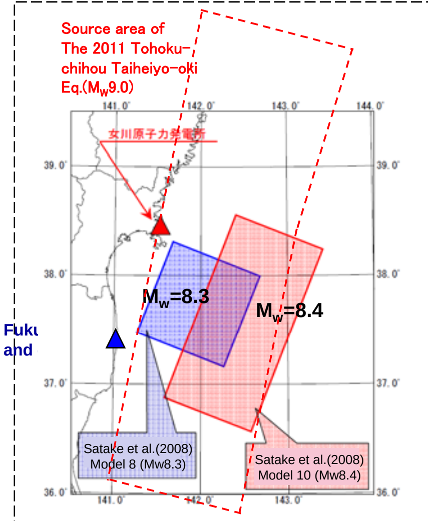

(a) Classification of sea area (source area) in Japan Society of Civil Engineers（2002）

(b) Moment magnitude ($M_w$) list

| 領 域 | 既往最大$M_w$ | 対応する既往津波 |
|---|---|---|
| 1 | 8.2 | 1952年 |
| 2 | 8.4 | 1968年 |
| 3 | 8.3 | 1896年 |
| 4 | 8.6 | 1611年 |
| 5 | 8.2 | 1793年 |
| 6 | 7.7 | 1978年 |
| 7 | 7.9 | 1938年 |
| 8 | 8.2 | 1677年 |

Classification of sea area (source area) in Japan Society of Civil Engineers（2002）

### 2011 Tsunami




Fault model from the 869 Jyogan tsunami by Satake et al.（2008）

（東北電力（合同W34-3-2）に加筆）

The surveys of tsunami deposit sand at Sendai and Ishinomaki plains by AIST show inundation of Jyogan tsunami in 869 ran up over 3 km from the coast.

（Yomiuri newspaper 2011･3･12）

## ■Handling of the Zyogan EQ（869）

● 32th Seismic design and structure sub committee EQ /tsunami and geology/ ground joint working group （June 24 2009 ）:

・Held for ground motion reviewing

・The member Okamura pointed that research reports on tsunami caused by the Zyogan EQ by AIST and Tohoku Univ. were not considered.

● 33th above working group （July 13 2009）

・NISA directed utility to study additionally on tsunami caused by this EQ, if new knowledge acquired, until final report.

## ③ Probabilistic tsunami hazard assessment and exceedance probability of design tsunami height

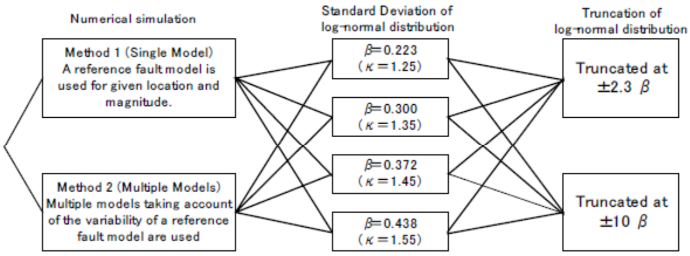
■ **Trend of probabilistic tsunami hazard assessment**

- ●**Method：JSCE tsunami working committee[Ⅱ2-4、Ⅱ2-5］now investigating**
  - ・**Uncertainty：Logic tree（Main parameters：EQ magnitude, amount of slide etc.)**
- ●**Trial example（FigⅡ-2-6）**
  - ・**LT：Questionnaire to experts**

**⇒ Almost equivalent source region of the off Tohoku earthquake tsunami（JTT1～3） are indicated**

**⇒EQ upper magnitude Mj8.6、slide upper amount 16m. These are yet small.**

| | | The maximum Mw in the past | Year in which the tsunami occurred |
|---|---|---|---|
| Near-field Tsunami | JTT1 | 8.3 | 1896 |
| | JTT2 | There is no historical record. It may be assumed to be the same Mw as JTT1. | |
| | JTT3 | There is no historical record. It may be assumed to be the same Mw as JTT1. | |
| | JTNR1 | 8.6 | 1611 |
| | JTNR2 | There is no historical record. It may be assumed to be the same Mw as JTNR1. | |
| | JTNR3 | 8.2 | 1677 |
| | JTS1 | 7.9 | 1938 |
| | JTN2 | 7.7 | 1978 |
| | JTN3 | 8.2 | 1793 |
| Far-field Tsunami | P1 | 9.0 | 1868 |
| | C1 | 8.8 | 1877 |
| | C2 | 9.3 | 1960 |



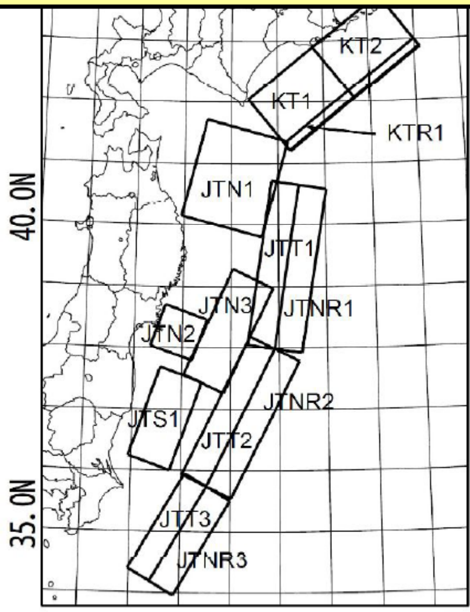
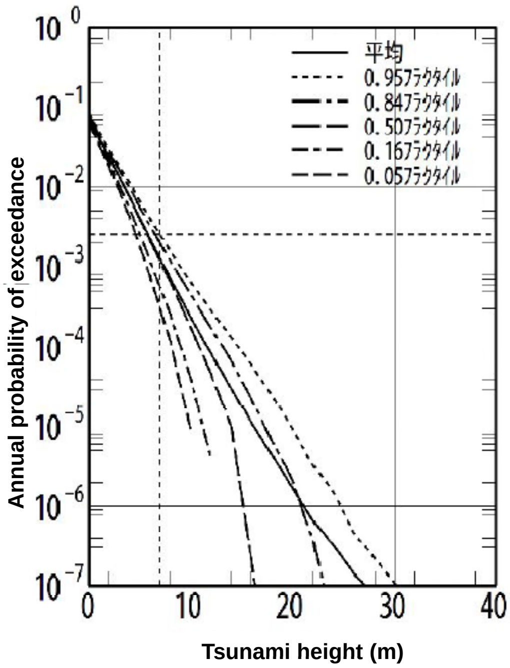




*FIGURE_2.* **Distribution of near-field tsunami source zones**



●**Example of tsunami hazard evaluation**

・**Example1 on ： Iwate prefecture Yamada village（JSCE paper）。**




**Example 1: Long-term Near-field+ Far-field Yamada village, Iwate Pref.**

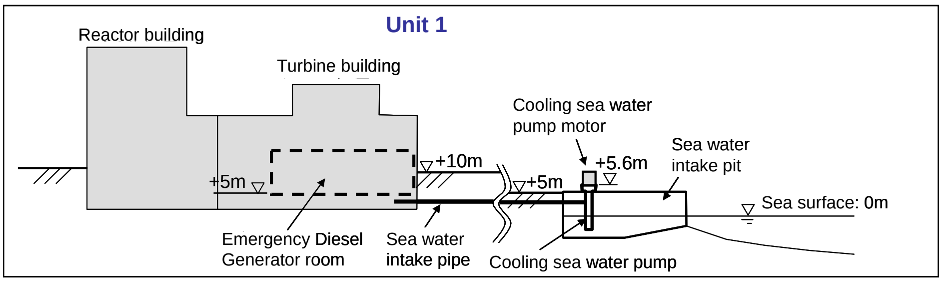
■**Comment on tsunami evaluation by Earthquake Research Committee Headquarters for Earthquake Research Promotion (HERP:地震調査研究推進本部)**

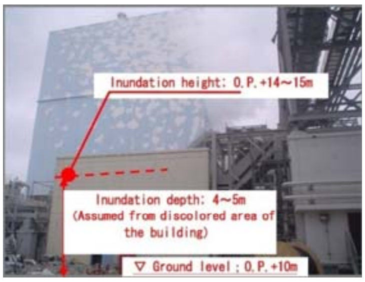
・**Within 3 years, HERP will assess and announce tsunami height, inundation area and occurrence probability on each coastal area**
**（May 13 2011）**

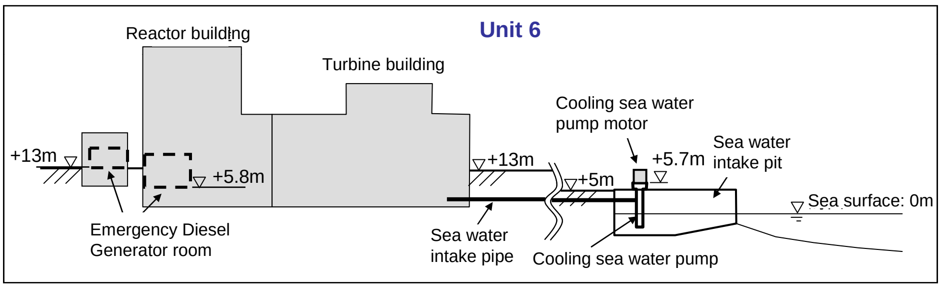


## （3）Damage
## ①Sea water pump, Emergency power

### Inundation



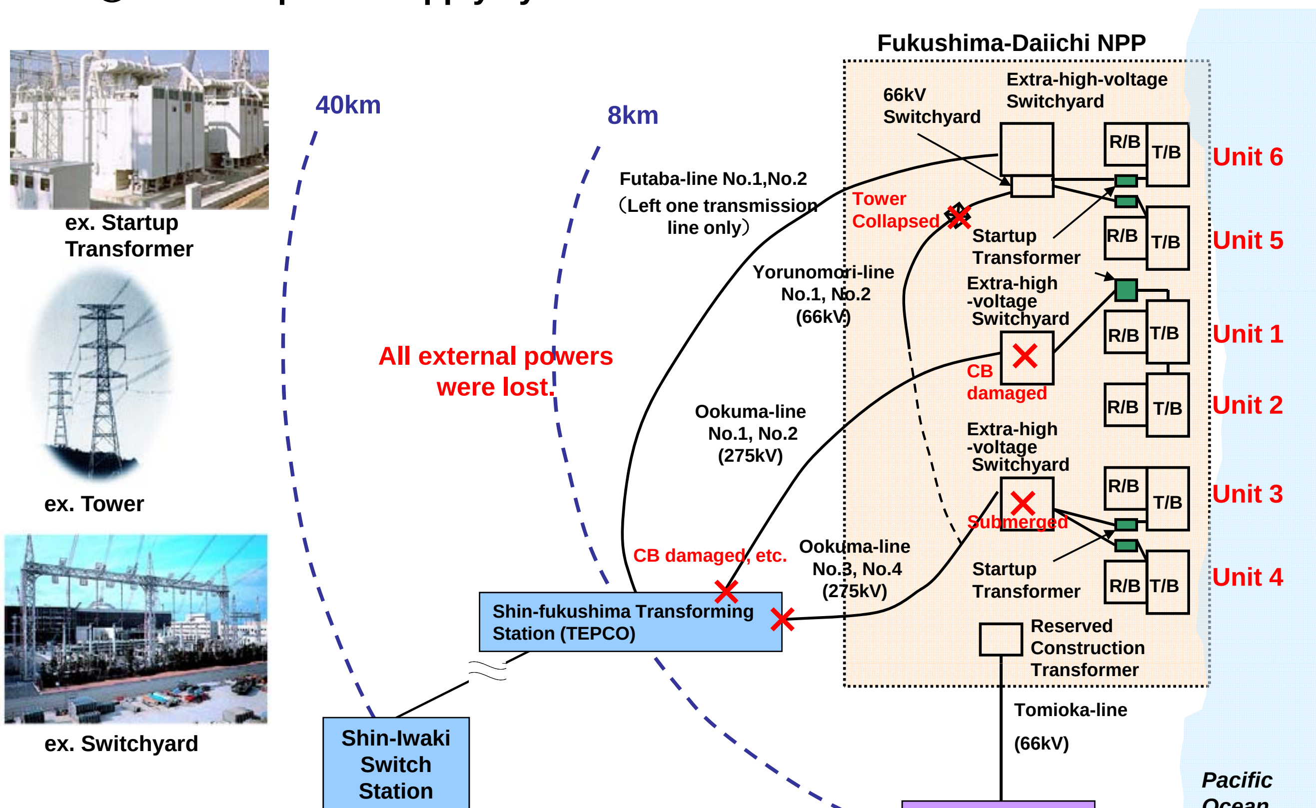





**Sea water system facilities of all units were inundated by tsunami.**
**Only one EDG of air cooling was survived in the site after tsunami.**

## ② External power supply system




Sources :
TEPCO HP http://info.nicovideo.jp/pdf/2011-03-18_1930_touden_genpatsu.pdf
TEPCO HP http://www.tepco.co.jp/nu/kk-np/info/tohoku/pdf/23032202.pdf



## ■External power supply system(1)

**■External power supply system to Fukushima Daiichi site ( Fig 2-7)**

- **Units 1 and 2 :** Commonly use the same two lines (offsite Okuma-lines 1 and 2), via an onsite extra high voltage switching station. These are connected to the Shin-Fukushima Substation 8 km upstream, to the Shin-Iwaki Switching Station about 40 km upstream, and further to such facilities as the Minami-Iwaki Switching Station (where connected to the transmission network of Tohoku EPCO) and the Shin-Motegi Switching Station.
- **Units 3 and 4 :** Also connected to the Shin-Fukushima Substation similarly.
- **Units 5 and 6 :** Connected to the Shin-Fukushima Substation via Futaba lines 1 and 2 ( transmission only) and Yonomori lines1 and 2 ( receiving only).

**■ Seismic damage to the external power supply system**

- **Units 1 and 2 :** Contactor of extra high voltage switching station damaged by earthquake
- **Units 3 and 4 :** Control panel of extra high voltage switching station inundated by tsunami
- **Units 5 and 6 :** Steel tower #27 to start up switchyard collapsed
- **Outside the site:**
  - Around the Shin-Fukushima transformer substation: Intensity 6 strong of JMA intensity
  - Facility of the station as switchgear etc. damaged by earthquake.
    2 system 4 feed line of 275kv for unit 1-4 and 1system 2 feed line for unit 5-6 failed.

**■Seismic PSA result**

**Key issue dominant for CDF:** LOSP (Station black out)

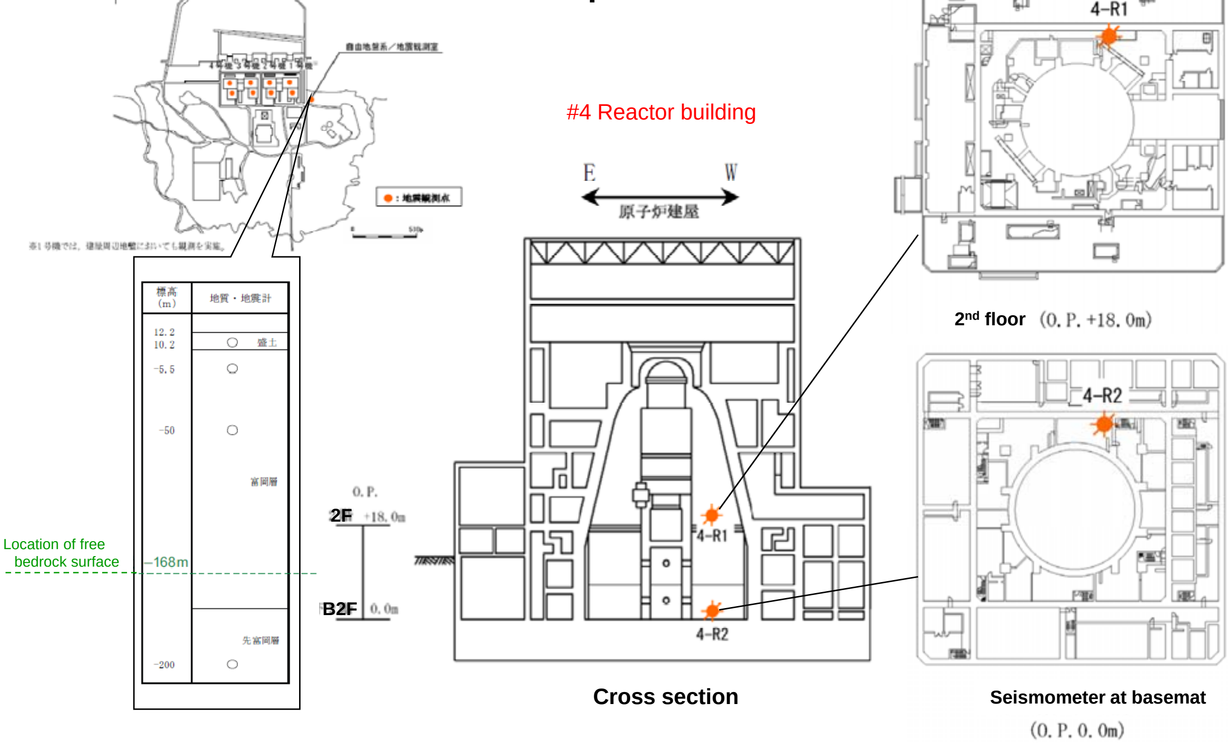
**Measure:**

- Base isolation for high voltage switchyard transformer with porcelain insulator
- Out of site steel tower reinforcement ( Fragility assessment revealed its effectiveness)
  - Reinforcement on base( enlarge, pile base)
  - Fence around base against tsunami protecting flow digging

# 2.2 Fukushima Daini NPP site

## (1) Ground Motion

### ① Seismic Observation System at Fukushima Daini : Example: Unit 4






### ②Comparison between DBGM Ss and Observed motion(1)

・Record stopped at around 130-150 sec. due to long EQ vibration (around 170 sec.)
・Table Ⅱ-2-2: Max.acc. of 3 components at RB basemat
Horizontal Max. acc.: 277 Gal at Unit3(NS)
Vertical Max. acc. : 305 Gal at Unit1

●Earthquakes to define DBGM :
ⅰ Interplate earthquake of Off-Fukushima, ⅱ Intraplate earthquake just beneath the site, ⅲ Earthquake due to active faults around the site, ⅳ Diffused earthquake around the site
● DBGM Ss :
Envelope of ⅰ ～ⅳ ; Ss-1, Ss-2, Ss-3

Table Ⅱ-2-2 Max. accelerations recorded in reactor buildings

| Loc. of observation (bottom floor of reactor bld.) | | Obs. Value※1 Max. value (gal) | | | Max. response acceleration to the DBGM Ss (gal) | | |
|---|---|---|---|---|---|---|---|
| | | NS | EW | UD | NS | EW | UD |
| Fukushima Dai-ni | Unit 1 | 254 | 230※2 | 305 | 434 | 434 | 512 |
| | Unit 2 | 243 | 196※2 | 232※2 | 428 | 429 | 504 |
| | Unit 3 | 277※2 | 216※2 | 208※2 | 428 | 430 | 504 |
| | Unit 4 | 210※2 | 205※2 | 288※2 | 415 | 415 | 504 |

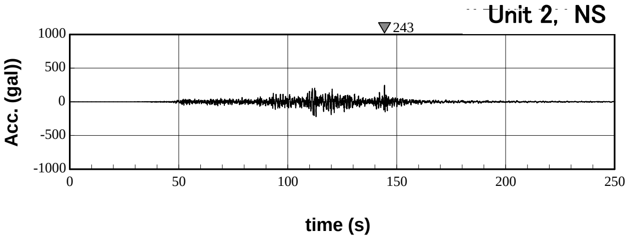
※1 These are temporal values, and may be corrected later.
※2 Each recording stopped at about 130-150 s from recording start time.

## ■Comparison between DBGM Ss and Observed motion（2）

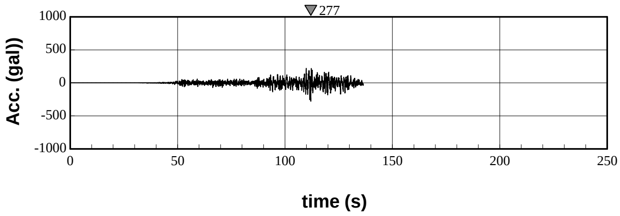
**■ Characteristics of response spectrum (ORS) of observed motions**
**･Observed ORS lower than Ss spectra (DBS) in all period**

**Acceleration seismogram at foundation mat**

Unit 2, NS

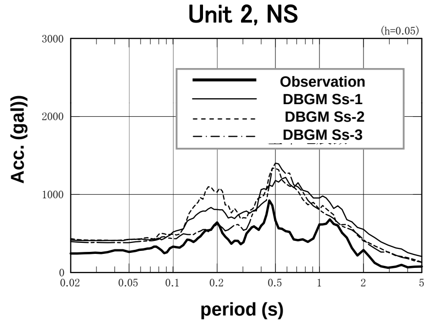



Unit 3, NS

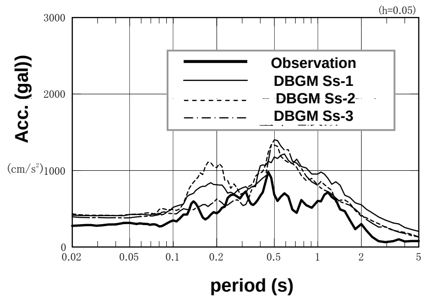



**Response spectrum on foundation mat**

Unit 2, NS




Unit 3, NS






## ③ Exceedance Probability of DBGM Ss and Probabilistic Seismic Hazard Evaluation

**Annual exceedance probability (AEP) of Fukushima Daini（Fig2-9）**

**AEP of Ss：10-4～10-5**

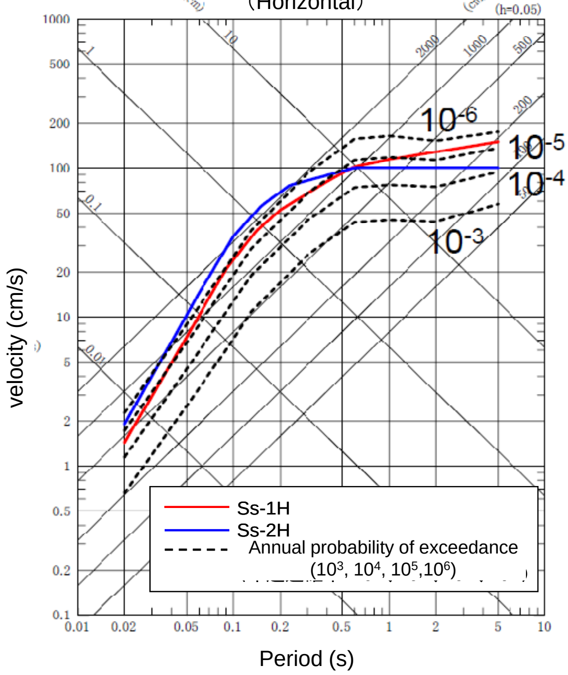



**Fig 2-9**

**Annual exceedance probability of DBGM Ss of Fukushima No2 site**

## (2) Tsunami

### ① Tsunami Observation System and Tsunami Records

■Tsunami observation system : Same as Fukushima Daiichi
Tide gauge at sea wall + Recording system inside building

■Outline of observed tsunami
- ・Tide gauge : Not preserved due to water invading to building. Tsunami time history and max. height were unknown
- ・Alternative : Assumption by trace of water invading
- ・Tsunami invading : Attacked from front sea area and invaded from south of Unit 1, sea water discharge outlet, to all most all of buildings area

■ Sea side area where sea water pumps located and South side of Unit1-3 building area invaded. Tsunami did not run up from sea side, crossing over the slope, to main building area

■ Observed tsunami height
- ・Sea side area: O.P. around +6.5 ～ 7m
- ・South side of 1U main building area including R/B, T/B etc : O.P. around +14 ～ 15m



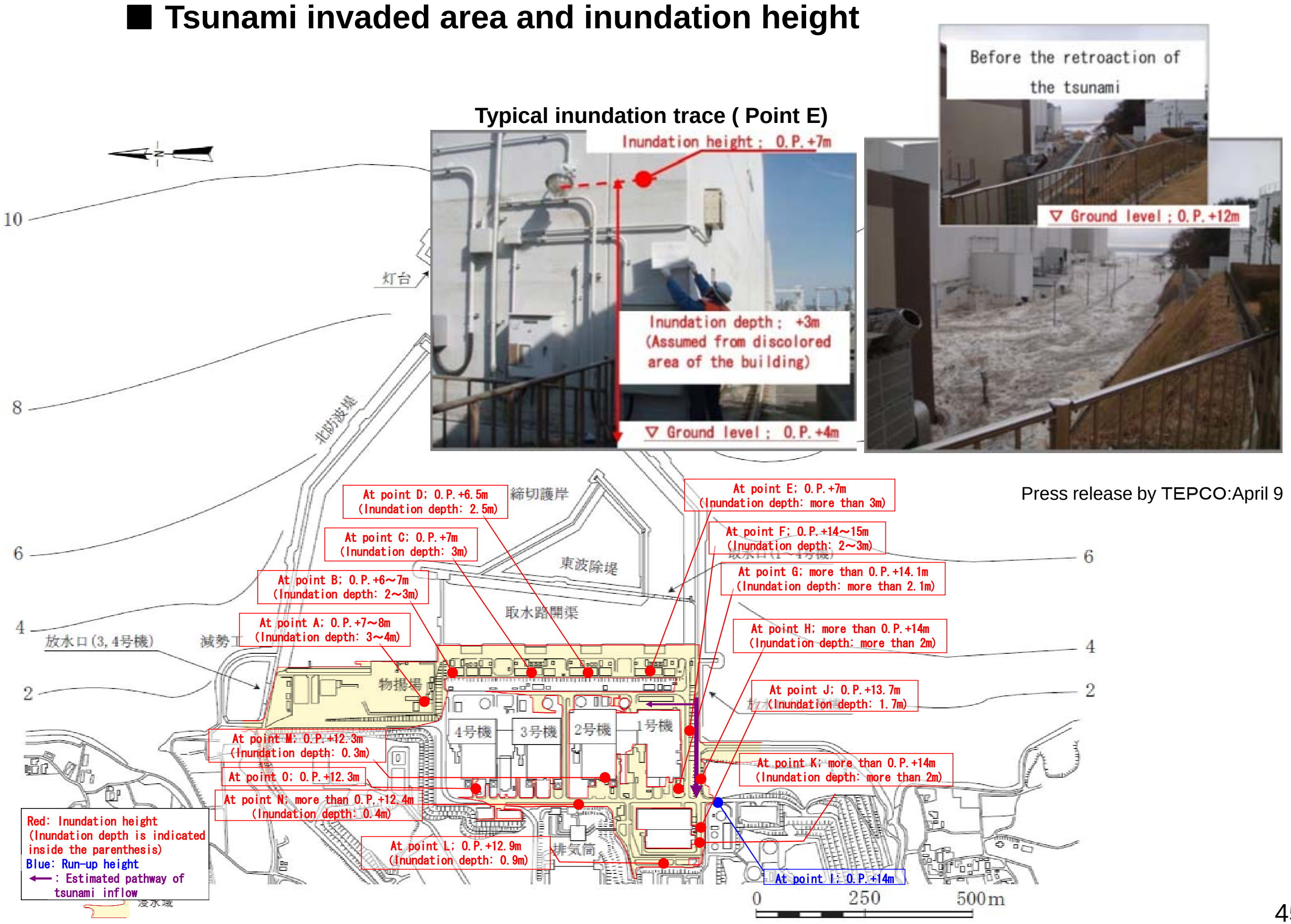
### ② Comparison between design tsunami height and observed (1)

- ・Evaluation method and condition: Same as Fukushima Daiichi
- ・Design tsunami height
  - ・Construction permit : 3.7m ( Chile EQ, M 9.0 1960)
  - ・2002 evaluation : 5.2m (Shioyazaki; off Fukushima EQ, M7.9 1938)
  - ・Seismic back-check : Not yet reported

These value is smaller than observed.

## (3) Damage

### ■ Tsunami invaded area and inundation height

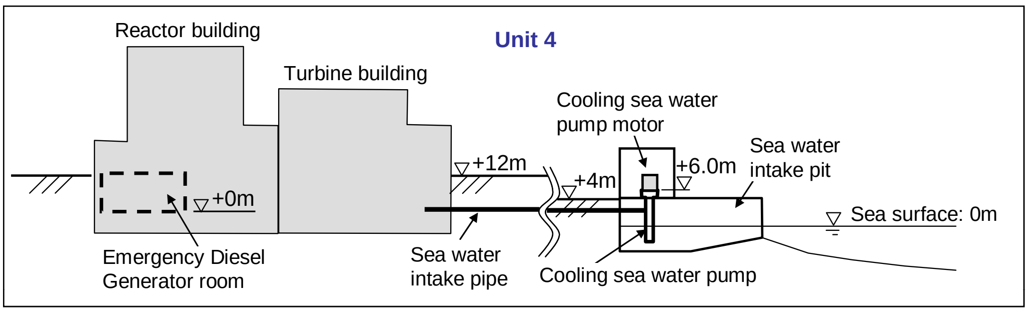



Press release by TEPCO:April 9



## ① Damage to sea water pump and emergency power

**Sea water system facilities of all units were inundated by tsunami.**
**Emergency DGs at underground floor of Reactor Building stopped after tsunami.**





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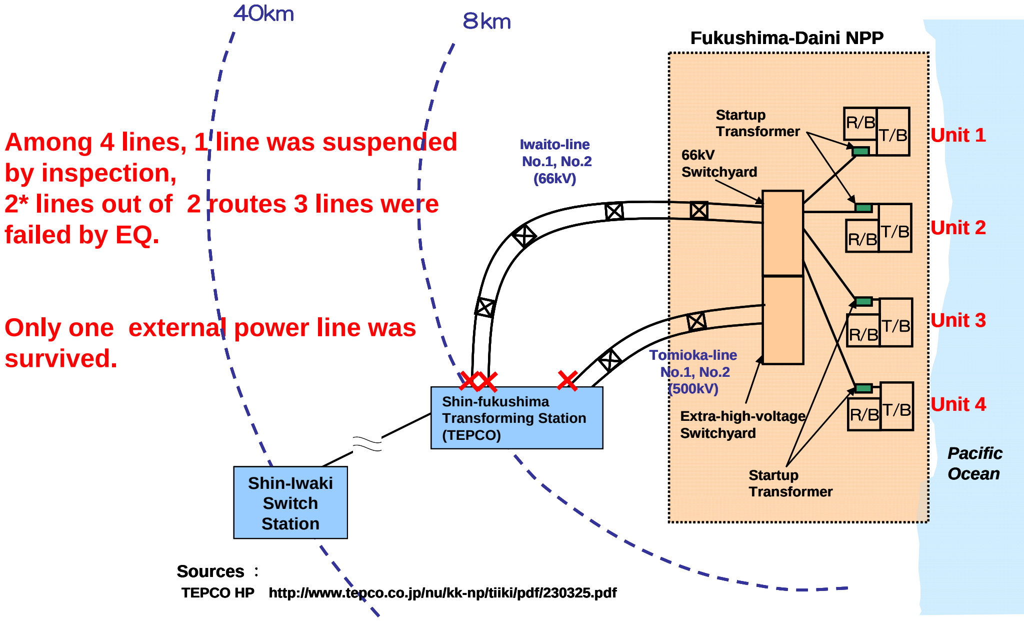
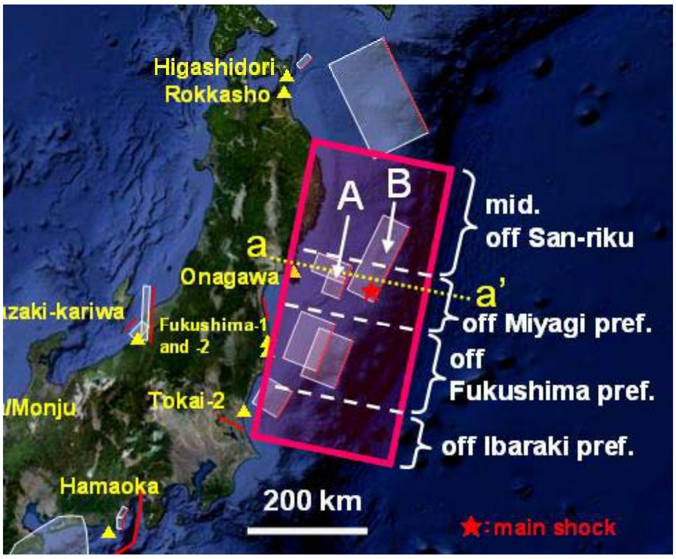
## ② External power supply system and damage

- External power was supplied through 2 routes 4 lines for Unit 1 to 4;
  - Tomioka route : line 1 and 2 (66kv) — 1 line serviced and 1 line failed
  - Iwaido route : line1 and 2 (500kv) — 1 line was inspection outage, 1 line failed
  - * Observed JMA intensity around the Shin Fukushima transformer station: Intensity 6 strong
- Unit 3 was brought to cold shut down thanks to survived EDGs and sea water pump next day.
- Sea water cooling pumps for #1, 2, 4 were failed, but thanks to survived external power and recovery works, these plants were brought to cold shut down in 4-5 days.






# 3 Case of Onagawa, Tokai Daini NPP sites



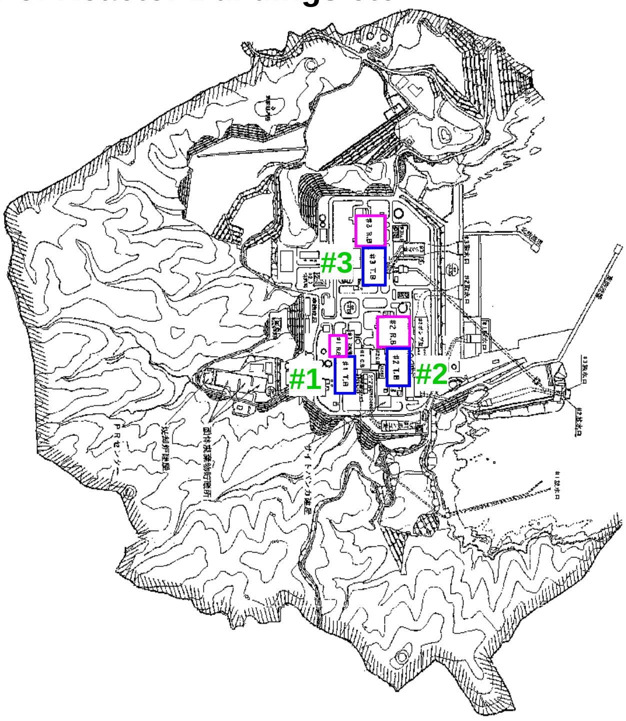

| Site | Unit | Ele. Output | OPC at EQ | OPC after EQ | OPC after Tsunami |
|---|---|---|---|---|---|
| Onagawa | #1 | 524 | OP | ASD | 3 lines of 4 external lines of 275kv and 1 of 1 line of 66kv : Lost by EQ<br>Start-up trans for #1 : lost by EQ. (light damage)<br>2 of 3 EDGs for #2 : Lost by Tsunami |
| | #2 | 825 | SU | ASD | |
| | #3 | 825 | OP | ASD | |
| Tokai | | Closed in 1998 | | | |
| Tokai Daini | | 1,100 | OP | ASD | All external powers(275kv:2lines, 154kv:1line) : Lost by EQ<br>1 of 3 EDGs :Lost by tsunami |
| Higashi-dori | | 1,100 | AI | – | No damage by EQ and tsunami<br>Max response acce. : 17Gal |

# 3-1 Onagawa

## (1) Ground Motion

### ① Seismic Observation System and observed ground motion

■ **Arrangement of Onagawa NPP Site and Outline of Reactor Buildings etc.**



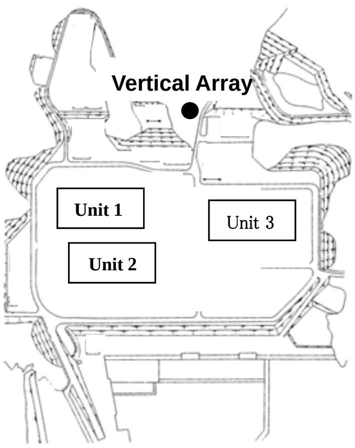


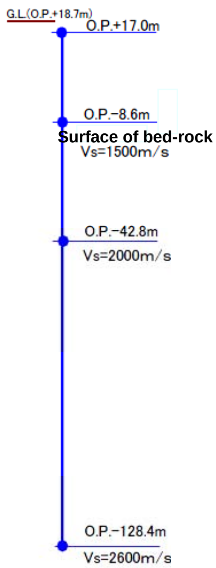

■ **Seismic Observation System in Onagawa NPP Site**

● **Composition of Observation System :**

- **Seismometers : Reactor buildings + Vertical array + Recording system**
  - **Unit 1 R/B : 4 places : Roof, Refueling floor(5F), 1st floor (ground F.), Base mat**
  - **Unit 2 R/B : Same as unit 1**
  - **Unit 3 R/B : Same as unit 1**
- **Specification of seismometer : Acceleration time history record, Two horizontal + vertical components**
- **Overwrite protection reflecting lessons learned at NCO EQ**

Seismometers in vertical array



## ■ Outline of Recorded Motions

- **All records were preserved in good condition**
- **Outline of recorded accelerations on base mats**
  - **Max. horizontal acceleration : 607 Gal (Unit 2, NS)**
  - **Max. vertical acceleration : 439 Gal (Unit 1)**

Maximum accelerations recorded in reactor buildings of each unit

| Location of seismomete | | Record Max.acceleration (Gal) | | | Max. acceleration to the DBGM Ss (Gal) | | |
|---|---|---|---|---|---|---|---|
| | | N-S | E-W | U-D | N-S | E-W | U-D |
| Unit 1 | Roof | 2,000 | 1,636 | 1,389 | 2,202 | 2,200 | 1,388 |
| | Ref. Floor(5F) | 1,303 | 998 | 1,183 | 1,281 | 1,443 | 1,061 |
| | 1st F. | 573 | 574 | 510 | 660 | 717 | 527 |
| | Base mat | 540 | 587 | 439 | 532 | 529 | 451 |
| Unit 2 | Roof | 1,755 | 1,617 | 1,093 | 3,023 | 2,634 | 1,091 |
| | Ref. Floor(3F) | 1,270 | 830 | 743 | 1,220 | 1,110 | 968 |
| | 1st F. | 605 | 569 | 330 | 724 | 658 | 768 |
| | Base mat | 607 | 461 | 389 | 594 | 572 | 490 |
| Unit 3 | Roof | 1,868 | 1,578 | 1,004 | 2,258 | 2,342 | 1,064 |
| | Ref. Floor(3F) | 956 | 917 | 888 | 1,201 | 1,200 | 938 |
| | 1st F. | 657 | 692 | 547 | 792 | 872 | 777 |
| | Base mat | 573 | 458 | 321 | 512 | 497 | 476 |



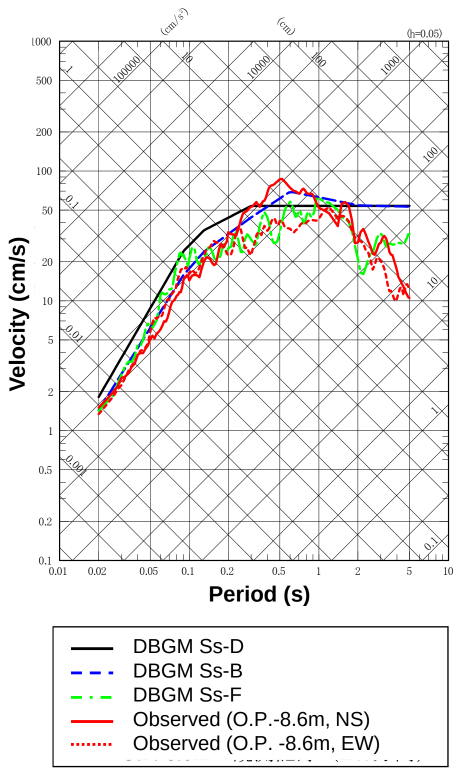
## ② Comparison between Design Basis Ground Motion (DBGM) Ss and Observed Motions (2)

**■ Outline of DBGM Ss**

- **●Seismic back-check : Review of DBGM Ss based on Revised Seismic Reviewing Gide**
- **●Earthquakes to define DBGM :**
  - **ⅰ Interplate earthquake of Off-Fukushima,**
  - **ⅱ Intraplate earthquake just beneath the site,**
  - **ⅲ Earthquake due to active faults around the site**
  - **ⅳ Diffused earthquake around the site**
- **● DBGM Ss :**
  - **Procedure : Should envelope ⅰ ～ⅳ**
  - **Ss-B, Ss-D, Ss-F**

**■ Characteristics of observed response spectrum (ORS) of recorded motions at the vertical array (O.P. -8.6m) :**

- **ORS overshoot Ss spectra (DBS) in the period between 0.2 to 1.0 second**
- **Tohoku Electric Co. : No safety related facility in this period**

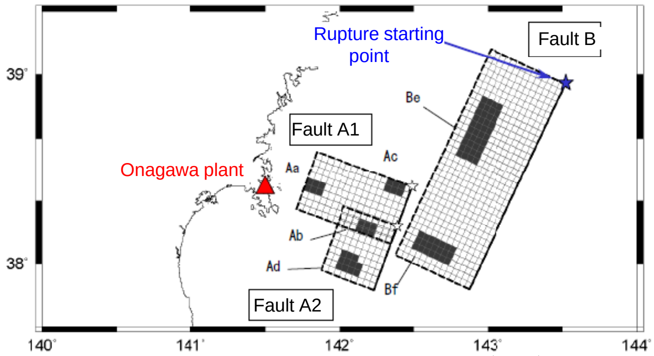


## ③ Exceedance Probability of DBGM Ss and Probabilistic Seismic Hazard Evaluation

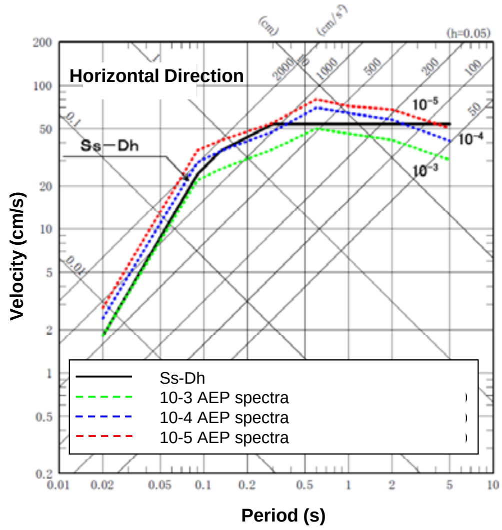
**■Velocity response spectrum of each exceedance probability and DBGM Ss of Onagawa**
**・Exceedance Probability of Ss : $10^{-4}$～$10^{-5}$**

- ●Source Models and Target Earthquakes
  Source Models with identified active faults
  - Interplate earthquake: the Miyagi-Oki earthquake
  - Intraplate earthquake: the 2003 Miyagi earthquake
  - Inland earthquake: active faults (F-6~F-9 faults)
- ●Diffuse Seismicity
  - Interplate earthquakes, intraplate ocean earthquakes, Inland earthquakes

Source models with identified active faults




Tohoku EPCO（2009）:B17-2-1




**Annual exceedance probability (AEP) of DBGM Ss of Onagawa site**

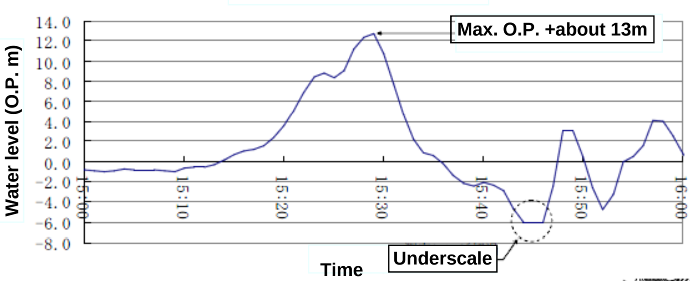


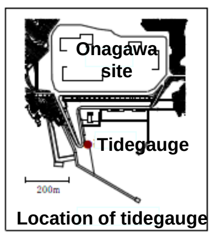
## (2) Tsunami

## ① Tsunami Observation System and Tsunami Records

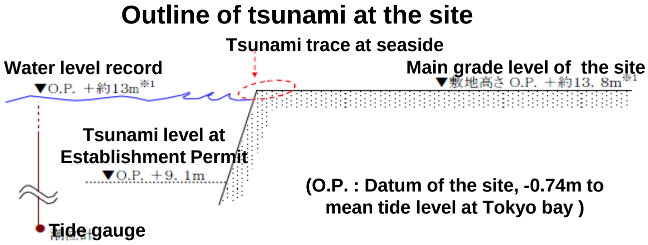
**■Tsunami observation system : Tidegauge (at sea wall) + Recording system (at building)**
**■Outline of recorded tsunami**
**・Height : around O.P. 13m**
**・Site grade level : 14.8m (before EQ, subsidense about 1m not refrected)**
**・Influence of tsunami : Traces at the seaside of the site, No ingress to buildings**

**Time history recorded at the site (March 11, 2011)**

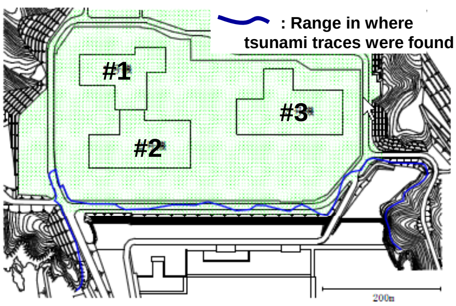



**Outline of tsunami at the site**




(O.P. : Datum of the site, -0.74m to mean tide level at Tokyo bay )



## ② Comparison between the Design and Observed Tsunami Heights

■**Design Tsunami Height**

- **Onagawa district is featured with a rias-type coast. Lessons learnt from historical tsunami disasters have taken root in this area. Caution against tsunami disaster has been a local climate.**
- **To apply for construction permit, local residents' opinions on tsunami run-up height and other tsunami damage were carefully listened and reflected in tsunami design.**
- **Based on the 2002 JSCE tsunami evaluation method and the 2011 BC seismic design, the Meiji Sanriku earthquake was selected as the target wave source. Moreover, evaluation results were refined by improving parameters of the wave source using the most up-to-date knowledge.**

■**Comparison of design tsunami height with observed tsunami height**

- **Design tsunami height is larger than the observed height even considering the 1m ground subsidence.**

| | Evaluation contents & periods | | |
|---|---|---|---|
| | **Construction permit** | **Based on the 2002 JSCE evaluation method** | **Back-check of seismic design (2011～)** |
| **Maximum tsunami water level(m)** | **O.P.9.1**<br>**(the 1611 Keichou Sanriku earthquake, M8.6)** | **O.P.13.6**<br>**（the 1896 Meiji Sanriku earthquake, M8.3）** | **O.P.14.4m**<br>**（the 1896 Meiji Sanriku earthquake, M8.3）** |

Grade level : O.P. 14.8m

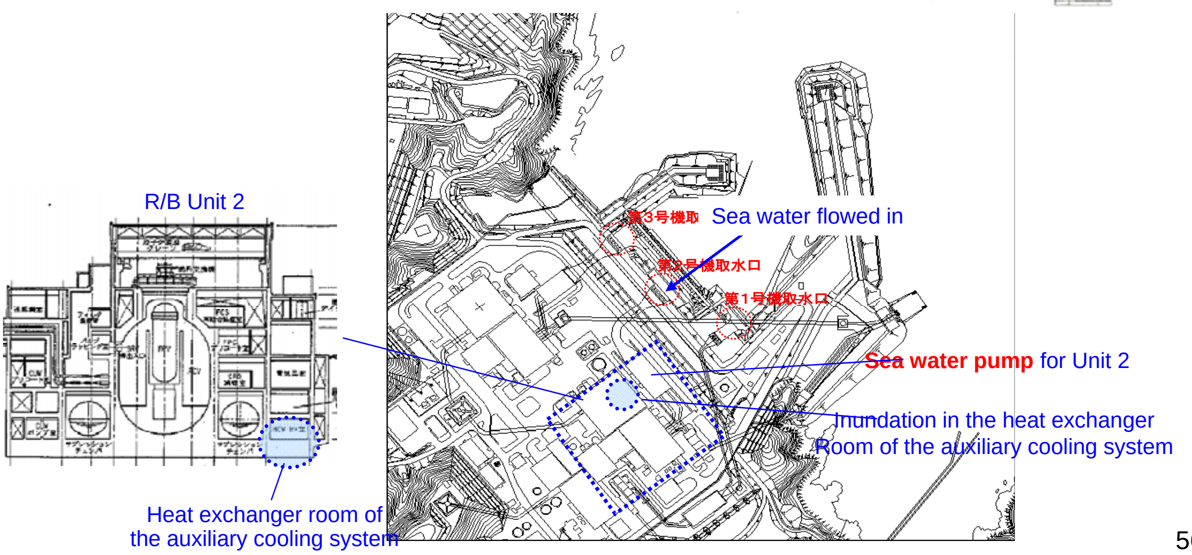


## （3）Damage

### ①Electric power system and sea water pump system in the site

- Construction Arrangement of the auxiliary cooling system ：Water intake port、Sea water pump, Sea water pump room, Heat exchanger room.
- Height of the sea water pump room: O.P. 30m.
- Tsunami damage situation: tsunami flowed into the sea water pump room through the water intake port of Unit 2; through the underground trench, it further inundated a basement room of RB, and the auxiliary heat exchanger room (subbasement of RB).

Inundation situation of the heat exchanger room of the auxiliary cooling

## ②External power supply system

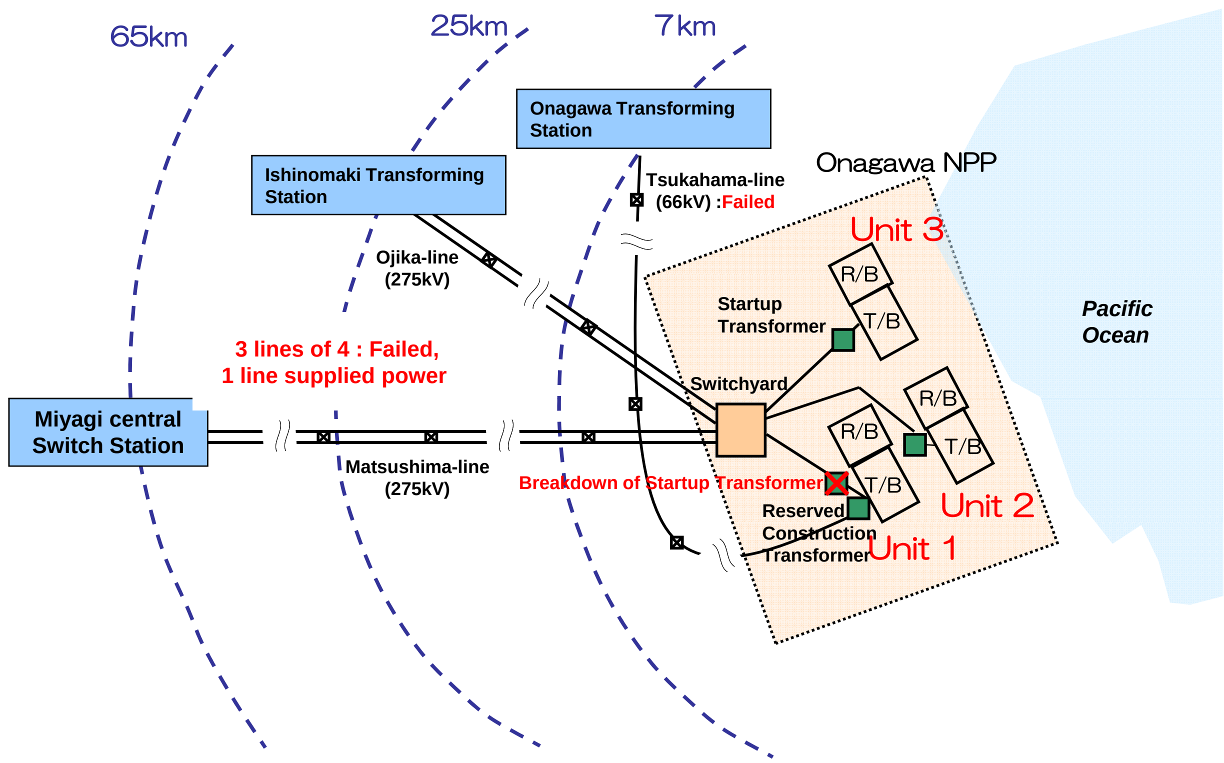
**■ Outline of the external power supply system and damage**

- External power supply system: In the case of starting, shutdown and accident, external electric power is supplied to Unit 1~3 through 275kV1 two lines from the Ishinomaki transformer substation (25km from the site), 275kV1 two lines from the Miyagi central switching station (65km from the site), and one 66kV1 line from the Onagawa transformer substation.

- Seismic damage to the external power supply system
  - JMA intensity observation
    - Around the Ishinomaki transformer substation: Intensity 6 strong
    - Around the Miyagi central switching station: Intensity 6 weak
    - 3 of 4 lines of 275kV were failed by EQ.
    - 1 of 1 line of 66kV failed by EQ.
  - (In-plant) power incoming unit
    - The starting transformer for Unit 1 malfunctioned, could not receive electricity.
    - The starting transformer was recovered on March 12, external power supply system was restored by converting to the 275kV power system.
    - 2 of 3 EDGs for unit 2 were stopped due to loss of pump of auxiliary cooling loop.



# External Electric Power Network




Sources :
Tohoku Electric Power CO HP http://www.tohoku-epco.co.jp/comp/gaiyo/gaiyo_data/setubi.html
Tohoku Electric PowerCO HP http://www.tohoku-epco.co.jp/emergency/8/1182594_1800.html

## (4) Integrity assessment of SSCs

### ①Integrity assessment of reactor buildings for the main shock (1)

■ **Background:**
- **Spectra of observed ground motions exceeded the DBGM Ss at some period band.**
- **NISA required the Tohoku EPCO to make a plan and to implement inspection and assessment of SSCs.**

■**Evaluation contents and results**
- **Assessment method**
  - **Tohoku EPCO followed the same procedure used for assessment of Kashiwa-Kariwa plant for the 2007 Chuetsu-Oki earthquake.**
- **Assessment conditions**
  - **Acceleration motions recorded on the building foundation mat were used as the input seismic motions for Unit 1~3.**
- **Assessment results**
  - **Shear strain calculated for each floor are lower than the JEAG4681-2008 standard level ($2.0x10^{-3}$). Shear stress and elastic limit stress are also lower than the standard levels.**
- **Comparison with JNES assessment results of Kashiwazaki-Kariwa NPP**
  - **JNES had assessed the integrity of reactor buildings of Unit 1, 5, 6, and 7 for the 2007 Chuetsu-Oki earthquake.**
  - **JNES results showed that the ratios ranged from 8.7~14.3.**
  - **Both the Onagawa R/B against the 2011 earthquake and the Kashiwazaki-Kariwa R/B against the 2007 earthquake have a safety margin of above 2 times.**



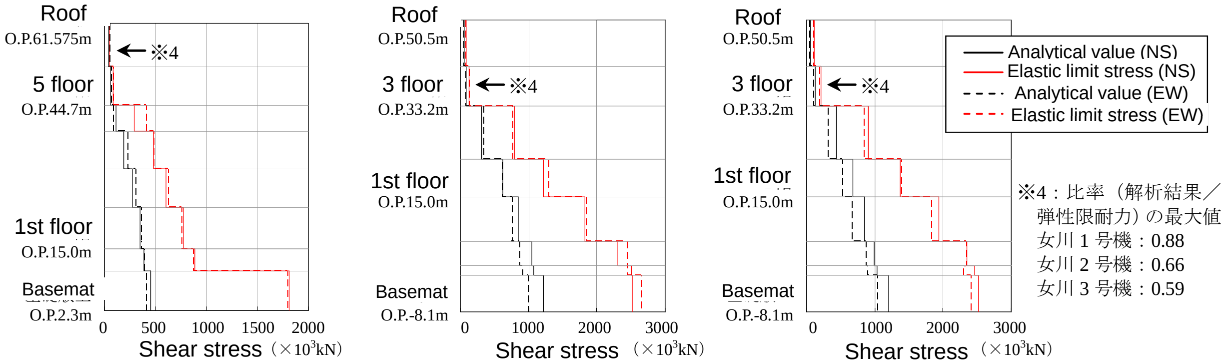
### ①Integrity assessment of reactor buildings for the main shock (2)

Maximum shear strain of R/B aseismic walls

| | | Analytical result | Standard Value[3] | (Comparison) DBGM Ss |
|---|---|---|---|---|
| ON Unit 1 | NS 方向 | $0.36\times10^{-3}$ | $2.0\times10^{-3}$ | $0.65\times10^{-3}$ |
| | EW 方向 | $0.35\times10^{-3}$ | | $0.56\times10^{-3}$ |
| ON Unit 2 | NS 方向 | $0.49\times10^{-3}$ | | $1.15\times10^{-3}$ |
| | EW 方向 | $0.28\times10^{-3}$ | | $0.55\times10^{-3}$ |
| ON Unit 3 | NS 方向 | $0.81\times10^{-3}$ | | $0.99\times10^{-3}$ |
| | EW 方向 | $0.18\times10^{-3}$ | | $0.41\times10^{-3}$ |

※3　評価基準値は、日本電気協会「原子力発電所耐震設計技術規程（JEAC4601-2008）」に定められており、鉄筋コンクリート造耐震壁の終局せん断ひずみに2倍の安全率を持たせたもの。

Shear stress of R/B aseismic walls at each floor




ON Unit 1　　ON Unit 2　　ON Unit 3

## ②Integrity assessment of reactor buildings for the aftershock（1）

- **Aftershock parameters (April 7, 2011) and ground motion summary**
  - **Depth: 66km; Magnitude: M7.4; Location: In the slab**
  - **Comparison of ground motions recorded in Unit 1~3 with maximum values of DBGM Ss**
    - **Vertical ground motions recorded on the 3rd floor and the roof of R/B of Unit 2 and the 3rd floor of R/B of Unit 3 exceeded the calculated values based on the DBGM Ss.**
- **NISA's Instruction to Tohoku EPCO**
  - **On April 26, NISA instructed Tohoku EPCO to assess R/B integrity using the recorded seismic data.**
- **R/B Integrity Assessment**
  - **Assessment Method: the same method used for the main shock**
  - **Assessment Results: R/B integrity confirmed.**

Maximum accelerations recorded in reactor buildings of each unit

| Location of Seismometers | | Record Max. acceleration (Gal) | | | Max. acceleration from DBGM Ss (gal) | | |
|---|---|---|---|---|---|---|---|
| | | NS | EW | UD | NS | EW | UD |
| Unit 1 | Roof | 2000 | 1494 | 1212 | 2202 | 2200 | 1388 |
| | Ref. Floor(5F) | 1280 | 90 | 724 | 1281 | 1443 | 1061 |
| | 1st F | 403 | 513 | 385 | 660 | 717 | 527 |
| | Base Mat | 378 | 373 | 381 | 532 | 529 | 451 |
| Unit 2 | Roof | 1975 | 1657 | 1386 | 3023 | 2634 | 1091 |
| | Ref. Floor(5F) | 1173 | 686 | 1002 | 1220 | 1110 | 968 |
| | 1st F | 465 | 516 | 426 | 724 | 658 | 768 |
| | Base Mat | 387 | 388 | 373 | 594 | 572 | 490 |
| Unit 2 | Roof | 1959 | 1775 | 963 | 2258 | 2342 | 1064 |
| | Ref. Floor(5F) | 750 | 1019 | 1333 | 1201 | 1200 | 938 |
| | 1st F | 420 | 688 | 477 | 792 | 872 | 777 |
| | Base Mat | 396 | 398 | 311 | 512 | 497 | 476 |

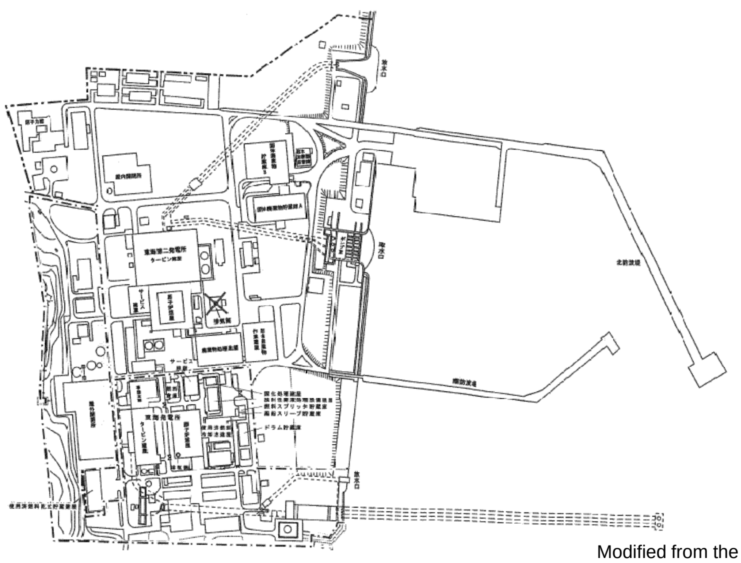


## 3.2 Tokai Daini

### (1) Ground motions

#### ① Seismic observation system and observed ground motion

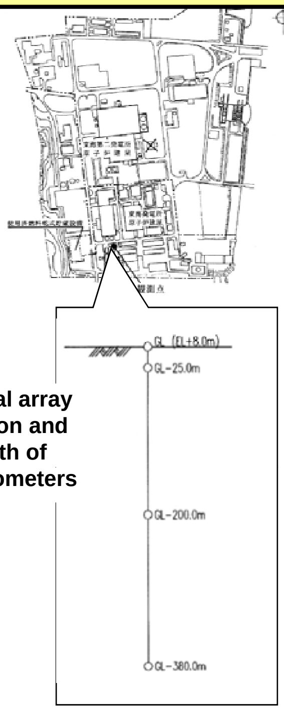
■ **Arrangement of Tokai Daini NPP site and outline of reactor building**



Modified from the Establishment License Application

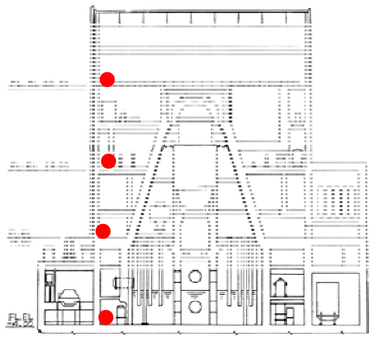
## ■ Seismic Observation System in Tokai Daini NPP Site

● **Composition of Observation System :**
- **Seismometers: Reactor building (4) + Vertical array + Recording system**
- **Specification of seismometer : Acceleration time history record,**
  **Two horizontal + vertical components**
- **Overwrite protection reflecting lessons learned at NCO EQ**




**Vertical array location and depth of seismometers**

Location of seismometers in R/B





## ② Comparison between DBGM and Recorded Motions

- **All records were preserved in good condition**
- **Outline of recorded accelerations on base mat**
  - **Max. horizontal acceleration : 225 Gal (NS)**
  - **Max. vertical acceleration : 189 Gal**

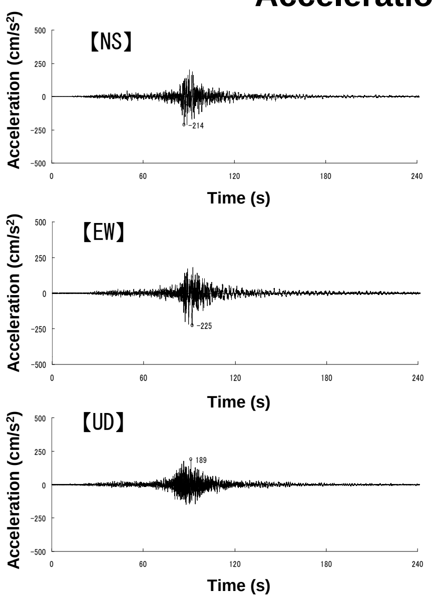
### Maximum accelerations recorded in reactor building

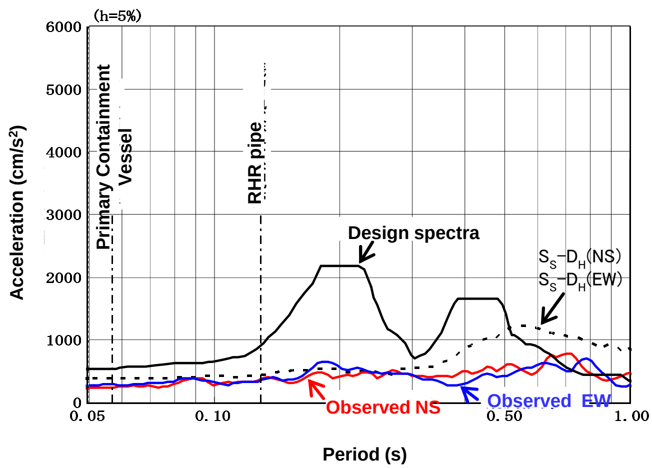
| Location of seismometer | | Record Max.acceleration (Gal) | | | Max. acceleration at construction | | Max. response accelerations to DBGM Ss (Gal) | | |
|---|---|---|---|---|---|---|---|---|---|
| | | N-S | E-W | U-D | N-S | E-W | N-S | E-W | U-D |
| Reactor building | 6 F | 492 | 481 | 358 | 932 | 951 | 799 | 789 | 575 |
| | 4 F | 301 | 361 | 259 | 612 | 612 | 658 | 672 | 528 |
| | 2 F | 225 | 306 | 212 | 559 | 559 | 544 | 546 | 478 |
| | Base mat (B2F) | 214 | 225 | 189 | 520 | 520 | 393 | 400 | 456 |

## ■ Time Histories and Acceleration Response Spectrum of Observed Motions(ORS)

**● Comparison result**
- **Max. acceleration of the observed motion is smaller than that of the Ss**
- **ORS overshoot Ss spectra (DRS) in the range between 0.65 to 0.9 second**
- **JAPC : ORS is smaller than DRS in the dominant period range of safety important equipment and piping**

### Acceleration time history on base mat (B2F)




Period (s)



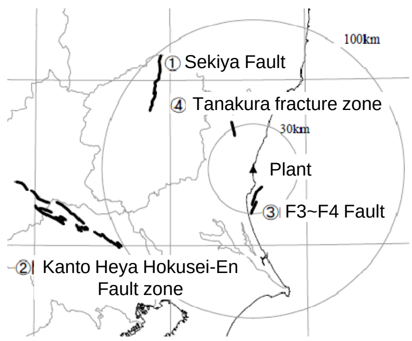
## ③ Exceedance Probability of Ss

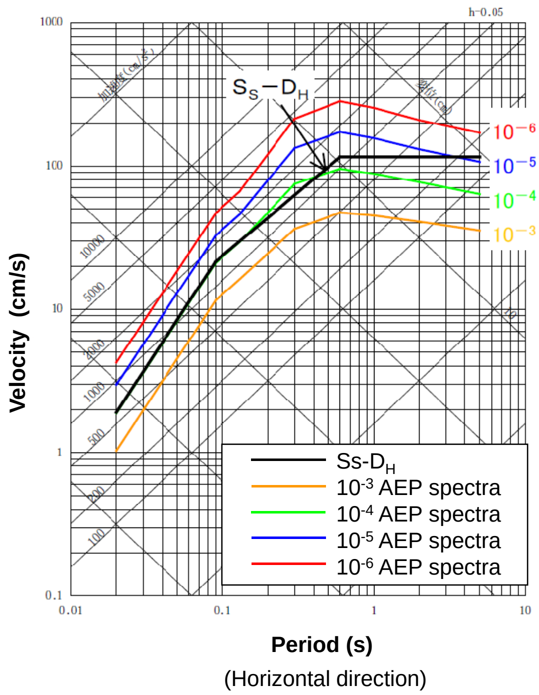
**●Exceedance probability of Tokai Daini NPP : $10^{-4}$～$10^{-5}$**

●Source Models and Target Earthquakes
Source Models with identified active faults
- •Interplate earthquake: the Kanto earthquake
- •Inland earthquake: active faults (F-3~F-4 faults)

●Diffuse Seismicity
- •Interplate earthquakes
- • intraplate earthquakes (South Ibaraki Earthq.)
- • Inland earthquakes

Source models with identified active faults




**Annual exceedance probability of DBGM Ss of Tokai Daini NPP**

## (2) Tsunami

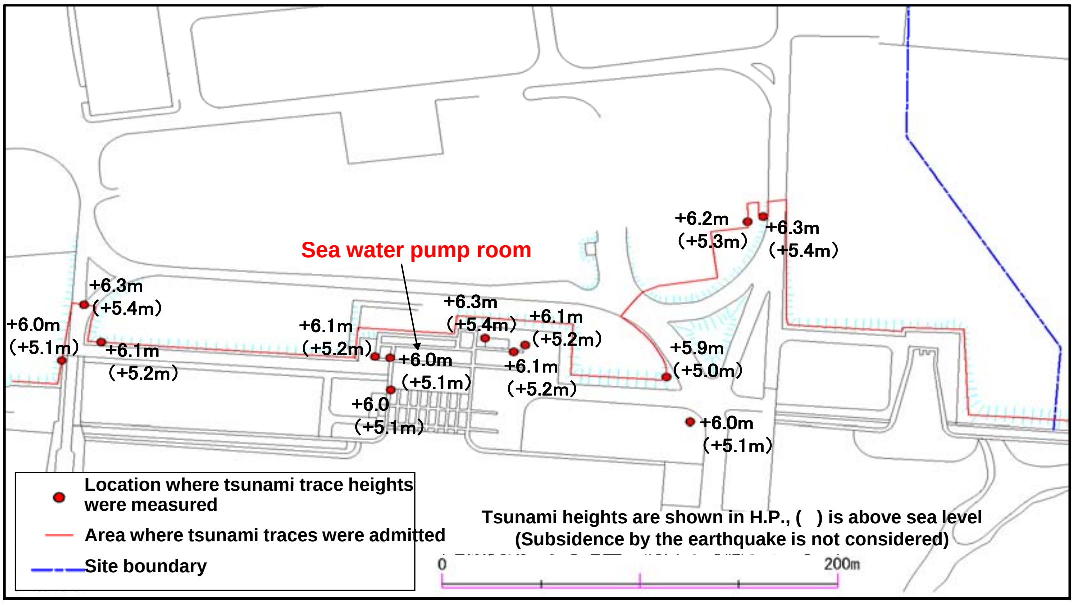
### ①Tsunami Observation System and Tsunami Records

■Tsunami observation system : Tidegauge (at sea wall) + Recording system (at building)

■Outline of recorded tsunami

- ･Record of tidegauge : Not preserved due to inundation of building
- ･Tsunami Height : H.P. +5.9m ～ H.P. +6.3m (Tentative)
- ･Run-up height : About H.P. *+6.3m (Tentative)

*:H.P. means mean sea leve at the nearest commercial Hitachi harber .






### ② Comparison between Design Tsunami Height and Observed Height

| | Evaluation Result （Time of Assessment) | | |
|---|---|---|---|
| | Establishment Permit | Evaluation based on JSCE Method (2002) | Seismic Back-Check（2011～） |
| Max. Tsunami Height (m) | Non-description | O.P.4.9m (Off-Boso Earthquake, M8.2、1677) | Report is not submitted yet |

## (3) Damage

### ①Sea water pumps and electric power system in the site (1)

〇Tsunami inundated emergency sea water pump area located in north part of sea water pump room and **one of three sea water pumps for emergency diesel generators was stopped** due to inundation

■Counter measures for Tsunami (Before the tsunami)

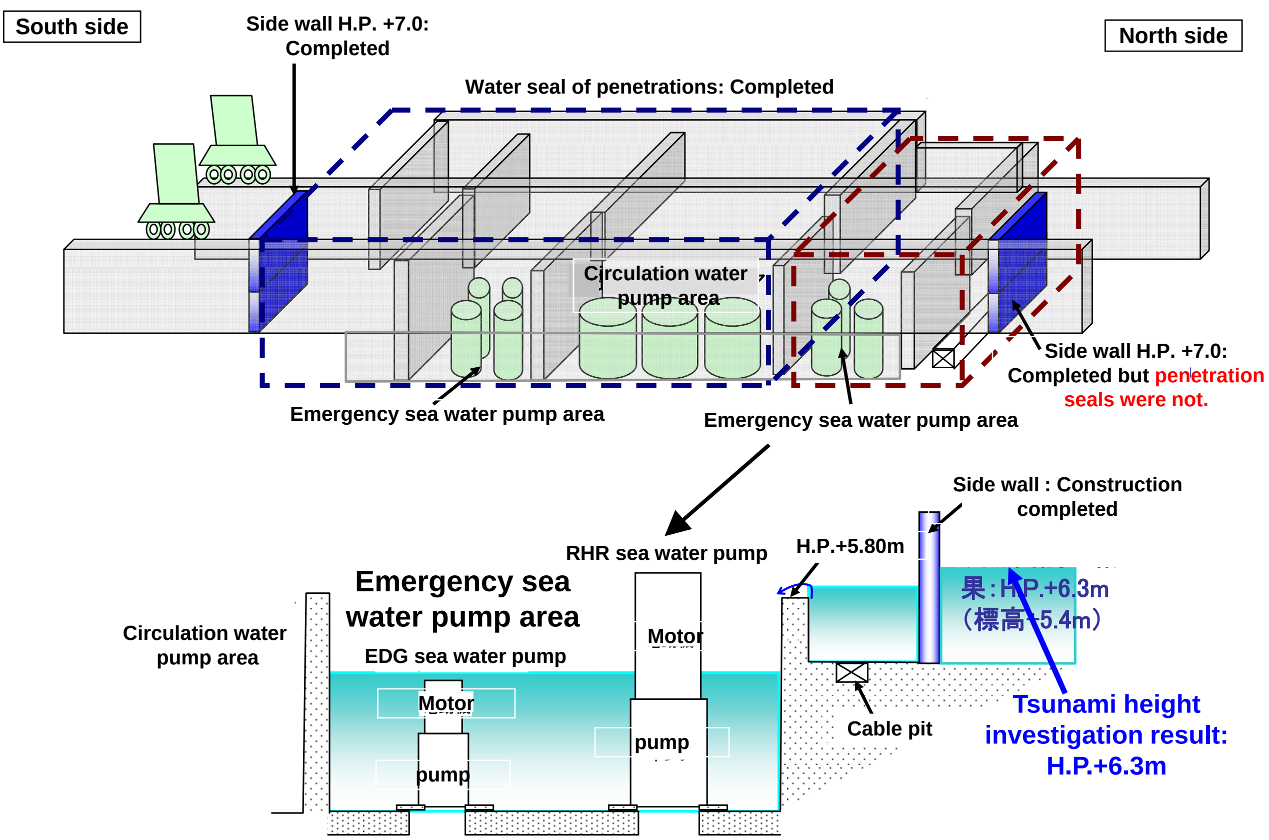
- Increase of height of side wall of sea water pump room : Under construction at the tsunami（H.P.+5.80m）
- Additional countermeasures:
  - New side wall construction outside of side wall (H.P.＋） and
  - Water seal of penetration holes on wall
- When the Tsunami attached the site, the work to increase the height of side wall was completed but water seal work of penetration holes were not.

■Outline of tsunami at the site：

- Run-up height: About **H.P.+6.3m**
- Tsunami did not exceed side wall H.P.+7.00m
- Inundation to north side pump room seemed to be caused by water infiltration through penetration holes. (South side pump room was secured.)
- Tsunami did not reach to main grade level (**H.P.+8.89m**) where main buildings were located



### ■Sea water pumps and electric power system in the site (2)



## ②External Electric Power (1)

■Grid for external power for Tokai Daini NPP :

・Start-up, Shut-down and Emergency :

From Naka transformer station, about 15km to the site, 275kV, one route two lines and

From Ibaragi transformer station (8km to the site), via switch yard of the site : external back-up, 154kV, one route one line

■Seismic intensity around Naka T. station : JMA6+, Around Ibaragi T. station :6-

■Outline of damage :

・Insulation oil leak : Main and start-up transformers

・All external powers failed but recovered as shown below.

- ・March 13 : Recovery of external back-up power line, 154kV, one route one line
- ・March 18 : Switch to main external power line, 275kV, resume to normal state

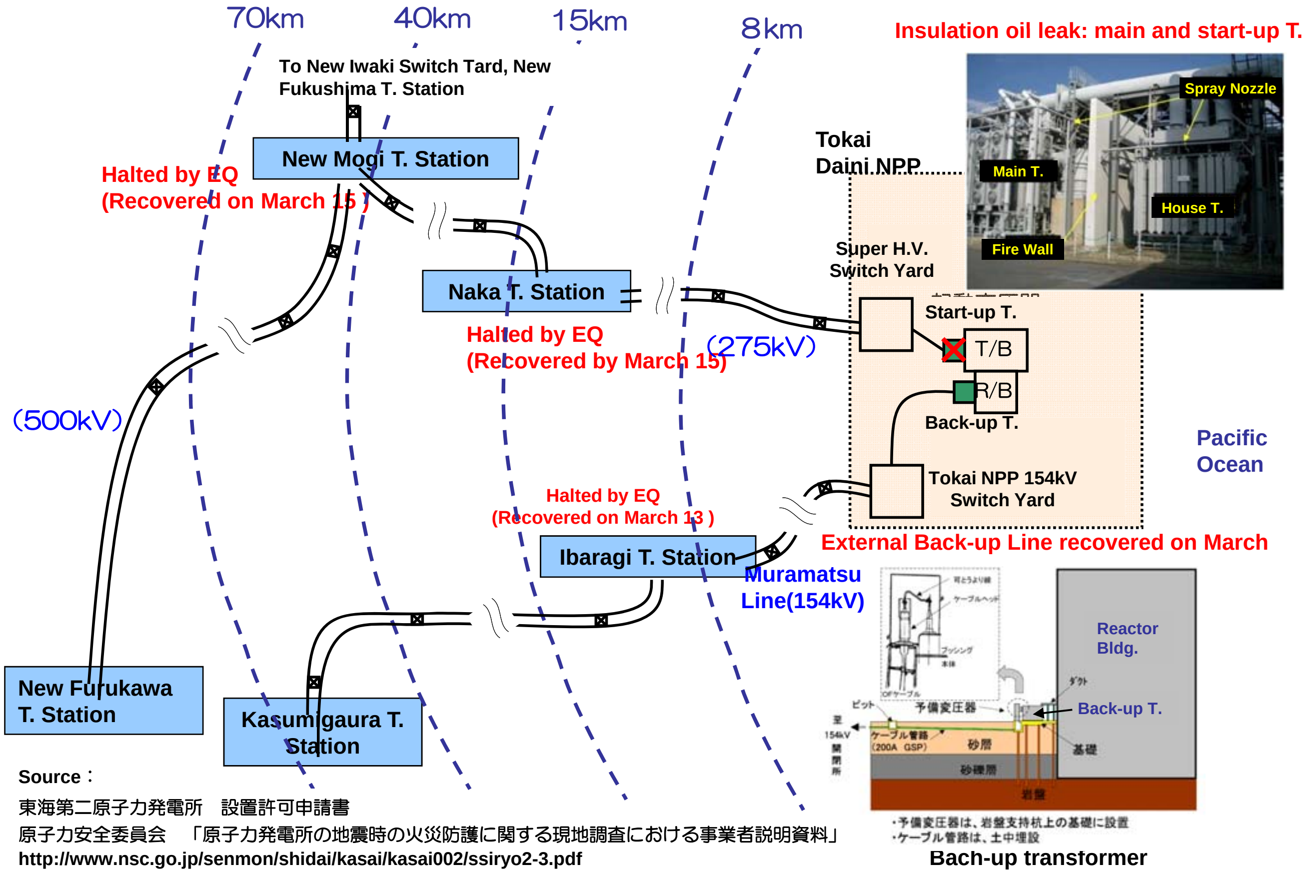
( All transformer stations outside of the site, at Naka and Ibaragi, were stopped and all power transmission was halted

⇒Bach-up line should be taken notice because it was recovered before main line)

・Two of three EDGs were started up due to external power loss, and emergency power was secured.



## ■Outline of Power Transmission Line outside of the Site (2)




Source：

東海第二原子力発電所　設置許可申請書

原子力安全委員会　「原子力発電所の地震時の火災防護に関する現地調査における事業者説明資料」

http://www.nsc.go.jp/senmon/shidai/kasai/kasai002/ssiryo2-3.pdf

## 4. Information sharing with international communities (1/2)

**1. Daily Notification**

(1) ENAC Website

NISA has constantly been providing facility-related and other relevant information on the Emergency Notification and Assistance Convention Website, designed for member states to exchange information on nuclear accidents.

(2) IEC (IAEA)

NISA has constantly been providing the Incident and Emergency Centre of IAEA with press releases and other relevant information, as well as responses to questions on such communication.

(3) Foreign Media Briefing

- NISA joins relevant government agencies in daily foreign media briefings at the PM's official residence on March 14, 17 and every day afterwards.
- NISA officials give account to damages suffered at Fukushima NPSs and respond to questions.

(4) Briefings for Diplomatic Representatives in Tokyo

- NISA joined the Ministry of Foreign Affairs in briefing sessions for Diplomatic representatives in Tokyo.
- Distributed press releases (English), provided explanations and answered questions.

(5) English information on the Web

- Nuclear and Industrial Safety Agency: http://www.nisa.meti.go.jp/english/index.html
- Office of Prime Minister： http://www.kantei.go.jp/foreign/index-e.html
- TEPCO News(Pictures, Movies in Japanese): http://www.tepco.co.jp/tepconews/pressroom/110311/index.html



## 4. Information sharing with international communities (2/2)

## 2. IAEA

(1) Technical Briefing on March 21st

Following the special meeting of the IAEA Board of Governors, NISA officials briefed the member state representatives on the overview of the earthquake itself as well as the status of and ongoing measures to address the Fukushima NPS accident.

(2) Side event on the "Fukushima Daiichi Accident and Initial Safety Measures Worldwide" on April 4th

NISA and MEXT officials explained the member state representatives the Status of Fukushima Daiichi NPPs and monitoring, action taken and Future plan as well as the implementation on emergency safety measures.

## 3. OECD

(1) MDEP Steering Technical Committee on April27-29

(2) OECD/NEA Steering Committee on April 28-29

(3) CNRA Highlevel Senior Task Group on May 4-6

## 5. Remarks

- Continue to make every possible efforts to bring the situation under full control
- Will identify the cause of the accident thoroughly and review safety assurance measures
- Offer the information as much as possible and share the lessons learned from the accident with the international community