[1]TEPCO's Tsunami Countermeasure Preparation and Tsunami Prediction Positioning

[Main Report 3.4 Tsunami evaluation (1) and (2)]

At 14:46 on March 11, 2011, the Tohoku-Chihou-Taiheiyo-Oki Earthquake with its epicenter at off-shore of Sanriku occurred, and the Fukushima Daiichi NPS was struck by a record-breaking tsunami.

TEPCO had tsunami countermeasures in place, but the scale of this tsunami far exceeded anything that had been predicted.

Some have commented that TEPCO had not taken appropriate tsunami countermeasures, even though TEPCO had envisioned the tsunami, pointing out that TEPCO had conducted a trial calculation, for the reference purpose of TEPCO's tsunami investigation, based on a supposition in reaction to assertions from earthquake research institutions.

However, even though TEPCO had deliberated various aspects of the investigations of tsunamis, the origins of these deliberations were simulations based only on hypothetical "wave sources," and there is no fact that suggests that these hypothetical tsunamis were regarded as an actual danger.

The following details the investigation into TEPCO's tsunami countermeasure preparation and confirmation of the positioning of such countermeasures.

[Tsunami Countermeasure Preparation]

- Each unit of the Fukushima Daiichi NPS obtained the establishing permit between 1966 and 1972. At the time there was no clear guideline for tsunamis so the units were designed based on past tsunami evidence. Therefore, the highest tidal level that had been observed at Onahama Port, which was observed following the Chile earthquake and tsunami of 1960, was used as a design condition. (O.P.* +3. 122m)

  * O.P.: Onahama Port construction standard level (0.727m below Tokyo-bay Mean Sea Level)

- Tsunamis were put forth as natural disasters that should be considered with the creation of the safety design review guidelines enacted in 1970 which referenced past records to require a design that could withstand the harshest of natural disasters. A government review was conducted based on these guidelines and the establishing permit was obtained as "the safe level is sufficient enough" to withstand a tidal level of the magnitude seen following the Chile earthquake and tsunami. The height of the tsunami that was written on the establishing permit remains unchanged to this day. However, as further discussed below, various opportunities were taken to assess tsunamis and the results of these assessments, including countermeasures, were reported to the government and ultimately used as actual design conditions.

- In February of 2002 the “Tsunami Assessment Methods for Nuclear Power Plants in Japan” which provided the first definitive tsunami assessment method in Japan was published by the Japan Society of Civil Engineers. This “Tsunami Assessment Method” has been used ever since in Japan by nuclear power stations to assess tsunamis.

  *1 According to the “Tsunami Assessment Methods”, a wave source model *2 is established for the largest tsunami that has been recorded in each tsunami region. Various numerical simulations that consider the uncertainty of position, direction, and angle, etc., of these wave source models are used to estimate the maximum size of the tsunami which is then in turn assessed.

  *2 Wave source model: Position, scale, displacement amount, etc., of an earthquake that generates a tsunami.

- Based on the assessment results of the height of a tsunami that may hit the Fukushima Daiichi NPS, tsunami level; O.P. + 5.4 to 5.7 m was delivered by “Tsunami Assessment Method”, and countermeasures, such as increasing the height of pump motors, were implemented in 2002. These assessment results were reported to, and confirmed by the government in March 2002.

- In June 2007, the tsunami estimate conducted by Fukushima Prefecture for disaster preparedness reasons was obtained, and it was confirmed that the tsunami height predicted by Fukushima Prefecture did not exceed TEPCO tsunami assessment results.

- In March 2008, tsunami wave sources were evaluated for disaster preparedness reasons in Ibaraki Prefecture, and it was confirmed that its tsunami height did not exceed TEPCO tsunami assessment results.

- In September 2006, the Seismic Design Review Guidelines were revised and instructions were given by the government to reconfirm anti-quake resistance based on the new guidelines (hereinafter referred to as, “Seismic Back Check”. During the seismic back check, geological surveys were conducted, and design-basis earthquake ground motion was created. After that anti-quake assessments were conducted on primary equipment all of which was reported to the government as the Interim report. In preparing a final report, tidal level observation data and the latest sea floor topography data were considered to reassess tsunami levels based on February 2009 “Tsunami Assessment Method” since it was deemed necessary to evaluate tsunamis as phenomena accompanying earthquakes in the final report.

  The tsunami level at Fukushima Daiichi NPS was calculated to be O.P. +5.4 to 6.1m and countermeasures for this tsunami height were implemented.

- As stated above, whereas tsunami assessment for Fukushima Daiichi is based on the "Tsunami Assessment Method" published by the Japan Society of Civil Engineers, independent action, such as confirmation based on the information regarding tsunamis compiled by the municipal government for disaster preparedness evaluations, had also been taken. In addition to this assessment, as knowledge and theories concerning tsunamis became available, independent action was taken to deliberate and investigate this information, including preparing estimates. As part of this action, the two estimations below were being deliberated, even though the knowledge, such as wave source models required for tsunami assessments, was still uncertain.

<1. Trial calculation based on the Meiji Sanriku-oki Earthquake (M8.3)>

- In July 2002, the Headquarters for Earthquake Research Promotion (hereinafter referred to as, "Earthquake Headquarters"), a government research institution, released a long-term earthquake assessment (hereinafter referred to as, "Earthquake Headquarters' stance") that said an earthquake could occur anywhere between the Sanriku Coast and the Bousou Coast. The earthquake headquarters' stance was that an earthquake with a magnitude of approximately 8.2 could occur in regions that had not previously suffered a large earthquake in recorded history (namely, along the Japanese Coast from Fukushima to Bousou). However, even earthquake headquarters did not envision large-scale interlocking earthquakes like that which occurred. Furthermore, the wave source models, which are indispensable for evaluating earthquakes in regions that have not experienced large earthquakes in recorded history, were not indicated.

- Even the Japan Society of Civil Engineer's "Tsunami Assessment Method" did not offer wave source models and did not consider the possibility of an earthquake occurring in this region.

- Meanwhile, the Japan Society of Civil Engineers had planned to deliberate on and assess methods based on probability theory as a new endeavor from FY2003. The Earthquake Headquarters' stance was to be incorporated within this assessment method. Using the probabilistic method to assess tsunamis was a groundbreaking attempt, and TEPCO planned to watch the deliberations of the Japan Society of Civil Engineers closely. TEPCO had also performed an assessment in Fukushima as a case study for the purpose of applying this method and making improvements based on the deliberation results * of the Japan Society of Civil Engineer's probabilistic assessment method. The results from a probabilistic assessment vary widely since the opinions of experts weighing in on the deliberation are also taken into account. Therefore, when actually conducting a probabilistic assessment, it is necessary to decide how to handle the results, including how to handle the assessment values (example: in the United States it is common to conduct the assessment of the probability over one year using the average value). TEPCO published a paper in 2006 that includes calculation

examples.

* As mentioned in the conclusion of the paper on probabilistic assessment methods published by TEPCO, the probabilistic assessment method introduced at the time was still being developed and continued to be examined by the Japan Society of Civil Engineers between 2006 and 2008. However, at present time it has not been developed enough to be used for tsunami assessment, and has not passed the experimental analysis phase yet.

- Around April to May 2008, while it was being discussed internally how to handle the Earthquake Headquarters' stance in regard to future seismic safety evaluations (back checks), calculations were performed assuming a wave source model for the Meiji Sanriku-oki Earthquake (M8.3) as reference for deliberations. Since a large earthquake had never occurred along the Japan Trench off the coast of Fukushima. Therefore, the wave source from the Meiji Sanriku-oki Earthquake (M8.3) which is the most strict wave source for the Fukushima site when applied, was brought about along the Japan trench off the coast of Fukushima and used for the estimate to calculate the tsunami wave height. Estimate results for Fukushima Daiichi yielded a tsunami wave height of O.P. +8.4 to 10.2m and a flood height of 15.7m (* tsunami wave height on the south side of the site with the elevation being taken into consideration.)

- Around the summer of 2008, as a result of the deliberations on how to handle the Earthquake Headquarters' stance, TEPCO considered that the calculated estimates were mere assumptions with no actual basis for the reasons below and TEPCO decided to ask the Japan Society of Civil Engineers to examine the creation of actual wave source models for assessing tsunamis based on the Earthquake Headquarters' stance (The Japan Society of Civil Engineers has been examining this issue from FY2009, but has not established any wave source models for the Fukushima Coast yet):
  (1) The Japan Society of Civil Engineers' "Tsunami Assessment Method," which was adapted by electric company operators as the rule for assessing tsunamis, does not consider the generation of a tsunami along the sea trench off the coast of Fukushima; and
  (2) The wave source model to be assumed as a wave source of the tsunami has not been established.

- On March 7, 2011, (four days before the earthquake on March 11) the Nuclear Agency asked TEPCO to explain the recent actions to revamp the Earthquake Headquarters' long-term assessment, in response to which TEPCO submitted materials and offered an explanation on the above trail calculation results along with the status of tsunami assessment at TEPCO to the head of the Licensing Safety Review (of Nuclear Facilities) and investigators. During this meeting, TEPCO was not instructed to immediately implement countermeasures.

- Furthermore, the Central Disaster Preparedness Council, which is responsible for creating and promoting regional disaster preparedness plans and the country' basic disaster preparedness plan, had been examining past earthquakes but had not examined any earthquakes on the sea trench off the coast of Fukushima prefecture or Bousou since no large earthquakes had ever occurred in these areas. As a result, earthquake headquarters' stance had no relevance to actual disaster preparedness as far as the Central Disaster Preparedness Council was concerned. (The same goes for knowledge related to the Jogan Earthquake to be discussed later)

<2. Trail calculation based on the Jogan Earthquake (M8.4)>

- In October 2008, a thesis entitled "Numerical Simulations of the Jogan Tsunami of 869 A.D. for the Ishinomaki/Sendai Plains" by Prof. Satake of the National Institute of **A**dvanced **I**ndustrial **S**cience and **T**echnology (AIST) was received (prior to publication). The thesis stated that the scale and the generation point of the Jogan tsunami were uncertain (in other words, there were no wave source models) and proposed two wave source models, but to be certain it is necessary to conduct tsunami sediment survey of the coast of Fukushima prefecture.

- Even though the proposed wave source models were uncertain, the two wave source models proposed in the thesis were used for tsunami estimates in December of 2008. The result of the trial calculation for Fukushima Daiichi was a tsunami wave height of O.P. +8.6 to 8.9 m.

- In December 2008, a plan to implement tsunami sediment surveys was devised since tsunami sediment surveys of the Fukushima Prefecture caused were deemed necessary in the thesis by Professor Satake of the AIST.

- In April 2009, the thesis was officially published. As mentioned earlier, the aforementioned thesis include wave source models for the Jogan tsunami, but the wave source models were based on tsunami sediment survey results for Sendai plains and Ishinomaki plains, and the generation point and scale of the tsunami were uncertain. The thesis stated that to be certain it was necessary to conduct tsunami sediment surveys on the coast of Fukushima prefecture.

- In June 2009, the Japan Society of Civil Engineers was asked to examine the earthquake headquarters' stance and the wave models for the Jogan tsunami.

- In June 2009, it was pointed out by Okamura of the AIST, during the Earthquake/Tsunami, Geology/Soil Joint WG (a government council to examine anti-quake back checks) of the Anti-Quake/ Structural Design Subcommittee of the Advisory Committee on Energy and Natural Resources' Nuclear Safety/Security Task

Force, that it is necessary to examine the Jogan Earthquake (from the perspective of tsunami assessment).

- TEPCO's Interim report on seismic assessment was examined by this WG, but no mention of tsunamis was made in the Interim report since tsunami assessment was to be discussed in the final report. Furthermore, the Nuclear and Industrial Safety Agency (NISA) had responded to TEPCO that "this WG is for examining the Interim report related to seismic assessment, and tsunami assessment should be included in the final report".

- In July 2009, the NISA deemed that the Interim report's assessment of seismic safety for Fukushima Daiichi Unit 5 and Fukushima Daiichi Unit 4 was adequate. In the report from the NISA it stated that, "based on the fact that surveys and research on tsunami sediment and tsunami wave sources related to the 869 Jogan Earthquake are currently underway at research institutions, it is the position of the NISA that operators should take appropriate action as suitable based on the results of the aforementioned research institutions from the perspective of tsunami assessment and seismic movement assessment".

- The status of consideration of the Jogan tsunami was submitted and explained to investigators in August 2009, and the assessment results for tsunami height was submitted and explained to the head of the Licensing Safety Review (of Nuclear Facilities) and investigators in September of the same year, upon request from the NISA (on March 7, 2011, a tsunami wave height of O.P. +8.7~9.2 m obtained by changing methods for considering high tide levels was explained once again in conjunction with the Earthquake Headquarters' stance).

- In the winter of FY2009 (agricultural off-season), a tsunami sediment survey was conducted on the coast of Fukushima Prefecture and sediment deposited by the Jogan tsunami was found at an elevation of approximately 4m in the northern part of Fukushima Prefecture, however in the southern part of Fukushima Prefecture (Tomioka to Iwaki) tsunami sediment was not found. Furthermore, it was determined that further surveys and research would be necessary to create accurate wave sources since the results of the tsunami sediment surveys did not match the proposed wave source models.

- The sediment survey results were published in January 2011 and announced at the Japan Geoscience Union Conference 2011 held in May 2011.

- Furthermore, the epicenter and scale of the Jogan tsunami (wave source model) have still yet to be determined.