(Provisional Translation)

Evaluation of the Tokyo Electric Power Company's Report Regarding Leakage from Contaminated-Water Transfer Hose at the Fukushima Daiichi Nuclear Power Station

Nuclear Regulation Authority (NRA)

January 20, 2016

1. Outline

At around 10:08, May 29, 2015, during the operation of pumping and transferring the water stored in the notch tanks (total capacity: 1,000-ton) to the Unit 3 turbine building, a subcontractor worker found that the water was leaking from the polyvinyl chloride (PVC) pressure hose (hereinafter referred to as "the hose in question") (see Figure 1). The leaking water outflowed into side ditch K-4-7 (where the hose in question was in place), and via downstream side-ditches K-4-2 and K-4-2, flowed into drainage channel K. Water in drainage channel K was pumped and transferred to drainage channel C and flowed into the port of the power plant. At 10:26, responding to the subcontractor worker's notification, the transfer pump from the notch tanks was stopped.

On the same day, the NRA received from the Tokyo Electric Power Company (hereinafter referred to as "TEPCO") an accident & failure report based on the provision of Article 62-3 of the Reactor Regulation Act.

On August 28, 2015, the NRA received from TEPCO the final report regarding the causes of and measures against the event (hereinafter referred to as "the report"). After closely examining the report, the NRA has compiled assessment results as follows.

The report from TEPCO
http://www.nsr.go.jp/activity/bousai/trouble/houkoku/00000037.html (Japanese only)

2. Outline of the report submitted by TEPCO

(1) Assessment of the radioactive leakage and environmental impact

Upon the leakage notification, total beta radioactive concentration at the drainage channel K outlet was checked by sampling, which revealed total beta radioactive concentration of about 29 Bq/L at 7:00, May 27. On May 28, however, the concentration of sample water increased to about 1,200 Bq/L (see Figure 2). On the assumption that the leakage event occurred during from when the water transfer started at 9:00, May 27 until the transfer was stopped on May 29, the maximum volume of water leaked was assessed to be about 15 m^3 on the basis of the size of the leakage section opening.

On the basis of the volume of water leaked and the total beta radioactivity concentration (about 1.1×10^6 Bq/L) of water stored in the notch tanks, radioactive leakage is estimated at about 1.7×10^{10} Bq in

terms of total beta radioactivity. Given that about 1.7×10^9 Bq of total beta nuclide radioactivity was recovered from drainage channel K and side ditch, about 1.5×10^{10} Bq is estimated to have flowed into the power plant port.

Any of the total beta radioactive concentrations periodically sampled at the port entrance were below detection limit from May 26 (before the occurrence of the leakage) to June 1 (after the occurrence of the leakage) (see Figure 3). Also continuous monitoring results did not show significant variation during this period (see Figure 4).

With regard to the plant vicinity (outside the port), an ad hoc analysis on May 30 based on samples from the port entrance's east side indicated a total beta nuclide radioactive concentration of 18 Bq/L, which is comparable to the detection limit of past analysis results. No significant variation was found also thereafter (see Figure 3).

Although environmental impact was indicated to occur inside the power plant port, no significant fluctuation was found outside the port, which suggests that any impact was confined to be within the port.

(2) Cause investigation results

○ Damage to the hose in question

The hose in question was laid in the side ditch in October 2013 as a transfer line from the notch tanks to the Unit 3 turbine building. The hose was installed without being anchored and with sufficient slack. The hose was repeatedly used for water transfer over an extended period, during which water flow and internal fluid dead weight caused a bend with a smaller radius than regulations allowed, resulting in the separation of the inner tube and the outer tube. Under such conditions, the pressure during water transfer caused the hose to crack (see Figure 5).

○ Installation of the hose in question in the side ditch

Since a hose was urgently required, it was laid inside the side ditch for ease of installation as well as causing less interference with other ongoing construction work.

○ The hose in question had not been inspected yet.

The hose in question was installed as a temporary measure and therefore no inspection program was prepared and no inspection was carried out yet.

○ Management of the replacement of the hose in question with a polyethylene (PE) pipe

In March 2014, work to replace the hose with a PE pipe started. However, because the hose work interfered with land-side impermeable wall installation work and Unit 2 transformer removal work, the hose laying work was suspended in October 2014. As the pipe installation work was not expected to be restarted, an acceptance inspection was carried out only on the already installed hose. Although the above-mentioned interference with other work was resolved in March 2015 and the hose replacement work was able to continue in April 2015, the replacement work

remained suspended (see Figure 6).

○ Inadequate past leakage event countermeasures and information sharing

The “Temporary Hose Inspection Guide”, applied from July 2011 as a recurrence-preventing measure based on reoccurring leakage events, was not intended for quality assurance management and only stipulated hose inspection items. Thus the guide was temporary, for use with hose installation, and lacked provisions such as hose inspection frequency.

○ Check prior to the transfer of underground storage tank water to the notch tanks

In May 2013, the notch tanks were set up to temporarily store contaminated water in anticipation of a contaminated water leak. The tanks were used to store in-dike rainwater, RO concentrated water (in rainwater) and water collected from drainage channels B and C and periodically transfer the water to the Unit 3 turbine building. Since approx. 1,000 m^3 of water accumulated in the underground storage tanks, the water inventory in the notch tanks was reduced to approx. 110 m^3 in order to transfer the water in the underground storage tank via the notch tanks to the Unit 3 turbine building. From May 15 to 25, the notch tanks received approx. 236 m^3 of the underground storage tank water. When the leakage from the hose in question occurred, about 2/3 of water in the notch tanks was water from underground storage tanks.

To transfer water to the Unit 3 turbine building, the hose in question was put in use on May 27. However, a specified pressure hose management method according to radioactive concentration was not in place.

○ Delay in the detection of contaminated water leakage at drainage channel K

Drainage channel K, into which rain water flows from the side ditch, is some distance from the contaminated water tanks. Therefore, the risk of contaminated water flowing into drainage channel K was disregarded and no equipment was installed to immediately detect the radioactive concentration of water in drainage channel K.

(3) Countermeasures

① Replacement of the hose in question with a PE pipe

Replacement of the hose in question with a PE pipe was completed on June 20, 2015 (see Figure 6). Similar sections were investigated and improvements were made, such as keeping the bending radius within tolerance and isolation from the side ditch (completed at the end of October 2015) (see Table 1). Pressure hoses outside buildings and the dike will be replaced with PE pipes (completion scheduled for March 2017).

② Enactment of *Pressure Hose Management Guide*

In this event, the radioactive concentration of the water in the underground storage tank was high, in the order of 10^6 Bq/L. Due to inadequate management of high concentration contaminated water transfer using a pressure hose, the *Pressure Hose Management Guide* (enacted in August 2015) specified management and inspection methods according to service period and radioactive

concentration.

③ Revision of the *Risk Management Meeting Administration Guide*

Remedial construction activities, measures against nonconformities requiring risk management, construction feedback and the prioritization of construction activities (to prevent mutual interference) derived from comprehensive checks were added to the guide (revised in August 2015).

④ Revision of the "Nonconformity Management and Corrective & Preventive Measure Guide" and the "Nonconformity Management Committee Guide"

Requirements for the Nonconformity Management Committee to report nonconformities and non-compliances (including those requiring reports to other meetings such as risk management meetings) were added (revised in August 2015).

⑤ Installation of continuous monitoring equipment at drainage channel K.

To immediately detect abnormal radioactive concentration in drainage channel K, continuous monitoring equipment will be installed (completion scheduled for March 2016).

⑥ Establishment of a contaminated water treatment system on the 35 m foundation on which the notch tanks are installed

To prevent the transfer of stored water from the notch tanks to the turbine building, a contaminated water treatment system will be constructed on the 35 m foundation on which the notch tanks have been installed (design and study for establishing the system have been ongoing since July 2015).

3. NRA's assessment of the report and future responses

(1) Environmental impact

Analysis results of the radioactivity of water samples taken from the port entrance and port entrance seawater monitoring did not suggest a significant variation from before and after the leak was found. No total beta radioactivity suggesting that the leaked water flowed outside the port was detected (see Figures 3 and 4). Therefore, it is estimated that no sea contamination occurred that would pose a threat to human health or the environment.

(2) Exposure dose

Gamma radiation effective dose and beta radiation equivalent dose (skin) were checked in workers who patrolled drainage channel K (see Table 2). No significant difference in the effective doses and equivalent doses were found before and after the leak occurred. Thus, it is estimated that any radiation they were exposed to was of no significant concern.

(3) Countermeasures

Measures against root causes derived through investigation are as follows:

○ Inadequate management of temporary hoses

In response to the fact that the damage to the hose in question had been long overlooked, all pressure hoses that transfer contaminated water will be checked comprehensively. Abnormalities such as hose damage and bends tighter than the allowable radius will be checked, and if an abnormal condition is found, necessary corrective measures will be taken. The Pressure Hose Management Guide shall be established to ensure the well-planned checks according to service period and contaminated water radioactive concentration and to avoid installing hoses in side ditches, thereby preventing the recurrence of contaminated water leakage.

○ Inadequate construction management

Due to interference with other construction activities, the construction work in question was suspended after adjustment by the foremen. The construction was not restarted even when the rescheduled construction period arrived. In response to this, the “Nonconformity Management Committee Guide,” “Nonconformity Management and Corrective & Preventive Measure Guide,” and “Risk Management Meeting Administration Guide” were revised (August 2015) as countermeasures. Risk management meetings will be held to ensure construction progress management and prioritization in construction activities in case construction schedules have overlapped as well as to establish a mechanism for cross-divisional information sharing, thereby preventing the recurrence of construction management failure such as the event in question.

○ Inadequate non-conformity management

In response to the event in question, TEPCO launched the development of a support tool enabling the search for non-conformity events in similar construction activities and measures for preventing their recurrence. Since October, data storage for the tool is being implemented. The tool is expected to strengthen nonconformity management.

○ Inadequate operation management for transferring high concentration contaminated water

Previously, no guide was in place that required a check in advance of transferring high concentration contaminated water using a pressure hose. This resulted in the transfer of underground storage tank water without a prior check. The newly enacted Pressure Hose Management Guide requires thorough checks in advance of transferring high concentration contaminated water.

Moreover, for contaminated water handled on the 35 m foundation, a system capable of treating such water will be established there, precluding the necessity of transferring it to the turbine building. This is intended to avoid the long-distance transfer of high concentration contaminated water, as in the case of the event in question, and reduce the risk of leakage (related study started in July 2015).

○ Prevention of unattended leakage

Continuous monitoring equipment will be installed in drainage channel K to detect abnormal

conditions such as the inflow of contaminated water (completion scheduled for March 2016).

As the event in question occurred due to the absence of preventive measures based on the implementation plan, the event was determined to be a violation of the implementation plan in the first quarter of FY 2015. By means of the 2nd operational safety inspection (FY 2015) and the 3rd operational safety inspection (FY 2015), the NRA checked TEPCO's remedial actions compensating for the violation of the implementation plan.

Based on the above, the NRA has judged that TEPCO is implementing measures for preventing the recurrence of leakage from a transfer line using a pressure hose. Also in the future, the NRA will check the state of each measure implemented by TEPCO, through operational safety inspections etc..

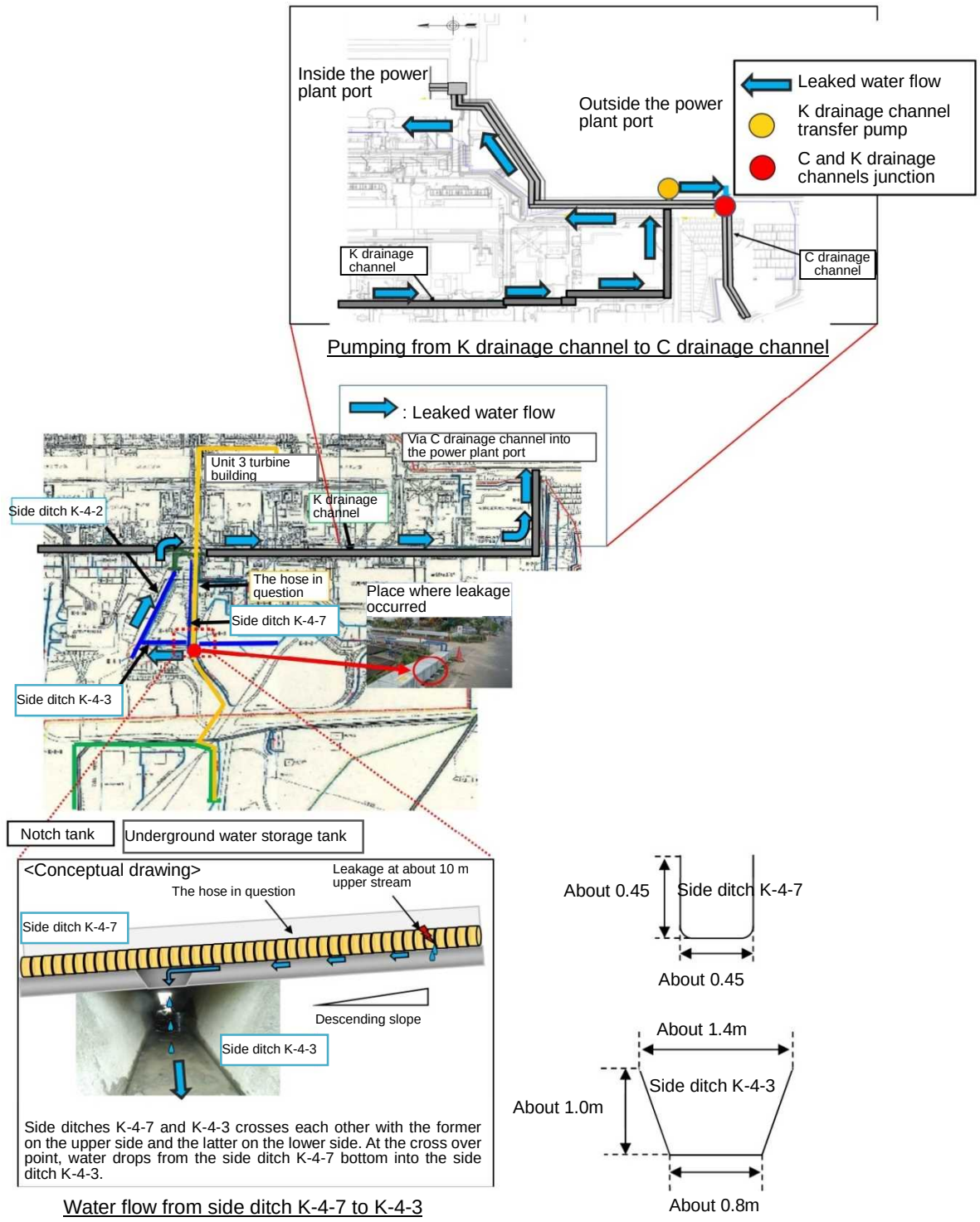
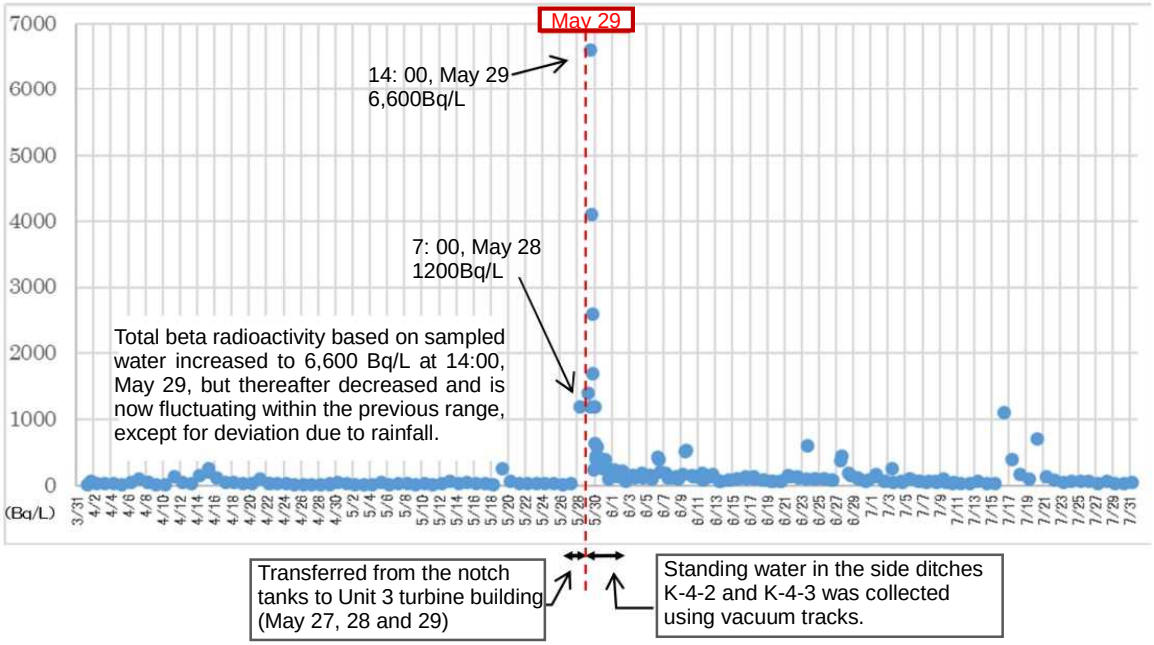


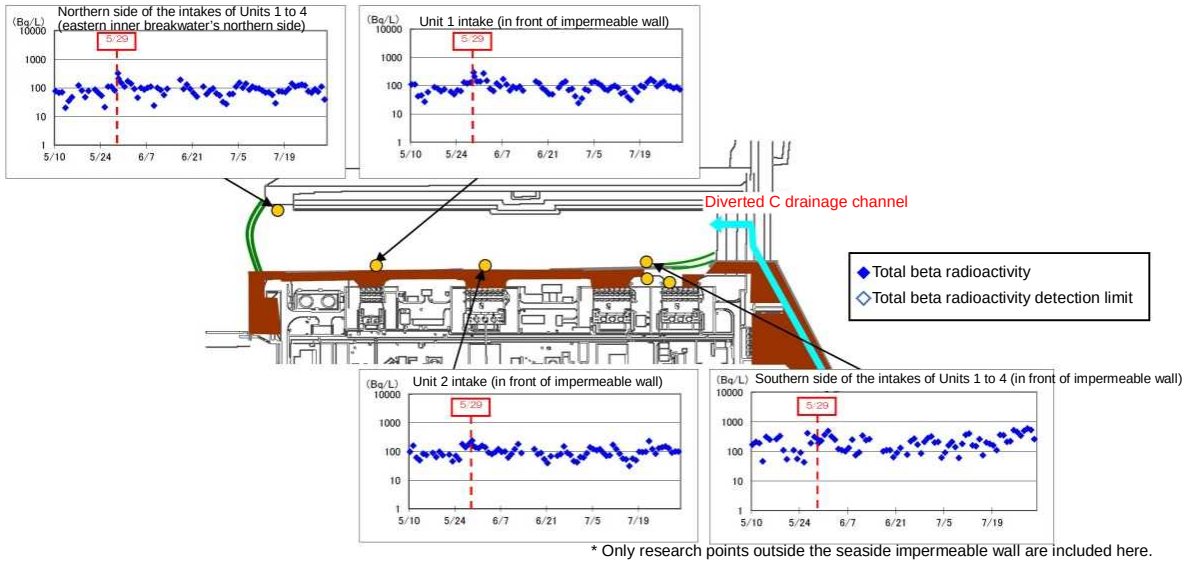
Figure 1. Situation at the time of the leakage
(Excerpt from the TEPCO report, with partial revision)

K drainage channel water outlet total beta radioactivity



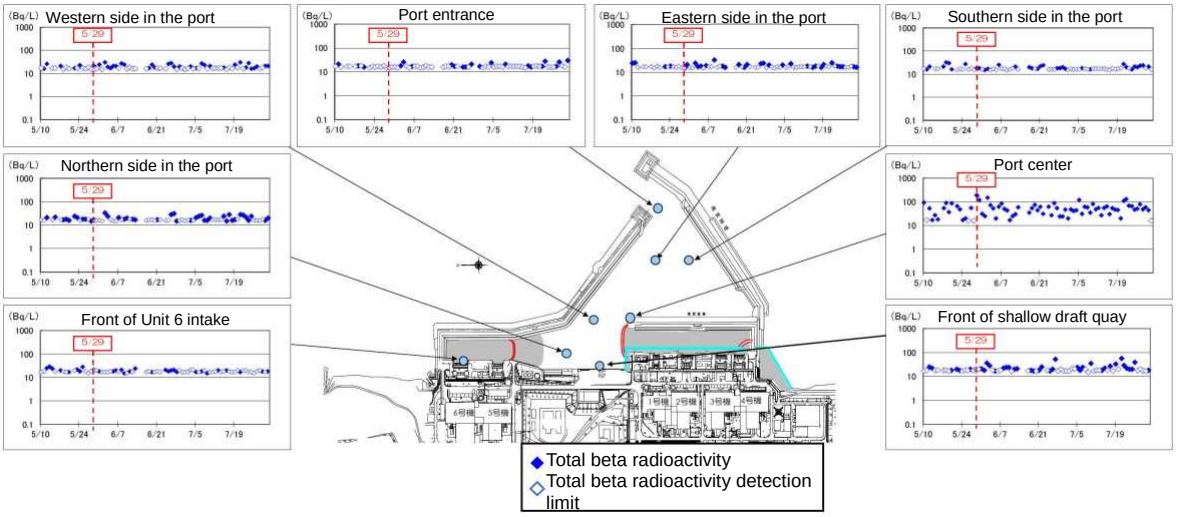
Radioactive concentrations of radionuclides in water stored in the notch tanks (14: 50, May 29)

Radionuclide	Radioactive concentration (Bq/L)
Cs−134	4.4×10^{1}
Cs−137	2.3×10^{2}
Sr−90	6.4×10^{5}
H−3	1.1×10^{4}
All beta	1.1×10^{6}



* Only research points outside the seaside impermeable wall are included here.

Figure 2. Results of monitoring at the K drainage channel outlets and Units 1 to 4 intakes (Excerpt from the TEPCO report, with partial revision)



Total beta radioactivity concentration at the port entrance (Bq/L)

Date of sampling	May 25	26	27	28	29	30	31	June 1
Clock time of sampling	6:55	8:25	8:55	8:50	6:57	7:56	8:0	6:57
Analysis results*	ND(17)	ND(16)	ND(18)	ND(15)	ND(15)	ND(16)	ND(16)	ND(15)

*ND: Not detected Transfer period

( ) The Detection limit is given in parenthesis

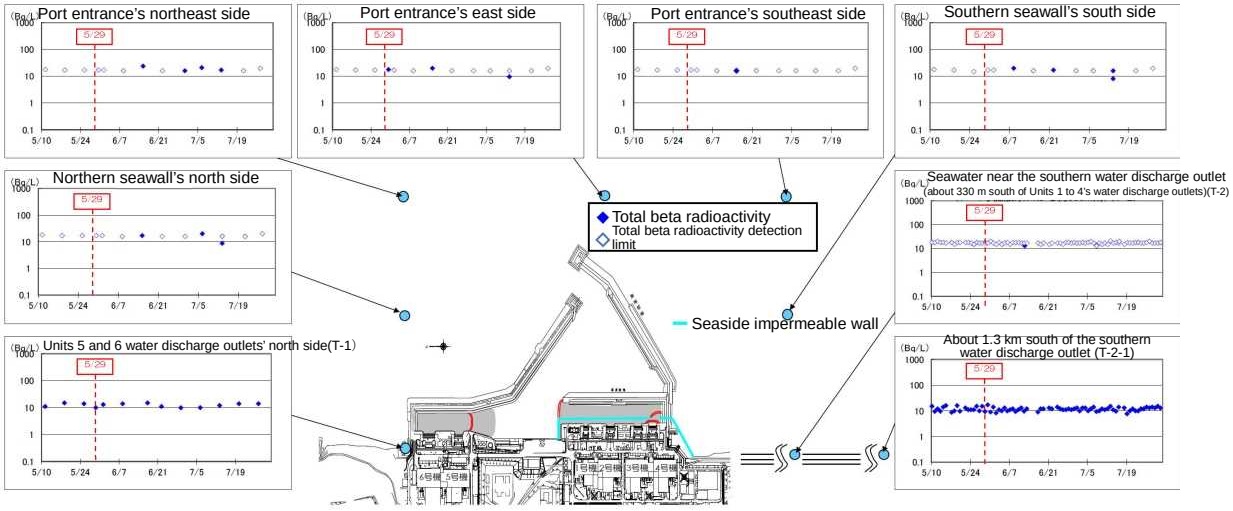
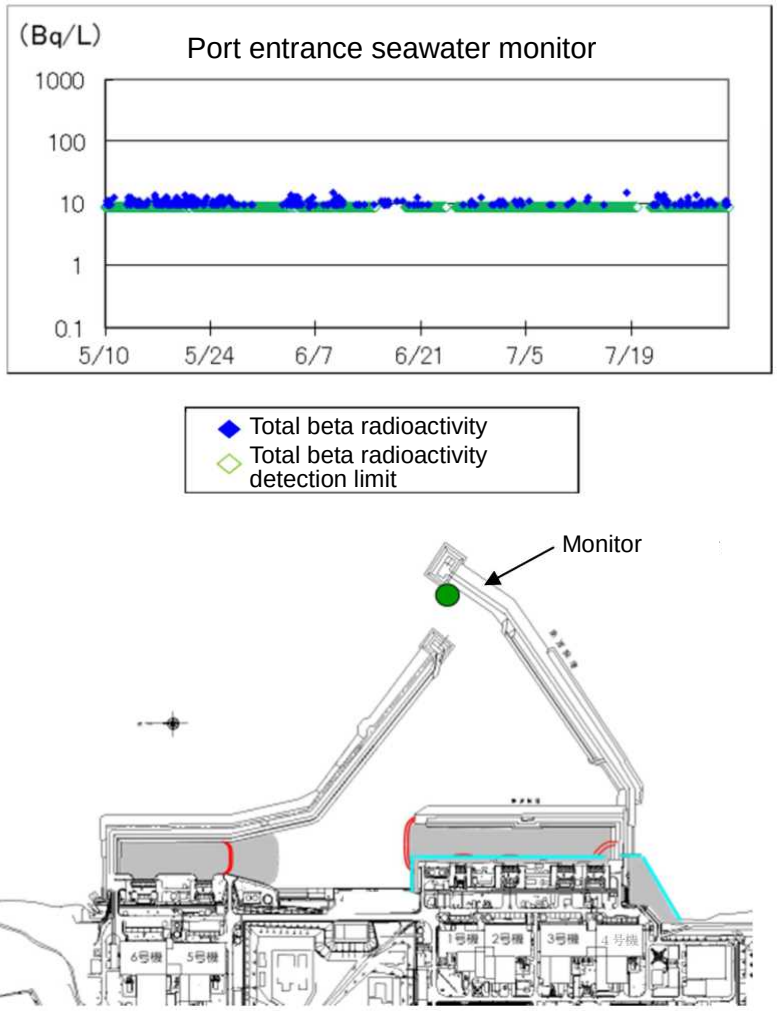


Figure 3. Monitoring results inside and outside the plant port (Excerpt from the TEPCO report, with partial revision)



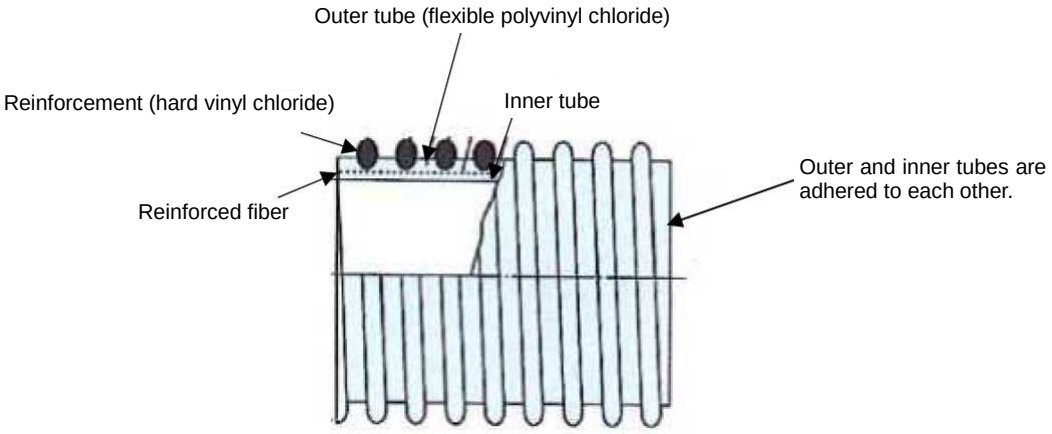
Note: Total beta radioactivity has been affected by naturally-occurring radionuclide potassium-40 (more than 10 Bq/L)

Figure 4. Results of monitoring port entrance seawater (Excerpt from the TEPCO report)

(1) Specification and structure

Specifications of the hose in question	
Name	Polyvinyl chloride pressure hose
Hose diameter (bore)	75A

Structure of the hose in question



(2) Inspection

- The section in question was checked visually, which showed an oval hole approximately 1 cm long and 0.2 cm wide.
- The section in question was the outer side of a bend. Around the section, the reinforcing ring interval was greater than normal and the hose was softer than usual.

Photo of the section in question

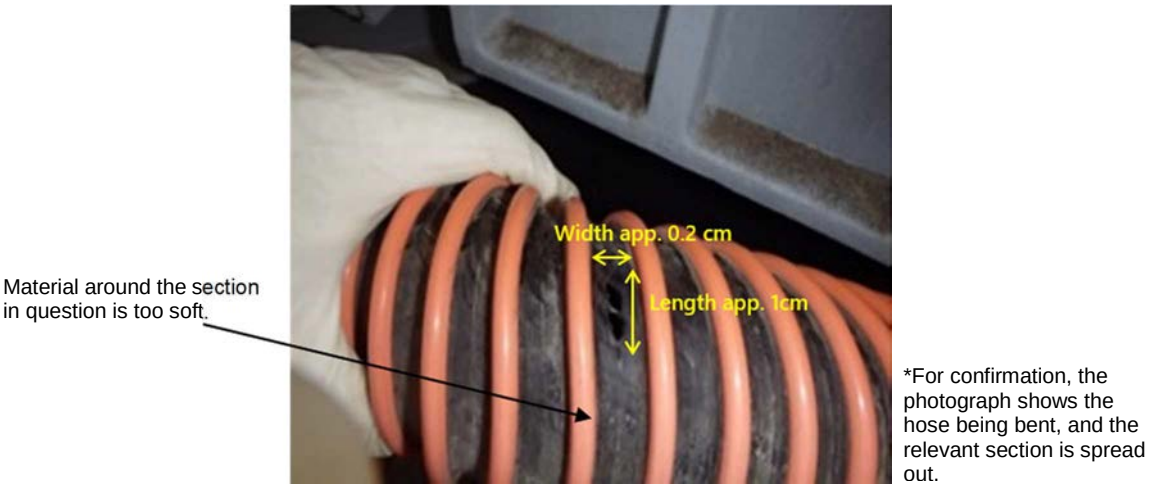


Figure 5. Specifications, structure and inspection results of the hose in question (Excerpt from the TEPCO report)

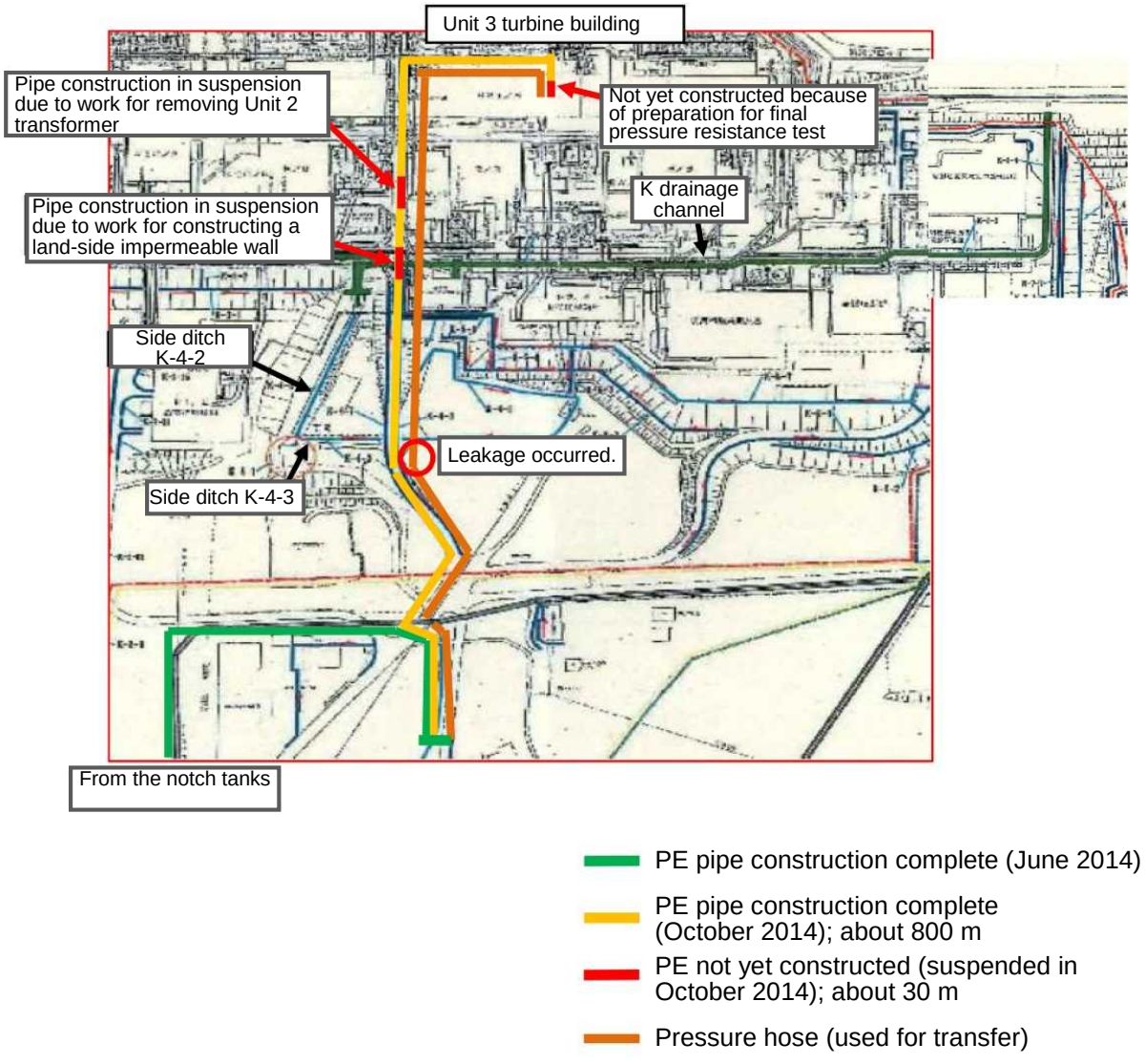


Figure 6. Situation of constructing PE pipes as of May 2015 (Excerpt from the TEPCO report, with partial revision)

Table 1. Results of inspecting similar sections (1) (excerpt from the TEPCO report)

(1) Category I: Pressure hoses for transferring high-concentration contaminated water (10^6 Bq/L or higher)

Location where a hose was used	Ongoing measures	Number and length of line(s)	Future measures
Transfer of water accumulated in seawater pipe duct	・Double tube method using a Sunny Hose ・Line check before using a pressure hose	4 lines (about 15 to 130 m)	Pressure hoses will be used until the remaining water transfer is complete, and will be removed thereafter.
Tank-to-tank connecting pipe	・Installed inside a dike, with connection valve in a “closed” state ・Heat insulating material already installed (to prevent ultraviolet degradation) ・Daily patrol	The number of line(s) depends on the number of tank(s) (about 1.2 m/unit).	Flexibility is necessary so pressure hoses will also be used in the future, but will be removed as the tanks are dismantled.
Transfer from underground storage tank to temporary notch tank	・Staffing of an administrator during water transfer ・Installation of receiving pan ・There were some places where weed prevention was inadequate, but because the line will no longer be used, this is no problem.	2 lines (about 45 m)	The lines are no longer used. The handling of water transferred from drain holes and detection holes to underground storage tanks is under review.
Line for transferring water remaining in a tank to an adjacent tank	・Installed inside the dike. Installation of receiving pan during water transfer ・Staffing of an administrator during water transfer ・Double tube method using a Sunny Hose	Temporary installation	Since the remaining water transfer is temporary work, pressure hoses will be used also hereafter.
Hoses for connection to and from RO equipment and advanced liquid processing system (ALPS) and drain hoses	・Installed inside building or dike ・Checked through daily patrol	ROs: 18 lines (about 2 m) Advanced liquid processing system (ALPS) Already installed: About 210 locations Additionally installed: About 100 locations High performance: About 110 locations	Pressure hoses are indoors, so weed growth, ultraviolet deterioration or damage from heavy machinery are not a concern. They will be used as permanent equipment also hereafter.
Hose connecting a submersible pump (for collecting water accumulated in a building) to a PE pipe	・Installed inside building ・Even in case of leakage, no outside leakage is anticipated because of vicinity to a pump	35 lines (about 10 to 50 m)	PE pipes cannot be directly connected to a submersible pump for collecting water accumulated in a building, so pressure hoses will be used also hereafter.
Water removal from high integrity container (HIC)	・Installed inside building and dike ・Installation of receiving pan during water transfer	One line (about 10 m)	Pressure hoses will be continuously used until permanent installation of water removal lines (scheduled for Feb. 2016).

The NRA has confirmed that major pressure hoses handling high-concentration contaminated water (10^6 Bq/L or higher) are adequately managed and used.

Even usable hoses, if not used in the future, will be removed according to schedule.

Table 1. Results of inspecting similar sections (2) (Excerpt from the TEPCO report)

(2) Category II: Pressure hoses (outside building and dike) for transferring other than high-concentration contaminated water

Hose Usage	Situation	Number of line(s)	Handling in the future	
Hoses for handling rainwater in contaminated water tank	Unusable lines*1	2 lines	Already removed on July 21	
	Lines usable but requiring improvement	99 lines	They will be used after improvement until replacement with PE pipes. *2	・Replacement with PE pipes The current plan is as follows: 1. Exceeding notice-based concentration ratio 0.22 (rainwater collection tank to treatment equipment) : Completion scheduled for the end of March 2016) 2. Exceeding notice-based concentration ratio 0.22 (inside dike to rainwater collection tank) Notice-based concentration ratio 0.22 or lower (excluding spray lines): Completion scheduled for the end of March 2017
	Lines not requiring improvement	4 lines	They will be used until replacement with PE pipes.	
Hoses other than the above (those for handling RO treated water, underground water, water leaked from underground storage tank, etc.)	Unusable line	0 line		
	Lines usable but requiring improvement	40 lines	Used after improvement or removed without being used (judged for each line)	・Partial replacement with PE pipes Currently-planned lines are those for underground storage tanks, drain holes, and drain holes to underground storage tanks (completion scheduled for the end of March 2016)
	Lines not requiring improvement	14 lines	Used further or dismantled without being used (judged for each line)	

* 1. Bends in the hose at the upper part of tank were significantly deformed due to weight.
* 2. When the use of hoses is inevitable before improvement, for example, to prevent overflow from dike during rainfall, they will be used after a patrol enhancement.

Inspection results of hoses for transferring high-concentration contaminated water outside of buildings and dikes found two unusable lines which were removed on July 21.

Regarding the other 139 lines, sections requiring improvement, such as those with inadequate bend radius, were found and improved (such as ensuring the allowable bend radius and curing for preventing water flow into the side ditch) with work being completed on October 27, 2015.

Even usable hoses will be removed according to schedule if they are not needed for future use.

* 1. A bend section deformed due to weight

Table 2. **Results of assessing exposure dose (Excerpt from TEPCO's document provided at the interview)**

Differences in worker exposure doses	Effective dose (gamma radiation) Annual dose limit: 50 mSv		Equivalent dose (skin) (beta radiation) Annual dose limit: 500 mSv		Number of persons per area access in a day (persons/day)
	Average dose per area access (mSv)	Maximum dose per area access (mSv)	Average dose per area access (mSv)	Maximum dose per area access (mSv)	
Results of patrolling around drainage channel K					
Before water transfer (May 22 to 26)	0.01	0.03	0.0	0.0	4.2
During transfer (May 27 to 29)	0.01	0.03	0.0	0.0	3.7
After leakage was found (May 30 to June 5)	0.01	0.05	0.0	0.0	3.4

Table 3 Schedule for completing each measure (Excerpt from TEPCO's document provided at the interview, with partial revision)

Cause		Contents of measures	Completion date
1	Damage to the hose in question	The hose will be replaced with a PE pipe reliably resistant to aging.	June 20, 2015
2	Installation of the hose in question in a side ditch	*Pressure Hose Management Guide* Among pressure hoses transferring contaminated water in the power plant site, those that may directly flow into a drainage channel will be provided with curing to isolate them from side ditch or to prevent side-ditch inflow. When it is impossible to carry out the above for any reason, a supervisor will be posted to check leakage every time contaminated water is transferred.	August 21, 2015
3	The hose in question was not yet inspected.	*Pressure Hose Management Guide* Temporary pressure hoses used for transferring contaminated water will be inspected according to the plan and when necessary repaired. Inspection plan and results will be managed according to the periodical inspection management table.	August 21, 2015
4	Process control for replacing the hose with a PE pipe	*Risk Management Meeting Administration Guide* Information on remedial construction activities, measures against nonconformities requiring risk management and construction feedback derived from comprehensive risk checks will be shared in risk management meetings as management enhancement and progress management. Construction activities will be prioritized to avoid mutual interference. Also regarding postponed construction activities, additional measures will be taken to minimize risk. *"Nonconformity Management and Corrective & Preventive Measure Guide"* and *"Nonconformity Management Meeting Administration Guide"* Non compliances judged necessary to be reported to meetings such as risk management meeting will be reported together with corrective measures.	August 17, 2015
5	Inadequate past leakage countermeasures and sharing of related information	"Nonconformity Management" To strengthen nonconformity management, knowledge and findings will be utilized to enable the sharing of information on the causes of and measures against past troubles in the organization. Lists classifying each event will be prepared to easily derive past similar nonconformities (including lessons learned and findings) from accumulated nonconformity data.	Scheduled for the end of March 2016
6	Prior check before transferring water from the underground storage tank to the notch tanks	*Pressure Hose Management Guide* To prevent environmental impact, when constantly transferring contaminated water inside the plant site (outside buildings), the radioactive concentration upper limit of contaminated water transferred using a pressure hose will be specified. Moreover, inspection frequency will be stipulated according to radioactive concentration.	August 21, 2015
7	Delay in detecting contaminated water leakage at drainage channel K	Continuous monitoring equipment will be installed at drainage channel K to detect abnormalities such as contaminated water inflow.	Scheduled for March 2016
8	Transfer of contaminated water from the 35 m foundation to the turbine building	Regarding contaminated water to be handled on the 35 m foundation, a system that can treat it on the foundation will be established, without transferring such water to the turbine building.	Since July 2015, designing and study for establishing the said system is ongoing.

Reference

Table. List of reports concerning accidents, failures, etc. at TEPCO's Fukushima Daiichi Nuclear Power Station – reports based on the provision of Article 62-3 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors

	Title	Date of occurrence	Report	Status quo
1	Leakage from contaminated water storage system's RO concentrate storage tank	August 19, 2013	June 30, 2014 Corrected on October 31, 2014	Discussed at the NRA December 10, 2014
2	Leakage from contaminated water storage system's RO concentrate storage tank	October 2, 2013	December 6, 2013 Corrected on October 31, 2014	Discussed at the NRA April 15, 2015
3	Leakage from contaminated water treatment system's desalination unit (reverse osmosis membrane unit) RO-3	October 9, 2013	December 6, 2013 Corrected on October 31, 2014	Discussed at the NRA April 15, 2015
4	Leakage from desalination unit's treated water transfer pipe double-strainer differential pressure indicator	February 6, 2014	June 30, 2014 Corrected on October 31, 2014	Discussed at the NRA April 15, 2015
5	Leakage from contaminated water storage system's RO concentrate storage tank (H6 area C1 tank)	February 19, 2014	January 23, 2015 Corrected on April 13, 2015	Discussed at the NRA April 15, 2015
6	Leakage of water accumulated in process main building into incineration workshop building	April 11, 2014	June 30, 2014 Corrected on December 12, 2014	Discussed at the NRA April 15, 2015
7	Leakage from 4,000-ton polygonal steel tanks	June 2, 2014	December 17, 2014 Corrected on April 20, 2015	Discussed at the NRA April 28, 2015
8	Malfunction of G4 south area A5-A6 tanks connection valve	September 4, 2014	April 28, 2015 Corrected on June 5, 2015	Discussed at the NRA June 17, 2015
9	Leakage from advanced liquid processing system (ALPS)'s treated water transfer pipe	December 17, 2014	June 3, 2015	Discussed at the NRA July 15, 2015
10	Generation of beta radiation concentration "high-high alarm" from on-site side ditch drainage radiation monitor (outflow of radioactive material from on-site drainage channel [drainage channel C] into the port)	February 22, 2015	July 3, 2015 Corrected on August 10, 2015	Discussed at the NRA September 2, 2015
11	Leakage via accumulated water transfer hose from 1,000-ton polygonal steel tanks to Unit 3 turbine building (leakage of radioactive material from on-site drainage channel into the port)	May 29, 2015	August 28, 2015 Corrected on December 16, 2015	Discussed at the NRA January 20, 2016
12	Leakage of in-dike rainwater from H4 north tank area's inner dike into outer dike	September 15, 2015	December 22, 2015	Under assessment