Evaluation of the report by Tokyo Electric Power Company regarding the leakage from piping transferring water treated at the Multi-nuclide Removal System (ALPS) at the Fukushima Daiichi Nuclear Power Station

Nuclear Regulation Authority
15 July 2015

1. Overview

At around 16:25 on December 17, 2014, when water treated at the Multi-nuclide Removal System (ALPS) (hereinafter referred to as "treated water") was being transferred to J6-A1 tank (hereinafter referred to as "the tank in question"), a worker who was monitoring the site found out the leakage of treated water from the end of piping under construction (Figures 1, 2 and 3). Because the opening of the piping was outside the dike for preventing leakage expansion, the leaked water (see Table 1) flowed out onto the ground (asphalt-paved and improved ground) near the piping opening and further into piping trench*[1] south of the leakage location (see Table 2). The piping trench was not connected to other trenches and the leaked water was accumulating inside it.

On the same day, the Nuclear Regulation Authority (NRA) received an accident and failure report pursuant to Article 62-3 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors from the Tokyo Electric Power Company (TEPCO).

Later, the NRA received a report concerning the causes of the event and countermeasures (final report), closely examined them and has compiled assessment results.

The report from TEPCO:
http://www.nsr.go.jp/activity/bousai/trouble/houkoku/2015_06_03.html

*[1] A gutter in which piping is installed and which is intended to bypass the road. The piping trench is not connected to other trenches.

2. Summary of the report submitted by TEPCO

(1) Investigation of impact on the environment (the expansion of the contaminated water)

The amount of leakage was estimated at about 6 m^3 at a maximum, judging from the transfer piping system flow rate (about 50 m^3/h) and transfer time (about 7 minutes from pump startup to shutdown). The leaked water was originally transferred from the ALPS sample tank C. The radioactive concentration of the treated water in the sample tank C was checked. Because total β*[2] level was 1.1×10^2 Bq/L and tritium level was 8.8×10^5 Bq/L (see Table 1), it was concluded that the amount of the radioactivity of the leaked water was about 6.6×10^5 Bq in terms of total β and about 5.3×10^9 Bq with tritium included.

The leaked water flowed onto the road, contaminated part of location where crushed stones and mound were laid (see Figure 3) and flowed into the piping trench, where it accumulated (see Figure 2). The water inside the piping trench and water accumulated on the ground (about 9 m^3) as well as earth and sand (about 5.7 m^3) contaminated by the leaked water were collected (see Figure 4).

*[2] Tritium is not included. The same shall apply hereinafter.

(2) Situation of treated-water transfer

① Preparation of the treated-water transfer manual

- The company's division in charge of contaminated-water transfer (hereinafter referred to as the "Equipment Management Division") was requested by a division managing the total amount of water stored in the tanks to transfer the treated water temporarily stored in a sample tank to the tank in question because the storage capacity of the sample tank was almost exceeded. On December 17, work for transferring the treated water into the tank in question was carried out. In the past, the Equipment Management Division had prepared a treated-water transfer manual every time before treated water was transferred to a newly-installed tank. Also this time, the Division has developed a transfer manual for the transfer work, which resulted in leakage.
- Because drawings indicating transfer route from the sample tank to the tank in question (hereinafter referred to as the "piping drawings") were necessary to prepare a transfer manual, the Equipment Management Division requested such drawings from the division in charge of tank installation work (hereinafter referred to as the "Construction Division"). However, the Construction Division had not prepared such drawings. Therefore, the Equipment Management Division obtained piping construction drawings that had been used for transfer-piping installation work instead.
- In the piping construction drawings, however, piping connections were divided, which made it difficult to grasp piping routes. Therefore, the Equipment Management Division, with advice from the Construction Division, prepared piping construction drawings in which transfer routes were clearly indicated using highlighters (hereinafter referred to as the "transfer route drawings") (see Figure 5). In so doing, however, the Equipment Management Division mistakenly judged that valve F765 was on a transfer route and prepared a transfer manual that required switchover of the valve F765 from "close" to "open." In fact, the valve F765 was located on a transfer route under construction and thus the procedure requiring the "open" operation of the valve F765 was wrong.

② Implementation of transfer

- Because the tank in question and part of the transfer piping were newly installed ones, the Equipment Management Division carried out the on-site check of the transfer route leading to the valve F765 on the basis of the prepared transfer manual before starting treated-water transfer. Because the valve F765 was located in the vicinity of the newly-installed transfer piping, the Division mistakenly judged that the valve F765 was on the transfer route as mistakenly indicated in the transfer manual. The Division failed to check transfer piping beyond the vale F765.
- Later, the Equipment Management Division judged that the system configuration for transferring the treated water was complete and activated the pumps to start treated-water transfer from the sample tank to the tank in question. As a result, a worker who was monitoring the site found treated water being transferred leaking from the opening of the transfer piping beyond the valve F765.
- Upon checking the site after the leakage occurred, the Equipment Management Division learned that the transfer piping connecting the sample tank to the tank in question branched in front of the valve F765, the valve F765 was located on the transfer piping under construction, the transfer piping beyond the valve F765 was under construction, thus in unconnected condition, and the end of the transfer piping was in an open state.

On the basis of the above, it was concluded that the manual used for the treated-water transfer was wrong, piping situation beyond the valve F765 (the fact that the transfer piping end was in an open state) was not checked before the start of the treated-water transfer and the gate valve (valve F765) leading to the piping under construction was opened based on the wrong transfer manual.

(3) Countermeasures

① Measure to correctly prepare a transfer manual (to prevent mistakenly recognizing transfer route):

Before the Equipment Management Division prepares a transfer manual for operating transfer piping used

for the first time after its construction is complete, the Construction Division shall prepare drawings clearly indicating piping routes and connections (piping system drawings [see Figure 6] or transfer route drawings) and submit them to the Equipment Management Division (implemented since February 13, 2015).

② Measure to ensure on-site check before starting treated-water transfer:
Before transferring treated water through transfer piping used for the first time after its construction is complete, the Equipment Management Division shall check whether the prepared transfer manual reflects actual transfer routes and the actual open or close condition of valves on the transfer routes by the time treated-water transfer starts and shall reflect the check results in the transfer manual (implemented since December 19, 2014).

③ Measure to avoid mistakenly opening a gate valve leading to piping under construction:
To avoid a gate valve between piping under construction and piping being used from mistakenly opened, the Construction Division shall close such a gate valve, manage its locking and provide it with a warning label (implemented since February 13, 2015) (see Figure 6).

3. NRA's evaluation of the report submitted by TEPCO and future measures

(1) Impact on the environment
No inflow of the leaked water to drainage channel was observed. The leaked water inside the piping trench was collected entirely. The earth and sand contaminated by the leaked water were also collected. No rainfall was observed during the period from the occurrence of the leakage until the collection of the contaminated earth and sand and workers in charge of monitoring checked the range of water expansion and the depth of wet earth and sand during the collection. No significant variation was observed regarding radioactive material concentrations in C drainage and the harbor in the vicinity of its discharge point after the leakage occurred (see Figures 7 and 8). Judging from the above, the NRA has concluded that the leaked water has not impacted drainage channels or the ocean.

(2) Exposure dose
Effective dose due to γ ray and equivalent dose to skin were checked for workers who had patrolled the J6 tank area (see Figure 3). As a result, the NRA has concluded that their radiation exposure was improbable.

(3) Countermeasures
On the basis of the causes of the event, TEPCO has completed the "measure for correctly preparing a transfer manual (to prevent mistakenly recognizing transfer route)," the "measure for ensuring on-site check before starting treated-water transfer" and the "measure to avoid mistakenly opening a gate valve leading to piping under construction." (See Table 4 and Table 5.)
Given the event having occurred this time, it cannot be concluded that TEPCO had properly carried out the requirement specified in the Implementation Plan III. Operational Safety of Specified Nuclear Facilities, Part 1, Chapter 2, Article 3 (Quality Assurance Program) 7, Work Planning and Implementation 7.1 Work Planning (3) b – namely "When planning work, the organization shall clarify the necessity of establishing processes and documents specific to work and Specified Nuclear Facilities and the necessity of the provision of resources." Therefore, the NRA judged the event as an implementation plan violation (requiring oversight) in the third quarter of FY 2014. During the fourth operational safety inspection in FY 2014 (February 24 to March 10, 2015), the NRA checked remedial actions taken after the implementation plan violation.
The NRA has checked the tank installation completion report and its preparation manual, operation manual for each system and equipment and carried out interviews. As a result, it has concluded that

TEPCO completed the measure for correctly preparing a transfer manual, the measure for ensuring on-site check before starting treated-water transfer and the measure for locking and labeling of gate valves under construction.
The NRA has evaluated that these measures are based on the analyses and assessment of the causes of the treated-water leakage and will be effective if properly implemented. Also in the future, the NRA is going to check by means of inspections such as operational safety inspections whether the planning and implementation of work required for quality assurance program will be carried out properly.

Layout drawing of the site (1F)

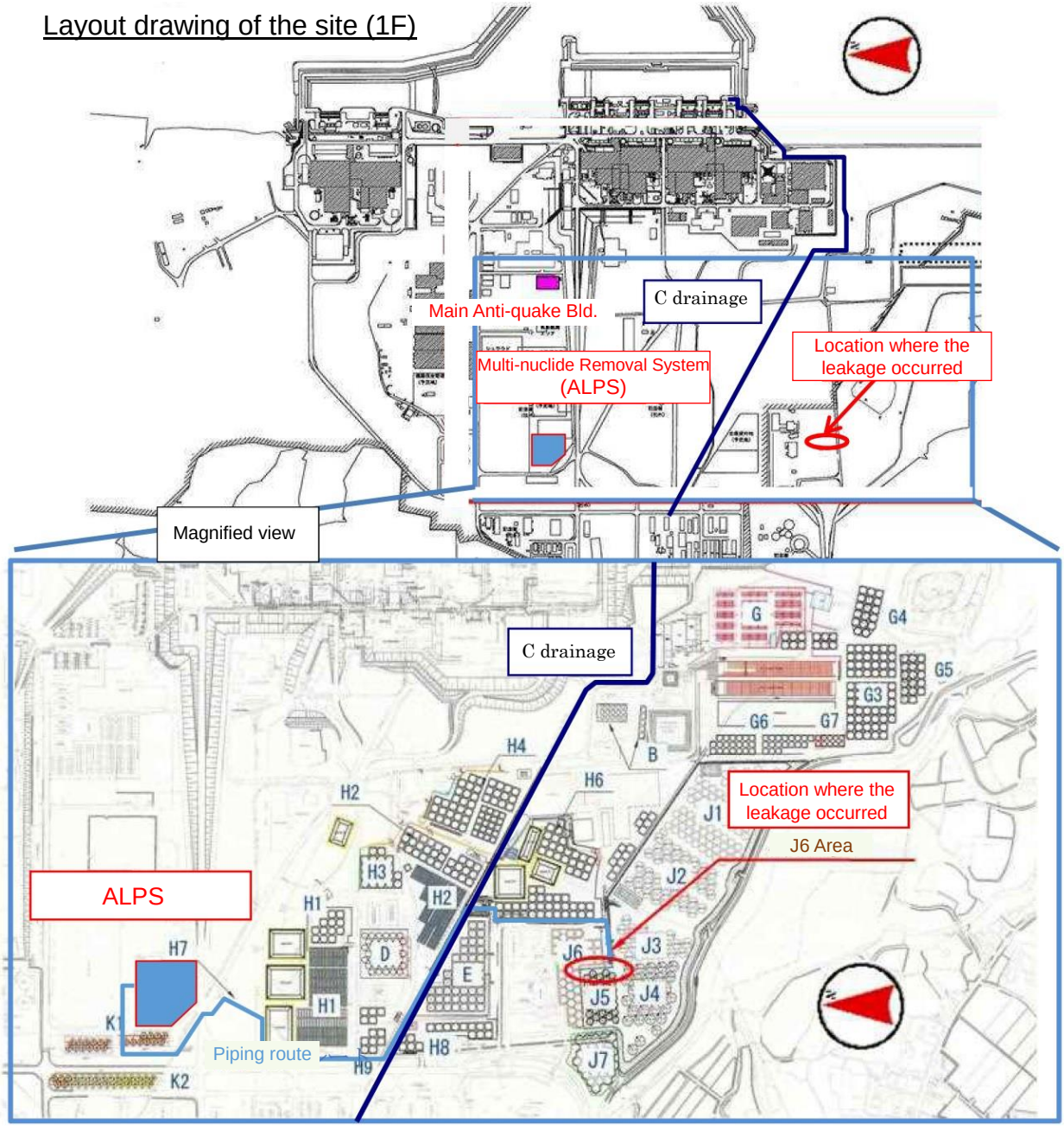


Figure 1. Layout drawing of J6 tank area *[3]

*[3]: Excerpt from a TEPCO report (partially revised)

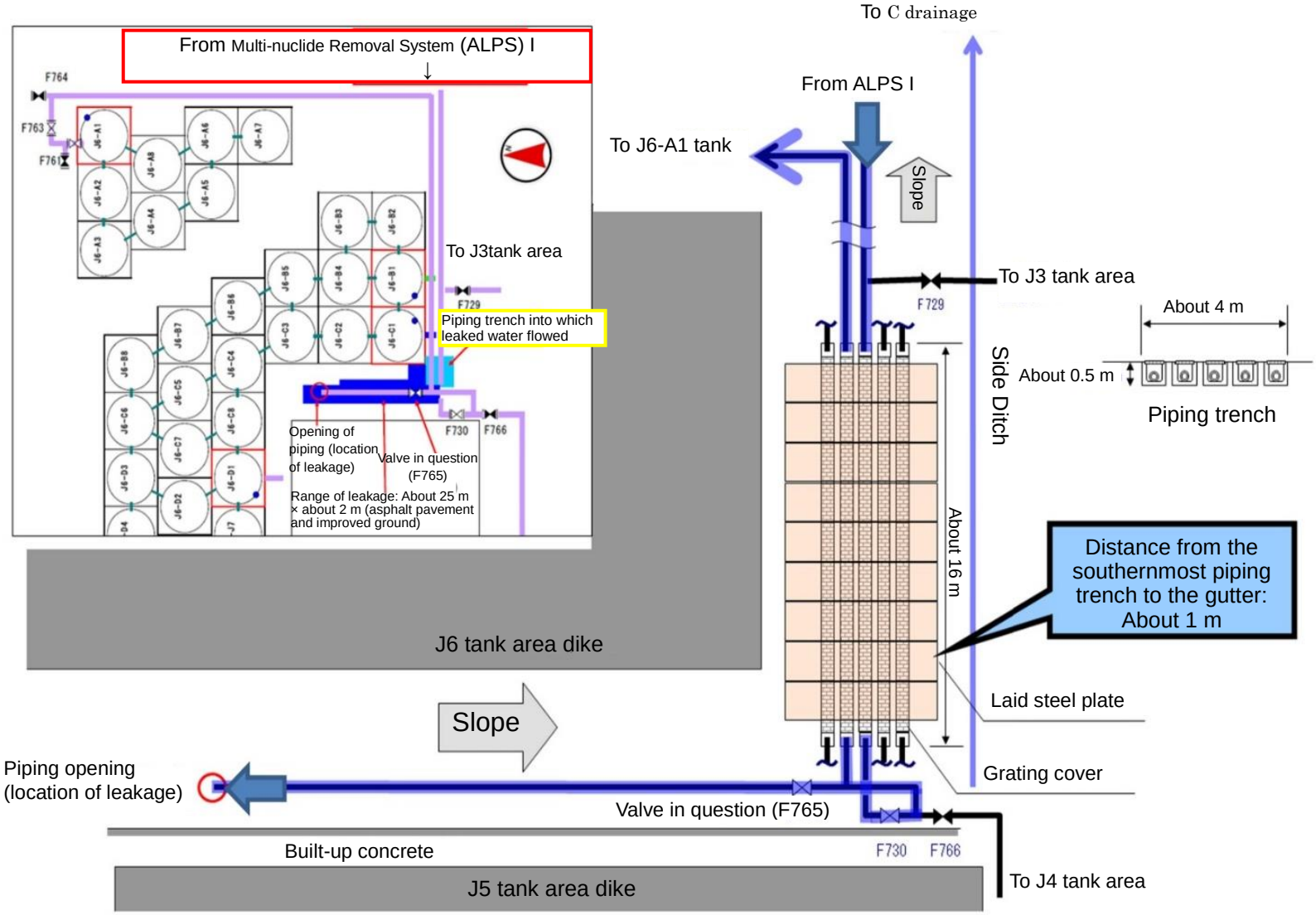


Figure 2. Schematic view of treated-water transfer piping*[4]

*[4]: Excerpt from a TEPCO report (partially revised)

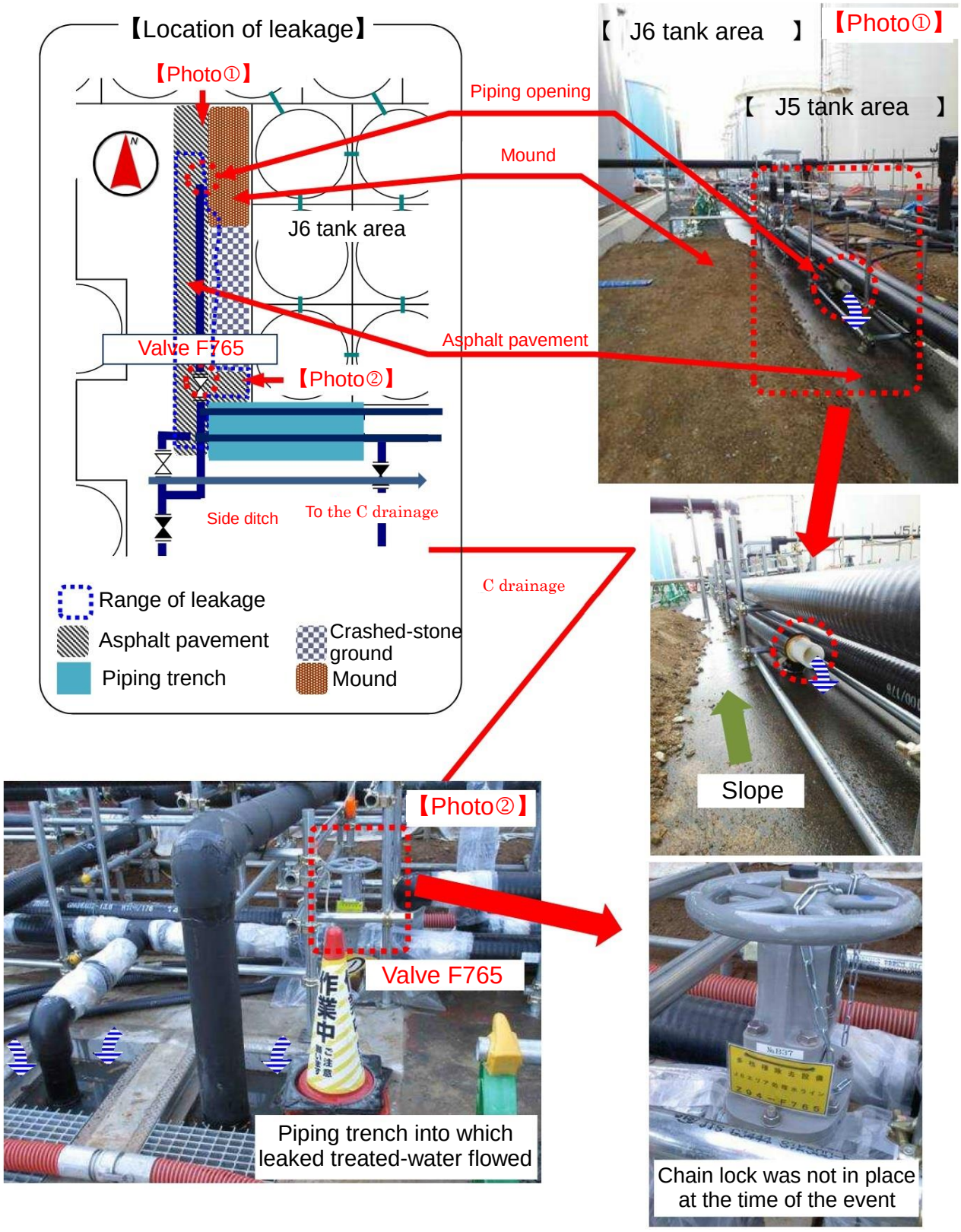


Figure 3. Situation of leakage on site*[5]

*[5]: Excerpt from a TEPCO report (partly revised)

Date of collecting earth and sand	Ground surface radiation dose (μSv/h) (maximum value)			Range of earth and sand collection
December 17 to 18	Before excavation	1 cm dose equivalent rate (γ ray)	8	About 2.4 m × about 15 m
	After excavation	1 cm dose equivalent rate (γ ray)	7	

During the collection of earth and sand

After the collection of earth and sand
(photographed from the opposite direction)

Figure 4. Collection of earth and sand*[6]

*[6]: Excerpt from a TEPCO report

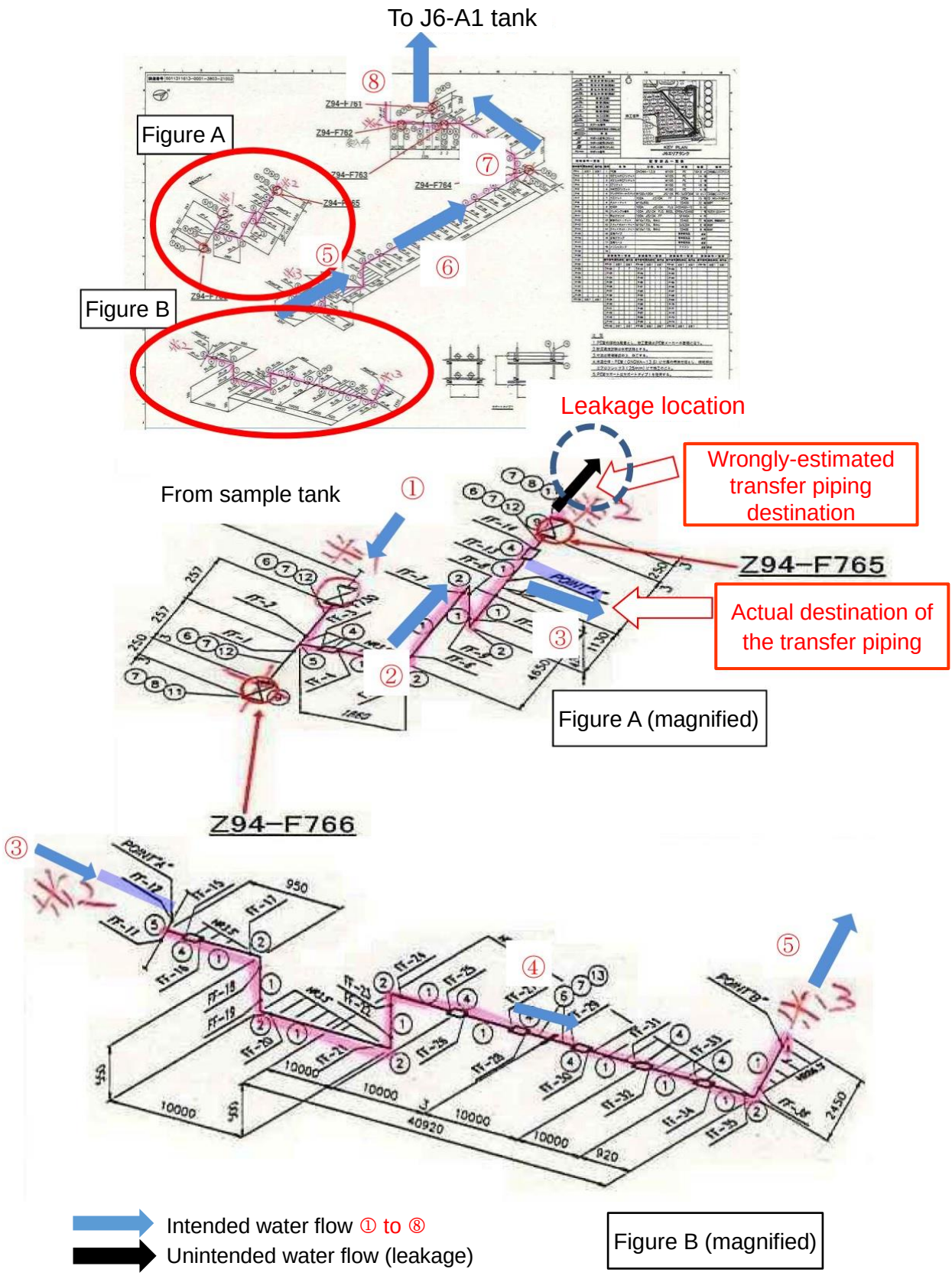
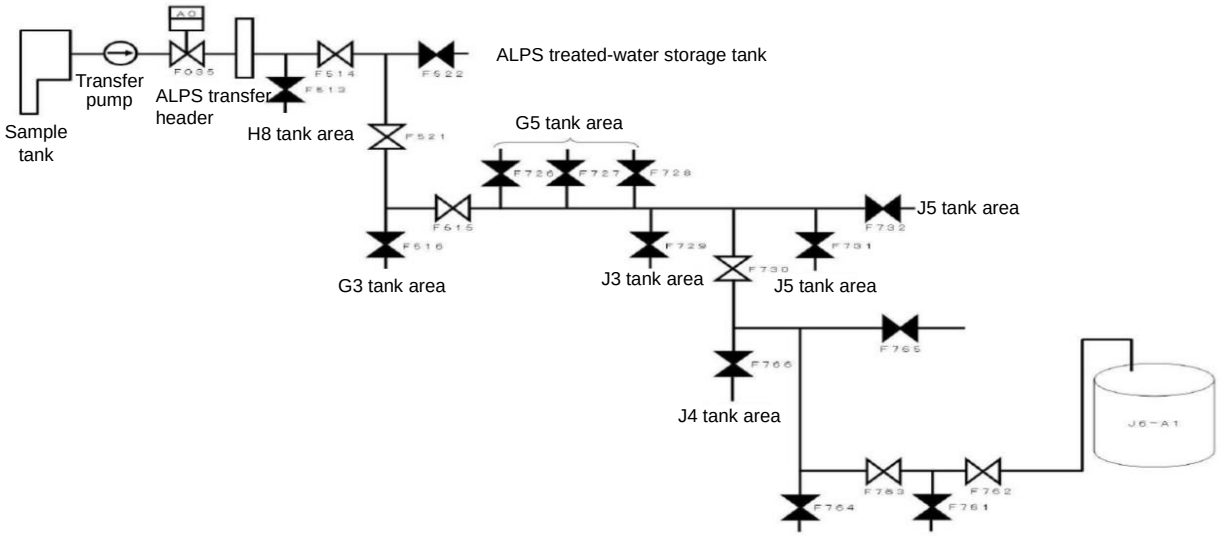


Figure 5. Treated-water transfer route map used during the preparation of the treated-water transfer manual*[7]

*[7]: Excerpt from a TEPCO report (partly revised)

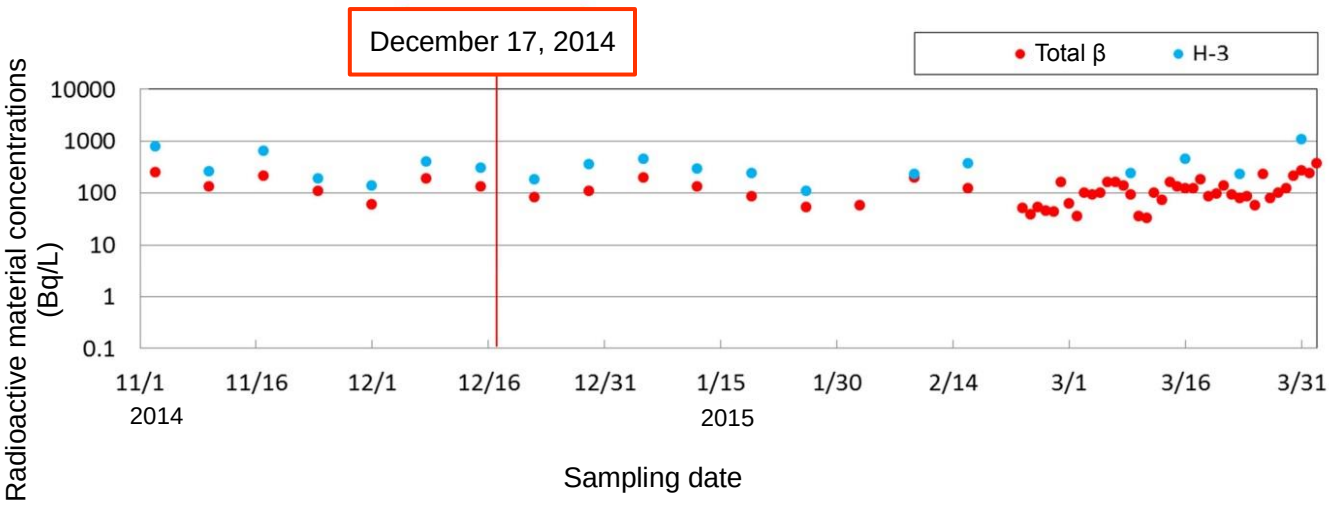
Drawing clearly indicating the piping routes and piping connections



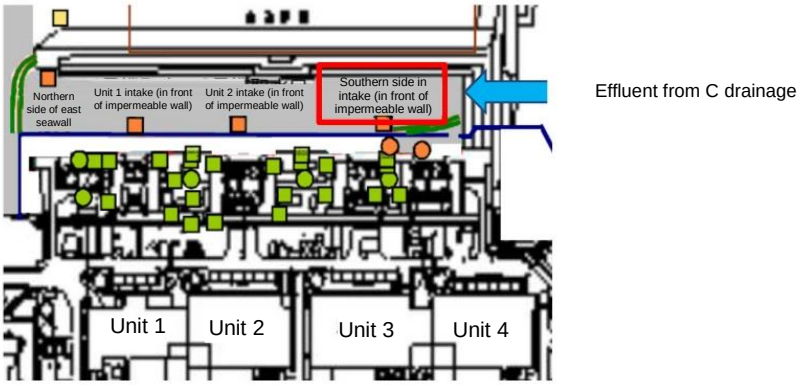
Locking and labeling of gate valves leading to piping under construction

Figure 6. Implementation of countermeasures*[8]

*[8]: Excerpt from a TEPCO report



(a) Concentrations of radioactive materials in seawater sampled at the southern side of the intake (in front of impermeable wall) (graph prepared by the Secretariat of the NRA on the basis of data from a report based on the Act on Special Measures Concerning Nuclear Emergency Preparedness, Article 25, Paragraph (2))



(b) Locations of seawater sampling (excerpt from a TEPCO document)

Figure 7. Concentrations of radioactive material in seawater after the leakage from the ALPS treated-water transfer piping

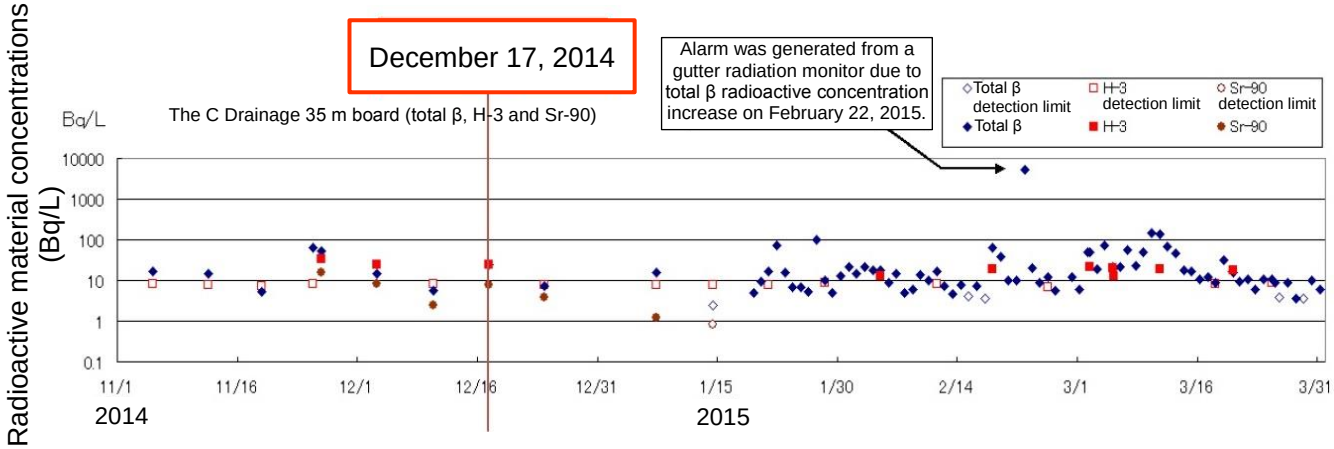


Figure 8. Concentrations of radioactive material in effluent sampled from C drainage before and after the leakage from ALPS treated-water transfer piping

Table 1. Results of analyzing the radioactive concentrations of treated water and leaked water*9

*9: Excerpt from a TEPCO report

Unit: Bq/L

Radionuclide	Treated water (sample tank C)	Stagnant water near the leakage location	Stagnant water inside the piping trenches*2
Cs-134	Less than detection limit (2.3×10^{-1})*1	4.3×10^{0}	Less than detection limit(1.5×10^{-1})*1 up to 4.8×10^{-1}
Cs-137	4.5×10^{-1}	1.4×10^{1}	1.2×10^{0} to 1.7×10^{0}
Total β	1.1×10^{2}	4.7×10^{1}	2.2×10^{0} to 6.6×10^{1}
Tritium	8.8×10^{3}	5.0×10^{5}	3.3×10^{2} to 3.8×10^{5}

*1: Value in the parenthesis indicates detection limit.

*2: Minimum and maximum values regarding five piping trenches are shown.

【Reference】

- The concentrations of Cs-134 and Cs-137 around the leakage location and in the stagnant water in the piping trenches are higher than those in the treated water. TEPCO has concluded that these higher concentrations are due to Cs-134 and Cs-137 released from the Fukushima Daiichi NPS accident to the environment.
- The concentrations of total β and tritium around the leakage location and in stagnant water inside the piping trenches have decreased compared with those in the treated water. TEPCO has concluded that they were diluted by being mixed with rainwater accumulated around the leakage location and in piping trenches.

Table 2. Situation of leaked water having flowed into piping trenches (excerpts from the secretariat of the NRA's document for a meeting with TEPCO)

■ Radioactive concentrations of leaked water inside piping trenches

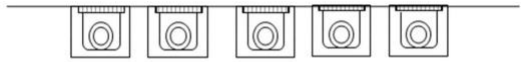
・Total β and tritium concentrations in piping trench ⑤ is lower than those in piping trenches ① to ④. Thus, TEPCO has estimated that the amount of leaked water flowed into trench ⑤ was small.

Radioactive concentrations of leaked water inside piping trenches (sampled on December 17)

Unit: Bq/L

Radionuclide	Piping trench ①	Piping trench ②	Piping trench ③	Piping trench ④	Piping trench ⑤
Cs-134	4.8×10^{-1}	3.1×10^{-1}	Less than detection limit (1.5×10^{-1})*1	Less than detection limit (1.6×10^{-1})*1	4.7×10^{-1}
Cs-137	1.6×10^{0}	1.3×10^{0}	1.2×10^{0}	1.7×10^{0}	1.6×10^{0}
Total beta	4.0×10^{1}	3.2×10^{1}	6.2×10^{1}	6.6×10^{1}	2.2×10^{0}
Tritium	2.1×10^{5}	1.5×10^{5}	3.8×10^{5}	3.7×10^{5}	3.3×10^{2}

*1: A value in each parenthesis indicates detection limit.



Piping trenches (northern side) ① ② ③ ④ ⑤ (southern side)

■ Site situation:

- The piping trenches are independent from one another and not connected to any side ditch.
- In piping trenches ① and ②, water accumulated almost to the fullest.
- No water flow into the gutter south of piping trench ⑤ was observed.

Judging from the above, TEPCO has concluded that, although the leaked water flowed into piping trenches ① to ⑤, it has not reached any side ditch.

Table 3. Assessment of radiation exposure doses
(Excerpt from the Secretariat of the NRA's document on the basis of interviews for a meeting with the TEPCO)

	Effective doses (γ ray)		Equivalent doses (skin) (β ray)	
	Annual dose limit: 50 mSv		Annual dose limit: 500 mSv	
	Average dose per access (entry) [mSv]	Maximum dose per access [mSv]	Average dose per access [mSv]	Maximum dose per access [mSv]
Before leakage was found (Dec 10 to 16)	0.01	0.05	0.0	0.1
The day the leakage was found (Dec 17)	0.02	0.06	0.0	0.0
After the leakage was found (Dec 18 to 24)	0.01	0.04	0.0	0.0

Table 4. Measures against leakage of water treated at the ALPS, found in J6 tank area
(excerpt from the Secretariat of the NRA's document on the basis of interviews for a meeting with the TEPCO)

Countermeasures	Date when the countermeasures completed
(1) Measure for preparing an appropriate treated-water transfer manual so as not to wrongly recognize treated-water transfer route: Before the Equipment Management Division prepares the treated-water transfer manual concerning transfer piping used for the first time after the completion of construction, the Construction Division shall prepare drawings clearly indicating piping routes and connections and submit them to the Equipment Management Division. Document in which the above countermeasure is to be specified: Document in the Construction Division, *Preparation Manual on a Tank Installation Completion Report*	Ongoing since Feb 13, 2015
(2) Measure for ensuring on-site check before starting the transfer of treated water: Before transferring treated water by using a transfer pipe used for the first time after the completion of its construction, site check shall be performed to ensure that no inconsistency exists between the prepared treated-water transfer manual and the actual transfer routes and the open/close condition of valves located on the transfer routes. The results shall be reflected in the manual. Manuals in which the above countermeasure is to be specified: Basic manual (secondary manual): DA-57 (decommissioning basic manual) Work manual (tertiary manual): DA-57 and 1F-W2-001 (Water Treatment Division's manual for operating and maintaining equipment for treating accumulated water of high-level radioactivity) Related manual and guide: DA-57 and 1F-W2-001-10 (Work manual concerning each equipment for treating accumulated water of high-level radioactivity)	Ongoing since Dec 19, 2014
(3) Measures for preventing the accidental activation of gate valve (sluice valve) connected to the piping under construction: To prevent the gate valve between the piping under construction and the currently-operated piping from being mistakenly activated, the Construction Division shall close and lock the gate valve and provide it with a warning label. Document in which the above measures are to be specified: Document in the Construction Division, *Preparation Manual on a Tank Installation Completion Report*	Ongoing since Feb 13, 2015

Table 5. Improvements after the implementation of the countermeasures (excerpt from the Secretariat of the NRA's document on the basis of interviews for a meeting with the TEPCO)

Contents of the measures	Before implementing the measures	After implementing the measures
Measure for preparing an appropriate treated-water transfer manual (to prevent the false recognition of transfer routes)	- The previous manuals failed to clearly stipulate that the Construction Division must prepare "drawings clearly indicating piping routes and piping connections" *[1] (piping system drawings*[2] and transfer route drawings*[3]).	- The Construction Division has prepared "drawings clearly indicating piping routes and piping connections" and provided them to the Equipment Management Division. - The Equipment Management Division has prepared the "treated-water transfer manual"*[4] based on the drawings prepared by the Construction Division.
Measures for ensuring on-site check before starting the transfer of treated water	- The Equipment Management Division failed to clearly obligate the advance on-site check of the transfer piping in the previous transfer manuals. - Therefore, the Equipment Management Division failed to check the entire transfer routes on site.	-The Equipment Management division has specified in the treated-water transfer manual that the advance check of transfer routes must be carried out before starting treated-water transfer. - In accordance with the transfer manual, the Equipment Management Division shall check the entire transfer routes on site before starting treated-water transfer using newly installed piping or rarely used piping.
Measures for preventing the accidental activation of gate valve (sluice valve) leading to the piping under construction:	- The Construction Division failed to ensure lock management.	- On the basis of the *Preparation Manual on a Tank Installation Completion Report*, the Construction Division shall ensure lock management.

* [1.] Drawings clearing indicating piping routes and piping connections:
Drawings prepared by the Construction Division, namely piping system drawings. When such drawings are not available, transfer route drawings in which routes are clearly indicated using a marker shall be used.

* [2]. Piping system drawings:
Drawings used by the Construction Division to clarify the piping system

* [3.] Transfer route drawings:
Drawings prepared when the Construction Division cannot prepare piping system drawings and used to identify transfer routes using pens such as highlighters.

* [4.] Treated-water transfer manual
Manual developed by the Equipment Management Division to specify transfer procedures

Table. Accident reports by the Tokyo Electric Power Co.'s Fukushima Daiichi Nuclear Power Station pursuant to Article 62-3 of the Act on the Regulation of Nuclear Source Material, Nuclear Fuel Material and Reactors

Event	Date of occurrence	Report	Current status
"High-high alarm" indicating a high β ray concentration, which alarm was generated by the on-site side ditch effluent radiation monitor (outflow of radioactive materials from on-site C drainage into the harbor)	Feb 22, 2015	Received on July 3, 2015	Under evaluation
Leakage from 1,000-ton steel square tank cluster to Unit 3 turbine building via transfer hose (leakage of radioactive materials from on-site drainage channel into the port)	May 29, 2015	Not yet received	