Reference
1

The Activity Status of the “Emergency Response Headquarters for Reliability Improvement at Fukushima Daiichi Nuclear Power Station”

May 16, 2013

Tokyo Electric Power Company

東京電力

TEPCO

1. Structure

- The HQ was established on April 7 as an emergency measure under TEPCO's Risk Management Committee.
- Under the command of senior management, the HQ compiles measures for improving the reliability of facilities for maintaining and strengthening plant stability at Fukushima Daiichi NPS as well as their administration and management, and conduct coordination work for the measures' swift implementation.
- The members consist of relevant executives, general managers and superintendent.
- Countermeasures teams for various categories are set up under the HQ. Each of the teams is joined by site managers and members of non-nuclear divisions (Transmission, Distribution, Thermal Power departments, etc.) to make cross-functional companywide efforts.
- The HQ has convened 9 times so far.

Risk Management Committee

<u>Emergency Response HQ for Reliability Improvement at Fukushima Daiichi NPS</u>

Chief : President

Deputy Chiefs: Executive Vice Presidents (Yamaguchi, Aizawa and Ishizaki)

Members: Relevant management executives, general managers and superintendent

- Contaminated Water Countermeasures Team
- Mechanical Equipment Countermeasures Team
- Electrical Equipment Countermeasures Team
- Civil Engineering and Construction Equipment Countermeasures Team
- Safety Response Team
- Information and Communication Team

2-1. Overview of HQ activities

- Policy of HQ activities

  Implementing initiatives based on the "Action Plan concerning Reliability Improvement Measures" as well as thorough reliability improvement activities under the following policies:

  - Ensuring that there is no functionality loss for fuel cooling facilities (RPV / RCV coolant injection facilities, spent fuel cooling facilities, shared pool cooling facilities, nitrogen gas injection facilities, RCV gas management facilities)
  - Ensuring that no additional radioactive materials are released into the environment outside the NPS site
  - Ensuring that no fires break out
  - Ensuring that there is no power outage to important-to-safety facilities

- Action items
  - Conducting thorough on-site investigations to identify facility risks and administration issues
  - Implementing a variety of countermeasures including the use of external perspectives

- Action description

  Each of the teams explored and implemented further actions on issues identified based on potential risks, confirmed in on-site investigations.

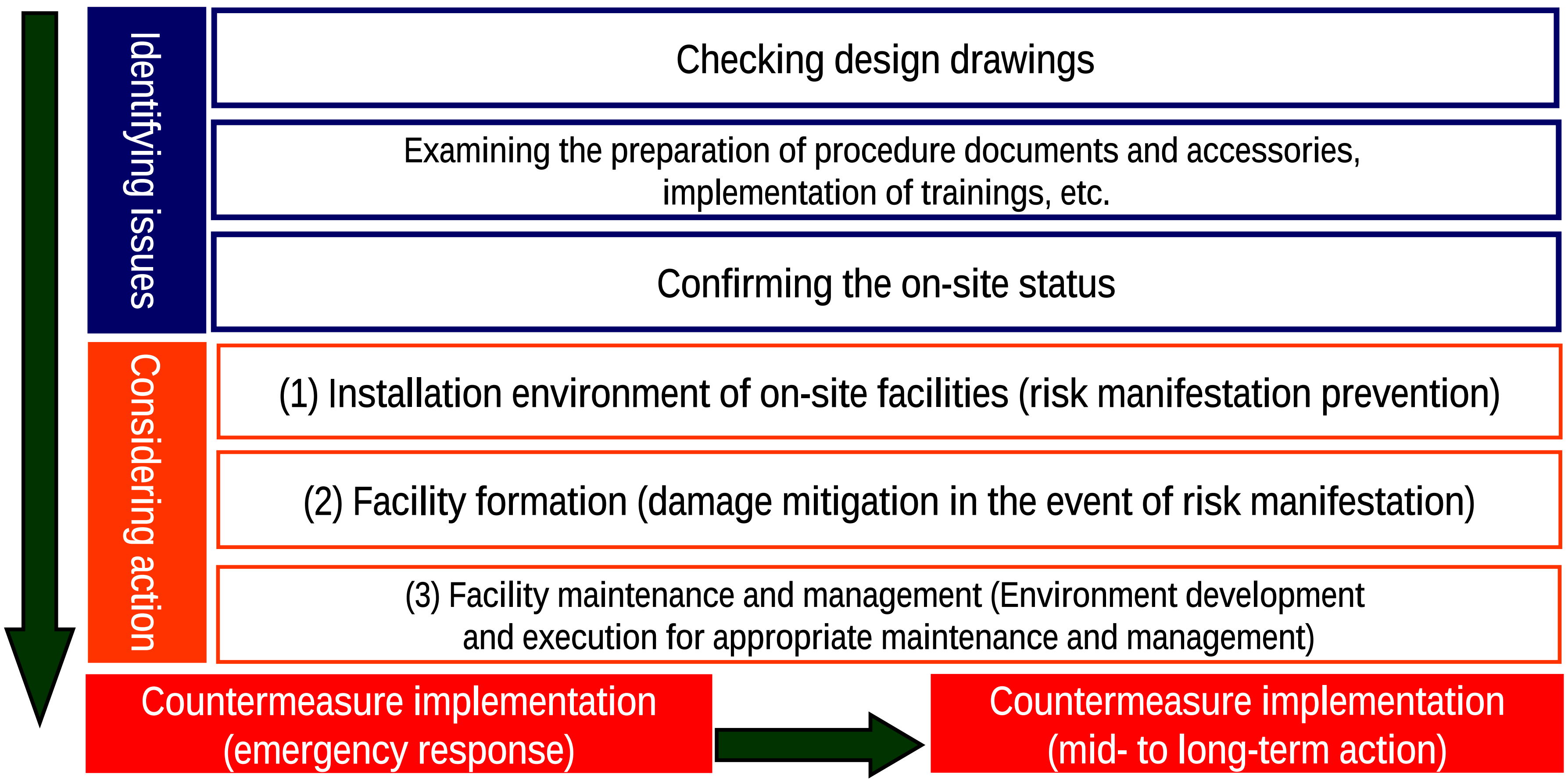
2-2. Implementation Steps

- Each of the countermeasures teams generally follows the steps below to identify on-site issues and consider actions.
- Three types of countermeasures

  (1) Countermeasures concerning the installation environment of on-site facilities, designed to prevent risks from manifesting

  (2) Countermeasures concerning the formation of on-site facilities, designed to mitigate damage if risks manifest

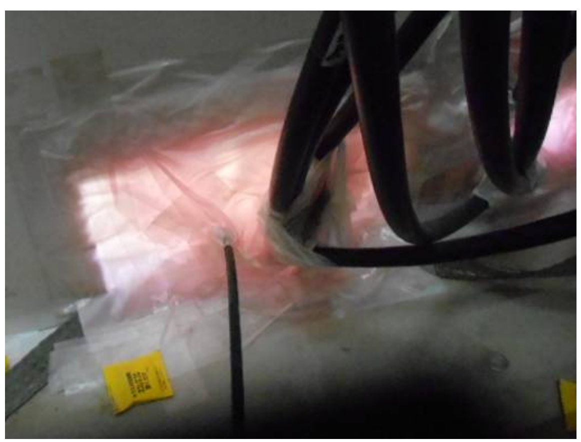
  (3) Countermeasures concerning the maintenance and management of on-site facilities, designed to develop an environment that enables appropriate maintenance and management



3. Emergency response (e.g. blocking small animals)

- Emergency responses that can be performed immediately have already been implemented.

Response result at Section A



Response result at Section B

Action taken in April 2013

4. Main issues identified this time and their countermeasures (1)

- Each of the countermeasures teams has identified issues and moved on to exploring actions (some emergency responses already taken) ⇒ See the reference.

Issues and actions / Team	Reference	Issues	Action examples
Contaminated Water Countermeasures Team	1	Insufficient protection for the contaminated water transfer facility at the location crossing a road, etc.	Installing guardrails
	2	Insufficient protection for the cover on water level gauge cables	Installing a protection cover
	3	Gaps at the low-voltage power panel and equipment control panel, large enough to allow entry to small animals	Installing covers for blocking small animals
Electrical Equipment Countermeasures Team	4	Reactor coolant injection facility's electrical system containing equipment that cannot have grounding detected	Installing a ground fault interrupter on the required circuit
	5	Gaps at the penetration of electrical panel cables for SFP cooling alternative facilities, large enough to allow entry to small animals	Curing the penetration to block small animals
Mechanical Equipment Countermeasures Team	6	Corrosion of some pipes / valves at reactor coolant injection facilities	Correcting pipe supports as a short-term measure and replacing the pipes / valves as a long-term measure
	7	Concern of vehicle collision / scrape for nitrogen gas injection facilities	Installing barriers such as guardrails
	8	Tilting with some pipe supports for RCV gas management facilities	Modifying the structures for reinforcement
	9	Potential delay in starting standby units for SFP cooling facilities in the case of failure	Reviewing the storage method for standby units during winter months

4. Main issues identified this time and their countermeasures (2)

Issues and actions / Team	Reference #	Issues	Action examples
Civil Engineering and Construction Equipment Countermeasures Team	**10**	Possible fall of damaged building materials to damage pipes and cables, and possible building damage to compromise cable support materials	Providing protection on / removing applicable pipes and cables, and adding support materials
	11	Insufficient maintenance inspections on emergency power supply facilities at the important anti-seismic building	Using in-house knowledge to step up maintenance and inspection of generators
Safety Response Team	**12**	Failure to fully observe 5S (organization, tidying, sanitation, cleaning, discipline) on site in some cases (construction tools / materials left unattended, etc.)	Instructing contractors to correct the practice according to rules demanded in the specifications, and checking the correction status
	13	Failure to fully observe basic action / safety rules on site in some cases (failure to use a safety belt / hook while working at an elevated location, etc.)	Instructing contractors to observe basic action / safety rules and checking for improvement
	14	Failure to fully cover open flames or charged surfaces on site in some cases (sparks seen flying from insufficiently covered locations during outdoor work involving open flames in strong winds)	Instructing contractors to observe rules demanded in the specifications, and checking the correction status

∗The Information and Communication Team has identified issues through examining past cases, and is exploring measures for achieving timely and appropriate information disclosure.

(Reference 1)

Preventing damage to contaminated water transfer facilities(at road-crossing locations, etc.)

Objectives	Preventing the loss of the water treatment function attributable to facility failure (including power outage)
Subject facilities	Contaminated water transfer facilities (at road-crossing locations, etc.)
Countermeasure type	Improving the site's installation environment (preventing risk manifestation)

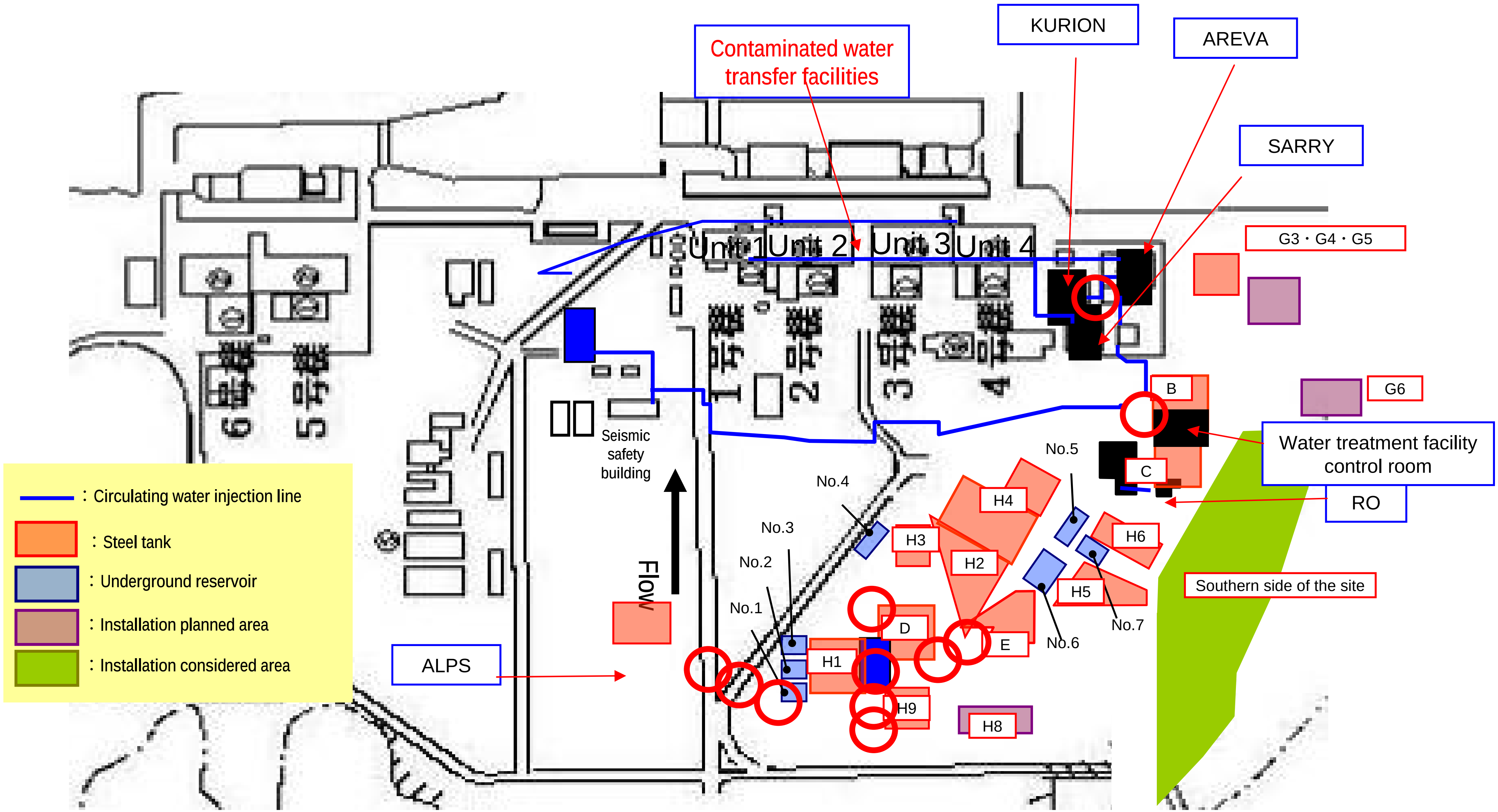
Tasks	Contaminated water transfer facilities had areas with no protection (e.g. guardrails) at locations where they are crossing a road or running near a road. A car accidentally driving into such a location could damage the facility and suspend the transfer of contaminated water, potentially losing the water treatment function. (There is also a risk of contaminated water leaking into surrounding soil.)
Countermeasures	Install makeshift guardrails, etc. at applicable locations to raise caution to passing vehicles and protect the facilities from damage at the same time. There are 12 locations that require countermeasures, according to on-site checks so far. Start the countermeasures from locations exposed to frequent traffic of large vehicles for completion by around the end of July.

Schedule	2013			
	May	June	July	August
Investigating and formulating countermeasures	Identifying applicable locations and determining priority order			
		Contract procedure		
Implementing countermeasures		Emergency action		
			Implementing countermeasures	

Example of a location requiring action (H1 – H9 areas)

【Reference 1: Supplementary information】
Locations requiring action

○: Applicable locations



Contaminated Water Countermeasures Team: Example 2

(Reference 2) Preventing damage to water level gauge cables

Objectives	Preventing damage to water level gauge cables
Subject facilities	Water treatment facilities
Countermeasure type	Improving the site’s installation environment (preventing risk manifestation)

Tasks	There are locations where the cables for reservoirs’ / tanks’ water level gauges are not in protective covers (Eflex pipes). Any damage to the cable could lead to overflow.
Countermeasures	Install protective covers to prevent the cables from becoming exposed. A total of four locations were identified in on-site check, to be addressed by the end of August 2013. In the mid- to long-term, consider adopting redundancy to water level gauges for tanks that make up a large circulation system.

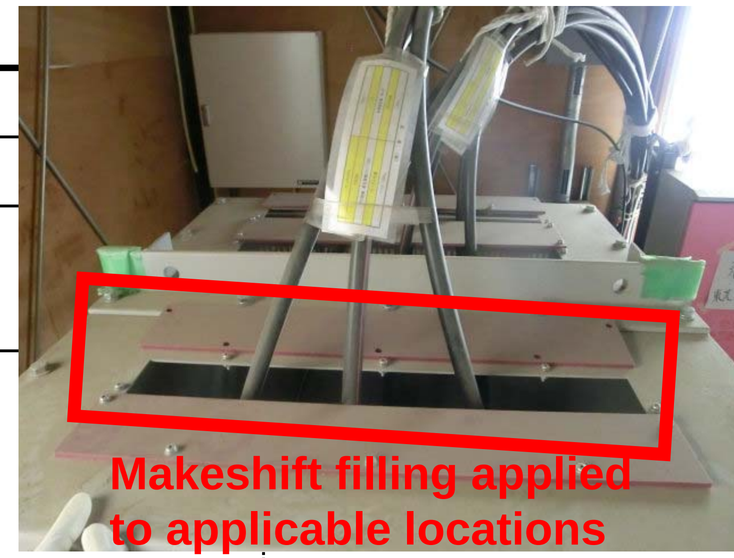
Schedule	2013				
	May	**June**	**July**	**August**	September
Investigating and formulating countermeasures		Identifying applicable locations			
Implementing countermeasures		Ordering materials for gradual delivery	Implementing countermeasures		

(Reference 3) Preventing the loss of functionality for water treatment facilities

Objectives	Preventing damage to mechanical control panels from small animals
Subject facilities	Water treatment facilities
Countermeasure type	Improving the site's installation environment (preventing risk manifestation)

Tasks	There are gaps at the low-voltage switchboards and equipment control panels, large enough to allow entry to small animals.
Countermeasures	Install covers for blocking the entry of small animals. Fill the openings with sealant that rodents hate. A total of 18 cases have been identified in on-site check, to be addressed by the end of September 2013.

Schedule	2013				
	May	June	July	August	September
Investigating and formulating countermeasures	Identifying applicable locations				
Implementing countermeasures		Ordering materials for gradual delivery			
	Emergency action				
				Implementing countermeasures	



(Reference 4) Preventing the loss of functionality for reactor coolant injection facilities

Objectives	Preventing the loss of functionality for fuel cooling facilities
Subject facilities	Reactor coolant injection facilities
Countermeasure type	Facility formation (damage mitigation in the event of risk manifestation)

Tasks	There are electrical loads with no ground fault interrupter, leaving some facilities unable to have grounding detected. Poor sensitivity settings for detecting ground fault could allow an upstream interrupter to activate first, causing the shutdown of reactor coolant injection facilities.
Countermeasures	Install ground fault interrupters to necessary circuits. Check the three sides of distribution panels to identify locations for installing ground fault interrupters. Complete the action by March 2014.

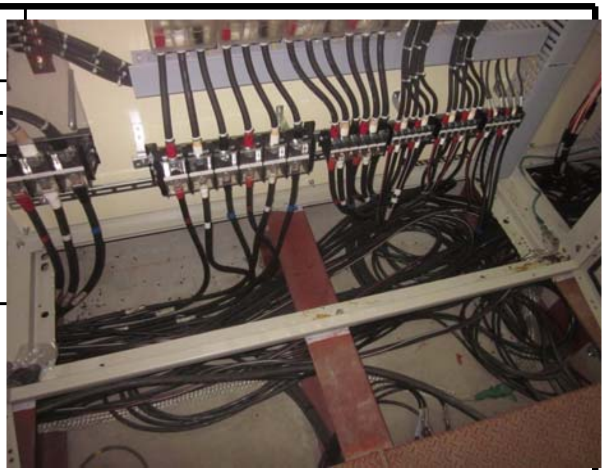
Schedule	2013						2014
	May	**June**	**July**	**August**	September	**October -**	**January -**
Investigating and formulating countermeasures			Identifying applicable locations and determining priority order				
Implementing countermeasures					Ordering materials for gradual delivery		Implementing countermeasures

(Reference 5) Preventing the loss of functionality for SFP alternative cooling facilities

Objectives	Preventing the loss of functionality of fuel cooling facilities
Subject facilities	SFP alternative cooling facilities
Countermeasure type	Facility maintenance and management (Environment development and execution for appropriate maintenance and management of facilities)

Tasks	The gaps at the penetrations for power panel cables allow small animals to enter inside, potentially causing a short-circuit / grounding, suspending power supplies to SFP alternative cooling facilities and halting the cooling function for SFP.
Countermeasures	Cover the penetration locations to prevent small animals from reaching power panels. A total of 56 locations have been identified in on-site check as locations that could allow the entry of small animals. Tentative sealing has been performed as emergency response in April. More permanent action is to be applied by August.

Schedule	2013					
	April	**May**	**June**	**July**	**August**	September
Investigating and formulating countermeasures			Identifying applicable locations and	determining priority order		
Implementing countermeasures	Implementing temporary countermeasures			Implementing countermeasures	Ordering materials for gradual delivery	



(Reference 6) Preventing the loss of functionality for reactor coolant injection facilities

Objectives	Preventing the loss of functionality for reactor coolant injection facilities
Subject facilities	Reactor coolant injection facilities
Countermeasure type	Installation environment of on-site facilities (risk manifestation prevention)

Tasks	The corrosion of feedwater system's pipes and valves at Units 2 and 3 could cause leakage from flange joints. Chain blocks are used to support pipes.
Countermeasures	Correct pipe supports at the two locations as a short-term measure, and replace the pipes and valves as a long-term measure.

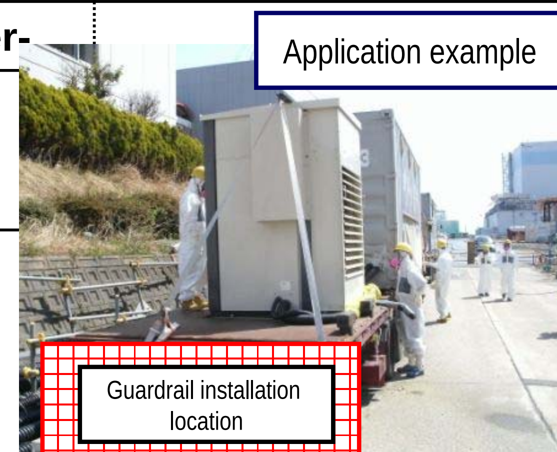
Schedule	2013										
	May	June	July	August	September	October	November	December	January	February	March
Correcting pipe supports (short term measure)	■										
Installing replacement pipes and valves (long term measure)	Considering installation	Considering installation									
			Procuring materials	Procuring materials	Procuring materials	Procuring materials	Procuring materials	Procuring materials			
									Installation		

(Reference 7) Preventing the loss of functionality for nitrogen gas injection facilities

Objectives	Preventing the loss of functionality for nitrogen gas injection facilities
Subject facilities	Nitrogen gas injection facilities
Countermeasure type	Improving the site's installation environment (preventing risk manifestation)

Tasks	Nitrogen gas separators A, B and C and makeshift IA air compressors (2 electricity-driven units and 2 D/G-driven units) have equipment and supply lines in locations facing roads or car park. If a vehicle crashes into or comes in contact with such a location, the facilities become damaged and shut down, potentially suspending the injection of nitrogen gas into the reactors.
Countermeasures	Install barriers such as guardrails and concrete blocks to prevent vehicles from directly crashing into the facilities. Apply this measure to the nitrogen gas separators A, B and C and makeshift IA air compressors (electricity- and D/G-driven units) (7 units in total). Complete the measures by the end of August 2013.

Schedule	2013					
	May	**June**	**July**	**August**	September	**October-**
Investigating and formulating countermeasures	Identifying applicable locations and determining priority order					
Implementing countermeasures		Ordering materials for gradual delivery		Implementing countermeasures		



(Reference 8)

Preventing the discharge of additional radioactive materials from RCV gas management facilities

Objectives	Preventing the discharge of additional radioactive materials beyond site boundaries
Subject facilities	RCV gas management facilities
Countermeasure type	Improving the site’s installation environment (preventing risk manifestation)

Tasks	Some pipe supports at Unit 2 have become tilted, possibly from external force. Leaving the supports in the tilted state could concentrate the load on flexible parts, potentially resulting in leakage.
Countermeasures	Remove the tilted supports and review the structure for reinforcement, e.g. changing the foundation structure from the screw-on system to the anchored system. Check the applicable locations and repair tilted supports at around ten locations (to be completed by the end of June).

Schedule	2013				
	May	**June**	**July**	**August**	September
Investigating and formulating countermeasures	Identifying applicable locations and determining priority order				
Implementing countermeasures	Ordering materials for gradual delivery Implementing countermeasures				

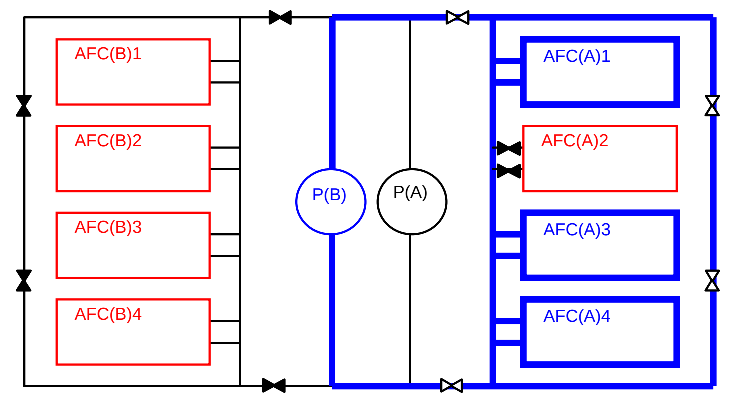
(Reference 9)

Shortening the startup time for the standby air fin cooler system at Units 1 / 4

Objectives	Preventing the loss of functionality for fuel cooling facilities
Subject facilities	SFP cooling facilities
Countermeasure type	Facility formation (damage mitigation in the event of risk manifestation)

Tasks	The standby air fin cooler system at Units 1 / 4 are in dry lay-up to prevent freezing in winter months. If any issue develops with an operational air fin cooler, restoring the functions of the standby system requires substantial time, as the procedure must start from filling it with water.
Countermeasures	Since antifreeze solution is already added to prevent freezing, place the standby systems to wet lay-up. The introduction of wet lay-up can shorten their startup time in case of issues with the main system, and also accommodate periodical switchover between the main and standby systems to even out the extent of hardware deterioration.

Schedule	2013				
	May	June	July	August	September
Exploring countermeasures		Considering the procedure (coordination with shift personnel)			
Implementing countermeasures		Arranging antifreeze solution			
			Placing the standby system at Unit 4 to wet lay-up		
	Placing the standby system at Unit 1 to wet lay-up				



Current status of the secondary spent fuel cooling system at Unit 4
Blue: In-service Red: Dry lay-up

(Reference10) Preventing damage to important facilities resulting from building damage

Objectives	Preventing the discharge of additional radioactive materials beyond site boundaries; Preventing power outage at important facilities
Subject facilities	Retained water transfer facilities, station power supplies
Countermeasure type	Installation environment of on-site facilities (risk manifestation prevention)

Tasks	Damaged building parts may fall, damaging retained water transfer pipes and power cables underneath to cause the leakage of retained water or power outage. Building damage could affect the supports for power cables running across the top section of the building, resulting in cable severing and power outage.
Countermeasures	Install protection materials on retained water transfer pipes and power cables, and remove materials that could fall. (short- to mid-term measure) Add supports for power cables. (long-term measure)

Schedule	FY2013						FY2014
	May	June	July	August	September	H2	
Investigating and exploring countermeasures	Identifying tasks and drawing up countermeasures (May – H2)						
Implementing countermeasures		Installing protection materials and removing materials that could fall (June – H2)					
						Implementing additional measures such as adding supports for power cables (H2 – FY2014)	


Auxiliary process building

(Reference 11) Improving the reliability of important anti-seismic building's emergency generator

Objectives	Preventing power outage at important facilities
Subject facilities	Important anti-seismic building's emergency generator
Countermeasure type	Facility maintenance and management (Environment development and execution for appropriate maintenance and management)

Tasks	Due to insufficient maintenance and inspection under high radiation levels, the important anti-seismic building's emergency generator could have trouble starting up in power blackout, causing the building's power outage. Due to the difficulty in performing a dissembling inspection on the gas turbines for driving the generator, the emergency generator may not be able to undergo repair work for an extended period of time and become inoperative, causing the building's power outage.
Countermeasures	In order to ensure continued use of the existing generator, increase the frequency of inspections, e.g. applying lubrication oil to the drive unit. In regard to the fluctuations of instrument readings and drive unit noise at the time of startup test, revamp maintenance and inspection with support from the Thermal Power department, which has knowledge on the gas turbine for driving the generator. (short- to mid-term measure) Consider and act on replacing the generator. (long-term measure)

Schedule	FY2013						FY2014
	May	**June**	**July**	**August**	September	**H2**	**April-**
Investigating and formulating countermeasures	Identifying tasks and drawing up countermeasures						
Implementing countermeasures	Revamping maintenance and inspection						
						Replacing the generator	


Important anti-seismic building's emergency generator

Safety Response Team: Example 1

(Reference 12) Correcting the failure to put away construction tools / equipment

Objectives	Other (Maintaining / preventing the degradation of safety and quality)
Applicable work	Work that could lead to a major risk or work with a high risk of industrial safety emergency (work associated with reactor coolant injection facilities, etc)
Countermeasure type	Improvement of on-site work environment (risk manifestation prevention)

Tasks (Issues)	Failure to fully observe 5S (organization, tidying, sanitation, cleaning, discipline) on site has been identified. ・Leaving disused items such as portable scaffoldings / ladders and scaffolding pipes without any sign prohibiting their use ・Leaving flammable items (wood shavings, etc.) in the proximity of locations for open-flame work (welding, etc.) These items could interfere with work, compromising work efficiency (reducing work quality), or might be used carelessly, due to the lack of appropriate labeling, resulting in injuries and other personnel accidents (compromising industrial safety). Sparks from open flame work could also ignite flammable items to cause fire.
Countermeasures	Relevant sections must swiftly examine on-site status and instruct contractors to correct such practices according to the rules demanded by the specifications. Based on TEPCO's instructions, the contractors must inspect their status of on-site work areas to verify whether they comply with the rules demanded by TEPCO in its specifications, and correct any non-compliances. TEPCO must continuously carry out on-site observation to confirm the status of response to its instructions, and issue renewed instructions for any failure to implement corrective action.

Schedule	2013 April	2013 May
Investigating and formulating countermeasures		Identifying applicable locations (on-site observation)
Implementing countermeasures		Instructing the applicable sections in charge to take action Implementing countermeasures


[Portable scaffolding left unused]

(Reference 13) Complying with basic action / safety rules

Objectives	Fire prevention and other (Maintaining / preventing the degradation of safety and quality)
Applicable work	Work that could lead to a major risk or work with a high risk of industrial safety emergency (work associated with reactor coolant injection facilities, etc)
Countermeasure type	Improvement of on-site work (risk manifestation prevention)

Tasks (Issues)	Failure to thoroughly enforce basic action / safety rules has been observed. ・Failure to use a safety belt / hook while working at an elevated location ・Using electric cables while they are still on a reel (possible fire from heating) ・Failure to use leather gloves when using blades ・Accessing work areas (off limit), etc.
Countermeasures	TEPCO must instruct contractors to observe basic action / safety rules at the meeting of the Safety Promotion Liaison Council, etc. The contractors must circulate the contents of the specifications TEPCO demands (common specifications, safety response specifications, etc.) on occasions for issuing safety instructions in order to ensure compliance with the basic action / safety rules. TEPCO must continuously carry out on-site observation to confirm the status of improvement.

Schedule	2013 April	2013 May
Investigating and formulating countermeasures		Identifying applicable locations (on-site observation)
Implementing countermeasures		Instructing the applicable sections in charge to take action Implementing countermeasures


[Electrical cable reel in use]

(Reference 14) Ensuring that open flames and charged sections are covered

Objectives	Fire prevention and other (Maintaining / preventing the degradation of safety and quality)
Applicable work	Work that could lead to a major risk or work with a high risk of industrial safety emergency (work associated with reactor coolant injection facilities, etc)
Countermeasure type	Improvement of on-site work (risk manifestation prevention)

Tasks (Issues)	Failure to fully cover open flames or charged surfaces on site has been observed. ・Sparks were seen flying from insufficiently covered locations during outdoor work involving open flames (in strong winds) ・During work in the control panels, an adjacent unit was charged, but was not sufficiently covered. During work involving open flames, the flames could ignite surrounding flammable items (Tyvek items, etc.) to cause fires / burns. In the control panels, an accidental contact with a charged section could lead to electric shocks and facility fault.
Countermeasures	Relevant sections must swiftly examine on-site status and instruct contractors to cover open flames and charged sections according to the rules demanded in TEPCO's specifications. Based on TEPCO's instructions, the contractors must inspect their status of on-site work areas to verify whether they comply with the rules demanded by TEPCO in its specifications, and correct any non-compliances. TEPCO must continuously carry out on-site observation to confirm the status of response to its instructions, and issue renewed instructions for any failure to implement corrective action.

Schedule	2013 April	2013 May
Investigating and formulating countermeasures		Identifying applicable locations (on-site observation)
Implementing countermeasures		Instructing the applicable sections in charge to take action Implementing countermeasures


[Work in the electric panel]

Reference 2

Transfer of Retained Water from the Underground Reservoirs No.3 and No.6 to G6 Tank

May 16, 2013

Tokyo Electric Power Company

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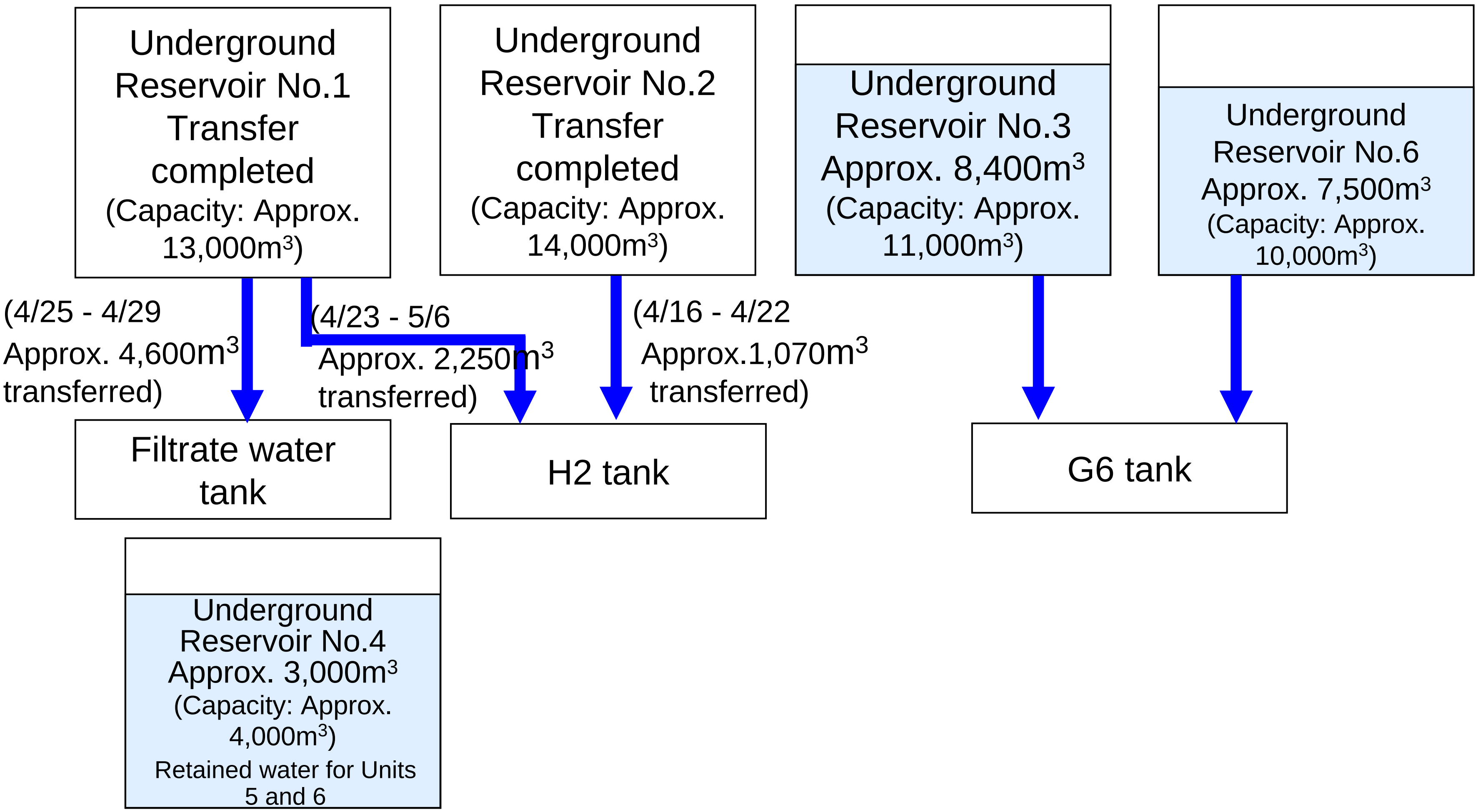
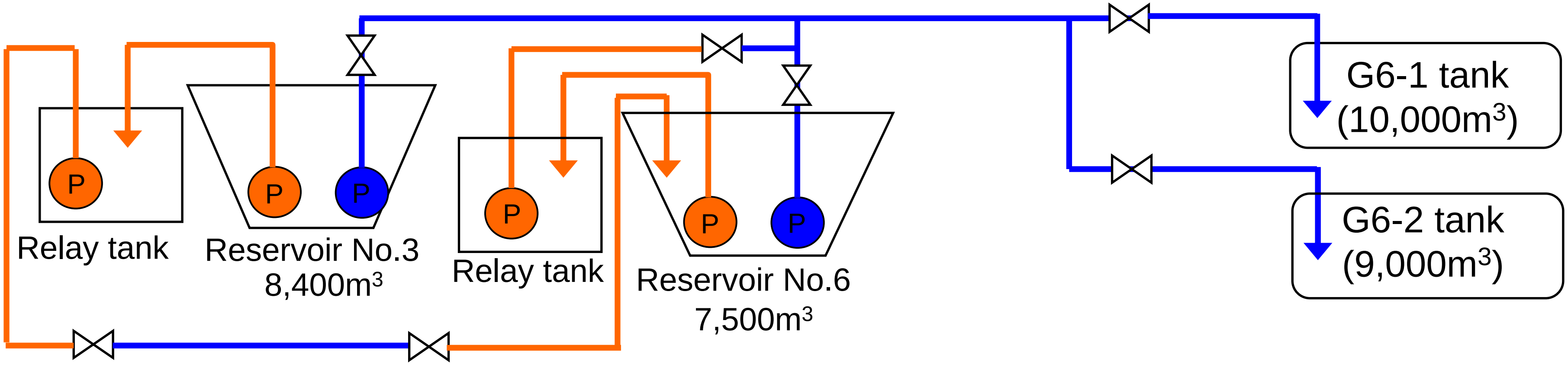
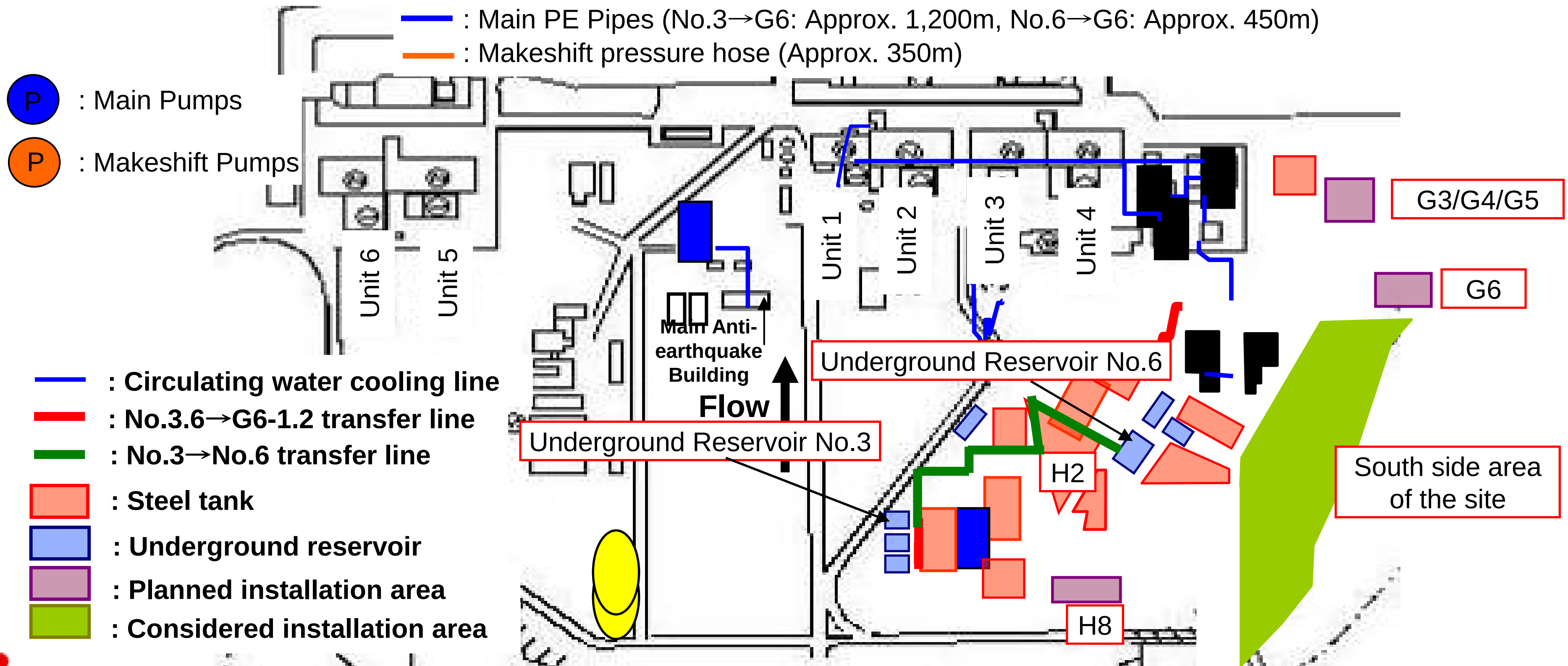
TEPCO

Current Water Storage Amount of Each Underground Reservoir



Transfer Method from the Underground Reservoirs No.3 and No.6 to G6 Tank





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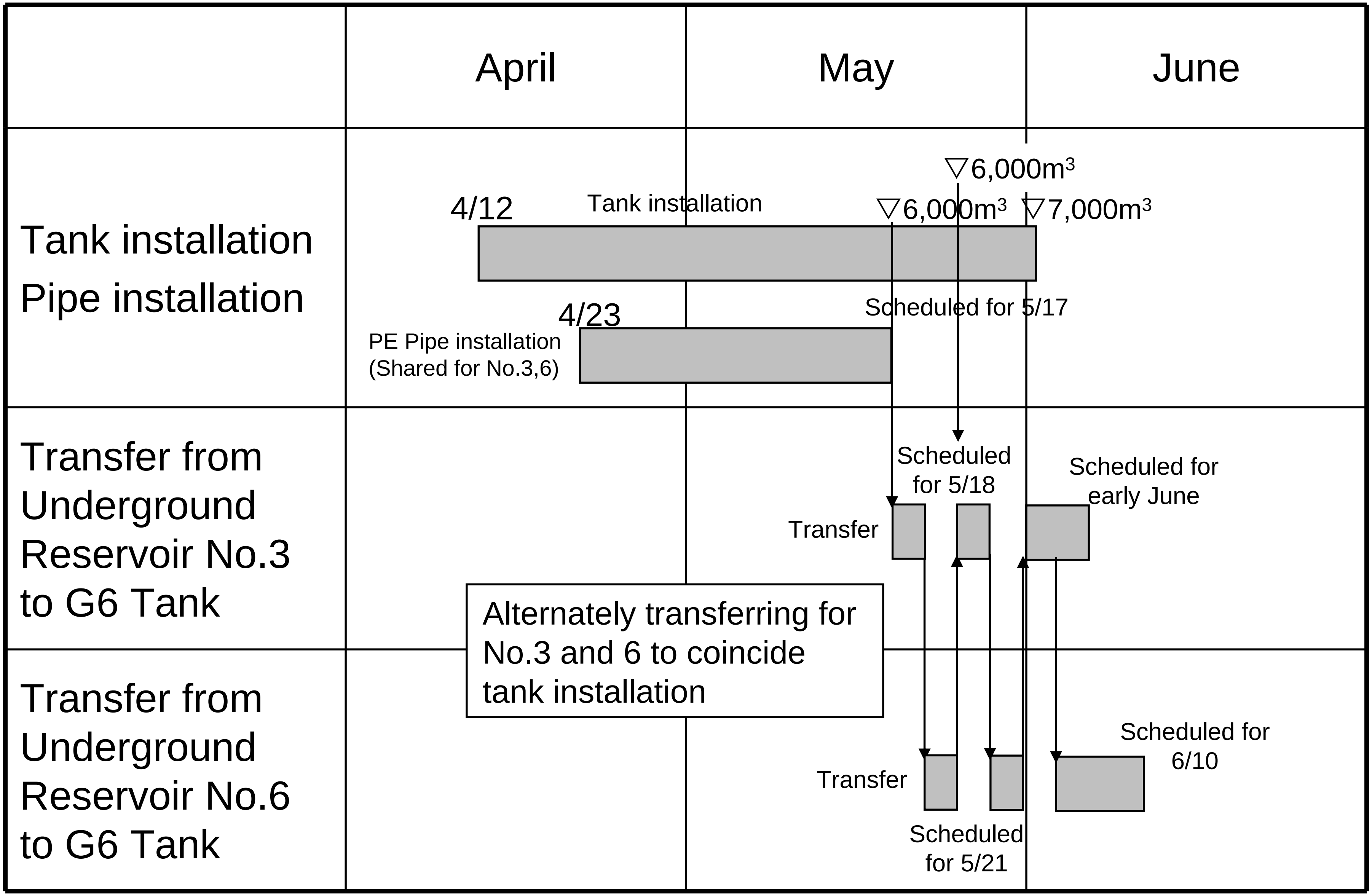
Work Schedule



Reference
3

Estimating the Volume of Leakage from Underground Reservoirs

May 16, 2013
Tokyo Electric Power Company

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TEPCO

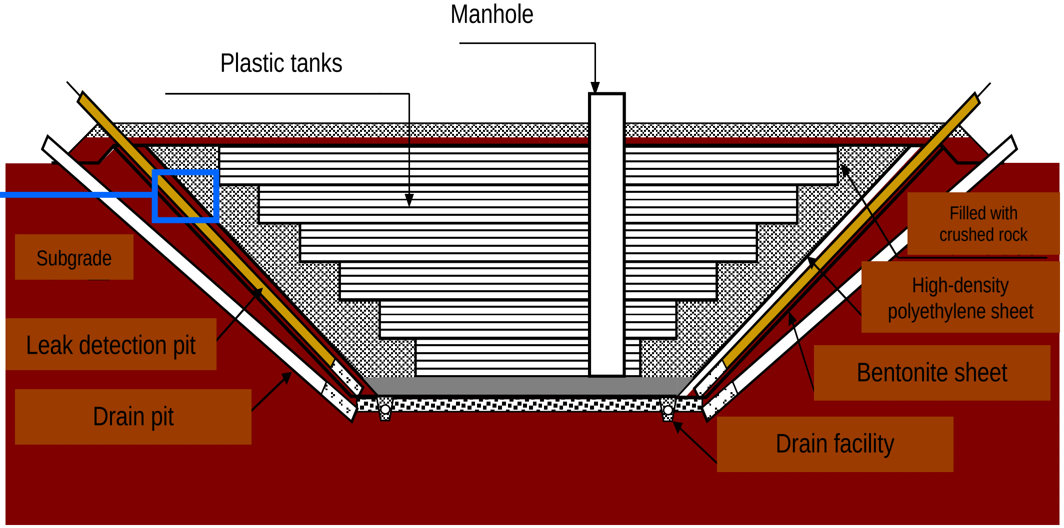
1. Investigation on the volume of leakage

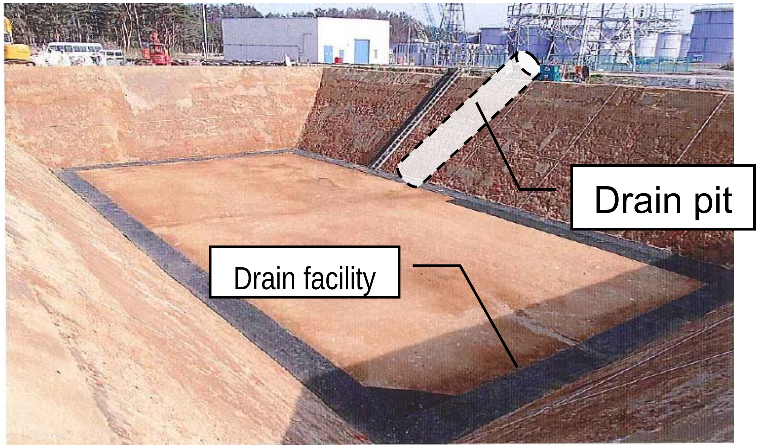
About 120 cubic meters of leakage was initially reported from Underground Reservoir No.2. A detailed investigation, as detailed below, has been conducted to clarify unnatural circumstances surrounding the volume of the leakage (i.e. 120 cubic meters), considering low water levels at leak detection pits and variations in radiation concentration.

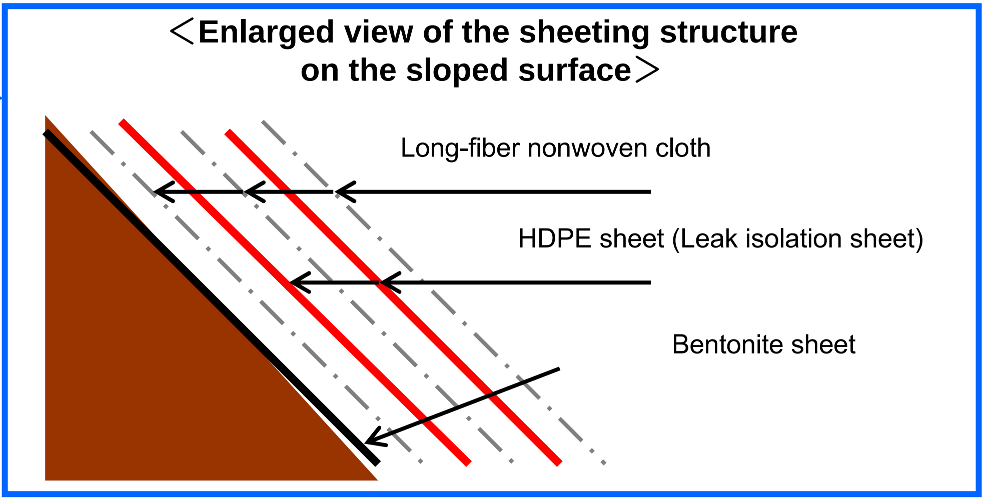
- Boring surveys
- Water collection from leak detection pits and its analysis
- Water collection from drain facilities and its analysis

＜Reference＞ Water level gauge inspection

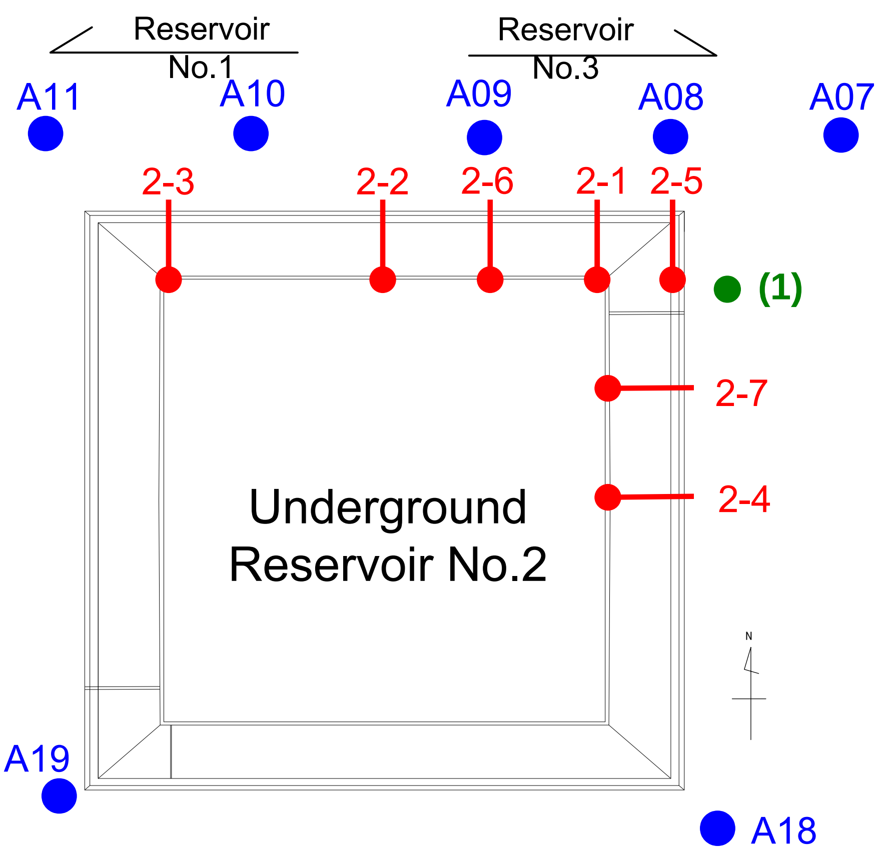
2. The structure of underground reservoirs

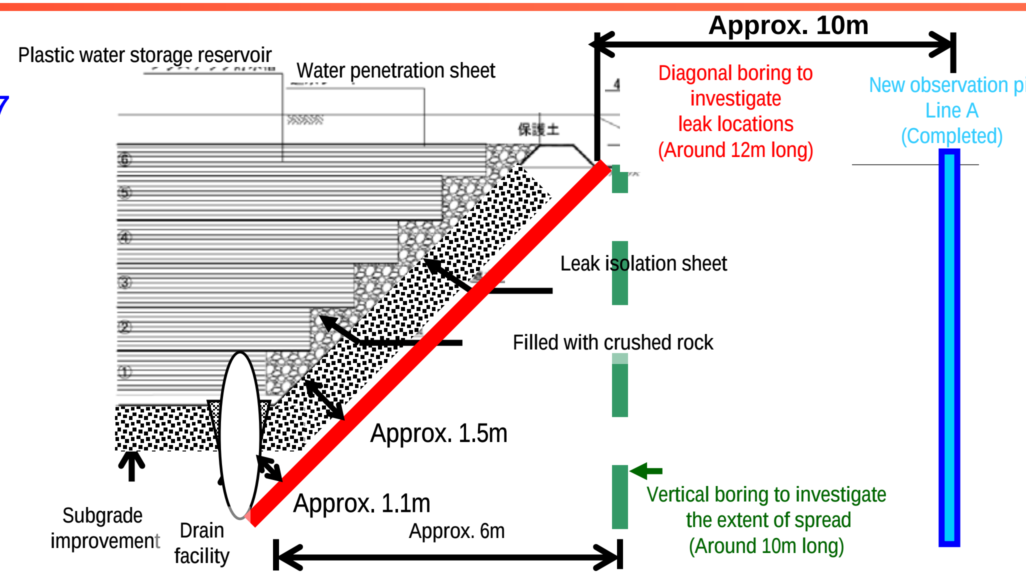






3. Boring surveys (1) Water analysis results





Underground Reservoir 2 observation pit	Collection date	Total beta level(Bq/cm^3)
2-1	May 10	ND
2-2	May 10	ND
2-3	May 8	ND
2-4	May 8	ND
2-5	May 12	ND
2-6	May 12	ND
2-7	May 13	ND

Geological survey pit	Collection date	Total beta level(Bq/cm^3)
①	May 12	ND

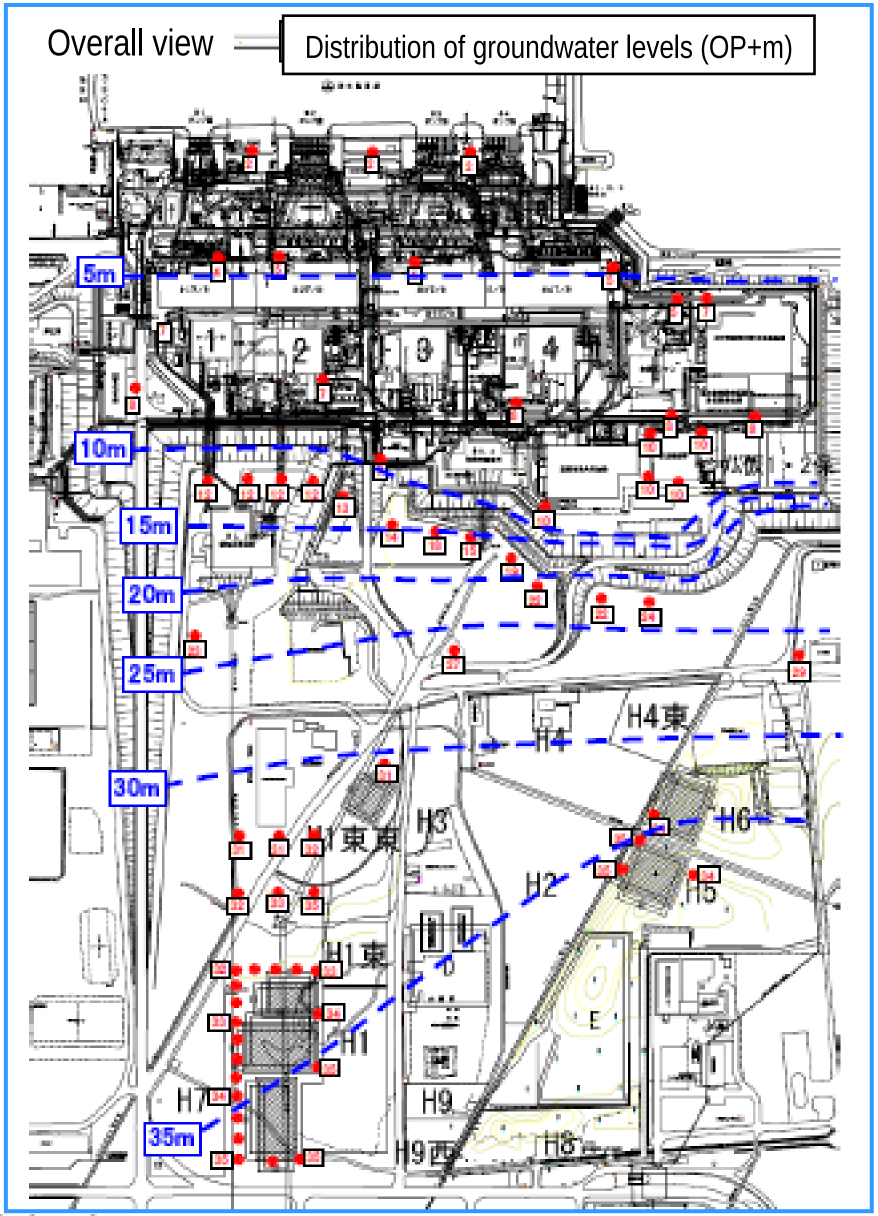
Underground reservoir observation pit	Collection date	Total beta level(Bq/cm^3)
A-7	'May 12	ND
A-8	'May 12	ND
A-9	'May 12	ND
A-10	'May 12	ND
A-11	'May 12	ND
A-18	'May 12	ND
A-19	'May 12	ND

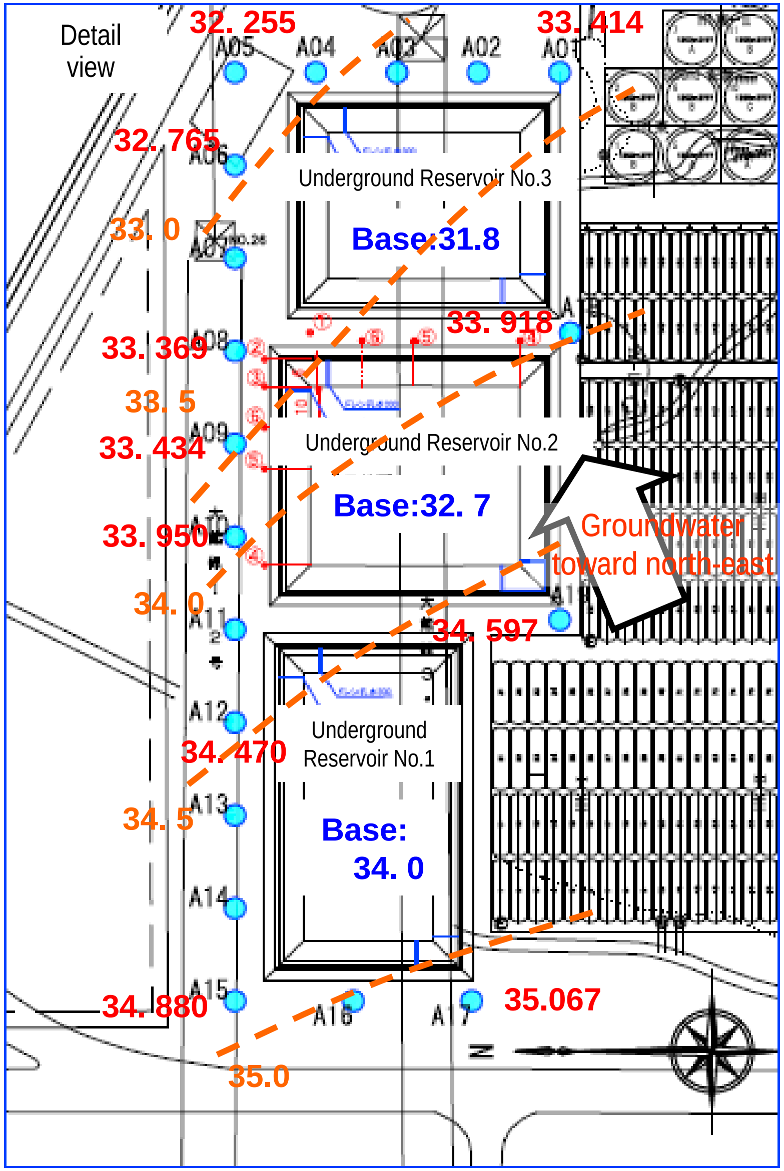
●: Underground reservoir observation pits, Line A (7 of the total of 19 locations)

●:Geological survey pit (to investigate the spread of leakage) (1 location)〔Vertical boring〕

●:Underground Reservoir No.2's observation pit (to investigate leak locations) (7 locations)〔Diagonal boring〕

3. Boring surveys(2)　Distribution of groundwater levels





3. Boring surveys (3)

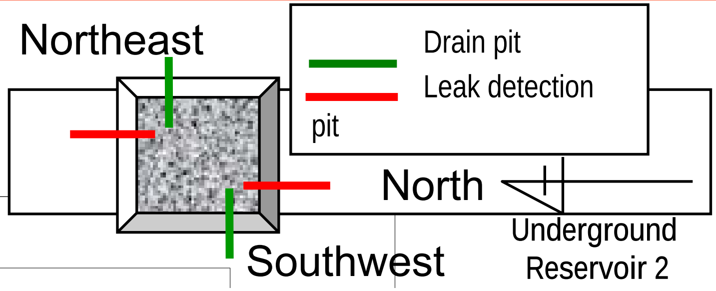
- Monitoring results around the underground reservoirs were below detectable limit.

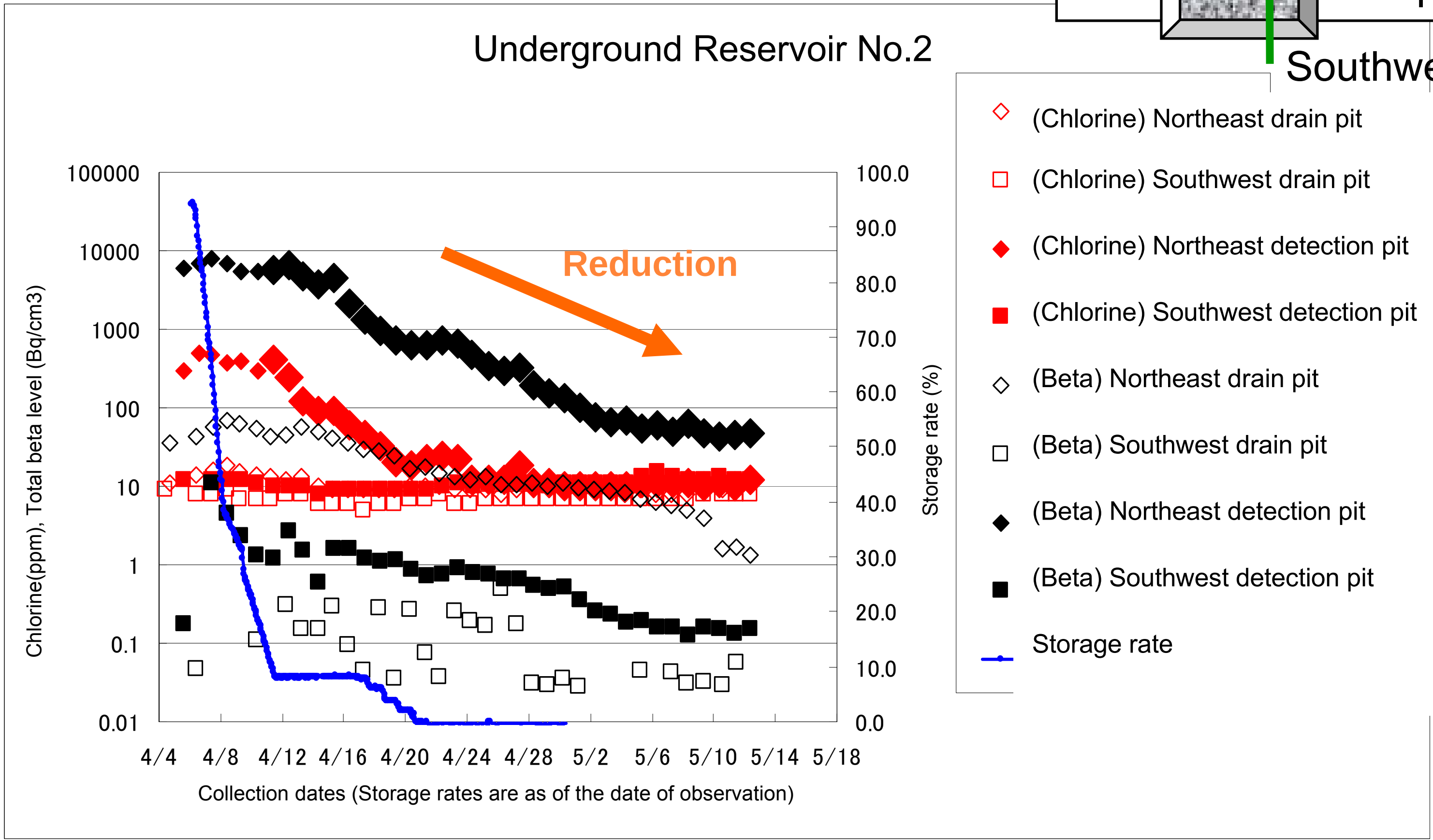
- Judging from the water levels inside the observation pits, groundwater is *flowing in the north-easterly direction* around the underground reservoirs, and changes direction to *eastwards* as it approaches the coastline.

- Analysis of groundwater levels around the underground reservoirs shows that the hydraulic gradient of the water table is around 2m / 200m = 0.01. Supposing that the permeability coefficient of the subgrade in the area is 5×10^{-4}cm/sec (bulletin figure from permeability testing), the flow rate near the water table around the underground reservoirs is approx. *1cm per day*.

Although leak locations could not be identified, the leakage of contaminated water beyond the Bentonite sheet is estimated to be extremely low.

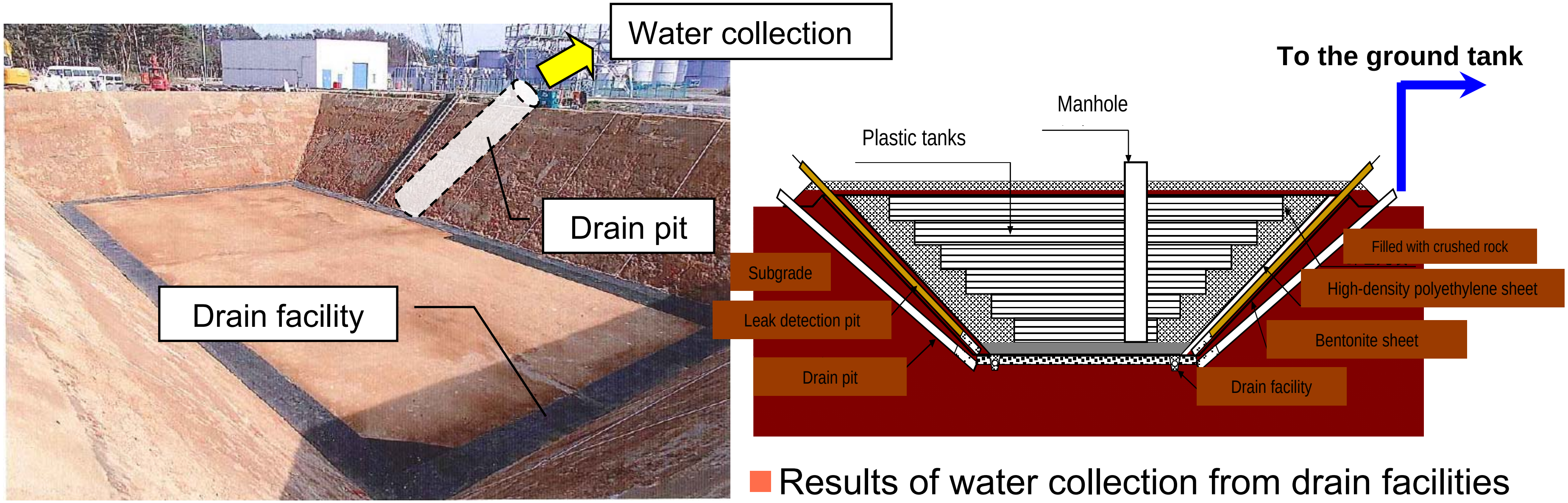
4. Water collection from leak detection pits and its analysis



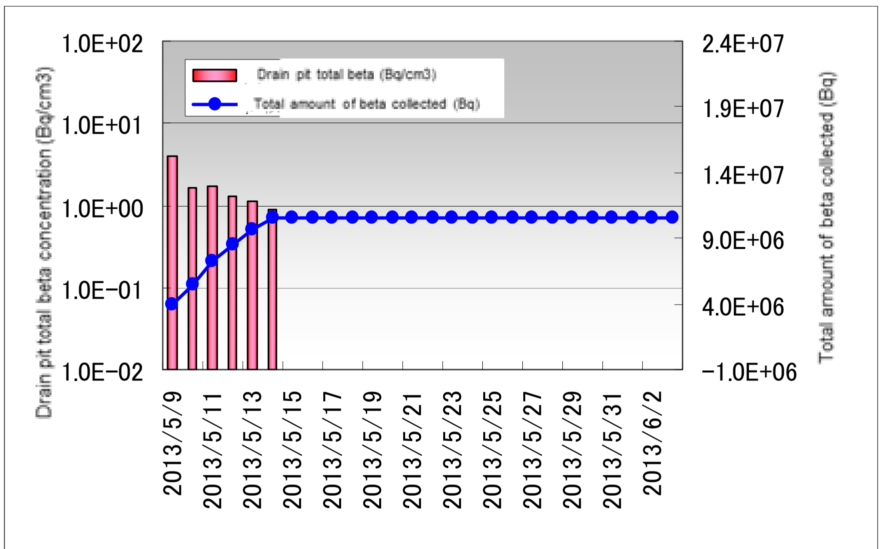


The recovery of contaminated water from detection pits at the rate of 50 liters per day (several liters in raw water equivalent) dramatically reduced the contamination level, indicating that the original volume of leakage was small.

5. Water collection from drain facilities and its analysis



Results of water collection from drain facilities



- Water collection from drain facilities began on May 9, 2013.
- As of May 14. 2013, 6 cubic meters of water has been collected (drain facilities' overall capacity: Approx. 17 cubic meters)
- Contamination level of collected water: Up to 3. 9Bq/cm^3
- Amount of radioactive materials collected: 1.1×10^7 Bq
- The fact that water with a high level of contamination was not found from drain facilities, where leaked water is most likely to stay, indicates that only a minute amount of contaminated water has leaked through the Bentonite sheet.

Collecting just $6m^3$(0.2 liters in raw water equivalent) has reduced the total beta concentration to around 1/4, suggesting that ***the volume of contaminated water is not large.***

6. Summary of investigations into leakage volume

Investigations thus far have found the following:

- Additional boring surveys indicate that contaminated water has not spread in soil around the underwater reservoirs. Most of it is believed to be trapped between the HDPE sheet and Bentonite sheet, or within the drain facilities.

Based on the above:

The leakage volume from Underground Reservoir No.2 is suspected to be much smaller than 120 cubic meters, as originally reported.

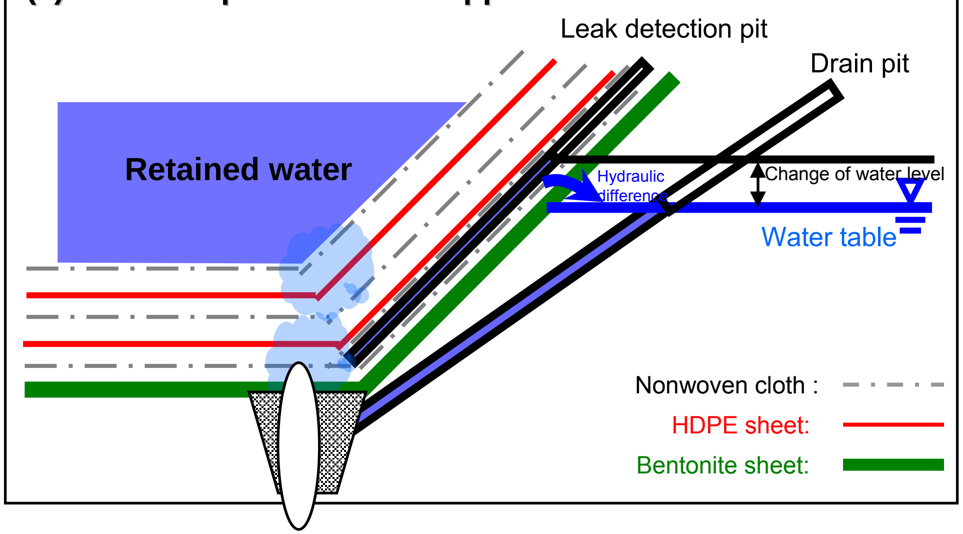
7. Estimating leakage volume

■How to estimate leakage volume

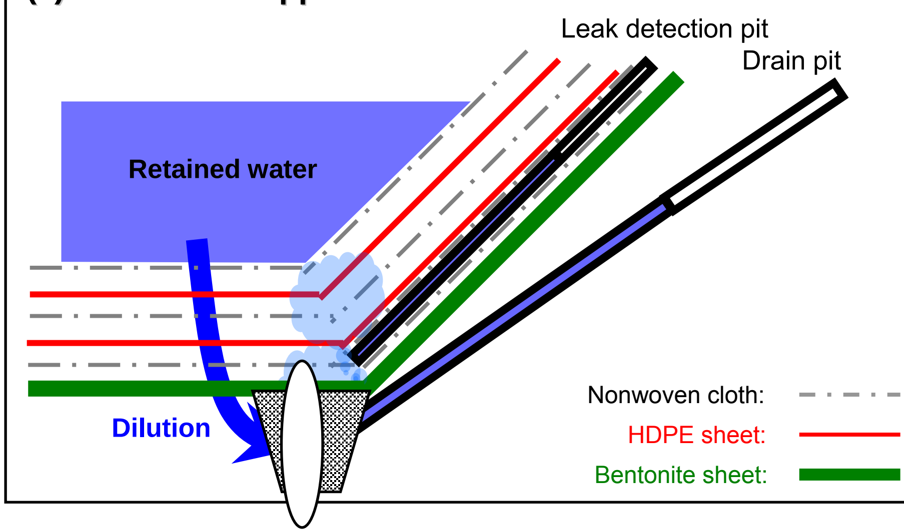
(1)Calculating leakage volume with the focus on leak detection pits and changes of water table (Detection-pit water table approach)

$$\frac{\text{(2)Total beta concentration in drain pits}}{\text{Total beta concentration in retained water}}$$ (Dilution rate)× Drain facility capacity(Dilution rate approach)

(1)Detection-pit water table approach



(2)Dilution rate approach



8. Estimated leakage volume

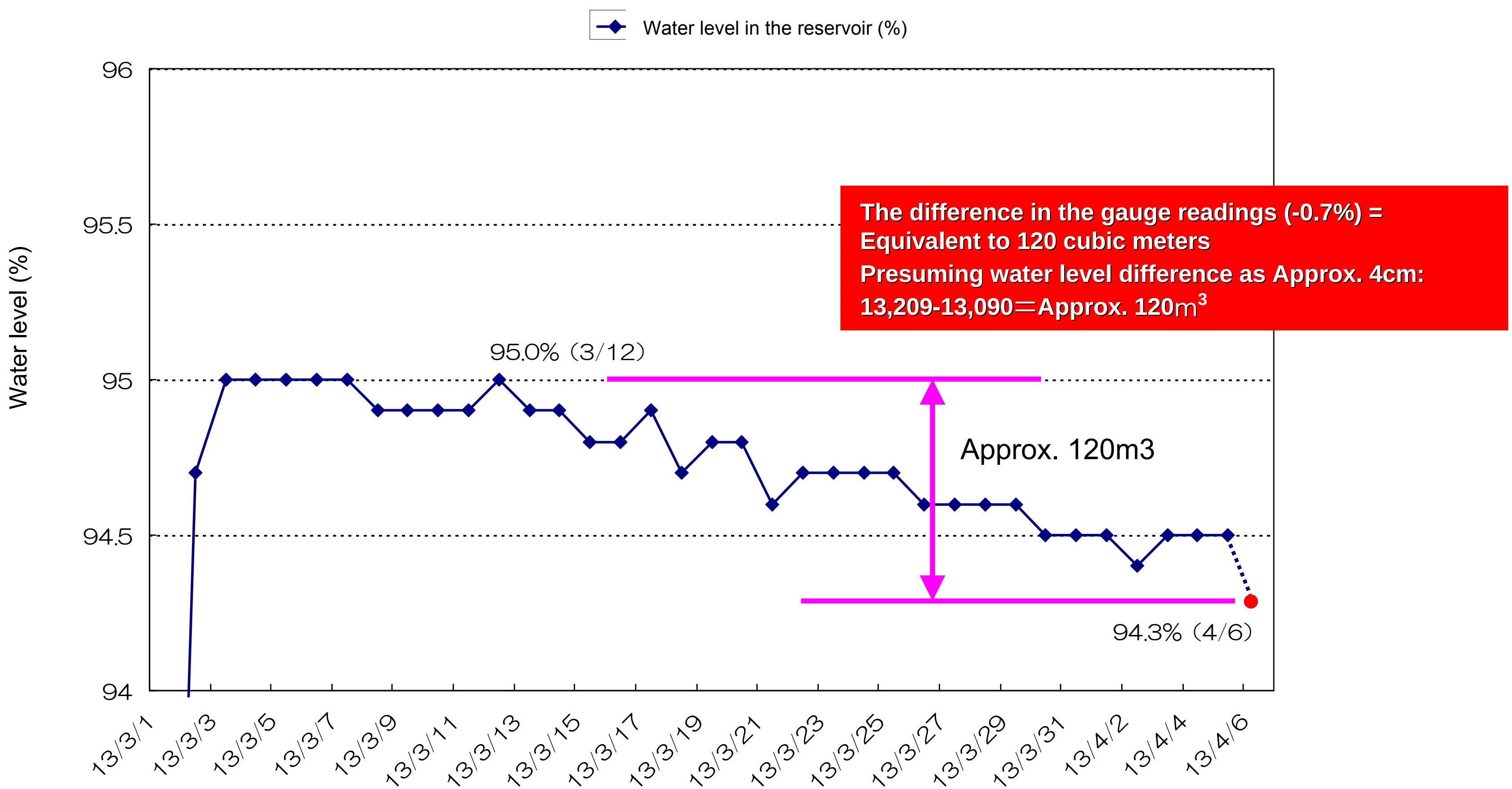
Leakage volume has been assessed as follows, with details of the assessment to be shown separately for reference:

Location	Estimation method	Underground Reservoir 1	Underground Reservoir 2	Underground Reservoir 3
Between the HDPE sheet and Bentonite sheet	Detection-pit water table approach	— (*1)	Approx. 300 liters	— (*2)
	Dilution rate approach	Approx. 70 liters	Approx. 300 liters	Approx. 20 liters
Outside the Bentonite sheet	Detection-pit water table approach	— (*1)	Approx. 20 liters	— (*2)
	Dilution rate approach	Approx. 10 liters	Approx. 10 liters	— (*3)

(*1)No detection-pit water table data
(*2)Cannot be estimated due to the absence of a rise in detection-pit water table
(*3)No significant leakage confirmed

＜Reference＞Inspecting water level gauges(1)

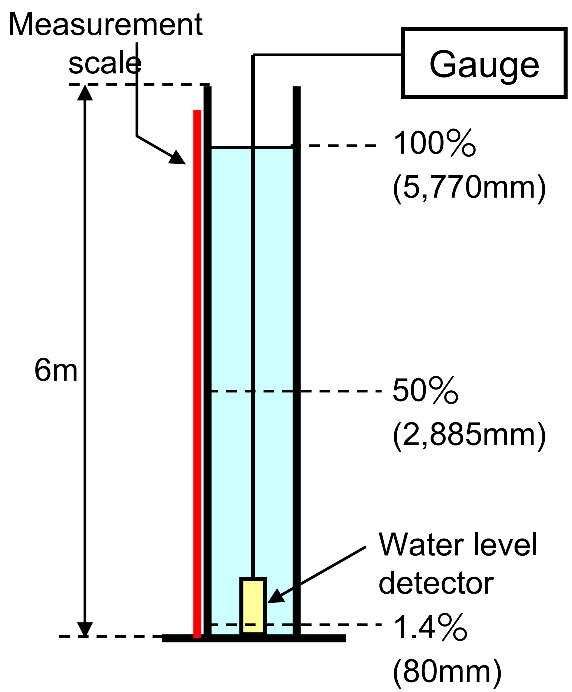
- When the possibility of a leak from Underground Reservoir No.2 was identified (as of April 6, 2013), 0.7% of level drop, shown in the water level gauges installed in the reservoir, was used to estimate the leakage volume to be up to 120 cubic meters.



＜Reference＞Inspecting water level gauges(2)

- A makeshift water column (filtrate) was used to compare the reading of water level gauge against the actual water level. These two levels must ordinarily be a 100% match, but the comparison confirmed that the level gauge's reading has a drift* of -0.6%.

※Gradual lag of readings over time



Details of water level gauges

	Actual water level measurement	Level gauge reading	Difference
At the completion of Underground Reservoir 2	98.06% (5,658mm)	98.0% (5654. 6mm)	−0.06%
At the level gauge inspection (April 25)	100% (5,770mm)	99.4% (5,735mm)	−0.6%

Based on the above, it is believed that the water level gauge installed at Underground Reservoir No.2 did not represent the actual level of water level changes.

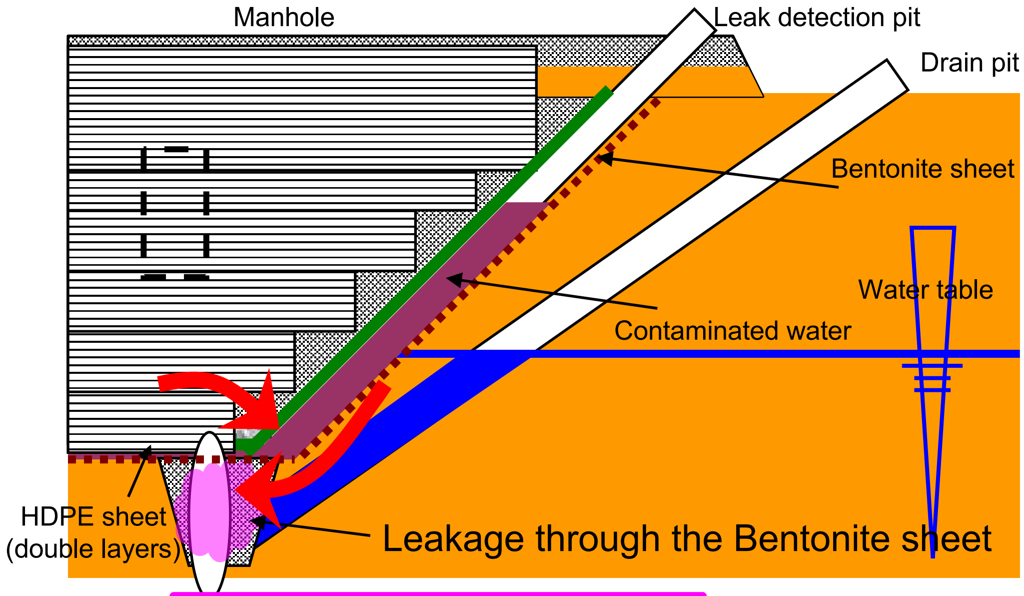
9. Summary

- The amount of leakage at Underground Reservoir No.2 is estimated to be approx. 300 liters inside the Bentonite sheet, and 20 liters outside the Bentonite sheet, most of which is believed to be contained in the drain facility. A similar method was used to estimate the leakage volume from Underground Reservoirs No.1 and No.3, which also found the leak to be minor.

- Regardless of the size of the leak, the fact remains that there was some leakage from Underground Reservoir No.2. TEPCO will continue to monitor the reservoirs, and release any findings to the public, while continuously investigating the causes and formulating countermeasures.

References

【Reference1】 Mechanism of leakage

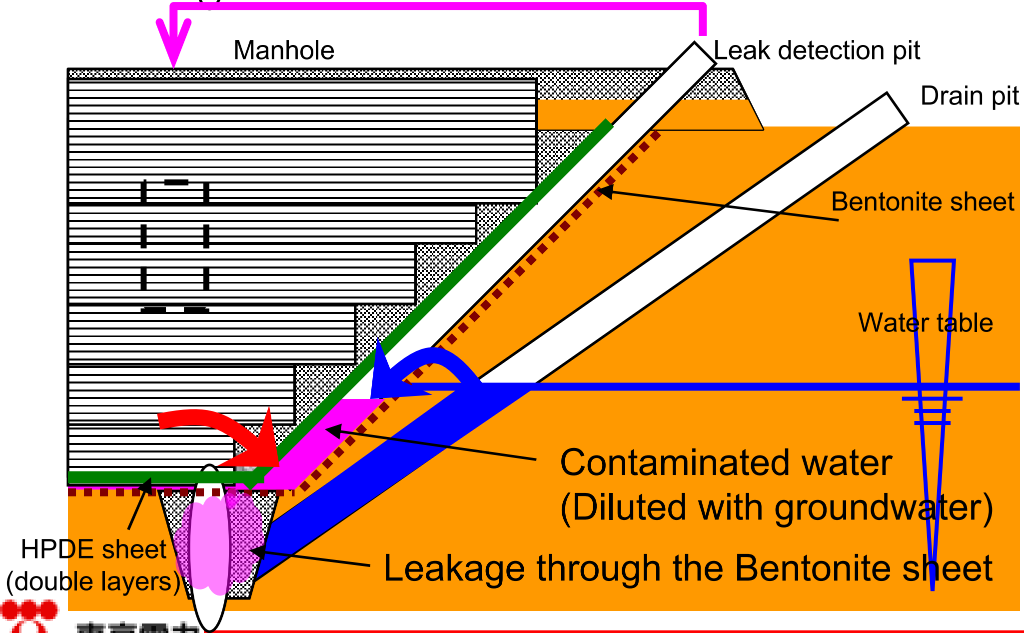


【Initial stage of leakage】

■Contaminated water leaked into the space between the HDPE sheet and the Bentonite sheet (in nonwoven cloth and gaps in leak detection pit).

■The pressure difference caused by the difference of water level in the leak detection pit and water table, led to the minor leakage of contaminated water through the Bentonite sheet.

■Since the subgrade is stabilized on the base and slope surfaces, the water leaked through the Bentonite sheet is believed to move toward the drain facility, which has a relatively high permeability.



【When collecting contaminated water】

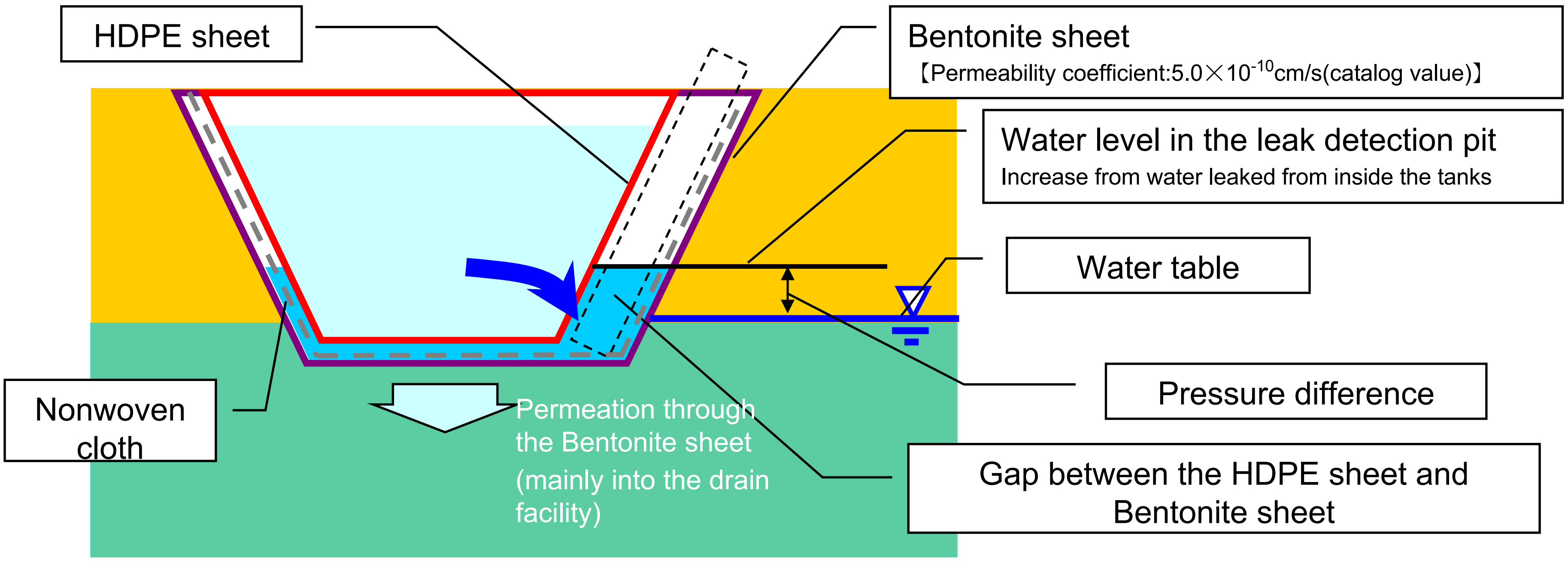
■The collection of contaminated water from the leak detection pit caused the water level in the pit to drop.

■A minute amount of groundwater permeated through the Bentonite sheet into the leak deteciton pit, diluting contaminated water.

■The diluted contaminated water was collected.

■This reduced and stopped the leakage of contaminated water through the Bentonite sheet.

【Reference 2-1】 Leak volume estimation method (overview) - Detection-pit water table approach

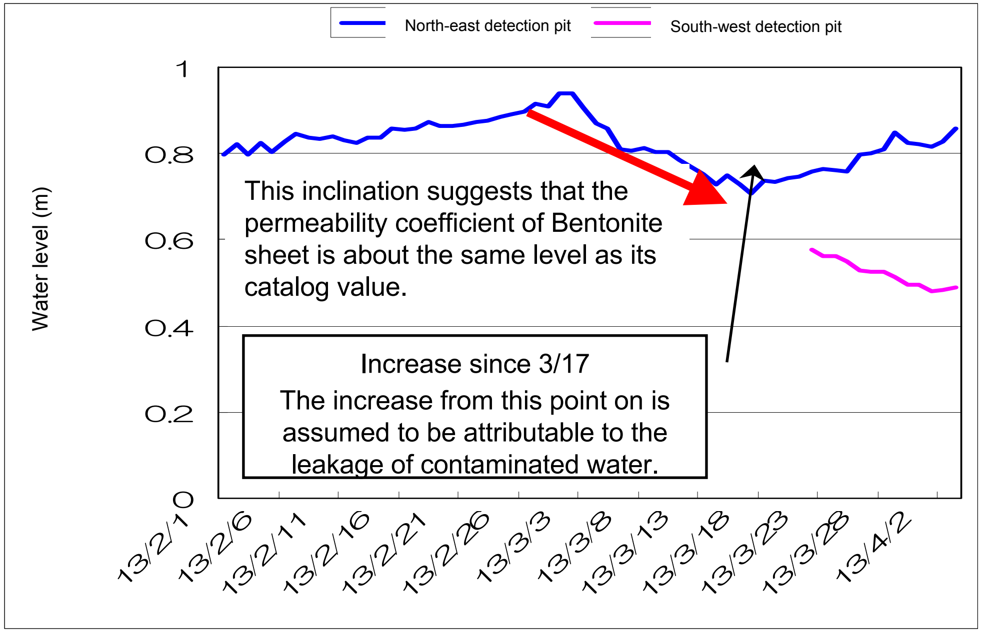


- Contaminated water leaked through the double layers of HDPE, and permeated into the gaps (nonwoven cloth) between the Bentonite sheet and HDPE sheet, and gaps in the leak detection pit.
  →Calculating leak volume based on the increase of water level in the leak detection pit and the volume of the gaps
- Pressure difference between the water level in the leak detection pit and the level of water table in the area, caused contaminated water to leak through the Bentonite sheet (mainly into the drain pit, which has higher permeability).
  →Calculating the volume of leakage through the Bentonite sheet based on the pressure difference, Bentonite sheet's permeability coefficient and the area in contact with water

【Reference 2-2】
Leak volume estimation method (details) - Detection-pit water table approach

- Leak volume based on the calculation of gap volume
  - Calculation formula:Leak volume
    = Increase of the water level in the leak detection pit (increase from 0.71m, the water level of the north-east detection pit measured on 3/17)
    ×Area of the nonwoven cloth soaked with water in the leak detection pit x Thickness of the nonwoven cloth
    ＋Volume for the increase of water level in the leak detection pit
  - Water level condition: Contaminated water filling the level of water in the north-east leak detection pit
  - State of nonwoven cloth: Nonwoven cloth is placed in-between the sheets. The calculation used the assumption that the cloth has the volume strain of 41% and pore volume ratio of 90% with the hydraulic head of 5.5m in full water.
  - Calculation result: Increase of water by ***73 liters*** from 3/17 to 4/10
    Based on the calculation below based on the permeability of Bentonite sheet, ***212 liters*** of water leaked through the Bentonite sheet during the abovementioned period. This means the volume of leakage into the gap between the HDPE sheet and Bentonite sheet is estimated to be ***285 liters***.

- Estimation based on the permeability of Bentonite sheet
  - Water pressure on the inside of the Bentonite sheet: Calculated based on the detection pit's water level
  - Bentonite sheet's permeability coefficient:
    5×10^{-10}cm/sec(catalog value)
  - Permeation volume: ***212 liters***※
    (※Including groundwater)
  - The ratio of contaminated water (water from the reservoir) against the permeation volume is approx. 7% (285 liters / 4385 liters).
  - Therefore, the volume of contaminated water that passed through the Bentonite sheet (water from the reservoir) is:
    212 liters ×7% ＝ Approx.***15 liters***

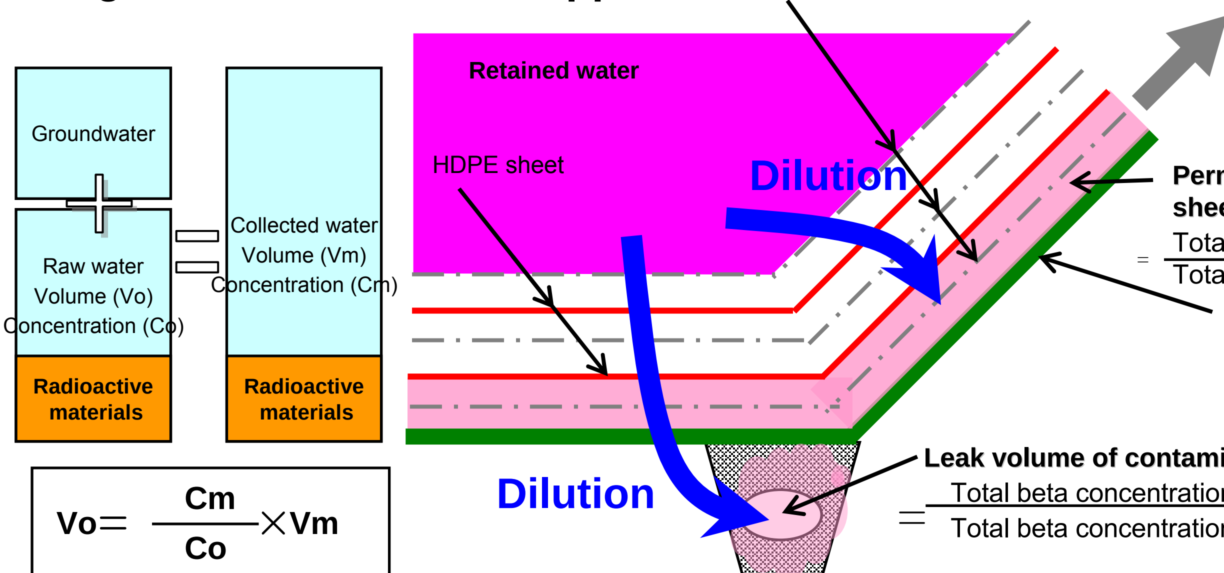


(Reference)Drain pit water level【4/14】:Approx. 0.78m(North-east), Approx. 0.62m(South-west)

【Reference3】 Leak volume estimation method (overview) - Dilution rate approach

- The collection of contaminated water from the leak detection pit caused the contamination level inside the pit to drop.
  → Volume of collected contaminants ＞ Volume of contaminants permeated into the gap between the HDPE sheet and Bentonite sheet
  → The volume of collected contaminants is conservatively estimated as being equal to the volume of contaminants permeated into the gap between the HDPE sheet and Bentonite sheet
- The amount of permeation into the gap between the HDPE sheet and Bentonite sheet is calculated based on the volume of water collected from the leak detection pit, total beta concentration and the ratio of the retained water's concentration against the total beta concentration* (dilution rate).
- The volume of leakage through the Bentonite sheet is calculated based on the capacity of the drain facility, total beta concentration and the ratio of the retained water's concentration (dilution rate).

Image of the dilution rate approach



$$Vo = \frac{Cm}{Co} \times Vm$$

Permeation volume into the gap between the HDPE sheet and Bentonite sheet (per day)

$$= \frac{\text{Total beta concentration in the detection pit}}{\text{Total beta concentration in the retained water}} \text{(Dilution rate)} \times \text{Amount of contaminated water collected}$$

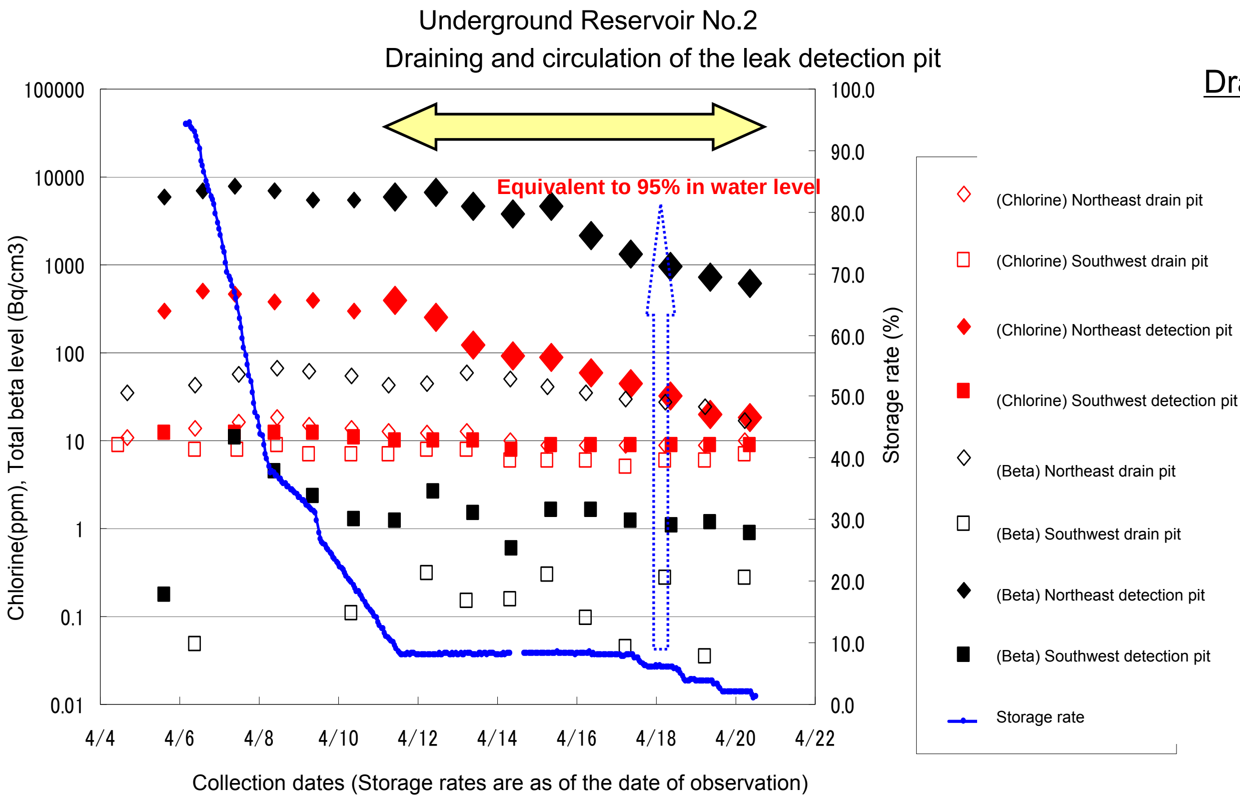
Bentonite sheet

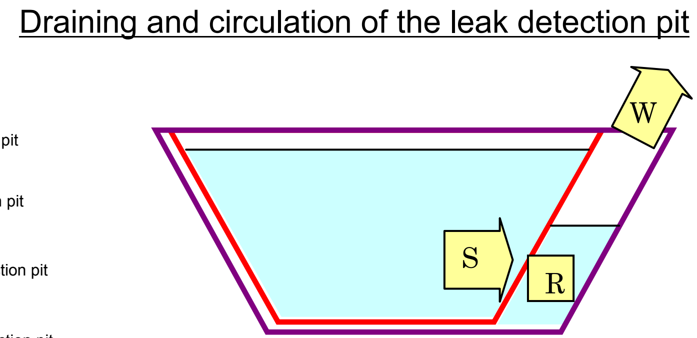
Leak volume of contaminated water through the Bentonite sheet

$$= \frac{\text{Total beta concentration in the drain pit}}{\text{Total beta concentration in the retained water}} \text{(Dilution rate)} \times \text{Capacity of the drain facility}$$

※ The total beta concentration (Bq/cm3) of the retained water at Underground Reservoir 2 has been measured as 6.6×10^4 and 1.4×10^5, and the more conservative figure (6.6×10^4) has been used

【Reference 3-1】Leak volume between the HDPE sheet and Bentonite sheet:Dilution rate approach





Radioactive material content of the extracted water W (Bq) ≫ Radioactive material content of the leaked water S (Bq)

W ＝ Volume of extracted water Qw× Detection pit concentration Bw

S ＝ Leak volume Qs× Raw water concentration Bs

- The draining and circulation of the leak detection pit at Reservoir No.2 on 4/11 – 20, brought the total beta concentration in the pit. This means the “radioactive material content of the extracted water (W)” was greater than the radioactive material content of the leaked water (S).
- However, in this calculation, W is conservatively assumed to be the same as S.
- The raw water concentration (total beta) of Underground Reservoir 2 was 6.6×10^4Bq/cm^3
- The daily volume of leaked raw water was Ave.(Qw×Bw/Bs)＝12 liters／day.

  (Since the water level in the reservoir dropped on 4/11-20, this figure was calculated as the equivalent of 95% in water level.)
- Assuming that the leak occurred on 3/17, around ***288 liters*** of contaminated water is estimated to have leaked by 4/10, when the contaminated water in the leak detection pit was collected.

【Reference 3-2】Leak volume through the Bentonite sheet: Dilution rate approach

■Estimation based on the amount of gap in the drain facility and the dilution rate

- Calculation method:Leak volume = $\frac{\text{Total beta concentration of the drain pit (Bq/cm3) x Gap volume of the drain facility (liters)}}{\text{Total beta concentration of the raw water in the reservoir (Bq/cm3)}}$

- Raw water concentration (total beta):$6.6 \times 10^4 Bq/cm^3$
- Maximum concentration in the drain pit (total beta):$68 Bq/cm^3$
- Capacity of the drain facility(Note):$9m^3$
- Leak volume: $\frac{6.8 \times 10 (Bq/cm^3) \times 9000 \text{ (liter)}}{6.6 \times 10^4 (Bq/cm^3)}$ = ***9 liters***

(Note)While the overall capacity of the drain facility is approx. $17m^3$, around half of that figure ($9m^3$) was used due to the fact that contamination was confirmed only in the north-east drain pit at Underground Reservoir 2, and that the drain facility has the water gradient from the center in the north-south direction.

【Reference 4】Results of leak volume calculations for Underground Reservoirs No.1 and No.3

- Calculating the leak volume of Reservoir No.1
  - Leak volume into the gap between the HDPE sheet and Bentonite sheet (total beta)
    - Same calculation method and raw water concentration as those for Reservoir 2
    - Assuming that the leak volume was balanced with the extraction volume on 4/10-22, the leak volume for one day during that period was:

$$\frac{\text{Average total beta concentration of extracted water (Bq/cm3) x Average volume of extracted water (liter)}}{\text{Total beta concentration of raw water in the reservoir}} = \frac{3.2\times10^{4}(\mathrm{Bq/cm^{3}})\times36(\mathrm{liter})}{6.6\times10^{4}(\mathrm{Bq/cm^{3}})} = \textit{17 liters/day}$$

    - Since contaminated water was not collected for 4 days from April 6 to April 9 at Reservoir 1, the leak volume is approx. ***68 liters.***
    - Not that this has already been collected.
  - Leak volume through the Bentonite sheet
    - Maximum total beta concentration in the drain pit was 6.8×10Bq/cm^3
    - Based on this figure, the leak volume is obtained as below:

$$\frac{\text{Total beta concentration of the drain pit (Bq/cm3)x Gap volume of the drain facility (liters)}}{\text{Total beta concentration of the raw water in the reservoir (Bq/cm3)}} = \frac{6.8\times10(\mathrm{Bq/cm^{3}})\times9000(\mathrm{liter})}{6.6\times10^{4}(\mathrm{Bq/cm^{3}})} = \textit{9 liters}$$

- Calculating the leak volume of Reservoir No.3
  - Leak volume into the gap between the HDPE sheet and Bentonite sheet (total beta)
    - Performing basically the same calculations as Reservoir 1 for the period of 4/15 – 29 (although with correction to the equivalent of 95% in reservoir water level), shows the leak volume to be ***0.3 liters per day*** (total beta concentration 6.3×10^{4}Bq/cm^3).
    - It is suspected that ***20 liters*** of contaminated water leaked between February 8, when the reservoir became full, and April 15, when the collection of contaminated water began.
    - However, it is believed to be recoverable as it is inside the Bentonite sheet.
  - Leak volume through the Bentonite sheet
    - The maximum total beta concentration in the drain pit is 1.1Bq/cm3, suggesting that there is no significant leakage.

【Reference 5】Water levels of Underground Reservoir No.2 and leak detection pit