Status of the Fukushima Daiichi Nuclear Power Station

～With focus on countermeasures for contaminated water～

January, 2014

Tokyo Electric Power Company, Inc.

東京電力
TEPCO

Current status of the contamimated water issue

The issue involves three challenges:

- **<u>Increase of contaminated water</u>**

  Some 400 tons of groundwater flows into the site buildings every day and becomes contaminated.

  This is largely a **<u>battle against nature</u>**.

- **<u>Outflow of contaminated water into the sea and its countermeasures</u>**

  Contaminated water around the site buildings is <u>flowing into the NPS's port</u>.

  The effect of the contaminated water is contained within the port, with the <u>concentration of radioactive materials remaining at a stable level with no impact</u>.

- **<u>Leakage from tanks</u>**

  Approx. 300 tons of contaminated water leaked from tanks (August)

  Rainwater overflow and leakage from slope-installed tanks at the time of typhoon (October)

  <u>Countermeasures have been stepped up for these management issues</u>.

Fukushima Daiichi NPS Map

Content

Main schedule for the decommissioning of Units 1 – 4

Milestones on the roadmap

December 2011 (Roadmap development) | December 2013 | December 2021 | In 30 – 40 years' time

Stabilization initiatives	Stage 1	Stage 2	Stage 3
<Achieving cold shutdown> ･Cold shutdown state ･Substantial suppression of discharge	Stage up to the commencement of fuel removal from spent fuel pools (SFP) (within 2 years)	Stage up to the commencement of fuel debris removal (within 10 years)	Stage up to the completion of reactor decommissioning (in 30 – 40 years' time)

Main schedule for the decommissioning of Units 1 – 4

Unit-specific schedule

- Carry out (1) fuel removal from SFP and (2) fuel debris removal as soon as practically possible for risk reduction. Build up work schedule and prepare multiple plans according to the status of each reactor unit.

	Fuel removal	Fuel debris removal
Current target	December 2013 (initial unit)	December 2021 (initial unit)
Unit 1 (Fastest plan = Plan 2)	H2 FY2017	**H1 FY2020 (brought forward by one and a half years)**
Unit 2 (Fastest plan = Plan 1)	H2 FY2017	**H1 FY2020 (brought forward by one and a half years)**
Unit 3 (Fastest plan = Plan 1)	H1 FY2015	H2 FY2021
Unit 4	**November 2013 (brought forward by one month)**	–

<Glossary>

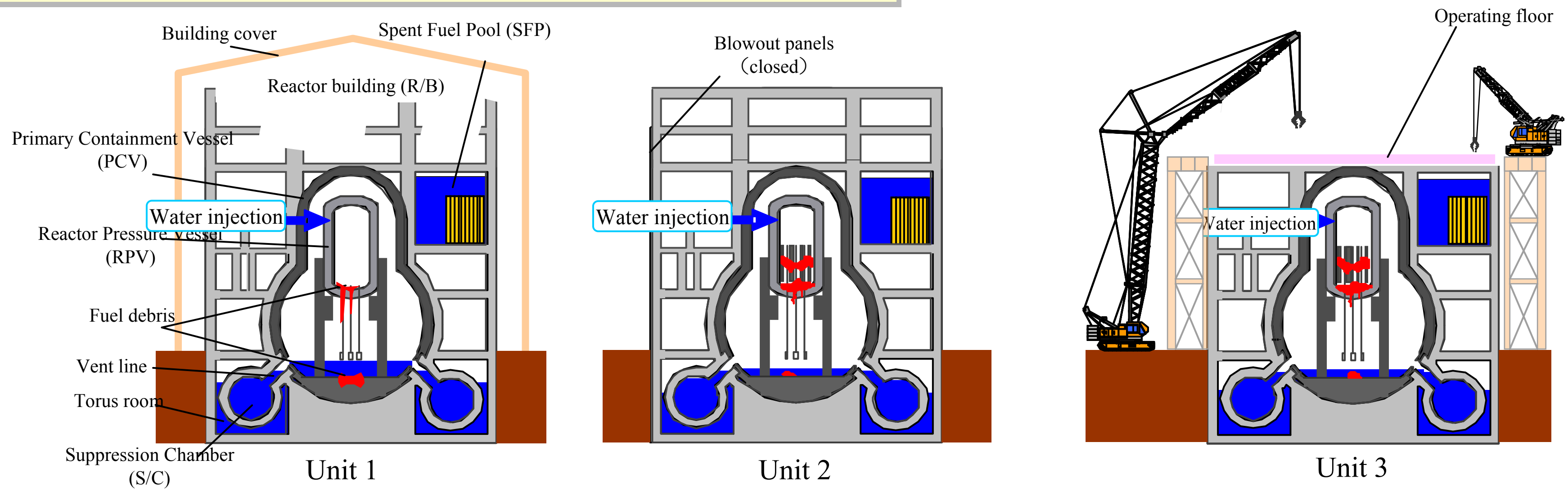
◆ **Cold shutdown state**
Reactor state in which the temperature of RPV bottom is, in general, below 100 degrees Celsius, with the release of radioactive materials from PCV substantially contained

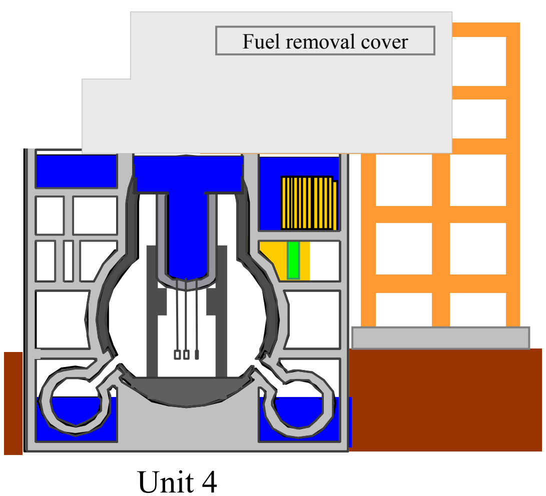
◆ **Spent Fuel Pool (SFP)**
Pool situated beside a reactor for storing and managing fuels that have been spent in the reactor

◆ **Fuel debris**
Fuel, cladding, etc. that have melted and become re-solidified

0. Introduction Status of Units 1 – 4

■ All units maintaining the cold shutdown state





	RPV bottom temperature	PCV temperature	SFP temperature	Reactor water injection volume
Unit 1	Approx. 23℃	Approx. 23℃	Approx. 17℃	Feedwater system: 2.4㎥/h Core spray system: 1.8㎥/h
Unit 2	Approx. 32℃	Approx. 32℃	Approx. 15℃	Feedwater system: 1.9㎥/h Core spray system: 3.4㎥/h
Unit 3	Approx. 30℃	Approx. 29℃	Approx. 13℃	Feedwater system: 1.9㎥/h Core spray system: 3.3㎥/h
Unit 4	–	–	Approx. 22℃	–

＜Glossary＞

◆ **Primary Containment Vessel (PCV)**
Steel vessel containing the Reactor Pressure Vessel (RPV) and other main reactor facilities

◆ **Reactor Pressure Vessel (RPV)**
Vessel containing fuel assemblies, control rods and other in-core structures, and generating steam from nuclear reaction with fuel

◆ **Torus room**
Room that contains the Suppression Chamber (S/C) (The name comes from the donut-like “Torus” shape of the suppression chamber)

◆ **Suppression Chamber (S/C)**
Facility that draws and cools steam from RPV for depressurization when the steam pressure in RPV elevates. It is also used as the source of water during emergency core cooling

◆ **Blow-out Panel**
Panel that is opened when pressure inside R/B becomes elevated

◆ **Reactor feedwater system**
Steam that passes through the turbine is cooled and condensed in the condenser. This system supplies this condensate as cooling water for the reactor.

◆ **Core spray system**
This system sprays cooling water over the top of the reactor core to prevent fuel and claddings from becoming overheated and damaged.

Current status and tasks of Units 1 – 4

- Common task among all the units
  Selecting the fuel / fuel debris removal plan from the perspective of seismic safety and workability

Unit 1

Current status

Building cover installed (November 2011)

Aimed at controlling the dispersion of radioactive materials from the reactor building, whose top section was blown off in an hydrogen explosion.

Sustained stable reactor cooling, which has reduced the amount of radioactive materials generated

Task

Removal of the building cover

Due to be dismantled, starting at the end of FY2013, to remove debris at the top of the reactor building

Identification of the status of debris on the operating floor and inside the pools

Countermeasures for the dispersion of radioactive materials during the removal of the building cover

Shortening of the building cover dismantlement period

Immediately after the earthquake

Now

Current status and tasks of Units 1 – 4

Unit 2

Current status

Very high radiation level in the building

Investigation into the operating floor's contamination status planned

Tasks

Radiation dole reduction measures

Measures for controlling the dispersion of radioactive materials during engineering work

Immediately after the earthquake

Now

0. Introduction Current status and tasks of Units 1 – 4

Unit 3

Current status

Debris removal from the top of the reactor building completed (October 11, 2013)

Installation of fuel removal cover and fuel handling facility planned

Steel frame debris dropped into SFP (September 2012)

Fuel removal target rescheduled to prioritize safety
（End of 2014 ⇒ H1 FY2015）

Task

Due to high radiation levels, radiation dose reduction measures must be carried out safely and steadily with remote-controlled heavy machinery.

Immediately after the earthquake

Now

Current status and tasks of Units 1 – 4

Unit 4

Current status

- Debris removal from the top of the reactor building completed (December 2012)
- Fuel removal cover installed
- Fuel removal facility installed inside the fuel removal cover
- Fuel removal from SFP commenced (November 18, 2013)

(Removal commencement: One month ahead of the initial schedule / Due to be completed at the end of 2014)

Tasks

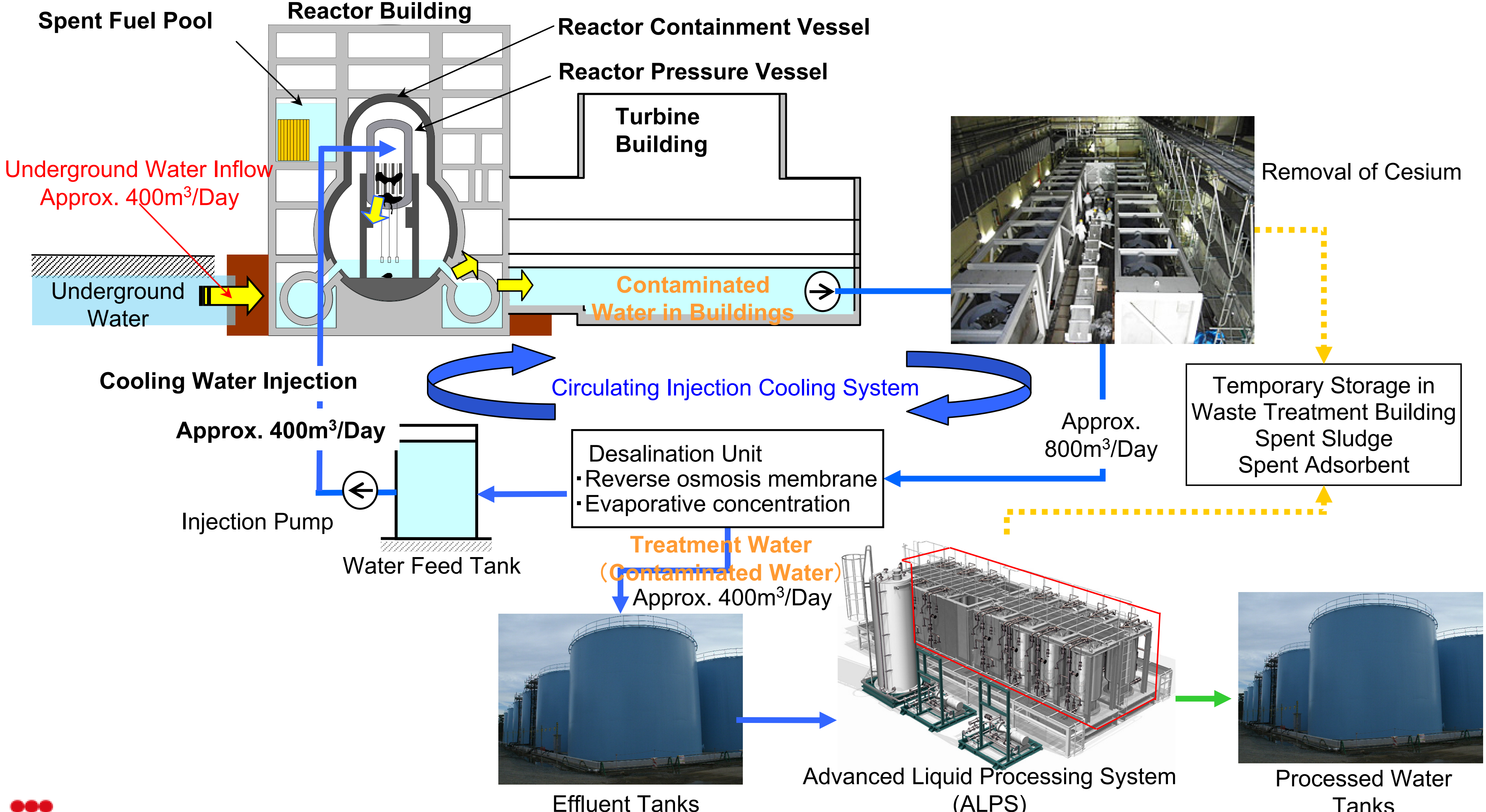
- Continuing work while assuring safety
- Exploring the method for removing fuel with confirmed leakage

Immediately after the earthquake

Now

Circulating Injection Cooling System

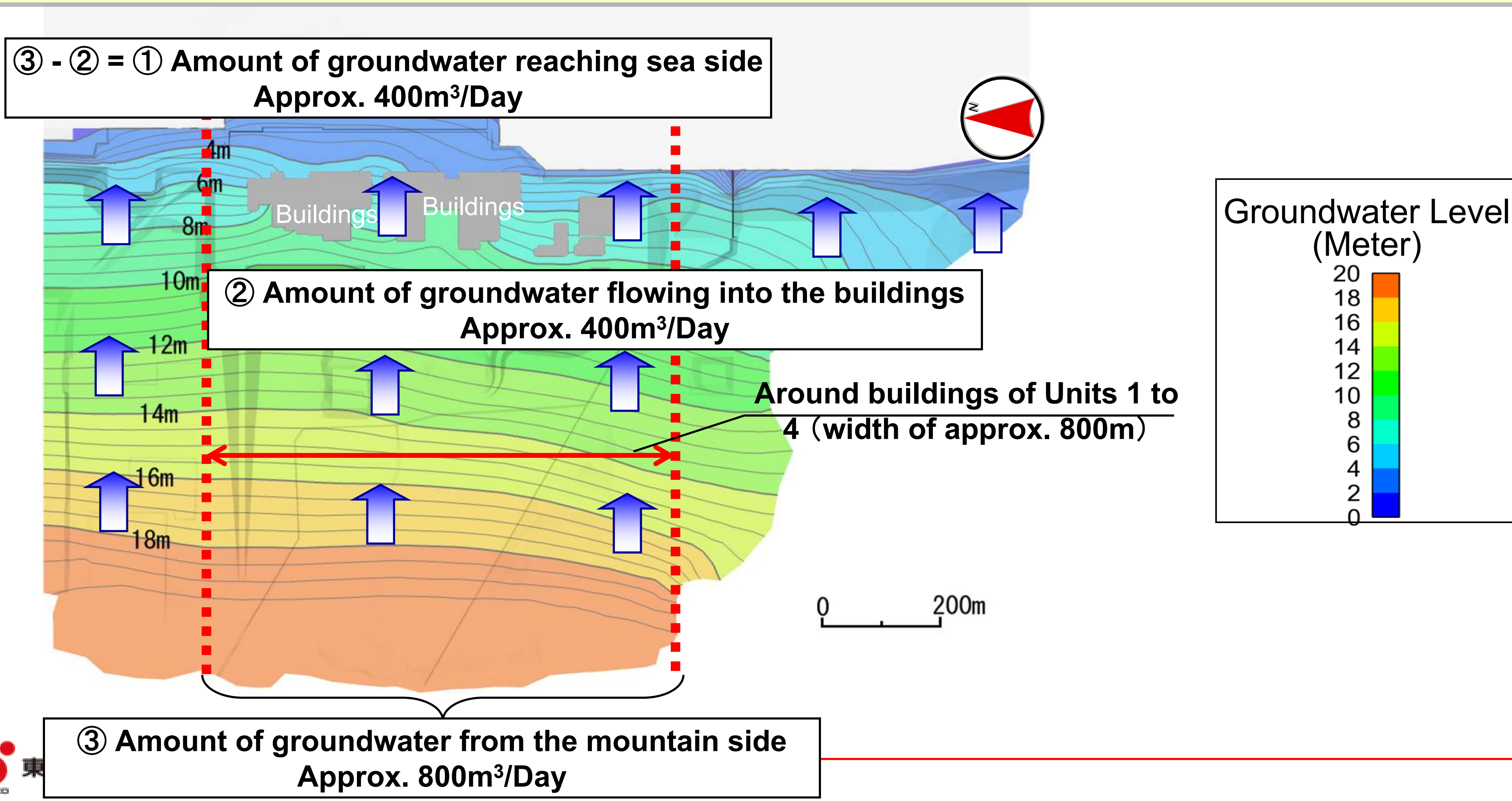
- Continuous operation of the circulating injection cooling system keeps the reactors in a stable condition at low temperature.



Flow of groundwater into the power station

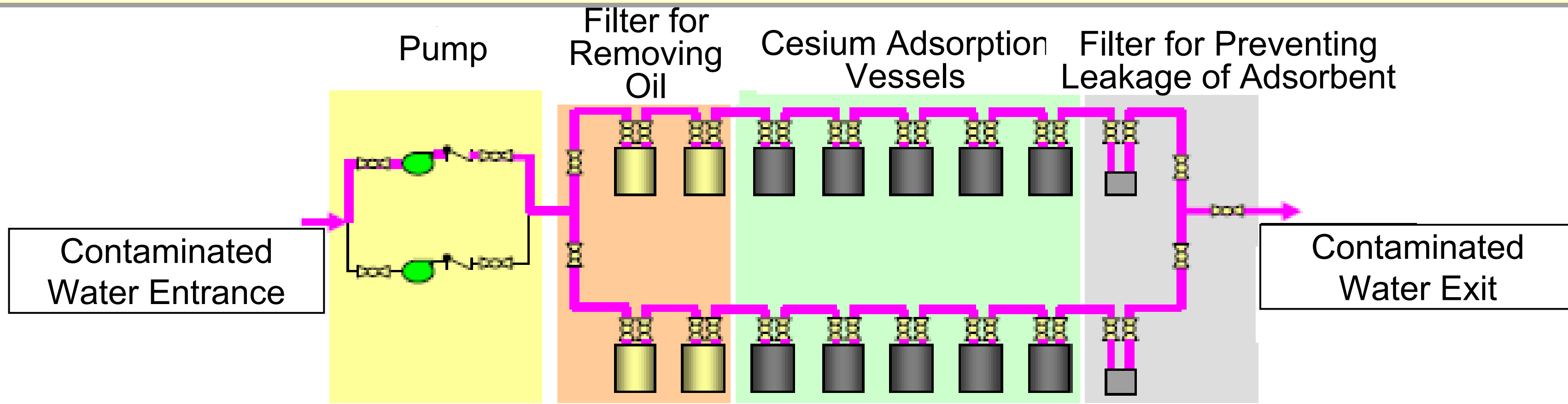
<Image of groundwater flow>

- Some 800 cubic meters of groundwater around Units 1 - 4 buildings is flowing from the mountain side into the NPS per day , with 400 cubic meters per day assumed to flow into the buildings per day, and the remaining 400 cubic meters traveling on to the sea. Groundwater that ends up in the buildings becomes contaminated and requires treatment.



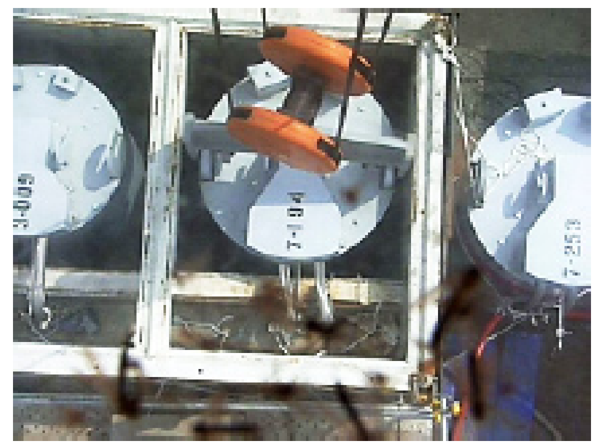
Cesium Adsorption Apparatus

- Start of operation: June 17, 2011 (KURION) , August 19, 2011 (SALLY)
- Amount of treatment: 1,200m^3/Day



Cesium Adsorption Vessels

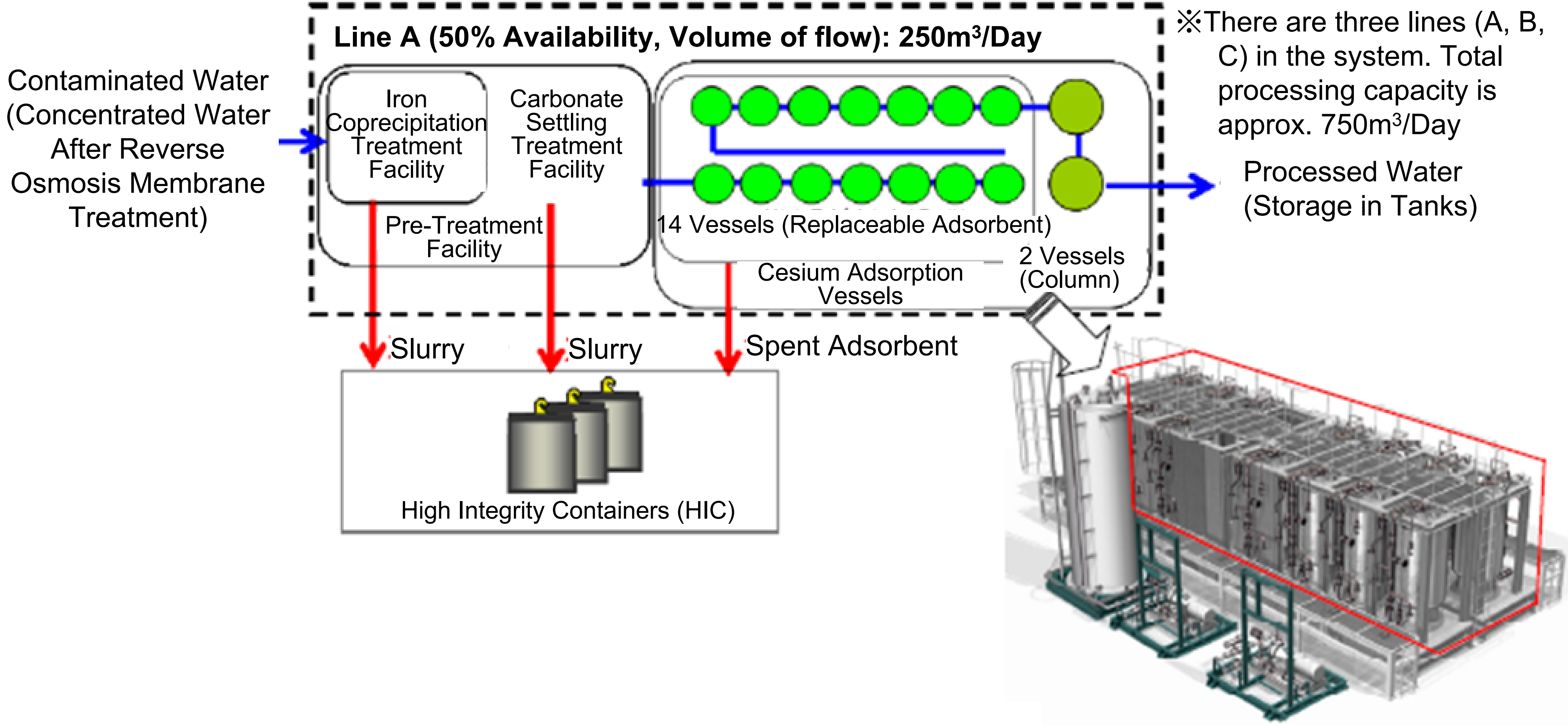
Installation of Cesium Adsorption Vessel



Changing Cesium Adsorption Vessels

Advanced Liquid Processing System (ALPS)

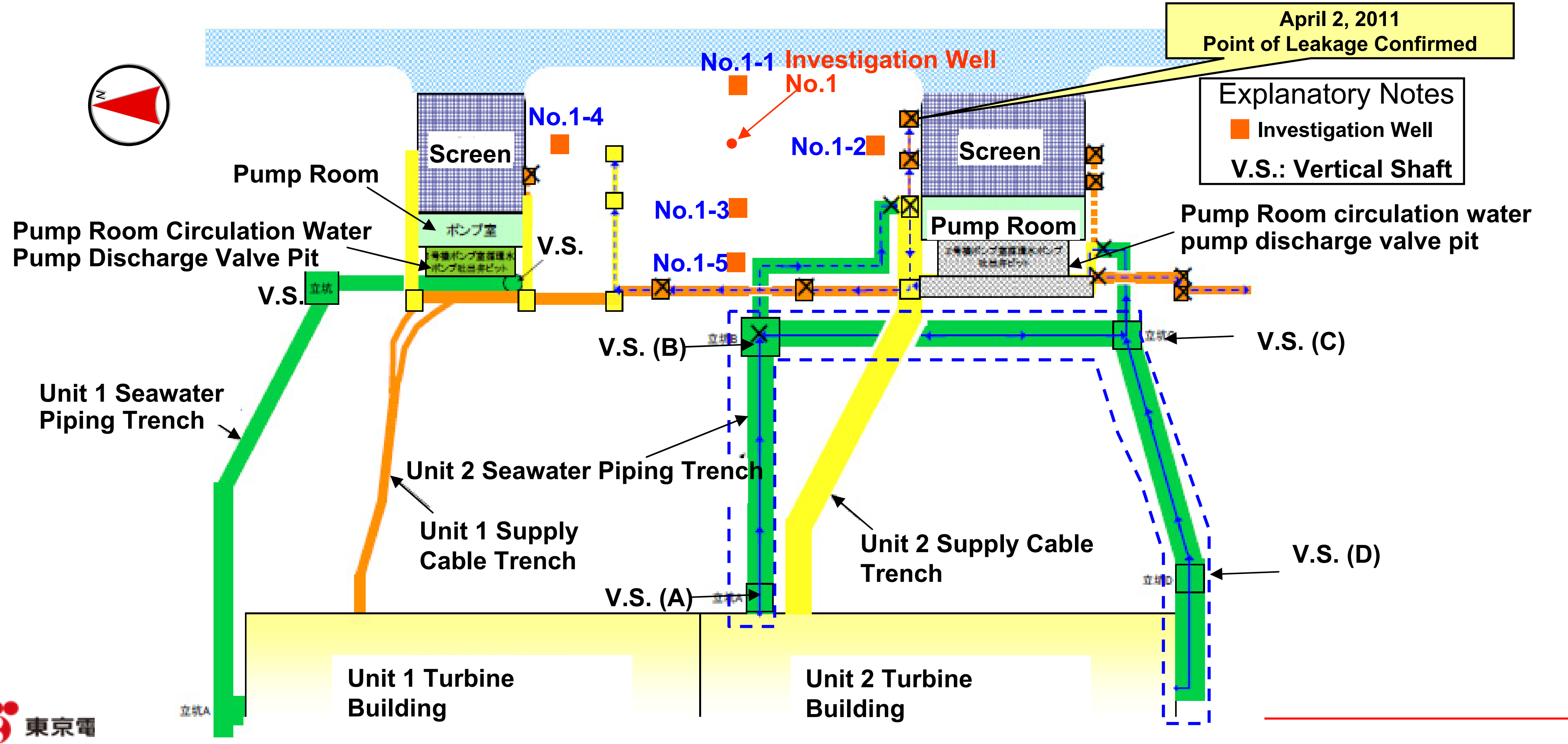
- Removal of radioactive materials (except Tritium) from contaminated water.
- Undergoing test operations using water containing radioactive materials.
- Confirmed that the density of 62 nuclides fell below the Designated Density Limits in verification tests.



※There are three lines (A, B, C) in the system. Total processing capacity is approx. 750m³/Day

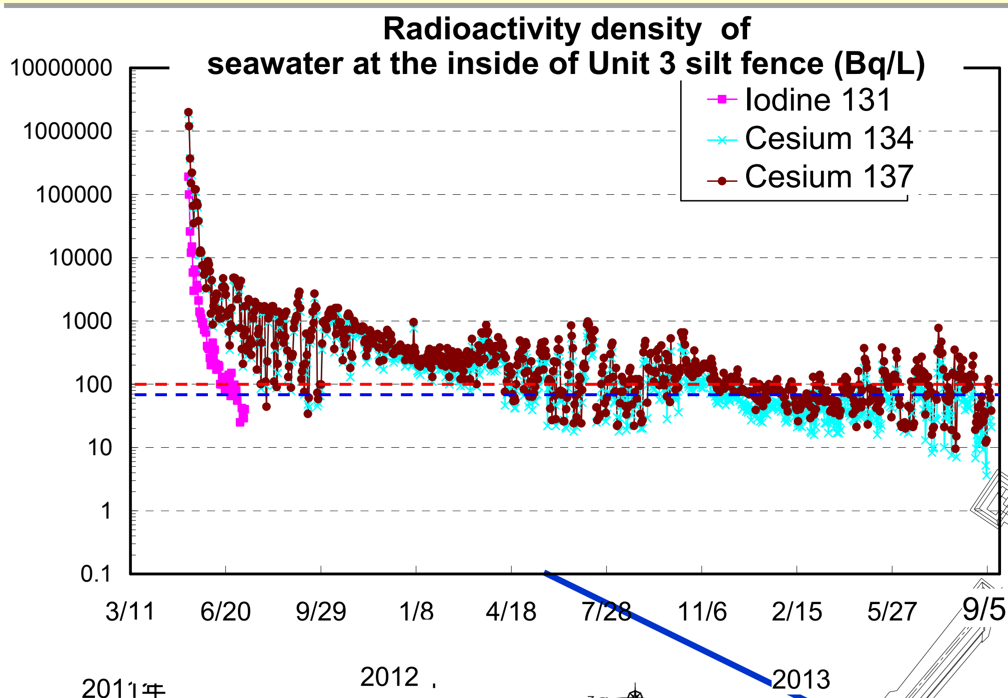
Outflow Out of Contaminated Water to the Ocean Immediately following the Accident

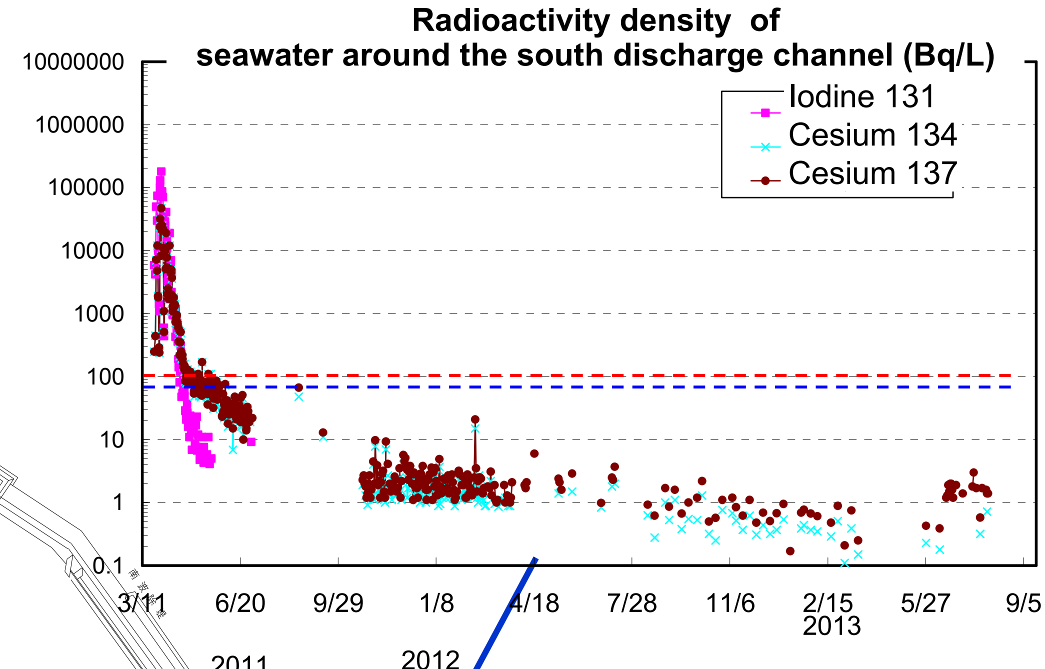
- Immediately following the accident, highly-concentrated contaminated water from the basement of the turbine building flowed out to the inner port through an underground trenches.
- Outflow between the port and the trenches has already been stanched, but highly-concentrated contaminated water remains in the underground structure.

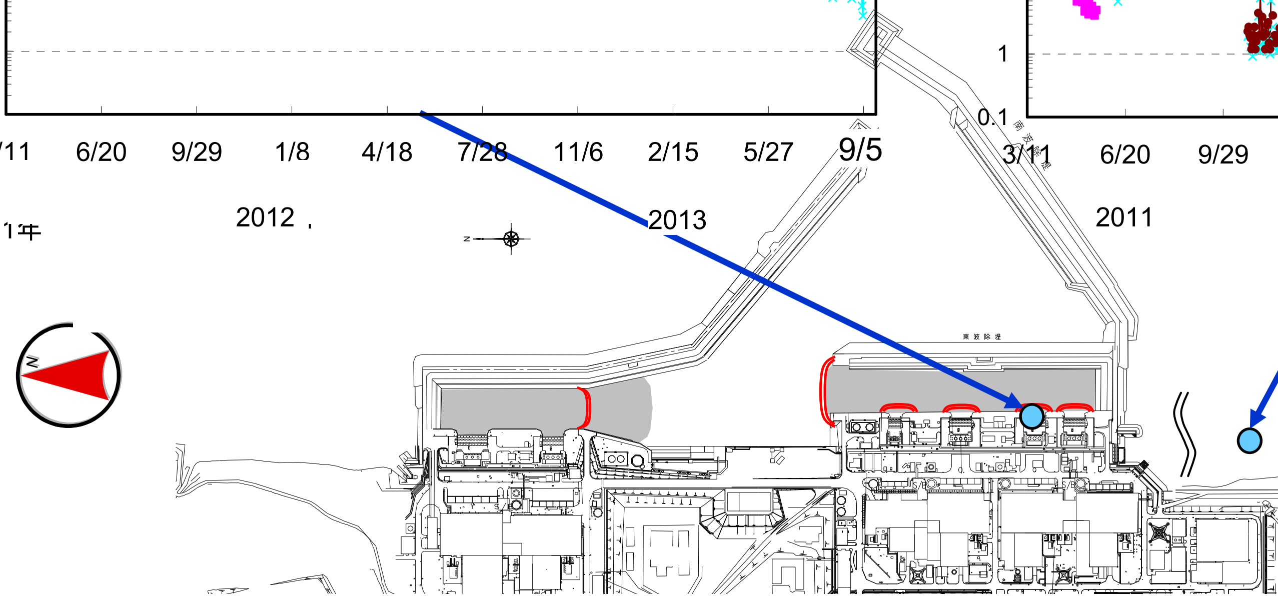


Change in Radioactivity Density of Sea After the Earthquake

- The results of continuous sampling of seawater in the port show that the radioactivity density gradually lowered, but recently it has remained at the same level.
- At present, over 100Bq/L of Cesium 137 is still being detected in front of Units 1-4's water intakes.







《Reference》

Designated Density Limits

(the density limit in the water outside the monitored areas)

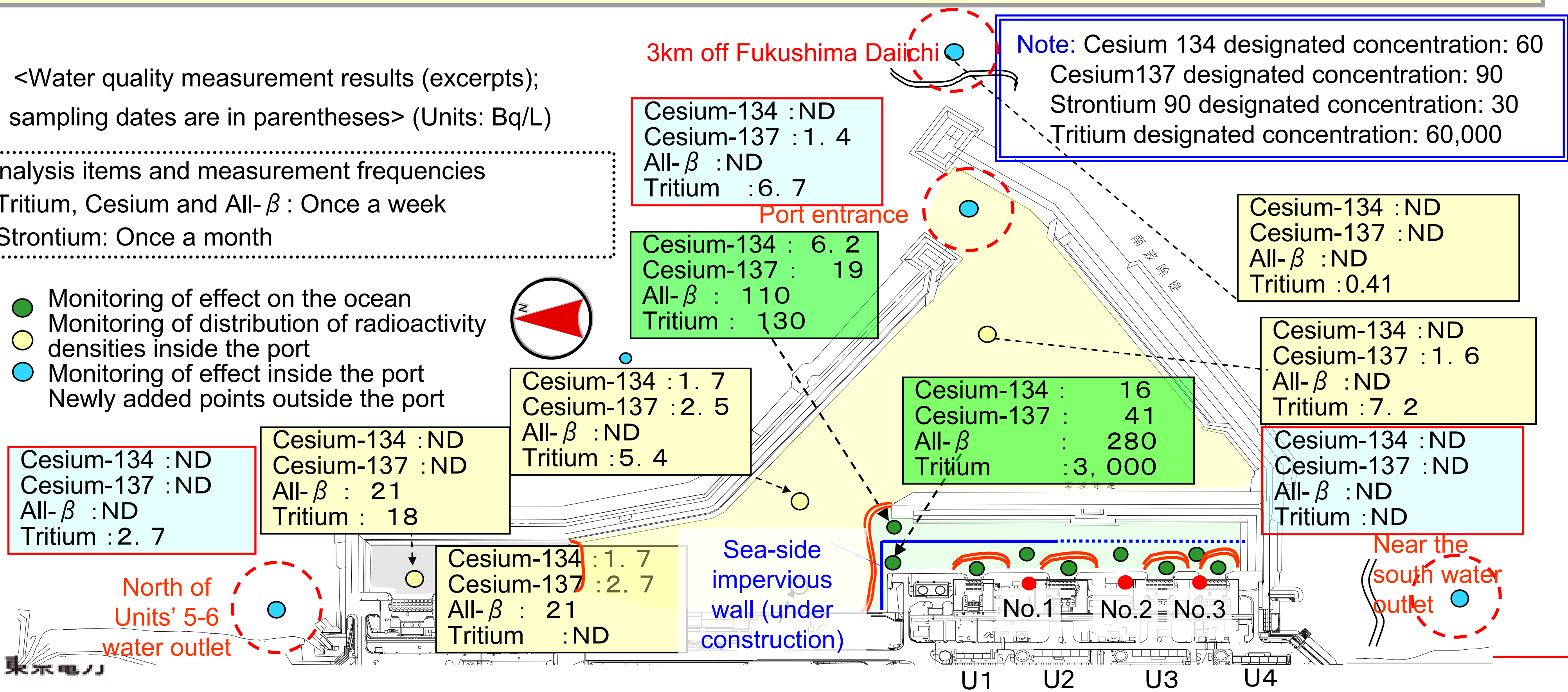
- Cesium 137: 90Bq/L
- Cesium 134: 60Bq/L

Current radioactivity density measurement results inside and outside the port

- At the locations in front of Units 1-4's water intakes (●), the All-β and Tritium densities in seawater have been showing repeated fluctuations.
- At the locations inside the port (○), the densities in seawater have been almost below the detection limit values.
- At the locations near the boundary of the port (●), the densities have been at the same levels or lower than those inside the port.
- At the locations 3km and 15km offshore the power station, and 3km offshore the Ukedo River, the All-β and Tritium densities have been below the detection limit values.

<Water quality measurement results (excerpts); sampling dates are in parentheses> (Units: Bq/L)

Analysis items and measurement frequencies
- Tritium, Cesium and All-β : Once a week
- Strontium: Once a month



Recent radiation concentration measured inside and outside of the port

- Mostly below the detectable limits (ND) at locations 3km (●) / 15km offshore of the NPS and 3km offshore of Ukedogawa

Sea-side monitoring posts around the NPS and most recent measurement results

( ): Sampling date

Southside of Ukedo port "T-6"

Cesium 137: 0.20 (10/1)
Total beta level: **ND** (10/1)
Tritium: 0.58 (10/1)

3km offshore of Ukedogawa (upper layer) "T-D1"

Cesium 137: 0.0099 (10/4)
Total beta level : **ND** (10/4)
Tritium: **ND** (10/4)

15km offshore of 1F site (upper layer) "T-5"

Cesium 137: 0.0029 (9/18)
Total beta level: **ND** (9/18)
Tritium: **ND** (9/18)

3km offshore of 1F site (upper layer) "T-D5"

Cesium 137: 0.013(10/4)
Total beta level: **ND** (10/4)
Tritium: 0.38 (10/4)

3km offshore of 2F site (upper layer) "T-D9"

Cesium 137: 0.016 (10/5)
Total beta level: **ND** (10/5)
Tritium: **ND** (10/5)

Near 2F north intake "T-3"

Cesium 137: 0.40 (10/1)
Total beta level: **ND** (10/1)
Tritium: **ND** (10/1)

Fundamental Measures (FM)

■"Stopping outflow into the ocean" --- ①Installation of a sea-side impervious wall. [Preventing leaks]

■"Suppressing increase of contaminated water and preventing outflow into the port" --- ②Installation of a land-side impervious wall (by soil freezing method). [Keeping away from contamination] [Preventing leaks]

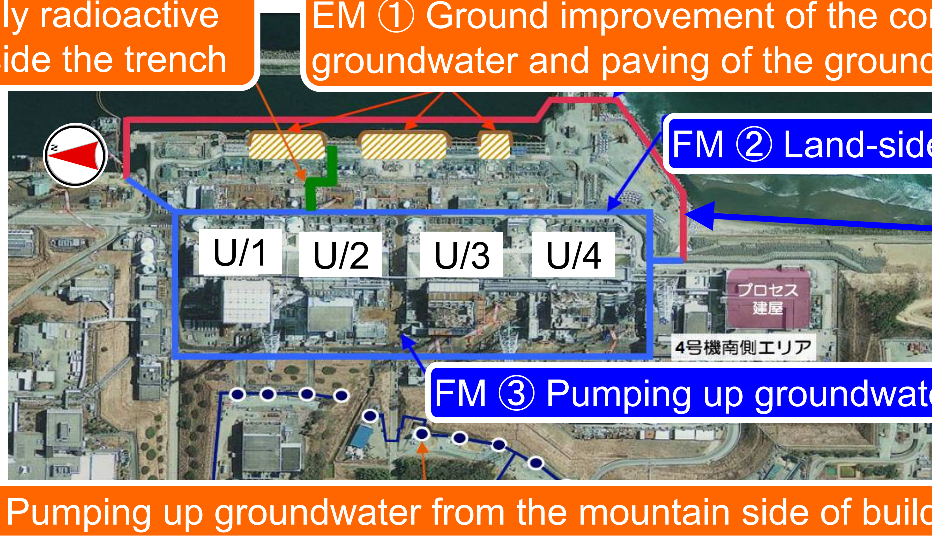
■"Stopping inflow of groundwater into the reactor buildings, etc" --- ③Pumping up groundwater through sub-drains. [Keeping away from contamination]

Emergency Measures (EM)

■"Preventing outflow of contaminated water into the port" --- ①Ground improvement of the contaminated area, pumping up of groundwater and paving of the ground surface. [Preventing leaks] [Keeping away from contamination]

■"Removing contamination sources" --- ②Removal of highly radioactive contaminated water inside the trenches. [Removing contamination]

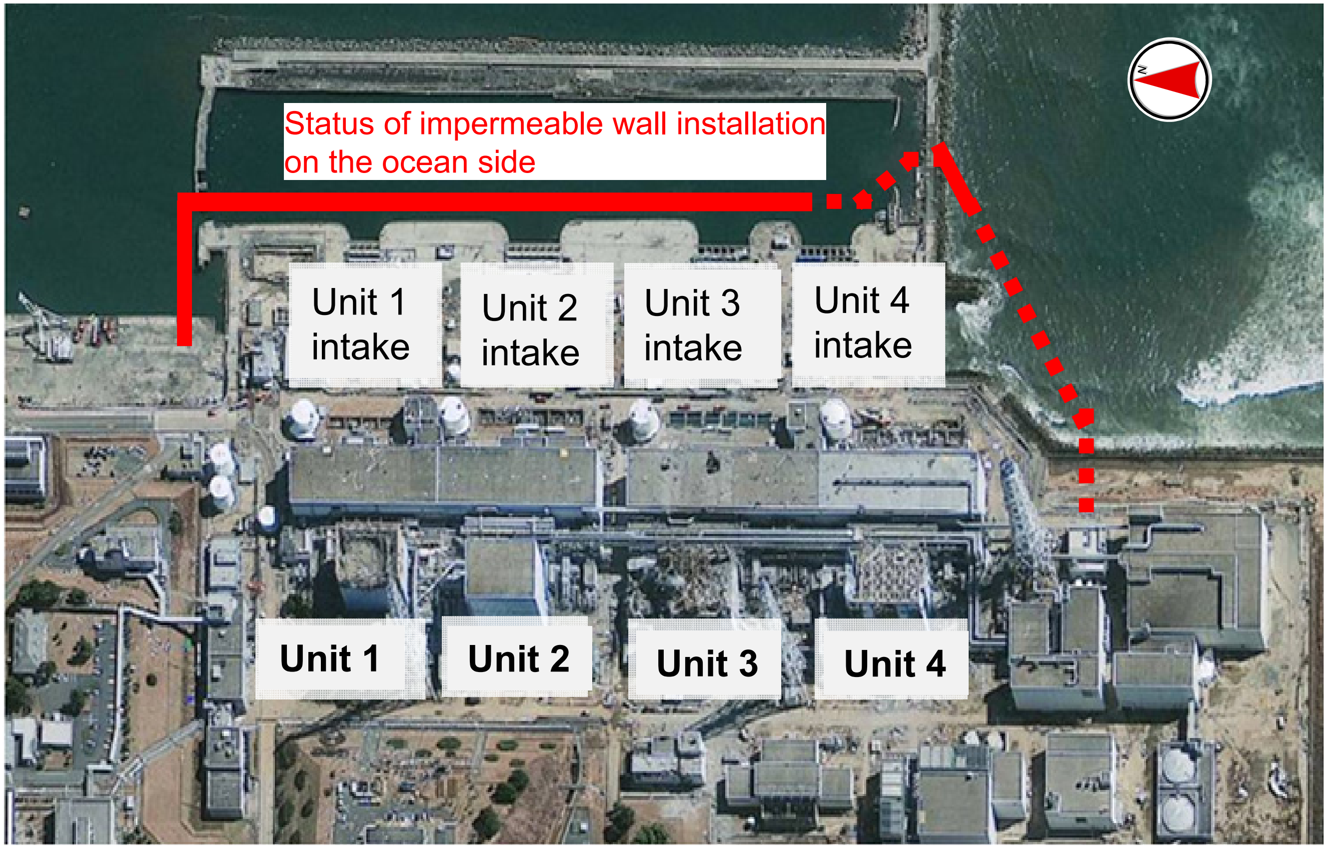
■"Suppressing increase of contaminated water" --- ③Pumping up groundwater from the mountain side of buildings (groundwater bypass). [Keeping away from contamination]

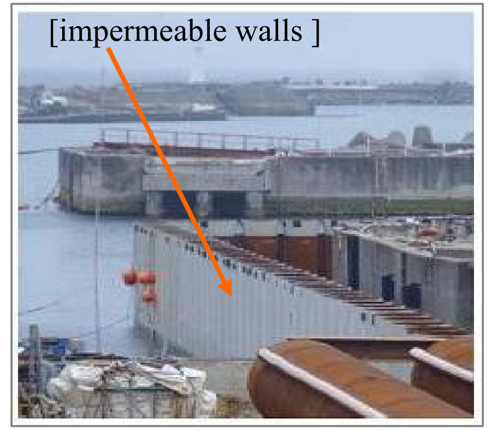


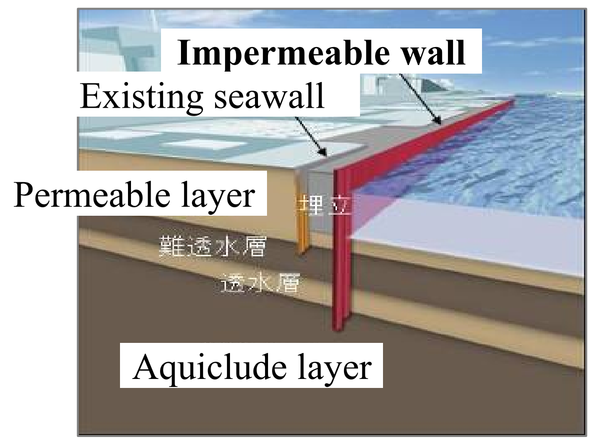
3. Countermeasures for contaminated water

Measure ① "Stopping outflow into the ocean" --- Installation of a sea-side impervious wall. [Preventing leaks]

- An impermeable wall is installed on the ocean side to suppress the outflow of groundwater to the seawall.
- The impermeable wall has been installed up to Unit 4's intake channel (see below). It is expected to be completed by September next year.



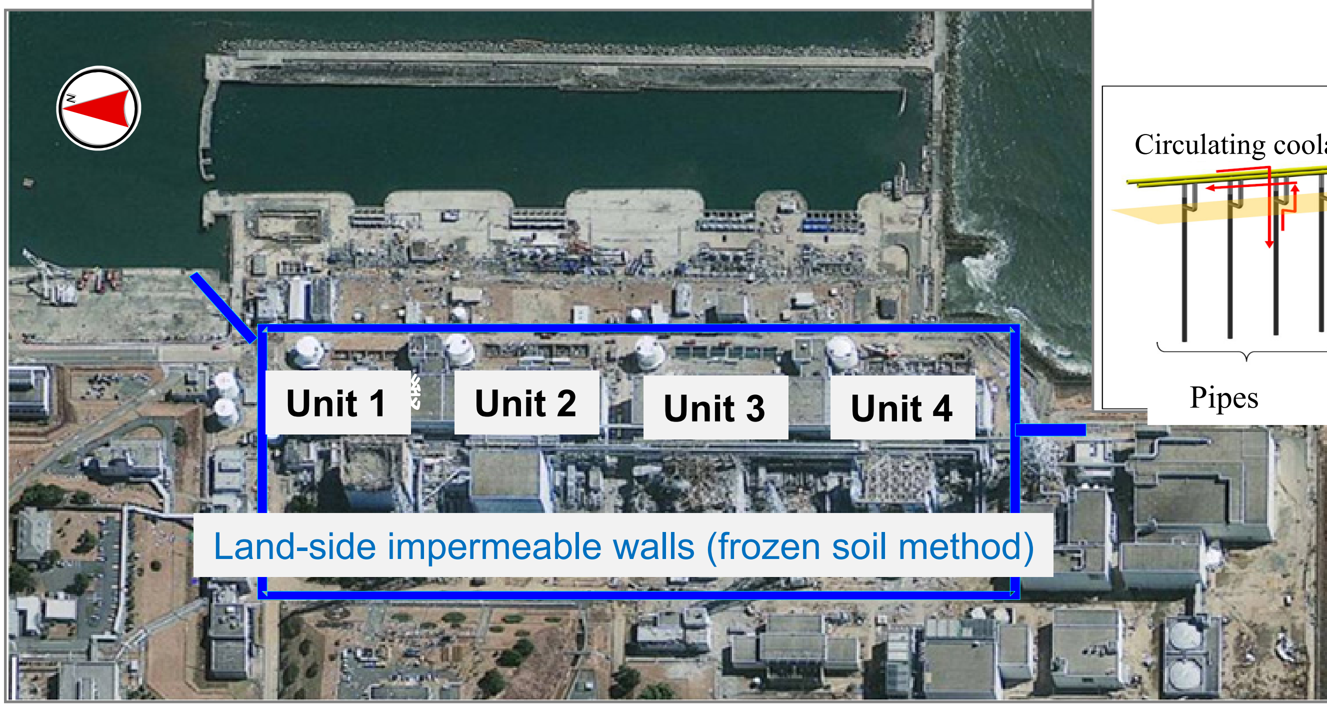


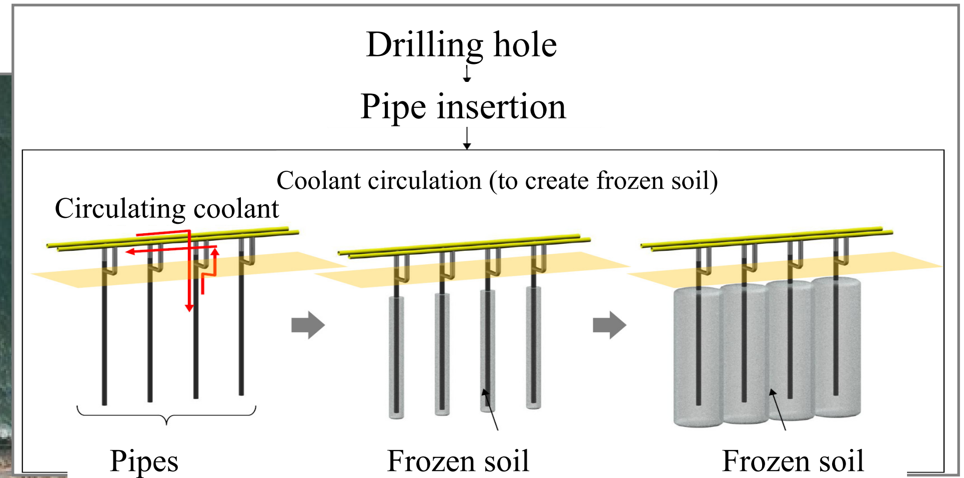


3. Countermeasures for contaminated water

Measure ② "Suppressing increase of contaminated water and preventing outflow into the port" --- Installation of a land-side impervious wall (by soil freezing method). [Keeping away from contamination] [Preventing leaks]

- Impermeable walls are installed on the mountain side of the NPS buildings to suppress the increase of contaminated water attributable to groundwater inflow.
- Feasibility study is conducted by the end of this fiscal year for the commencement of their use in H1 FY2015. [Project assisted by the Ministry of Economy, Trade and Industry]



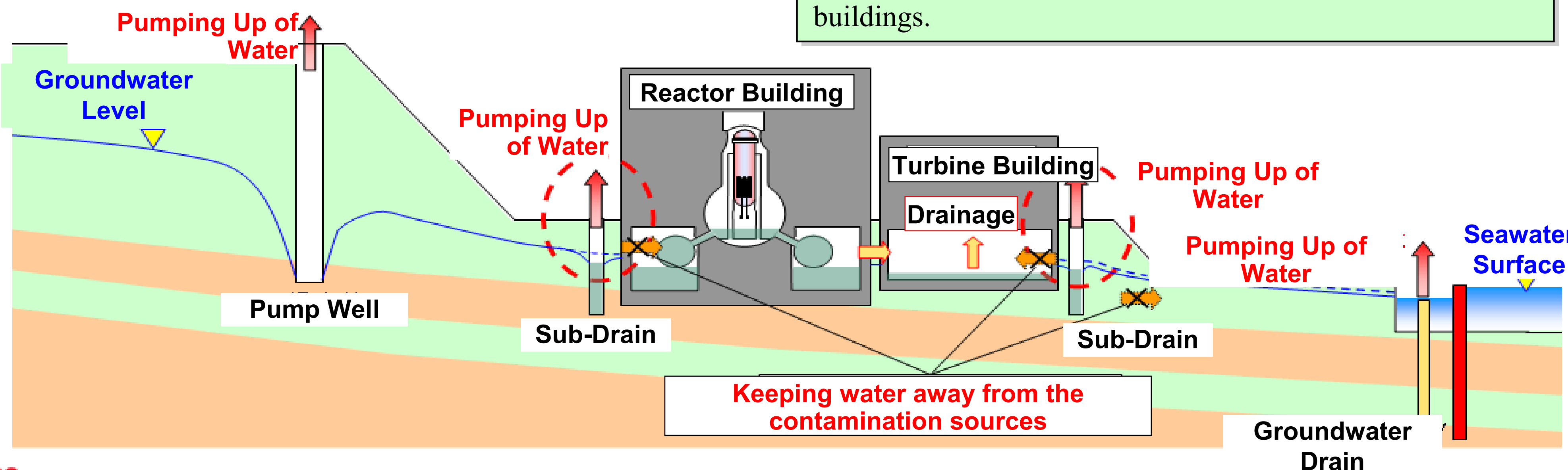


3. Countermeasures for contaminated water

Measure ③ "Stopping inflow of groundwater into the reactor buildings, etc" --- Pumping up groundwater through sub-drains [Keeping away from contamination]

- Inflow of groundwater into the buildings will be suppressed by restoring sub-drains and pumping up groundwater around the buildings through the sub-drains.
- Restoring sub-drains deeper in the mountain side and pumping up groundwater through such sub-drains is more effective in reducing the amount of groundwater that flows into the bank protection area.

◆ **Subdrain**
Well installed near site buildings. Groundwater in subdrains has been pumped up to prevent it from seeping underneath the buildings or prevent the buildup of buoyancy for the buildings.

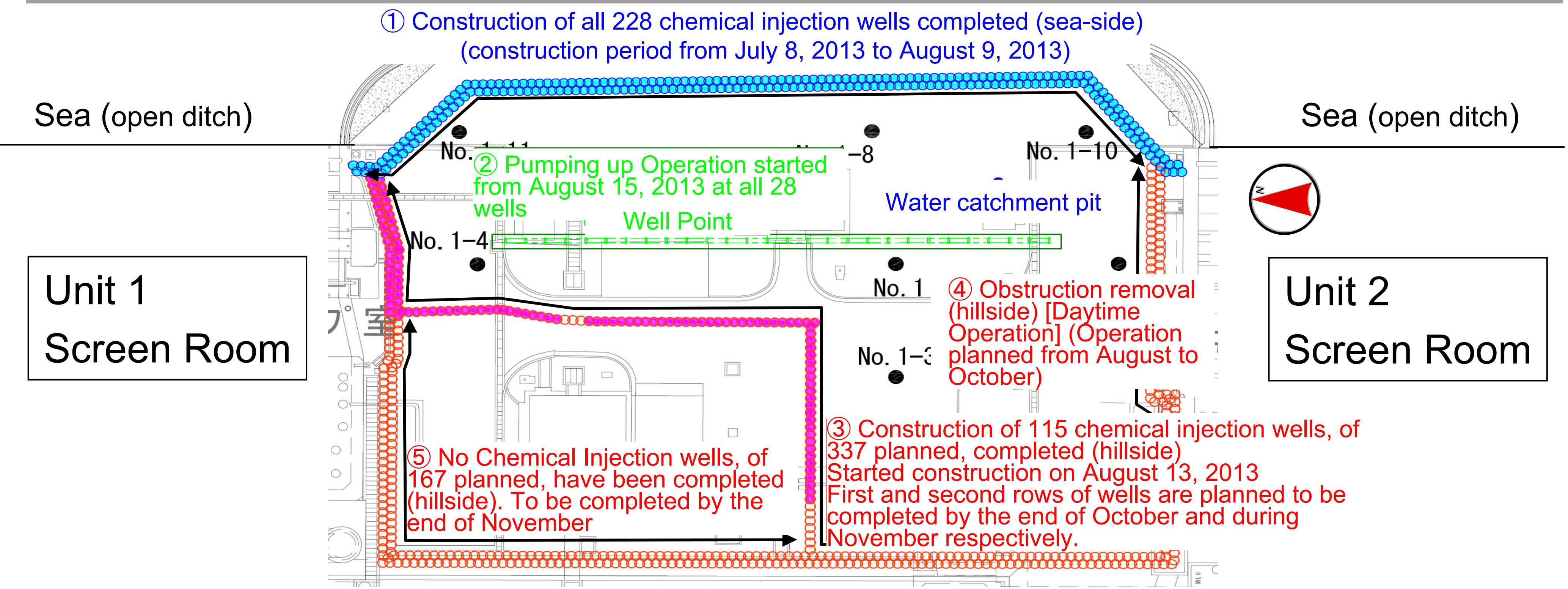


3. Countermeasures for contaminated water

Measure ① **"Preventing outflow of contaminated water into the port"**

Ground improvement of the contaminated area, pumping up of groundwater and paving of the ground surface. [Preventing leaks] [Keeping away from contamination]

- Ground improvement was carried out for the purpose of reducing contaminated groundwater outflow. Ground improvement began on July 8 between Units 1 and 2, on August 29 between Units 2 and 3, and on August 23 between Units 3 and 4. Operations are continuing.
- Ground improvement was carried out and groundwater pumped up.
- The ground surface will be paved.



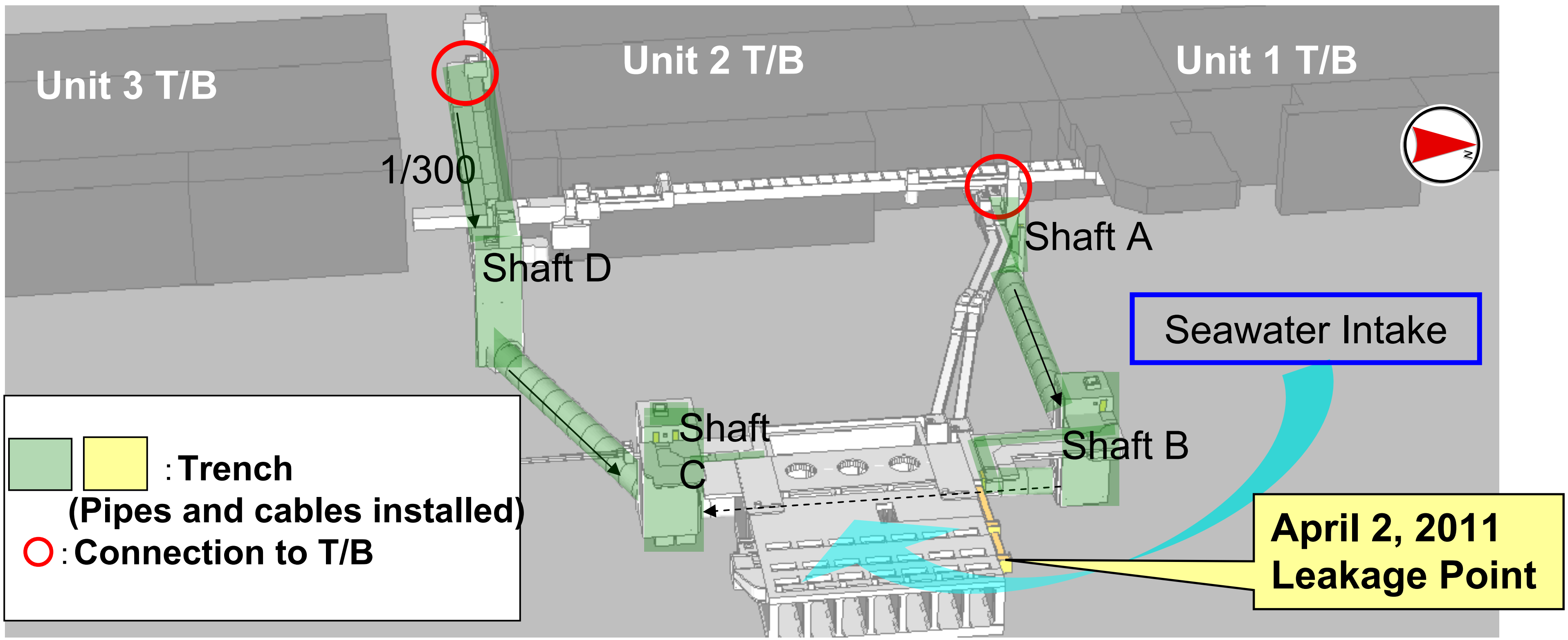
Current status of the ground improvement and pumping up of the groundwater between Unit 1 and 2 (as of September 25, 2013)

※Area of construction may be changed due to situation of the site

Measure ② “Reamoving contamination sources” --- **Removal of highly radioactive contaminated water inside the trenches**

- The contaminated water leaked into the ocean through the trenches.
- The leakage stopped, but contaminated water remains in the trenches.
- Contaminated water inside the trenches will be removed and the trenches will be blocked.

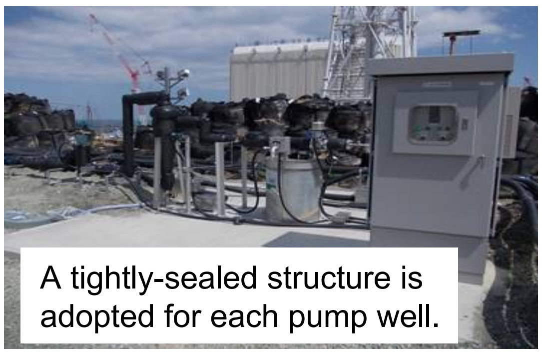
Turbine building (sea side) Underground Construction



3. Countermeasures for contaminated water

Measure ③ **"Suppressing increase of contaminated water" ---**
(3) Pumping up groundwater from the mountain side of buildings (Groundwater bypass) [Keeping away from contamination]

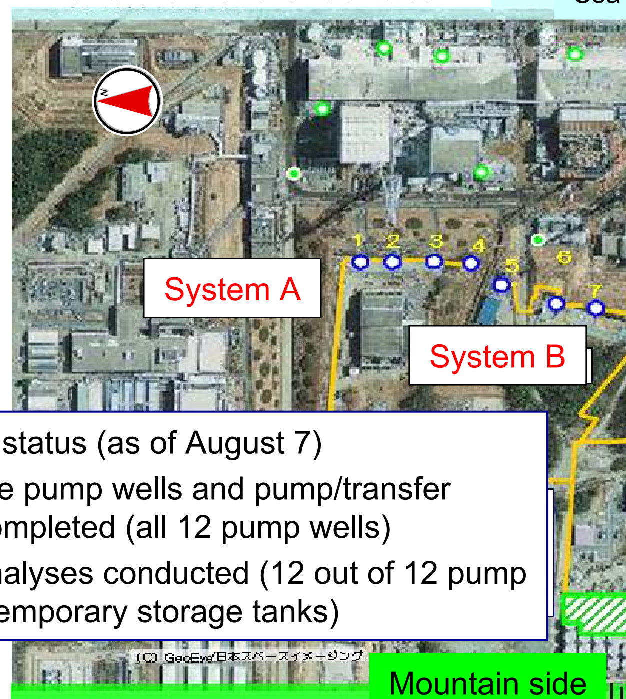
- Groundwater from the mountain side is pumped up and bypassed at upstream of the buildings to reduce the amount flowing into them.
- The properties of groundwater sampled from pump wells and temporary storage tanks were examined to confirm that its contamination levels were below detectable limit or sufficiently low.



A tightly-sealed structure is adopted for each pump well.

Dedicated pipes and tanks are installed.

<Overview of the facilities>



■Work progress status (as of August 7)

- Installation of the pump wells and pump/transfer piping facilities completed (all 12 pump wells)
- Water quality analyses conducted (12 out of 12 pump wells; 3 out of 9 temporary storage tanks)

○ : Pump well (Installation completed; water quality analysis completed)

: Piping route (construction completed)

: Temporary storage tank (installation completed)

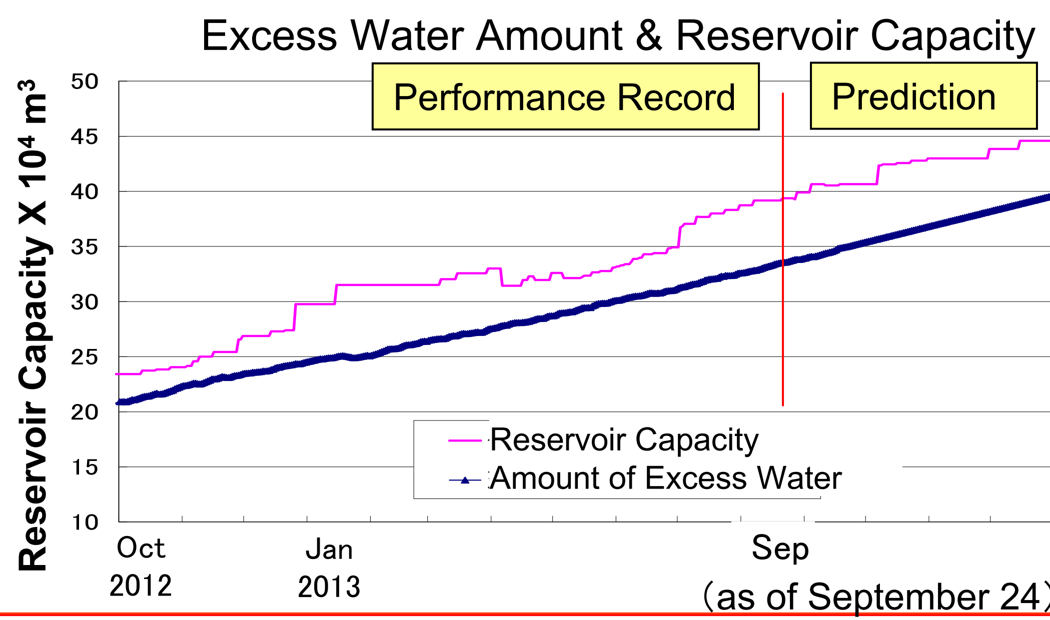
● : Observation well (newly installed; installation completed)

○ : Observation well (sub-drain pit water level measurement point)

[Reference] Contaminated Water Storage

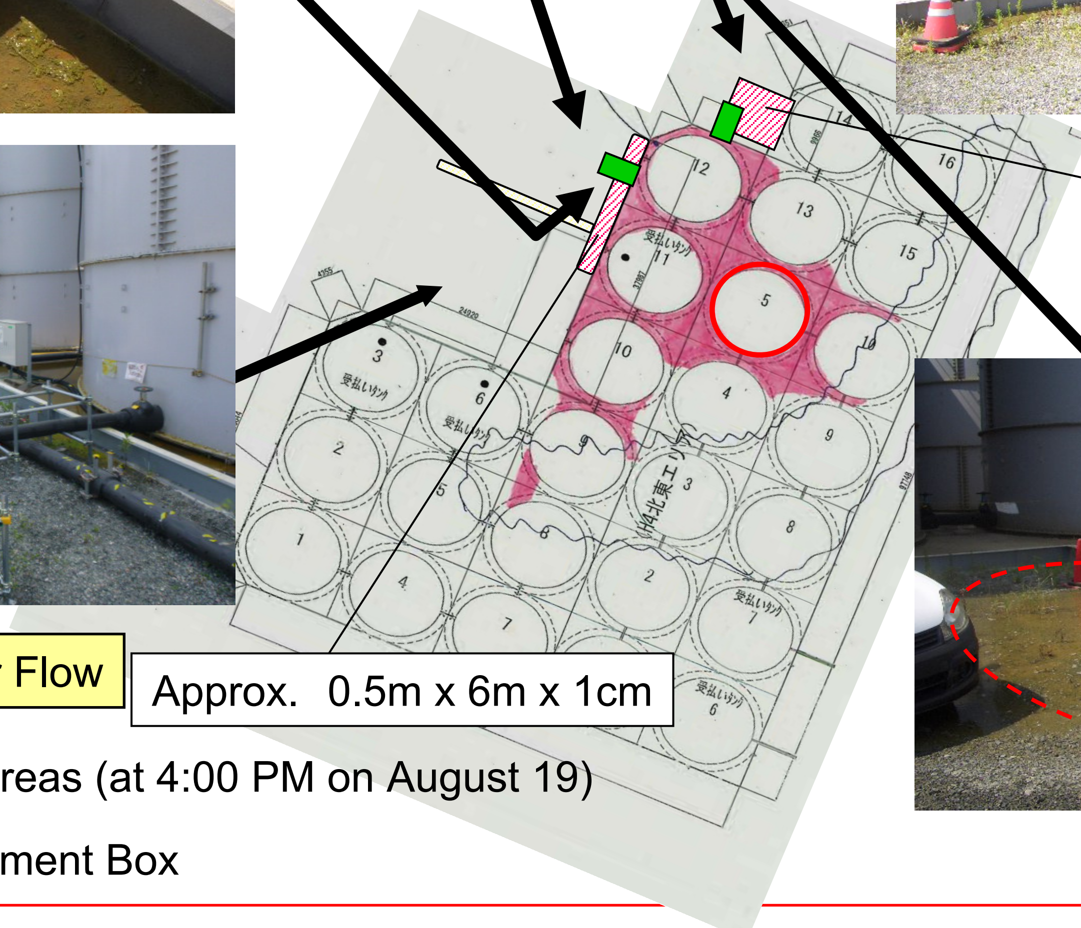
- Water Reservoir Capacity: 4.1 x 10^5 m^3
- Excess Water: 3.5 x 10^5 m^3
- Capacity Requirement: Predicted to achieve 8.0 x 10^5 m^3

Steel Transverse-Mounted Tanks



Situation when Leak Occurred

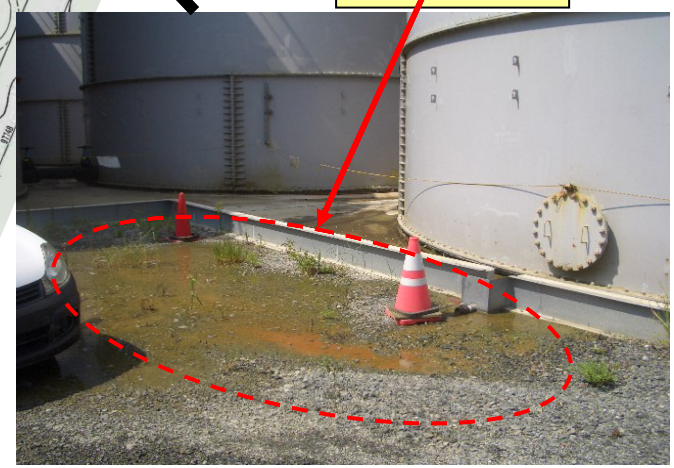
Trace of Water Flow



Approx. 0.5m x 6m x 1cm

Approx. 3m x 3m x 1cm

Puddle



: Puddle Areas (at 4:00 PM on August 19)

: Water Catchment Box

Patrol Reinforcement

- Increased patrol frequency from twice a day to 4 times a day from September 2 onward. Before the tank leak, the patrol frequency was twice a day.
- Increased the number of patrol personnel to 30 for the day, 6 for the night (total of 96 persons across patrol times/day) from September 2 onward, and further increased to 30 for each patrol (total of 120 persons across patrol times/day) from September 21 onward.
- Introduced comprehensive observation combining "Visual check" and "Dose measurement," to comprehend and record any sign or occurrence of leakage.
- Water–level indicators will be introduced by this November, and a remote central monitoring system will be initiated.

Fukushima Daiichi NPS H4 area Patrol (September 12, 2013)

Replacement of Flange-Type Tanks with Welded-Type Tanks

- Accelerate the replacement of flange-type tanks with welded-type tanks.
  - To increase the number of tanks, considering installation of tanks constructed by several companies, in several areas at the same time.
  - Accelerate the increase of welded-type tanks to remove contaminated water from flange-type tanks.

Steel Cylindrical Tank
(Flange-Type)

Replacement

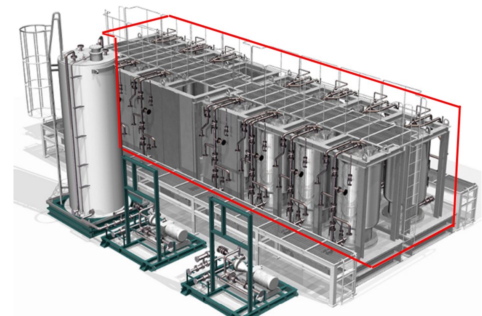
Steel Cylindrical Tank
(Welded-Type)

Accelerate the Purification of Highly Contaminated Water

- To purify (remove all nuclides except Tritium) the highly-concentrated contaminated water promptly, the following measures will be taken:
  - Activate ALPS, which is now under suspension, promptly. (Hot testing began on September 27)
  - Consider the installation of high-performance ALPS this fiscal year. (METI subsidiary enterprise)
  - Addition to the present ALPS.

<Performance comparison of ALPS systems>

- **Present ALPS: 250m^3/day x 3 systems**
- **High-performance ALPS: 500m^3/day x 1 system**
- **Additional ALPS: 250m^3/day x 3 systems**



To suppress the increase of contaminated water due to the inflow of groundwater, the water in the groundwater bypass and around the turbine buildings will be pumped up.

By taking the above measures, processing of the 3.5 x 10^5 m^3 of contaminated water stored in the tanks will be accelerated.

6. Fuel removal from Unit 4

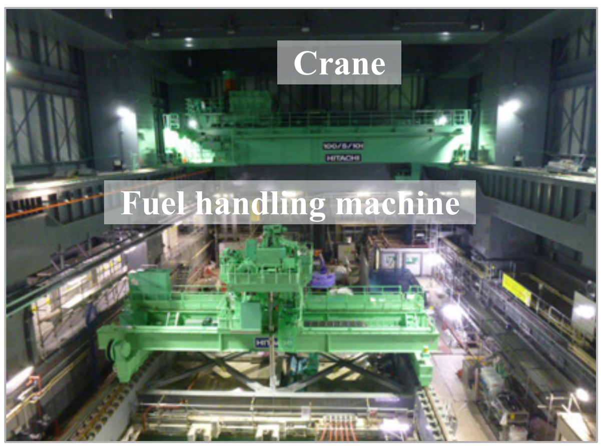
- Fuel removal from Unit 4 SFP commenced on November 18, 2013.
- Transferring the fuel to the shared pool enables its storage in a more reliable condition.

Unit 4 at the accident

- Fuel removal cover installed (completion certificate for pre-operation inspections received from the Nuclear Regulation Authority on November 12, 2013)
- Crane for lifting fuel-transporting casks (steel containers) installed inside the fuel removal cover
- Large debris inside SFP removed

Removal of felled debris
Photographed in late September 2013

Today's Unit 4

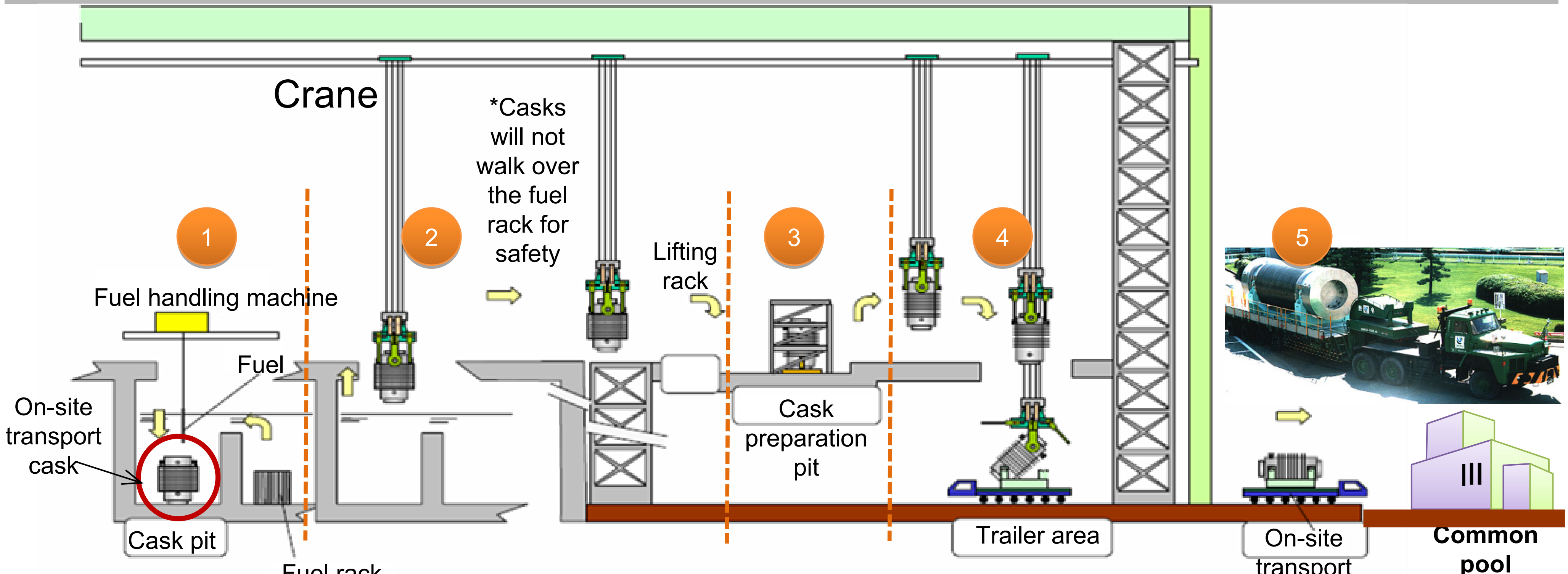


Inside the fuel removal cover

SFP after the removal of felled debris
Photographed on November 5, 2013

6. Fuel removal from Unit 4

- Using a facility that has the same structure, design and safety level as conventional facilities for fuel handling
- TEPCO has the experience of transferring the cask pit over 1200 times thus far.



1. Grab fuel assemblies stored in the fuel rack and load them to the cask inside the cask pit (underwater)
2. Lift the cask from the cask pit and transport it to the cask preparation pit on the lifting rack inside the cover
3. Seal the lid on the cask preparation pit and perform decontamination
4. Lift the cask by crane, put it down to the trailer area and load it to the transport vehicle
5. Transport the cask to the on-site common pool

Invitation of Leading TMI Decommissioning Expert

- We have determined to invite Mr. Lake H. Barrett (former US Nuclear Regulatory Commission, and former US Department of Energy), an overseas expert well versed in clean-up and decommissioning technology, as an outside expert to the "Contaminated Water and Tank Countermeasures Headquarters.“ He will guide and advise us.

Has international knowledge and experience, acquired by engaging in control of the Three Mile Island accident at the US Nuclear Regulatory Commission.

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Will participate in the meetings of the Contaminated Water and Tank Countermeasures Headquarters and each project team, and will provide advice regarding decommissioning issues, including contaminated water countermeasures.