Current Status of Fukushima Dai-ichi NPP and Future Plan

November 7, 2013

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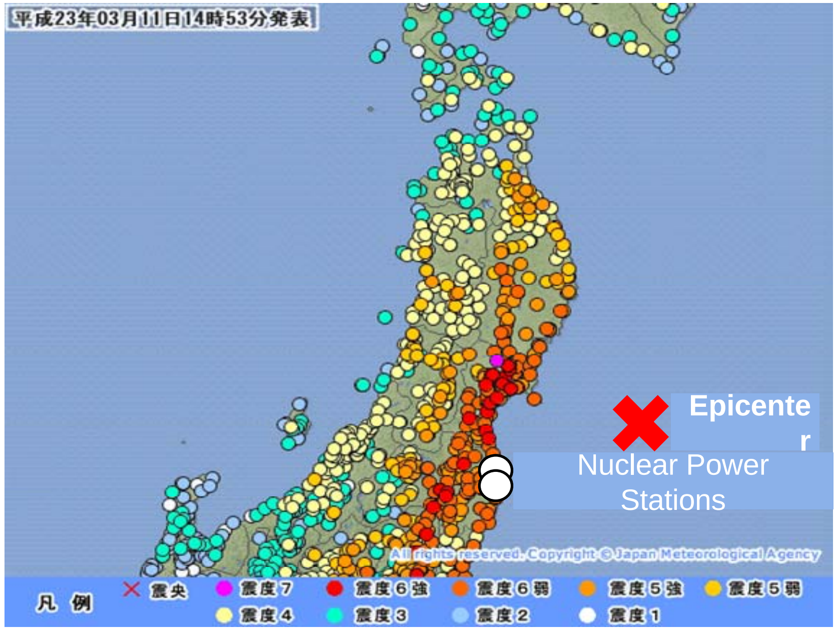
Contents

Bird's-eye view of 1F Plant Status

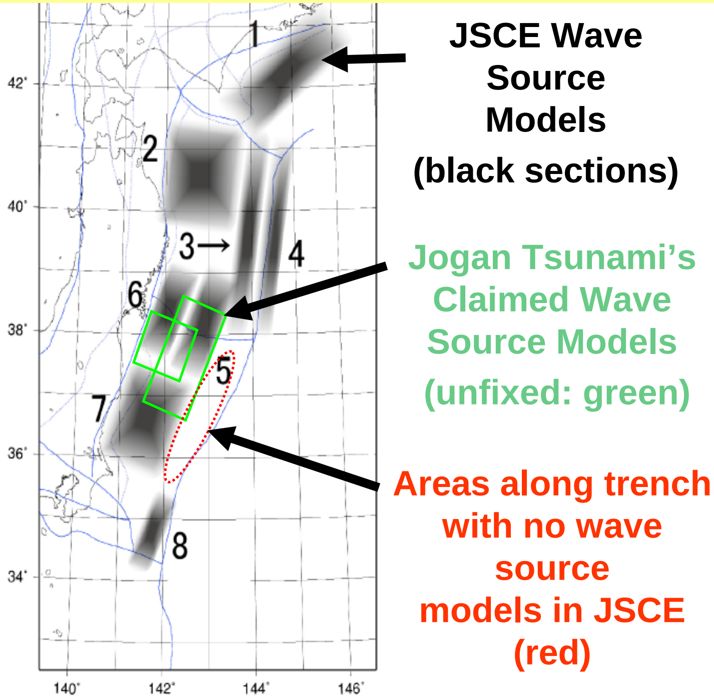
1. Overview of Earthquake and Tsunami

Scale of Earthquake and Tsunami

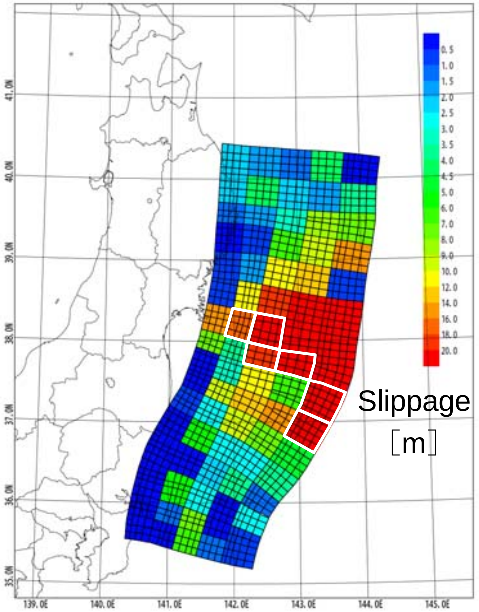
- massive earthquake (magnitude 9.0 and the fourth largest ever recorded worldwide)
- Caused by simultaneous move of several regions: Area of 500 km x 200 km slipped off the coast along the trench
- Evaluation of all Tsunami was based on Methodology by Japan Society of Civil Engineers: It defines eight wave sources



Distribution of Seismic Intensity on 3-11



JSCE Method and Jogan Tsunami Claimed Sources



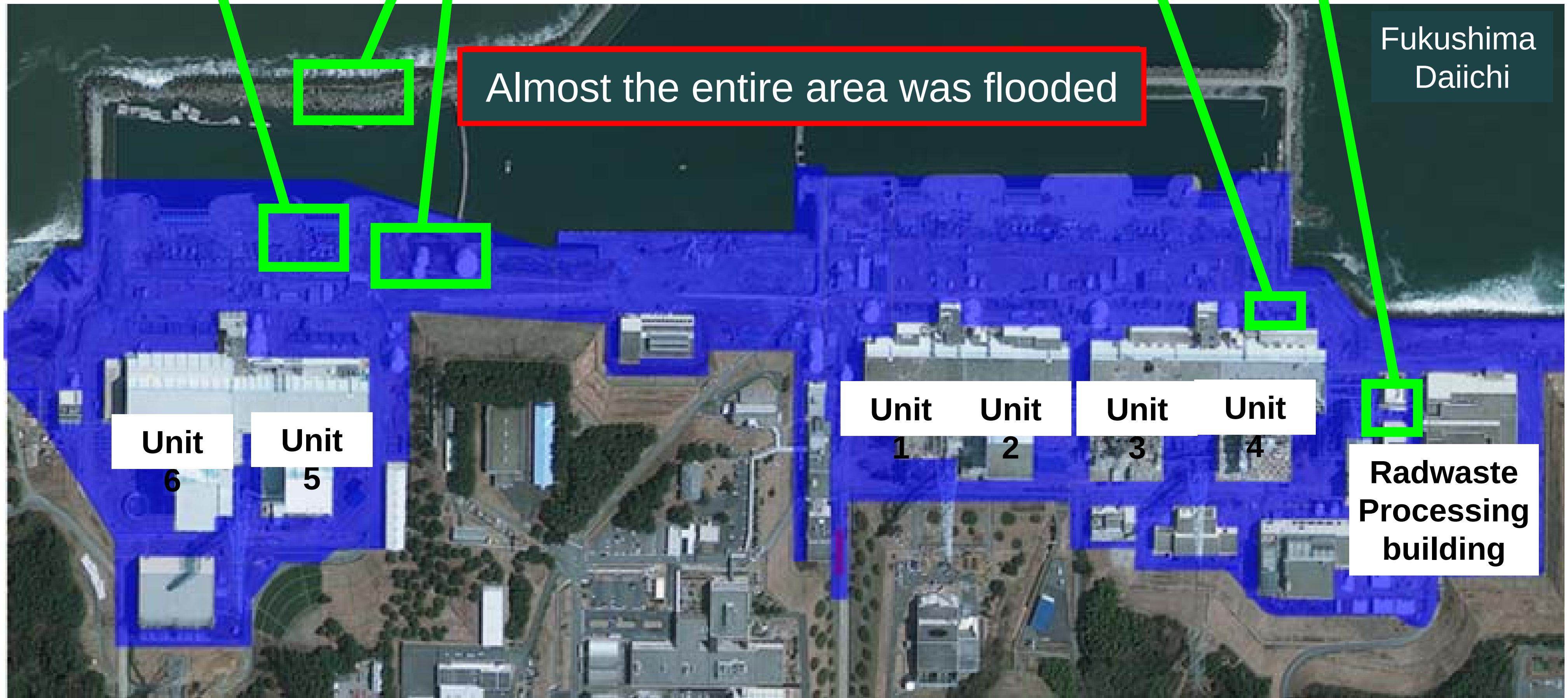
Tsunami Wave Source on 3-11
(Evaluated by TEPCO)

Time/date of earthquake: Friday, March 11, 2011 at 14:46pm
Epicenter: Off the Sanriku coast (38° N, 142.9° E) Focal Depth of 24km Magnitude 9.0
The Japan Meteorological Agency Seismic Intensity Scale: (Range: 0-7, 10 grades with 5-U/L, 6-U/L)

7: Kurihara City, Miyagi Prefecture
6-Upper: Naraha, Tomioka, Okuma, and Futaba Towns in Fukushima Prefecture
6-Lower: Ishinomaki City & Onagawa Town, Miyagi Prefecture; Tokai Village, Ibaraki Prefecture

Impact of Earthquake/Tsunami at 1F

- Tsunami severely flooded most of the major buildings located at 10-13m ASL



(C)GeoEye

2. Outline of Accident and Lessons Learned

Image of Tsunami Damage

Unit5 Sea water pump area

Unit1 PCV cooling sea water pump

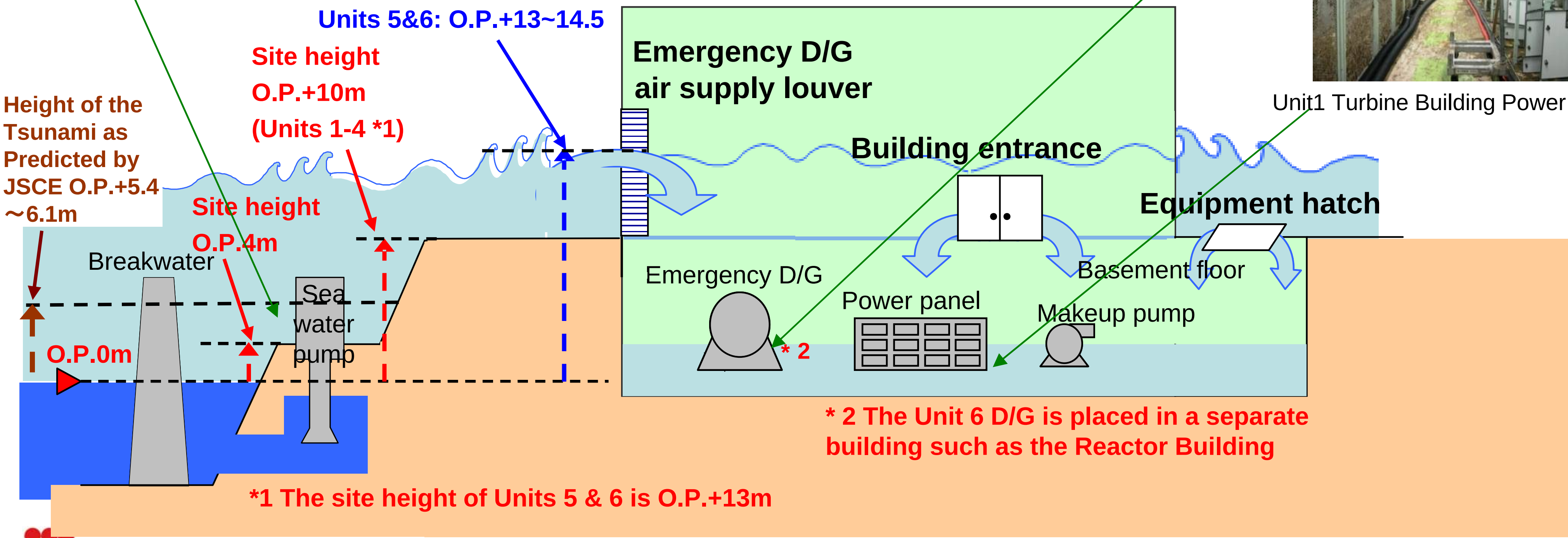
The main inundation routes identified through an on-site walk-down of the area are:

1) Building entrance
2) Equipment hatches
3) Emergency D/G air in-take louvers
4) Trenches, ducts (cable penetrations, etc.) etc.

➡ The D/G and electric panel room etc were flooded through those routes

Unit1 D／G（1B）

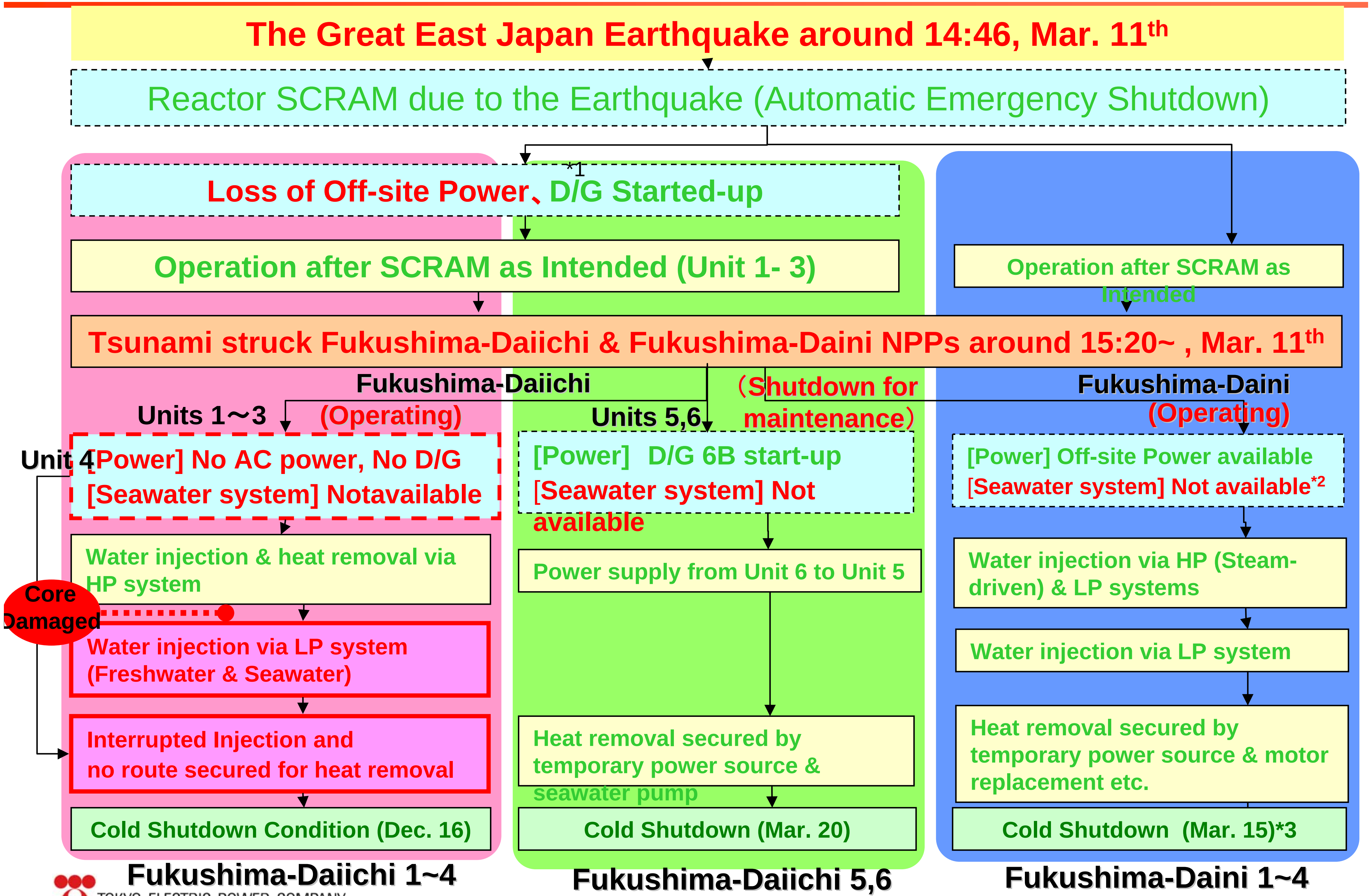
Unit1 Turbine Building Power par



* 2 The Unit 6 D/G is placed in a separate building such as the Reactor Building

*1 The site height of Units 5 & 6 is O.P.+13m

Sequence of Events after the Earthquake



*1 D/G：Emergency Diesel Generator *2 RHR Seawater System *3 Fukushima-Daini Emergency State was Lifted on Dec.26th

Summary of Lessons Learned

- The 1F accident was caused by the simultaneous loss of multiple safety functions , as follows

  1) loss of all AC power and DC power

  2) loss of heat removal function, including core water injection system for a extended period of time.

- Loss of Off-site power occurred because of transmission line damage caused by earthquake.
- Preparations had been previously made to receive power from neighboring units in the event of power loss.

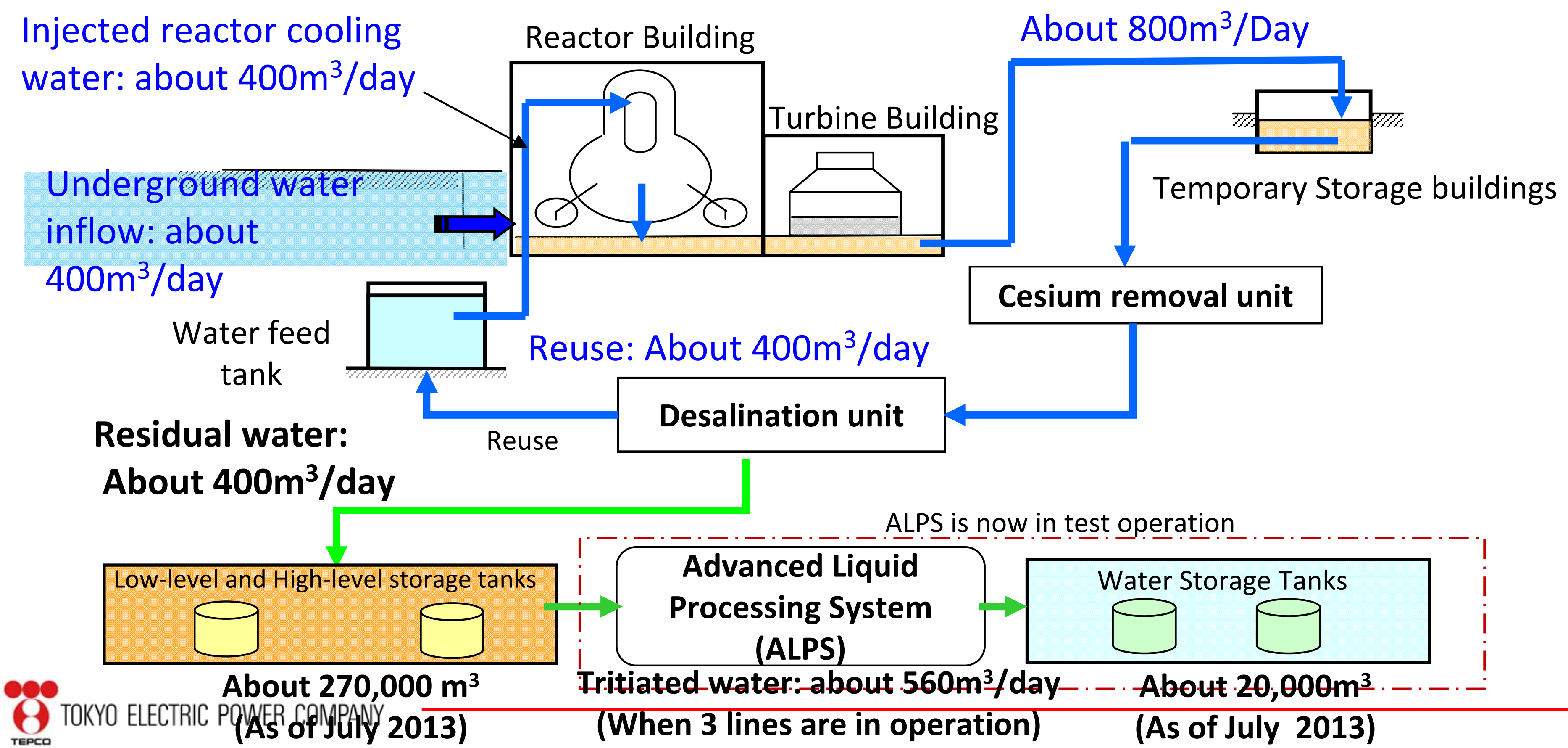
  During the accident, direct tsunami damage was so widespread that the neighboring units were all in the same condition.

"We should Carefully consider the robustness of current design of nuclear power plants and emergency preparedness against **beyond design basis events** that could lead to **common cause failures** regardless of their assumed probability, demonstrating a continuous **learning organization**."

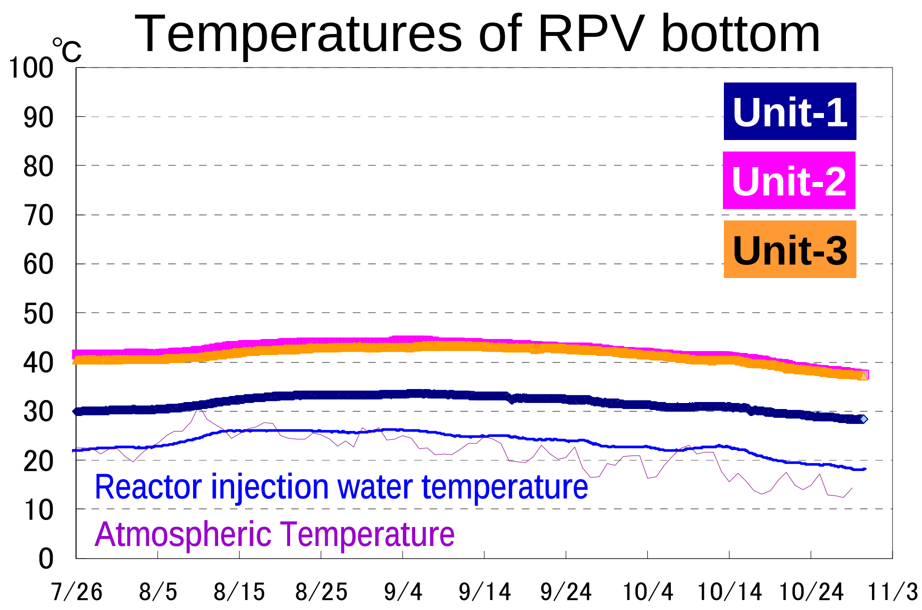
3. Current Status of Fukushima Dai-ichi NPP(1F)

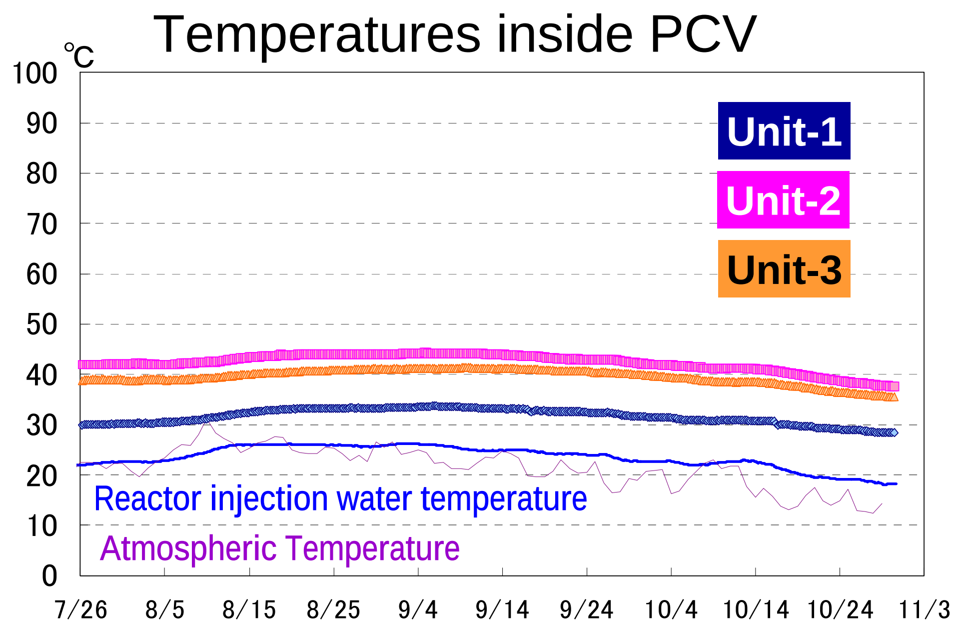
Status of Contaminated Water after the Accident

- Treating water in buildings is an issue because of in-coming under-ground water
- Underground water level is high in the site, resulting in an increase of inventory of contaminated water
- Releasing treated water has not been approved because of concern among locals
- Measures to deal with the water issue:
  1) Fundamental measures to prevent underground water coming into reactor buildings
  2) Enhance contaminated water treatment facilities
  3) Construction of new tanks to manage contaminated water



Status of Core & Spent Fuel Pool Cooling



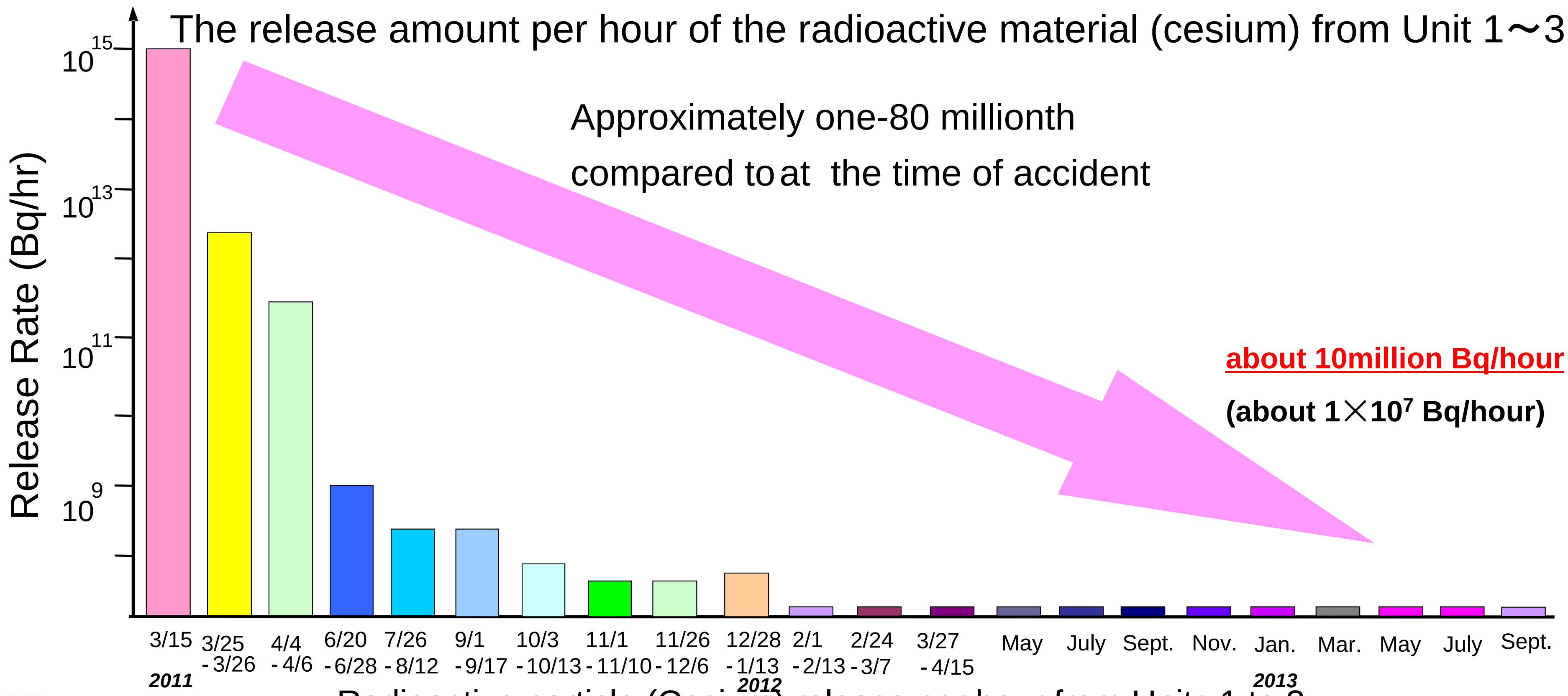


		Unit1	Unit 2	Unit 3	Unit 4	Unit 5/6
Shutdown		○	○	○	(Shutdown for Outages in 3/11)	
Cooling	**Reactor**	○ Cooled by Circulation Water System			—	○ Cold Shutdown
	Spent Fuel Pool	○ Cooled by air-cooled heat removal system				○
Containment		△ Contaminated water accumulated in building				○

Controlling the Release of Radioactive Materials

- **The amount of radioactive materials (cesium) released from Unit 1-3 PCV is assessed based on airborne radioactive material concentrations (dust concentration) at the top of Reactor Buildings**
  - **→Calculated the assessed value of total release amount (as of May 2013) as about 10 million Bq/hr.**
  - **→About one-80 millionth compared to immediately after the accident.**
- **Accordingly, assessed the exposure dose at site boundary as 0.03mSv/yr. at maximum.**

(Excluding effect of already released radioactive materials)　Note: Exposure limit established by law is 1mSv/yr.

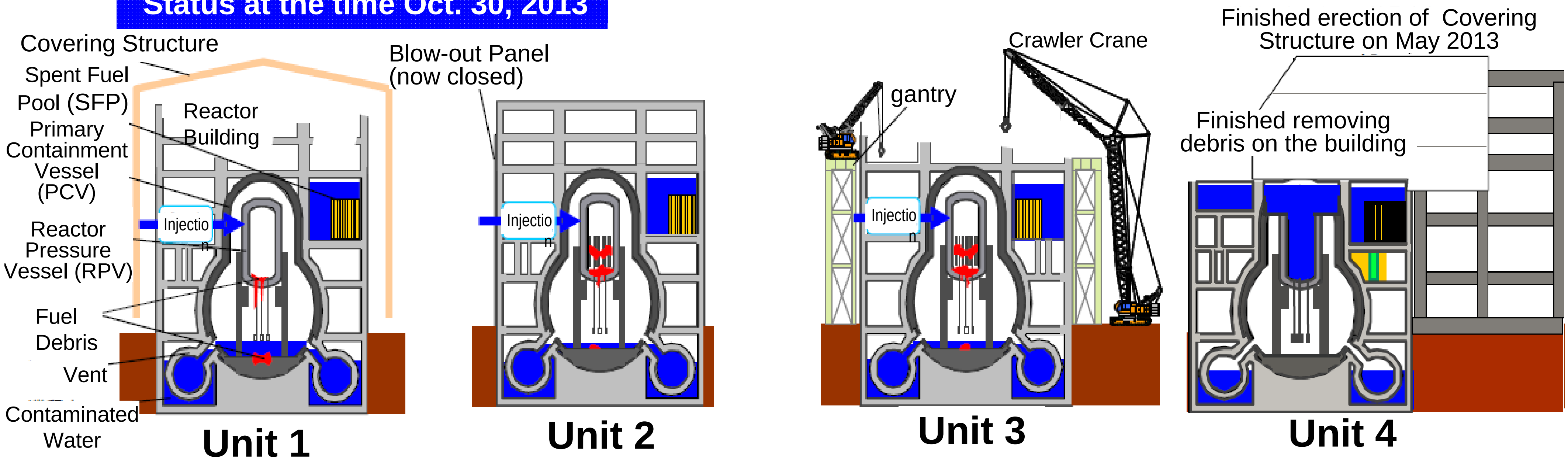


Radioactive particle (Cesium) release per hour from Units 1 to 3

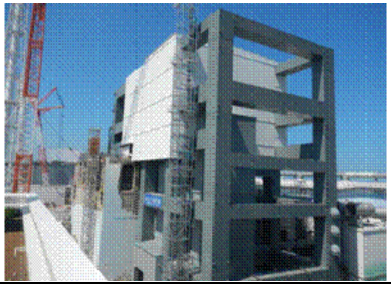
Current Status of Units 1~4

- At Units 1 through 3, circulatory water cools reactors. The temperature of the bottom of each of Units 1 and 3 reactor pressure vessels (directly measured from outside) has been kept between 30 and 50 degrees centigrade.
- We continue circulatory water-cooling system for Spent Fuel Pools of Units 1 through 4 to cool down spent nuclear fuels there.

Status at the time Oct. 30, 2013



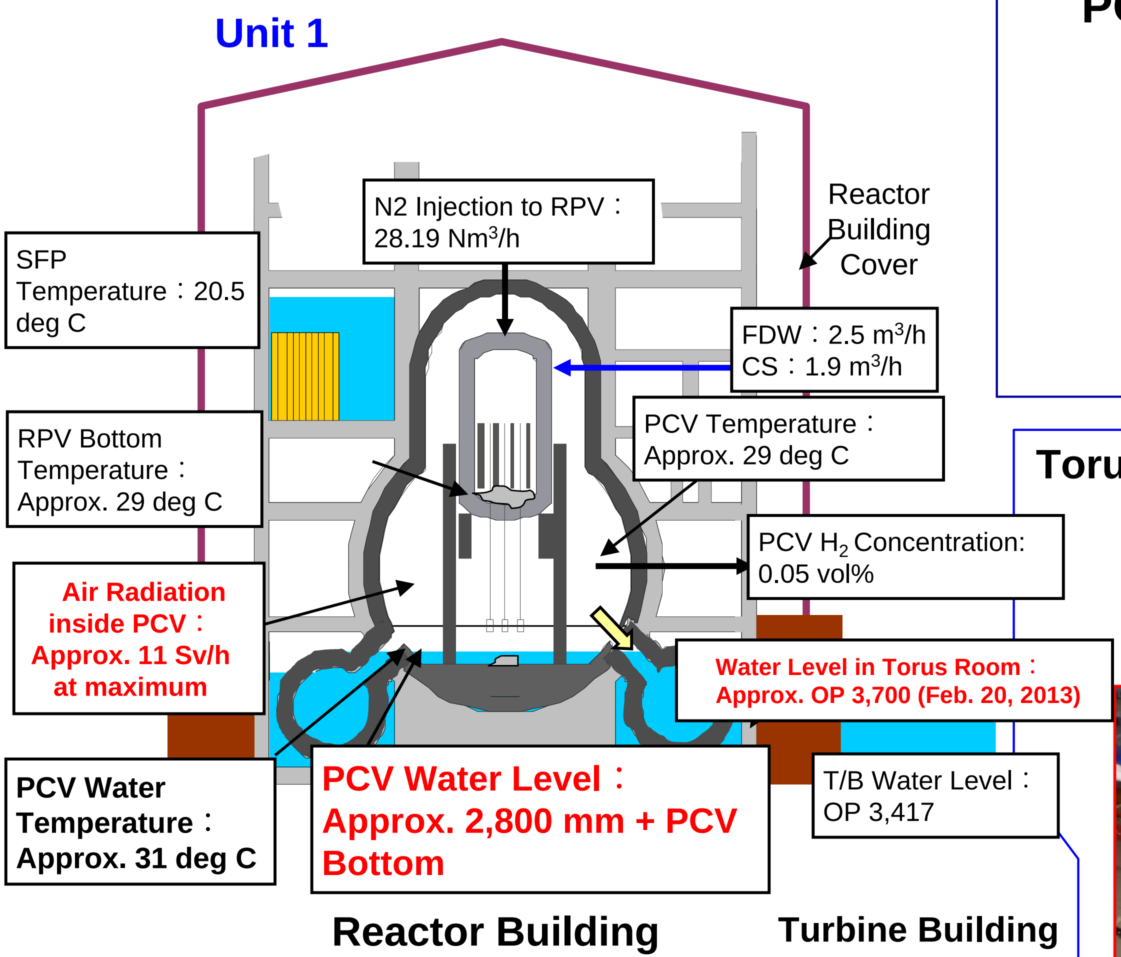


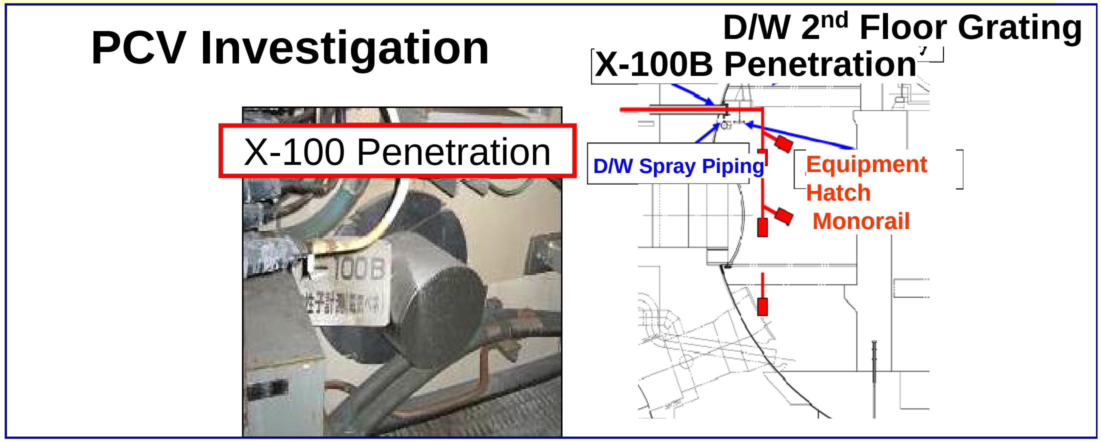
	Unit 1	Unit 2	Unit 3	Unit 4
RPV	28.4℃	37.5℃	37.2℃	No fuel
PCV	29.1℃	37.6℃	35.5℃	
SFP	20.5℃	19.3℃	18.7℃	26.0℃

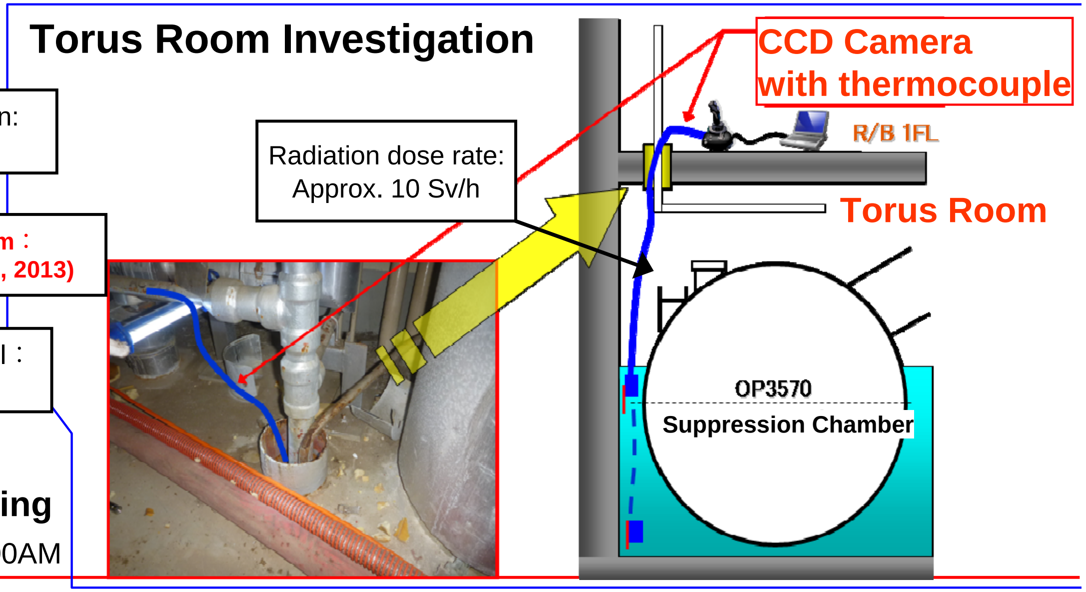
Current Status of Unit 1

- **PCV investigation with CCD camera** (2012/10)
  - ⇒**Water Level: Approx. 2,800 mm + PCV Bottom**
  - **Water Temperature：Approx. 35 deg C**
- **Torus Room Investigation with CCD camera.** (2012/6)
  - ⇒ **Torus Room Water Level: Approx. OP 4,000, Temperature: 32-37 deg.C**



*Parameters as of Oct. 30, 2013 11:00AM

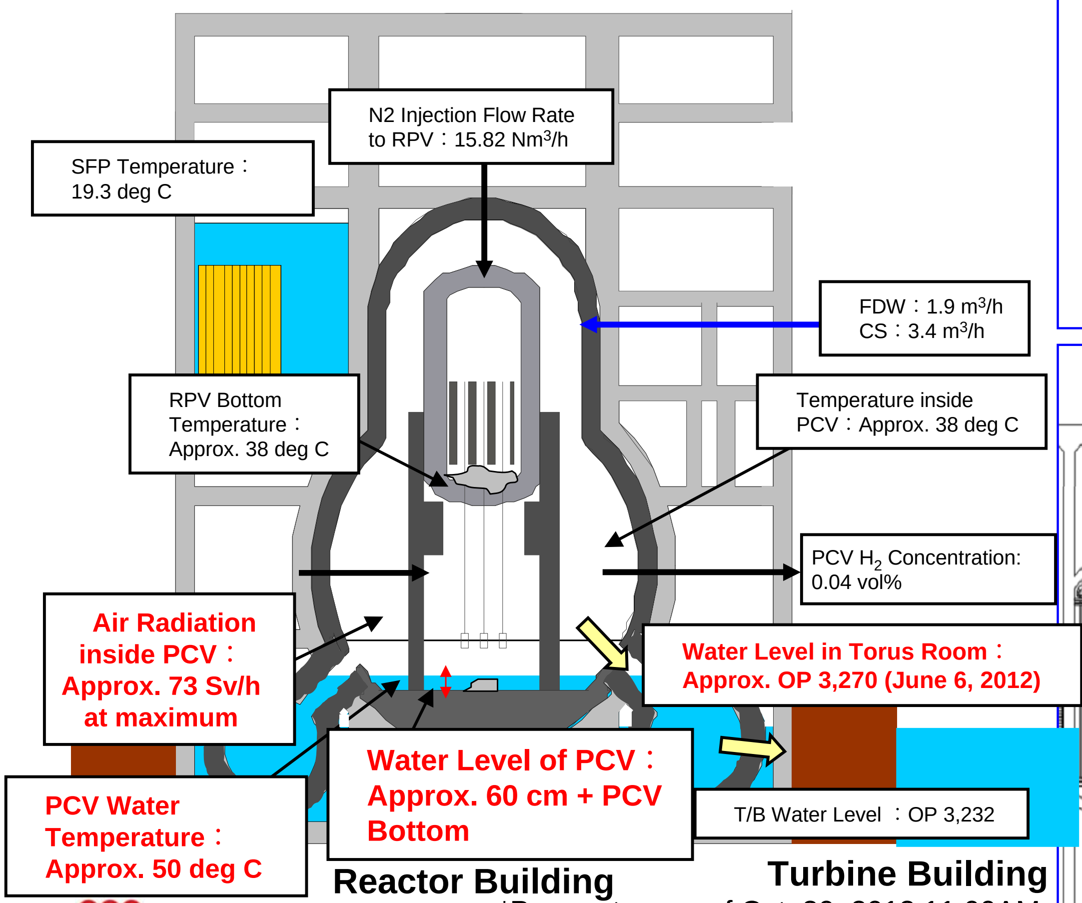




Current Status of Unit 2

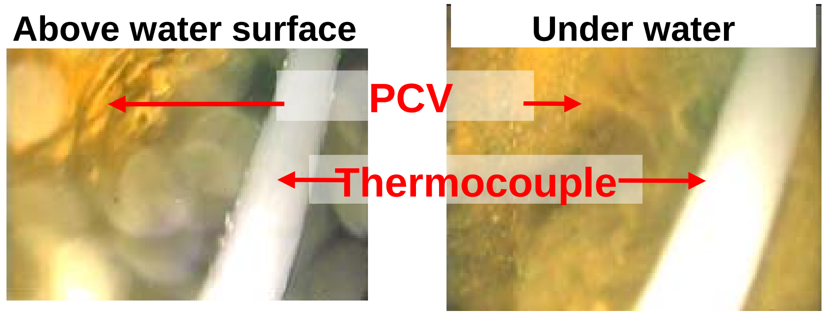
- **PCV Investigation by Borescope** (2012/1, 3)
  - ⇒**Water Level: Approx. 600 mm + PCV Bottom, Water Temperature：Approx. 50 deg C**
- **Robot survey in the Torus Room** (2012/4)
- **Water level measurement in the Torus Room** (2012/6)
  - ⇒**Torus Room Water Level OP3270**

Unit 2

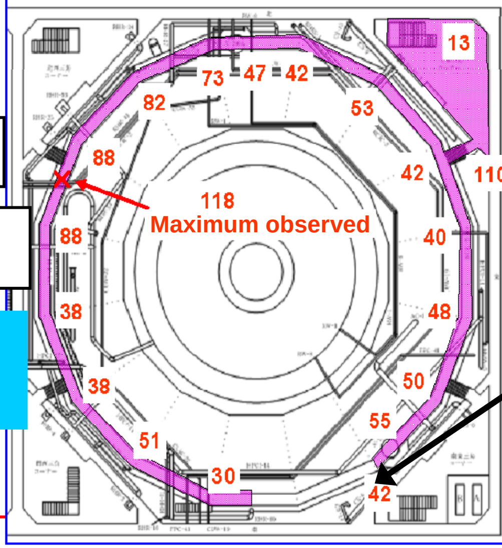


*Parameters as of Oct. 30, 2013 11:00AM

PCV Investigation



Robot survey in the Torus Room



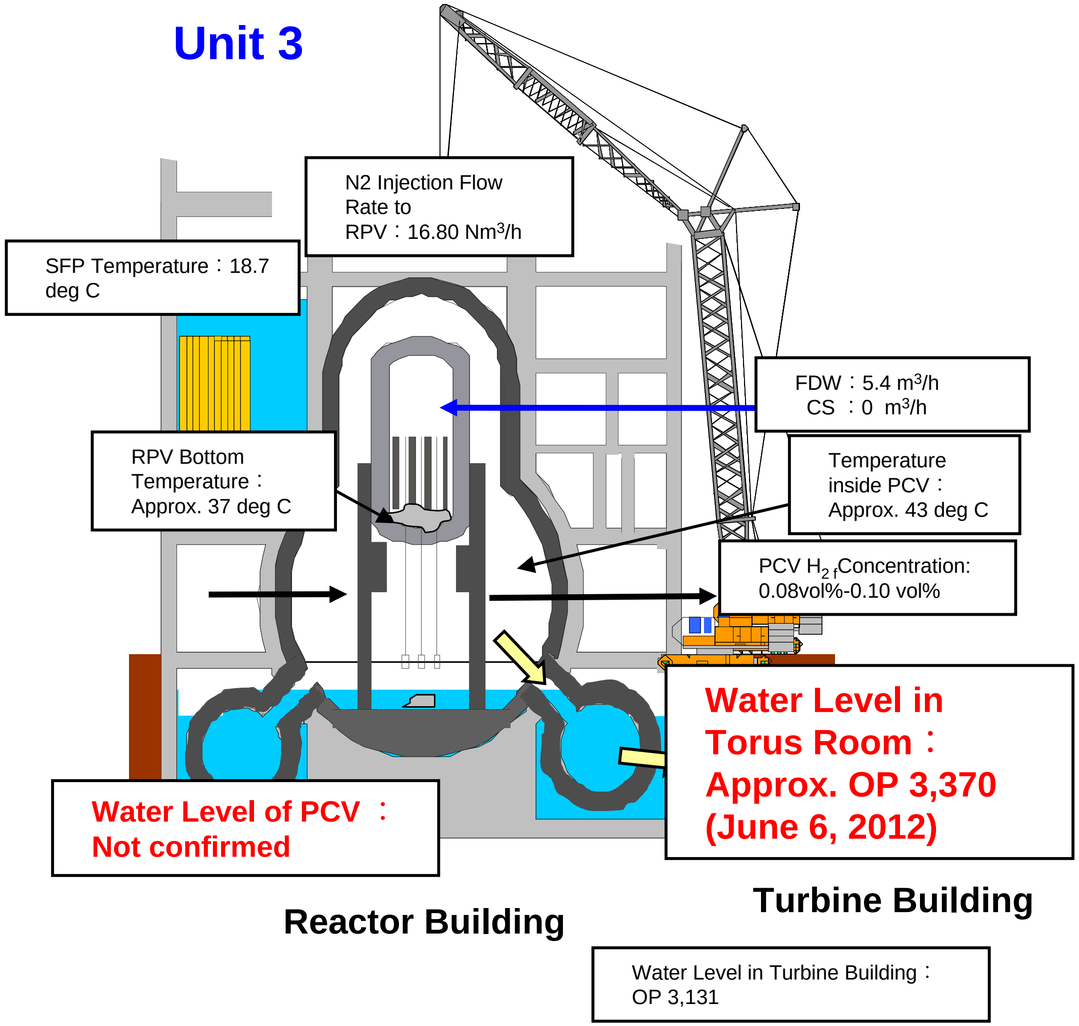
Access Route

S/C Manhole (Southeast)

Red：Radiation (mSv/h)

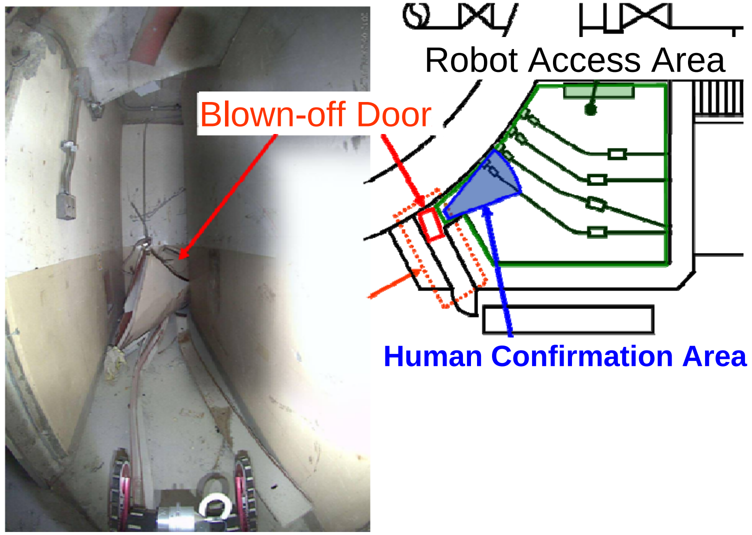
Current Status of Unit 3

- **Robot survey in the TIP room in the Reactor Building** (2012/3)
- **Water level measurement in Torus Room**(2012/6, 7)
  - ⇒ **Torus Room Water Level：Approx. OP 3,370**



*Parameters as of Oct. 30, 2013 11:00AM

Robot Survey in the TIP room



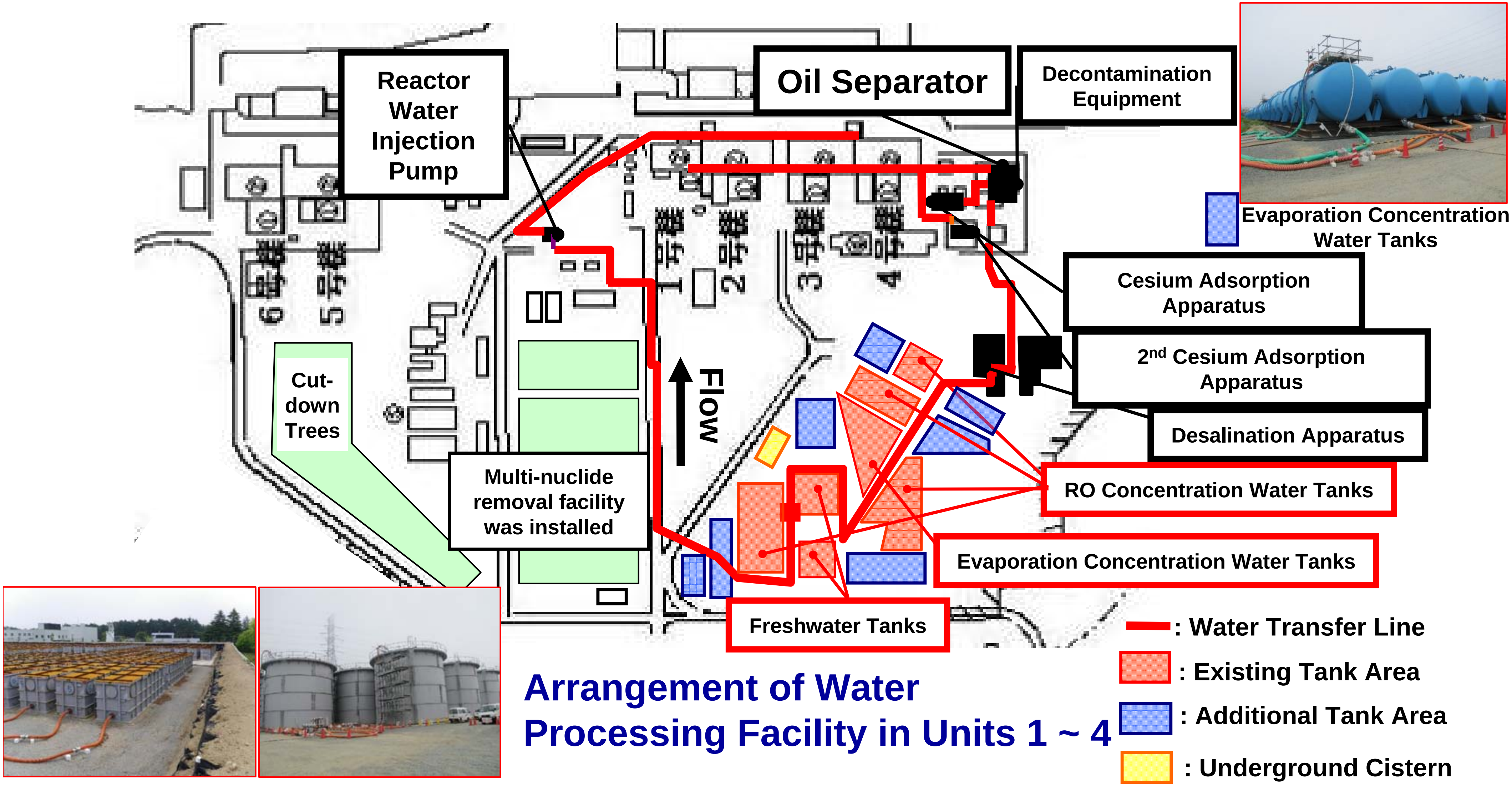
Water Level Survey in Torus

Northwest staircases area

	Water Level
Torus Room	OP 3370
Staircase area	OP 3150

Accumulation of Contaminated Water

- ✓The capacity of existing tanks is approx. 400ktons (as of Sept.2013).
- ✓Additional installation of tanks are planned to increase the capacity to Max. 800 ktons.



Arrangement of Water Processing Facility in Units 1 ~ 4

Fresh Water, RO Concentration Tanks

1. Status of Contaminated Water after the Accident

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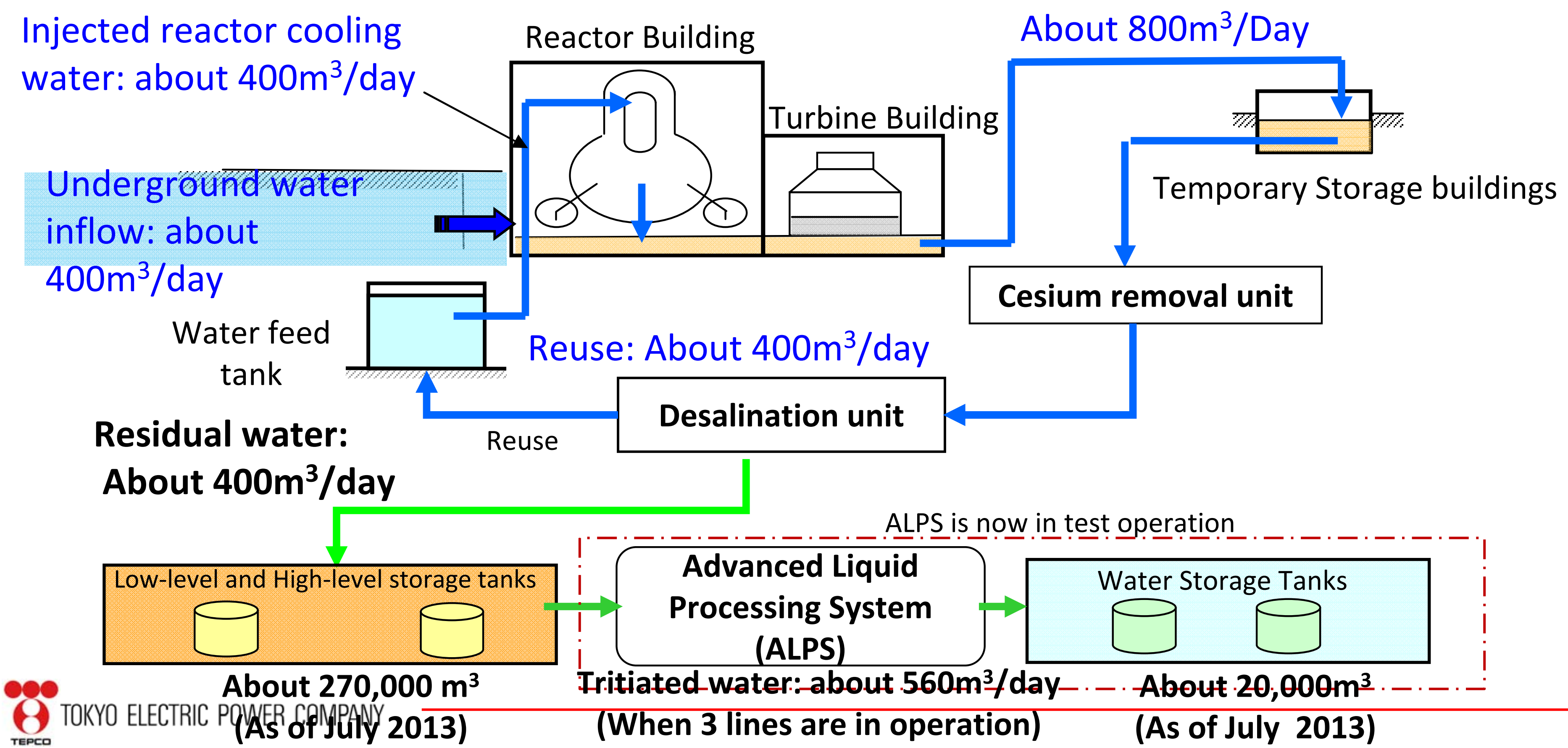
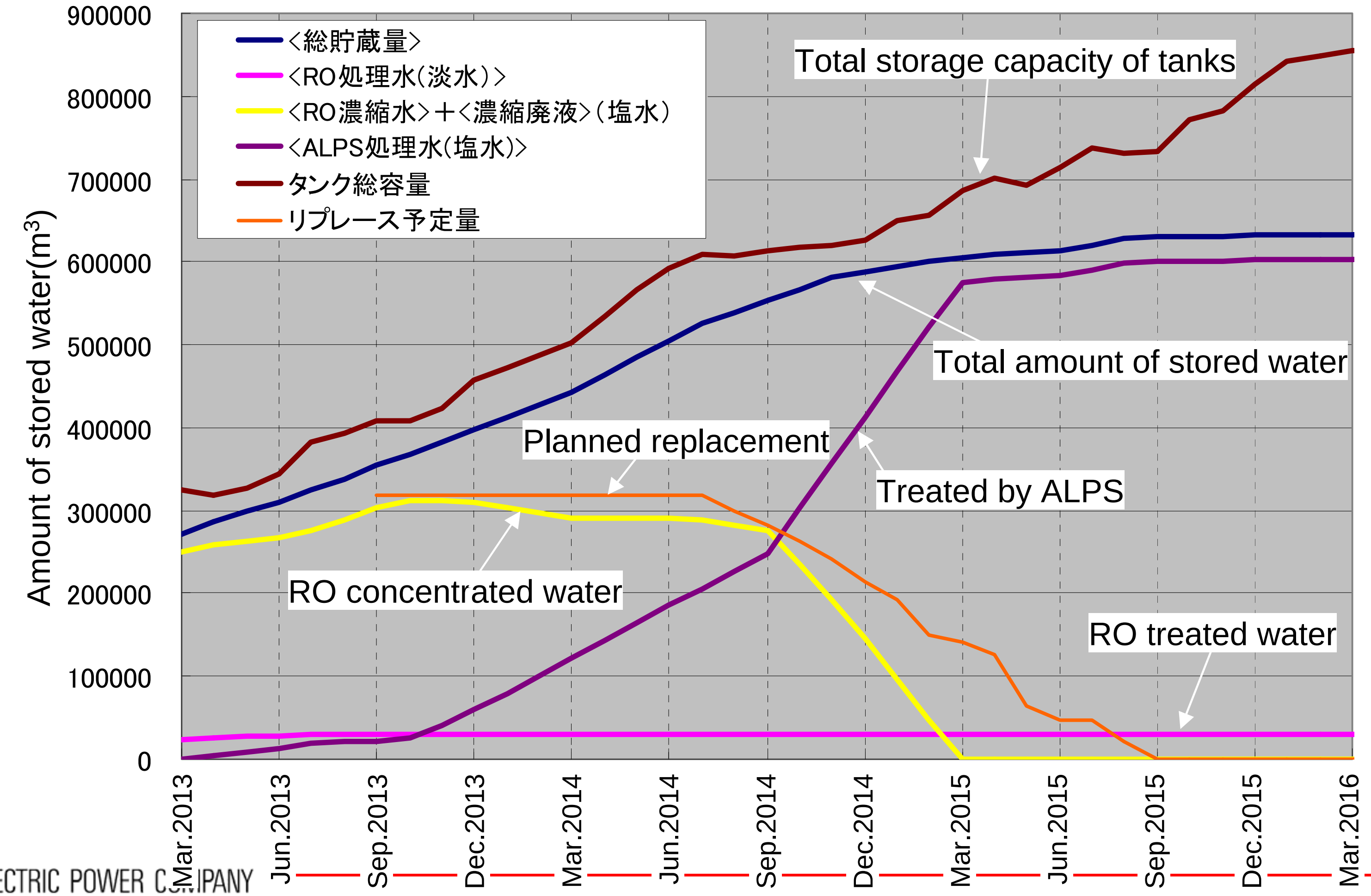
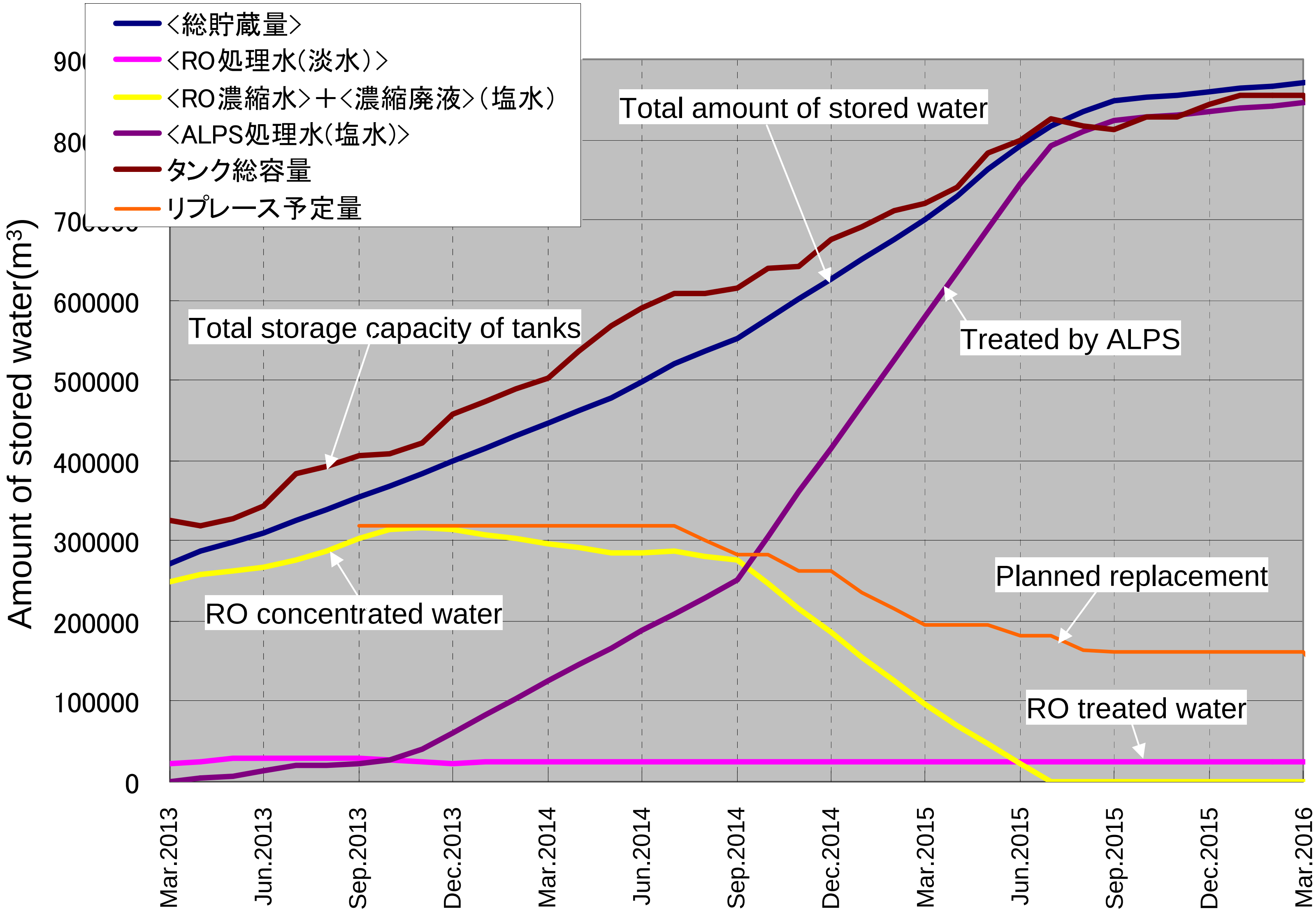


Total amount of water storage (optimistic evaluation)

- Although TEPCO has been building additional storage tanks, there is a concern how to secure a storage tank capacity.
- TEPCO is proceeding some countermeasures, including discharging clean water, such as by-passing groundwater and sub-drain water, to the ocean by coordinating with the government and all stakeholders.

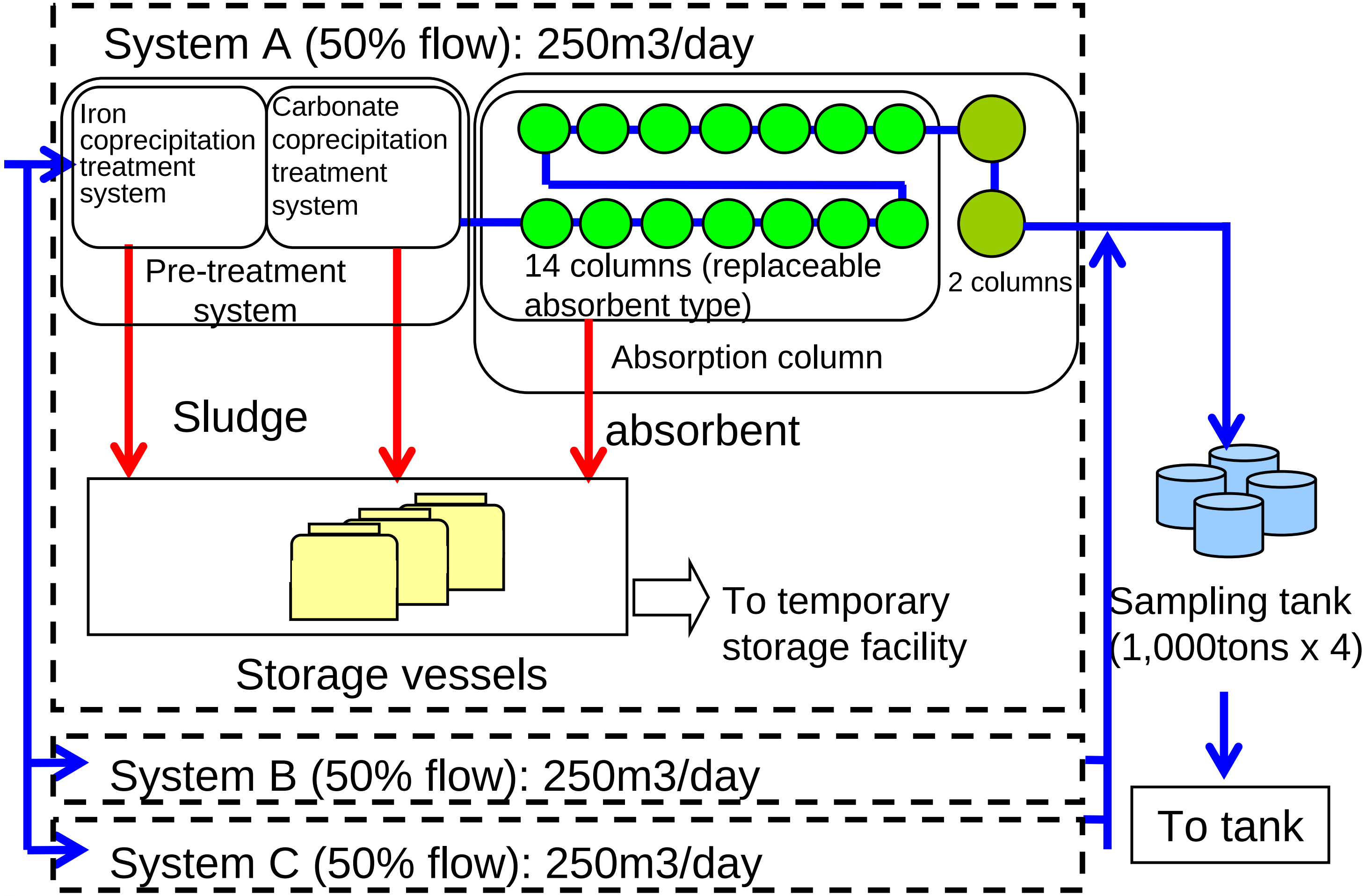


Total amount of water storage (Example : Most rough estimation)



Multi-Nuclides Removal Equipment（ALPS）

Treatment Water by
① Desalination sys
② Cs absorption sys



Emergency measures and fundamental remedies for underground water

- TEPCO has deployed some emergency measures and fundamental remedies in consultation with the government.

The three principles for countermeasures to contaminated water

1. **Remove** the source of the contamination
2. **Keep** the water **away** from the source of contamination
3. **Prevent** contaminated water **from leaking**

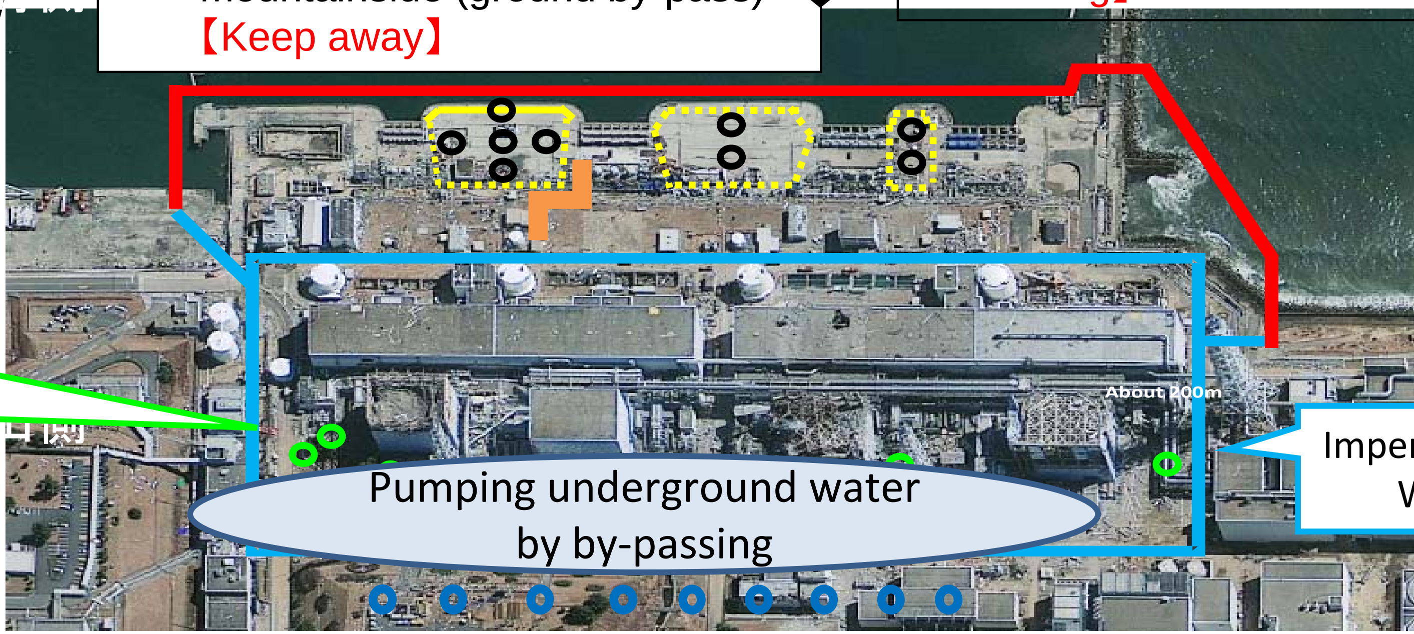
Emergency countermeasures

① Implement remove the contaminated water in the trench 【Remove】
② Ground improvement in the contaminated area, Pavement of the surface of the earth with asphalt, Pumping underground water 【Keep away】【Prevent from leaking】
③ Pumping groundwater from mountainside (ground by-pass) 【Keep away】

＋

fundamental measures
（in1～2year）

④ Pumping groundwater by sub-drain around the Turbine and reactor building 【Keep away】
⑤ Installation of the impermeable wall on the seaside 【Prevent from leaking】
⑥ Installation of the frozen wall 【Keep away 】【Prevent from leaking】



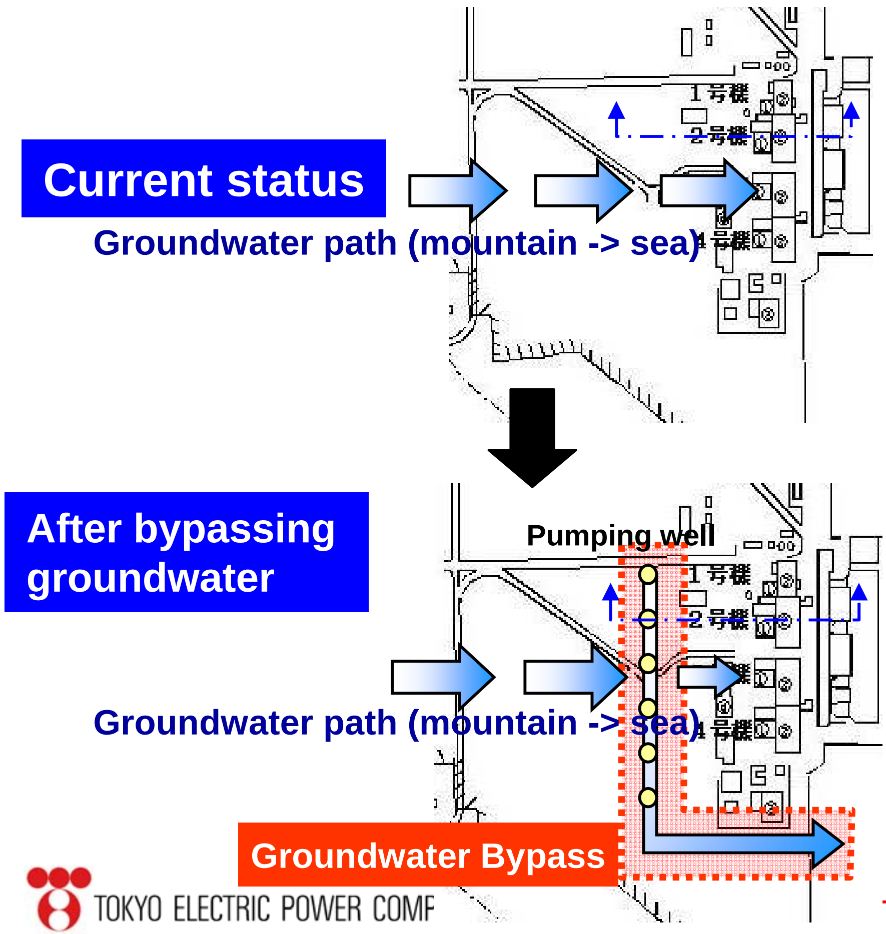
Groundwater Bypass

Groundwater bypass : Suppressing groundwater inflow to the buildings by changing the water path via pumping up the water flowed from the mountain side.

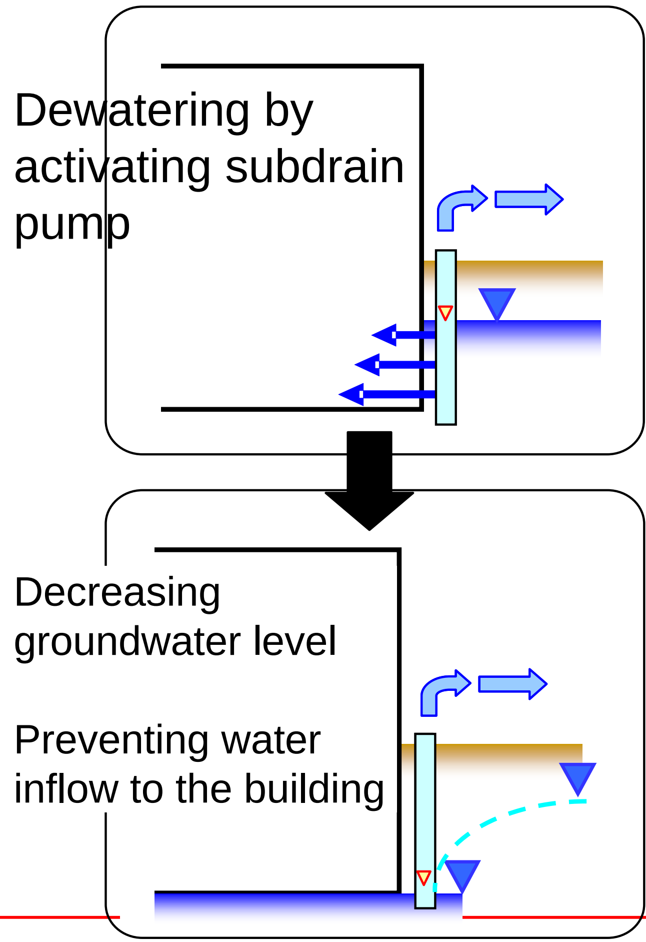
Pumping up groundwater (subdrain*) : Suppressing groundwater inflow to the buildings by decreasing groundwater level via pumping up the subdrain water.

*In order to balance groundwater level, groundwater in subdrain pits is periodically pumped up.

Groundwater bypass

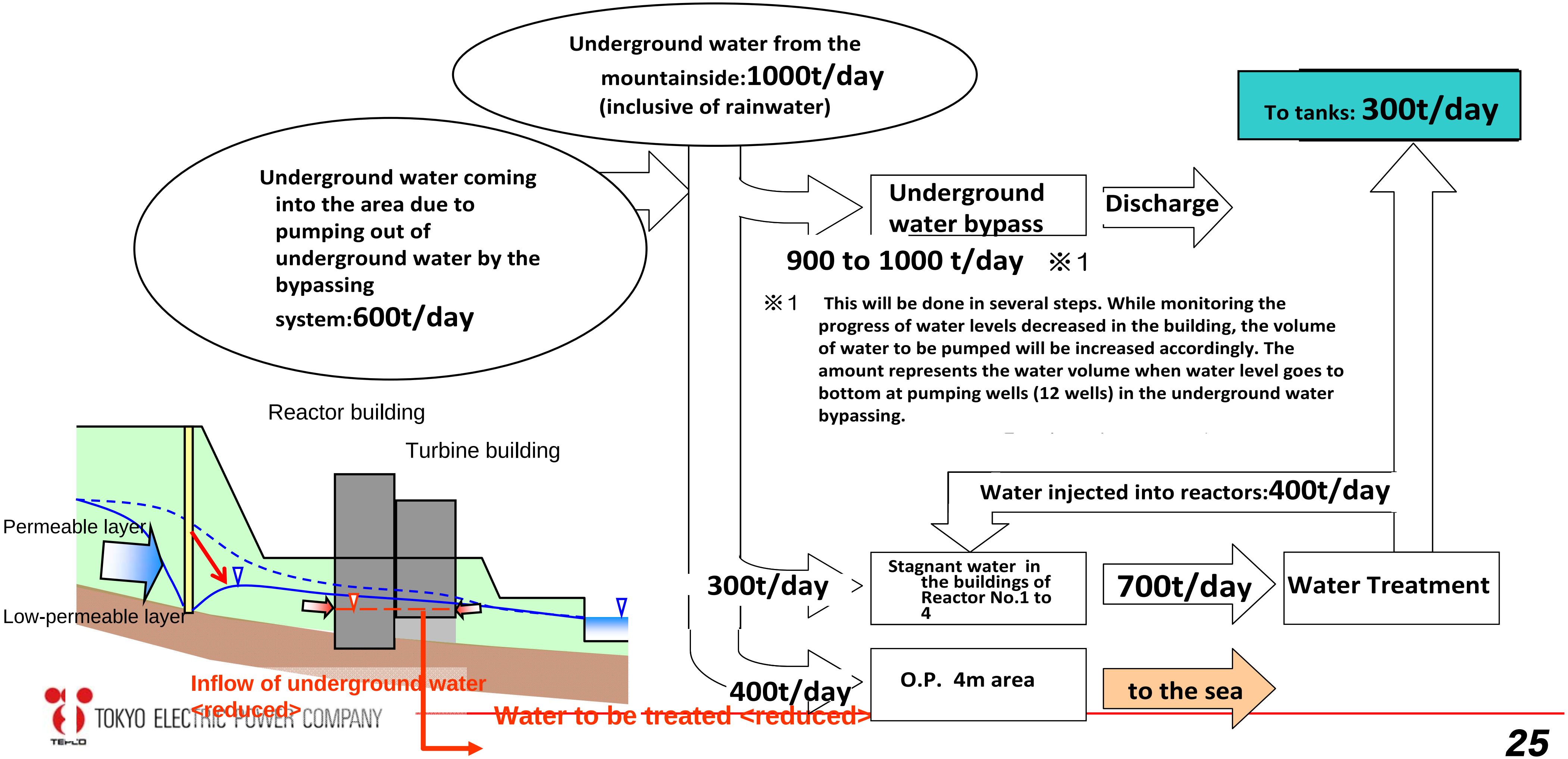


Pumping up groundwater (subdrain)



Emergency measures（③By-passing the Underground Water）

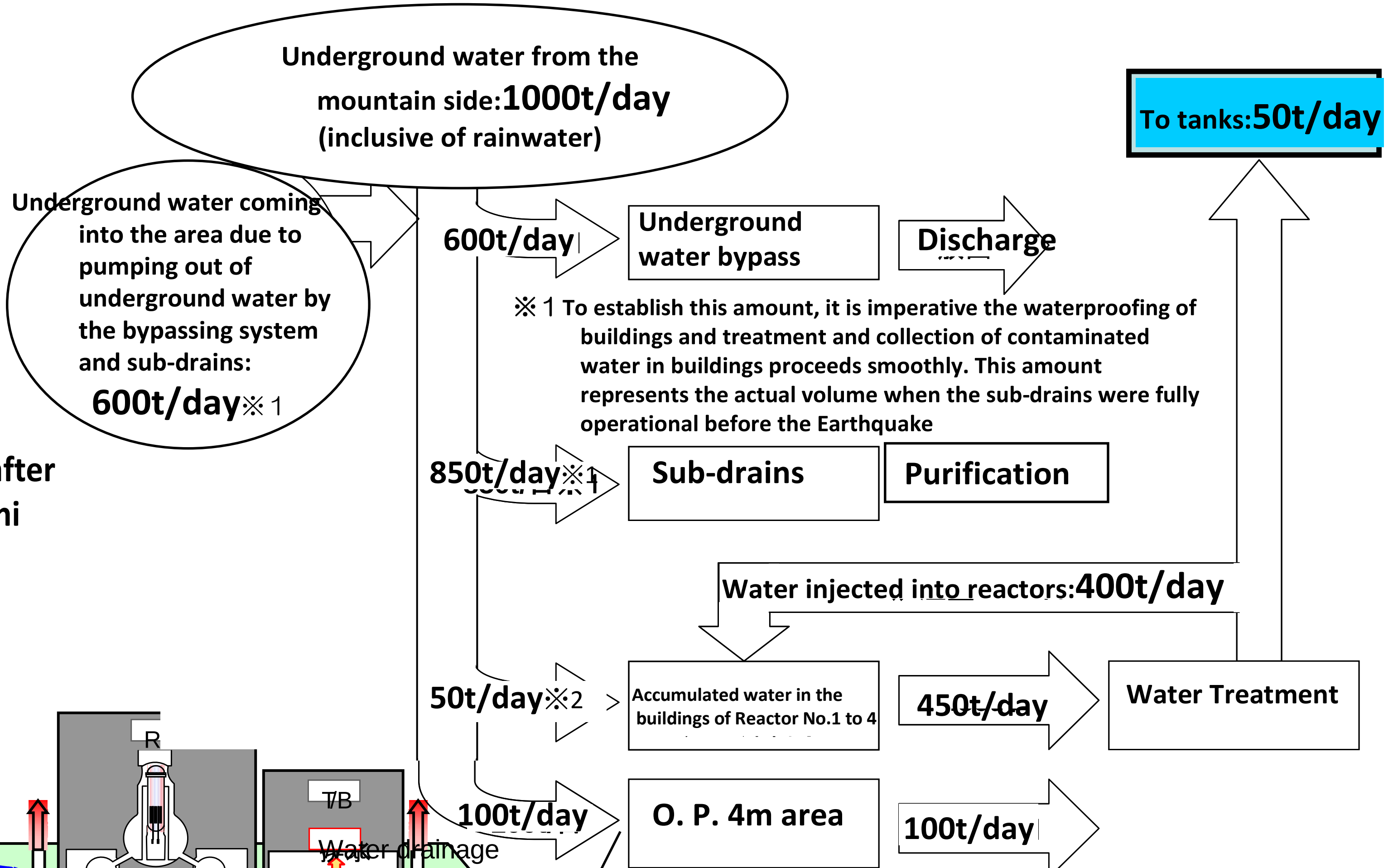
- To avoid contamination, twelve(12) new wells have been dug in a mountain area away from the reactor building. Approx. 1,000tons/day of underground water will then be pumped up before it approaches the contaminated area and discharge it to the ocean.
- Although TEPCO has been continuing to consult with all the concerned parties for their feed-back and consensus, TEPCO hasn't get their understanding yet.

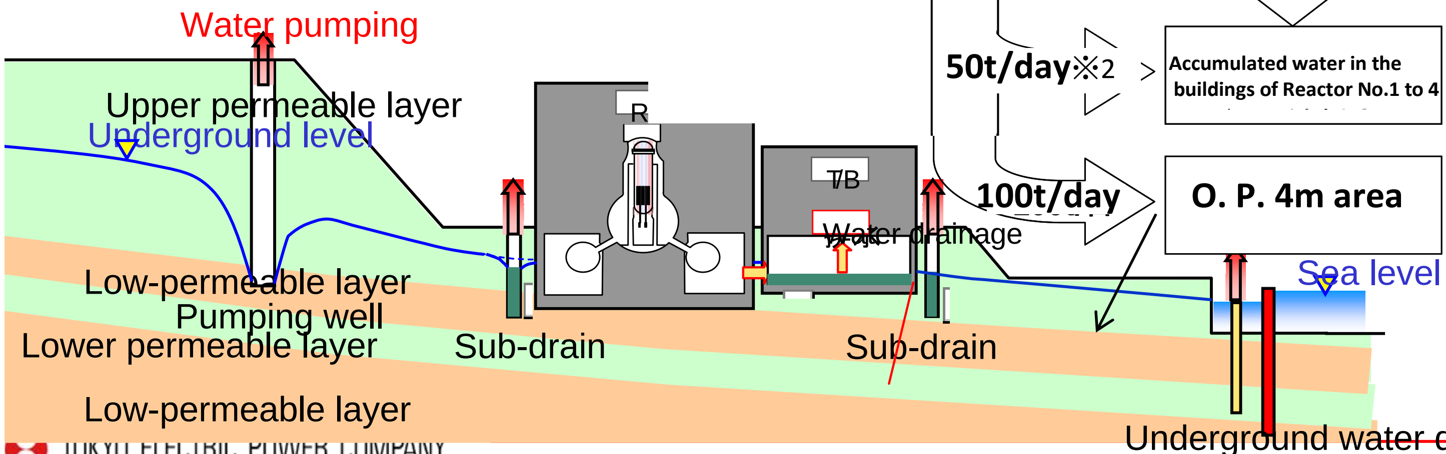


4-3. Fundamental remedies(④Sub-drain)

- Pumping the underground water up by sub-drain near the turbine/reactor building and purify the water.

The pits filled with debris inside after the lid broke due to the tsunami

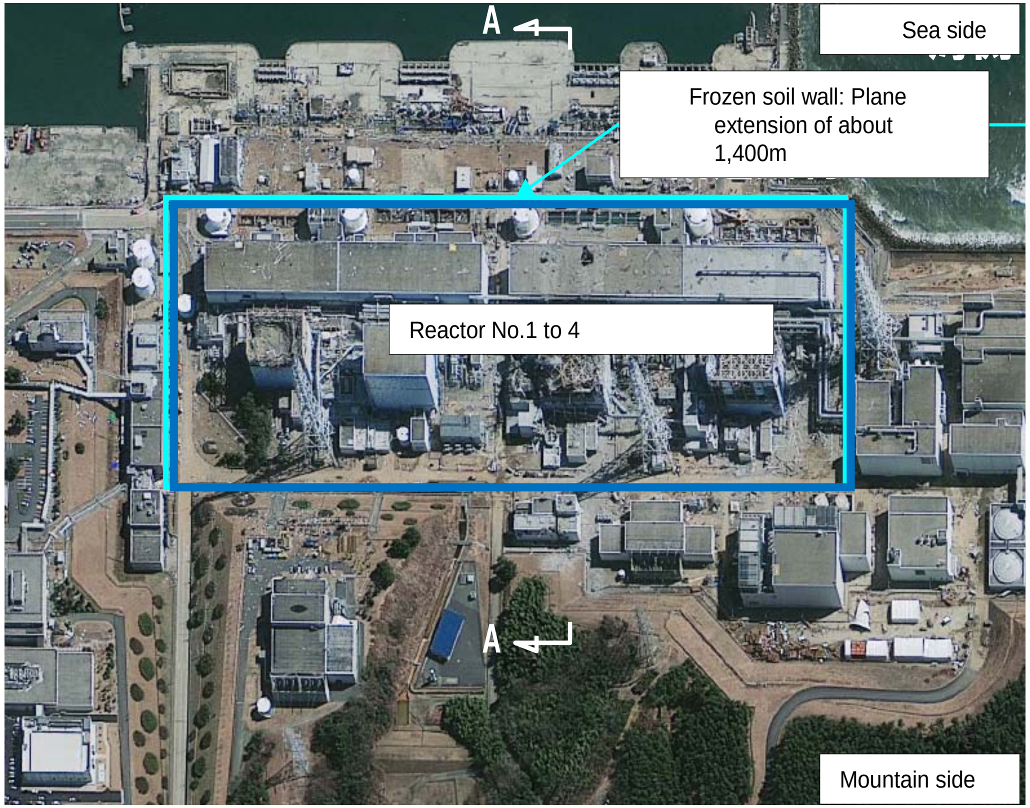


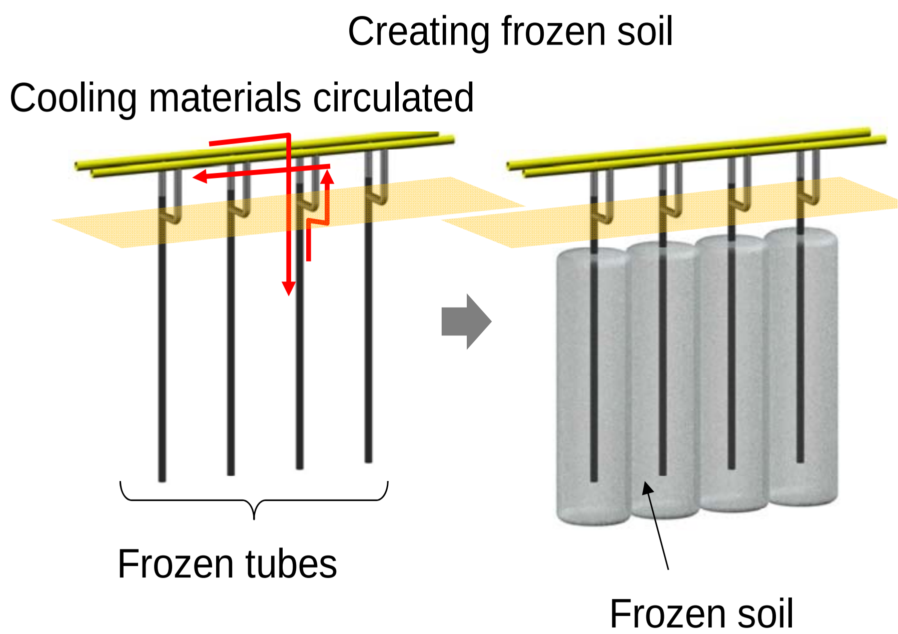


※2 Underground water, etc., that cannot be pumped by the sub-drains

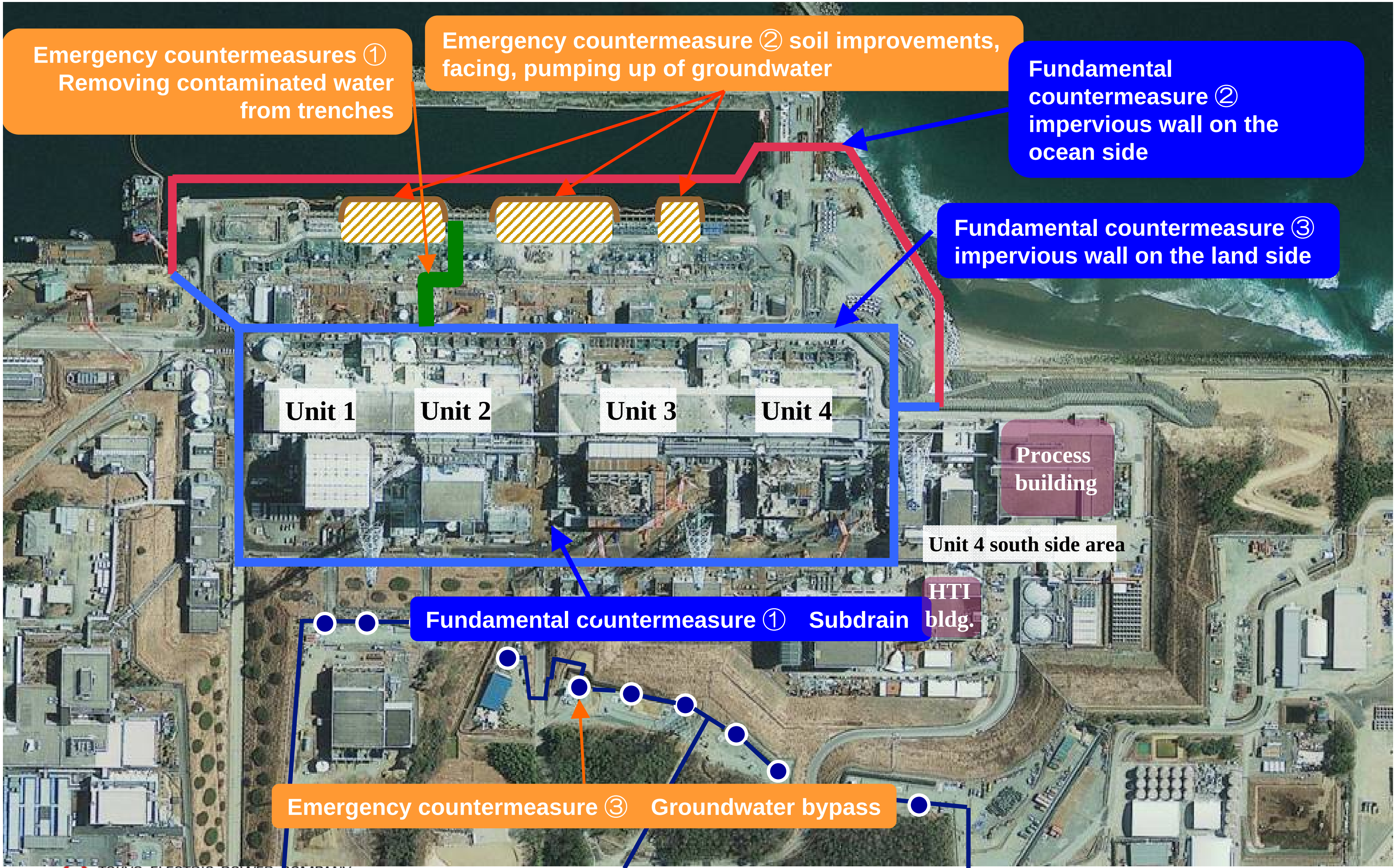
4-3. Fundamental remedies (⑥Land-side Impermeable Wall)

- Surround the turbine/reactor building with frozen soil wall.
  Prevent the groundwater from flowing in the area and contaminated water from flowing out from the area.
- Following the feasibility study, targeted completion is in the first half of 2015



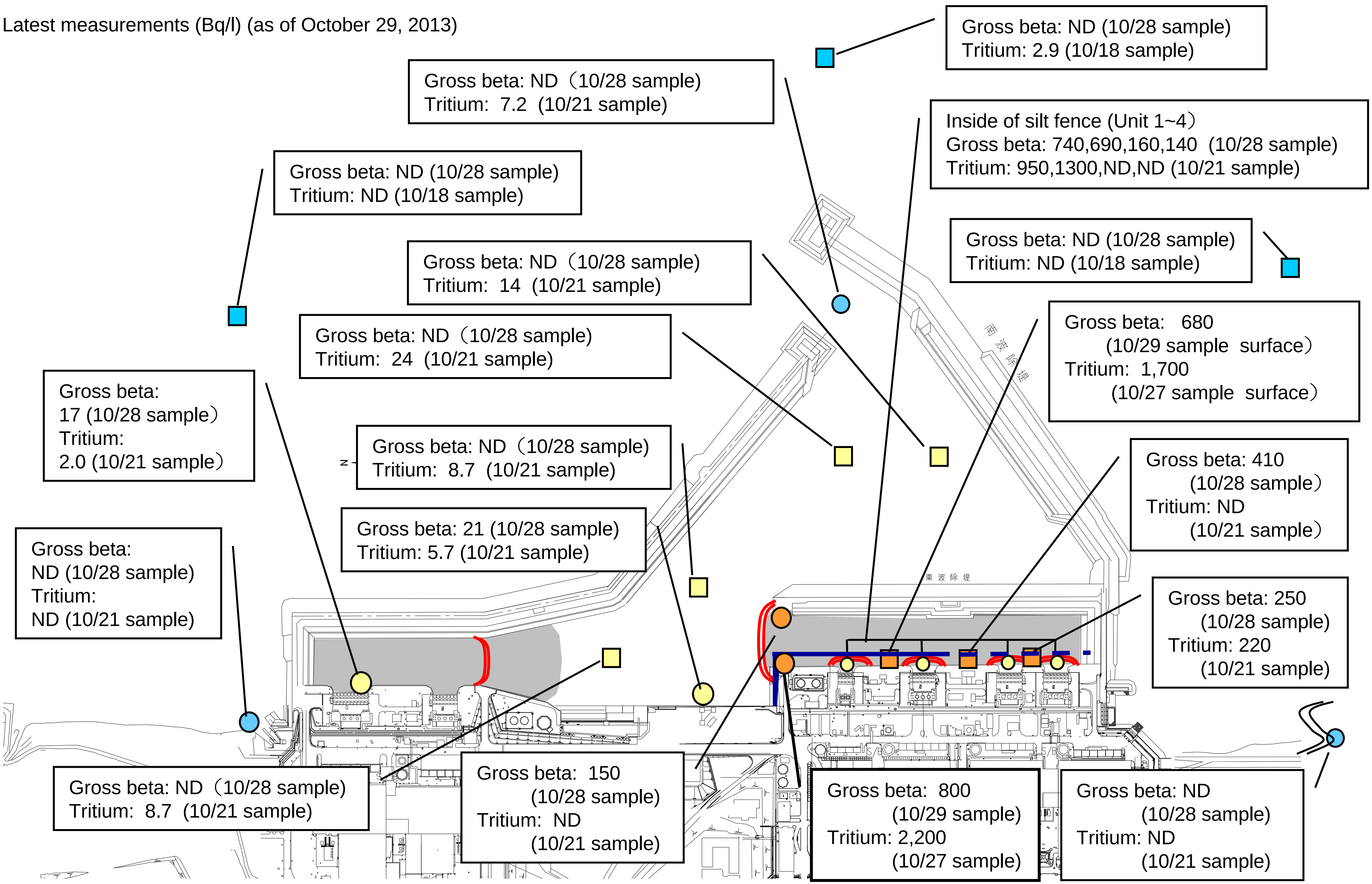


Overall contaminated water countermeasure plan



Ocean water concentration measurement results from inside and outside of harbor

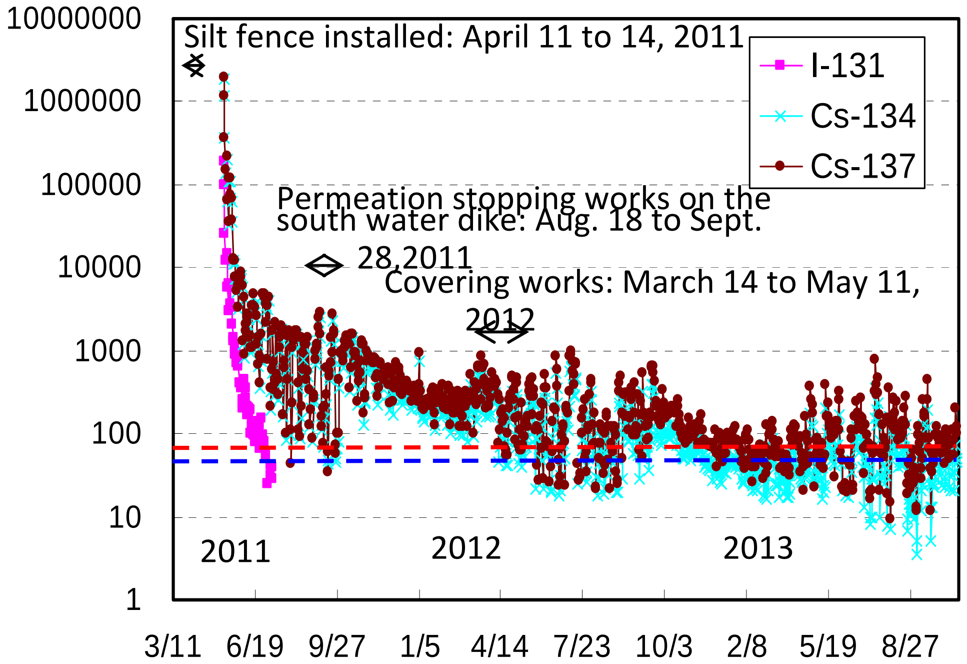
Latest measurements (Bq/l) (as of October 29, 2013)



2. Water Contamination in the port

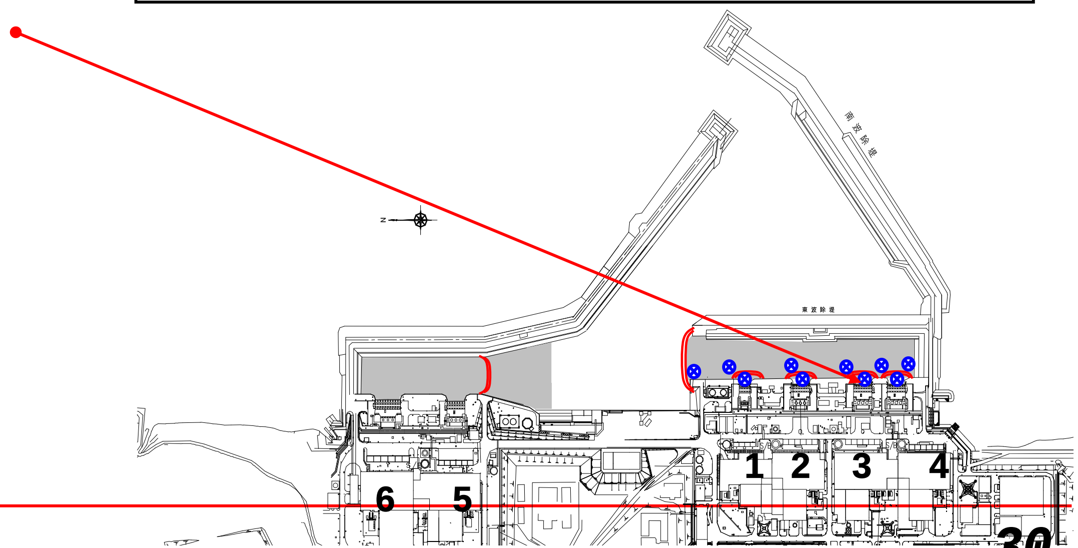
- The concentrations of radioactive material in the seawater in the port increased right after the accident(April 2013～March 2013).
- TEPCO has continuously been monitoring radioactive materials since soon after the accident. Although the numbers have been showing healthy decrease until recently, it was observed that the decreasing curve of the concentration of radioactive materials has bottomed near the opening channel in front of Units 1,2,3 and 4.

Contamination at the Water Intake of Reactor No. 3 (inside the Silt Fence)



[Reference] Concentration noted in the METI minister's notification (in-water radioactive concentration limit other than the Surrounding Monitored Areas)

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

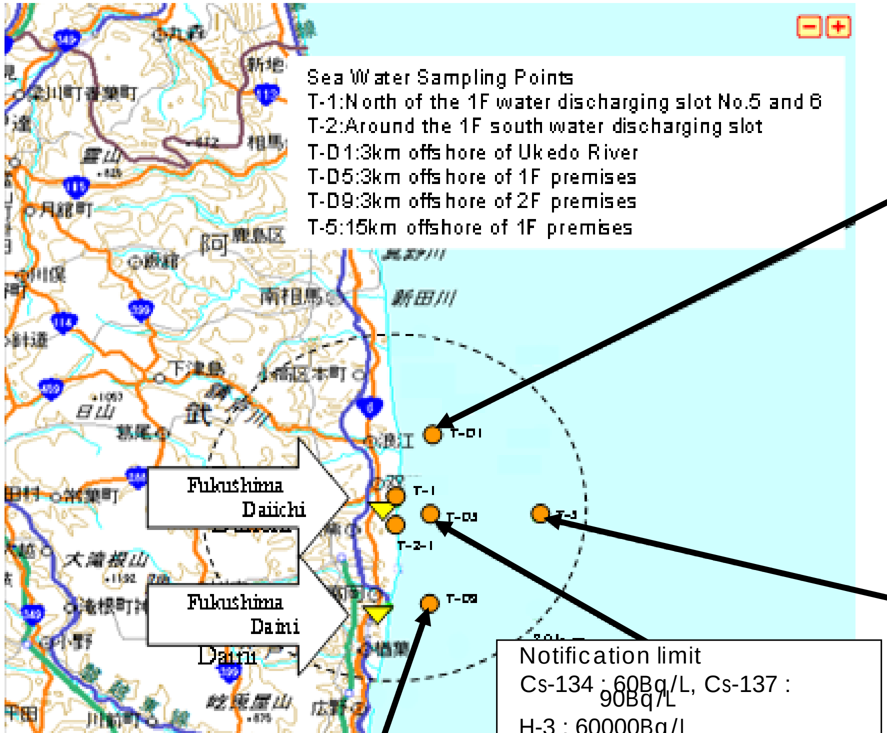


Legend

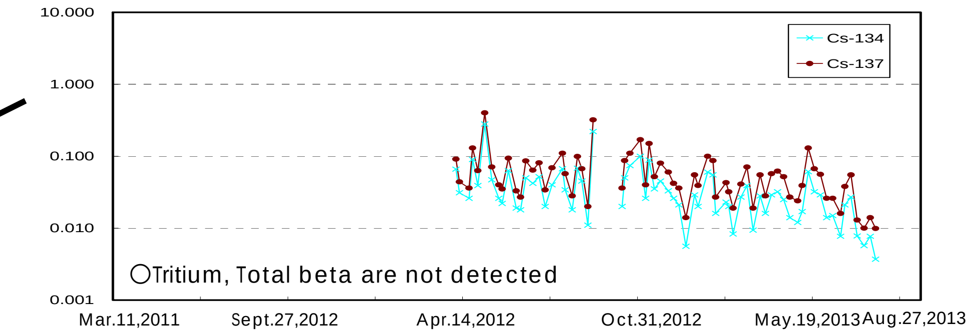
- : Sampling points (daily)
- : Silt fence
- : Areas where covering seabed soil is completed

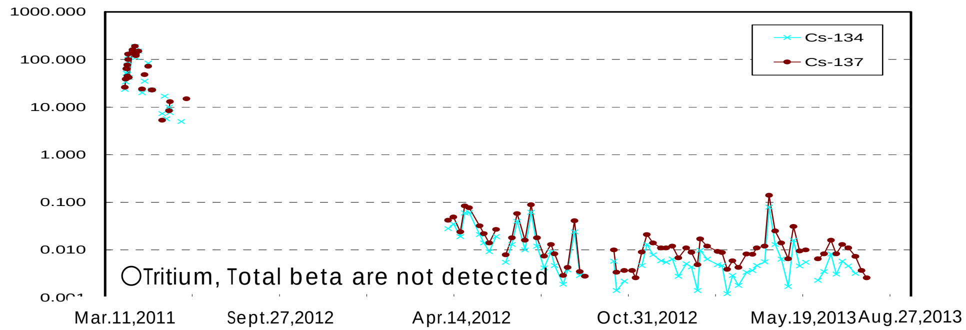
3. Status of Sea Water Radioactive Concentration

- The concentrations of the tritium and gross β in the sea water outside of the plant harbor have been continuously below the detection limit. Therefore, the impact to the outer sea has been minimal.

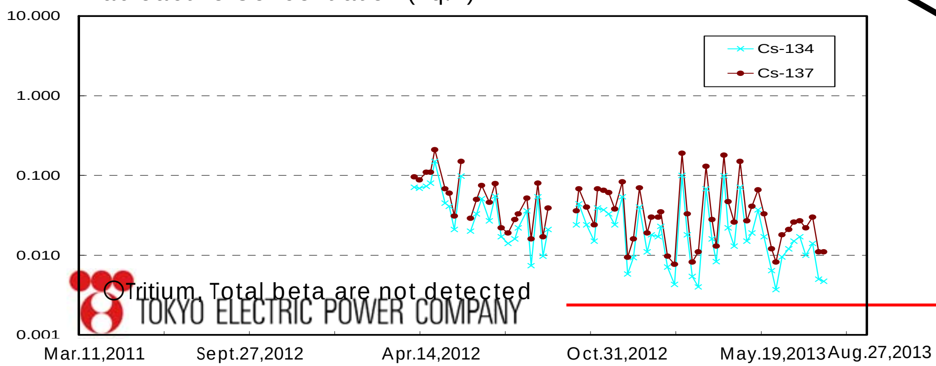


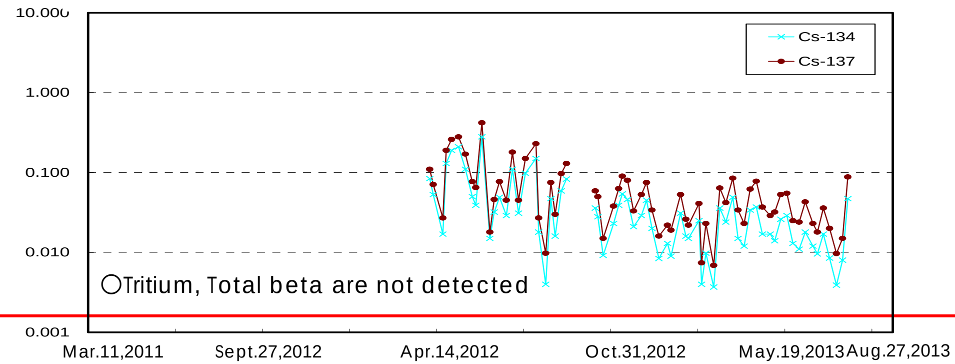
3km Offshore of Ukedo River(T-D1)Upper Layer Sea Water Radioactive Concentration





3km Offshore of Fukushima Dai-ni Premises(T-D9)Upper Layer Sea Water Radioactive Concentration (Bq/L)





4. Mid/Long -Term Roadmap for Decommissioning

Mid/Long- Term Roadmap

- **Primary Target**

  Present all possible schedules pertaining to the main on-site works and R&D.

- **Target Timeline and Holding Points**

  Regarding the schedules, established holding points, which are significant to judge whether to go ahead in accordance with the schedule, to implement additional R&D, or to re-schedule the process.

Present | At the end of 2013 | 2020 | After 30-40 Years

Step 1, 2	Phase 1	Phase 2	Phase 3
Achieved Stable Conditions - Quasi-Cold shutdown -Sufficient Suppression of Emissions	**Period to the start of fuel removal from the spent fuel pool** - Reduce the radiation impact due to additional emissions from the whole site and radioactive waste generated after the accident. - Maintain stable reactor cooling and accumulated water processing and improve their credibility. - Commence R&D and decontamination towards the removal of fuel debris - Commence R&D of radioactive waste processing and disposal	**Period to the start of fuel debris removal** - Complete preparations for the removal of fuel debris such as decontamination of the insides of buildings, restoring PCVs . - Complete the processing of accumulated water - Continue R&D on radioactive waste processing and disposal, and commence R&D on the reactor facilities decommission	**Period to the end of decommissioning** - Complete the fuel debris removal (in 20-25 years) - Complete the decommission (in 30-40 years) - Implement radioactive waste processing and disposal

Actions towards systematic staff training and allocation, motivation improvement, and securing of workers' safety will be continuously implemented.

Plan to remove spent fuels in Unit 4

- The cover for fuel removal already installed in order to improve work environment and to prevent radioactive materials from scattering and releasing during the work.
- Start of fuel removal at Unit 4 is planned at Nov. 2013.

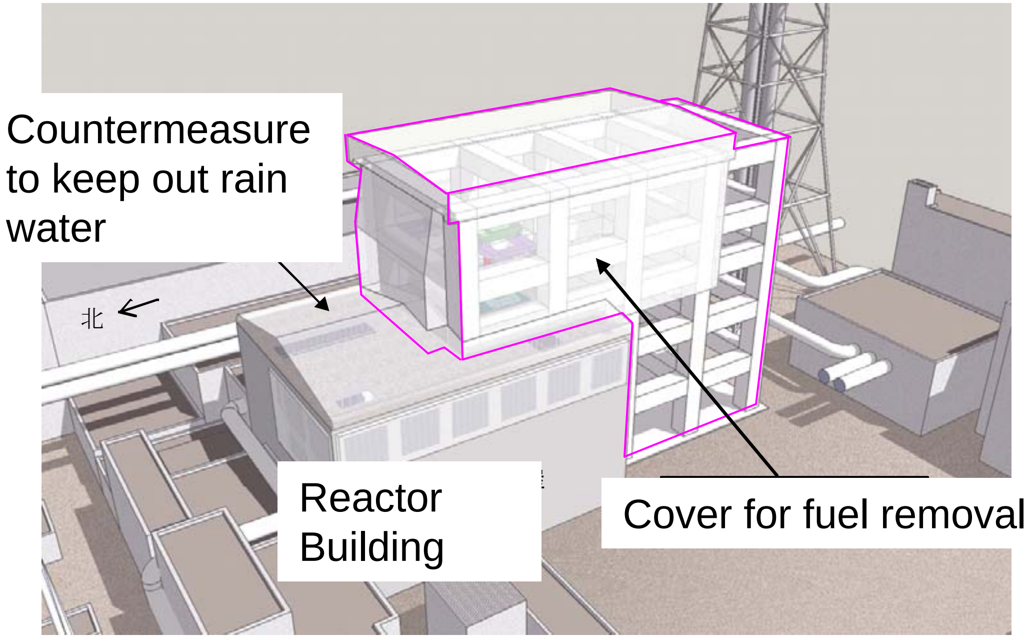


Image of the cover for fuel removal in Unit 4
(This picture shows only a image of the general plan.)

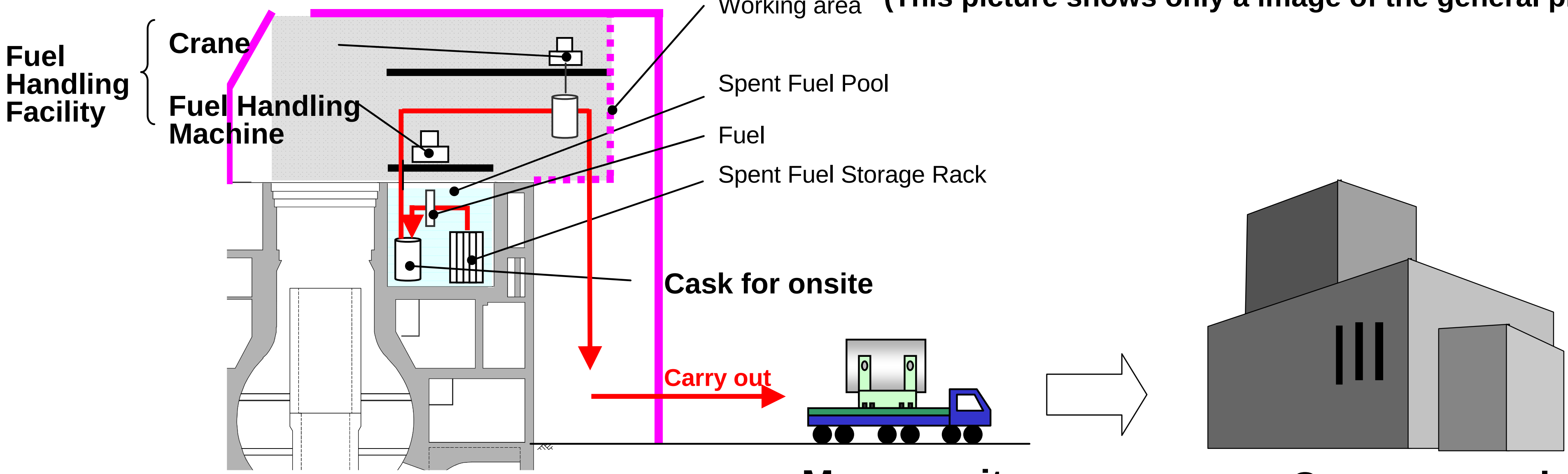


Image of fuel removal **Move onsite** **Common pool**

Fuel Removal from Spent Fuel Pools （transport・custody）

- **Transportation of fuels in the spent fuel pool**

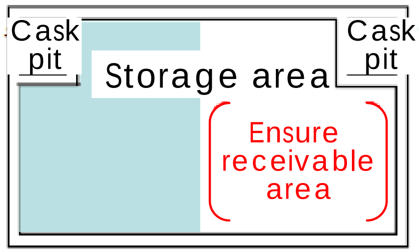
  ①Transfer fuel in the spent fuel pool to the common pool

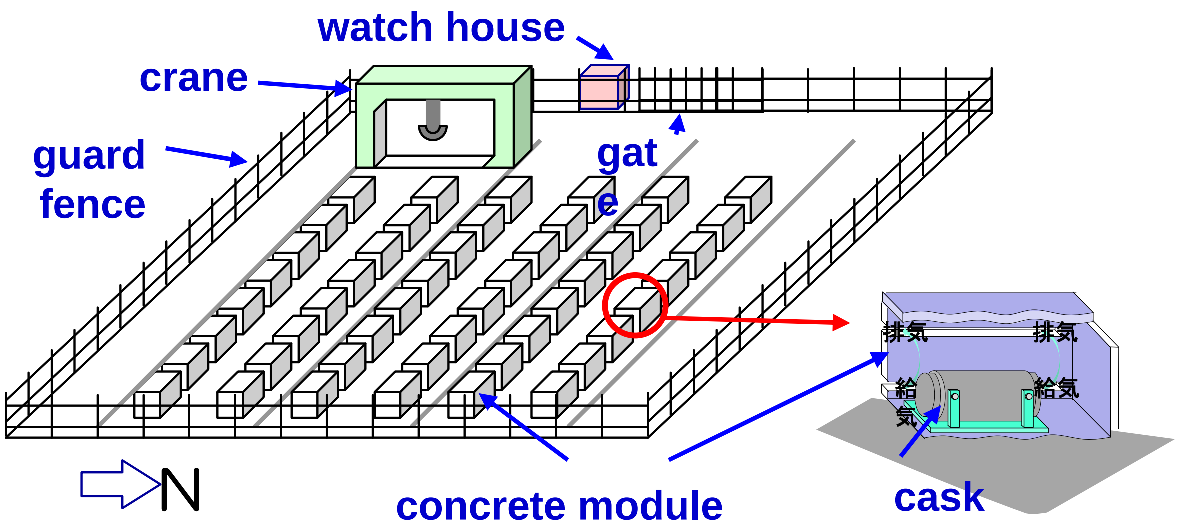
  ②Transfer fuel in the common pool to the temporary cask custody area

- **Temporary cask custody area**

  ・Ensure an area to receive and store the fuel removed from the spent fuel pools

  ・The spent fuel currently stored in the common pool will be stored in dry casks and move out of the common pool, and temporary stored.





①Fuels in the spent fuel pools are transferred to the common pool by shipping cask

②Fuels in the common pool will be stored in casks and move to Temporary cask custody area.

Transportation and Custody of Fuel in the Spent Fuel Pool (image)

Major Challenges in Decommissioning procedures

- Final goal is to remove fuel debris from the Reactor Building (R/B) and to clean up Fukushima Daiichi site.
- Fuel debris removal procedure would be much more complicated than TMI-2 case due to differences like:

	TMI-2	Fukushima Daiichi
R/B Damage	Limited	Damaged by H_2 explosion (Units 1,3,4)
Water Boundary	RV remained intact	Both RPV/PCV have leakage (Units 1~3)
Fuel Debris Location	Remained in RV	Fallen out from RPV
Bottom of the Vessel	Simple bottom head structure	Complicated structure with Control Rod Drives

- TMI-2 Experience can be utilized more efficiently for post-defueling procedures in decommissioning.

Plan for reactor facilities decommissioning

○ Deliberating and planning of a decommissioning scenario by gathering and sorting out of domestic and international relevant information regarding ways to secure safety of decommissioning while keeping in consideration for the final state

□ It is imperative to establish the so-called "End State"

□ : Not determined Information

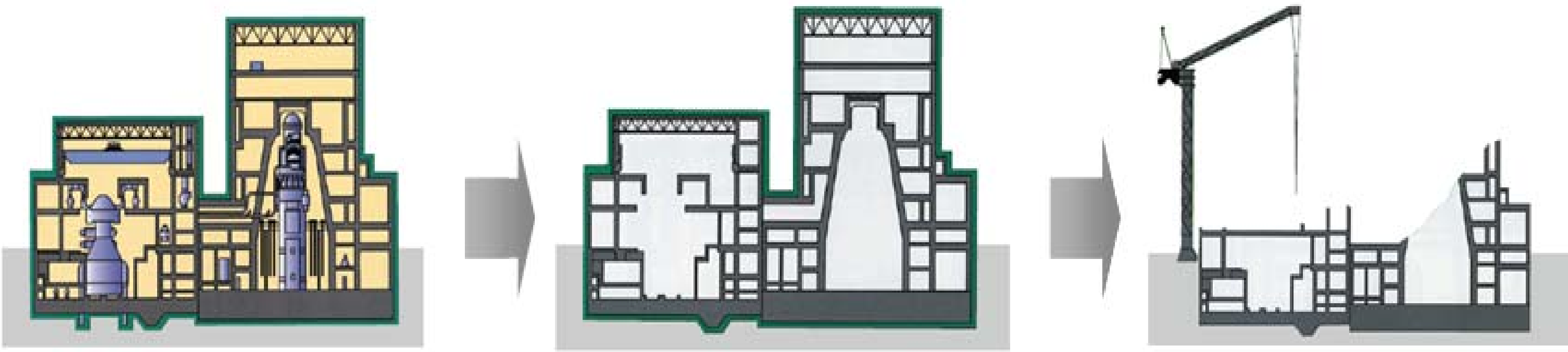


Image of reactor facilities decommissioning

R&D Programs for Decommissioning

Black: On going
Blue: Planned

1. Removal of spent fuel from Spent Fuel Pool

- **1.1 Long-term Integrity of Spent Fuel Assemblies (FY2011–2015)**
- 1.2 Damaged spent Fuel Processing (FY2013–2017)

2. Preparation for removal of fuel debris

- **2.1 Fuel debris removal using remote control equipment and devices**
  - **2.1.1 Remote Decontamination of the Reactor Building Interior (FY2011–2013)**
  - **2.1.2 Identifying Leak Areas in the PCV (FY2011–2014)**
  - **2.1.3 PCV Repair Technologies (FY2011–2017)**
  - **2.1.4 Investigation of the PCV Interior (FY2011–2016)**
  - 2.1.5 Investigation of the RPV Interior (FY2013–2019)
  - 2.1.6 Removal of Fuel Debris and Internal Structures in the Reactor (FY2015–2021)
  - 2.1.7 Containment, Transport and Storage of Reactor Fuel Debris (FY2013–2019)
  - **2.1.8 Assessment of RPV/PCV Integrity (FY2011–2016)**
  - **2.1.9 Controlling Fuel Debris Criticality (FY2012–2018)**
- **2.2 Ascertaining and analyzing reactor core status**
  - **2.2.1 Analysis of Accident Progression to estimate reactor status (FY2011– 2020)**
- **2.3 Ascertaining the characteristics of and preparing to process fuel debris**
  - **2.3.1 Study of Characteristics using Simulated Fuel Debris (FY2011–2015)**
  - 2.3.2 Analysis of Properties of Actual Fuel Debris (FY2015–2020)
  - **2.3.3 Development of Technologies for Processing of Fuel Debris (FY2011–2020)**
  - **2.3.4 Establishment of a new accountancy method for Fuel Debris (FY2011–2020)**

3. Processing and disposal of radioactive waste

- **3.1 Processing of Secondary Waste from the Contaminated Water Treatment (FY2011~)**
- **3.2 Processing and Disposal of Radioactive Waste (FY2011~)**

5. Long-Term Process In Preparation For Fuel Debris Removal

Technical Challenges for Fuel Debris Removal

Decontamination of Reactor Buildings

- Various targets of decontamination; floor, wall, ceiling….
- Not only structural objects, but puddles and atmospherics should be decontaminated.
- Technologies for coating or shielding the radiation sources will also required.

Inspection of Inner PCV interior & Leaking Points

- Most inspection (photographing, dose measurement, acoustic diagnostics) will be done in the contaminated water or in little/crowded space.
- Various situation such as high temp, high humidity, under water….
- All measurement instruments must have high tolerability to radiation and long distance control system

Repair Works for PCV & Leaking Points

- Leakage mending methods under the highly contaminated water
- Water injection to a reactor cannot be stopped during the PCV/leakage repair.

Decontamination of buildings interior (Unit 1, 3)

Background

- There are plans to remove the debris inside the reactor building of Fukushima Daiichi Unit 1 and Unit 3 field preparations, conducting a containment vessel leak survey, etc.,starting in September 2013

- Dose rate surveys have shown that the radiation environment inside reactor buildings is from 200 to 4700Sv/h on the south side of Unit 1 and an average of 50mSv/h at Unit 3. It is necessary to bring these levels down to 5mSv/h in accordance with building internal work procedure objectives.

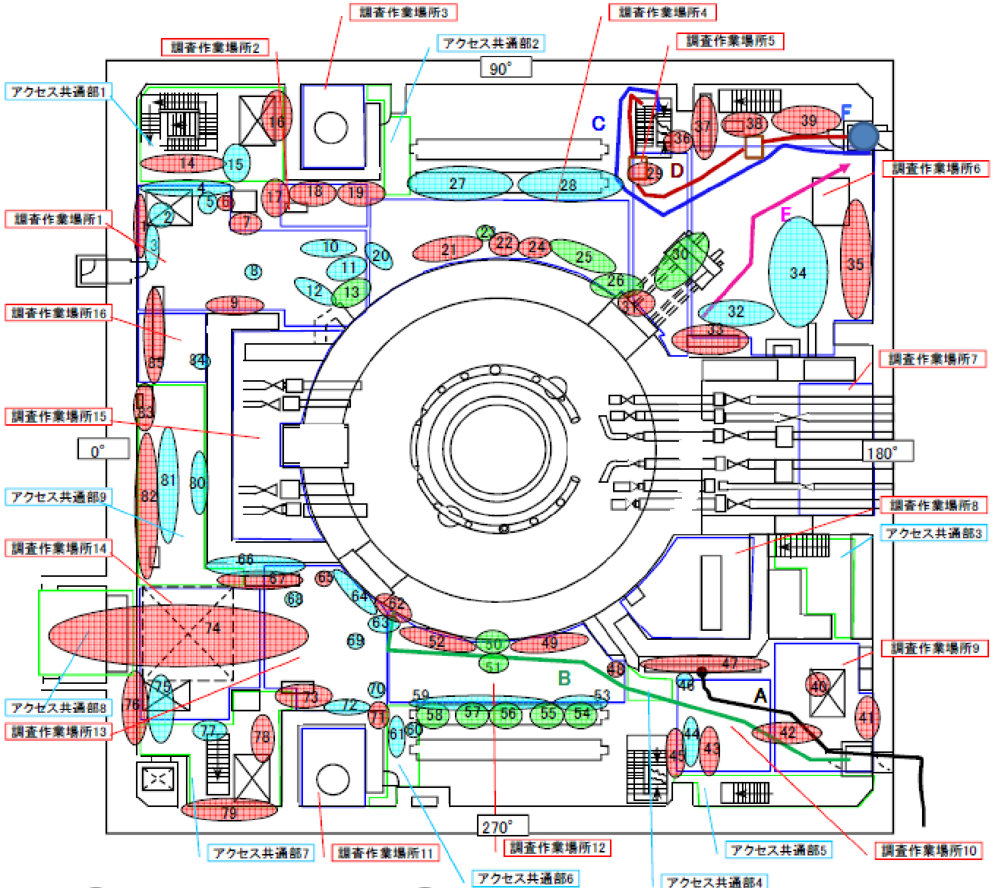
- As a result of the hydrogen explosions that occurred the inside of the Fukushima Daiichi Unit 1 and Unit 3 reactor buildings, the floors are littered with debris, such as concrete fragments and ducts, etc. these debris must be removed before decontamination devices can be brought in. At Unit 1 it is necessary to move the temporary shielding to use the equipment hatch.

Objective

Before decontamination work can commence, obstacles, such as debris, must be removed by unmanned equipment in order to avoid workers exposure and secure access routes for decontamination devices and internal surveys of the PCV.

Decontamination of buildings interior (example of Unit 3)

【Target Area】



Access route obstacle obstacle / Dose reduction / decontamination work

【Target Area】

【Examples of debris and removal concept】

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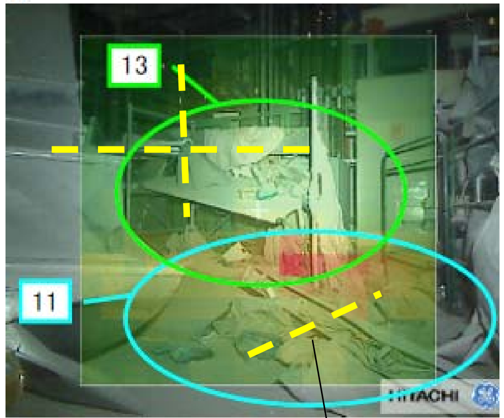

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Material

N2 hose and HCU fence

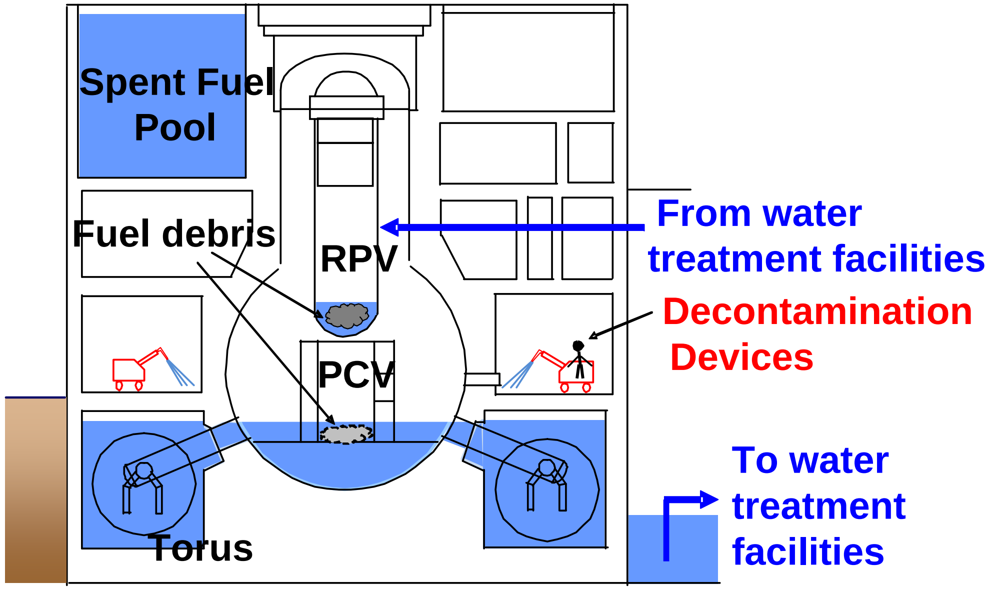
Fallen duct

Hoses and cables need to be organized

Large objects and objects attached to supports need to be cut free

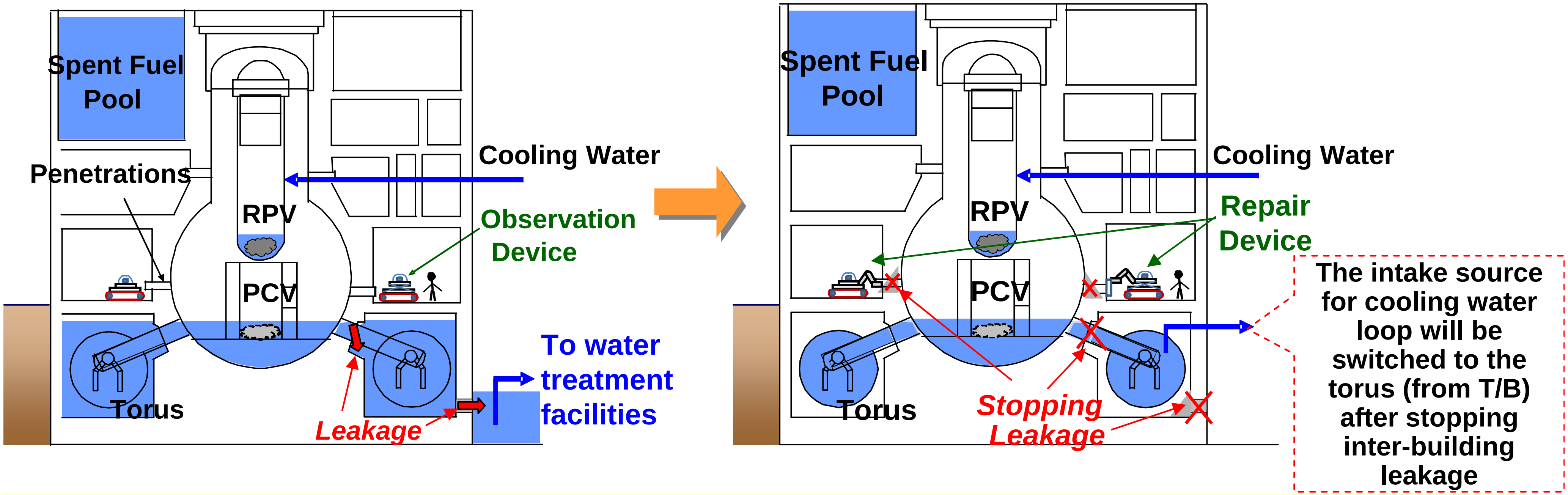
※The achievements of the government project entitled "Creating General Dose Reduction Plans" have been used to formulate the scope of debris removal

Step 1: Reactor Building Decontamination



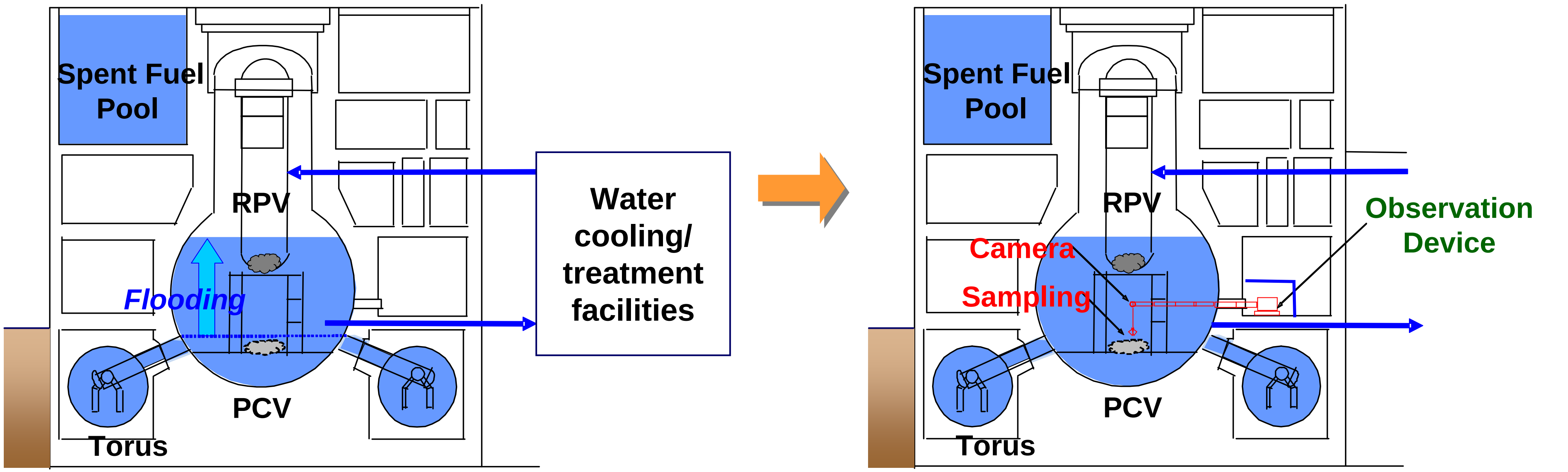
- **Decontamination of the area is essential to following procedures.**
  - Feasibility of high-pressure washing, coating, scraping and etc. are investigated in the National R&D program.
  - Combined usage of shielding maybe necessary
- **Major Challenges and Difficulties:**
  - High dosage (~ 5 Sv/h).
  - Obstacles like rubble scattered in R/B.
  - Smaller space due to the compact design of BWR4

Steps 2, 3: Identification and Repair of the Leakage Points of PCV



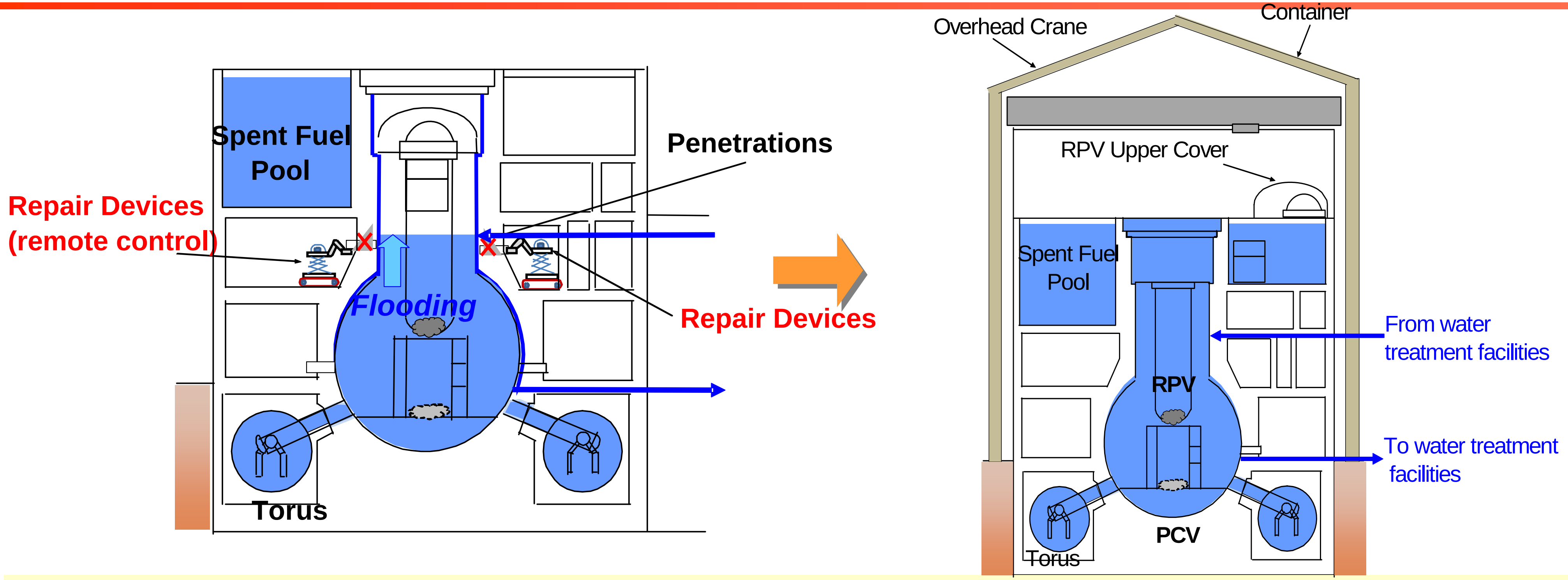
- **Leaking Locations will be investigated from Outside of PCV and will be repaired**
- **Major Challenges and Difficulties:**
  - High dose rate and humidity inside PCV.
  - Major part of "suspicious locations" are underwater with poor visibility.
  - Repair work has to be conducted while highly radioactive cooling water is running for continuous fuel cooling

Steps 4, 5: Flooding of the Lower PCV, PCV Inspection & Sampling



- **Filling the lower PCV with water (Flooding)**
- **Distribution and Characteristic of fuel debris will be investigated**
- **Major Challenges and Difficulties:**
  - High dose rate, Limited accessibility and Poor visibility.
  - Leak-tight penetration is required for the investigation device once PCV flooding is achieved.
  - Subcritical assessment

Steps 6,7: Upper PCV repair, Flooding of Entire Reactor Well

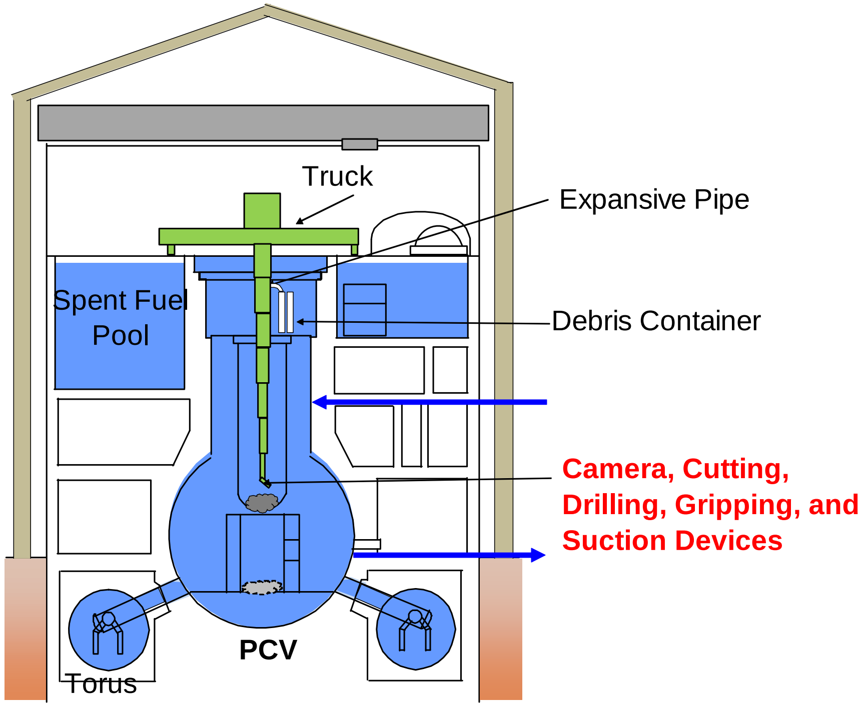


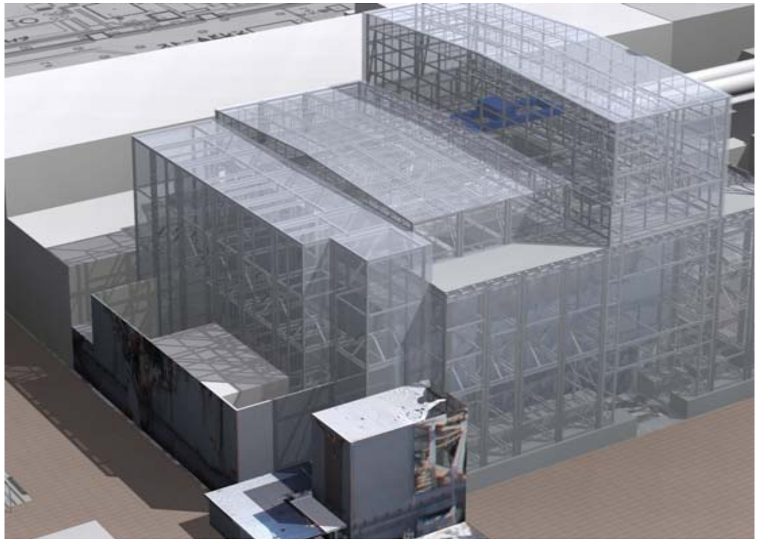
(1) Filling entire PCV/RPV with water after repairing upper PCV
(2) R/B container and overhead crane will be installed for defueling.
(3) RPV/PCV top heads will be removed after sufficient water is attained

Major Challenges and Difficulties:

- High dose rate, Limited accessibility.
- Seismic stability after flooding has to be maintained considering water mass.
- Prevent radioactive substances release from PCVs
- Subcritical assessment

Step 8: Internal RPV interior Inspection& Sampling



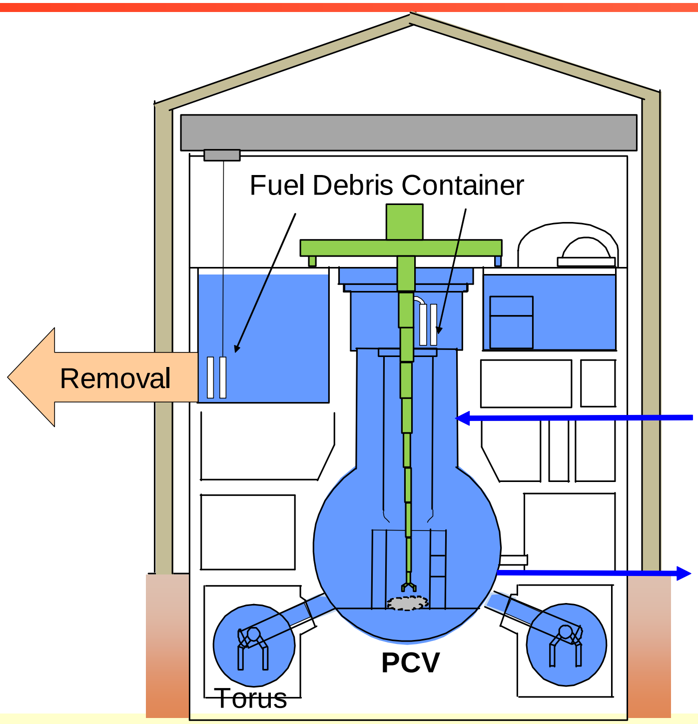


- Condition of RPV interior and Fuel debris will be investigated

- Major Challenges and Difficulties:

- High dose rate, Limited accessibility and Poor visibility.
- Development of necessary device
- Subcritical assessment
- Store the removed debris

Step 9: Defueling from RPV and PCV

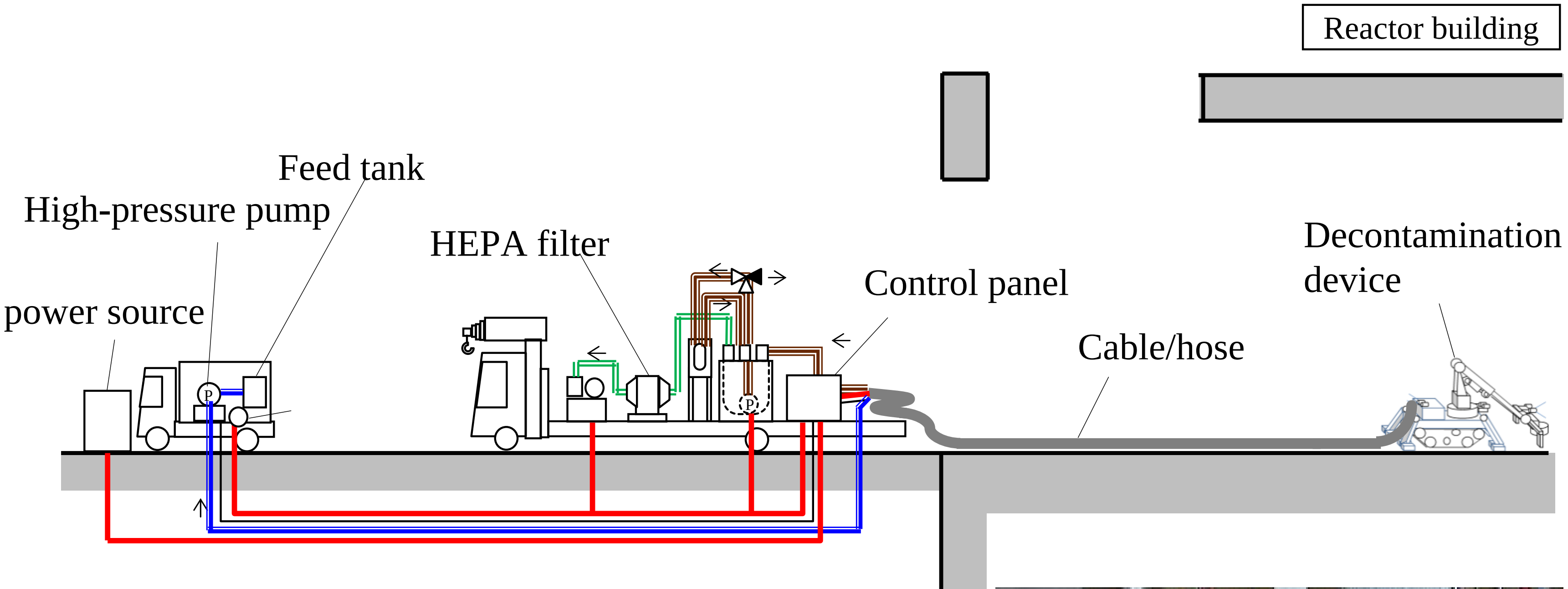


- Fuel debris and RPV internal structure will be removed

- Major Challenges and Difficulties:

- Fuel debris is assumed to have fallen onto the complicated RPV bottom structure (BWR has much more complicated one than PWR)
- Debris may have fallen even out of RPV (Debris remained in RV in TMI-2)
- Diverseness of Neutronic-, Mechanical- and Chemical- property of debris as mixture with different types of metal and concrete
- Subcritical assessment
- Store the removed debris

Mechanical decontamination of surfaces by spraying high-pressure water .



With arm extended

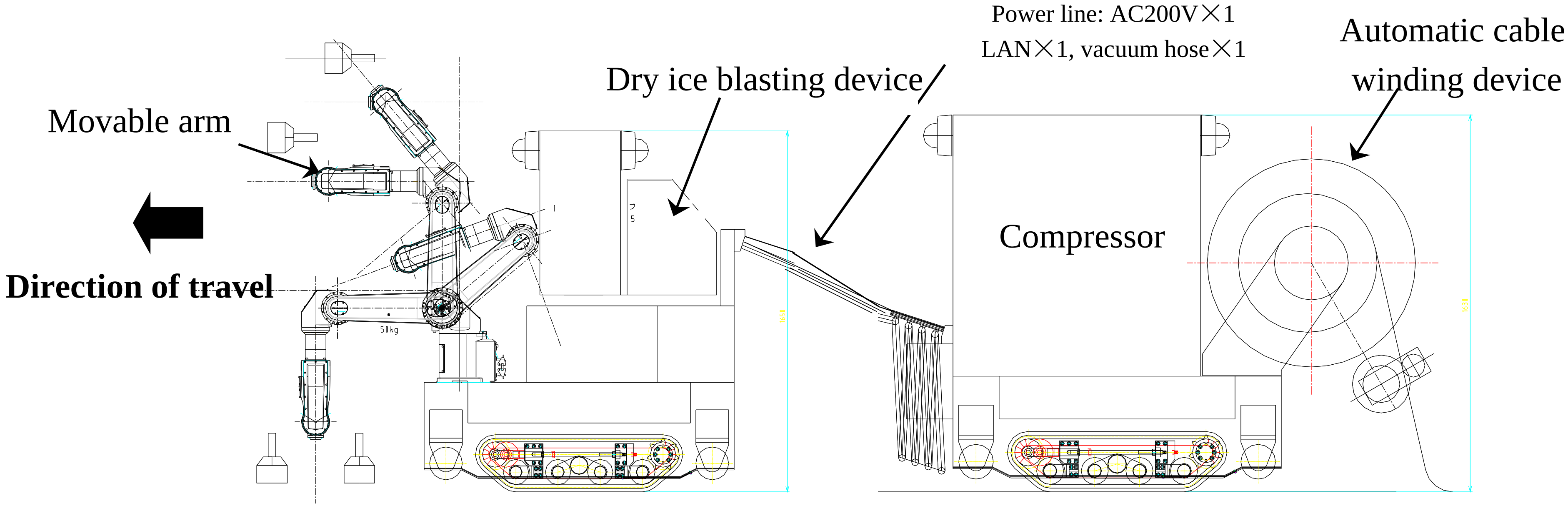
In motion

【Example】Dry ice blasting Decontamination device

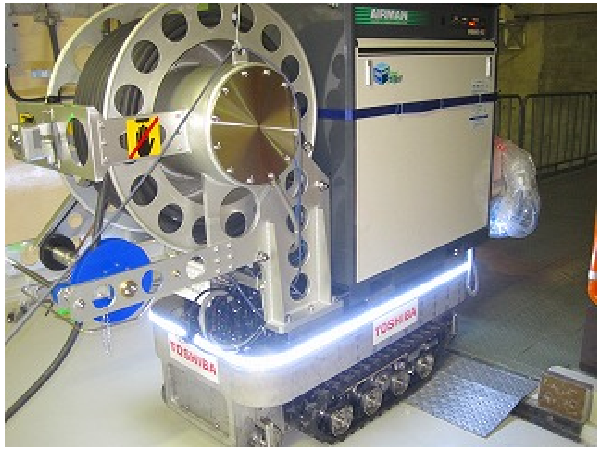
Mechanical decontamination of surfaces by spraying dry ice powder.

It leaves little secondary waste because dry ice sublimates.

It doesn't damage decontaminated surface.



Decontamination platform

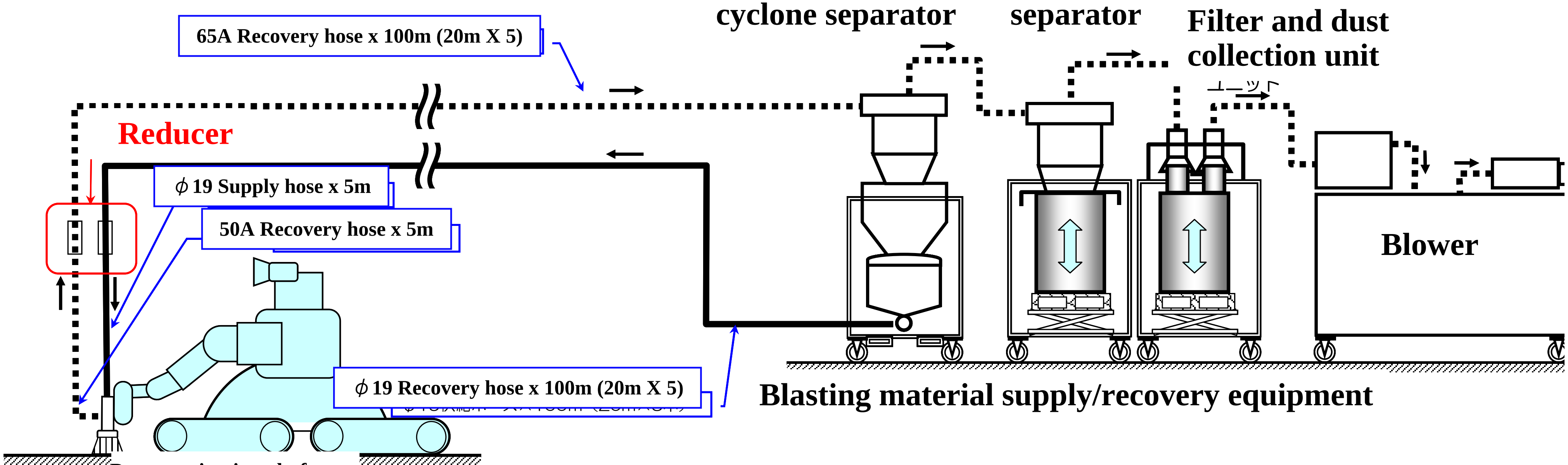


Support platform

This device sprays a abrasive and grinds contaminated surfaces.

It uses steel grit as an abrasive and recycles it by recovering it after spraying and separating it from contamination.

It can be running in suction only mode and is capable of recovering debris as small as 1 cm in size.



Decontamination platform

Blaster with cyclone separator

#2 cyclone separator

【Example】Unit 1～3 reactor building contamination survey results

Dose level/radiation source surveys of the Units 1 through 3 reactor buildings, and analysis of contamination samples have been conducted in order to formulate a decontamination plan

Does/radiation source survey results

●Dose rate survey results
Unit 1：3.2～8.9mSv/h
Unit 2：6.8～30.3mSv/h
Unit 3：15.8～124.7mSv/h

●Radiation source survey results
the primary hotspots are containment vessel penetration seals, hydraulic control units (HCU) and the Unit 3 equipment hatch railing

Radiation source survey(γ camera) results example
（Unit 3 South side HCU)

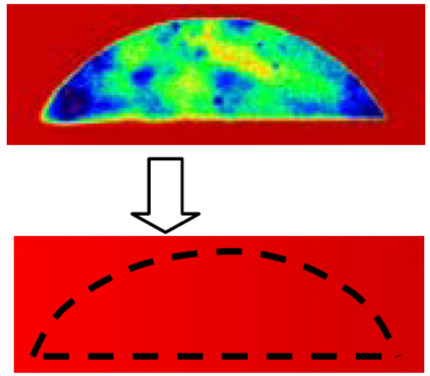
Contamination sample analysis results

● α / γ ray spectrometry measurement results
-There are no differences in γ nuclides between the units with Cs134 accounting for 40% and Cs137 accounting for 60%.
-α nuclides were not detected in any of the units

●Imaging plate (IP) measurement results
-Contamination has permeated epoxy coated surfaces up to a maximum of approximately 1mm at Unit 3 and approximately 0.5mm at Unit 3 (there has been no permeation of contamination at Unit 1)
-Permeation was stopped by the painted surface and the concrete has not been contaminated.

Measurement surface

Before surface machining



After machining 1.5mm

Example of imaging plate measurement results

PCV Leak survey and repair (Submersible robot)

◆The necessity to develop submersible robot technology

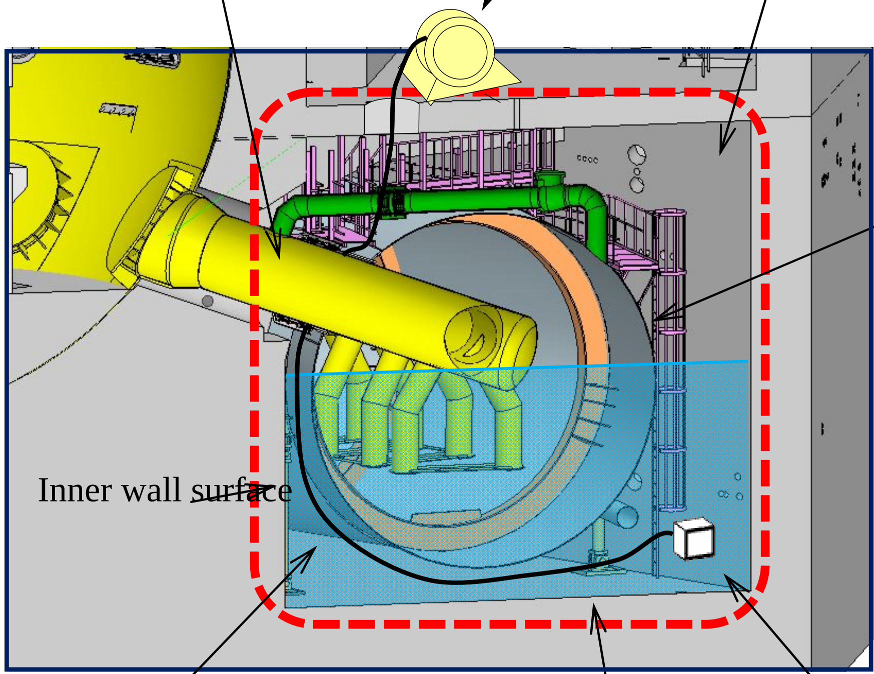
Eventually a submersible robot will be used to survey the inside of the containment vessel and pressure vessel, which are filled with water, however fundamental technology that allows the robot to self-locate does not exist.

Required equipment

- Submersible robot

Required technology

- Self-location technology
- Long cable handling technology
- Shape/water flow detection technology



◆Schedule

- FY2012: Element tests
- FY2013: Combination tests
- FY2014: Application of real device

PCV Leak survey and repair (S/C water level measurement robot)

◆The necessity of measuring the water level inside the suppression chamber (S/C)

It is possible to narrow down where leaks are in the containment vessel from the water levels in the S/C and torus room, however there is no method for measuring the water level inside the S/C using remotely operated technology.

Required equipment

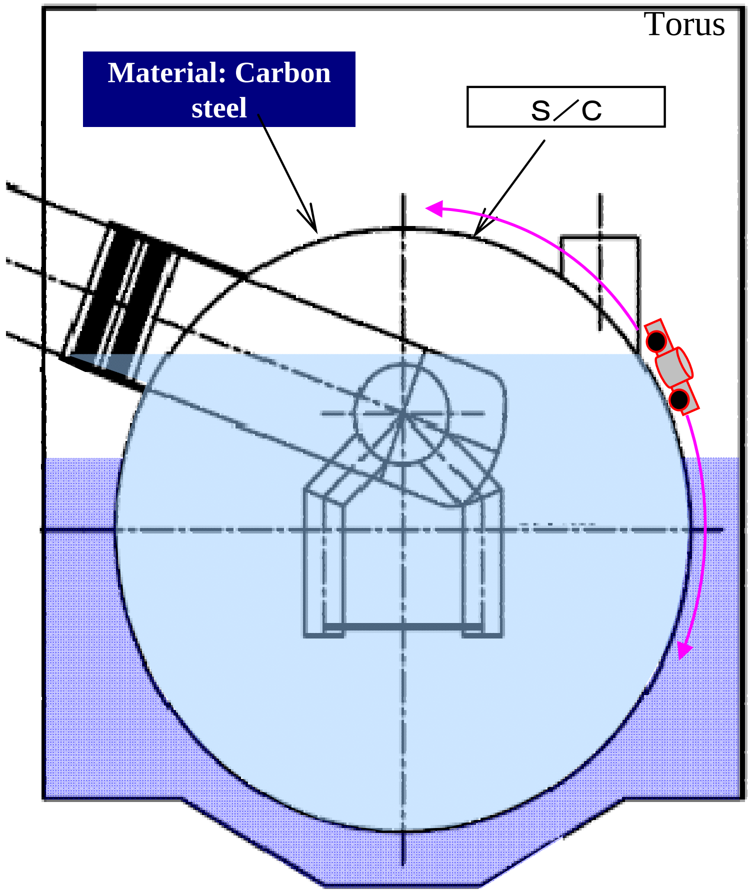
・Water level measurement robot that can move on curved steel surfaces

Required functions

・Must be able to measure the water level inside the S/C from outside the S/C

Required technology

・Technology for nondestructive measurement of water levels inside steel containers
・Technology for moving on curved steel surfaces
・Self-locating technology
・Technology related to accessing the Torus room



◆Schedule

・FY2012: Device design
・FY2013: Device manufacturering/examination of real equipment
・Fy2014: Application of real device

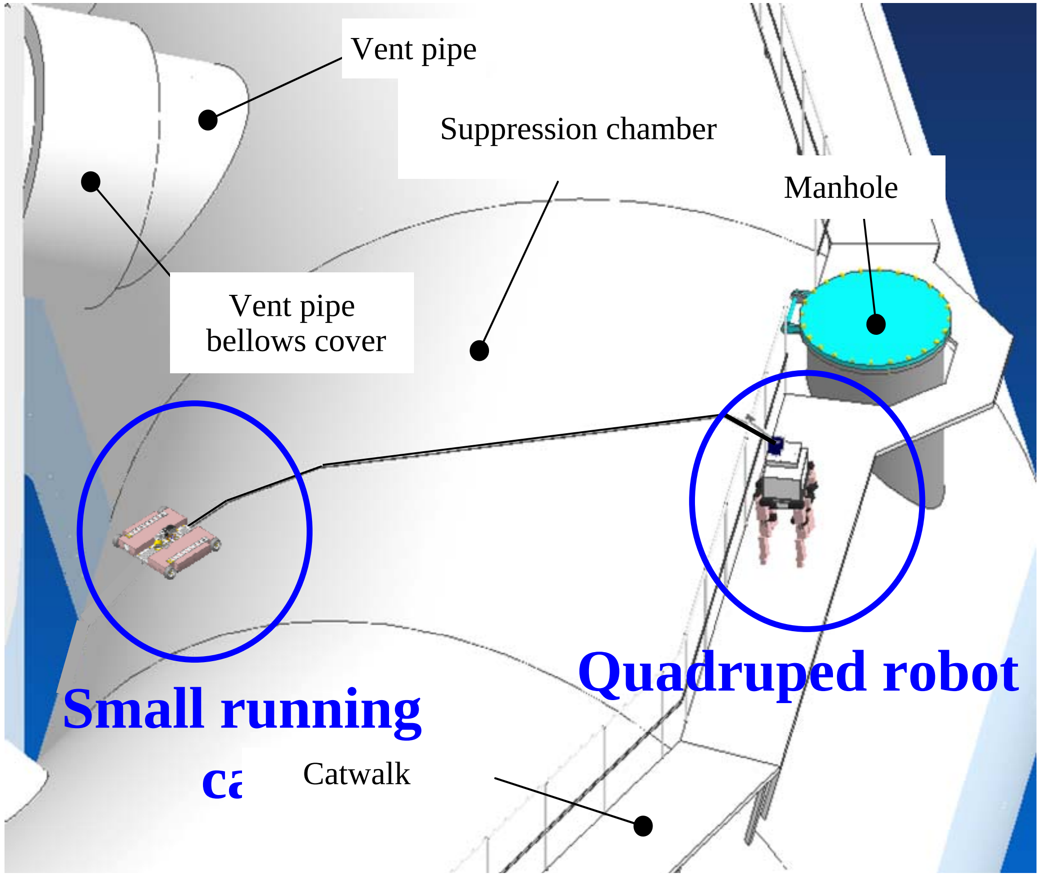
PCV Leak survey and repair (Quadruped robot (objective/background))

Objective/Background

■Being used (Unit 2) before robot developed by government PJ in order to detect leaks from the bottom of the containment vessel as quickly as possible. Survey results will be used as feedback for government PJ equipment and device development.

■Whereas a survey of one area was completed on December 11 of last year, thereafter the three problems occurred. An expert working group has been established under the jurisdiction of the remotely operated task force (TF) and improvement measures are being deliberated.

■Mockup tests of Unit 5 using the improved robot have been completed so the survey will recommence on March 5.



313mm(L)×327mm(W)×47mm(H)

Quadruped robot

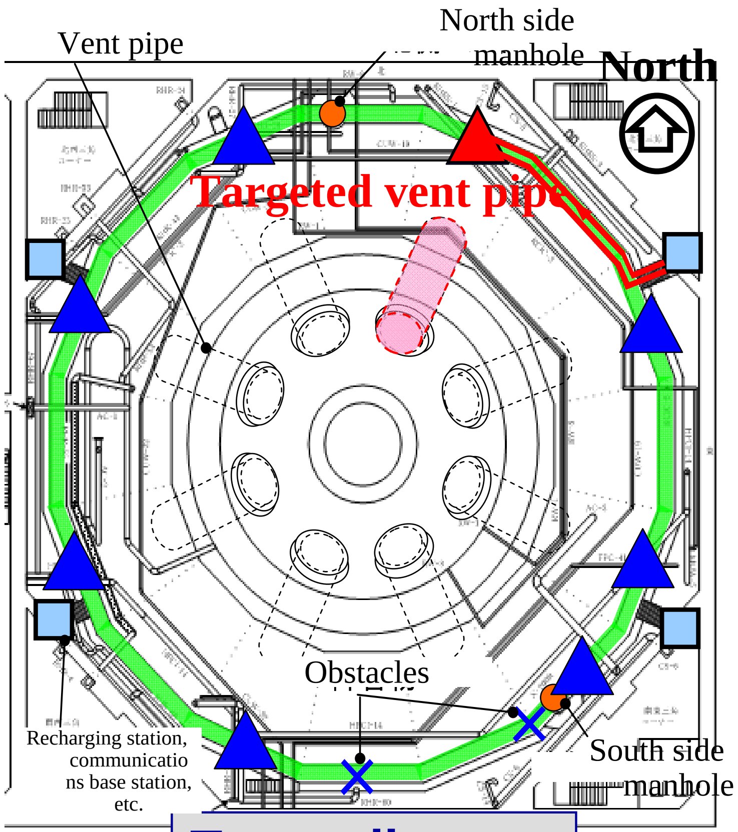
Small running car

■Specific locations on within the torus can be accessed using the quadruped robot

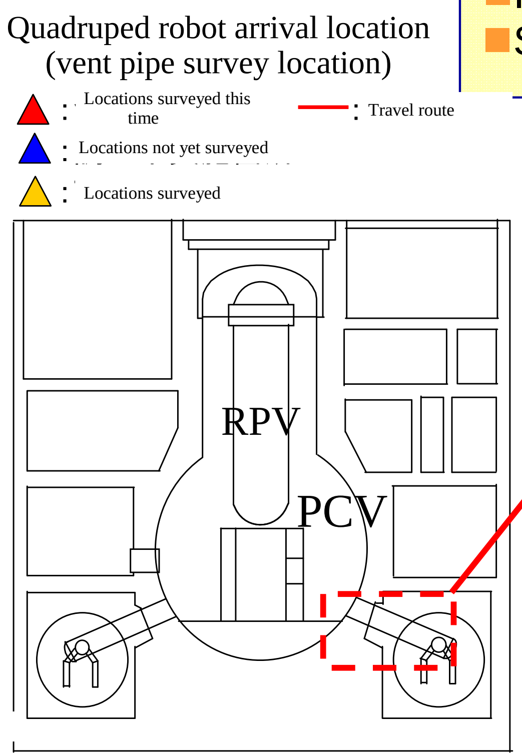
■After being put in position, a small running car attached to the end of the quadruped robot arm will be put on the top part of the S/C and moved near the vent pipe in order to take pictures and record sounds.

PCV Leak survey and repair (Quadruped robot （survey results））

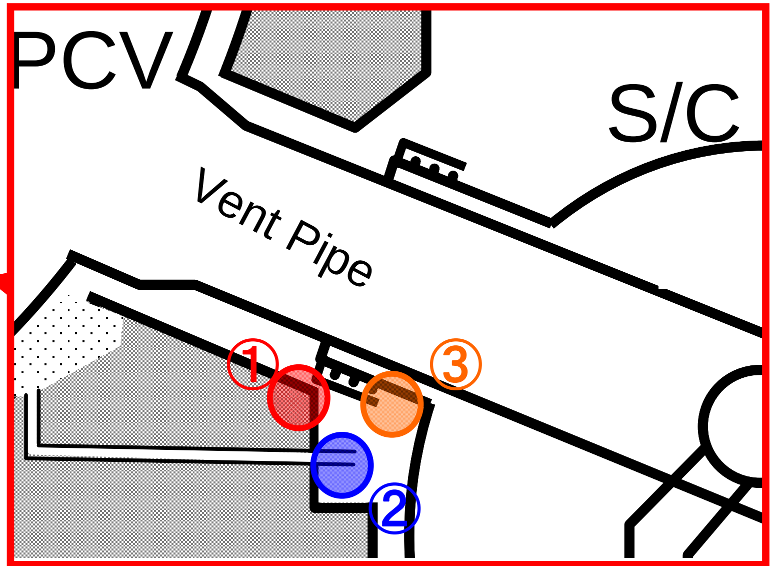
■Implementation Date：December 11, 2012
■Survey Target: Refer to left diagram



Torus diagram



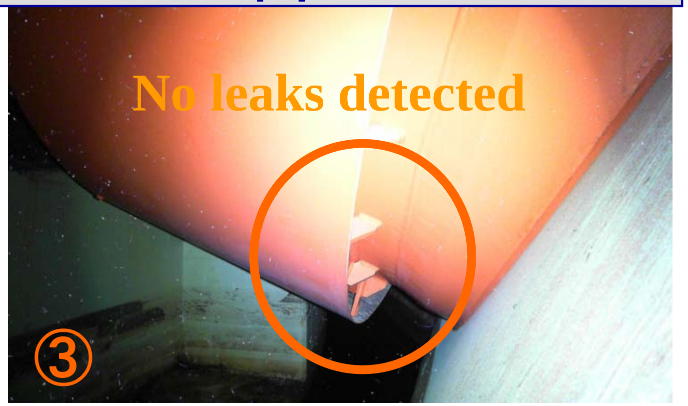
PCV cross-section



Enlarged view of area beneath pipes

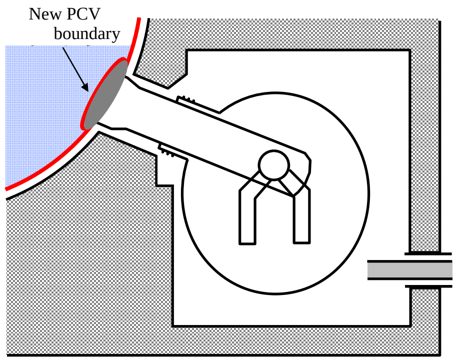
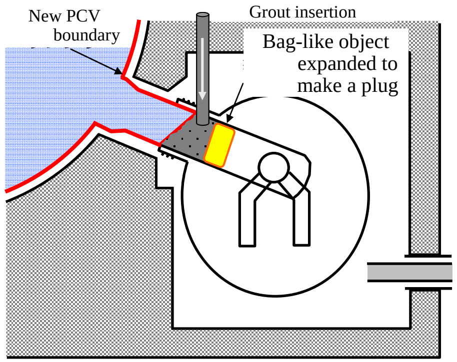
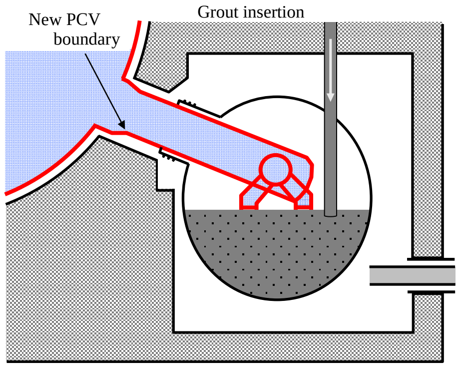
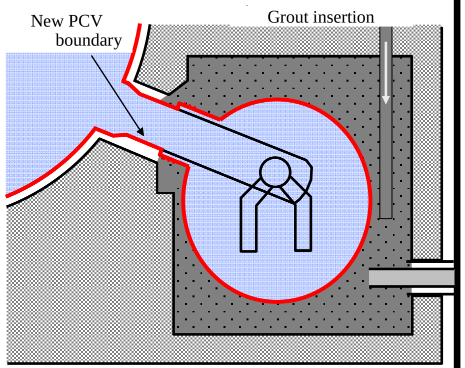
Vent pipe sleeve end

San cushion drain pipe end



Bottom of vent pipe bellows cover

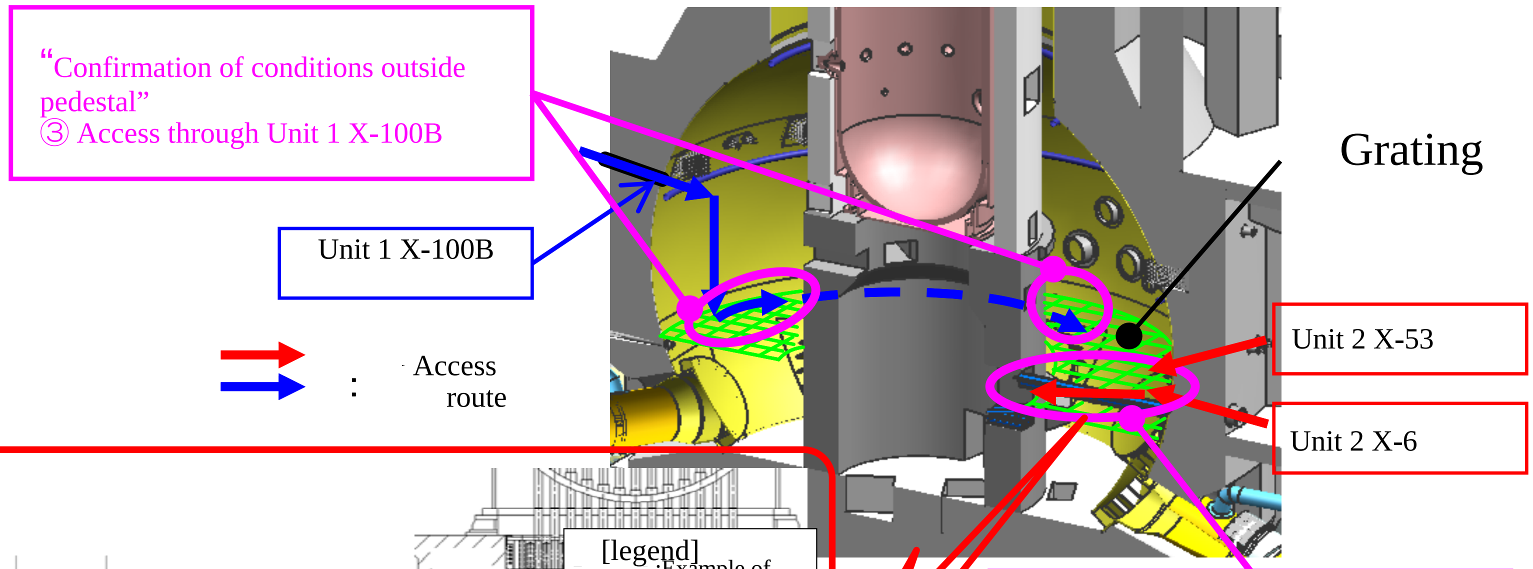
PCV Leak survey and repair (Methods for repairing the bottom of the PCV)

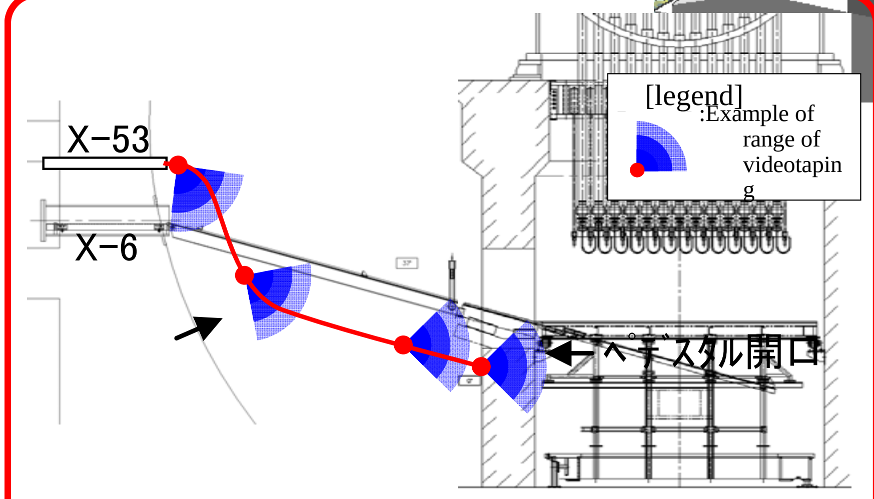
	Stopping leaks at the jet deflector	Stopping leaks at the vent pipe	Stopping leaks at the downcomers	Stopping leaks at the torus
Concept diagram				
Characteristics	The dry well becomes the only boundary and the suppression chamber is removed from being a boundary (minimizing of boundaries)	The dry well and part of the vent pipe become boundaries and the suppression chamber is removed from being a boundary	The dry well, vent pipe, vent header, and downcomers become boundaries, and suppression chamber is removed from being a boundary	The suppression chamber and system piping connected to the suppression chamber become boundaries (maximizing boundaries)
Primary issues	Eight routes need to be secured for inserting leak stopping material into the drywall vent nozzles	Locations need to be secured for inserting leak stopping material into the vent pipe	･Routes need to be secured for inserting filler into the suppression chamber ･It is necessary to confirm the presence or absence of debris inside the suppression chamber prior to inserting leak stopping material	･The torus, which contains many obstacles, must be completely filled without gaps with leak stopping material ･It is necessary to confirm the presence or absence of debris inside the torus prior to inserting leak stopping material

PCV internal survey (Future plans)

Unit 1: Survey devices inserted into the PCV from spare penetration seal (X-100B) Equipment moved to above the first floor grating to survey the outside of the pedestal

Unit 2: CRD replacement rail and vicinity of pedestal opening to be surveyed from penetration seal (X-53) If the amount of information acquired from the survey through X-53 is insufficient, survey equipment will be inserted through the CRD equipment hatch (X-6)





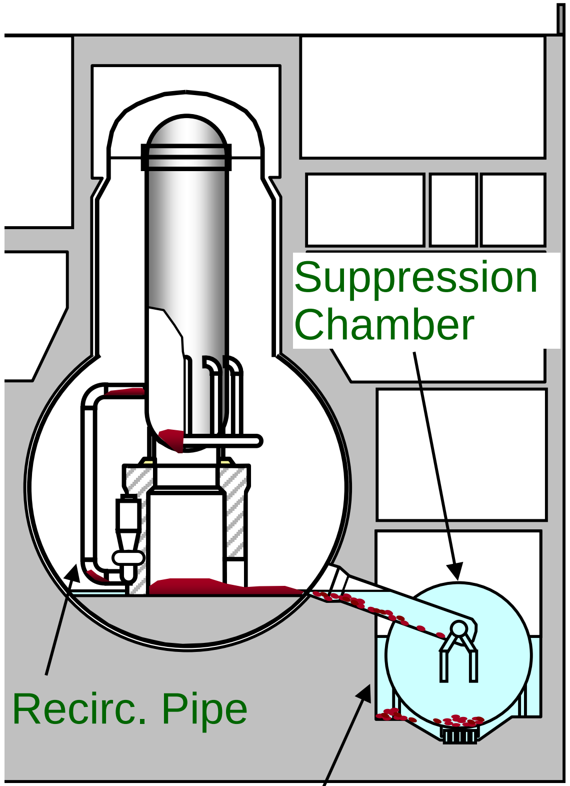
Scope of advanced survey from X-53

Preliminary survey implementation items and accessories

Advance survey: Survey on inside of PCV in preparation for detailed survey (survey to ascertain the location of fuel debris)

6. Remaining Challenges for Fuel Debris Retrieval

Items to be Tackled



1. Identification of debris location

- SA codes predicts that molten debris has fallen downward, out of RPV
- No enough evidence at this moment to deny the existence of debris in recirculation pipes, suppression chamber or torus room
- Attempts such as further visual inspections, SA code improvement and MUON technology are continuing

2. Debris Sampling

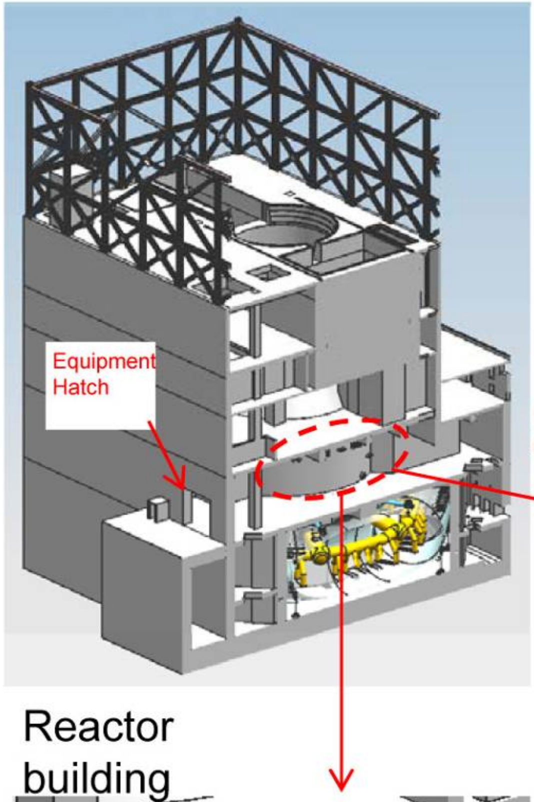
Analyses of actual debris samples will be valuable for subsequent processes of decommissioning, however;

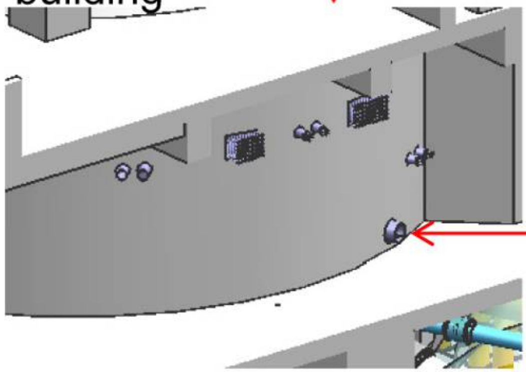
- Large number of samples can be required to assure enough representativeness of various forms of debris
- Debris properties are needed to take out debris samples (Chicken and Egg situation)

3. Debris Property Evaluation (Main Topic of this Presentation)

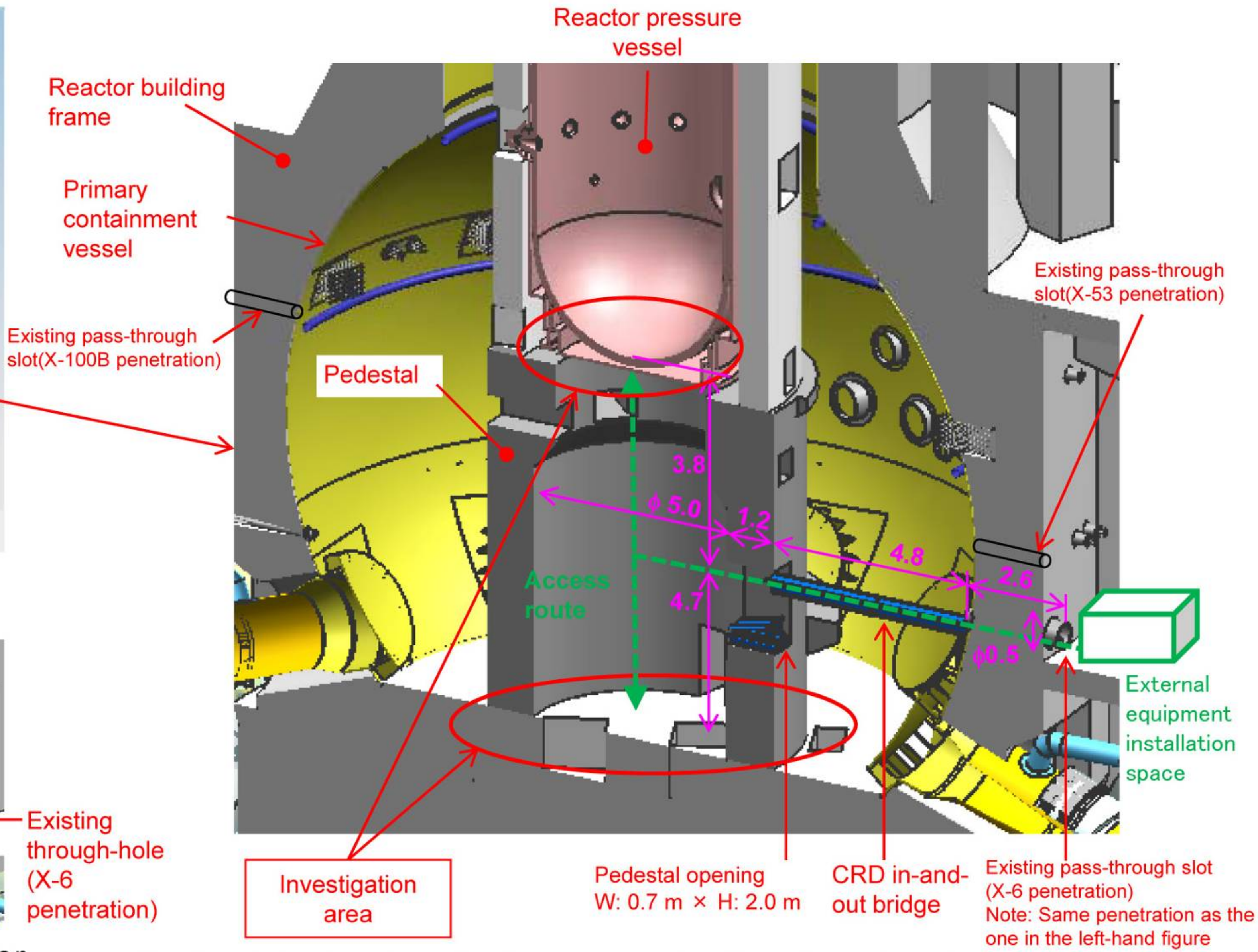
Simulate Debris samples can be useful

Identification of Fuel Debris Location





Reactor building, first floor



Sectional drawing, investigation area, and outline dimensions (m)

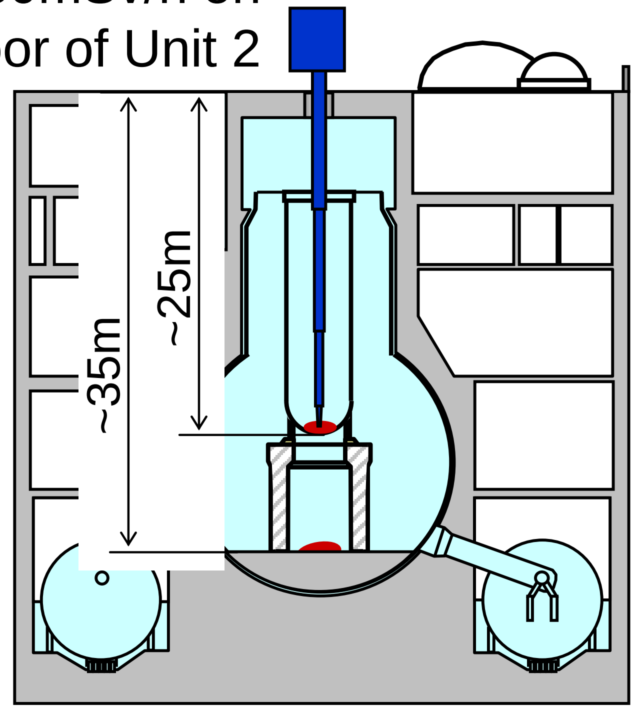
Current Situation toward Debris Retrieval

Limited accessibility to debris:

- High dose rate (~880 mSv/h on the top floor)
- Damaged reactor building structure
- Physical distance between Operating Floor and PCV bottom

Remote operation capability required:

- Core boring
- Plasma arc
- Shearing
- Bulk removal (Vacuum, Gripping)

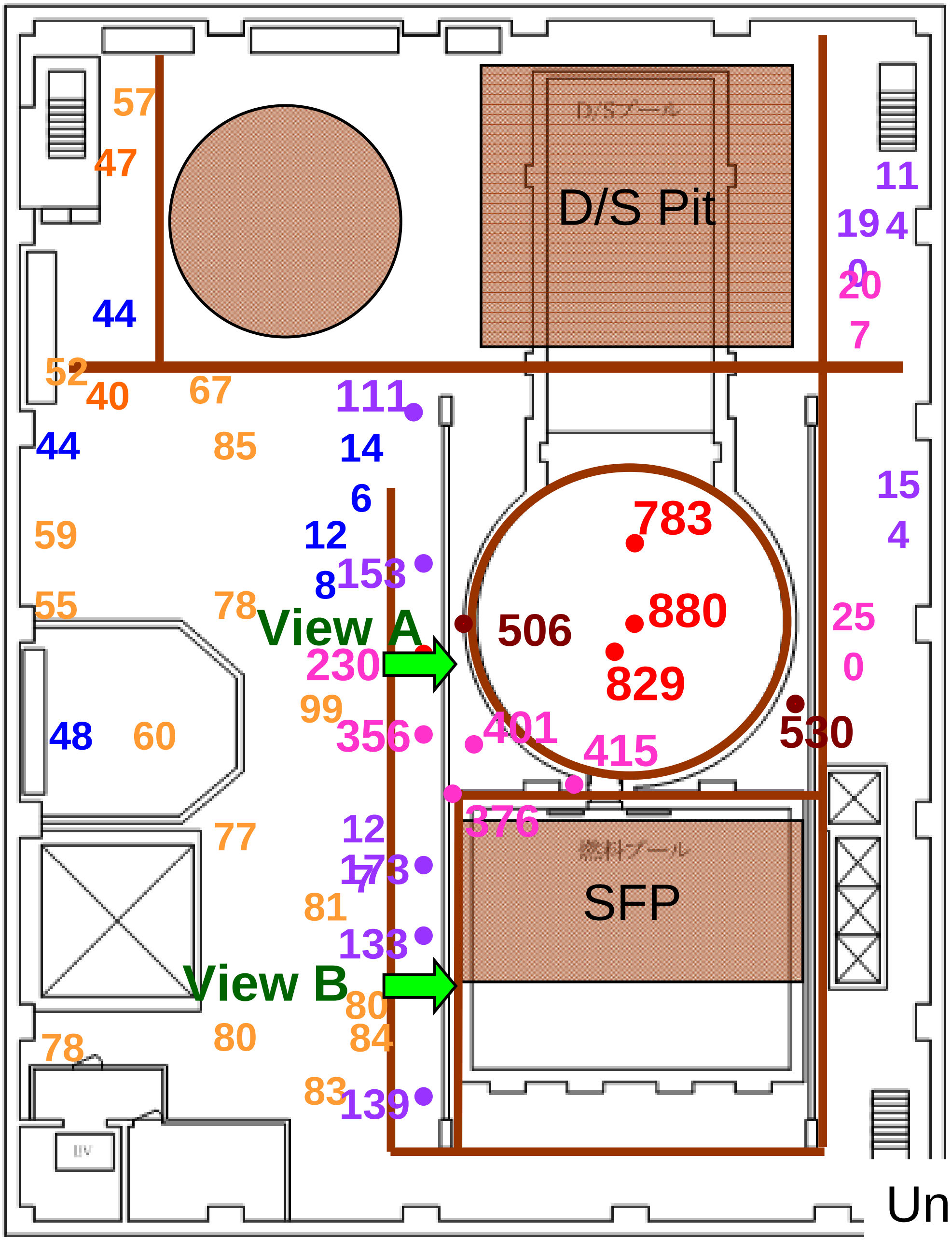


Dose Rate Map of Operating Floor (Unit 2)

Reactor Building
Operating (Top) Floor, Unit 2

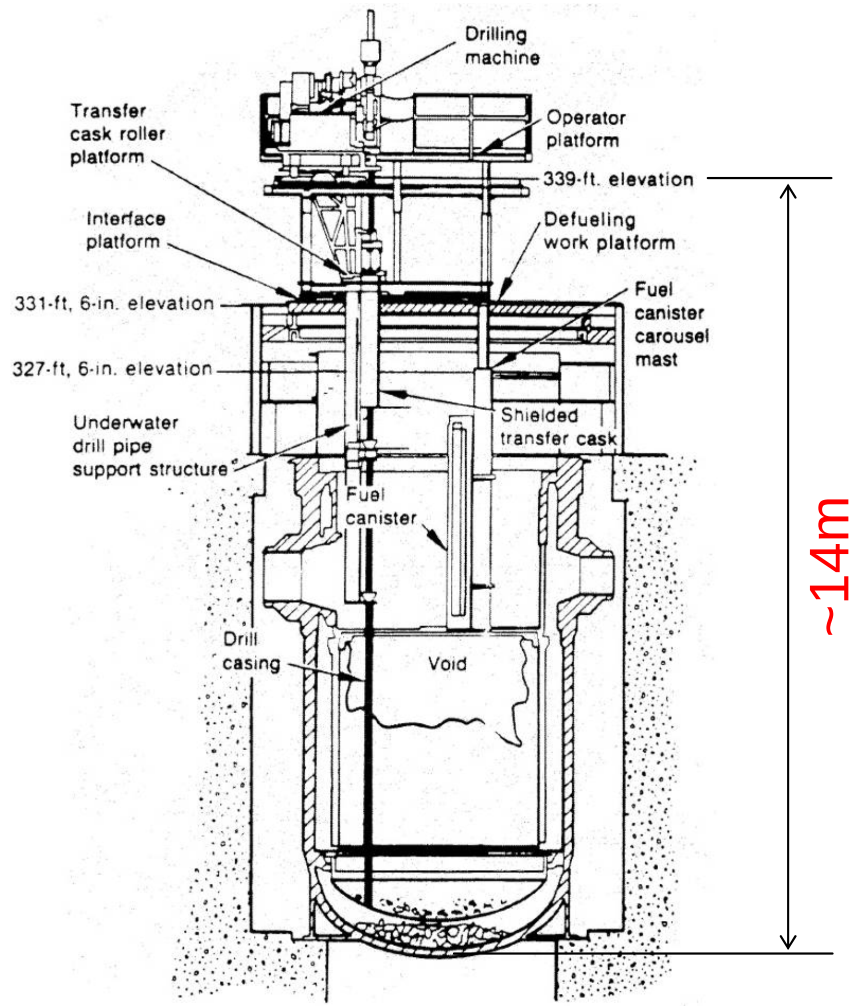
View A

View B



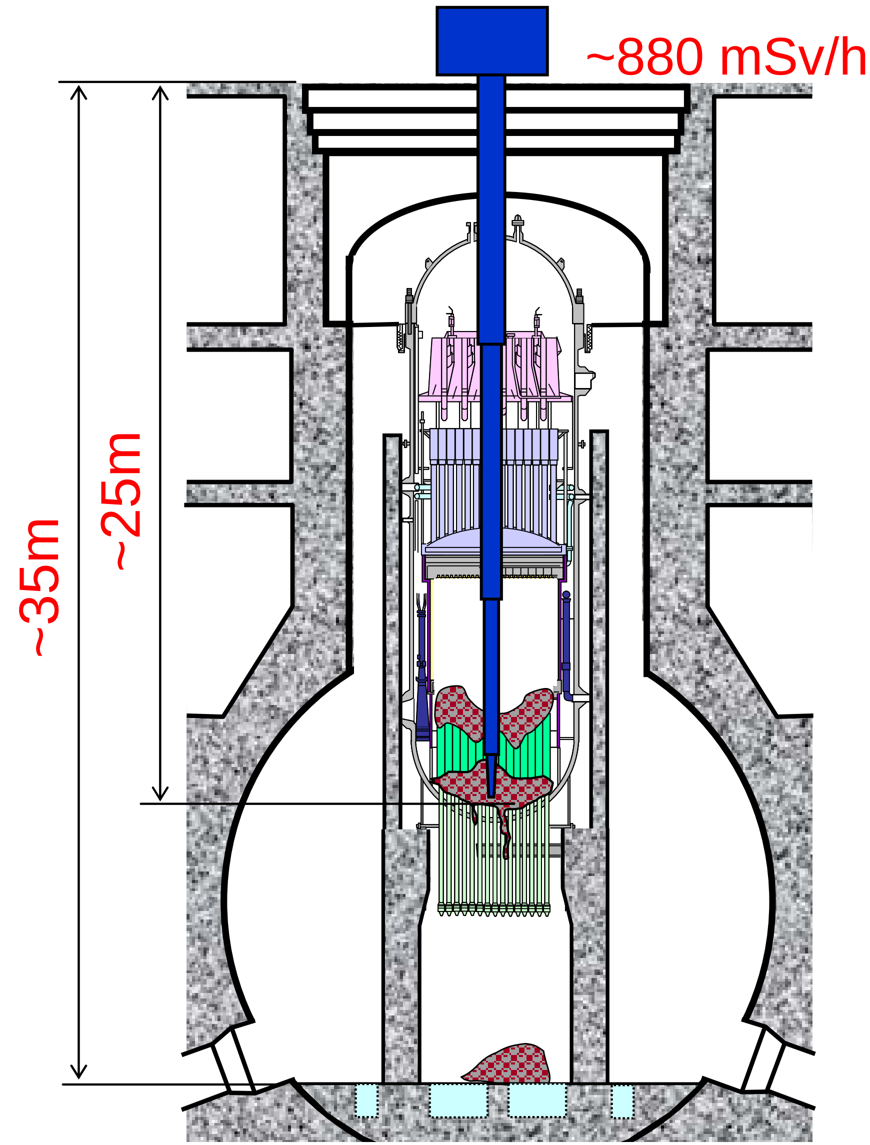
Unit: mSv/h

Comparison with the TMI case



Core Boring Machine for TMI-2

The Cleanup of Three Mile Island Unit 2,
Project 2558-8 Final Report, EPRI NP-6931 (1990)



Fukushima Daiichi

More elaborate tool development is important

Available Information about Fuel Debris

Necessary properties of debris:

- Hardness
- Toughness
- Workability
- Machinability

Available properties are limited.

- Various information from TMI-2 and SA-related research programs are available
- But not directly applicable due to the BWR-PWR differences and Fukushima-specific conditions
  > U/Zr ratio
  > Larger amount of metal (Fe/Ni) mixture (from RPV Internal structure and RPV itself)
  > Concrete mixture (from MCCI (Molten Core-Concrete Interaction))
  > Duration period of high temperature condition

International Studies on Molten Corium

Multiple international projects working on molten corium have been conducted

- OECD/NEA Projects
  - > RASPLAV-1, 2 (Chemical Property of corium),
  - > MASCA-1, 2 (In-Vessel Retantion),
  - > MCCI-1, 2 (MCCI)
- European Projects
  - > SARnet-1,2(,3) (SA code ASTEC)
- ISTC (International Science and Technology Center) Projects
  - > METCOR, CORPHAD, PRECOS (Corium phase diagram)

Main focus was on Chemical- or Thermal- properties and reaction

Few mechanical property information was extracted from those projects

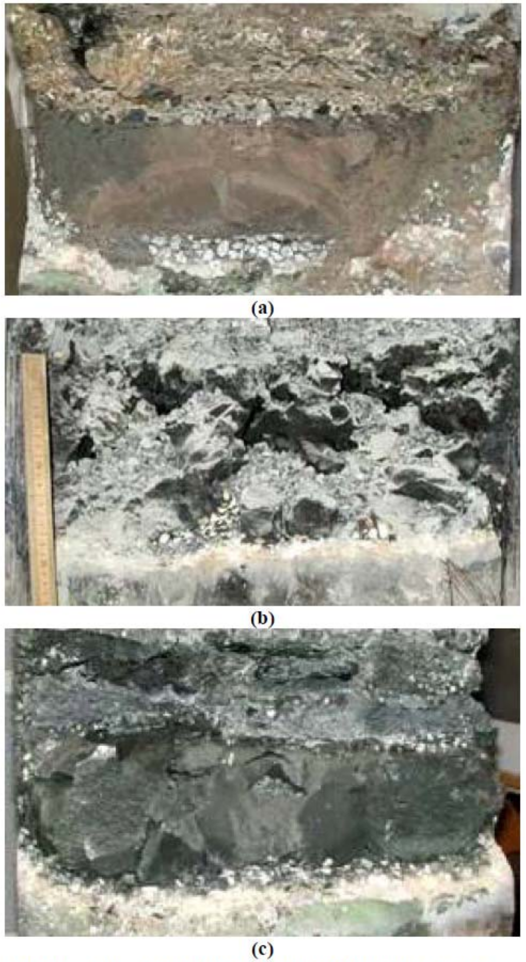


Figure 3-9. Axial Debris Morphology for Test:
(a) CCI-1, (b) CCI-2, and (c) CCI-3.

OECD MCCI Project Final Report
OECD/MCCI-2005-TR06(2006)

Examples of Lessons learned from Foreign Organization

- Integrated Waste Management

  ✓ Fukushima Daiichi(1F)-specific waste management strategy is needed. It has to be regarded as key principles in designing decommissioning procedures.

  ✓ The waste management strategy should include not only long-term storage but also re-using and recycling of materials. The facility and site plans should be established considering their prioritization.

  ✓ Precise estimations of the future waste generation is important in long-term decommissioning planning. Close communication between decommissioning process management- and waste management-teams is indispensable.

Current Activities for decommissioning

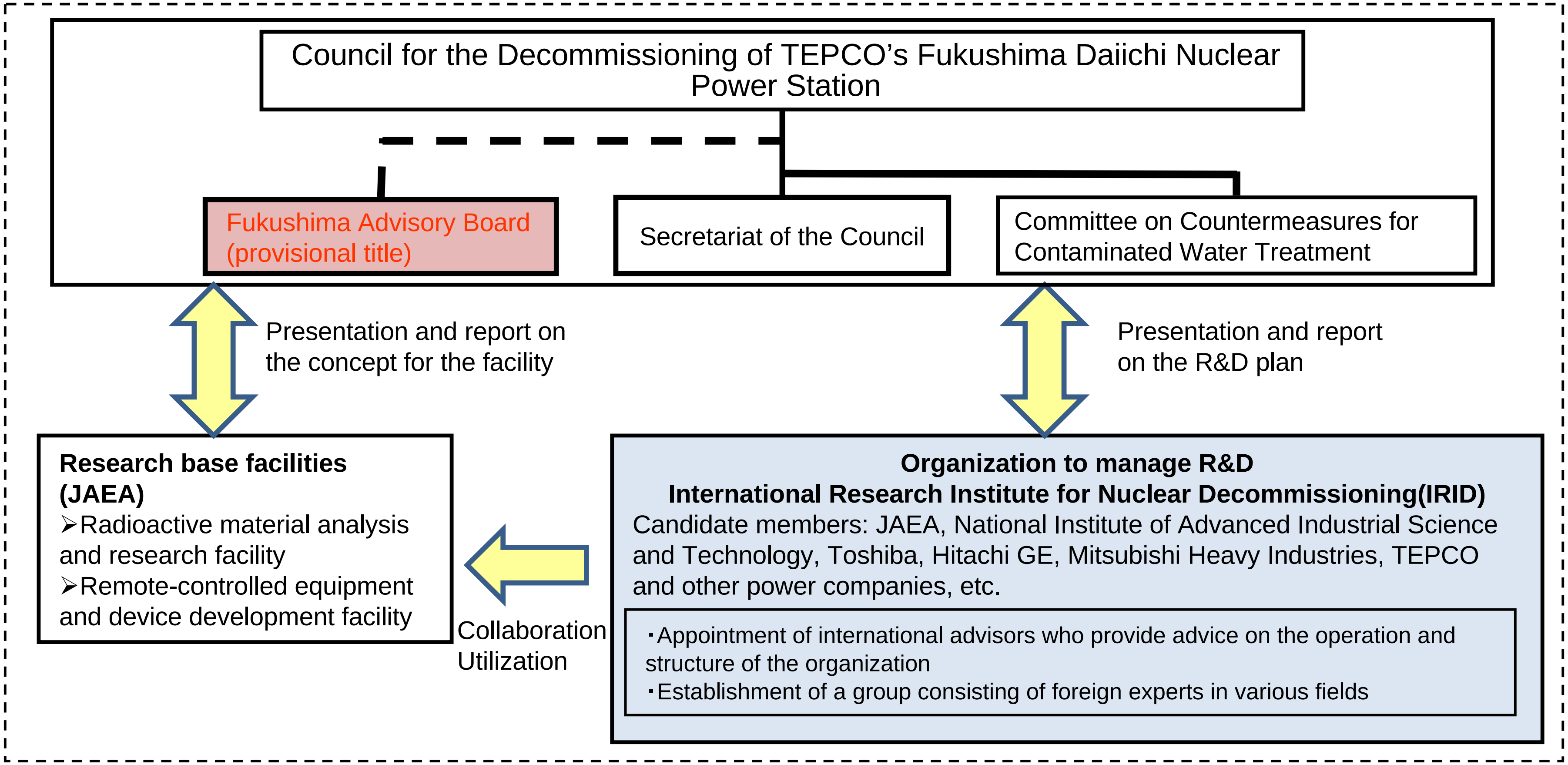
- Due to the much more complicated situation than TMI-2;
  - So many uncertainties still remain
  - Many R&D activities are needed to be conducted in parallel to the defueling procedures
- Government-supported R&D team has been organized.
  - Government (METI, MEXT)
  - National Labs. (JAEA, AIST etc.) and CRIEPI
  - Fabricator (Toshiba / Hitachi GE / Mitsubishi Heavy Ind.)
  - Academic experts
  - TEPCO (and Japanese LWR owner's group)
- Thirteen R&D projects have been commenced. (Nineteen projects are planned)

- With perspective of enhancing technological basis for nuclear decommissioning for the future, International Research Institute for Nuclear Decommissioning **(IRID)** was founded in August.

- Reaching out for advice and counsel to world community steadily
  US, UK, France, Russia, Ukraine and Other Countries

Coexistence with Local Communities and Communication with All Levels of Citizens

- In order to enhance providing information and communication with local stakeholders, the Fukushima Advisory Board (provisional title) will be established under the Council for the Decommissioning, with the participation of Fukushima prefecture, the surrounding local communities, relevant local organizations, and experts in the fields of regional development and communications.



Summary

- Situation in Fukushima is assumed to be much more complicated than the case of TMI-2
- Construction of fuel extraction cover for unit 4 was completed, and spent fuel extraction from unit 4 will start this month.
- Tentative plan is to start Defueling from RPV within 7 years.
- It is assumed that the Defueling process can take over 20 to 25 years to complete.
- Government supported R&D activities are commenced to achieve defueling and Fukushima Daiichi-Cleanup by IRID.
- Many unexpected situations are expected. Flexible program management will be necessary.
- We have to have discussions with all stakeholders to overcome various difficult problems.
- Advices and counsels from the world community would be very much appreciated.

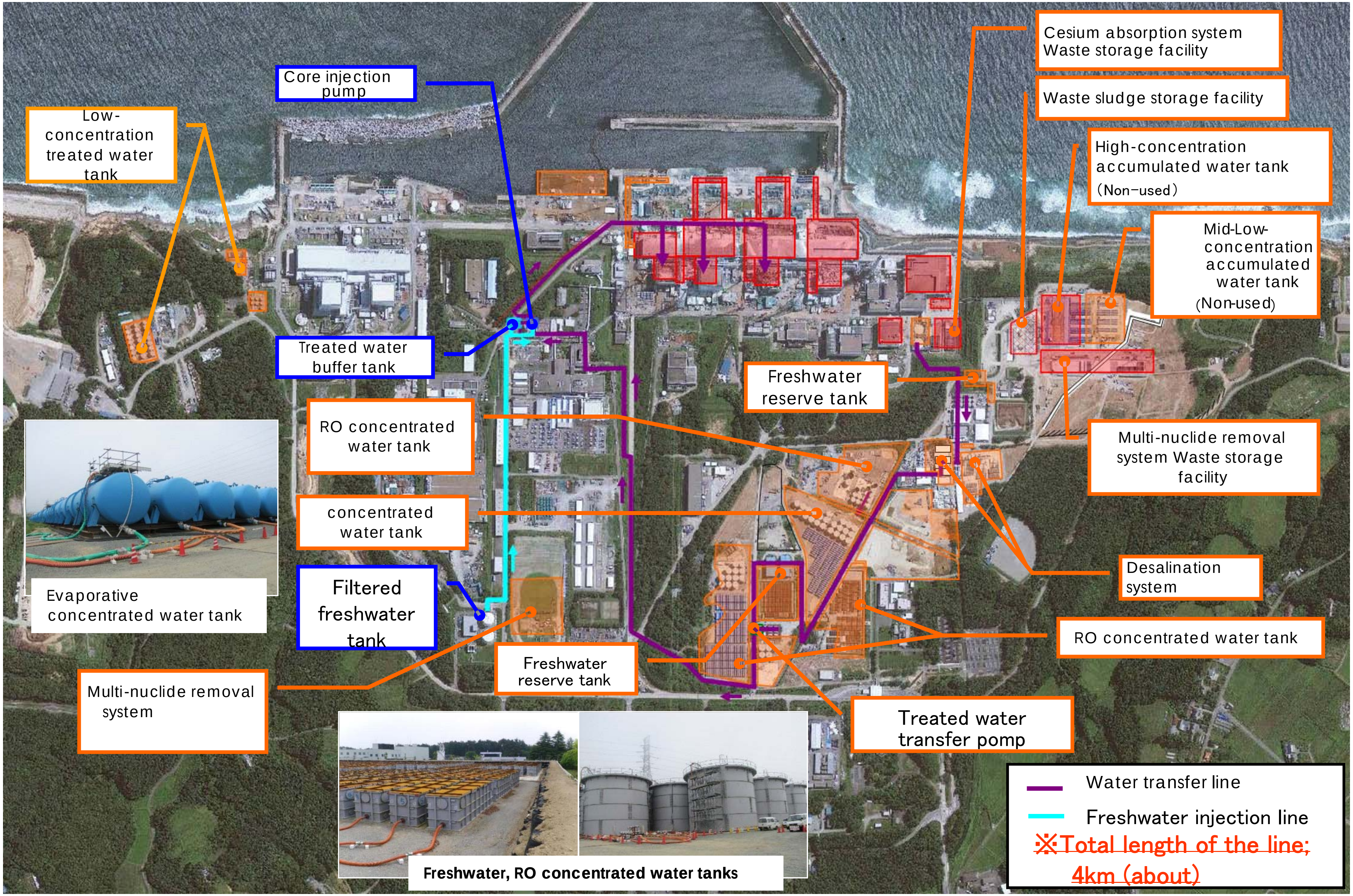
Thank you for your attention

and

Thank you so much for all of your supports extended for us

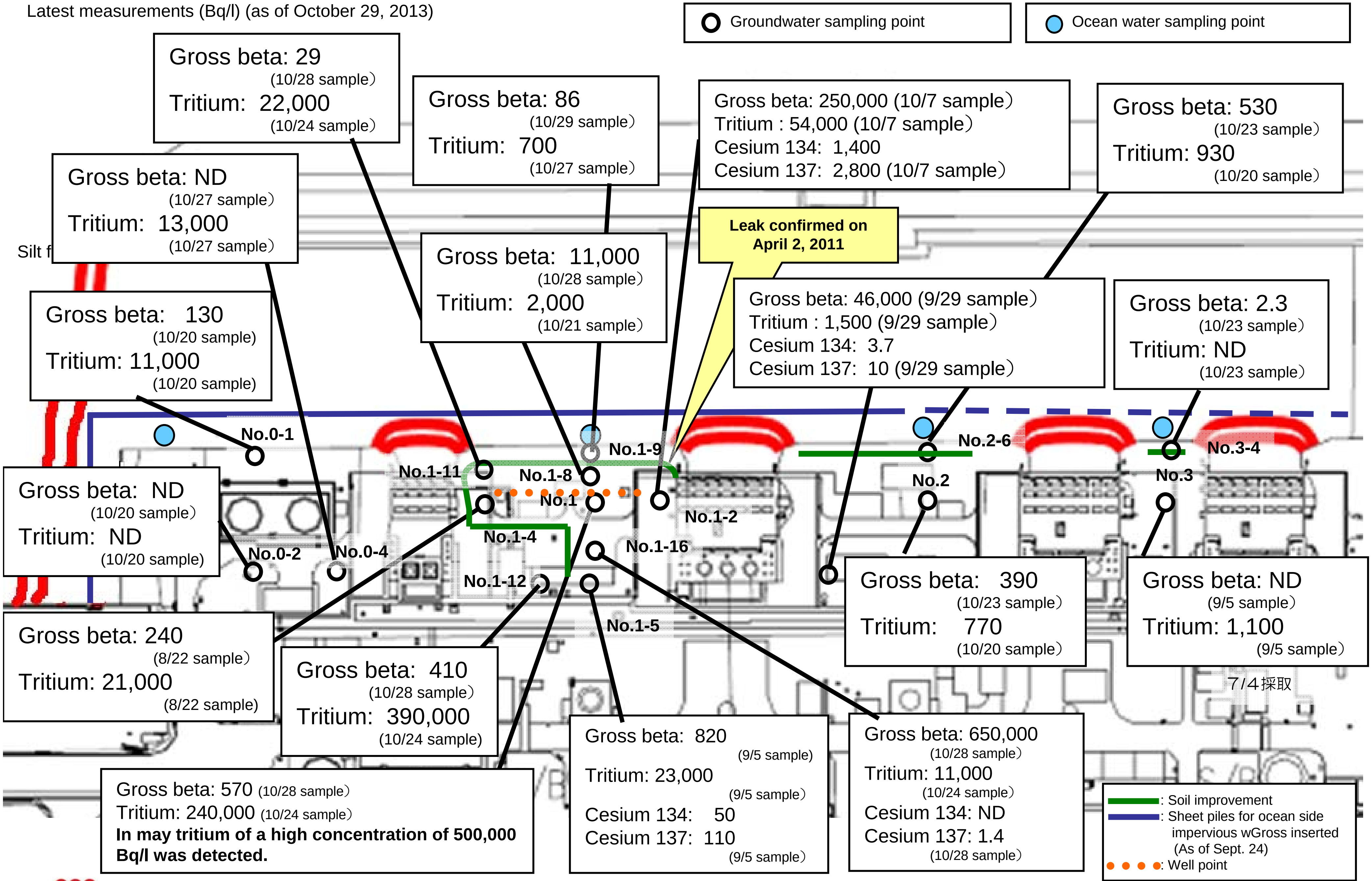
Additional　Information

Status of Accumulated Water Storage Tanks



Groundwater concentration measurement results from the east side of the turbine building

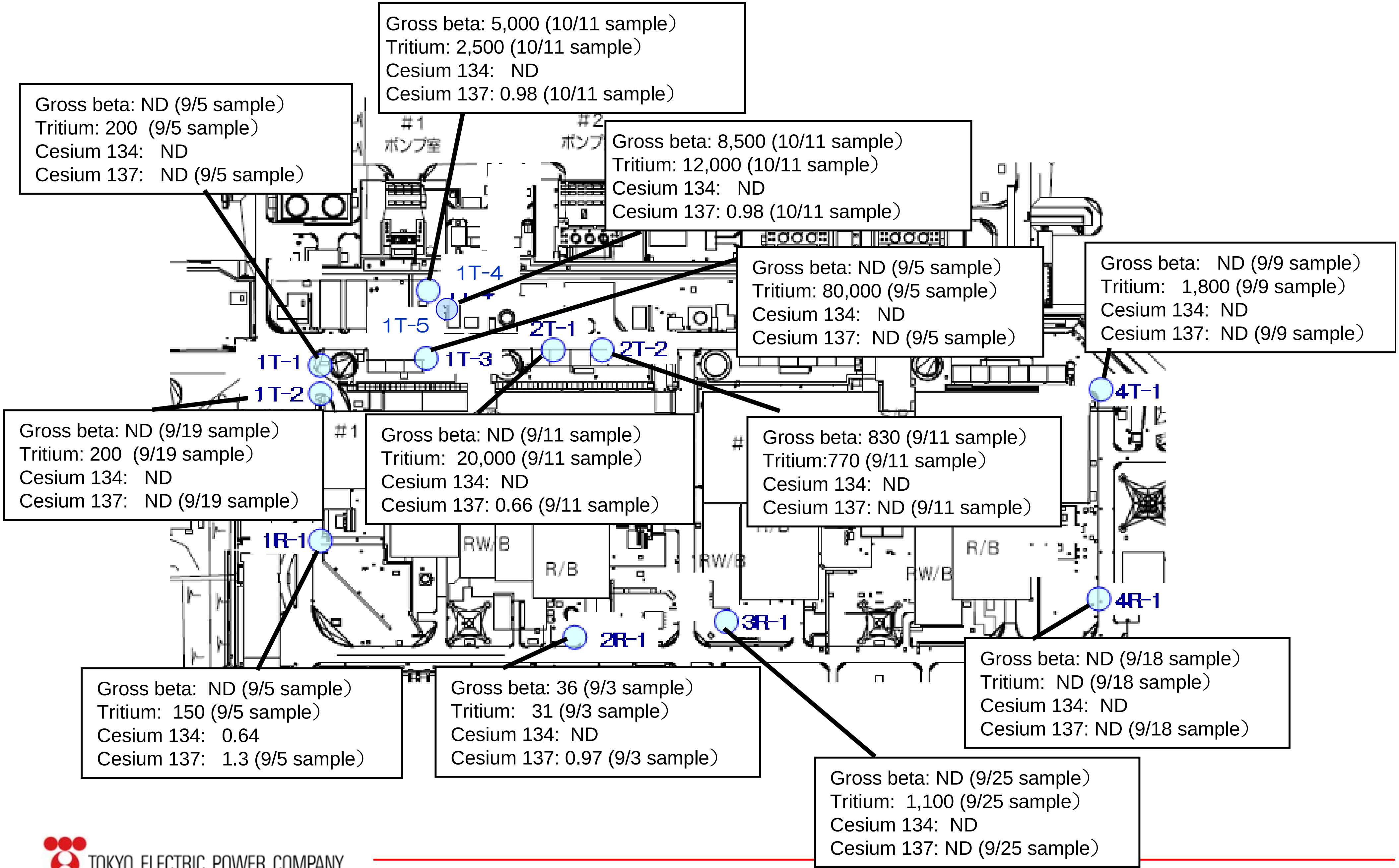
Latest measurements (Bq/l) (as of October 29, 2013)



Groundwater concentration measurement results from around the buildings

Latest measurements (Bq/l) (as of October 11, 2013)

○ Sampling point



Mid-and-Long-Term roadmap (Unit 1)

- The roadmap is revised in Jun. 2013
- Prepare multiple plans for flexibility depending on on-site situation
- At unit 1, reactor building cover was installed in Oct. 2011 for reducing radioactive materials release
- Release of radioactivity have been reduced as reactor core is cooled
- Plan 1) To build container for both spent fuel / debris removal, Plan 2) To add upper container on R/B, Plan 3) To build cover for spent fuel removal and then container for

	Phase 1		Phase 2								Phase 3
	FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021	After FY2022

HP1-1: HP1-1:the first half of FY 2014

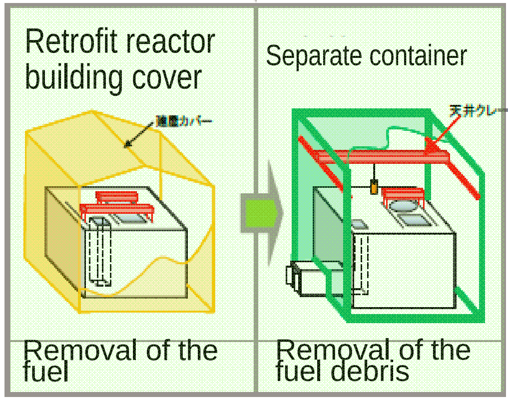
Removal of reactor building cover (FY2013)

- Plan 1) : Removal of rubbles → Retrofit reactor building cover → Removal of the fuel → Removal of reactor building cover, Install separate container → Removal of the fuel debris
- Plan 2) : Removal of rubbles → Install Upper container → Removal of the fuel → Retrofit upper container → Removal of the fuel debris
- Plan 3) : Removal of rubbles → Install cover for removing the fuel → Removal of the fuel → Removal of cover for removing the fuel Install separate container → Removal of the fuel debris

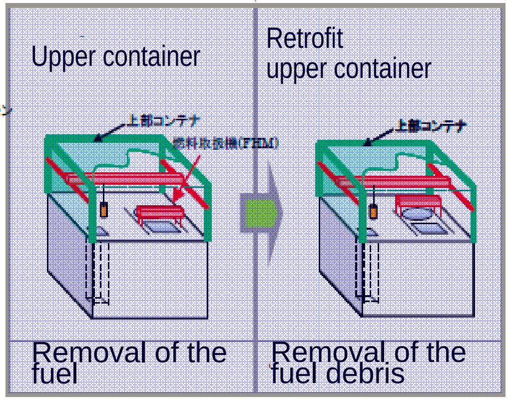
Hold Point (HP1-1): assessment flow on the first half of FY 2014

Assessment start → a) Feasibility of retrofit reactor cover*1, b) Securing R/B seismic safety *2 → *3

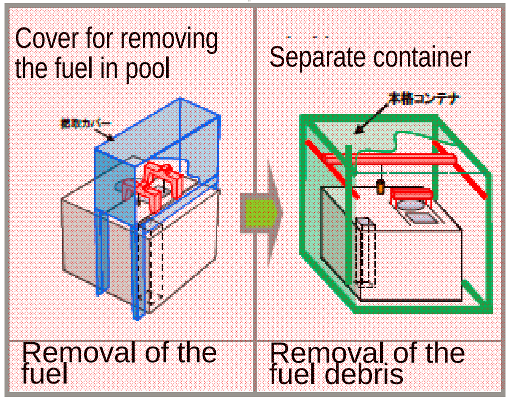
- a) feasible, b) infeasible → Plan 1)
- a) infeasible, b) feasible → Plan 2)
- a), b) infeasible → Plan 3)



Plan 1)



Plan 2)



Plan 3)

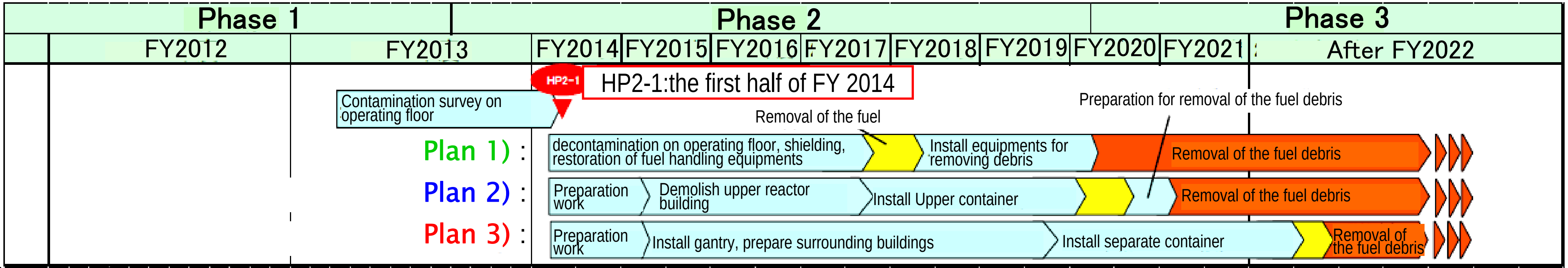
*1: Including safety for installing fuel handing equipments (roof crane, fuel handing machine)

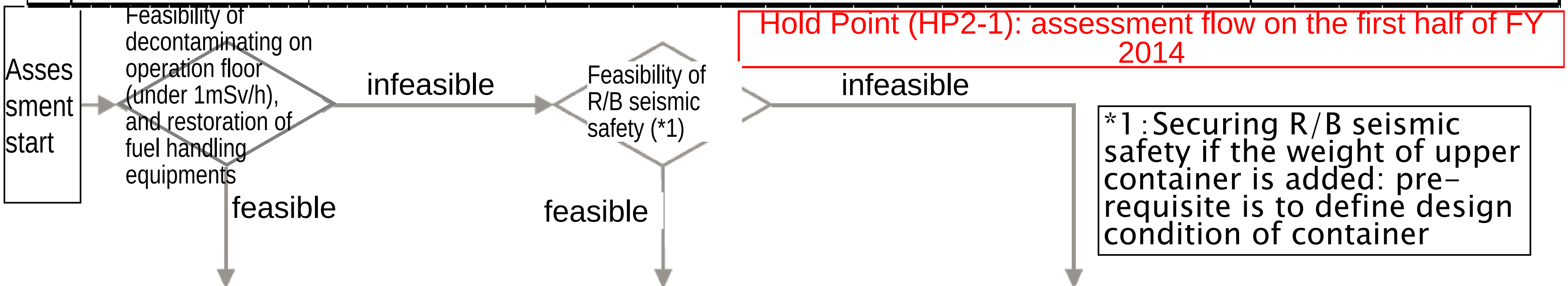
*2: Securing R/B seismic safety if the weight of upper container is added: pre-requisite is to define design condition of container

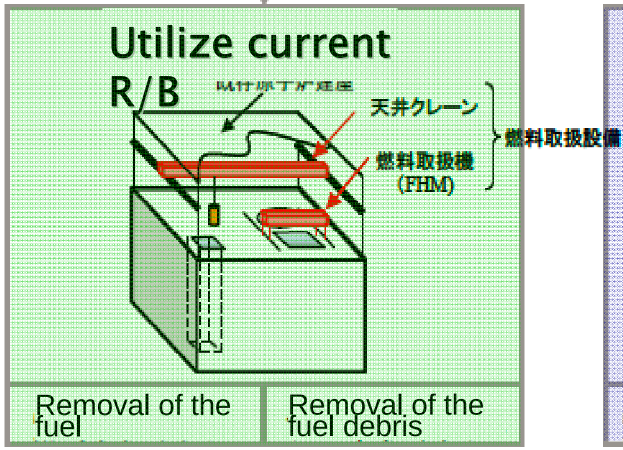
*3: Selection of plans be made in terms of reduction of risk

Mid-and-Long-Term roadmap (Unit 2)

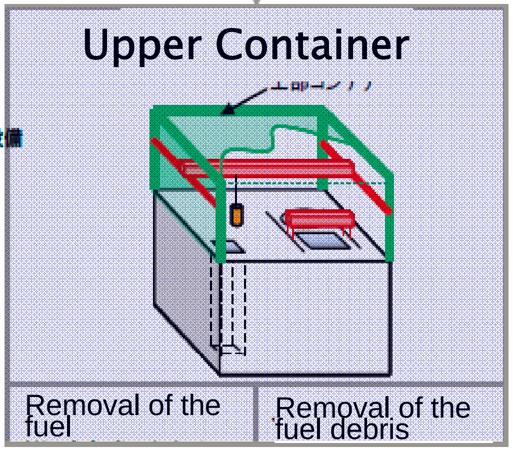
- Unit 2 R/B has no damage by hydrogen explosion
- Radiation dose inside reactor building is still high, requiring further monitoring
- Plan 1): Current R/B, Plan 2): Upper Container, Plan 3): Separate Container



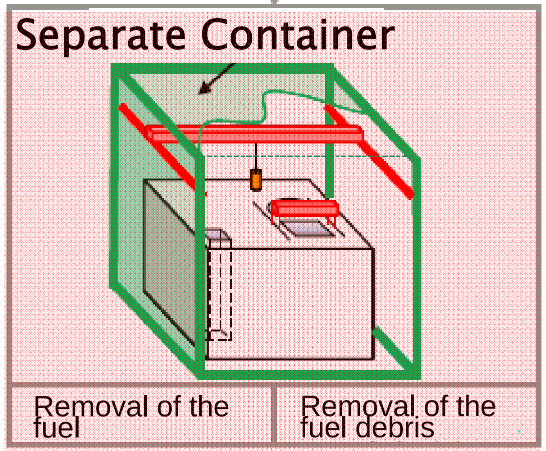




Plan1)



Plan2)



Plan3)

Mid-and-Long-Term roadmap (Unit 3)

- High dose rate at operating floor due to piled rubble
- We are removing rubles on operating floor and in spent fuel pool
- Plan 1): Retrofit cover for defueling, Plan 2): Build separate container for debris

Phase 1		Phase 2									Phase 3
FY2012	FY2013	FY2014	FY2015	FY2016	FY2017	FY2018	FY2019	FY2020	FY2021		After FY2022

HP3-1:the first half of FY 2015

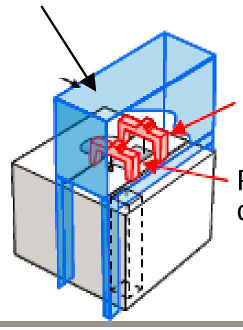
Removal of rubbles on operating floor → decontamination on operating floor, shielding, → Install cover for removing the fuel

Plan1): Removal of the fuel → Retrofit cover for removing the fuel → Removal of the fuel debris

Plan2): Removal of the fuel → Remove cover for removing the fuel, install separate container → Removal of the fuel debris

Hold Point (HP3-1): assessment flow on the first half of FY 2015

Cover for defueling



Removal of fuel in pool

Fuel handling equipment

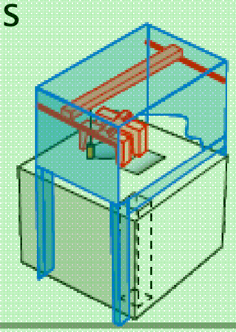
Feasibility of retrofit cover for debris removal

(seismically safe construction)

infeasible

feasible

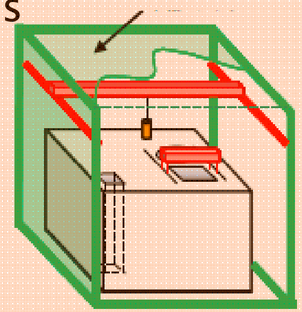
Retrofit cover for debris



Removal of debris

Plan1)

Separate container for debris

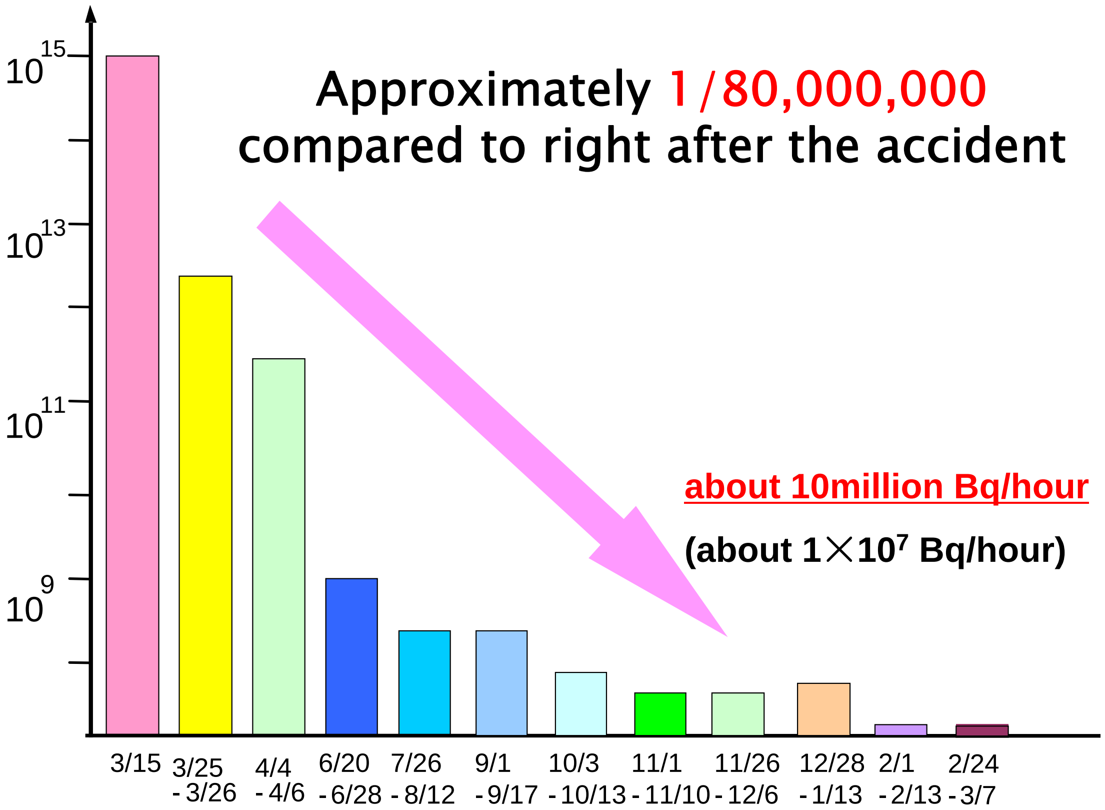


Removal of debris

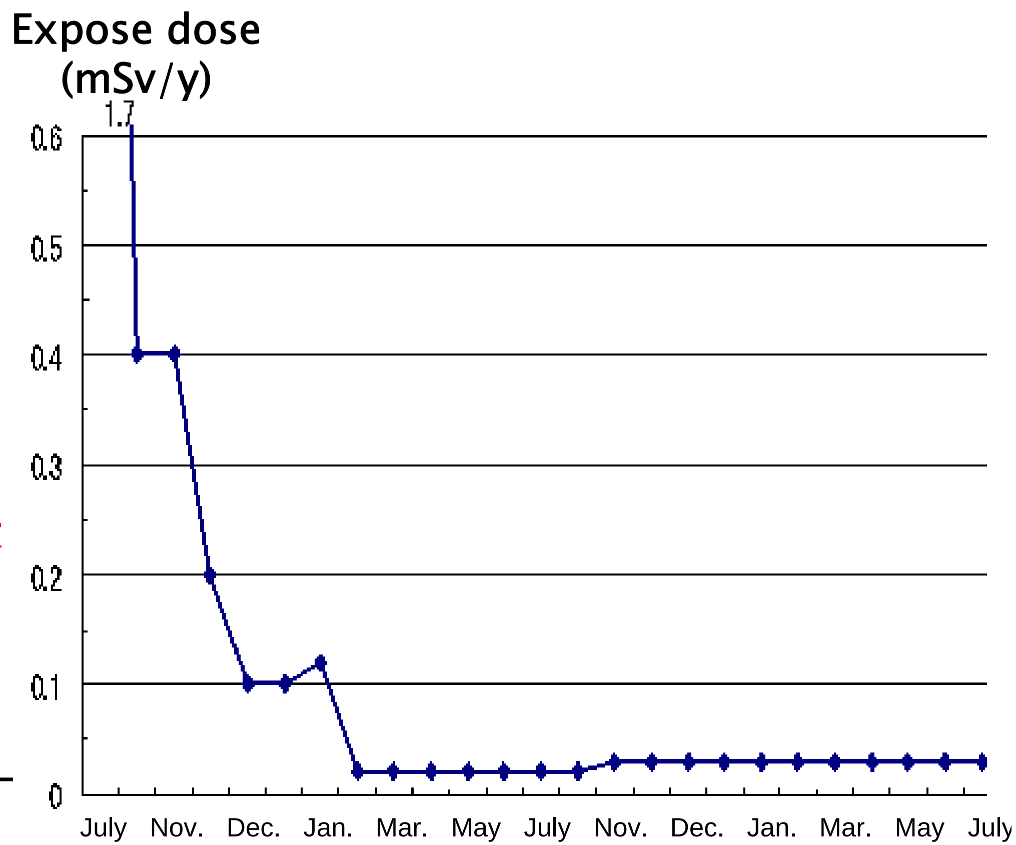
Plan2)

Reduction of Radioactivity Release

- The amount of activities (cesium) released from Unit 1-3 PCV is assessed based on airborne radioactive material concentrations (dust concentration) at the top of Reactor Buildings
  - Calculated the assessed value of total release amount (as of July 2013) as 10 million Bq/hr (One-80 millionth compared to right after the accident)
  - Assessed the exposure dose at site boundary as 0.03mSv/yr at maximum (Excluding already existent released radioactive materials Exposure limit by law is 1mSv/yr)



Radioactive particle (Cesium) release per hour from Units 1 to 3



Expose dose at site boundary

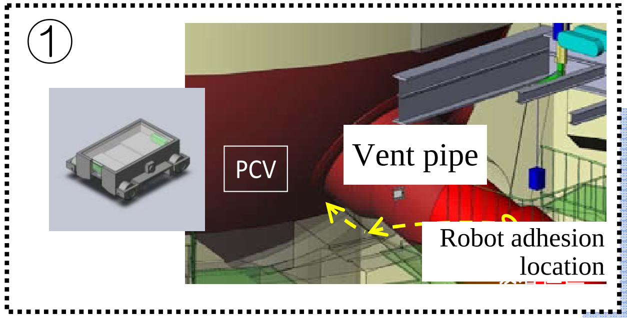
Fuel Debris Removal

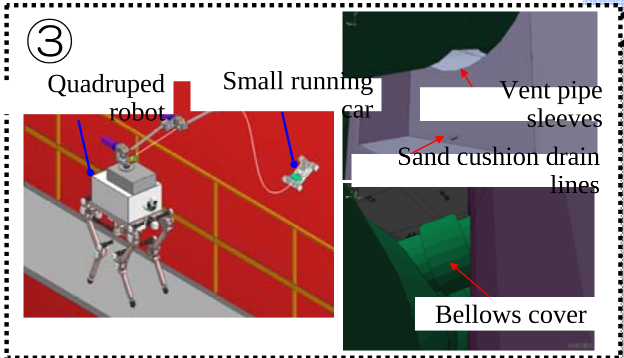
- **Plan to start fuel debris removal in the first unit within 10 years after completion of Step 2.**
- **Removal of fuel debris will be implemented in accordance with the following steps in light of the site situation, safety requirements, and R&D progress of the remote control technologies required in the operations.**

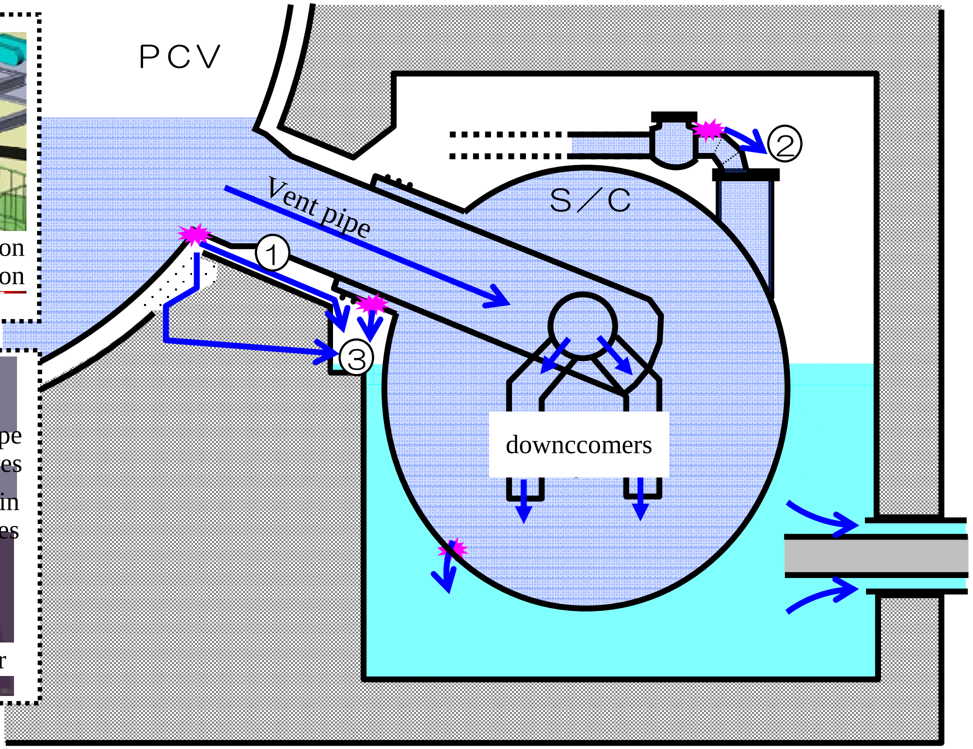
(1) Reactor Building Decontamination
(2) PCV Leakage Point Inspections
(3) Stopping Inter-building Water Leakage and PCV Lower Parts Repair
(4) Filling the Lower Part PCV with Water
(5) Internal PCV Inspection and Sampling
(6) PCV Upper Parts Repair
(7) Filling PCV and RPV with Water⇒ Open the upper cover on RPV
(8) Internal RPV Inspection and Sampling
(9) Fuel Debris Removal

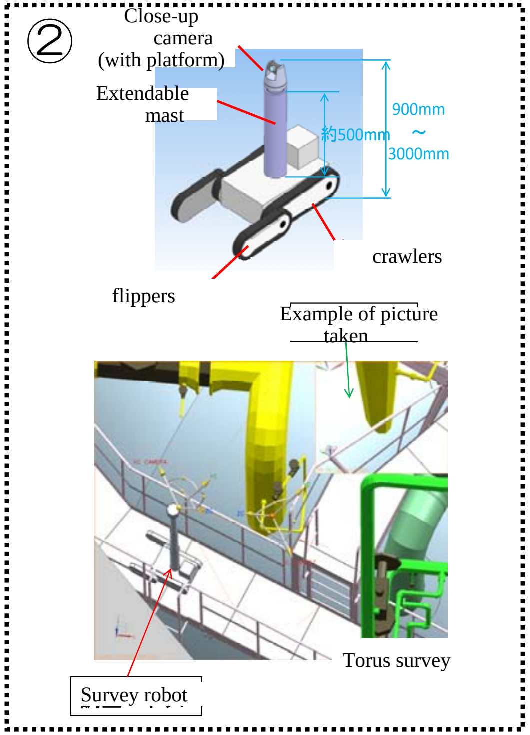
PCV Leak survey and repair (Devices for surveying the bottom of PCV（１））

	Main development organization	Develops device	Characteristics	Location
Open air robot	Government PJ	Vent pipe joint survey robot	This robot adheres itself to the surface of the outside of the vent pipe and approaches joints between bent pipes and the D/W from between the vent pipe and concrete wall in order to survey the damage	Diagram ①
		Robot for surveying the upper part of the S/C	This robot checks for leaks from structures at the top of the S/C, which is high up (Approx. 3m at its highest), after accessing it from the catwalk outside the Torus	Diagram ②
	Developed independently by manufacturers	Quadruped robot (&small running car)	This robot is used to ascertain conditions (advance survey) inside the torus room, such as the presence of leaks, within the scope that can be photographed from near the area beneath the vent pipe Unit 1's triangular corners are currently submerged and cannot be accessed.	Diagram ③









PCV Leak survey and repair (Devices for surveying the bottom of PCV (2))

	Main Development Body	Develops device		Characteristics	Location
Submersible Robot	Government PJ	Robot for surveying submersed torus walls	Submersible robot	This submersible robot is remotely operated (used in very narrow places) by an operator viewing a video screen and will be used to check for damage at building penetration seals (this robot is expected to be put into use during the second half of fiscal year 2013)	Diagram ④
			Floor walking robot	This robot walks on the floor underneath the water and uses ultrasound to check for leaks in distant places	Diagram ⑤
		Robots for surveying the bottom part of the S/C		This robot adheres itself to the outer surface of the S/C to check for damage on the outside of the S/C, at structures on the outside and at penetration pipes.	Diagram ⑥
	Remotely operated technology TF※	Development of basic technology for “self-location”, “ long cable handling” and “ shape/flow detection” that submersible robots are to be equipped with (elemental technology shall be reflected in government PJ as suitable)			Next slide
		Development of technology related to “nondestructive measurement of water levels inside steel containers”, “ movement on curved steel surfaces” “self-location” and “torus room access” that is needed to measure the water level inside the S/C			Slide after next

※ Remotely operated technology TF (task force) : deliberates and makes proposals in regard to the latest remotely operate technology, solutions and backup plans.