Fukushima Accident and Decommission Work

Fukushima Daiichi Nuclear Power Station
Then and Now

September 6, 2013

"Nuclear Energy and its Future"

POLITECNICO DI MILANO

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TEPCO

What I will talk about:

1. What happened – Outline of Accident
2. Fukushima Daiichi NPS Now – Ongoing Activities
3. Mid/Long-Term Roadmap for Decommissioning
4. Remediation / Decontamination of Surrounding Area
5. Lessons Learned and Issues

1.Outline of Fukushima Accident

1-1 The Earthquake and Tsunami

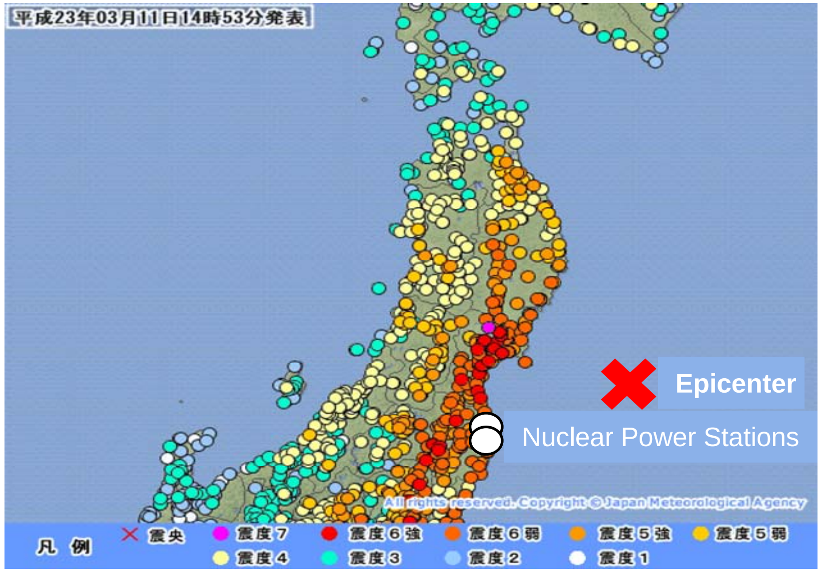
1-2 Plant Response

1-3 Radiation Release

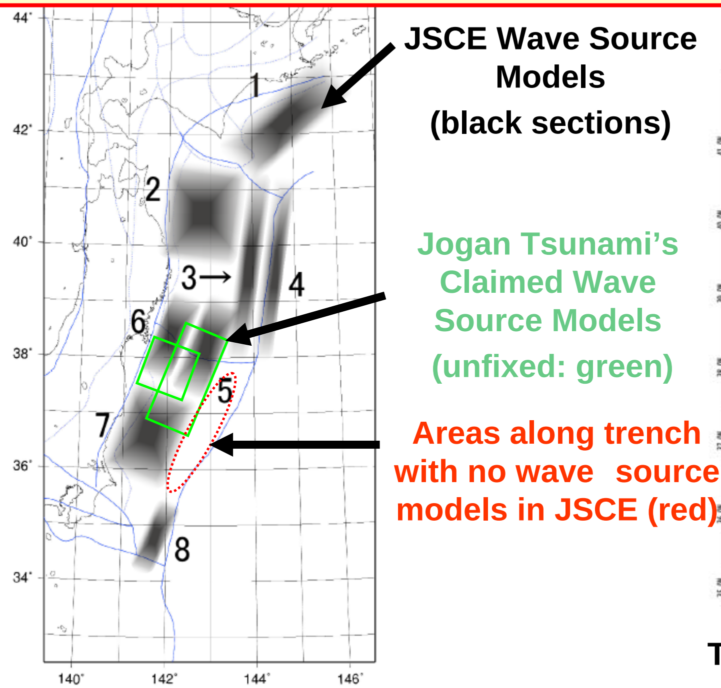
Scale of Earthquake and Tsunami

- A 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
- Design of all NPS tsunami based on Methodology by Japan Society of Civil Engineers: It defines eight wave sources
- Discussion was on-going how to handle Jogan / “no source area” in JSCE, and it was in final stage to conclude on 3-11
- JCES nor Gov’ts SSRPHQ* have not assumed M9.0 of simultaneous multiple moves

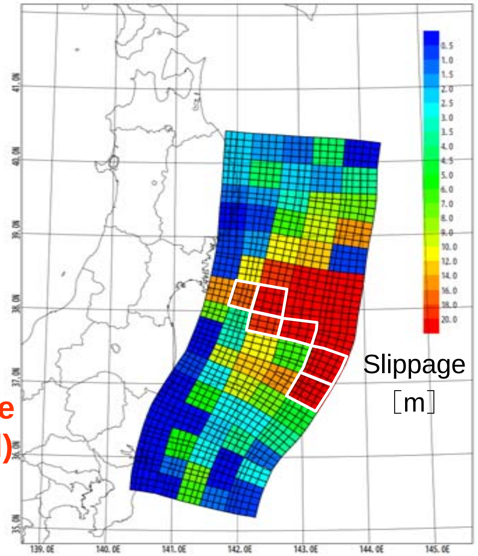
＊Seismic Studies and Research Promotion HQ



Distribution of Seismic Intensity on 3-11



JSCE Method and Jogan Tsunami Claimed Sources



Tsunami Wave Source on 3-11

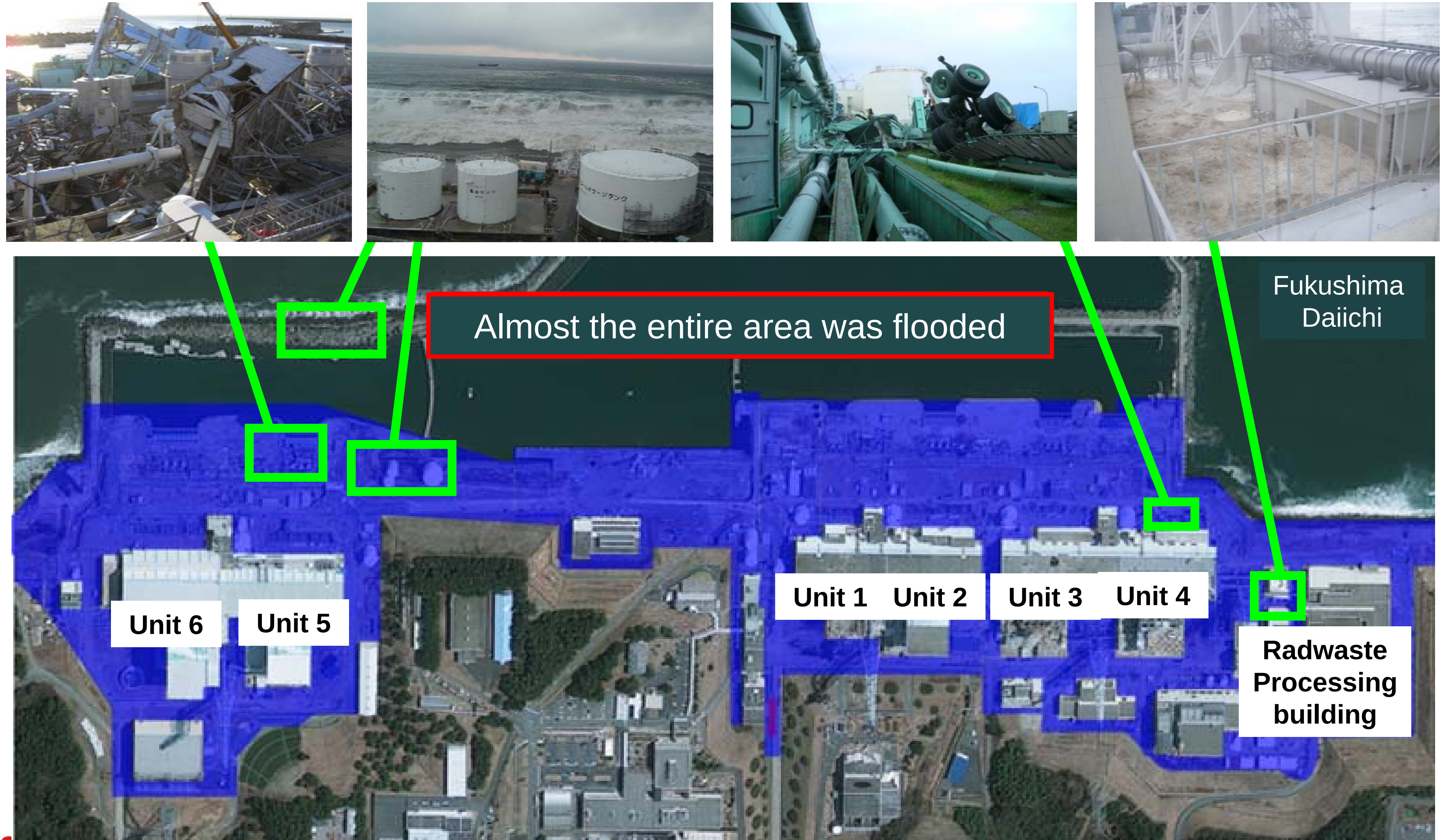
(Evaluated by TEPCO)

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

Image of Tsunami Damage

Unit5 Sea water pump area

Unit1 PCV cooling sea water pump

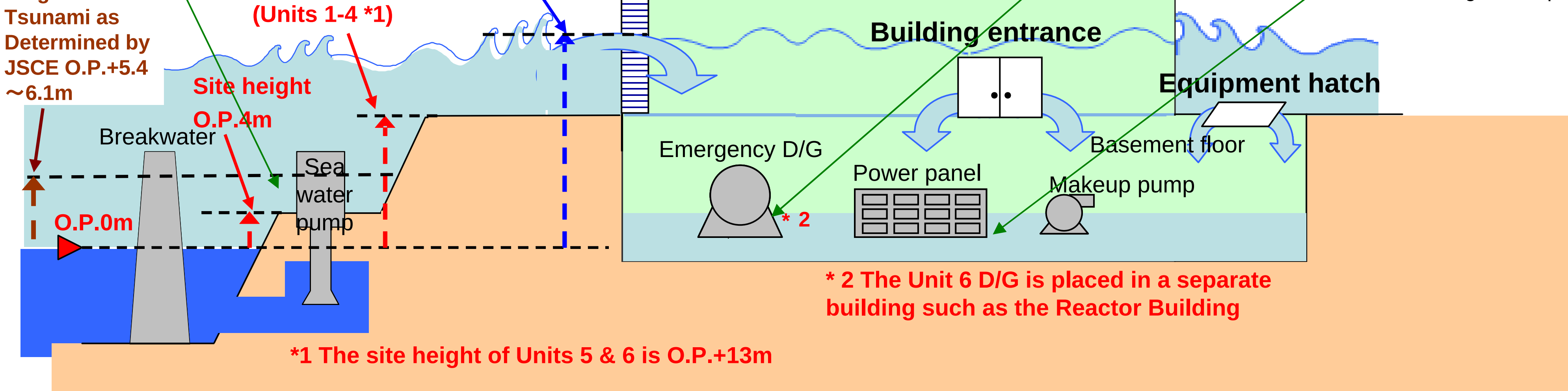
The main inundation routes identified through an on-site walk-down of the area are:

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 panel



* 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

The Great East Japan Earthquake around 14:46, Mar. 11th

↓

Reactor SCRAM due to the Earthquake (Automatic Emergency Shutdown)

↓

Loss of Off-site Power、D/G Started-up *1

↓

Operation after SCRAM as Intended (Unit 1- 3)

Operation after SCRAM as Intended (Fukushima-Daini)

↓

Tsunami struck Fukushima-Daiichi & Fukushima-Daini NPPs around 15:20~ , Mar. 11th

Fukushima-Daiichi

Units 1～3 (Operating)

- **Unit 4** / **[Power] No AC power, No D/G**
- **[Seawater system] Not available**
- ↓ **Water injection & heat removal via HP system**
- **Core Damaged**
- ↓ **Water injection via LP system (Freshwater & Seawater)**
- ↓ **Interrupted Injection and no route secured for heat removal**
- ↓ **Cold Shutdown Condition (Dec. 16)**

Fukushima-Daiich 1~4

Units 5,6 (Shutdown for maintenance)

- **[Power] D/G 6B start-up**
- **[Seawater system] Not available**
- ↓ **Power supply from Unit 6 to Unit 5**
- ↓ **Heat removal secured by temporary power source & seawater pump**
- ↓ **Cold Shutdown (Mar. 20)**

Fukushima-Daiichi 5,6

Fukushima-Daini

(Operating)

- **[Power] Off-site Power available**
- **[Seawater system] Not available** *2
- ↓ **Water injection via HP (Steam-driven) & LP systems**
- ↓ **Water injection via LP system**
- ↓ **Heat removal secured by temporary power source & motor replacement etc.**
- ↓ **Cold Shutdown (Mar. 15)*3**

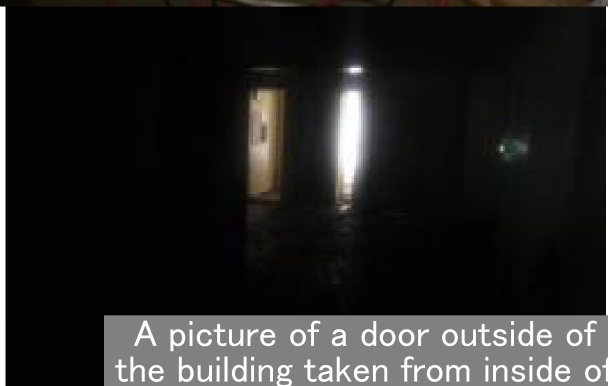
Fukushima-Daini 1~4

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

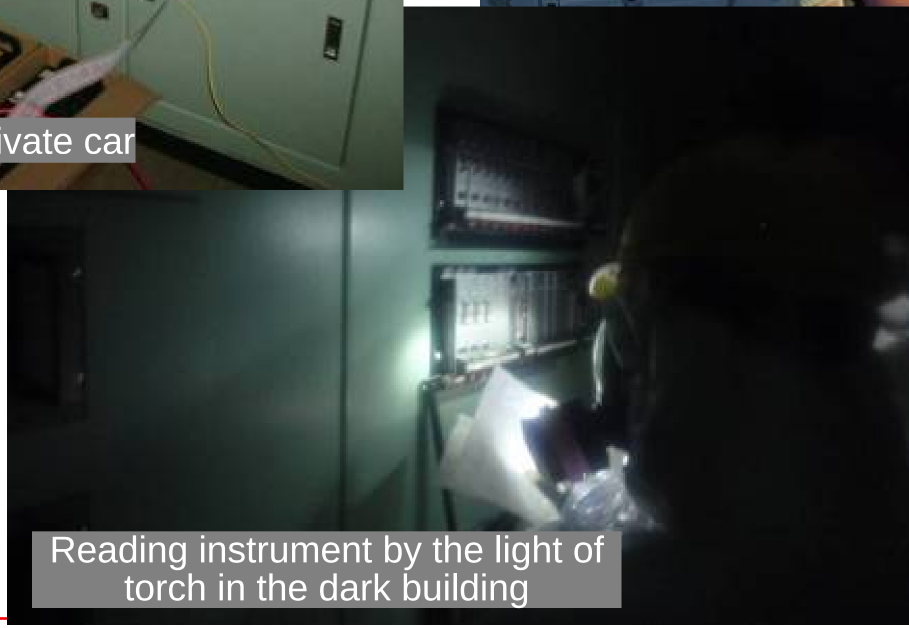
Accident Response – In Main Control Room

Shift Supervisor's Testimony
"When the power source failed, I felt completely helpless"
"Heated discussions broke out among the operators regarding whether it was important to remain in the control room or not"
"I bowed and asked them to stay here. And they agreed"

Connected portal Batteries of staffs' private car



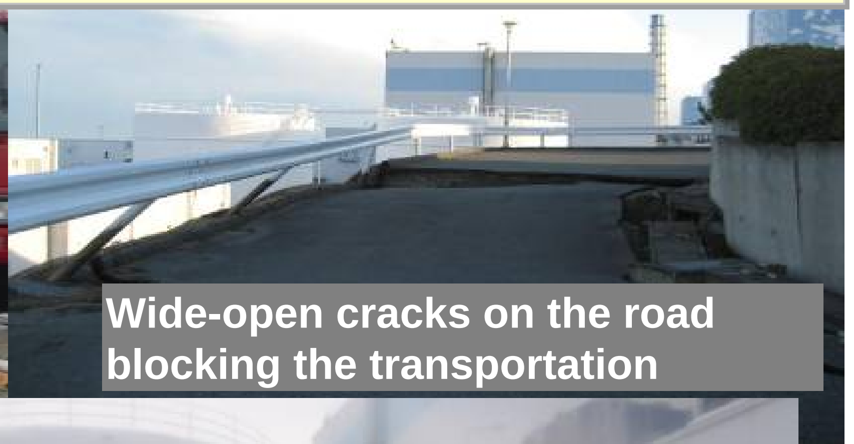
A picture of a door outside of the building taken from inside of unlighted building



Reading instrument by the light of torch in the dark building

Accident Response – Water Injection

On-site testimony:
"As tremendous aftershocks occurred, with our full face masks still on, we frantically headed off to the upper ground."
"While laying down cables at night, entailing the search of penetrations and terminal treatment work, we were terrified that we might be electrocuted due to the outside water puddles."



Wide-open cracks on the road blocking the transportation

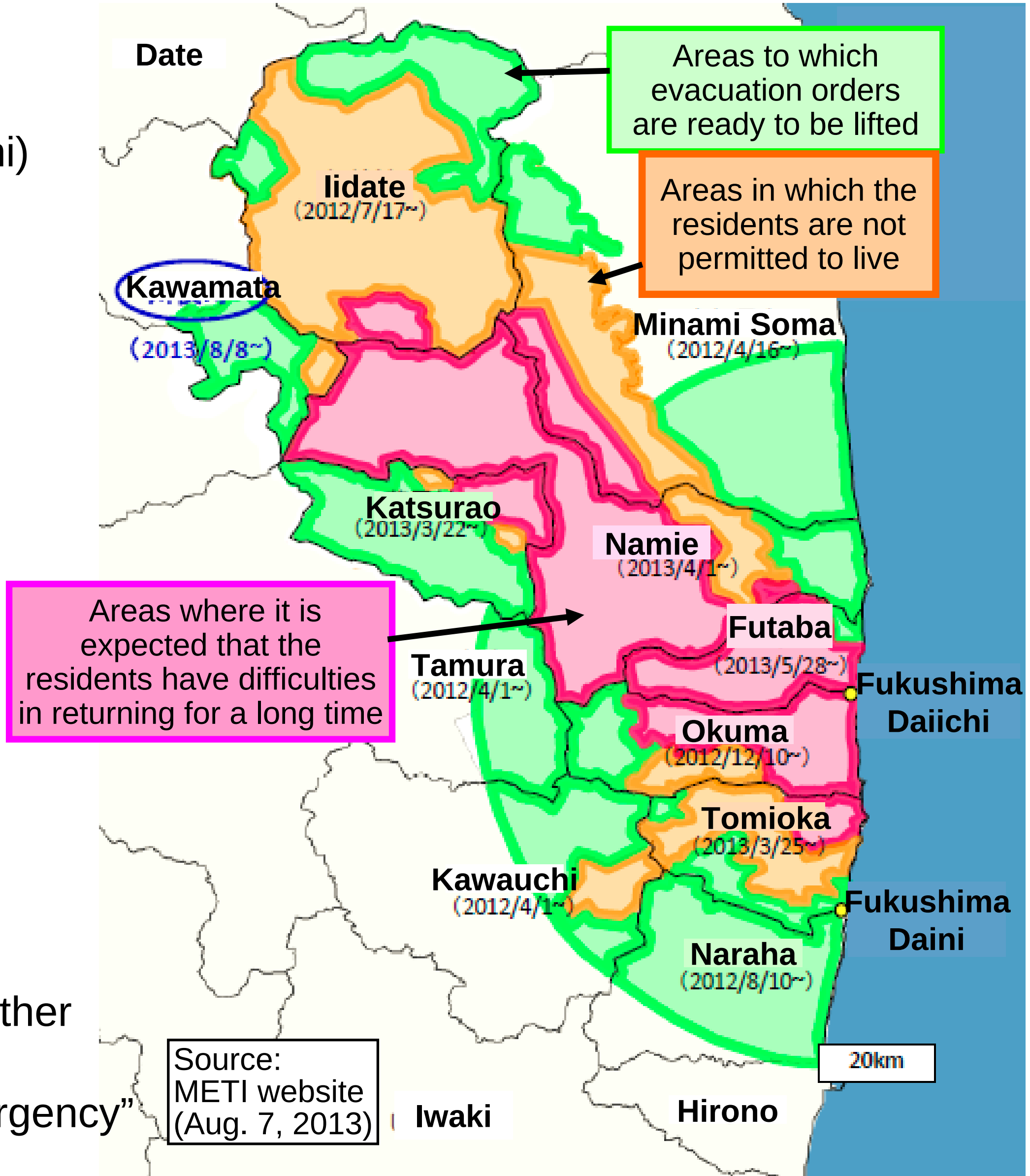
Fire truck and scattered driftage

Heavy oil tank washed away by the tsunami and blocking the road

Off-site Evacuation

■ The government had directed evacuation / sheltering right after the accident

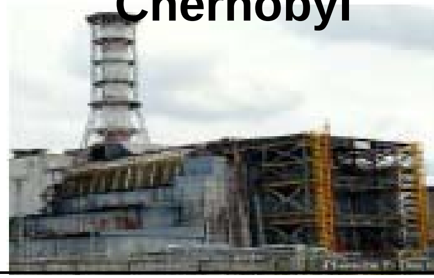
Fri, March 11, 2011
14:46 The earthquake
19:03 Emergency Declaration by the Gov't (Daiichi)
21:23 Evacuation in 3 km radius of Daiichi
Taking shelter in 10 km radius of Daiichi
Sat, March 12
5:44 Evacuation in 10 km radius of Daiichi
7:45 Evacuation in 3 km radius of Daini
Taking shelter in 10 km radius of Daini
17:39 Evacuation in 10 km radius of Daini
18:25 Evacuation in 20 km radius of Daiichi
Tue, March 15
11:00 Taking shelter in 20-30 km radius if Daiichi
Thu, April 21
11:00 20 km radius of Daiichi is designated as "Restricted Area"
Evacuation lifted 8km radius of Daini and farther
Fri, April 22
9:44 Taking shelter lifted 20-30 km radius and farther
Set "Deliberate Evacuation Area" and "Evacuation Prepared Area in Case of Emergency"



Source: METI website (Aug. 7, 2013)

Fukushima, Chernobyl and TMI

Source : ATOMICA

	Fukushima Daiichi 	**Chernobyl** 	**TMI** 
Date of the accident	March 11, 2011	April 26,1986	March 28, 1979
INES	Level 7	Level 7	Level 5
Type of reactor	BWR (with PCV)	RMBK (without PCV)	PWR (with PCV)
The Number of Units	Unit 1～4 (all 6 units)	Unit 4 (all 4 units)	Unit 2 (all 3 units)
electrical output	Unit 1 : 460MW Unit 2～4 : 784MW	1000MW	960MW
Start of Commercial Operation	May 1971 (Unit 1) ～ October 1978(Unit 4)	May 1984	December 1978
Occurrence and process	SBO and lost all cooling function damaged by the Earthquake: External AC source Tsunami: D/G and cooling system	Reactor has burst during test operation, and much radioactive material has released.	Coolant has run off because of duplication of failure and human err. 45% of the core melt.
Response	Injection of sea water or flesh water to core	Sealed off by the sarcophagus	Cooling pomp run again and blown over
Radioactive release	900PBq(I131 equivalent)* (5.24 2012 TEPCO)	5200PBq (I131equivalent)	93PBq (noble gas) 0.56TBq (I131)
Number of evacuee	113,000	116,000 (30km area)	200,000 (estimated,24km area)
death toll from radiation injury	0	33	0

Estimated Air-borne Radioactivity Release

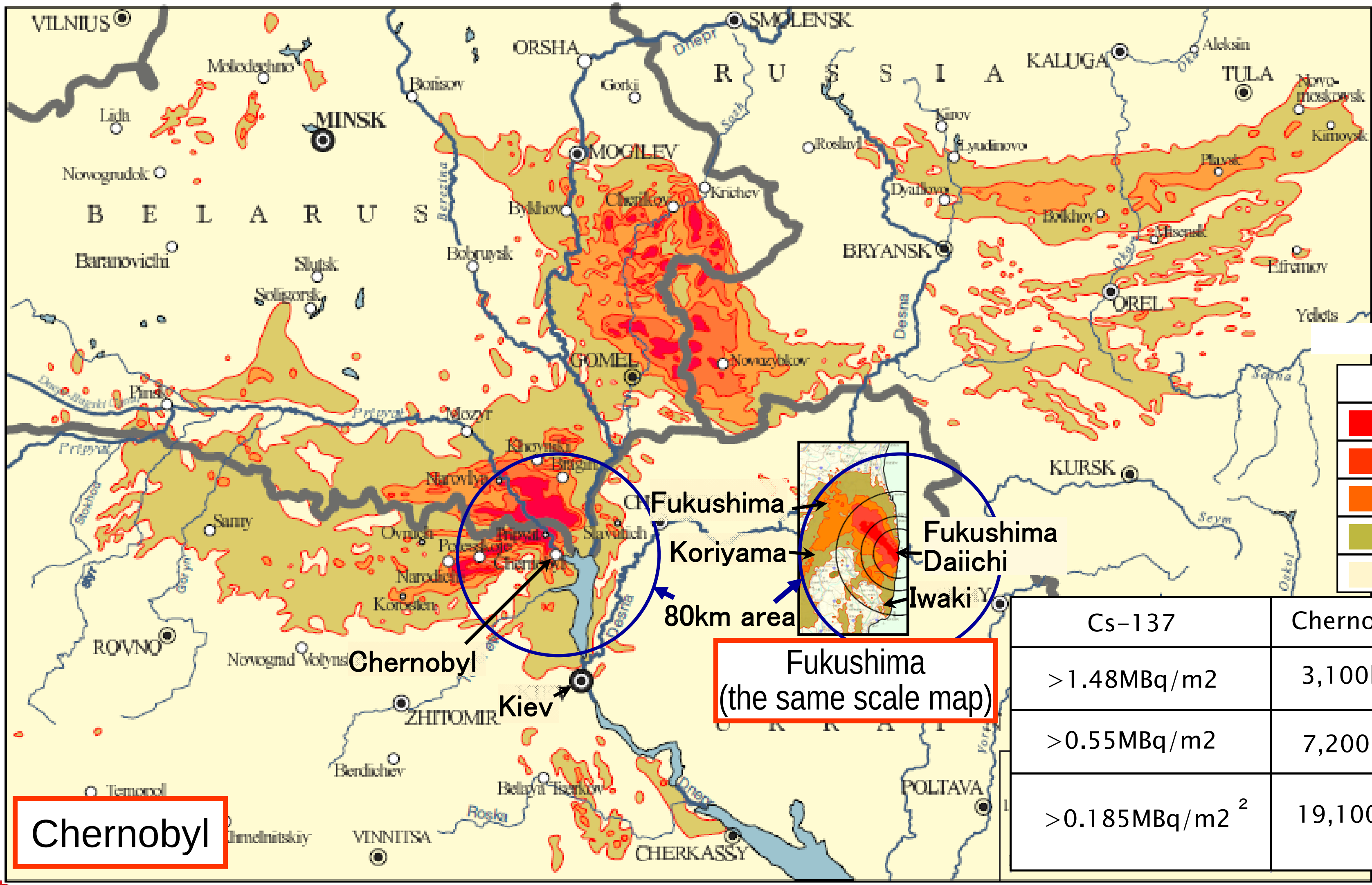
- Estimated as of May 24, 2012.
- Evaluation period : from March 12 to March 31, 2011.
- Release after April is less than 1 % of those in March, 2011.
- Estimations varies by organizations because of differences in method as well as limited amount of data.
- Of the order of 10E17 Bq (A few hundred PBq)

	Release Unit : PBq (*1)				
	Noble Gas	I-131	Cs-134	Cs-137	INES (*3)
TEPCO (*2)	Approx. 500	Approx. 500	Approx. 10	Approx. 10	Approx. 900
Japan Atomic Energy Agency Nuclear Safety Commission (Apr. 12, May 12, 2011)	—	150	—	13	670
Japan Atomic Energy Agency Nuclear Safety Commission (Aug. 22, 2011)	—	130	—	11	570
Japan Atomic Energy Agency (Mar. 6, 2012)	—	120	—	9	480
Nuclear and Industrial Safety Agency (Apr.12,2011)	—	130	—	6.1	370
Nuclear and Industrial Safety Agency (Jun.6,2011)	—	160	18	15	770
Nuclear and Industrial Safety Agency (Feb.16,2012)	—	150	—	8.2	480
IRSN (France)	2000	200	30		—
Chernobyl (Reference)	6500	1800	—	85	5200

(*1) 1 PBq = 10^{15} Bq
(*2) Bq at the time of release. Rounded off at 2nd figure. Equivalent of 0.5 MeV for noble gas.
(*3) Radioactivity is converted to Iodine in INES. For comparison, only I-131 and CS-137 are used.
Example: approx. 500 PBq + 10 PBq X 40 (conversion factor) = approx. 900 PBq

Distribution of Cs-137 Contamination

- Contaminated area is roughly 1/10 of Chernobyl
- Population around site is larger than Chernobyl
- In Fukushima effort to decontaminate to recover habitat is now going on



Source:
- Environmental Consequences of the Chernobyl Accident and their Remediation: Twenty Years of Experience (IAEA)

Dose Map (MOE)

Cs137 (Bq/m²)

	Chernobyl	Fukushima
(red)	1480～	1000
(red-orange)	555～1480	300～1000
(orange)	185～555	100～300
(olive)	37～185	30～100
(cream)	～37	～30

Cs-137	Chernobyl	Fukushima
>1.48MBq/m2	3,100km2	600km2
>0.55MBq/m2	7,200km2	700km2
>0.185MBq/m2 ²	19,100km2	1,500km2 (>0.15MBq/m2)

2. Status of Fukushima Daiichi

2-1 Core /Reactor Buildings

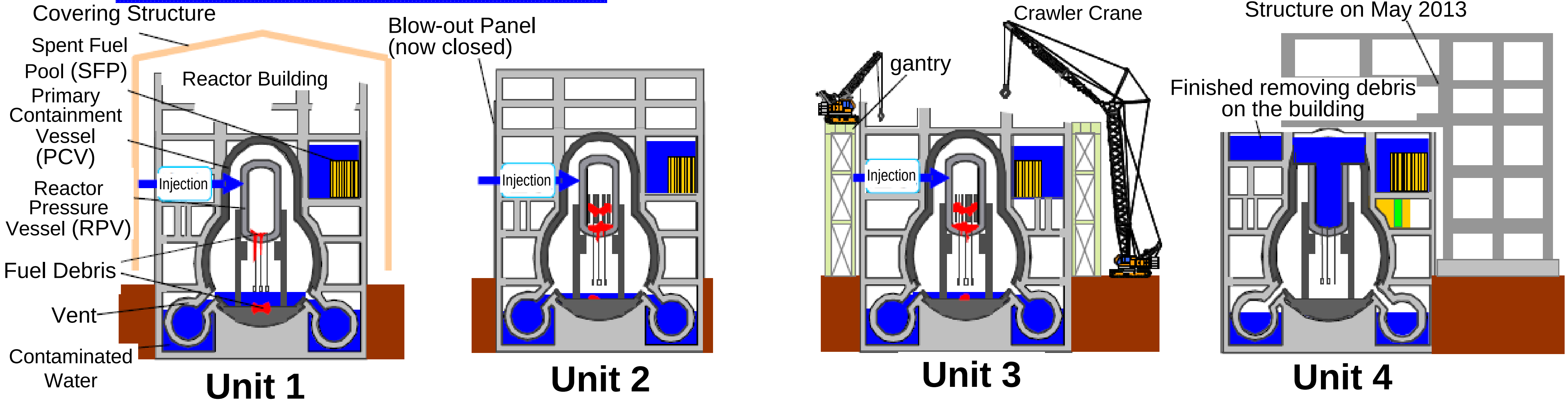
2-2 Spent Fuel Pools

2-3 Dose in the site

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 Aug. 29, 2013

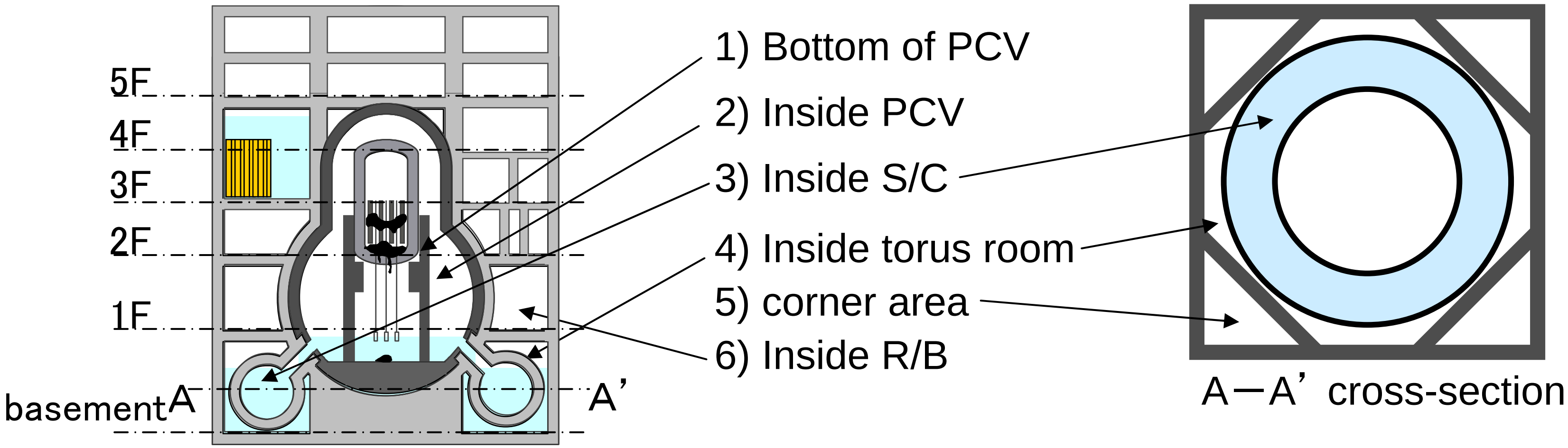




	Unit 1	Unit 2	Unit 3	Unit 4
RPV	33.2℃	43.7℃	43.0℃	No fuel
PCV	34.0℃	44.1℃	41.1℃	
SFP	29.0℃	27.5℃	26.2℃	38.0℃

Methods for Identifying Reactor Core Status

Area		Unit 1	Unit 2	Unit 3
1) Bottom of PCV		Original Thermometer	Original Thermometer New Thermometer through the penetration to PCV (Oct. 2012)	Original Thermometer
2) Inside PCV		Original Thermometer Instrument through PCV Penetration (Oct. 2012)	Original Thermometer, Instrument through PCV Penetration (Jan-Mar. 2013)	Original Thermometer
3) Inside S/C		Un-checked	Un-checked	Un-checked
4) Inside Torus Room		Instrument through R/B 1F penetration (Jun. 2014) Investigation through borings on northeast R/B 1F (Feb. 2013)	Investigation by worker (Mar. 2012) Investigation by robot (Apr. 2012) Investigation through borings on south R/B 1F (Apr. 2013)	Investigation by worker(Jun.2012) Investigation by robot (Jul. 2012)
5) Corner Area		Suspend monitoring instruments from R/B 1F stairs area (9.20.2014)	Investigation by worker (3.14.2014,6.6)	Investigation by worker (Mar. 2012)
6) Inside R/B	2～4F	Un-checked	Investigation by robot (Oct. 2012)	Un-checked
	5F	Investigation by balloon (Oct. 2012)	Investigation from outside blowout panel*(Sept. 2011 Feb. 2013) Investigation by robot (Oct. 2011)	Suspend monitoring instruments from crawler crane (Aug. 2011)



＊Blowout panel is the panel which opens to reduce pressure in reactor building in case leakage of steam in reactor building.
At unit2, blowout panel was estimated to open by coincidence because of impact by hydrogen explosion at unit1.

Presently Known Status in Reactor Building

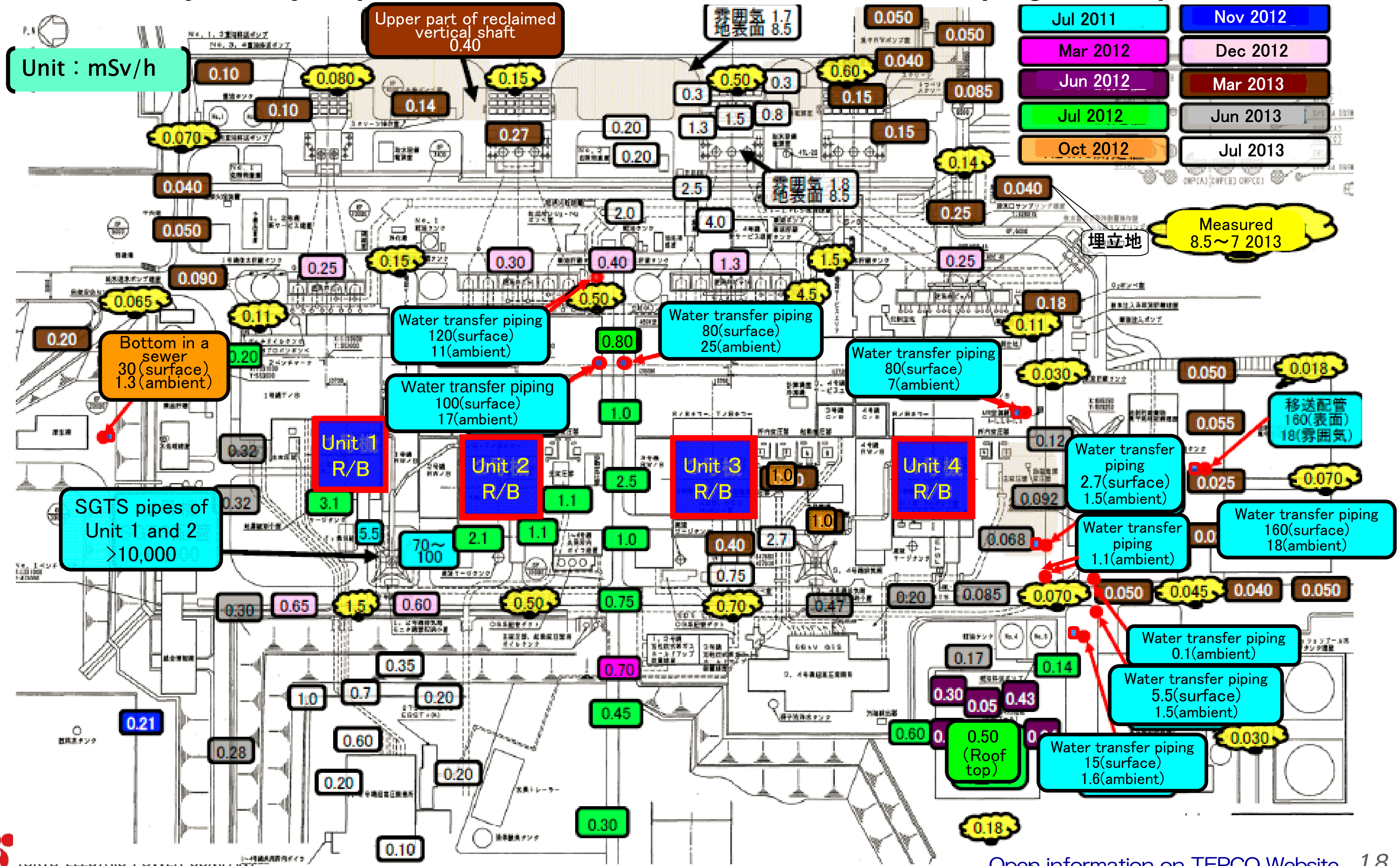
	Area	Unit 1	Unit 2	Unit 3
Water Level	2) Inside PCV	2.8m from the bottom (measured in Oct. 2012)	60cm from the bottom (measured in Mar. 2012)	unconfirmed
	3) Inside S/C	Unconfirmed (estimated to be full of water)	unconfirmed	unconfirmed
	4) Inside Torus Room	OP 3700mm (measured on 2.20.2013)	OP 3260mm (measured on 4.12.2013)	OP 3370mm (measured on 6.6.2014)
	5) Corner Area	OP 3910～4420mm (measured in Sept. 2012)	OP 3050～3190mm (measured in Jun. 2012)	OP 3150mm (measured in Jun. 2012)
Temperature	1)bottom of PCV	About 33℃ (monitored by 6 thermometers) (as of Oct. 2012)	About 45℃(monitored by 1 thermometer) (as of Oct. 2012)	About 45℃(monitored by 9 thermometers) (as of Oct. 2012)
	2) Inside PCV	About 35℃(monitored by 10 thermometers) (as of Oct. 2012)	About 45℃(monitored by 5 thermometers) (as of Oct. 2012)	About 42℃(monitored by 10 thermometers) (as of Oct. 2012)
	3) Inside S/C	unconfirmed	unconfirmed	unconfirmed
	4) Accumulated Water in Torus Room	19.8～22.9℃ (measured in Feb. 2013)	25.2℃ (measured in Apr. 2013)	unconfirmed
	5) Accumulated Water in Corner Area	32.4～32.6℃ (measured in Sept. 2012)	30.2～32.1℃ (measured in Jun. 2012)	unconfirmed
Radiation Dose	2) Inside PCV	About 11Sv/h (measured in Oct. 2012)	About 73Sv/h (measured in Mar. 2012)	unconfirmed
	4) Inside Torus Room	180～920mSv/h (measured Feb. 2013)	6～134mSv./h (measured in Apr. 2013)	100～360mSv/h (measured on Jul. 2012)
	6) Inside R/B	Max. 5150mSv/h (at southeast on 1F, measured in Jul. 2012)	Max. 880mSv/h (at upper reactor well on 5F, measured in Jun. 2012)	Max. 203.1mSv/h (at northeast on 1F, measured in Jun. 2014)

Spent Fuel Pool

	Unit 1	Unit 2	Unit 3	Unit 4
Stored Fuel	Spent 331 Fresh 100	Spent 587 Fresh 28	Spent 514 Fresh 52	Spent 1331 Fresh 202
Debris / Damages	• Building roof fell over fuel pool • Refueling machine did not fell into pool	• No debris on pool	• Building roof / wall and refueling machine fell in pool	• Building roof / wall and refueling machine fell in pool
Sea Water Injection	No	Yes 88 tons (Mar. 20-25)	Yes 126 tons (Mar. 17-27)	Yes 721 tons (Mar. 22-27)
Activities	• Visual Inspection by camera on balloon (Oct. 2012) • Building cover made after will be disassembled for debris removal	• Visual Inspection around pool by camera on robot (Feb. 2012)	• Clean-up /desalination of water (March 2013) • Removal of fallen structures now on • Covering of pool for prevention of damage	• Two fresh fuel taken out for inspection • No corrosion found • Desalination of water (Oct 2012) • Building cover now built for fuel removal

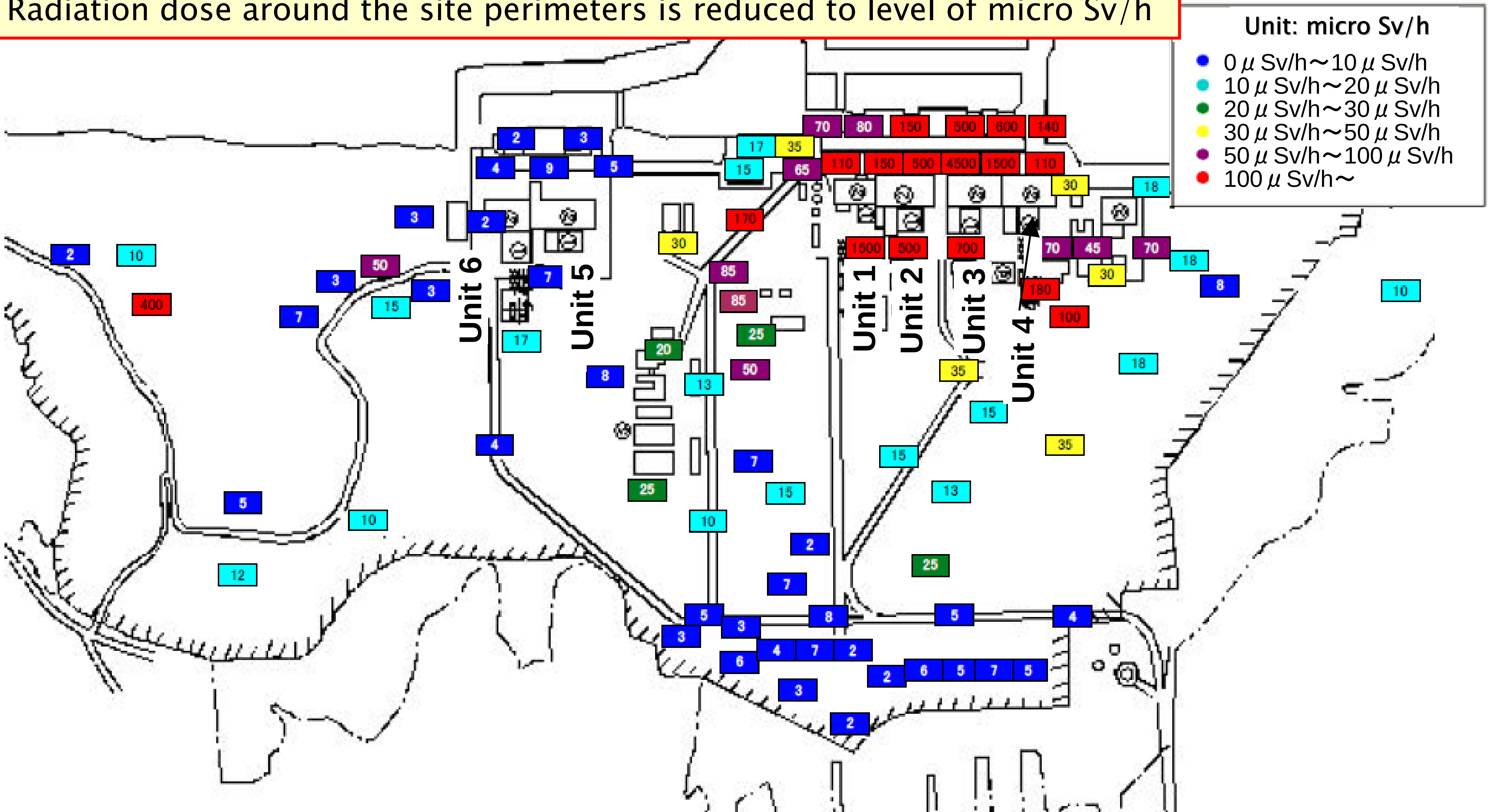
Radiation Dose at the Power Station (1)

Radioactivity Survey Map, Fukushima Daiichi Nuclear Power Station (Aug. 8, 2013)



Radiation Dose at the Power Station (2)

- Radiation dose around reactor building is still high at some points
- Radiation dose around the site perimeters is reduced to level of micro Sv/h



Radioactivity Survey Map, Fukushima Daiichi Nuclear Power Station
（measured on Aug.5～7, 2013）

Concentration of Environmental Samples Around the Site

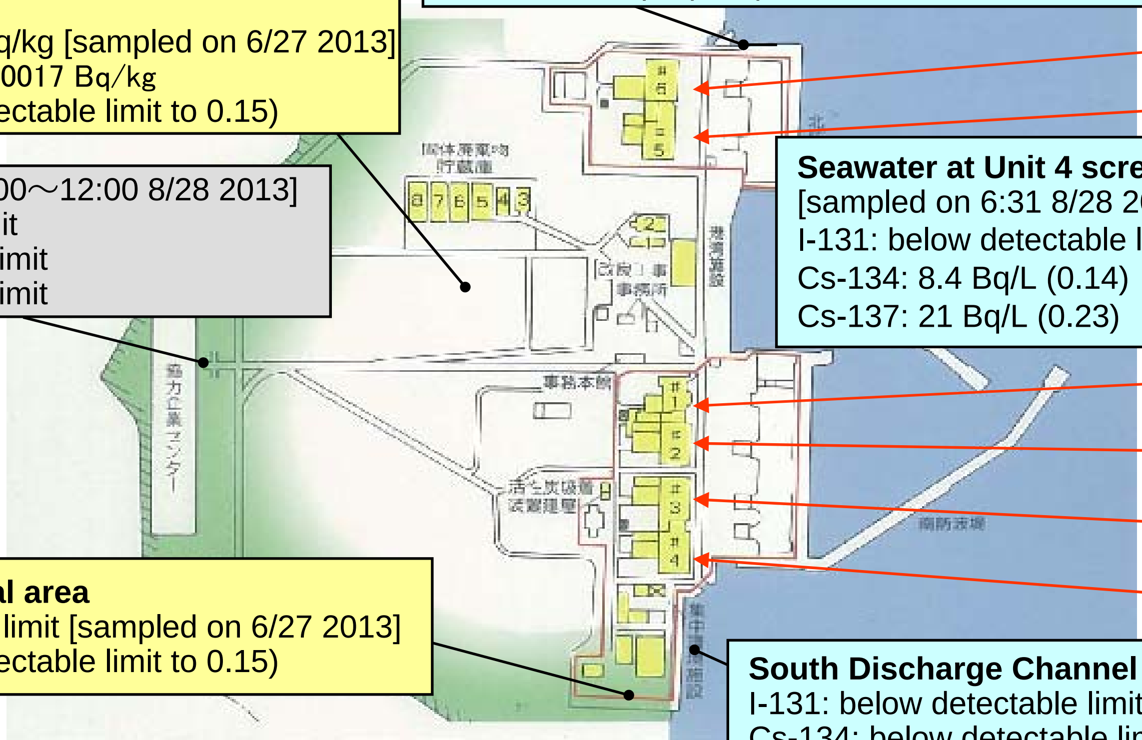
- Plutonium and strontium were detected from the soil at the site as well as other gamma emitting nuclei.
- Level of Pu remains at the fall out level as before

＜Radionuclide analyses results*＞

Units 5&6 North Discharge Channel [sampled on 6:45 7/28 2013]
I-131: below detection limit
Cs-134: below detection limit
Cs-137: 2.7Bq/L (0.03)

Ground
Pu-238: 0.038±0.0074 Bq/kg [sampled on 6/27 2013]
Pu-239,Pu-240: 0.095±0.0017 Bq/kg
(normal level is below detectable limit to 0.15)

West gate [sampled on 7:00～12:00 8/28 2013]
I-131: below detectable limit
Cs-134: below detectable limit
Cs-137: below detectable limit



Unit 6
Unit 5

Seawater at Unit 4 screen (outside the silt fence)
[sampled on 6:31 8/28 2013]
I-131: below detectable limit
Cs-134: 8.4 Bq/L (0.14)
Cs-137: 21 Bq/L (0.23)

Unit 1
Unit 2
Unit 3
Unit 4

Industrial waste disposal area
Pu-238: below detectable limit [sampled on 6/27 2013]
(normal level is below detectable limit to 0.15)

South Discharge Channel [sampled on 5:10 8/28]
I-131: below detectable limit
Cs-134: below detectable limit
Cs-137: below detectable limit

*Representative nuclides concentration described out of detected nuclides
(times in the bracket is the ratio of concentration limit by law)
*We have been sampling many other places.

(: sea water : air : soil
I : Iodine, Cs : Cesium, Pu : Plutonium)

3. Mid/Long-Term Roadmap for Decommissioning

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 debris removal

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

Removal of reactor building cover

HP1-1

HP1-1:the first half of FY 2014

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)

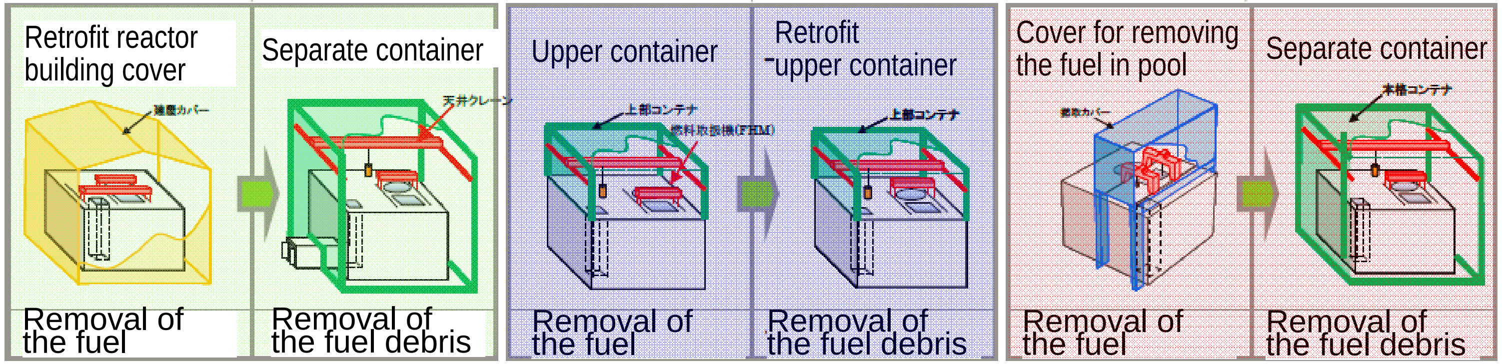
a) infeasible, b) feasible → Plan 2)

a), b) infeasible → Plan 3)

*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

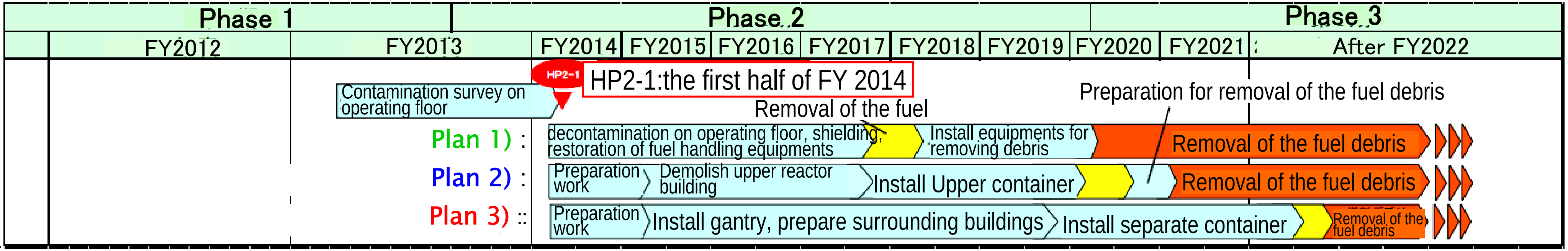
*3 : Selection of plans be made in terms of reduction of risk

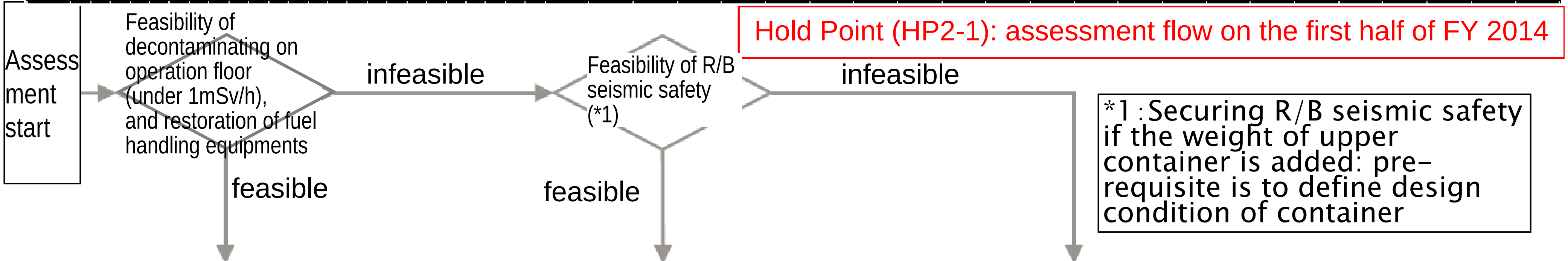


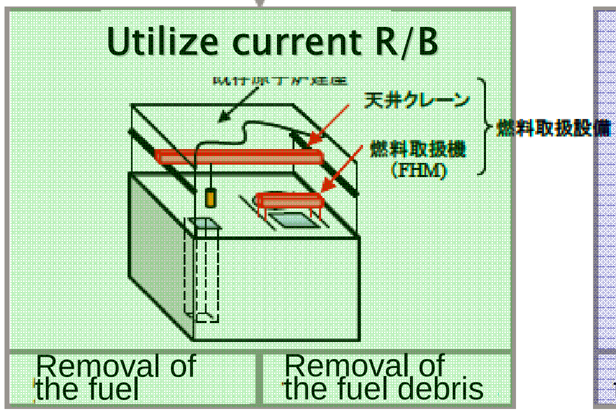
Plan 1) Plan 2) Plan 3)

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

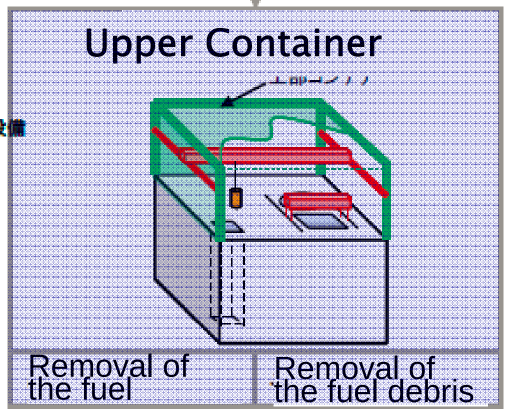
- Unit 2 R/B has no damage by hydrogen explosion
- Radiation dose inside reactor building is still high, requiring further monitoring
- Plan 1): Current R/B, Plan 2): Upper Container, Plan 3): Separate Container



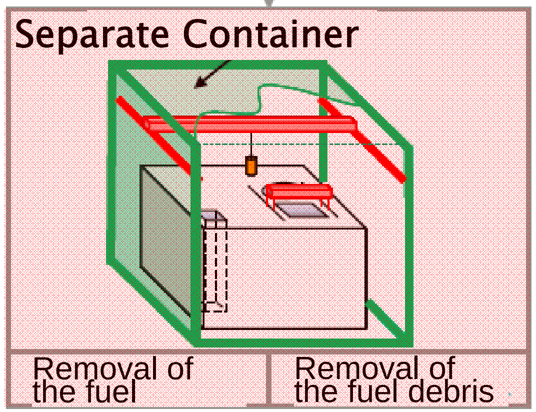




Plan1)



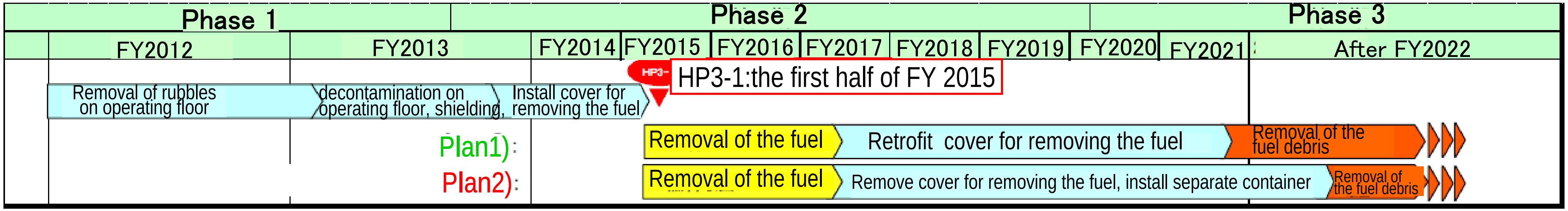
Plan2)

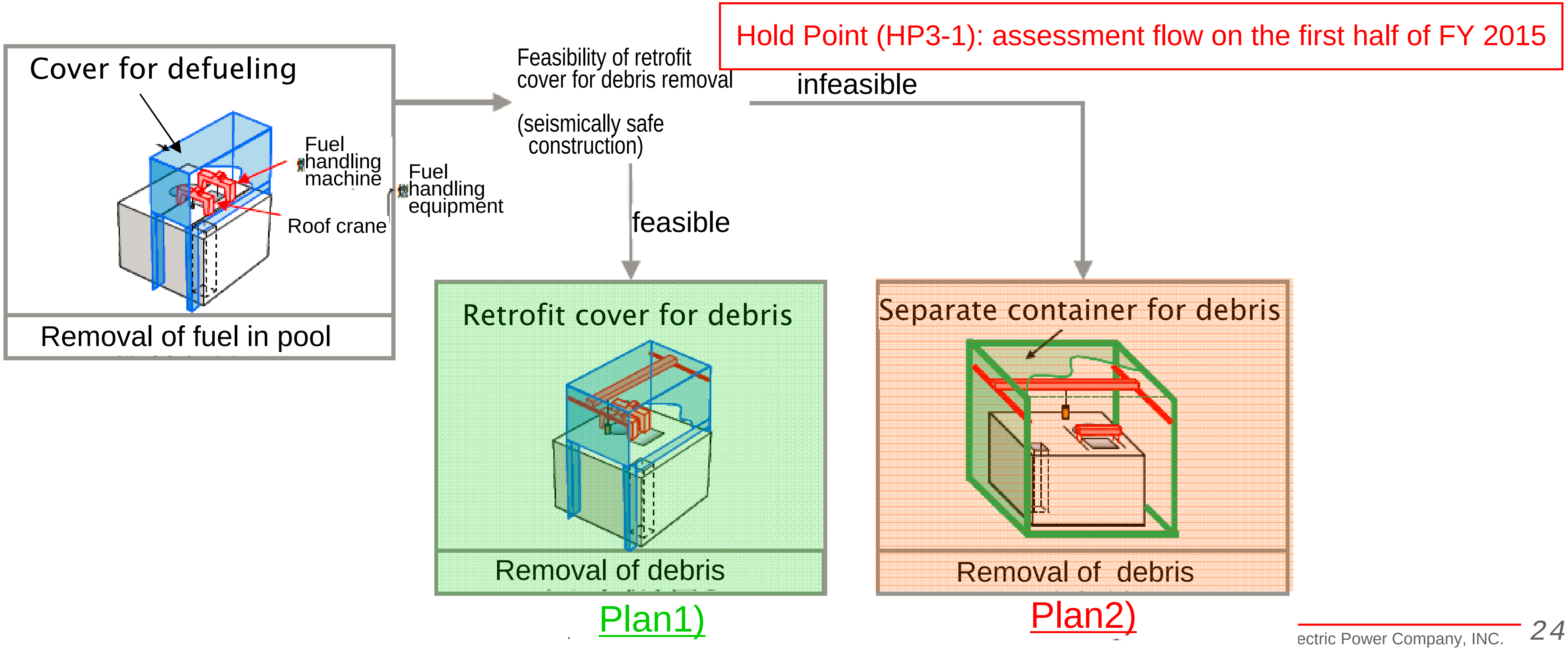


Plan3)

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

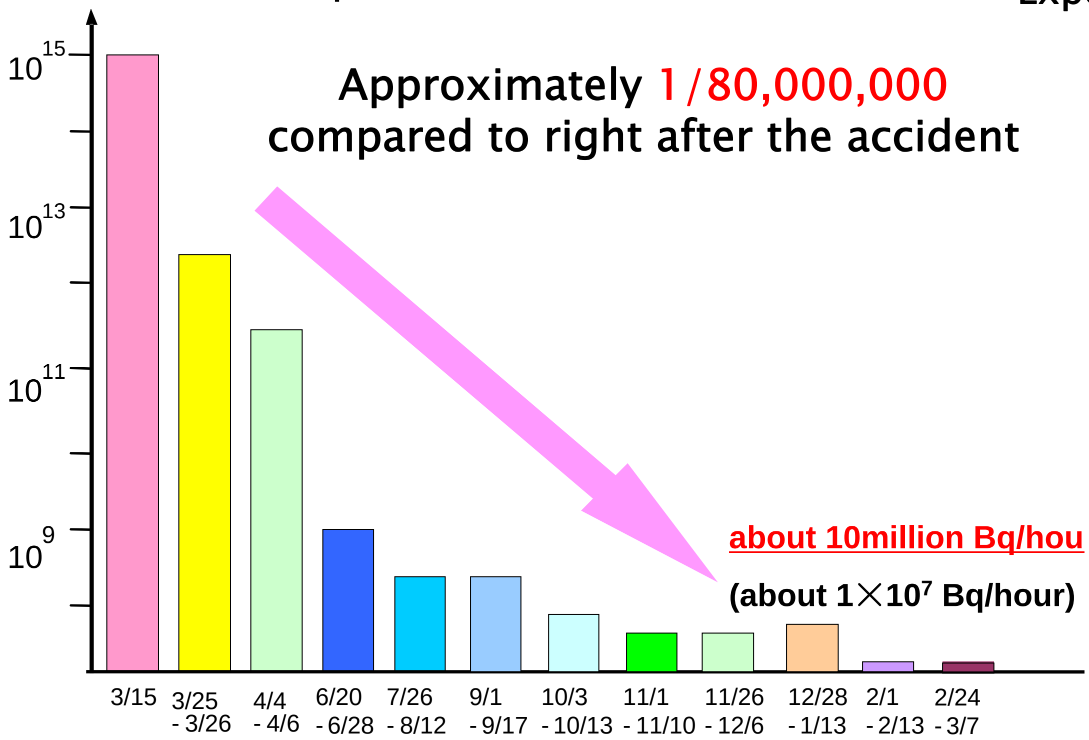




Reduction of Radioactivity Release

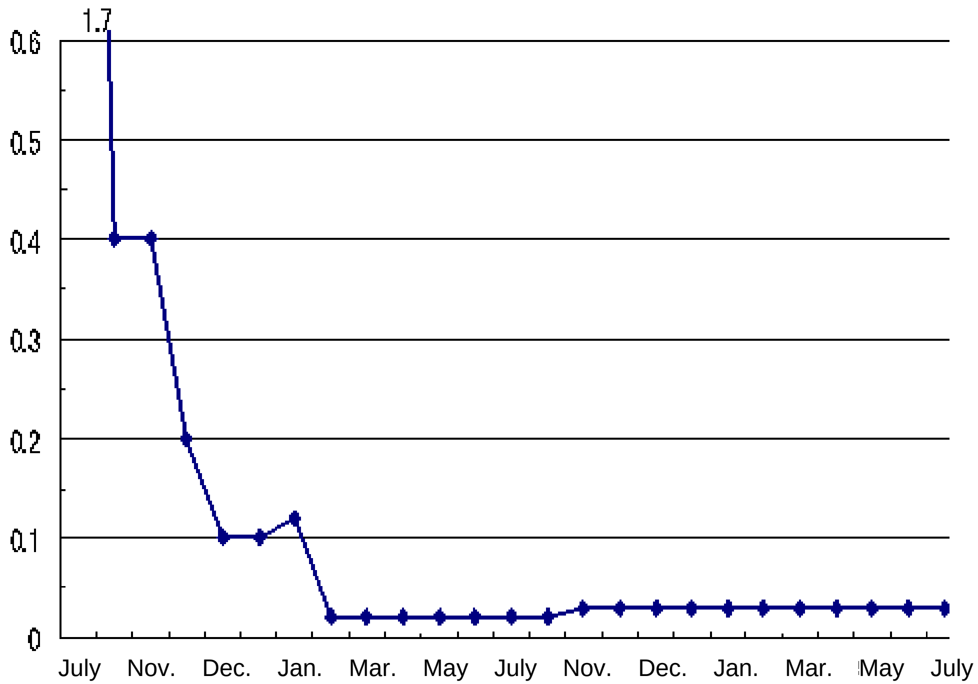
- The amount of activities (cesium) released from Unit 1-3 PCV is assessed based on airborne radioactive material concentrations (dust concentration) at the top of Reactor Buildings
  - Calculated the assessed value of total release amount (as of July 2013) as 10 million Bq/hr (One-80 millionth compared 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)

Release Rate (Bq/hr)



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

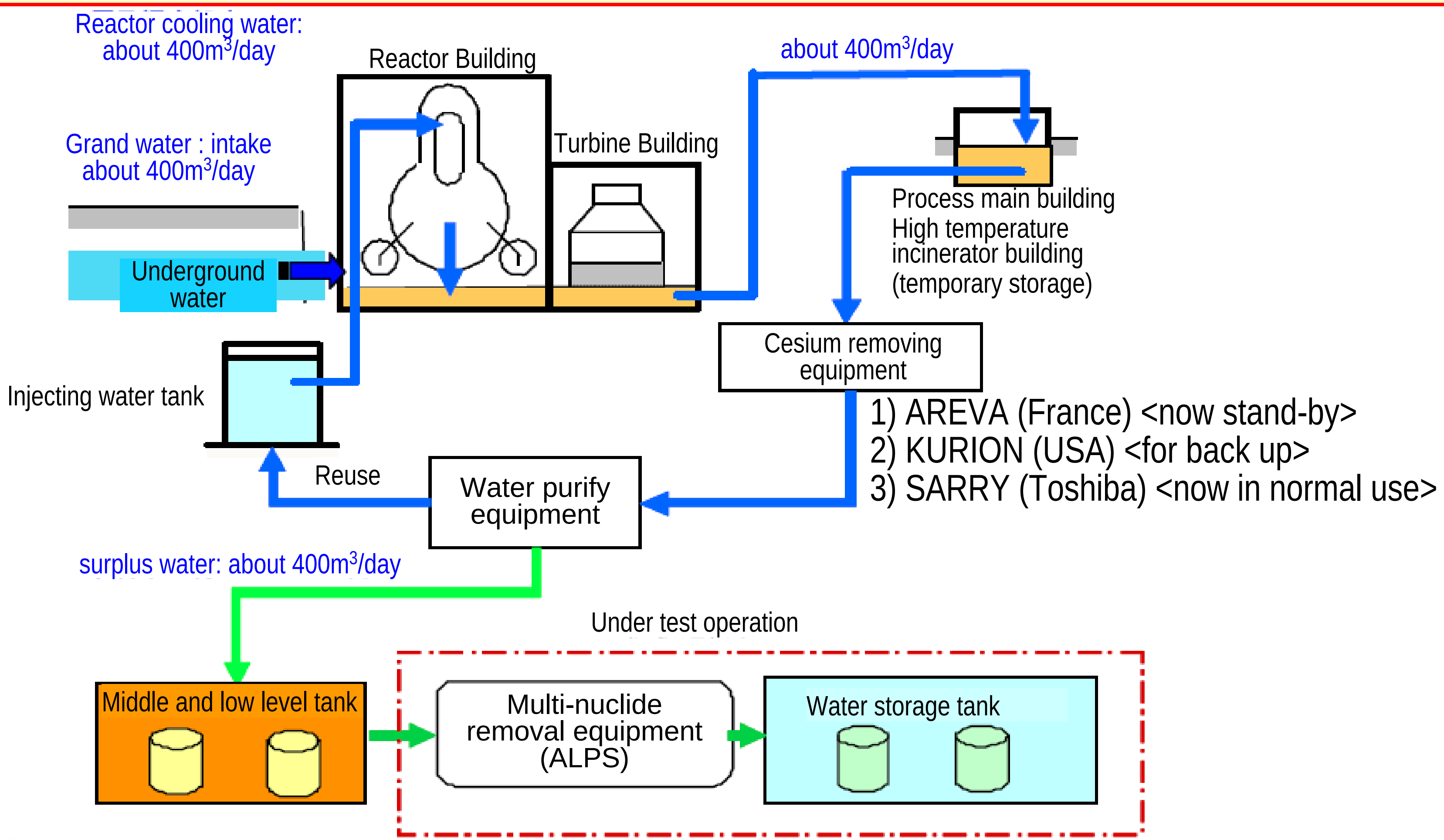
Expose dose (mSv/y)



Expose dose at site boundary

Contaminated Water in Rx/Tb Buildings and Measures for Treatment

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



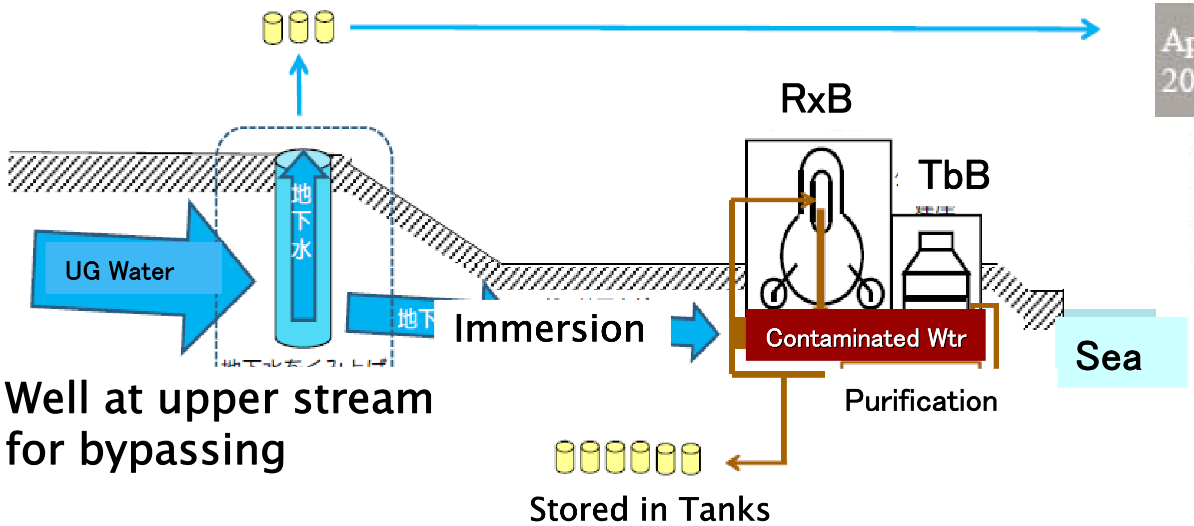
Measures against Underground Water Immersion

- Multiple countermeasures for water immersion prepared
- Underground Water Bypassing to decrease UG water level
- Restoring sub-drains around buildings to pump up UG water
- Frozen underground wall to decrease UG water level now under evaluation of feasibility
- Consensus as to release of water is not build yet

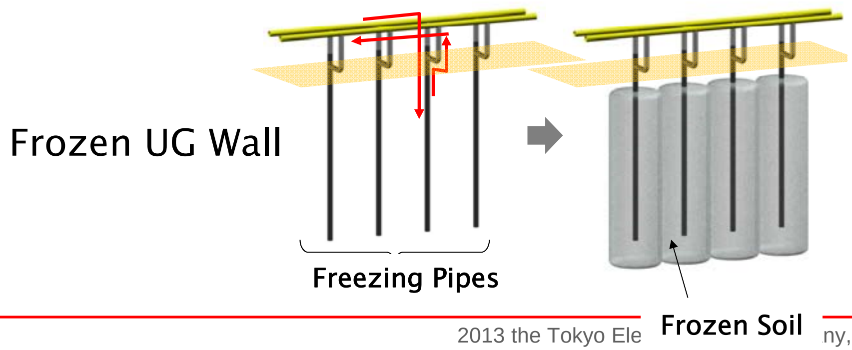
Underground Water Bypass

Pumping up at upper stream well

and release after monitoring

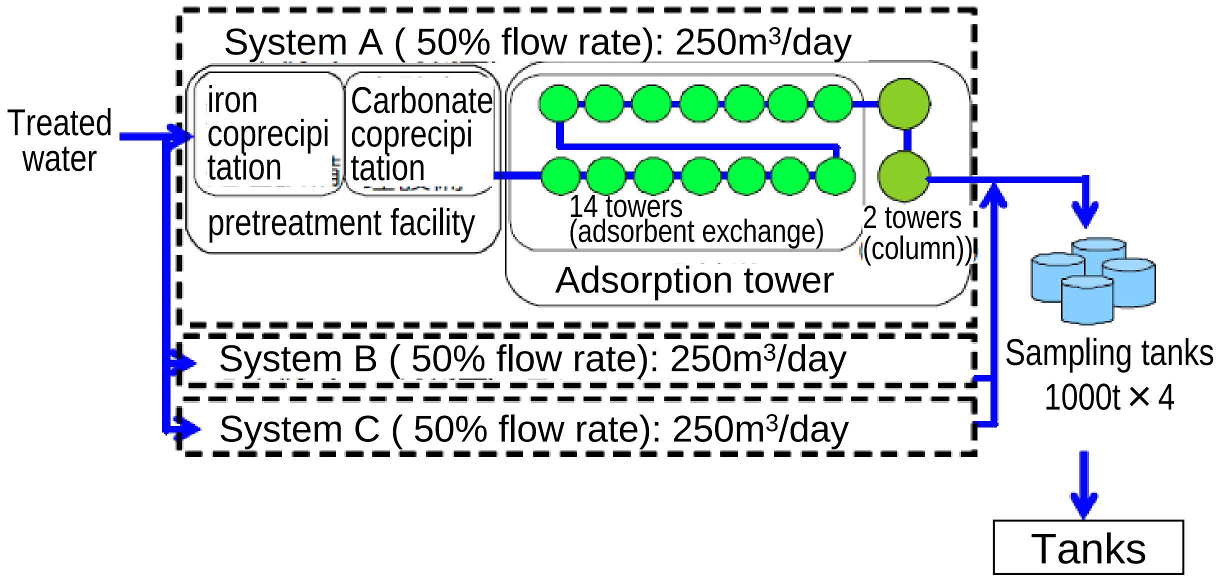


Plan of Shielding Walls around Buildings

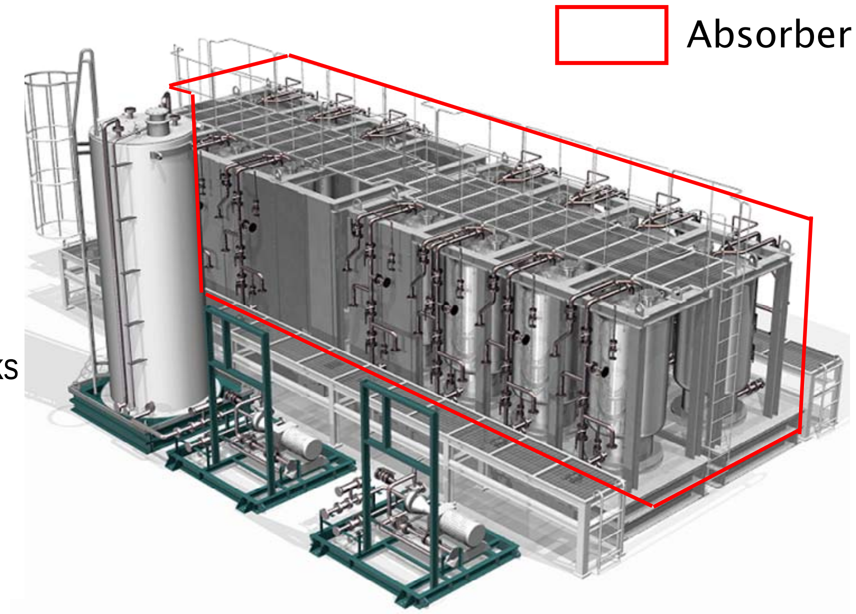


Improvement of Water Treatment Facilities

- Contaminated water treatment systems remove mainly Cesium
- Other nuclei except for tritium will be removed by new Multi-Nuclide removal System
- Test results show all targeted 62 nuclei can be removed to the level less than allowed concentration
- Further efforts to enhance the reliability of contaminated water treatment facilities will be made to decrease accumulation of contaminated water



Multiple Nuclide Removal System



Main Equipments (Absorbers)

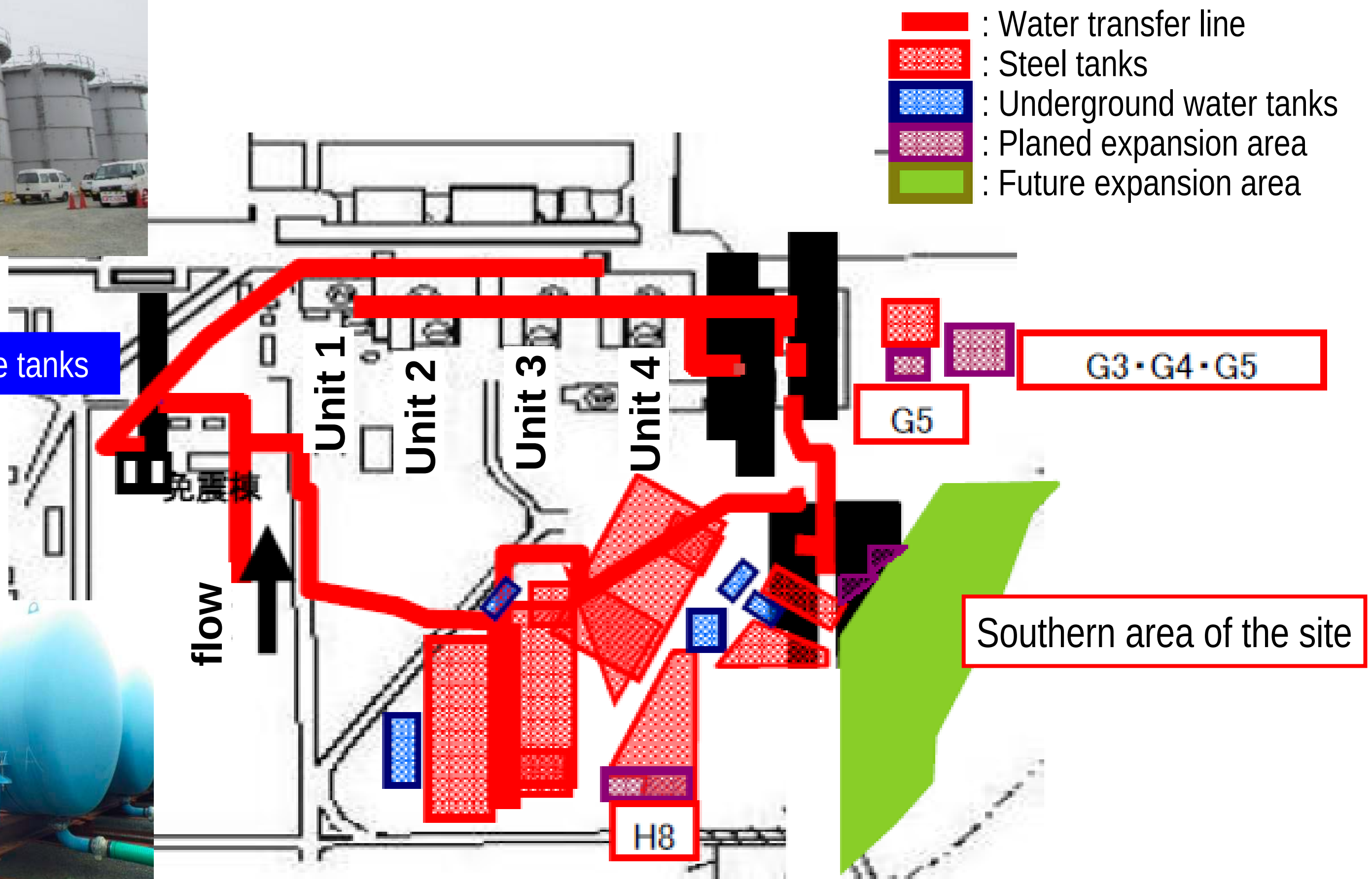
Construction of New Tanks to Manage Contaminated Water

- Based on the estimated tank capacity required on a mid-and-long-term basis, a plan to construct new tanks will be set up. A plan to increase the capacity to 0.8 million m3 by FY2016 will be examined.
- Construction plans should be reviewed and implemented flexibly depending on the circumstances.

Steel cylindrical tanks

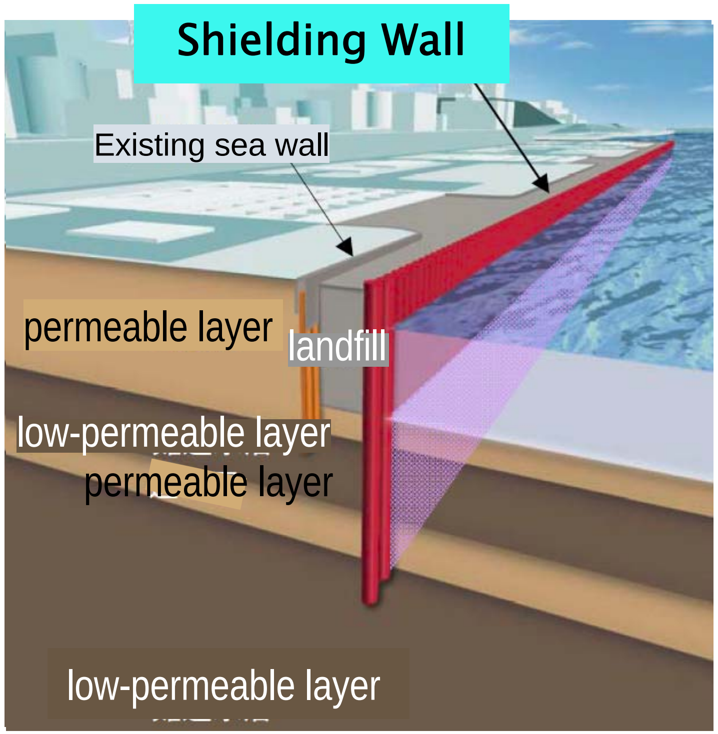
Steel square tanks

Steel horizontal tanks

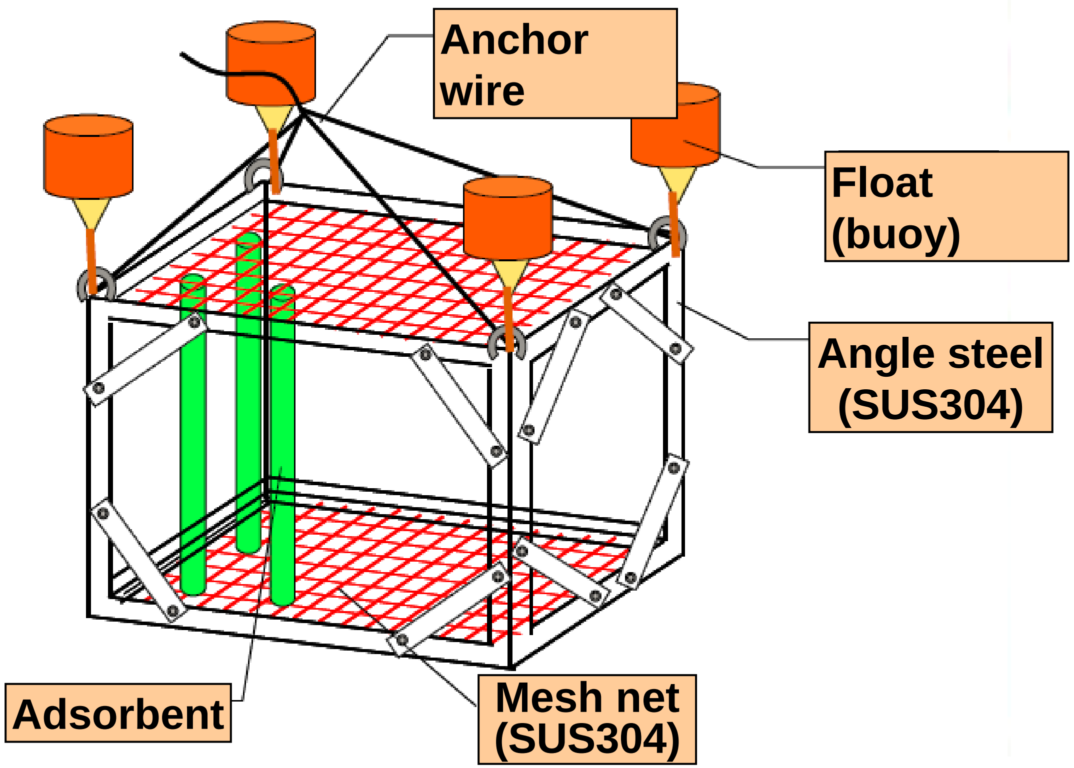


Shielding and Decontamination of Sea Water

- For prevention of further ocean contamination, shielding walls on the sea side be made
- Fiber Adsorbent Purification Equipment Installed in Units 1-4 intake channels
- Additional measures be taken, including land improvement to prevent the expansion of contamination and the removal of contaminated water in trenches on the seaward side
- Enhancing monitoring of underground water and identifying contamination routes



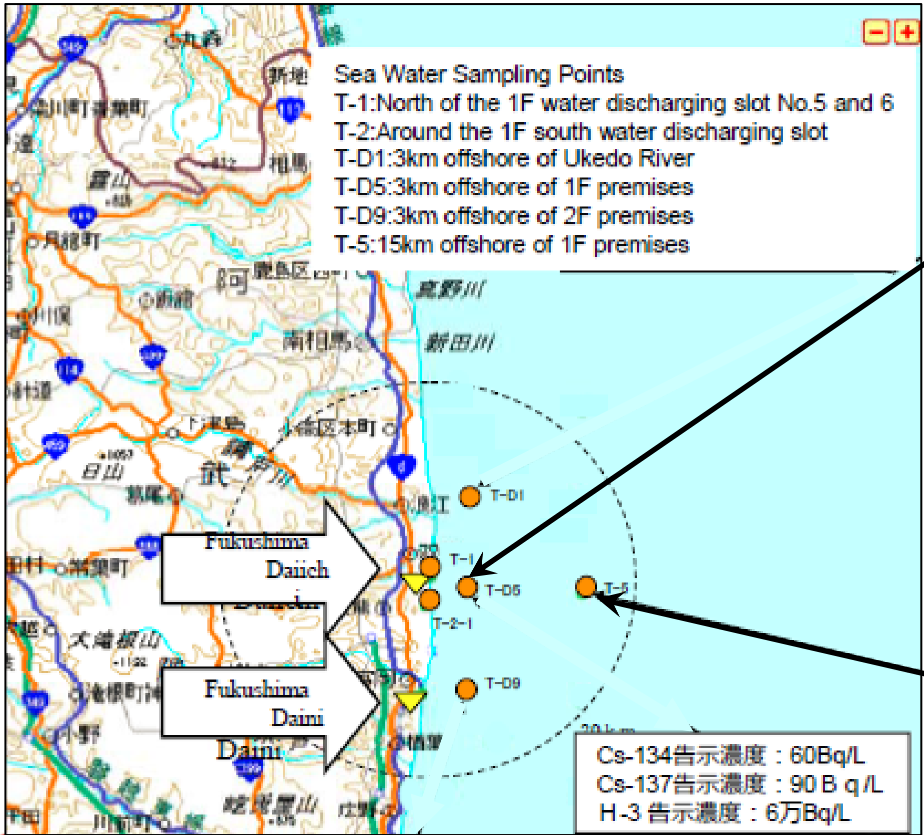
Shielding Wall on Sea Side

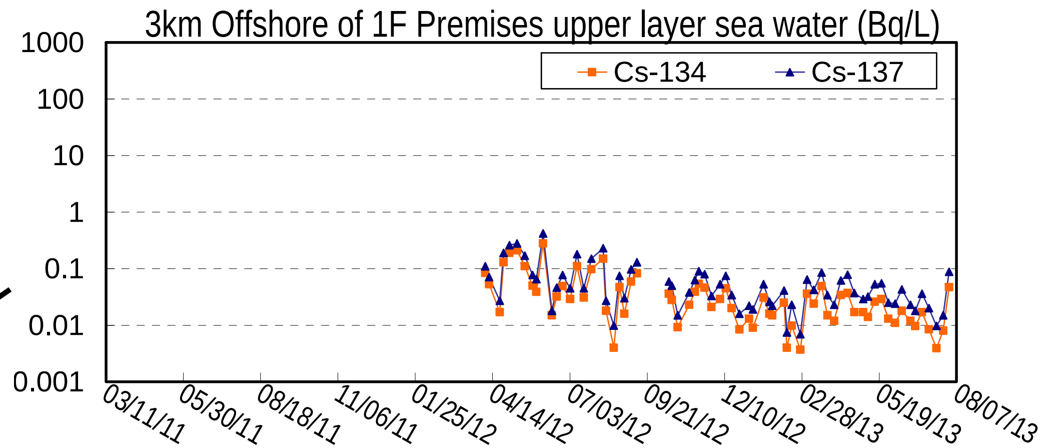


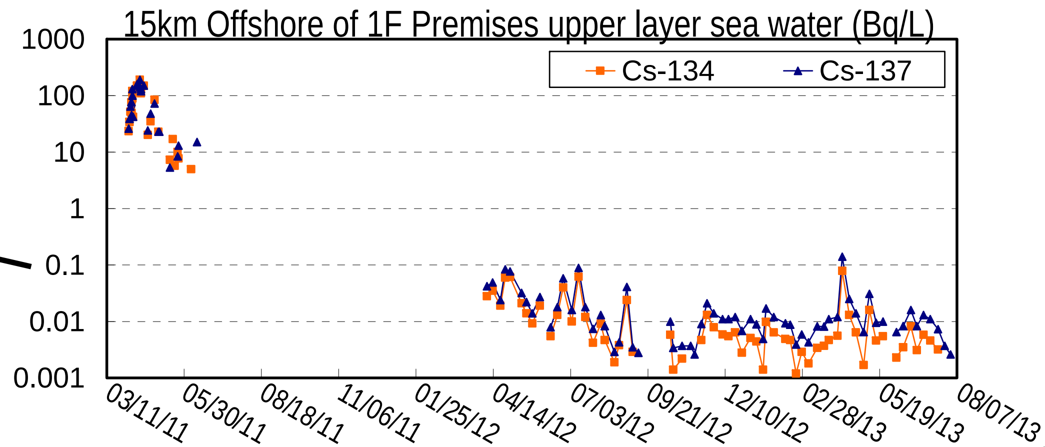
Fiber Adsorbent Purification Equipment

Radioactivity in Sea Water near the Opening Channel

- 300 tons of contaminated water leaked to ground from tank in August
- Cesium and salt was removed by treatment systems but it contained strontium and other nuclides to be removed by new WT system
- Water was soaked in soil but monitoring was enhanced without excluding possibility that it might reach ocean
- Radioactivity in sea water has been monitored and it is low
- Water in leaked tank has been transferred: Removal of soil planned



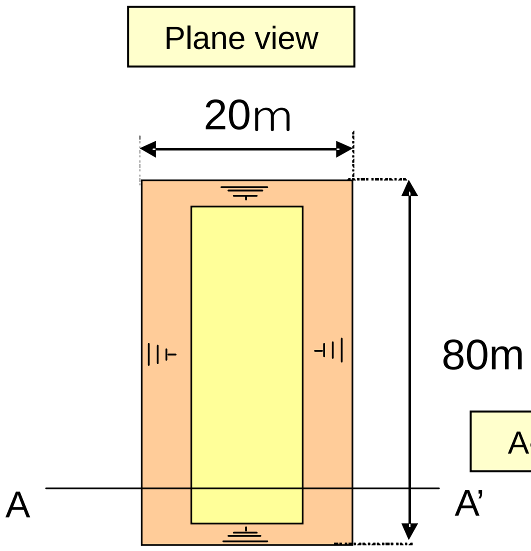


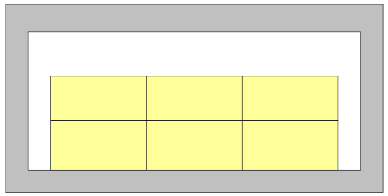


Waste Management and Dose Reduction at Boundaries

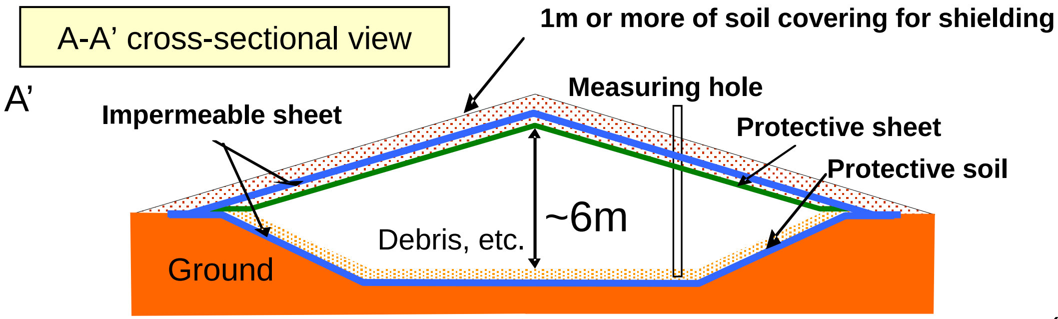
- All of wastes in decontamination work are stored on site
- Additional dose (except for existing contamination) from waste and new release is required to be < 1mSv/y including sky-shine
- Shielding measures are taken for high dose rate wastes
- Locating high dose rate waste far from periphery is also planned

Shield measures (ex.)

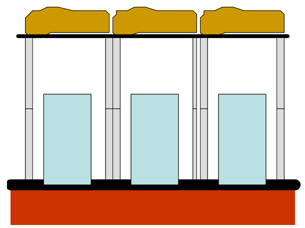




Building-shielding (debris)



Shielding with soil (debris)

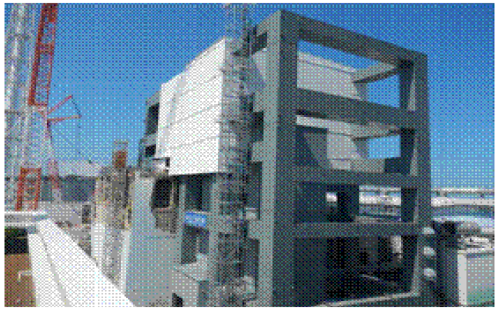


Shielding with sandbags, etc.
(water treatment secondary waste)

Removal of Fuel Bundles in Spent Fuel Pool

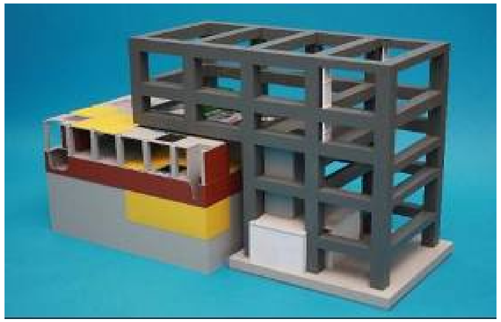
- In Unit 4, debris removal on top floor completed in Dec. 2012, and structure to support cranes and defueling now being built
- In Unit 3, removal of debris by remote handling rigs now carried out, and then structure for defueling be built

Unit 4



Defueling Structures
(as of June)

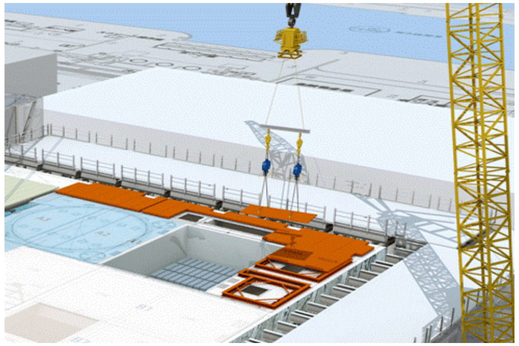
Overhead Cranes Brought in
(On June 7)



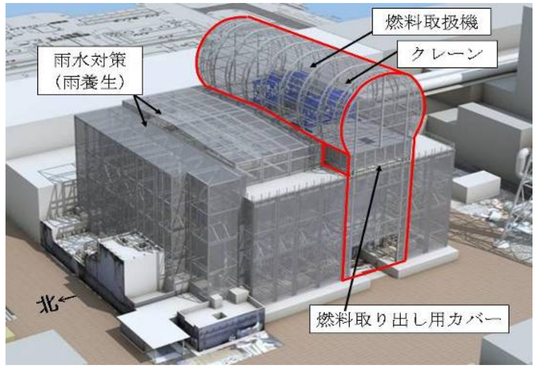
Frame of Defueling Structure

Overhead Crane on Base
(on June 7)

Unit 3



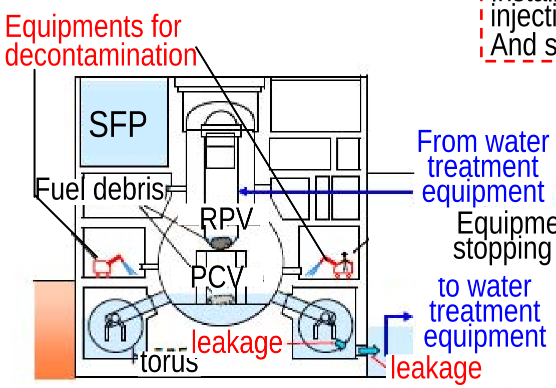
Shielding of Floor for Dose Reduction



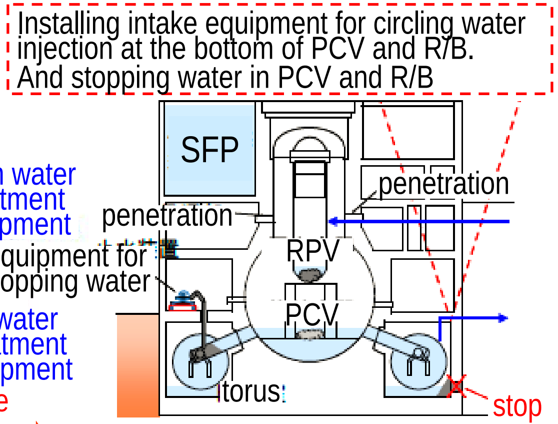
Defueling Cover (Planned)

Image of Removing Debris

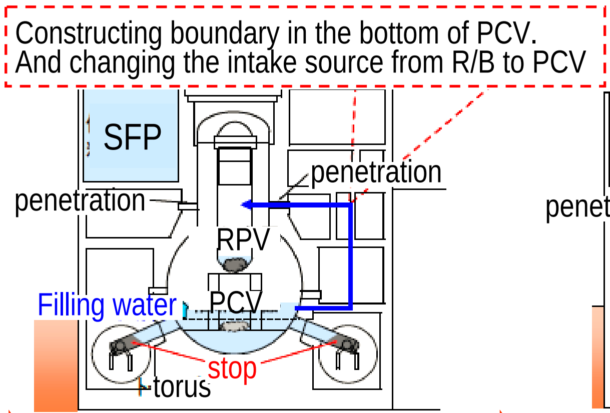
- The most reliable method of fuel debris removal is to remove the fuel debris in keeping them covered with water in terms of reducing the risk of radiation exposure during work processes.
- Accordingly, the fuel debris will be examined and the primary containment vessel (PCV) will be examined and repaired for filling the PCV with water. Furthermore, R&D for the removal and storage of fuel debris will be implemented.



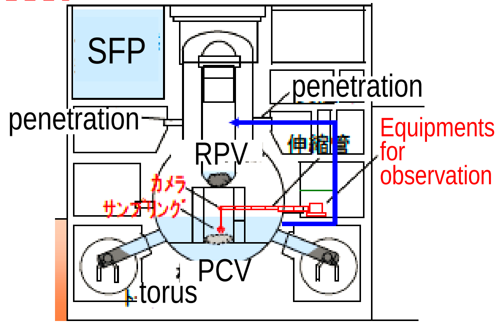
1) Decontamination in R/B
2) Surveying the bottom of PCV



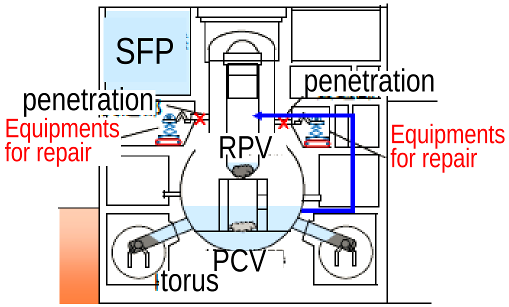
3) Stopping water at the bottom of PCV and R/B



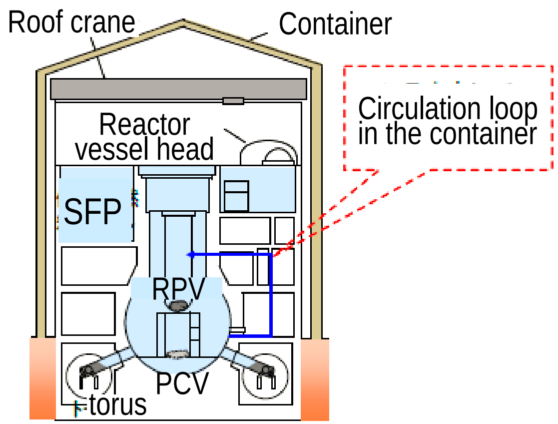
4) Filling water in a part of PCV



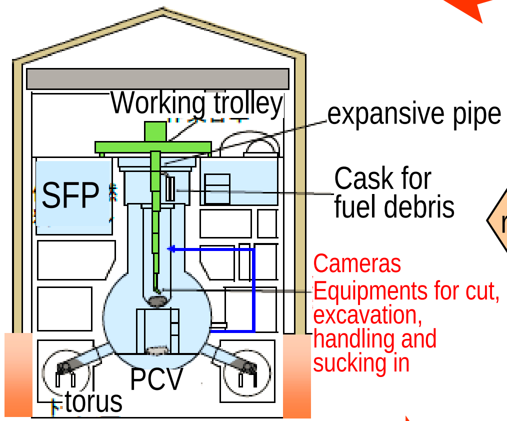
5) Surveying and sampling in the PCV



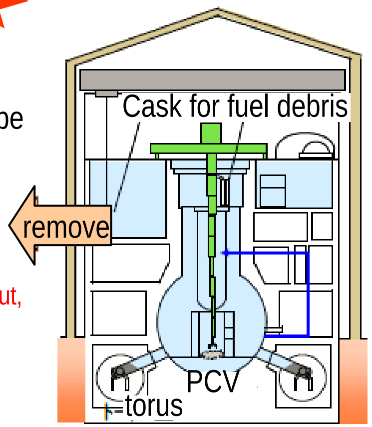
6) Repairing the top of PCV



7) Filling water in the PCV / RPV
⇒Opening the reactor vessel head



8) Surveying and sampling in the RPV



9) Removal of the fuel debris

4. Remediation / Decontamination of Fukushima

4-1 Current Dose Rate in the Area
4-2 Rearrangement of Evacuation Zones
4-3 Principles for Decontamination
4-4 Monitoring
4-5 Decontamination Activities
4-6 Interim Storage Facilities

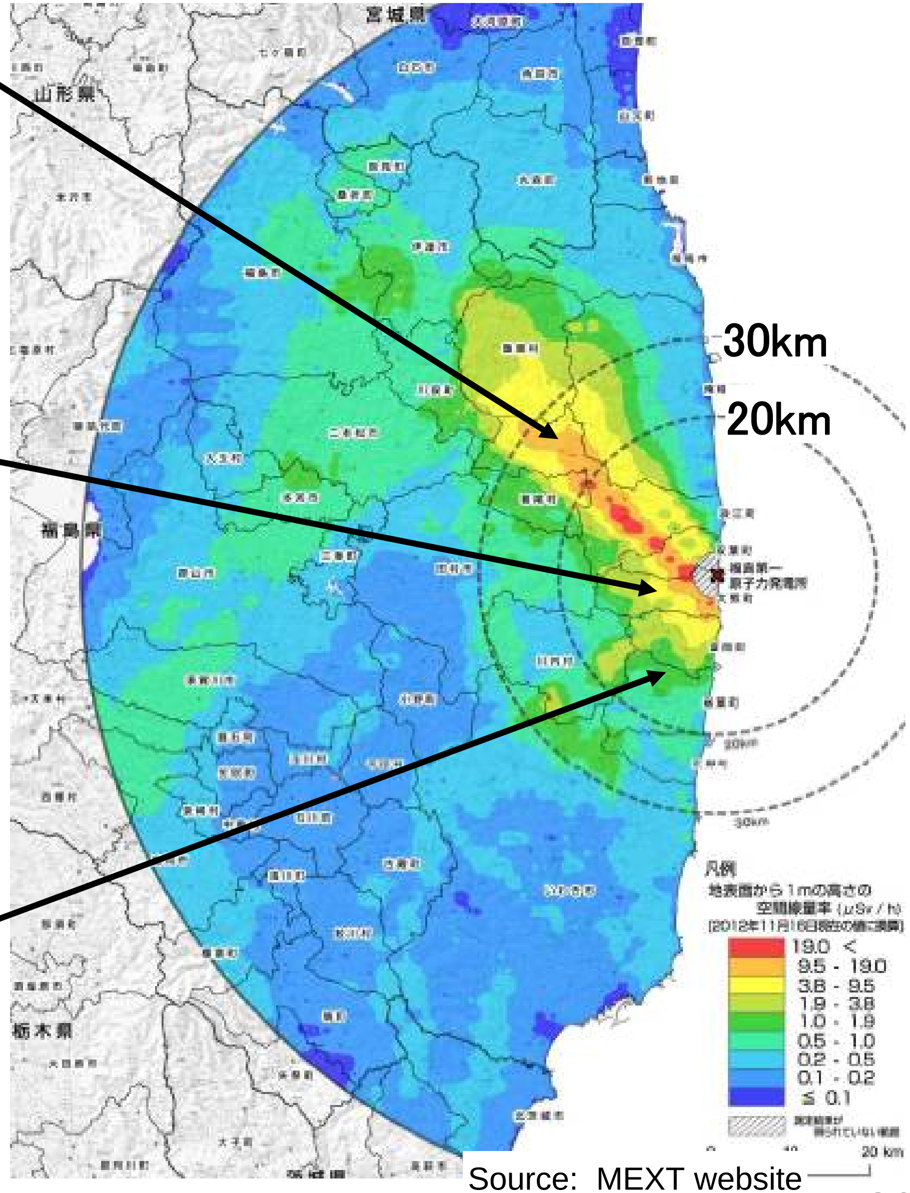
Current Dose Rate in Fukushima Prefecture

【 Areas in orange and red 】
Areas with the annual radiation dose ＞50mSv
- No immediate prospect for evacuees to return
- 50mSv/year is equivalent to the annual maximum dose of exposure allowed for workers at a nuclear power station in operation.

【 Areas in yellow 】
Areas with the annual dose of 20-50mSv
- Restricted access only permitted for the public services or temporary home-return by evacuees
- ICRP recommends the annual radiation dose of 1-20mSv as areas suitable for post-accident residential use and normal living.
- 20mSv is equivalent to the amount of radiation received in three CT scans.

【 Areas in lime and green 】
Areas with the annual dose of 5-20mSv
- "Evacuation-Order-Lift-Ready Zone", specified by the government, is areas that have been subject to the evacuation instruction but have the annual radiation dose of no more than 20mSv.
- 5mSv is equivalent to twice the annual radiation dose humans are exposed to from the natural environment (world average).

Results of the 6h aerial monitoring conducted by MEXT
(Atmosphere dose rate at 1 meter off the ground surface in areas within 80km radius of the Fukushima Daiichi Nuclear Power Station) (As of Nov.16, 2012)



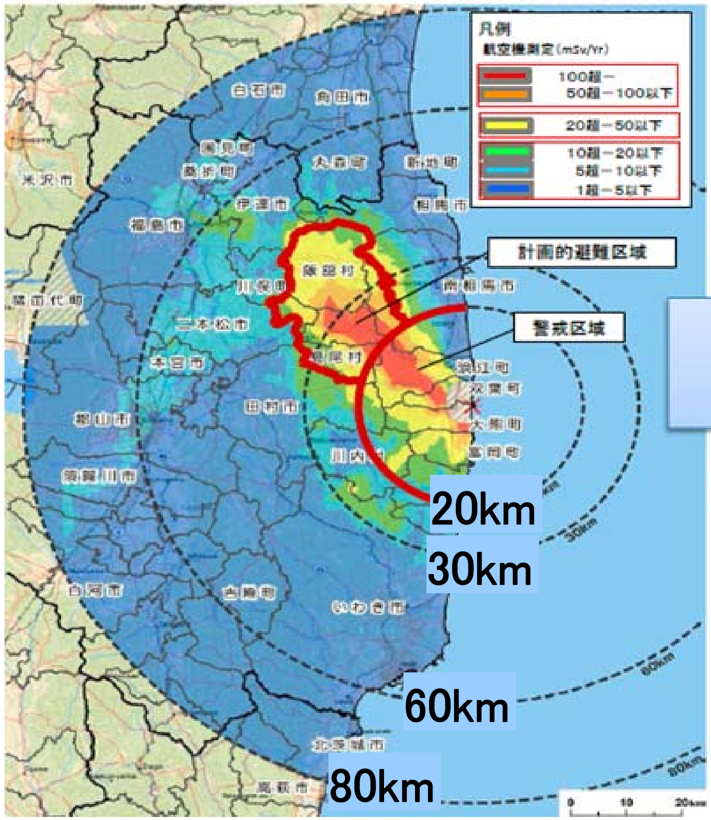
Source: MEXT website

Rearrangement of Evacuation Zones

Depending on dose rate, zones are rearranged for return

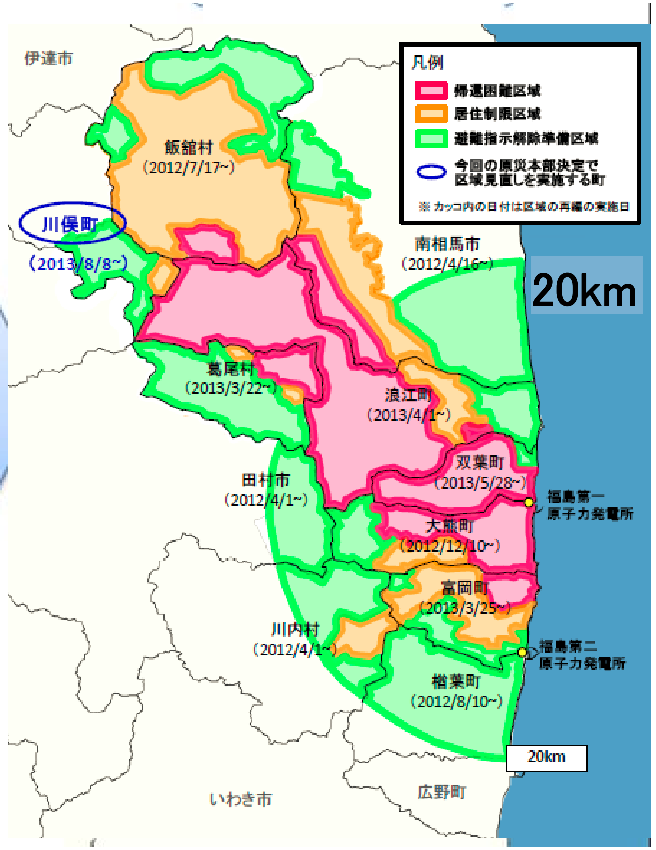
"Areas where it is expected that the residents have difficulties in returning for a long time", "Areas in which the residents are not permitted to live", "Areas to which evacuation orders are ready to be lifted"

Dose Distribution on Apr. 29 2011



Before Rearrangement on Dec. 10 2012

Zones as of Aug. 8, 2013



Principles for Decontamination

- Principles and Target of Decontamination by National Government

Areas to which evacuation orders are ready to be lifted

Current Dose <20mSv/y

- In FY2012, to set out to decontaminate areas with 10-20mSv/y
  (>5mSv for schools)
- By Mar. 2013, to set out to decontaminate areas with 5-10mSv/y
- By Mar. 2014, to set out to decontaminate areas with 1-5mSv/y
- For areas with >10mSv/y, to aim <10mSv/y, and for schools to aim < 1 μSv/h

Areas in which the residents are not permitted to live

Current Dose 20-50mSv/y

- In FY2012-2013, set out to decontaminate
- To try to cut down areas with 20-50mSv/y promptly and stepwise

Areas where it is expected that the residents have difficulties in returning for a long time

Current dose >50mSv/y

- For the time being, perform model decontamination

(All subject to availability of interim storages and consensus of community)

Source MOE

Wide Range / Detailed Monitoring (In 2011)

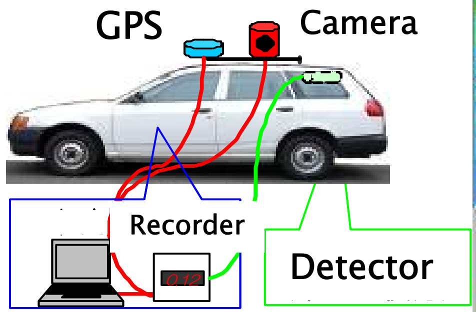
- As a part of consolidated monitoring plan, Cabinet Office and MEXT carried out monitoring inside the evacuated zones
- Experts in TEPCO performed monitoring

Wide Range Monitoring (June-Aug, 2011)

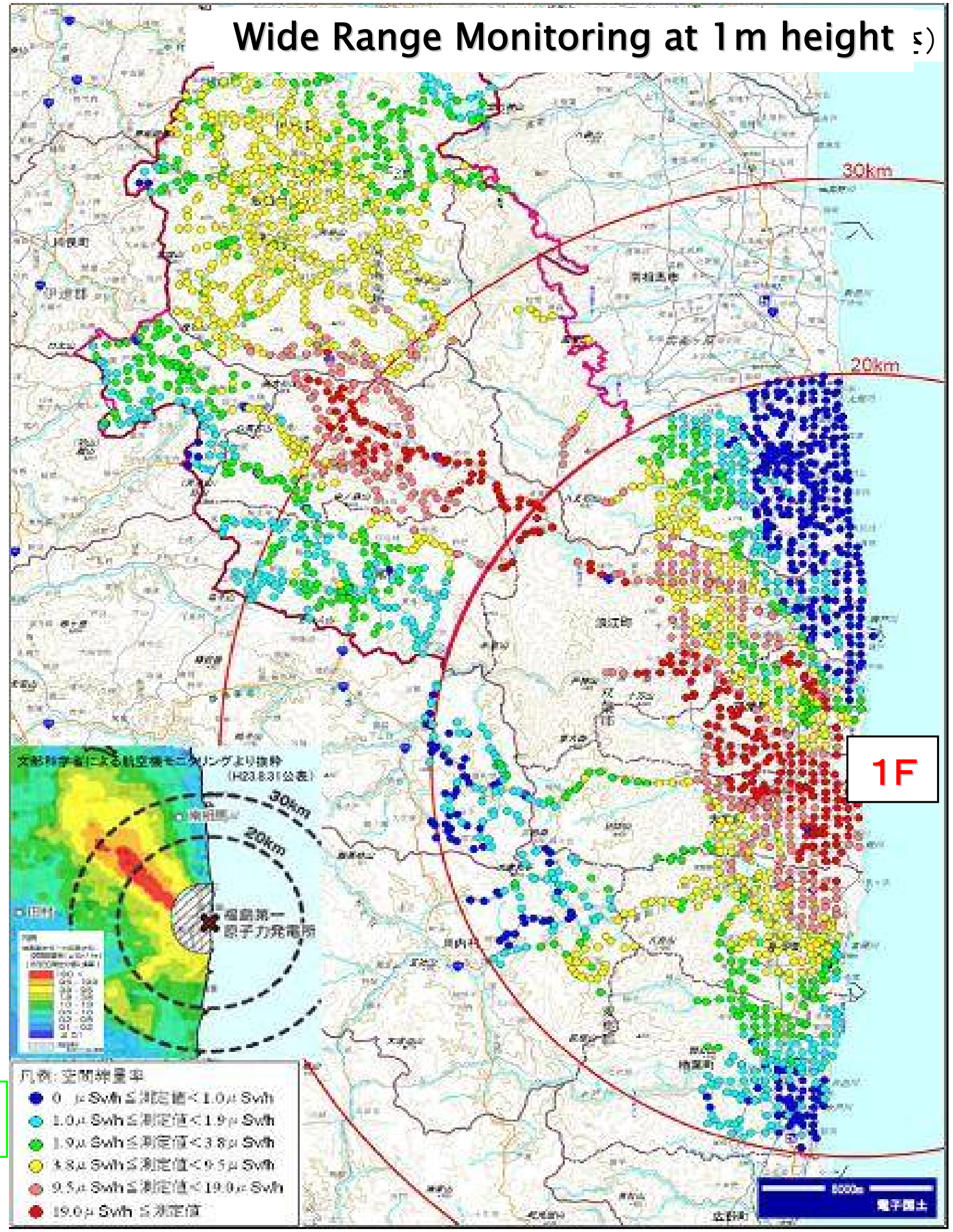
- ✓ Alert Zone / Planned-evacuation Zone
- ✓ 500x500m mesh, two dimensional
- ✓ Open to public in Sept. 1, 2011)

Detailed Monitoring (July-Oct 2011)

- ✓ Basic data for decontamination work
- ✓ By monitoring cars
- ✓ Soil, forests, buildings, roads, water
- ✓ Open to public in Nov. 16, 2011)
- ✓ Continued rundown by monitoring cars



Monitoring Car



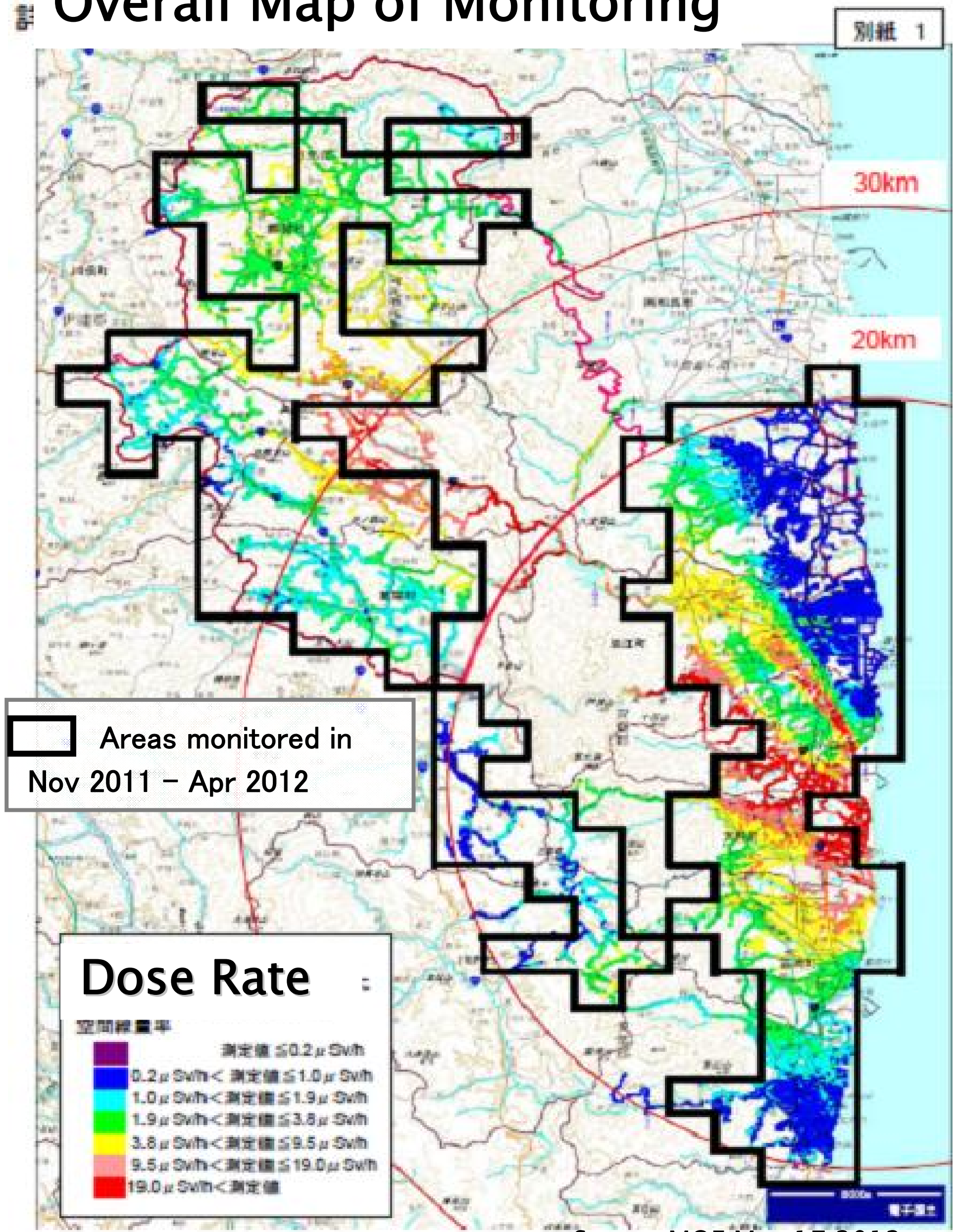
Source: Cabinet Office, MEXT

Detailed Monitoring for Decontamination Work Planning (2011-12)

- Detailed Monitoring by MOE for decontamination planning in areas that national government does decontamination work
  (Nov. 2011-Apr.2012)

- Worked by TEPCO staff with monitoring cars
- Detailed dose map with 100m x 100 mesh made mainly in residential areas
- Areas with lower dose (<20mSv/y) also monitored
- Results open to public on May 17, 2012

Overall Map of Monitoring



Source MOE May 17 2012

Decontamination Work by MOE/Self-Defense Force/Local Governments

- MOE leads decontamination around local government office/infrastructures to make bases for full scale work
- Self-Defense Force decontaminated Local Government Office Buildings
- MOE decontaminated infrastructures then
- In Tamura and other towns, full scale decontamination started
- TEPCO as well staffs for those activities

Work by SDF at Local Gov't Building

Work by MOE at public building

Monitoring on wall surface in public building

Monitoring on Joban Highway Model Decontamination

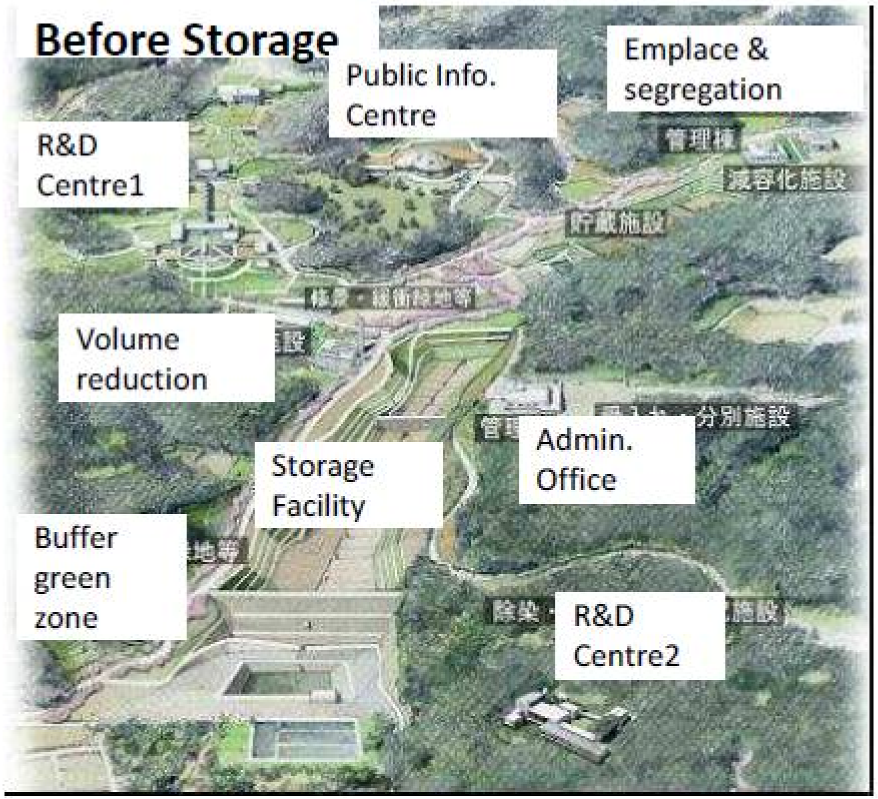
Work by Local Government

Plan for Interim Storage Facility

- Removed soil (Total storage volume ranges 15-28 million_m^3) and designated high density waste in Fukushima prefecture will be stored.
- In addition to the storage facility, laboratory for final disposal and public relations center will be built.

※ The image is conceptual. Actual facilities and their layouts may differ depending upon sites selected

Plan for the interim storage facility



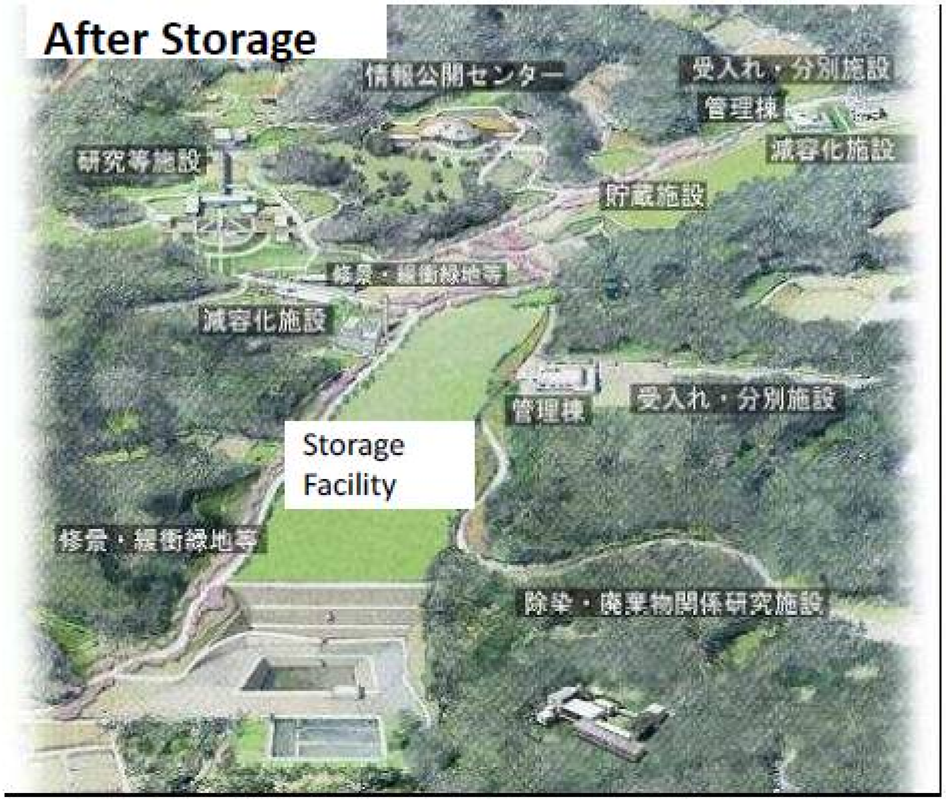
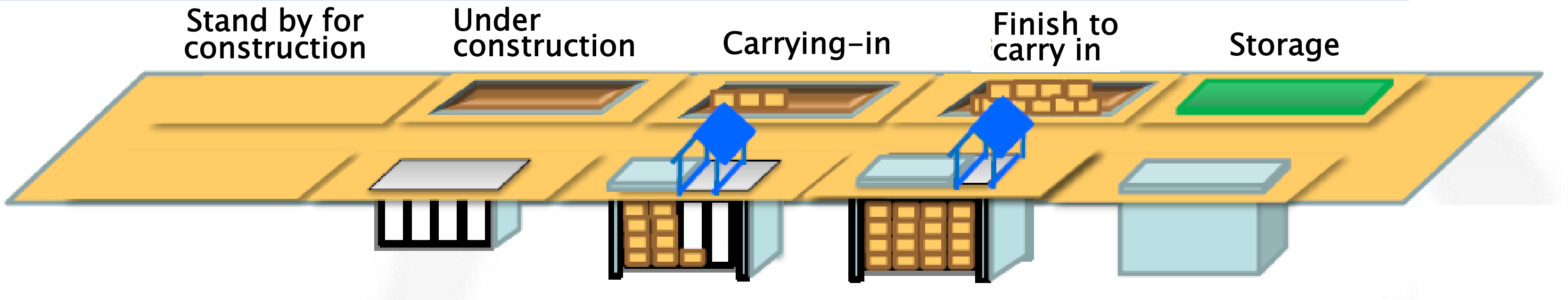


Image of Interim Storage Facility

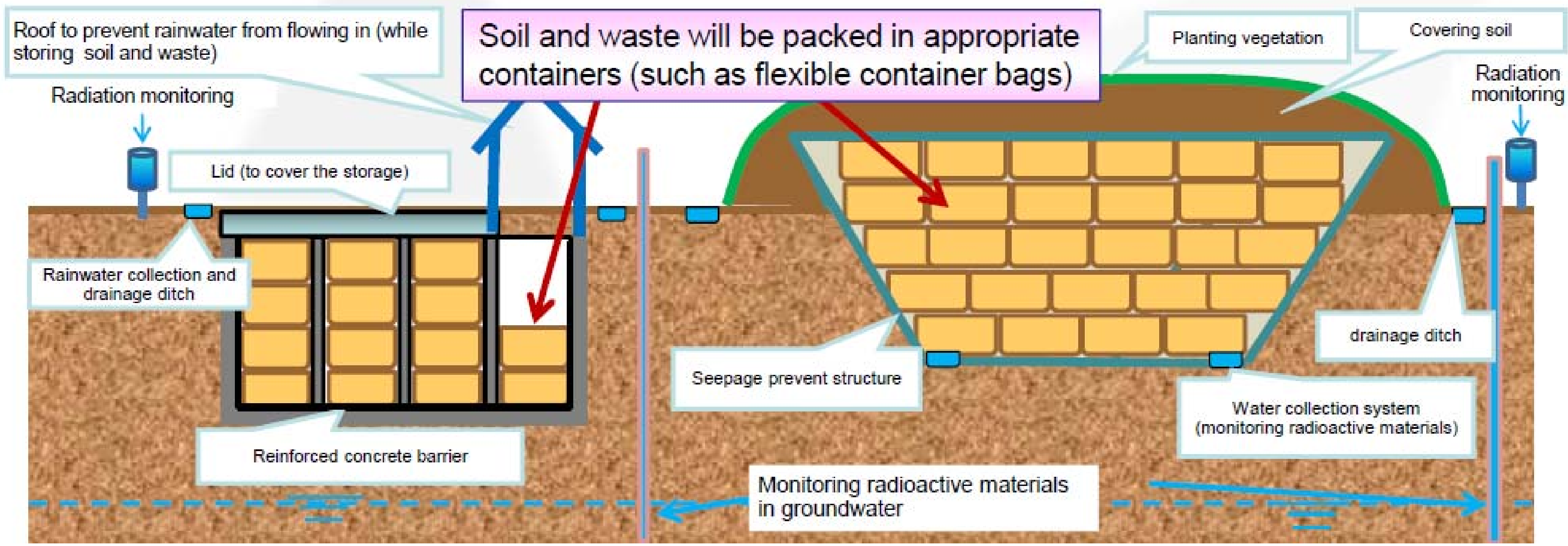
Constructing cell by cell for earlier services



Example of facilities for radioactive waste which can generate leachate

Example of facilities for radioactive waste which does not generate leachate

Soil and waste will be packed in appropriate containers (such as flexible container bags)



Source :Roadmap for interim storage (MOE)

Lessons Learned and Future Issues

5. Lessons Learned and Future Issues

Enhancing Safety -1 (Design / Equipments)

Lessons Learned from Tsunami and Subsequent Consequences

I. Prevention of Events	1) Multiplexed Tsunami Countermeasures
II. Mitigation of Events	・Ensuring Shutting Down Functions (operated as intended in Fukushima)
III. Prevention of Rx Core Damage	Reinforce: 2) Power Supply (incl. temporary supply) 3) Water Sources (fresh/sea water for Rx cooing) 4) High Pressure Injection of water to RX 5) Depressurization Measures of Rx 6) Low Pressure Injection of water to Rx 7) Hear Removal
IV. Mitigation of accident	**8) Venting, Power source, Water source, Injection**
V. Accident prevention countermeasures	・Evacuation-related measures
Fuel pool cooling	9) Strengthen Heat Removal and injection into fuel pool Reinforce various Power Supply Reinforce Water Sources (fresh / sea water)
Further Aseismic Reinforcement	10) **Re-evaluation of Design Bases Accelaration and Reinforcement of Structures**
Strengthen Supporting Functions	11) Enhancement of Instrumentation and peripherals - plant parameter monitoring, **work environment of the main control rooms and seismic-isolated buildings, communication tools, access routes** to the yard

Defense in Depth

Even for Beyond DBA Events

Enhancing Safety -2 (Command and Operations)

Beyond DB Tsunami

12) Insufficient Accident Assumptions

Multiple Units

13) Insufficiency for accidents in multiple plants

Sharing / Evaluating plant conditions

14) Insufficiency in information sharing

Materials / Equipment in Short

15) Insufficiency in Shipping Capabilities

Severe Contamination

16) Insufficient preparation for radiation control

12) Re-evaluate consequences in beyond design base tsunami
- Exceeded preparations (procedures / training) for severe accident

13) Prepare for managing damages in multiple plants by external events

14) Reinforce plant monitoring / communication tools for evaluation / sharing information

15) Deploy in advance at the power station materials and equipment needed right after accident. Prepare a framework for delivering materials and equipment to restricted areas

16) Improve reliability of monitoring posts and augment monitoring cars, augment radiation measuring and protection equipments to the emergency response centers and main control rooms, train personnel in radiation measuring, prevent radioactive contamination of emergency response centers and strengthen shielding

International Collaboration

- Collecting versatile knowledge and experience is important both domestically and internationally
- We share experiences and information, and project is open to any expertise / nuclear communities around world
- International Advisory Team has been set up
- International Research Institute for Nuclear Decommissioning has been founded
- Cooperation with IAEA, OECD/NEA,
- Cooperation under multi-lateral / bi-lateral agreements

IAEA

OECD/NEA

Peer Review

Venue

Decommissioning Work

Support

Info / Needs

International Advisory Team

–Assistance in R&D、Recommendation for strategy (Road Map / End State)、Support in field、Screening of technology、Information sharing

International Research Institute for Nuclear Decommissioning

–Founded in Aug. 2013 for R&D for decommissioning

<Cooperation with IAEA>

In April 2013 Review Mission of IAEA visited and issued report with evaluation and recommendation

Restoration of Fukushima

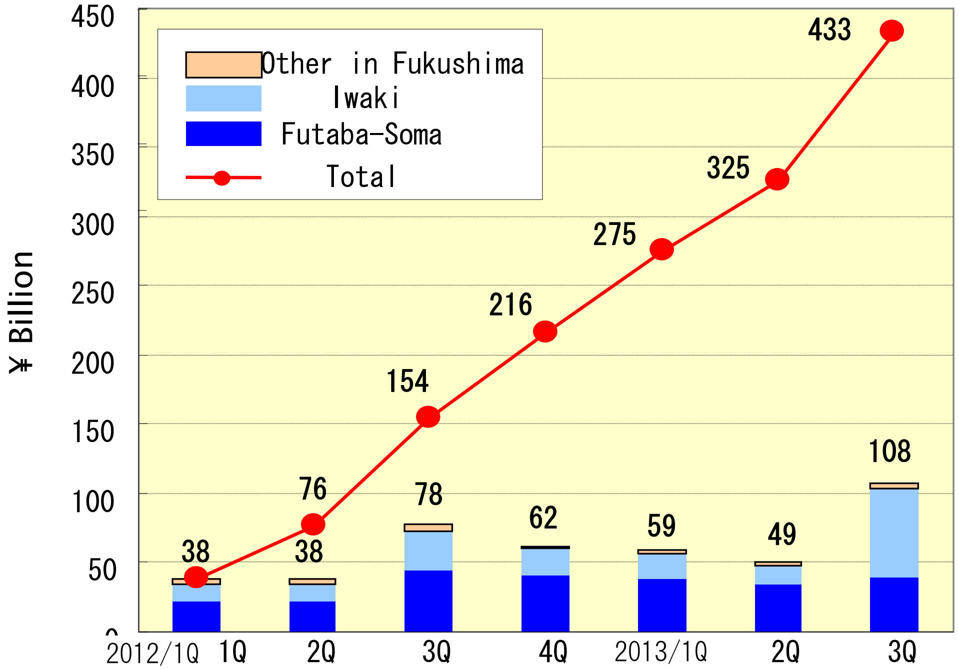
- Response to afflicted local governments' / residents' request
- Volunteering work with 300+ resources and technical assistance for decontamination
- Proactive restoration activities with resources of 100,000 man-day staffs /y

Restoration of areas and assistance in evacuation	Assistance for early return to home
➢ Resources for temporary return to home ➢ Assistance in temporary housing ➢ Cleaning/mowing of cemeteries ➢ Radiation monitoring for temporary activities ➢ Closing gas valves of houses ----	➢ Removal of debris in evacuated area ➢ Clean-up of evacuated houses ➢ Cooperation in decontamination work by Gov't ➢ Radiation monitoring for return ➢ Drilling wells for early returner

Restoration of Local Economy and Employment

- Newly Built State-of-the-art Coal-fired Plant
- Restoration of J-Village (Football Park)
- Projects for Housing and Restoration Base
- Transfer Business to Fukushima for Local Employment
- Recruiting New Graduates from Local School
- Assistance for Organic Farming
- Procurement of Goods from Locals

<Stored Manure>



Local Procurement

Low Level Radiation Exposure

- Psychological consequences are important
- Consensus as to effect by low level radiation exposure is vital for restoration
- WG for “Risk Management for LLRE” by Cabinet Office issued report in Dec. 2011
- UNSCEAR* is in the process of study to assess radiation doses and its effects

(*United Nations Scientific Committee on the Effect of Atomic Radiation)

- ICRP Report
  - “The accident has reconfirmed that psychological consequences are a major outcome”
- Cabinet Office Report
  - “Increase of carcinogenic risk by exposure less than 100mSv is small enough to be buried in other risks, and 20mSv/y is low enough compared to other risk factors”
- UNSCEAR report as to health effect
  - “To date, there have been no health effects among workers, the people with highest exposures”
- Concept for radiation protection and actual adverse effects are different
  - LNT (Linear No Threshold Model) is used for radiation protection as a conservative assumption
- Issues to communicate these risks
  - Risk communication and fostering information sharing are important
  - Alleviating anxiety needed overcoming “Risk Aversion Bias” and “Information Asymmetry”

Summary

Decommissioning of Fukushima Daiichi

- **Be prepared for the unpredicted**
- **Technical Challenges are:**
  - High Dose Rate and Water Issue
  - Decontamination, Debris Identification/Removal, Water Treatment, Waste Management, Dose Management
  - Process Choices, R&D, Definition of End Status, Safety / Quality of Field, and Risk Management
- **Socially Challenging Aspects are:**
  - Credibility to Safe Operation, Convincing Transparency / Accountability, and Risk Communication
  - Anxiety to Low Dose Radiation should be Alleviated and Importance of Other Factors incl. Psychological Consequence should be Addressed
- **Collecting International Experiences, Expertise and Knowledge is Important**

Thank you for your attention

and

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