Lessons Learned from the Fukushima Daiichi Nuclear Power Plant Accident

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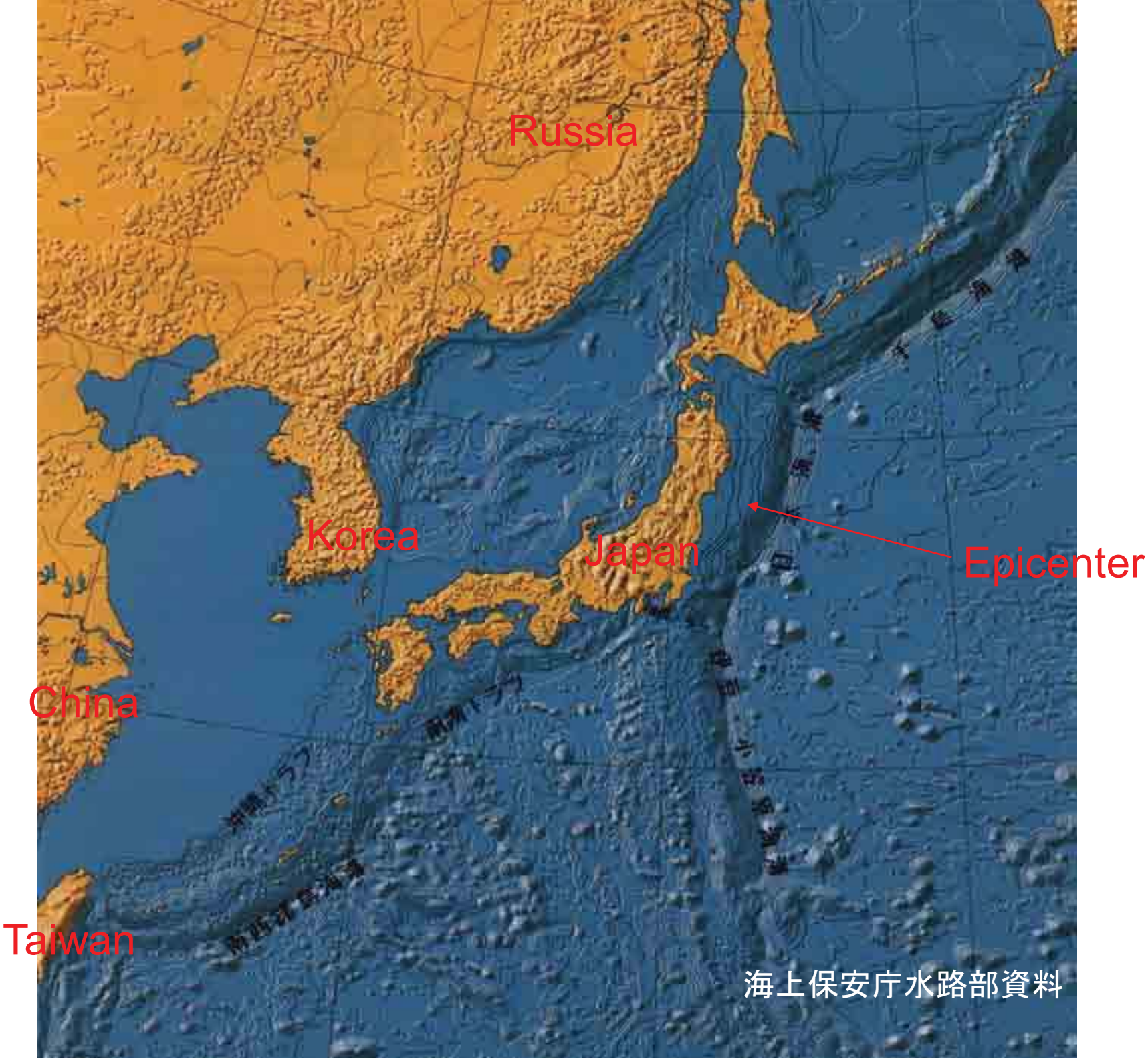

Russia
Korea
Japan
Epicenter
China
Taiwan
海上保安庁水路部資料

Earthquake and Tsunami on March 11, 2011

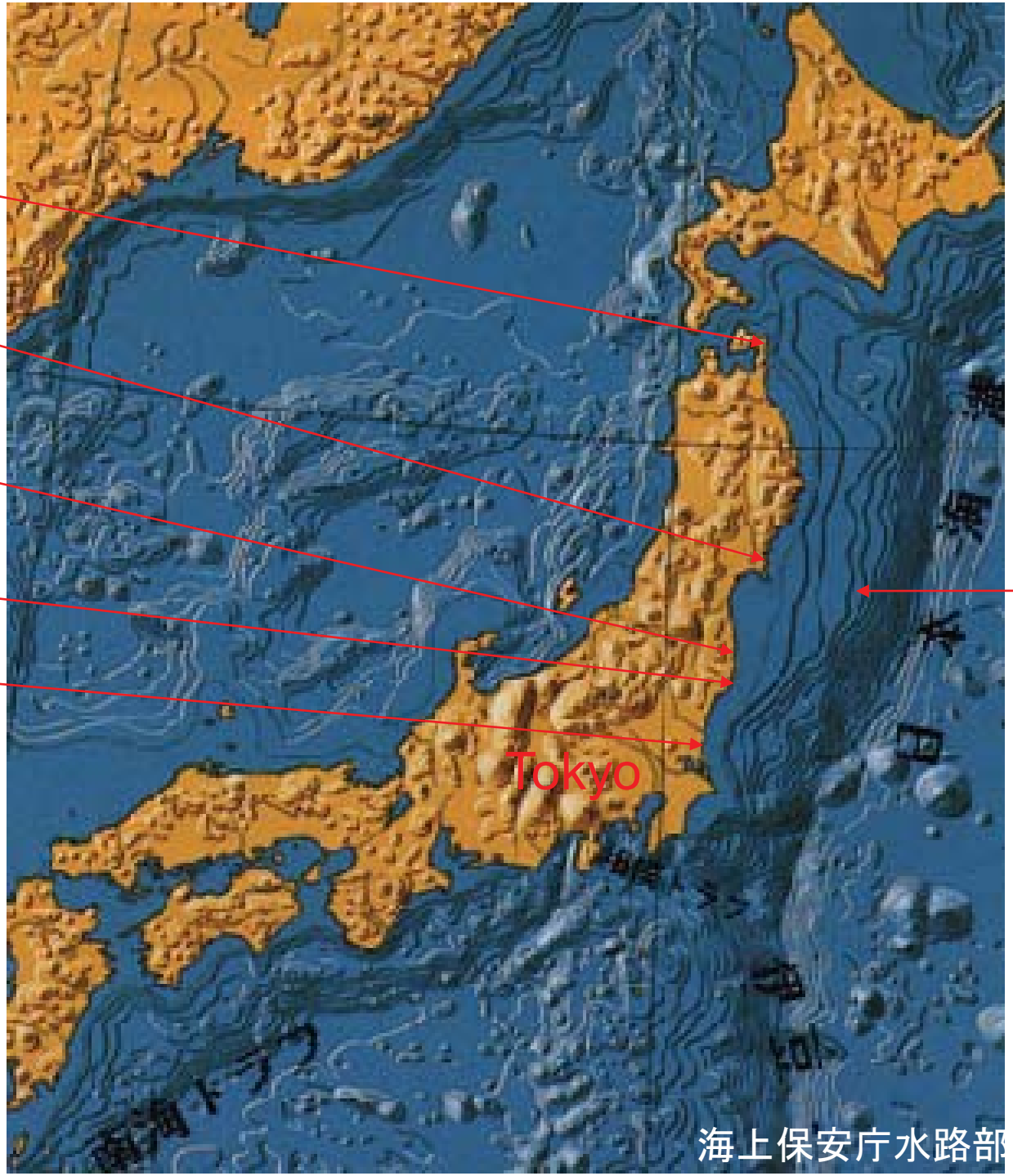
On March 11, 2011, at 14:46 (Japanese standard time)

Earthquake with Mw 9.0 at the Pacific Ocean of Tohoku

From 40 minutes to 1 hour later
Several waves of large tsunami attacked the coast of Tohoku-Kanto area

Peoples, buildings, thermal and nuclear power plants and every structures on the coast were suffered

More than 15,000 persons: died
Almost 4,000 persons: missing


Higashidori NPS
Onagawa NPS
Fukushima Daiichi NPS
Fukushima Daini NPS
Tokai Daini NPS
Epicenter
Tokyo
海上保安庁水路部

Nuclear Power Plants in Japan and in Tohoku Area

Operating Nuclear Power Plants in Japan

Total 54 plants, BWR 30 and PWR 24

Tohoku and Kanto Area

Total 15 BWR Plants

- Higashidori NPS (Tohoku EPCO): 1 plant
- Onagawa NPS (Tohoku EPCO): 3 plants
- Fukushima Daiichi NPS (TEPCO): 6 plants
- Fukushima Daini NPS (TEPCO): 4 plants
- Tokai Daini NPS (JAPCO): 1 plant

Fukushima Daiichi Nuclear Power Station

Fukushima Daiichi NPS: Japan's Oldest NPS

Unit 1 (BWR3) : constructed by GE
commercial operation from Jan. 1971
Unit 6 (BWR5) : constructed by Toshiba
commercial operation from Oct. 1979

At the Earthquake and Tsunami
Unit 1,2,3 plants were under normal operation

Unit 4,5,6 plants were under periodic inspection

Generation Facilities at the Fukushima Daiichi NPS

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
Electric output (MWe)	460	784	784	784	784	1100
Commercial operation	71/03	74/07	76/03	78/10	78/04	79/10
Reactor model	BWR3	BWR4			BWR5	
PCV model	Mark-1					Mark-2
Number of fuel assemblies in the core	400	548	548	548	548	764

Cited from Japanese government report to IAEA, June 7

Accident sequence at Fukushima Daiichi NPS

By the earthquake

Operating 3 plants(Unit 1,2,3): automatically shut down

All off-site power was lost

Emergency diesel generator power systems started

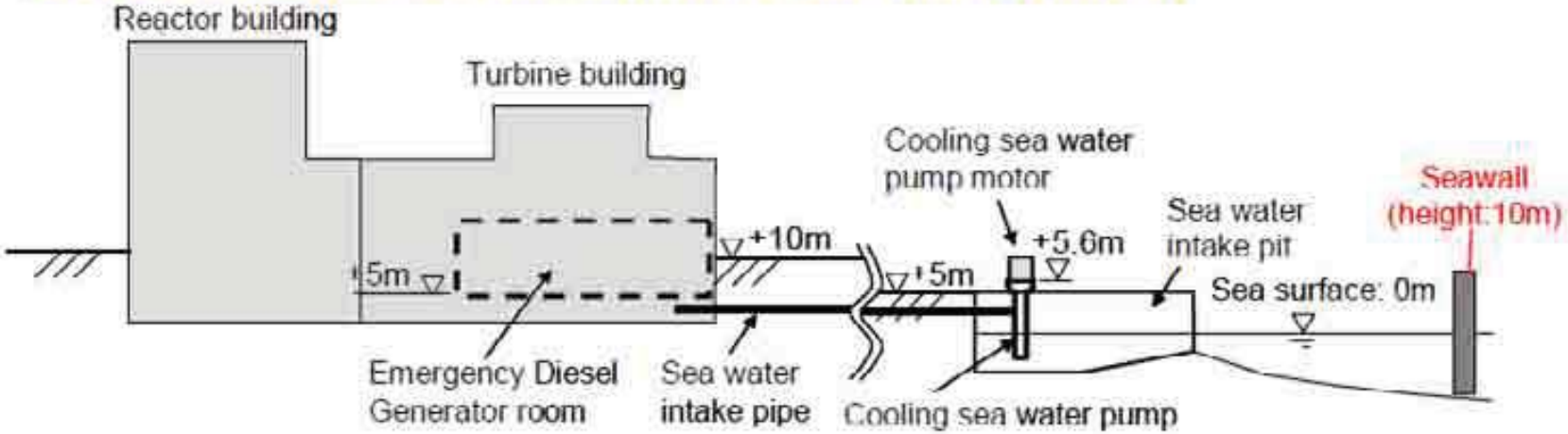
Emergency Cooling systems started

Isolation Condenser (IC):Unit 1

Reactor Core Isolation Cooling System (RCIC): Unit 2 &3

High Pressure Injection Cooling System (HPIC):Unit 3

Cross section of Fukushima Dai-ichi (Unit-1)



Reference: The Tokyo Electric Power Co., Inc. Release
[Online].http://www.tepco.co.jp/tepconews/pressroom/110311/index-j.html

Fig. III-2-5 Tsunami getting over seawall at the Fukushima Dai-ichi NPS.

Cited from Japanese government report to IAEA, June 7

Accident sequence at Fukushima Daiichi NPS

By the tsunami of almost 15 m high

All Emergency Diesel Generator Power Supply was lost
for Unit 1 to 4
Loss of all AC power
Loss of all terminal heat sink

Emergency cooling system did not work so long time
Resulting the heat-up and meltdown of the fuels

One emergency diesel (air cooled) generator was alive
It could supply power for Unit 5 and 6

Sequence at Fukushima Daiichi Unit 1

After earthquake at 14:46 and Tsunami at around 15:40

- Loss of all electric power
- Isolation condenser was stopped at the attack of Tsunami.
- Loss of cooling water for reactor fuels (14 hours with no cooling)
- Loss of all terminal heat sink

Nuclear fuels are estimated to start melting at around 17:00. (one hour and 20 min. later of the Tsunami attack.)

- Melted fuel moved to the bottom of reactor vessel and possibly some of the fuels dropped on the dry well floor.

Hydrogen generated by the Zirconium-Water reaction.

Containment Pressure increased.

Wet well venting at 14:30 on March 12, and hydrogen explosion at 15:36 on March 12. Destruction of reactor building

Sequence at Fukushima Daiichi Unit 2

After earthquake at 14:46 and Tsunami at around 15:40

Loss of all electric power
RCIC was continued to inject the water to the fuel.
Loss of all terminal heat sink: feed and bleed operation

RCIC stopped at 13:25 on March 14. (Loss of cooling water for 6 hour and 30min., until sea water injected.)

Nuclear fuels are estimated to start melting at 18:00 on March 14.
Melted fuel moved to the bottom of reactor vessel.

Containment pressure increased. Wet well venting at 11:00 on March 13.

Sound of explosion around the torus room of containment vessel at 6:00 on March 15. No visible damage for reactor building.

Sequence at Fukushima Daiichi Unit 3

After earthquake at 14:46 and Tsunami at around 15:40

Loss of all electric power
RCIC was started to inject the water at 16:03 on March 11.
Loss of all terminal heat sink: feed and bleed operation

RCIC stopped at 11:36 on March 12. HPIC started at 12:35 on March 12 and stopped at 2:42 on March 13. (Loss of cooling water for 6 hour and 40 min., until sea water injected.)

Nuclear fuels are estimated to start melting at 8:00 on March 13. Melted fuel moved to the bottom of reactor vessel.

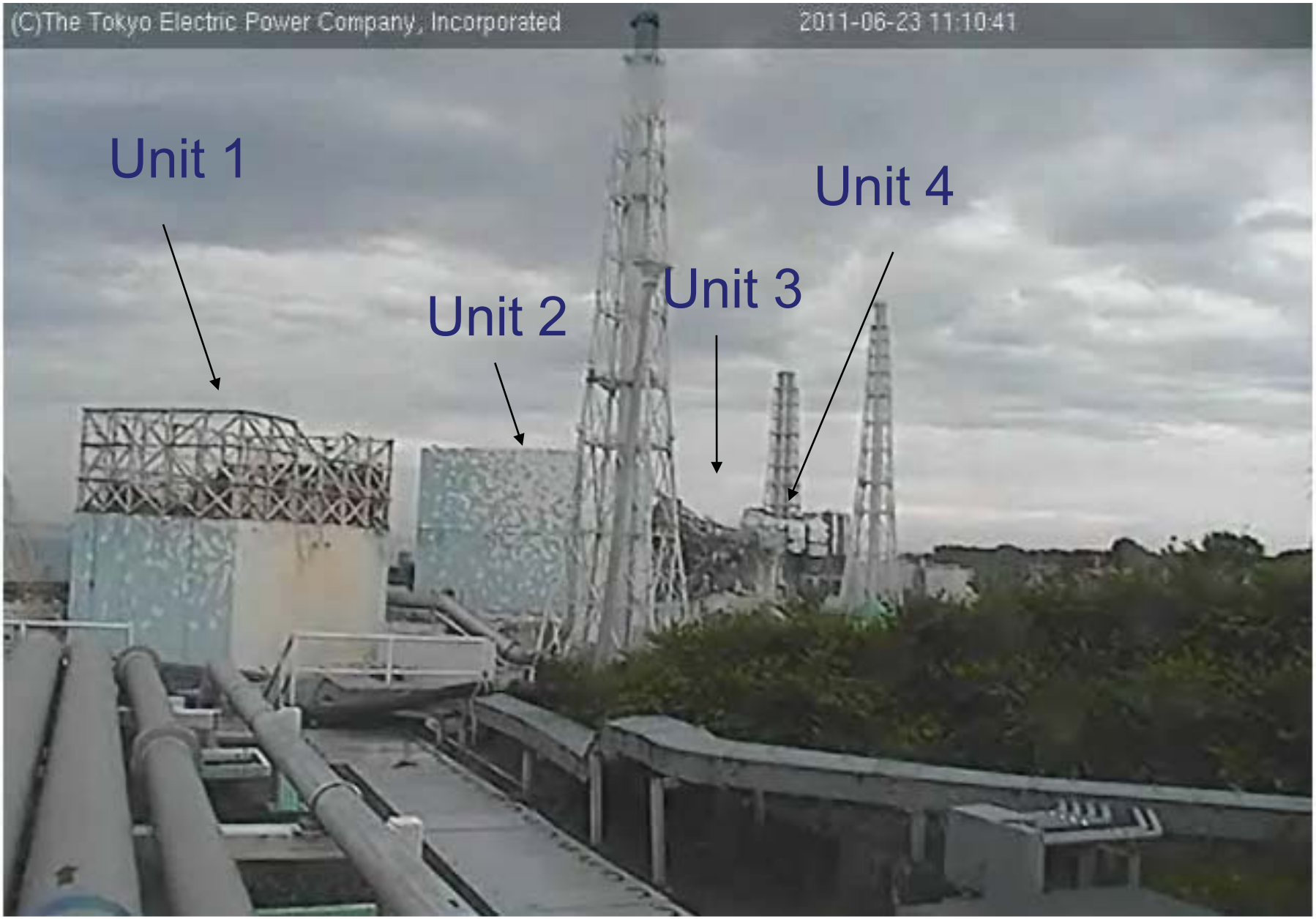
Wet well venting at 5:20 on March 14, and hydrogen explosion at 11:01 on March 14. Destruction of reactor building

Sequence at Fukushima Daiichi Unit 4

Unit 4 was shut down for periodic inspection
all of the fuels were transferred to the spent fuel pool

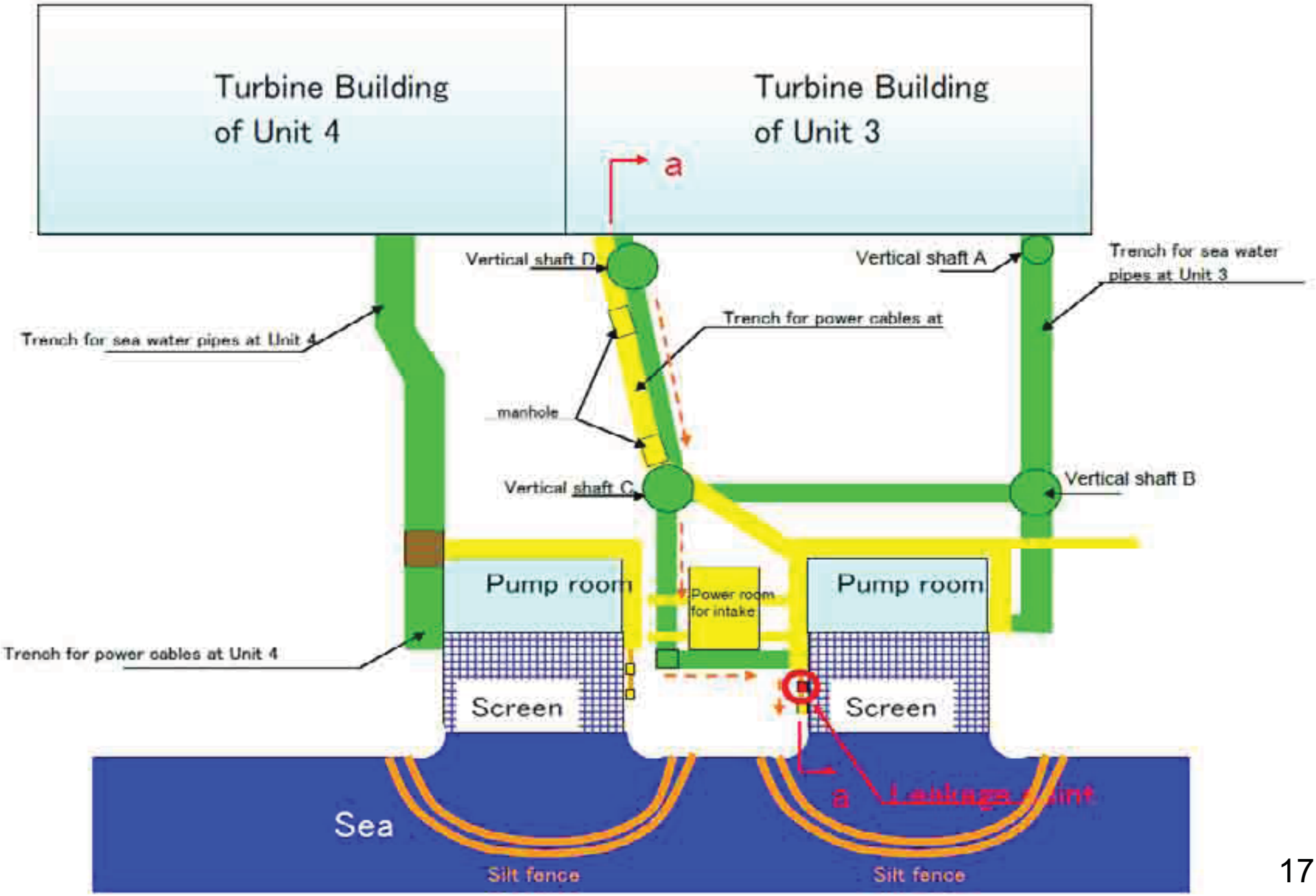
External power was lost by the Earthquake and emergency diesel generator stopped by the Tsunami:
The function to cool the spent fuel pool and to feed the water was lost

At around 6:00 on March 15, explosion of No.4 building occurred. Cause of the explosion is estimated to be the inflow of Hydrogen through the piping from the Unit 3



Cited from TEPCO homepage

Trench for sea water pipes at Unit 3 (plain view)



Cited from Japanese government report to IAEA, June 7

Sequence of Other 11 Plants

Important Items for the plants

(1) External AC power supply : alive or lost
(2) Emergency diesel generator : alive or lost
(3) RHR (Residual Heat Removal system) : alive or lost
(4) Plant status : in operation or under periodic inspection

(1) External AC power supply alive: Operating 6 plants.

(1-1) RHR/auxiliary cooling system alive, and RCIC et al. alive:
3 plants. Onagawa Unit 2 and 3, and Fukushima Daini Unit 3.
Cold shutdown status was reached on March 12.

(1-2) RHR system lost. Later Temporary Cable installed for RHR :
3 plants. Fukushima Daini Units 1,2 and 4.
Cold shutdown status was reached on March 14 or 15.

Sequence of Other 11 Plants

(2) External AC power supply lost: Operating 2 plants.

(2-1) Emergency Diesel Generator on, and RHR alive:
2 plants. Onagawa Unit 1 and Tokai Daini Unit.
Cold shutdown status was reached on March 12 and 15.

(3) External AC power supply lost: Under periodic inspection, 3 plants.

(3-1) Emergency Diesel Generator on, and RHR lost, Later it recovered.
2 plants. Fukushima Daiichi Unit 5 and 6.
Cold shutdown status was reached on March 20.

(3-2) Emergency Diesel Generator on. Fuels were outside reactor:
1 plant. Higashidori Unit.

Either External AC Power or Emergency Diesel Generator was alive,then plants could be reached to the cold shutdown status

Evacuation of the residents surrounding the NPS

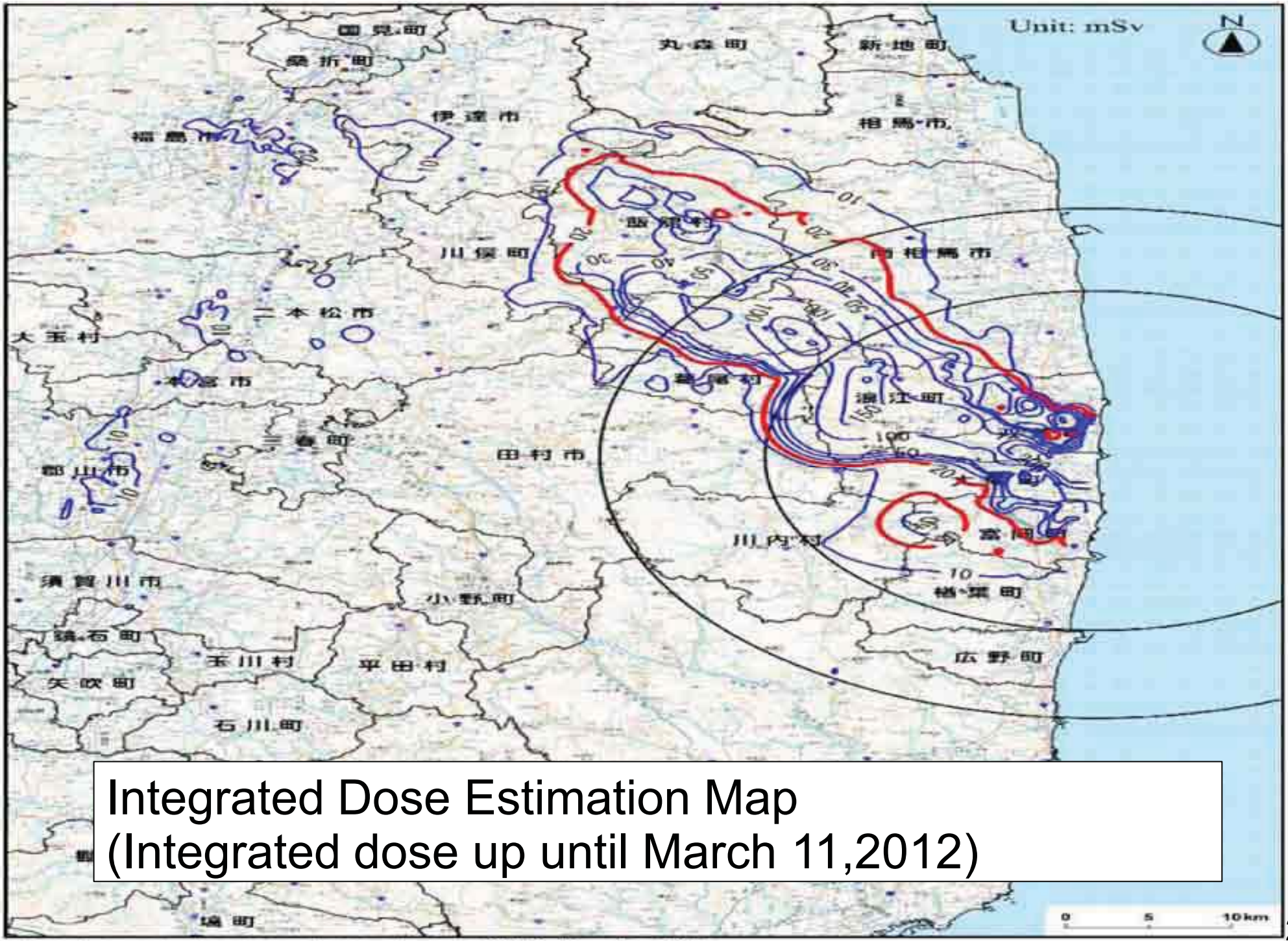
At 21:30 on March 11, Prime Minister instructed to evacuate the residents within 3 km radius from NPS, and to stay in house within 10 km radius

At 5:44 on March 12, Prime Minister instructed to evacuate the residents within 10 km from NPS

At 18:25 on March 12, Prime Minister instructed to evacuate the residents within 20 km from NPS and to stay in house within 20 to 30 km radius

Evacuation area was expanded and additional evacuation area was set afterward

Evacuated persons are about 78 thousand.



Integrated Dose Estimation Map (Integrated dose up until March 11,2012)

Based on actual values observed up to 24:00, May 11, 2011

Cited from Japanese government report to IAEA, June 7

Road map for the settlement of the accident

TEPCO announced on April 17

Basic Policy

Reactors and spent fuel pools:stable cooling condition

Mitigating the release of radioactive materials

Every effort to enable evacuees to return to their home

All citizens to secure a sound life

Targets: two steps

Step 1: Time line is Middle of July

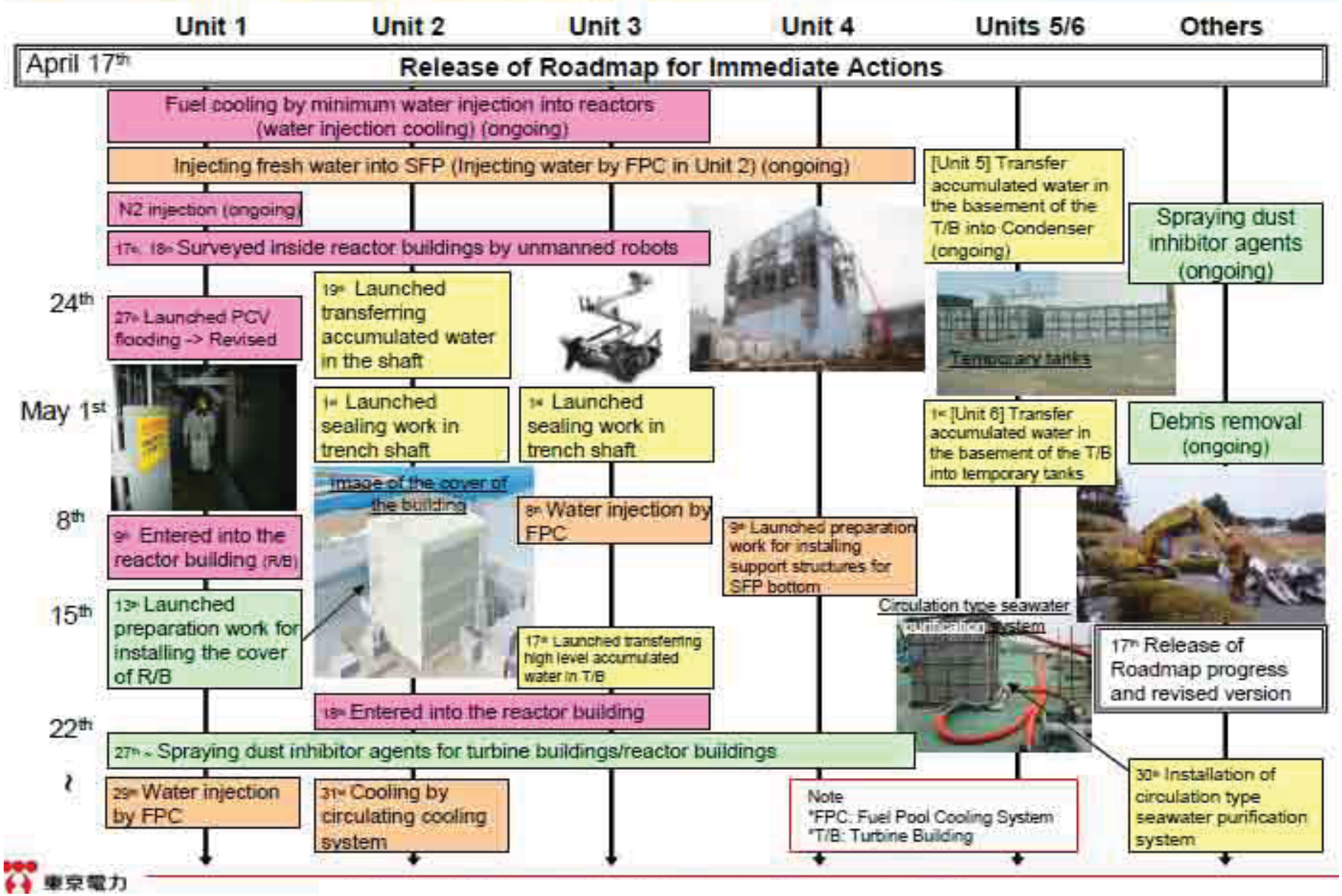
Radiation dose in steady decline

Step 2: Time line is 3 to 6 months after step 1

Release of radioactive materials under control

Radiation doses being significantly suppressed

Work Progress at the Site As of May 31



Cited from TEPCO homepage

Evaluation of Step 1 and Target of Step 2

Evaluation of Step 1

(1)Stable cooling was established for reactors and fuel pools. The temperature at the bottom of reactor pressure vessel are keeping about 100 to 120 ℃.

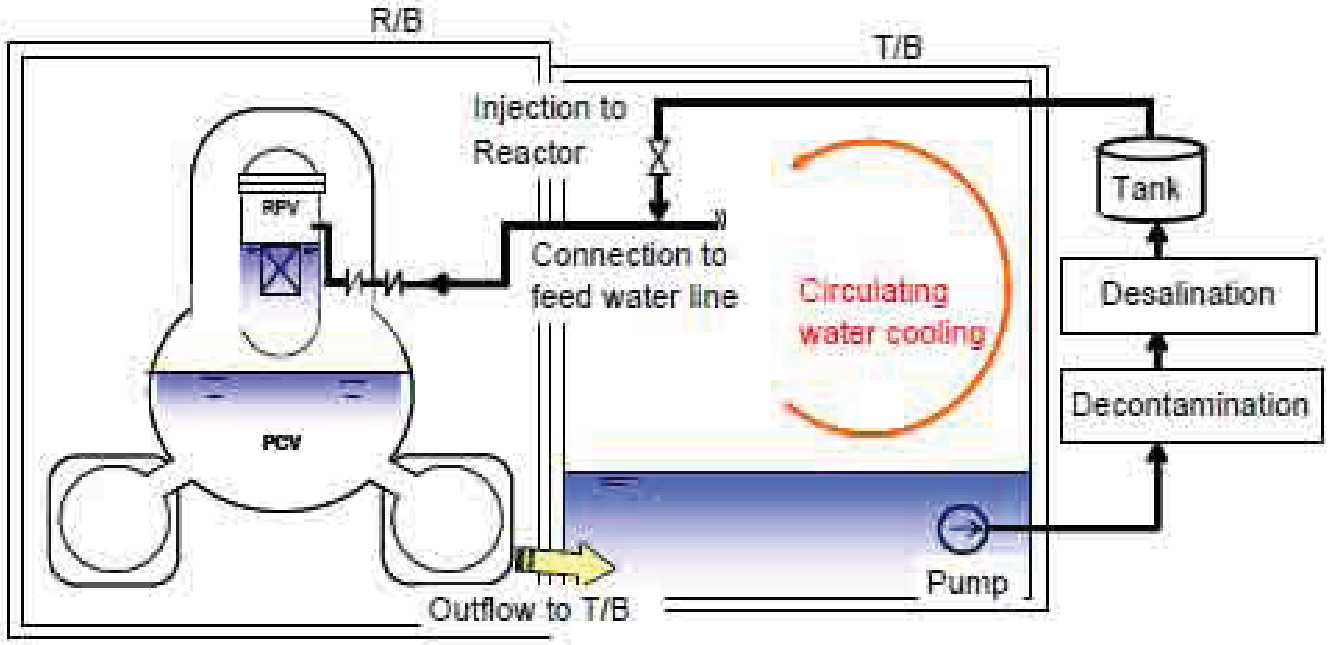
(2)The radiation dose has been declining during the period of Step 1 and confirmed that the exposure dose at the site boundary is approximately 1.7 mSv/year at the most (Cs134, 137).

Target of Step 2

(1)Continue the circulating cooling and bring cold shutdown status.

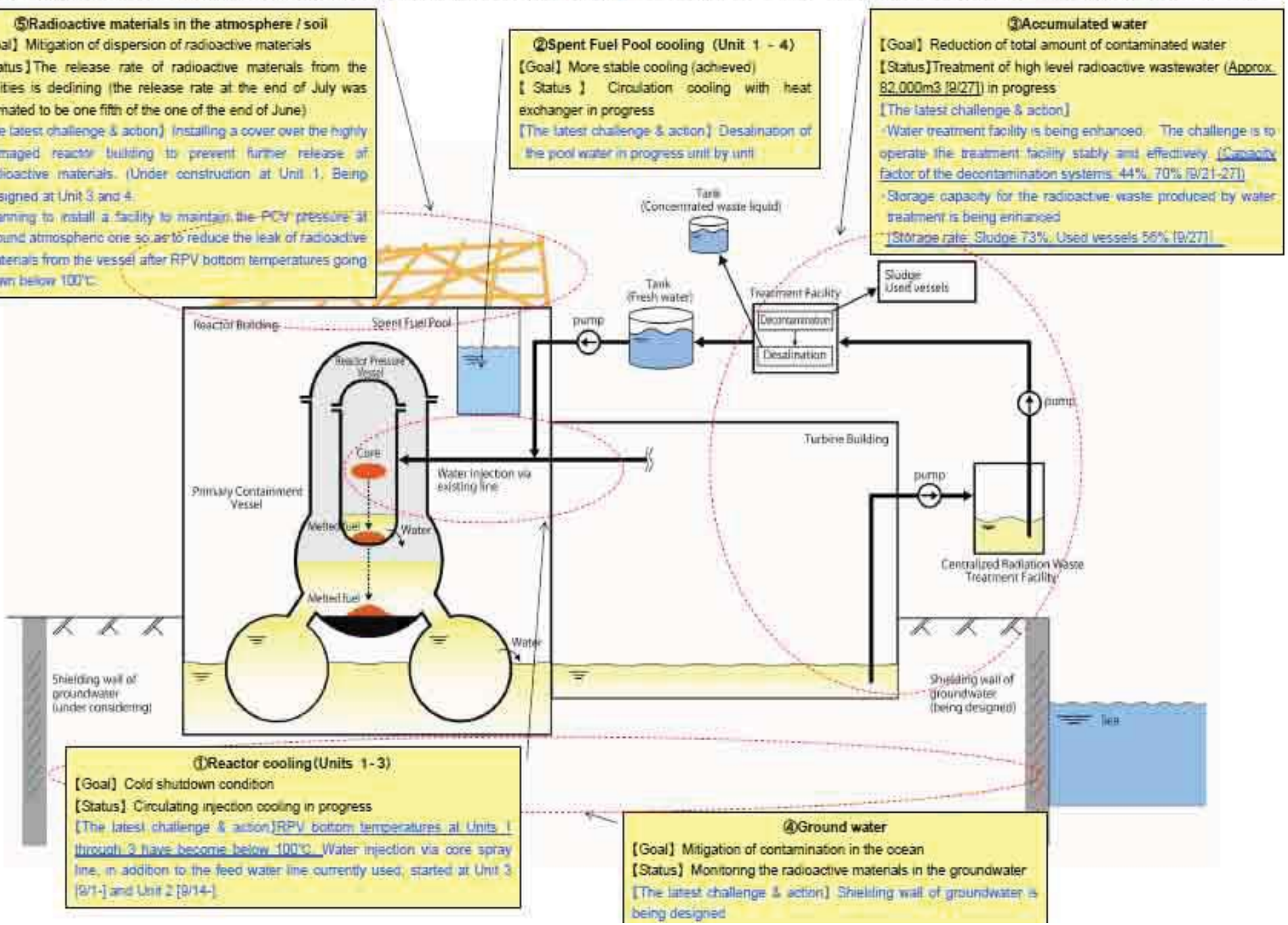
(2)Release of radioactive materials under control and radiation dose is significantly held in.

Circulating Water Cooling System



System outline of water reuse as reactor coolant by processing accumulated water

Overview of the status of countermeasures at Fukushima Daiichi Unit 1 - 4 (Sep. 22nd-28th Refer to the attached table for details of ①-⑤)



Cited from JAIF Homepage

Lessons learned from the accident (5categories and 28 items)

Category I: Strengthen measures against a severe accident measures against earthquakes and Tsunami et al.

Categoruy 2: Enhancement of response measures against severe accident: measures to prevent hydrogen explosion, containment venting et al

Category 3: Enhancement of nuclear emergency responses Combined emergencies of both large-scale natural disaster and prolonged nuclear accident et al

Category 4: Reinforcement of safety infrastructure Reinforcement of safety regulatory bodies, reinforcement of legal structure, criteria and guidance et al.

Category 5: Thoroughly instill a safety culture

Actions Regarding to the Lessons Learned

(1) Overall Safety Evaluation

Evaluate the robustness of plants for external events

(2) Revision of Safety Guideline
Seismic safety and severe accident

(3) Revise of the Regulatory Bodies
NSC, NISA and a part of MEXT will become one agency

(4) Restart Condition of the Stopping Plants

(5) Investigation Committee on the Accident at the Fukushima Nuclear Power Stations of TEPCO
Comprehensive investigation for fundamental cause of the accident

Regarding the Accident

1. First Reactor was Introduced by turn-key contract
   from GE (BWR) and Westinghouse (PWR)
   Lack of fundamental R&D experience in Japan
2. First Plant constructed more than 40 years ago
   Science & Technology developed sharply after then
   How to feedback in old plants with long life time
3. Wide Scientific & technological fields are concerned
   Cooperation among various fields required
4. Companies existed with high technology in Japan
   Very important in today's highly developed technological society

We will do our best for the Nuclear Energy Safety in the world

Thank you very much