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on Occupational Exposure Management at Nuclear Facilities
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Radiation Protection Management in Fukushima Daiichi NPS and Post-accident Measures

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Radiation Protection and Management Group
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TEPCO TOKYO ELECTRIC POWER COMPANY

My Background

- ’92~’97:Tokyo University
  - BS/MS in metallurgical engineering
- ’98~:TEPCO
  - ’98~’01:Radiation Protection Dept., Fukushima Daiichi NPS
  - ’01~’07:Radiation Protection Dept., Tokyo H/Q
  - ’07~’10:Operation Management Dept., Tokyo H/Q
  - ’10~’12:Radiation Protection Dept., Fukushima Daiichi NPS
    - Mar. 11 / 2011 Great East Japan Earthquake
    - Mar. 11~ Health Physics Team
      - Liaison between NPS and H/Q
      - Recording external dose
    - Apr.06 Going home for the first time in one month
  - ’12~:Radiation Protection Dept., Tokyo H/Q

Recollection of the Post-Accident Activities

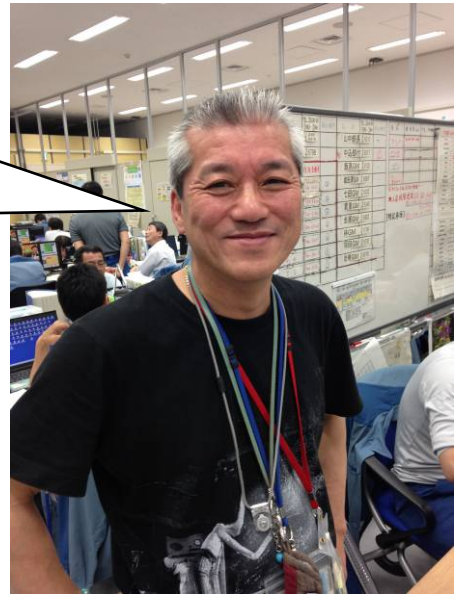
- **I felt the great shake I have never met on Mar.11,2011.**

- **I acted as the health physics team in the seismic building.**

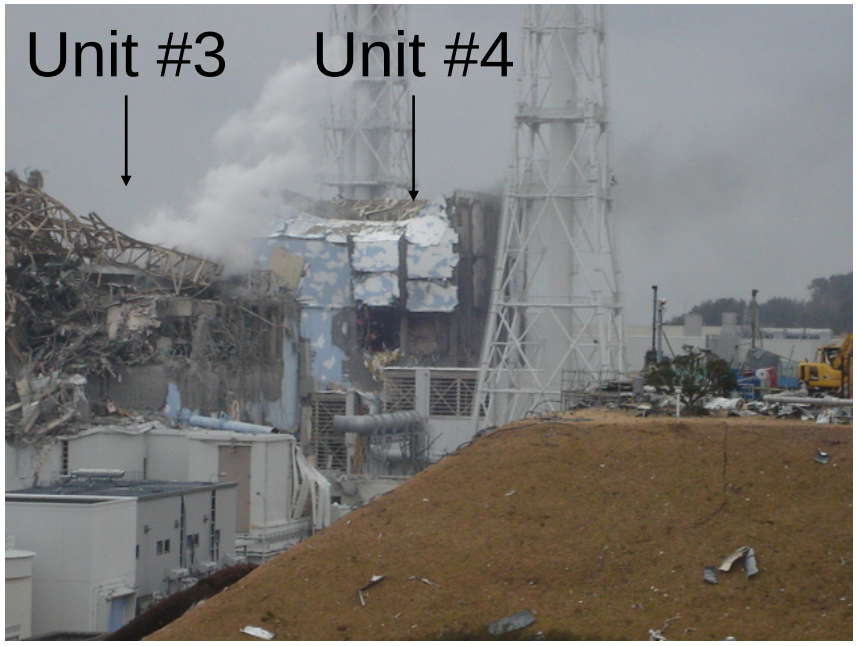
Recollection of the Post-Accident Activities

Mar. 15

I did not want to take you a dangerous place, but I cannot but do so. I'm sorry. Would you come with me?



Mr. Honma



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- Radiation situation inside Fukushima Daiichi NPS
- Radiation protection issues
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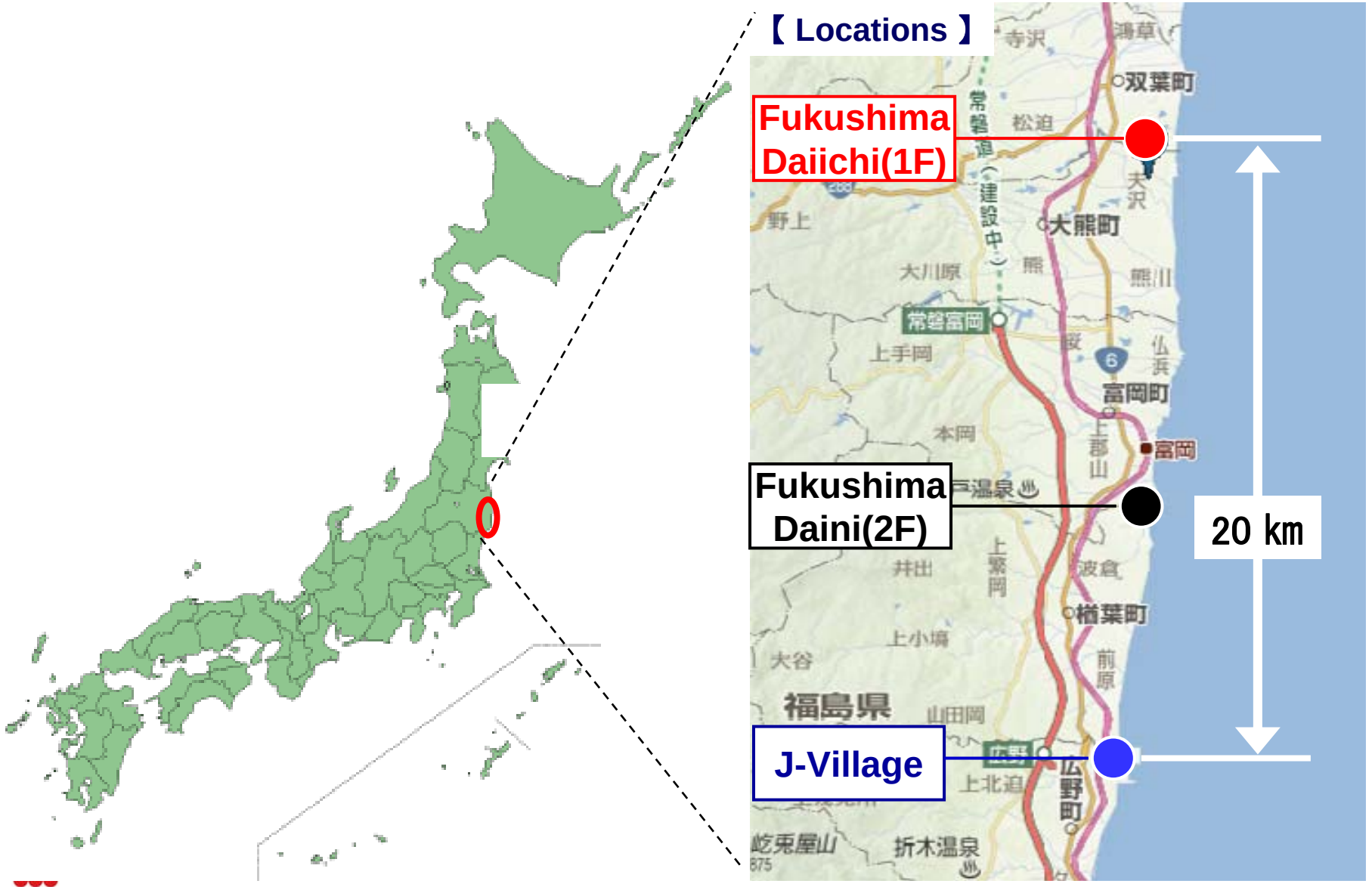
  - Exposure exceeding dose limit
- Post-accident Activities
  - Decontamination and dose reduction
  - Trend of occupational exposure
- Deployment of lessons learned

Locations of the Fukushima Daiichi NPS and J-Village



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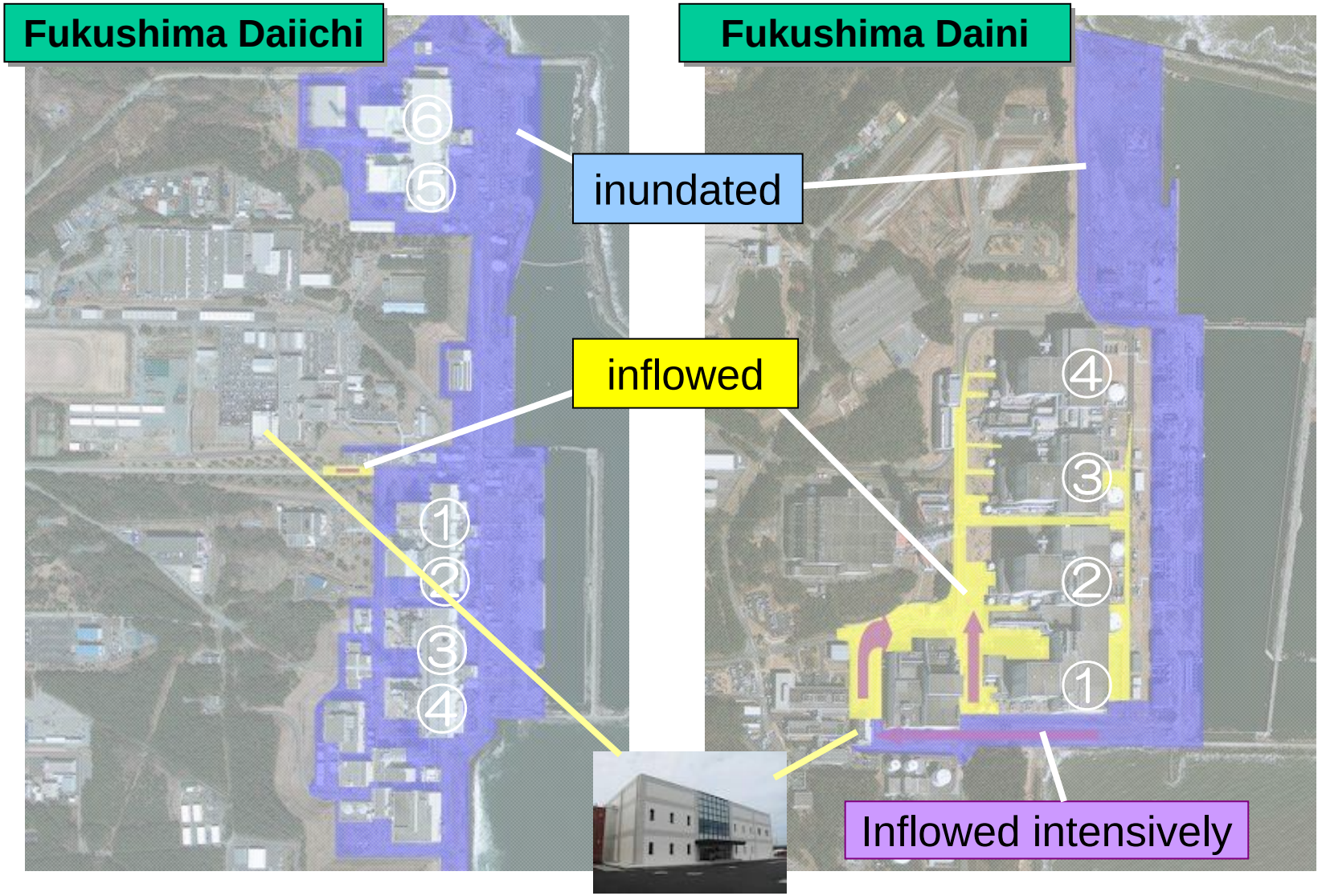
Inundated and Inflowed Area at Fukushima Daiichi and Daini Site



Seismic building

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Tsunami attacked Fukushima Daiichi NPS

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The situation at the earthquake and the tsunami

- Unit 1, 2, 3 were in operation, unit 4,5,6 were outage at the earthquake.
- Emergency control room was in seismic building, which has been the front line of all emergency activities since the accident.
- Hydrogen explosion blew off the top ceiling and walls of reactor buildings of unit 1,3,4.
- Debris, road damages caused by the earthquake and tsunami, rubbles by hydrogen explosion disturbed the restoration work.
- All electric power supply was lost for Unit 1-4 after the tsunami. For Unit 5&6, only one diesel generator was survived.

Dose limit regulation

- Dose limit in Japan is 100mSv per 5 years and 50mSv per one year (5mSv per 3 months for female)

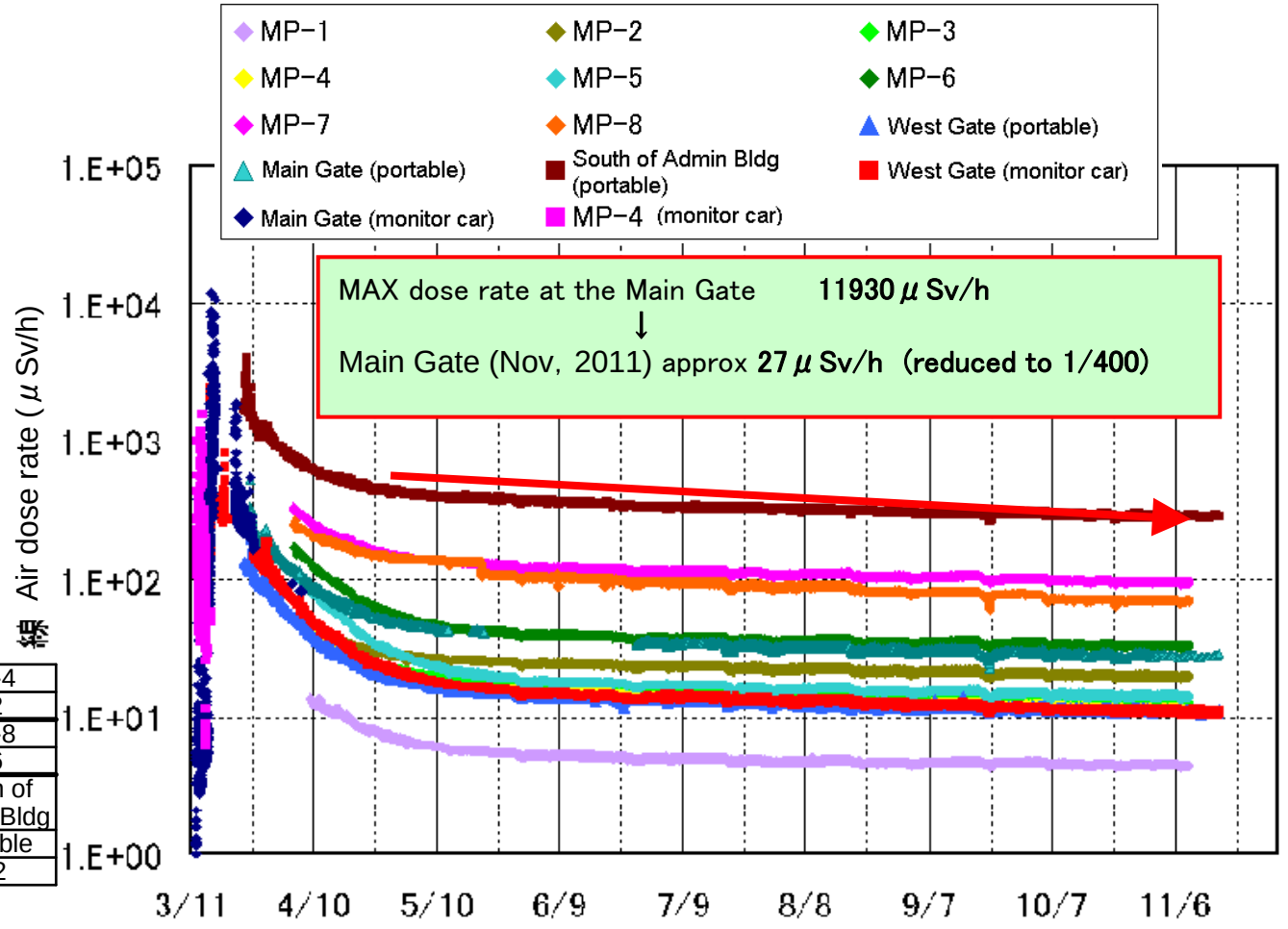
- Dose limit for emergency workers was 100mSv by regulation before the accident, but it was raised to 250mSv on March14, 2011.
  - After November 1 2011, the limit of new comer for emergency was back to 100mSv.
  - After December 16 2011, the limit for emergency workers returned to 100mSv.

Dose rate monitoring at Monitoring Post

- **The air dose rates at each point were dramatically increased by the accident. After that, indicated steady downward trend and at this moment, at the background level at each point.**

MP-1	MP-2	MP-3	MP-4
2.4	4.1	4.6	4.2
MP-5	MP-6	MP-7	MP-8
4.4	1.6	2.3	2.6
West gate		Main gate	South of Admin Bldg
monitar car	Portable	Portable	Portable
2.6	12	4	122

Measurement date: May 6, 2014



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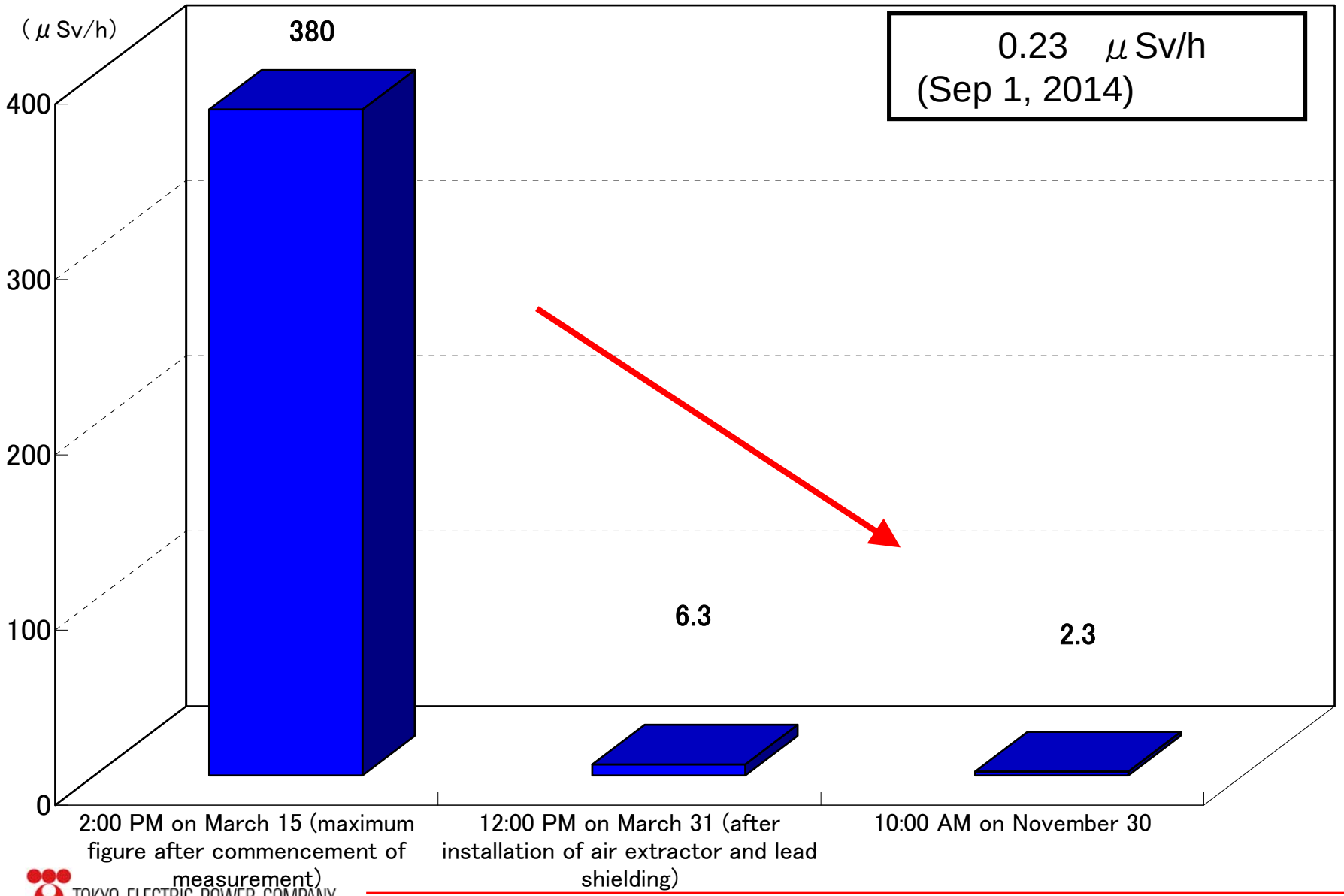
Air dose rate on seismic building on second FL.



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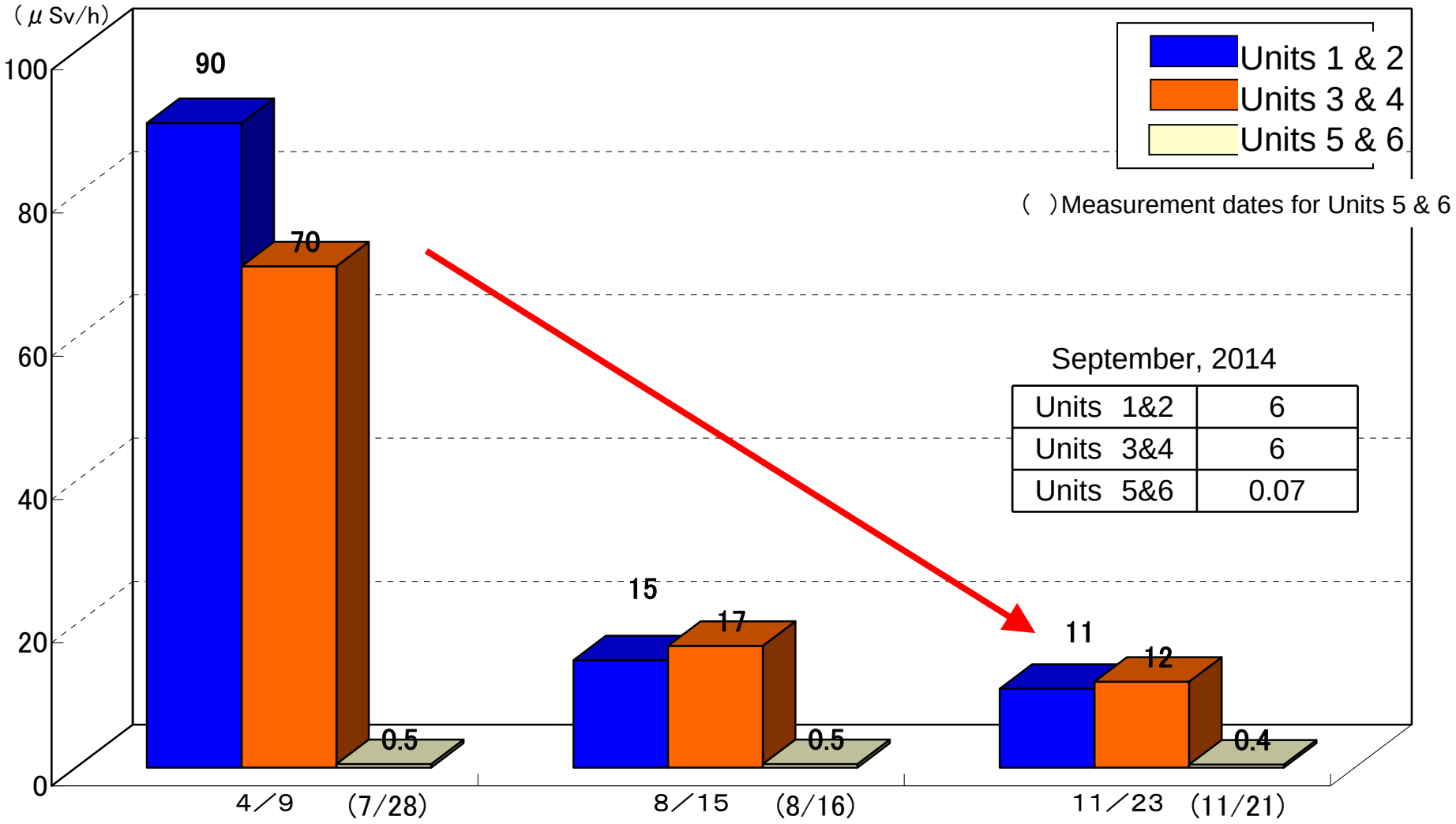
Air dose rate in the main control room



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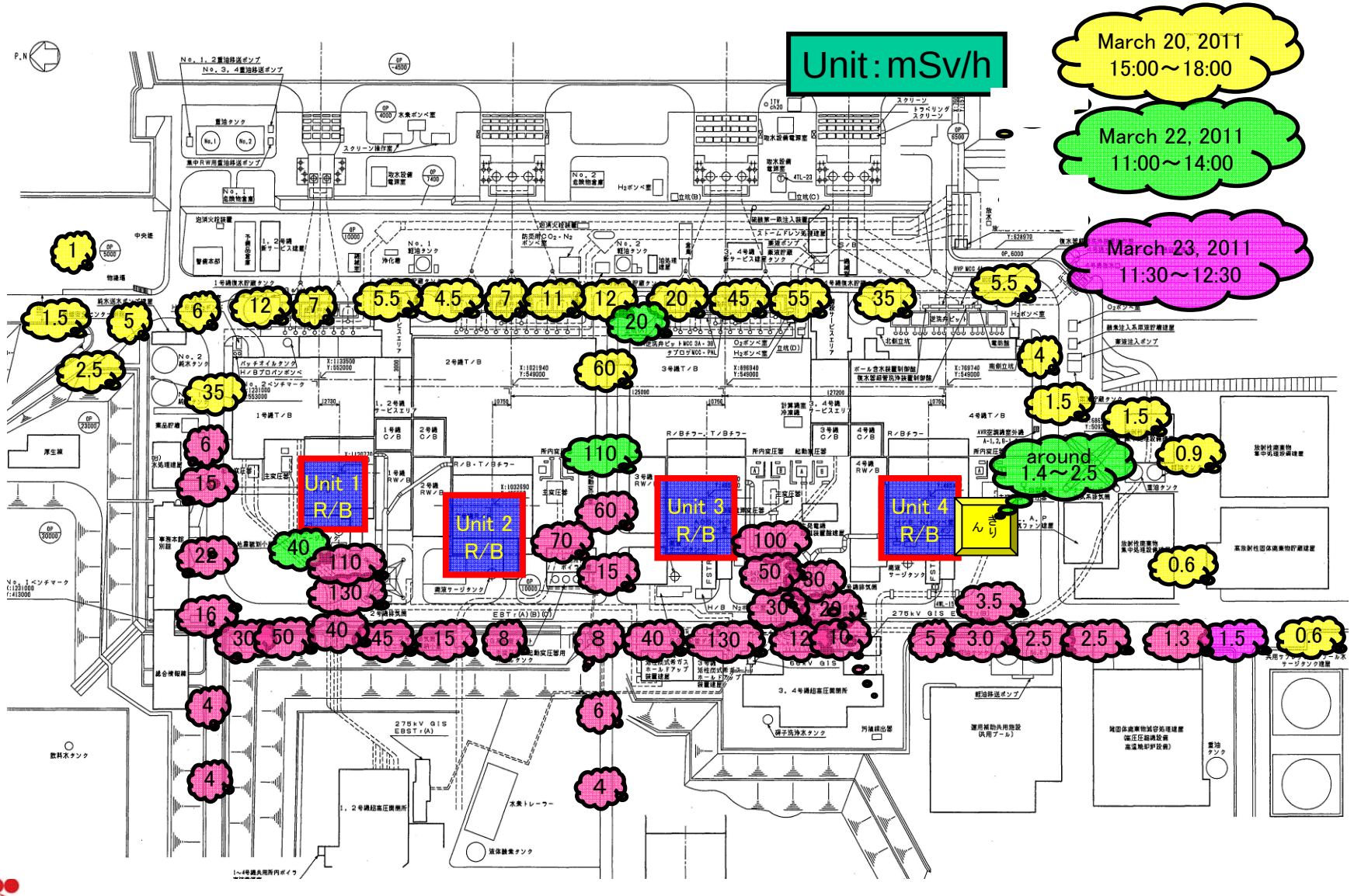
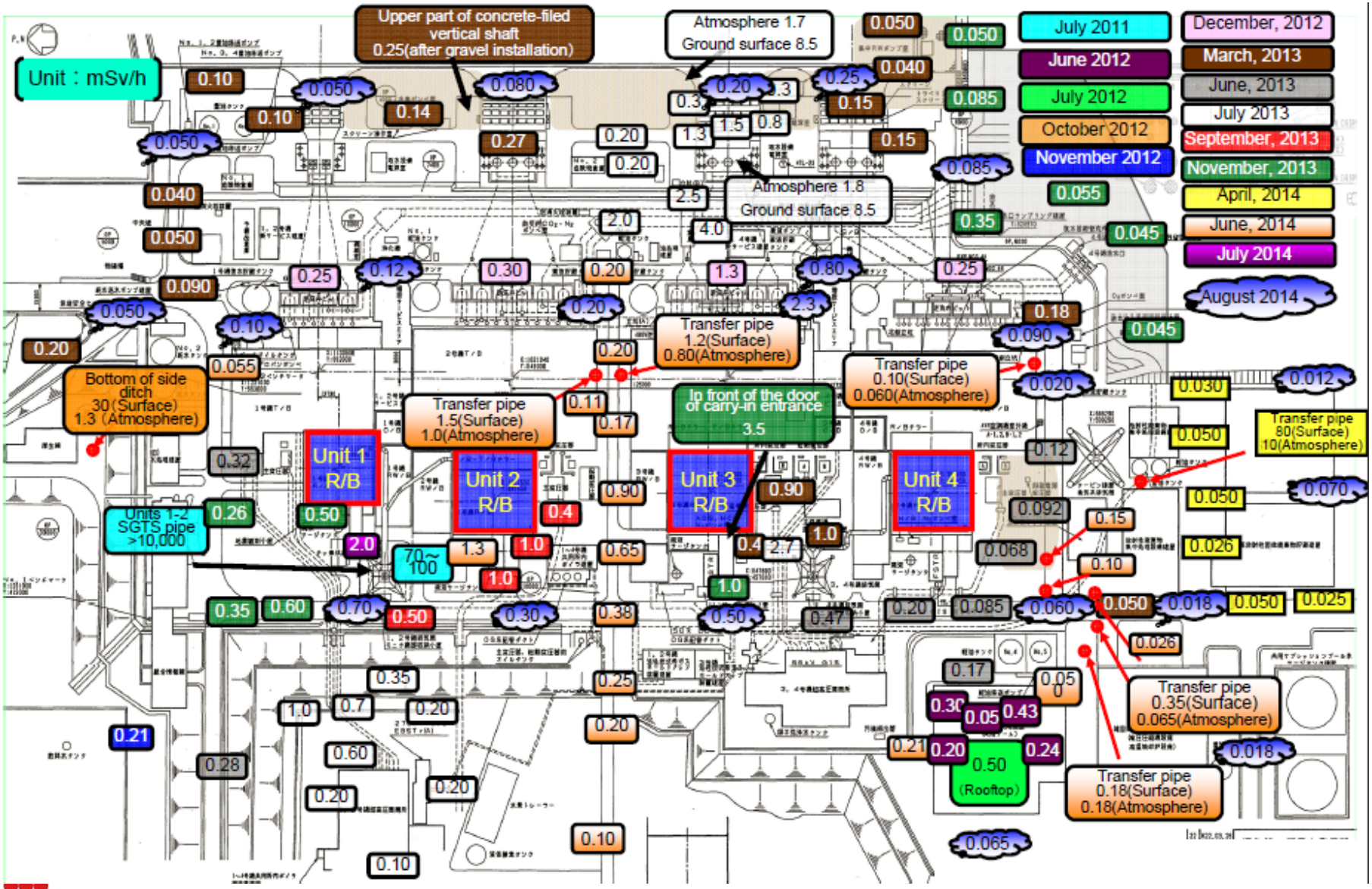
Survey map of inside Fukushima Daiichi NPS (Unit 1 to 4) on March 23, 2011

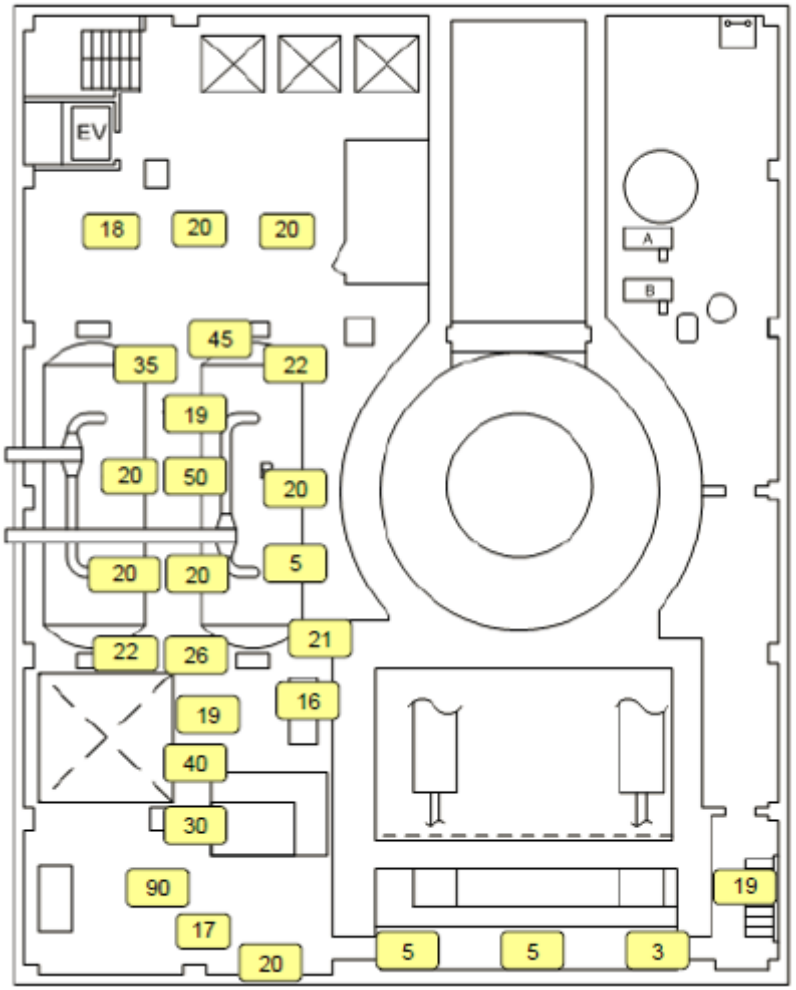


Survey map of inside Fukushima Daiichi NPS (Unit 1 to 4) on August 7, 2014

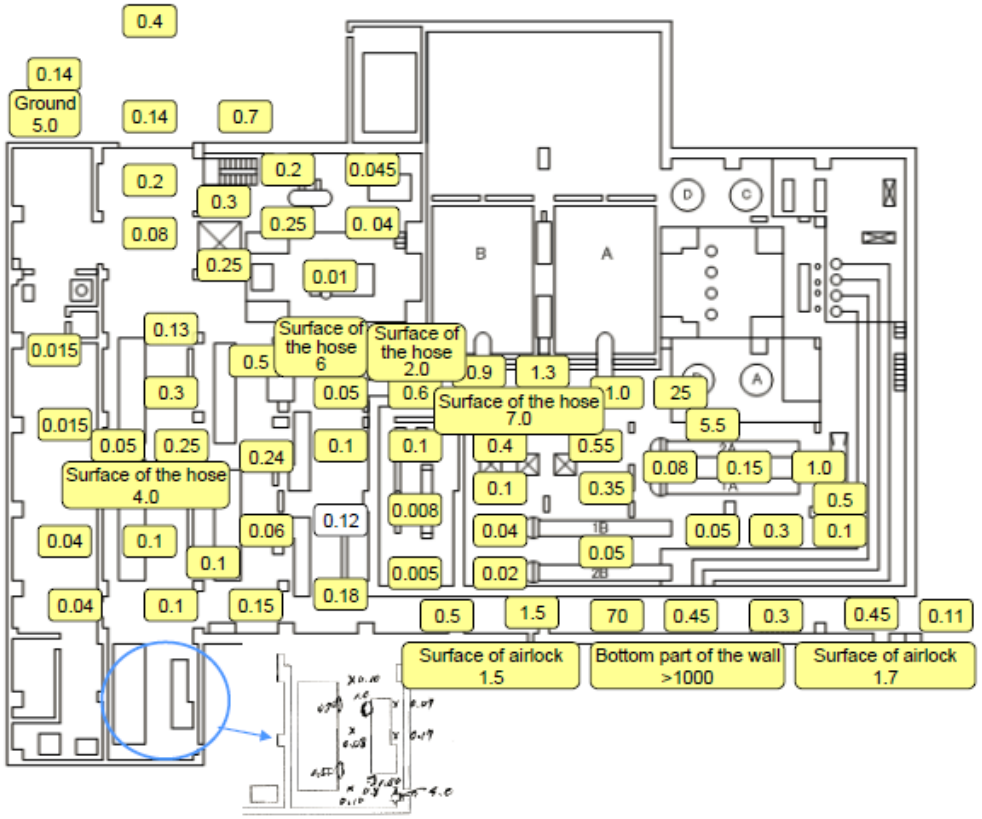


Air dose rate in the building

- 4FL, R/B, Unit 1



- 1FL, T/B, Unit 1



Unit: mSv/h

http://www.tepco.co.jp/en/nu/fukushima-np/f1/surveymap/index-e.html

Monitoring(1)

[Before the Earthquake]

- **There are 8 monitoring posts around 1F site.**
- **We were monitoring air dose rate continuously.**
- **We also transmitting monitoring data to the self-governing body and disclosed it on our homepage continuously.**

Monitoring post No.2

Monitoring(2)

[Emergency responses]

- Because of power loss, all monitoring posts became inoperable.(~Apr.8 2011)
- We measured air dose rate by two monitoring cars and three portable monitoring posts.

Monitoring car (KK)

Portable monitoring post at main gate

Monitoring(3)

[Post-accident measures]

- **Because of fallout, dose rate of monitoring post kept high level.**
- **We reduced the influence of fallout by surface soil stripping or shielding around monitoring post.**

Monitoring post No.2

	Air dose rate (μSv/h)	
	Before (Feb 2012)	After (Apr 2012)
MP-2	18.5	7.9
MP-7	83.6	9.7

External exposure management(1)

[Before the Earthquake]

Radiation management system

RCA access control

ID and APD data are checked by the system before entering and leaving RCA.

Access control system

Measurement of individual dose

Workers must have electric alarm pocket dosimeter (APD) in RCA.

APD system

Input work type information

At each entry, work type information is entered.

Radiological work management system

Management of external dose

Individual dose management (Daily, Monthly, Yearly)

- Dose limit
- Dose distribution
- Dose notification to workers

Collective dose management (by work type)

- Radiation work planning
- Radiation work report

External exposure management(2)

[Emergency responses]

■ Radiation management system lost function and APDs unavailable

- ➢Tsunami and power loss caused the system down and about 5,000 APDs and their battery chargers cannot be used

■Registration of emergency workers at seismic building and J-Village

- ➢ Each worker was specified in the notebook written by hand.

■External dose management

- ➢ Gathered 50 APDs stored in the seismic building and found 270 available APDs in the plant. (total of about 320 APDs)
- ➢ Due to the insufficient number of APD, one representative of each working team had APD under the limited conditions.
- ➢ Exposure during travel to the seismic building and stay there should be taken into consideration.

External exposure management(3)

[Post-accident measures]

- After April 1, 2011, APDs were provided and sufficient for emergency workers
  - Glass dosimeter have been provided for all TEPCO personnel since November 2011. (Some workers have been already used glass dosimeter since the earthquake.)
- Workers registration using barcode reader at the seismic building (April 2011), at the J-Village (June 2011)
  - Added receipt issuing function (August 2011)
  - New individual dose management system released (Nov. 2011)
- New building for controlling radiation workers entry to 1F in operation （June 30,2013）

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Internal exposure management (1)

[Before the Earthquake]

Measurement and assessment with Whole Body Counters (WBC)

Whole Body Counter (WBC)

Fukushima Daiichi: 4 units
(1 for spectrometry analyses)
Fukushima Daini: 4 units
(1 for spectrometry analyses)

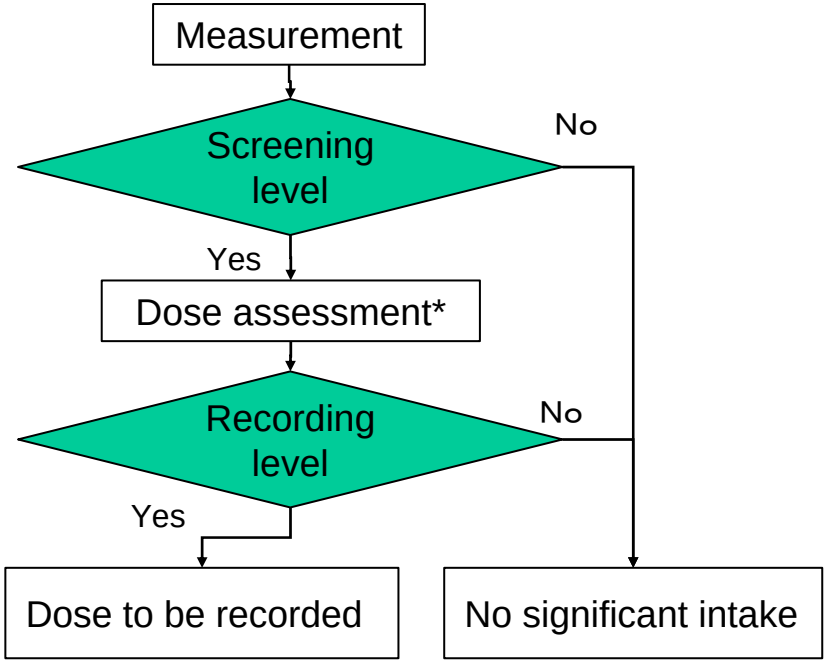
Management of internal dose

Periodic measurement

•Once every 3 months (monthly for female personnel)

Measurement as needed

•When internal intake is suspected



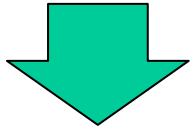
*Spectrometry WBC measurement

Internal exposure management (2)

[Emergency responses]

■**All WBC of Fukushima Daiichi and Daini were unavailable**

➢**Because of power loss, contaminated equipment and high background of ambient environment.**



■**Support from the Japan Atomic Energy Agency (JAEA)**

➢**In-vehicle WBC (NaI type) was deployed in the low background location (Onahama Call Center 21 March, 2011).**

➢**Measurement of radionuclide spectrometry analysis by WBC in JAEA (Tokai)**

■**Use WBC of Kashiwazaki Kariwa and recover of Fukushima Daini**

➢**Prior examination of female workers in the seismic building and the workers who had external exposure in excess of 100mSv.**

➢**It took time to determine the internal exposure because of the uncertainties of the date of intake and Iodine contributions.**

Internal exposure management(3)

[Post-accident measures]

- 11 WBCs have been operated at Hirono Football Stadium (close to J-village).
- Measuring internal exposure once a month for emergency workers.

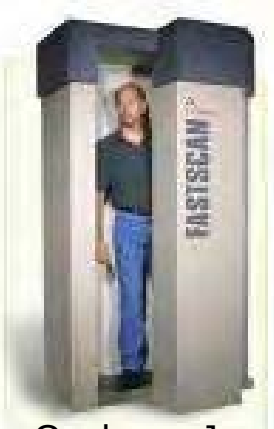
WBC center at Hirono Football Stadium

Inside the building

Source :Fuji Electric Co.

Source :JAEA

Source :Fuji Electric Co.



Source :Canberra Japan KK.

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Difficulties of collecting exposure data

- **We can not get in touch with some emergency workers listed in the notebook.**
  - **Notebook (written by hand) was used for the registration of emergency work at the seismic building and J-village.**
  - **Because of bad writing, lack of information (no affiliation, only family name etc.), it was difficult to identify the workers when the individual data was entered into the new dose management system.**
  - **10 workers on the list are still no contact**

- **Delayed evaluation of internal exposures**
  - **WBC were unavailable and physical contamination affected the WBC measurement**
  - **It took time for identifying the intake date of radioactive materials and not ready for the assessment methodology.**

  →*As very conservative evaluation of the internal exposure, first day of the work is the date all radionuclide were taken.*

Exposure exceeding dose limit (1)

1) Exposure exceeding the emergency dose limit of 250mSv

- **6 workers engaged in emergency works exceeded 250mSv, which is the dose limit raised temporarily after the Fukushima accident.**
- **The exposure was firstly managed based on the external dose due to an insufficient WBC units. After the measurement and evaluation of internal dose, the exposure exceeding 250mSv was observed.**
- **Those workers had medical examination by a specialized doctor at the National Institute of Radiological Sciences; no health effects, such as an acute disorder, were observed.**
- **We will continue to provide a periodic medical examination for the follow-up of those affected.**

Employees	Internal exposure	External exposure	Distribution of effective dose
A	590	88.08	678.08
B	540	105.56	645.56
C	241.81	110.27	352.08
D	259.7	49.23	308.93
E	433.1	42.4	475.5
F	327.9	31.39	359.29

Exposure exceeding dose limit (2)

[cause]

- The 6 employees were operators, maintenance workers of electrical or instrument team who engaged in monitoring and restoring at main control room (MCR)
- They ingested radioactive materials in MCR
  - **Invasion of radioactive materials into MCR through door which was damaged by the hydrogen explosions of the plant. (Emergency ventilation system in MCR was installed, but it did not work due to loss of all AC power.)**
  - **With the rapid escalation of the event, They could not respond quickly to wear masks.**
  - **They had no choice to eat and drink in MCR for long time severe accident operation.**
  - **There may be gaps between masks and faces due to temples of the glasses.**

[measures]

- **To avoid the internal exposure at severe accident,**
  - Supply for enough quantities of radiological equipments (mask, filter, wear)
  - Prohibition of eating and drinking within the restricted area
  - Awareness activities and education about wearing mask and radiation protective equipment
  - Sharing of survey information

Exposure exceeding dose limit (3)

2) Exposure to female employees exceeding the dose limit

- **19 female employees at work after the Earthquake.**
- **2 female employees (G and H) exceeded the dose limit specified by the law (5 mSv/3 months).**
- **Another 2 female employees (I and J) in the seismic building who were not designated as radiation workers exceeded the dose limit for the public(1 mSv/y).**
- **These employees had a medical examination by an industrial doctor and no health effects were observed.**

Unit：mSv

Employees	Internal exposure	External exposure	Distribution of effective dose	Remarks
G	13.6	3.95	17.55	
H	6.71	0.78	7.49	
I	2.81	0.61	3.42	Non-radiation worker
J	2.59	0.78	3.37	Non-radiation worker

Exposure exceeding dose limit (4)

[cause]

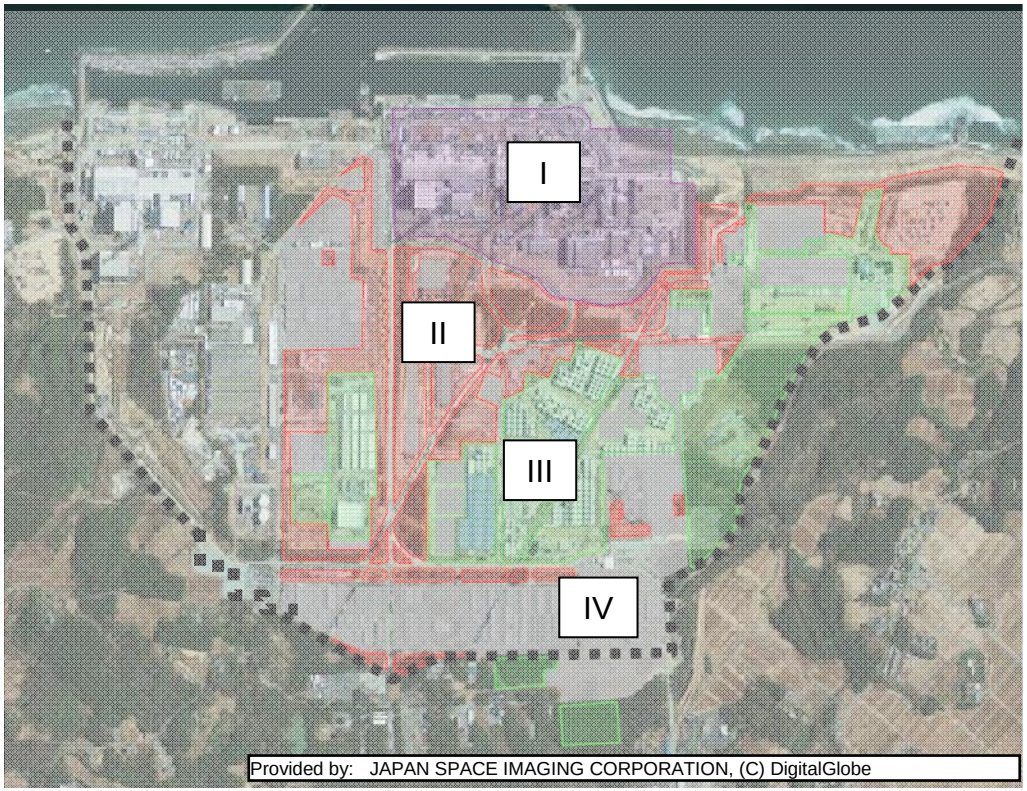
- The 2 female employees (G and H) were engaged in fire engine refueling in the field and working in the seismic building.
  - **They took appropriate radiological protection measures (full face mask with charcoal filters), so it is likely that they ingested radioactive materials in the seismic building.**
  - **It was difficult to completely prevent the invasion of radioactive materials inside seismic building by the effort to survey and check at the entrance, because the double door was not airtight and was deformed by the hydrogen explosions of the plant.**
  - **There was a delay in setting and operating a buffer area that would prevent the radioactive materials into the seismic building.**

[measures]

- **After March 23, all female employees evacuated from 1F.**
- **To reduce the concentration level of radioactive materials inside the seismic building,**
  - Setting and operating a buffer area at the entrance for preventing radioactive material invasion
  - Replacing the floor materials with radioactive material-resistant tiles
  - Deploying local air-exhaust ventilators.

Implementation policy for the reduction of on-site dose at the Fukushima Daiichi Nuclear Power Station

[Objective]
Strengthen the foundation for securing the long-term safety of the reactors affected by the accident and carry out decommissioning by;
-Use field measurements to monitor the impact of fall-out contamination and direct rays from the plant on the Fukushima Daiichi Nuclear Power Station's entire site,
- Proceed to reduce dose through deforestation, top soil removal, deep plowing and masking, etc., improve working conditions at the Fukushima Daiichi Nuclear Power Station, and prepare a basis for securing the long-term safety of the reactors affected by the accident and carry out decommissioning.



Area Ⅰ
Areas in the vicinity of Units 1-4 where radiation dose equivalent rates are particularly high

Area Ⅱ
Planting areas and areas with remaining woods

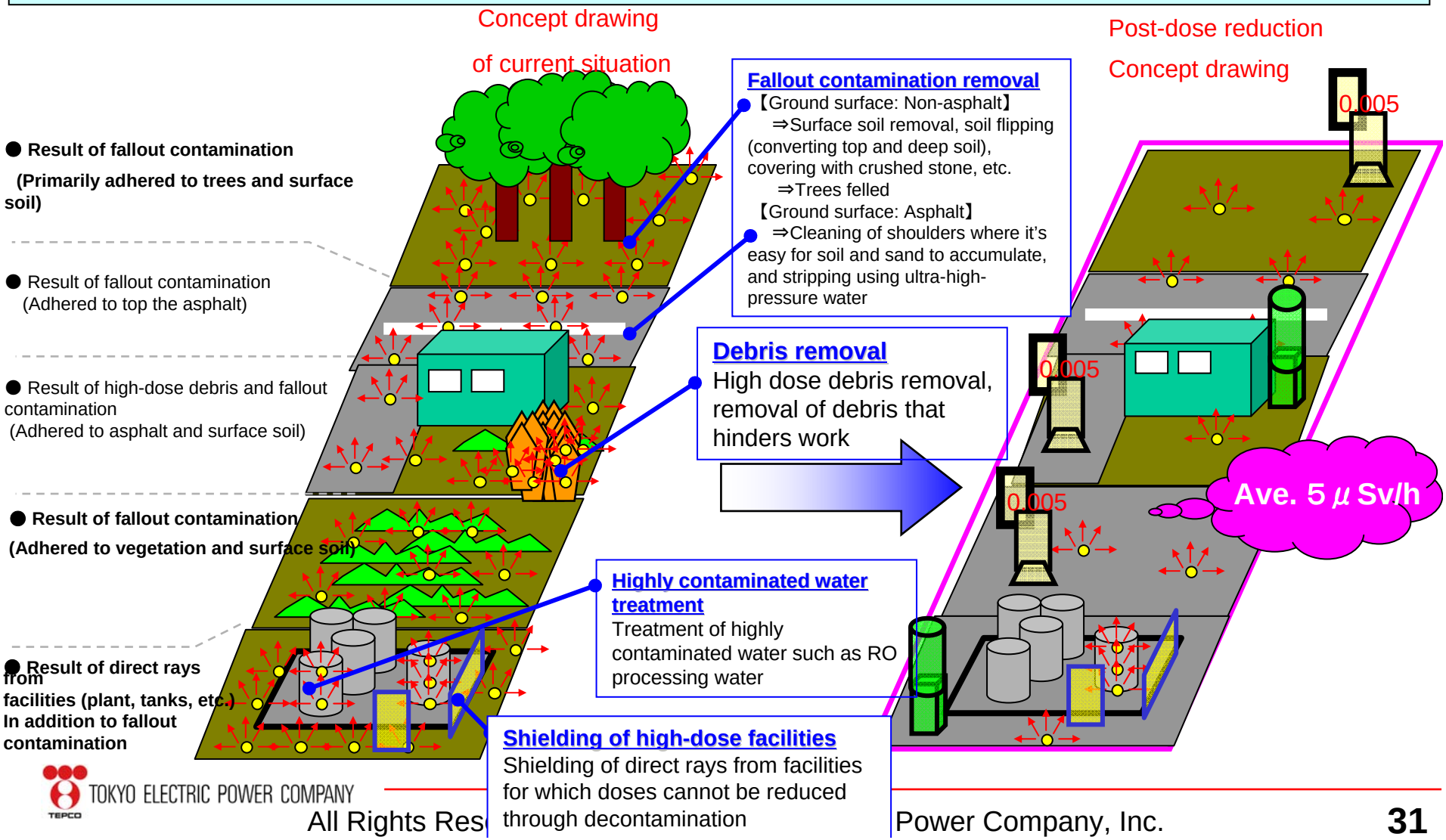
Area Ⅲ
Areas where facilities are installed or are to be installed in the future

Area Ⅳ
Already paved areas, such as streets and parking lots

Scope of the implementation policy for reducing on-site dose

Setting of target dose rates and evaluation method

The target dose rate in the site's southern part (areas Ⅱ, Ⅲ and Ⅳ) is set to **average of 5μSv/h** , and the dose rate is **evaluated at chest position**. **Evaluation of dose rates at ground surface level will be used concurrently** for **locations that are affected by direct rays** from the plant.

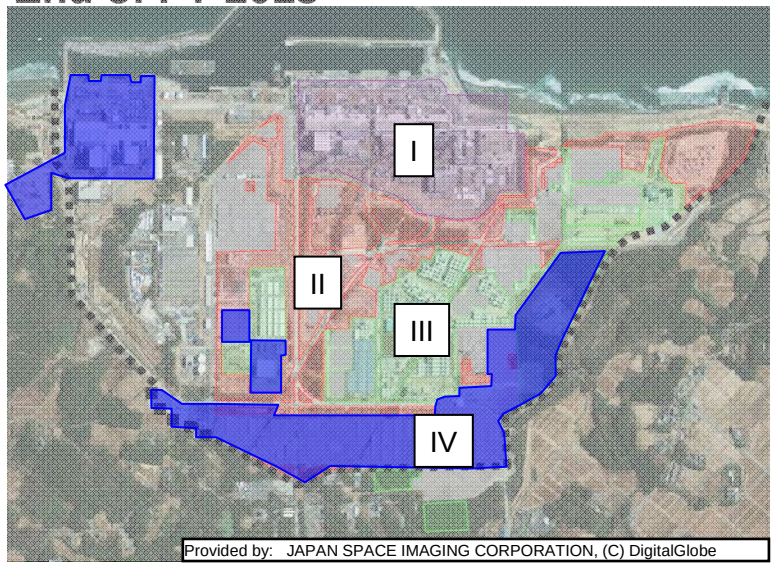


Images of Expansion of 5 μSv/h areas

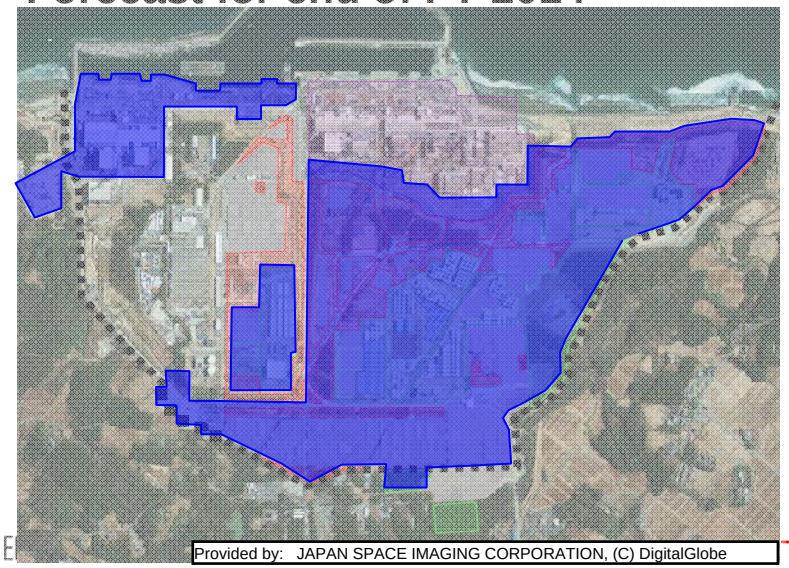
* Areas with about 5 μSv/h are marked with

We have been reducing dose in the area surrounding Units 1 to 4 (area I) by removing debris hindering work and shielding work areas; given the presence of places with high dose in the plant and facilities, we will continue reducing dose in conjunction with the removal of high-dose facilities and rubble removal from the reactor building.

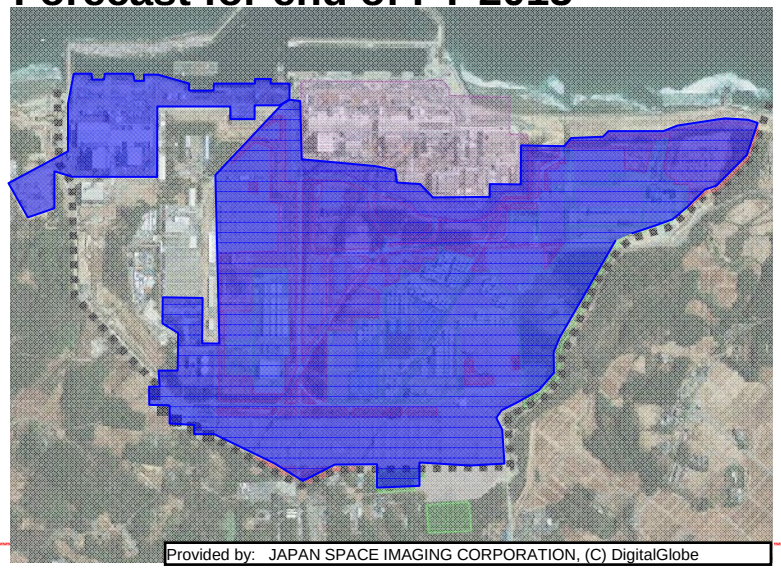
End of FY 2013



Forecast for end of FY 2014



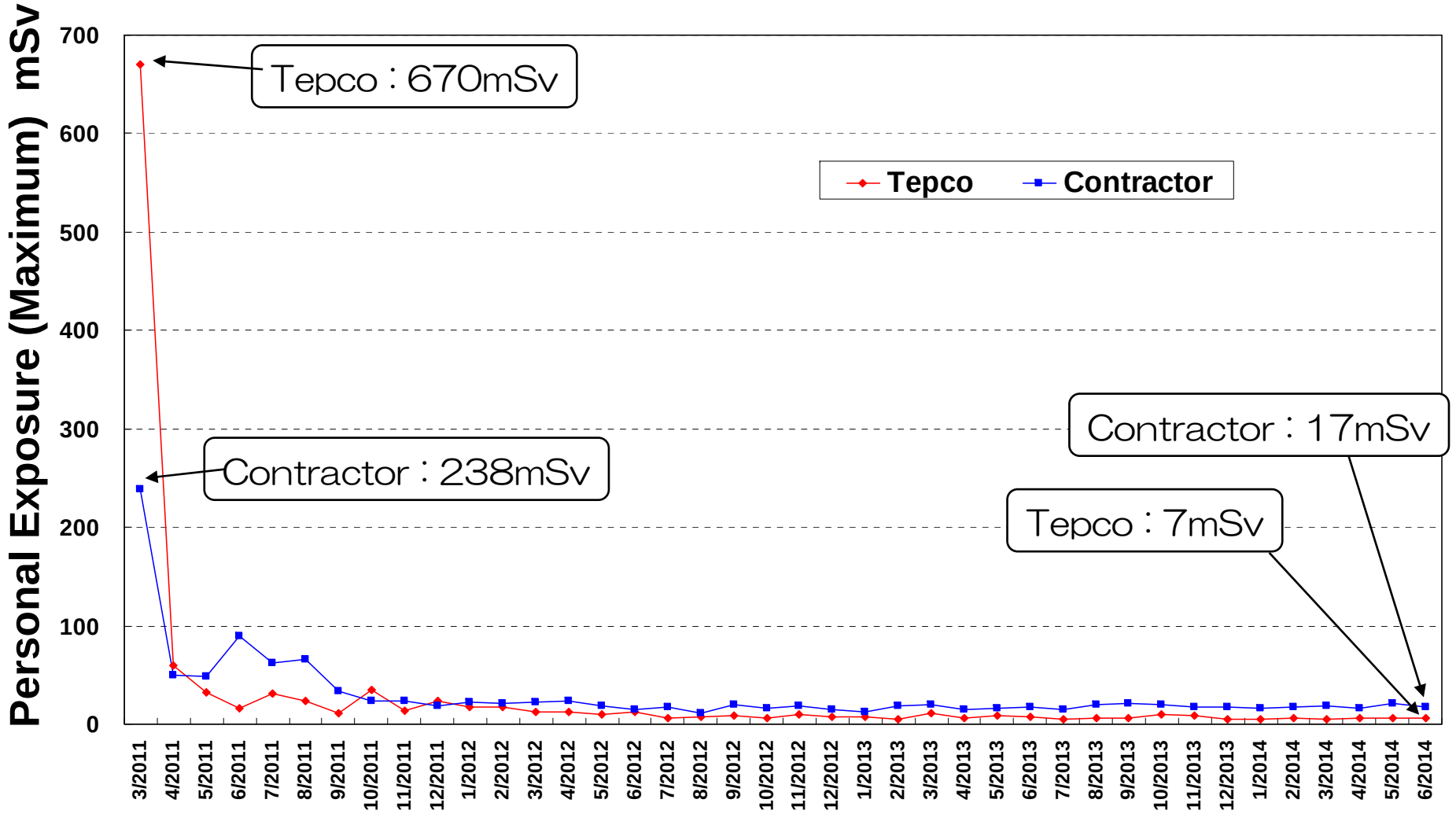
Forecast for end of FY 2015



Total of external exposure and internal exposure doses combined

Classification (mSv)	March 2011-February 2014			March 2011-March 2014			Fluctuation		
	TEPCO	Contractor	Total	TEPCO	Contractor	Total	TEPCO	Contractor	Total
Over 250	6	0	6	6	0	6	0	0	0
200 - 250	1	2	3	1	2	3	0	0	0
150 - 200	25	2	27	25	2	27	0	0	0
100 - 150	118	20	138	118	20	138	0	0	0
75 - 100	264	123	387	266	129	395	2	6	8
50 - 75	319	914	1233	319	948	1267	0	34	34
20 - 50	615	4382	4997	615	4454	5069	0	72	72
10 - 20	545	4071	4616	551	4157	4708	6	86	92
5 - 10	438	3807	4245	444	3899	4343	6	92	98
1 - 5	727	7083	7810	725	7271	7996	-2	188	186
1 or less	1065	8023	9088	1068	8240	9308	3	217	220
Total	4123	28427	32550	4138	29122	33260	15	695	710
Maximum dose (mSv)	678.80	238.42	678.80	678.80	238.42	678.80	-	-	-
Average dose (mSv)	23.66	11.05	12.64	23.64	11.02	12.59	-	-	-

Worker's exposure dose (Maximum value of the month)



Lessons learned(1)

Reinforcing monitoring system

- It is important to reinforcing the power supply of monitoring posts and to prepare two or more transmission system.
- It is also important to arrange portable monitoring posts in preparation for the case where monitoring posts are inoperable.

Preparing radiation protection equipments beforehand

- Enough amounts of radiation protection cloths, variety types of mask, shielding suit, dosimeter, WBC, survey meter etc. in appropriate locations.
- Air purifiers and temporary shielding for reducing the exposure in the seismic building and main control room
- Management system tools for easy calculation of exposures

Lessons learned(2)

Establishing emergency access control center

- **Potential locations for transportation to serve with materials and equipment near NPP in advance.**
- **Radiation education and training for the delivery team regularly.**
- **Methods and procedure for establishing the center in advance (Locations, operation procedure, providing necessary equipment for emergency etc.).**

Education and training of radiation protection

- **Basic training for NPP staff members handling survey meter and radiation protection knowledge to back up radiation protection staff members.**

Reinforcing Radiation Control System in Case of an Accident (1)

Reinforcing monitoring system

- **Adding portable monitoring posts**
- **Reinforcing the power supply of monitoring posts (emergency generator)**
- **Reinforcing the transmission system of monitoring posts (satellite antenna)**

Portable monitoring posts

Generator to backup power supply to monitoring posts

Satellite antenna for monitoring posts

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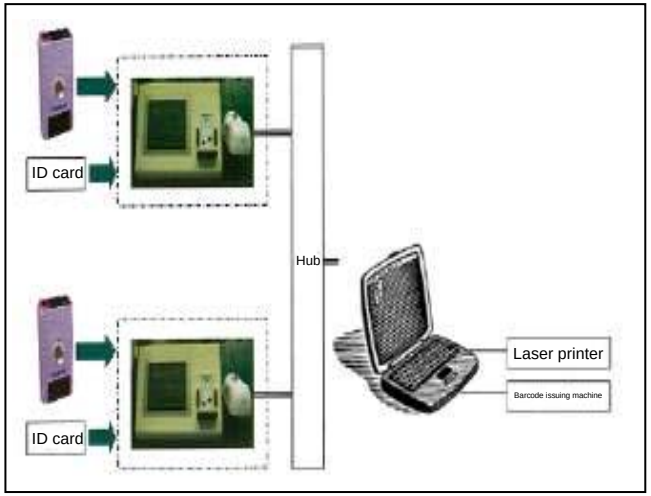
Reinforcing Radiation Control System in Case of an Accident (2)

Deployment of radiation protection materials/equipment

- **APDs are added to the important anti-seismic building (120 units→500 units).**
- **(March 2012) 7 units of APDs are installed in each MCR.**
- **A simple access control system is deployed.**
- **Radiation protection equipment for 8 days are stored for restoration staff.**



Simple Access Control Device (Image)

APD **120→500 units**

Radiation control materials/equipment

Reinforcing Radiation Control System in Case of an Accident (3)

Establishing emergency access control center

- **We determined KK energy hall and Shinanogawa power system office as emergency access control center.**
- **Members of head office and KK assigned as a establishing staff of emergency access control center .**

Training to setup access control area

Training of setup screening area

Reinforcing Radiation Control System in Case of an Accident (4)

Training

- **Materials used to prevent radioactive substances from flowing into the emergency response room are secured. Staff training has already been made conducted.**
- **Most of employees have undergone radiation measurement training for the entire company.**

Training of radiation measurement

Training to suppressing contamination at emergency response room

Training to setup screening area at emergency response room

Thank you very much

for your support to

TEPCO and Japan!