Fukushima Incident

Preliminary Analysis, Consequences and Safety Status of Indian NPPs

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Chairman & Managing Director
NPCIL & BHAVINI

Contents

- Introduction
- Overview of the Incident
- Sequence of Events & Present Scenario
- Preliminary Analysis
- Safety Status of Indian NPPs
- Actions taken by Indian & International agencies
- Radiation & Emergency Preparedness aspects

Nuclear Power Reactors in Japan

Total Reactors in Operation : 54

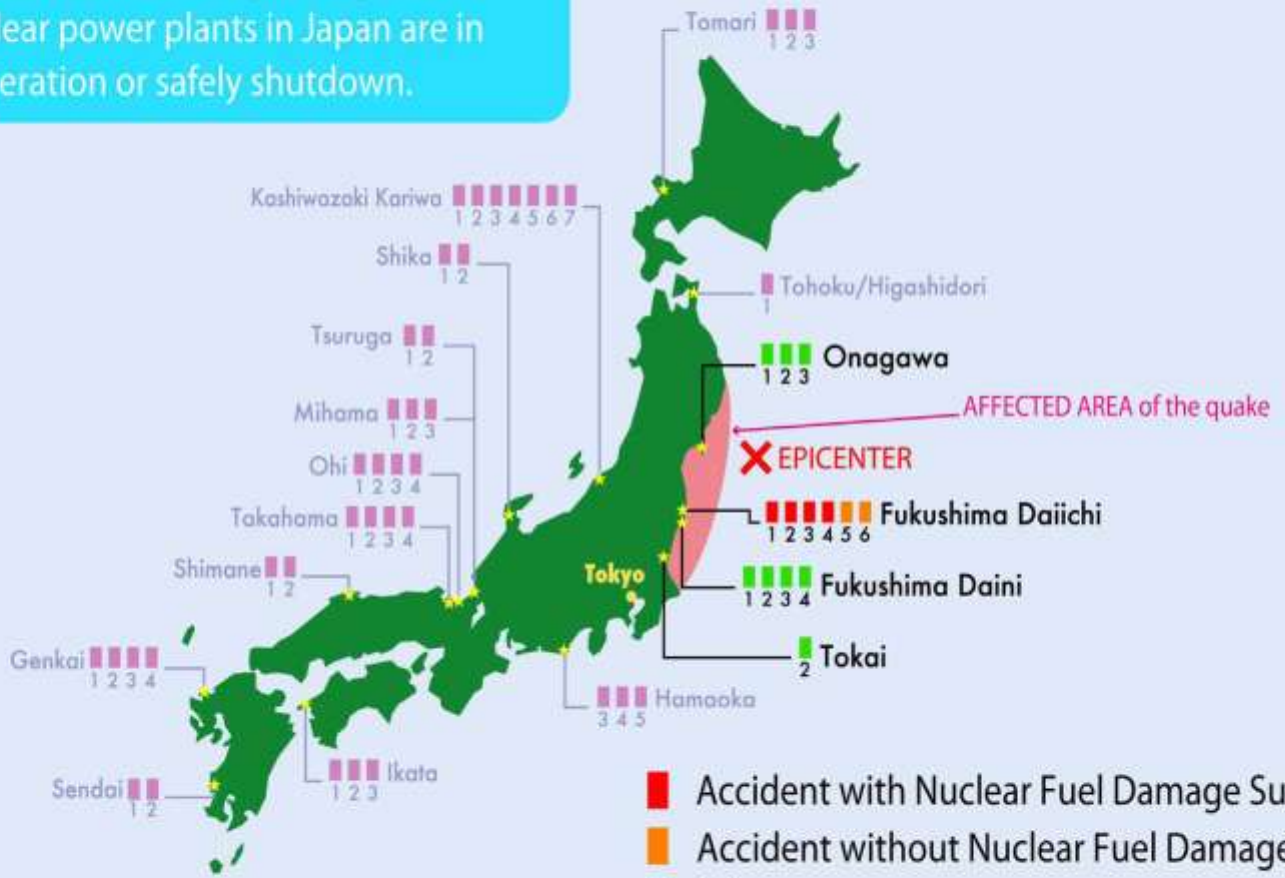
Under Construction : 02

Reactors in the zone of event : 13

Fukushima-Daiichi(6), Daiini(4), Onagawa (3)

Status of the Nuclear Power Plants after the Earthquake

Every efforts and measures have been taken at Fukushima Daiichi nuclear power plants. Other nuclear power plants in Japan are in normal operation or safely shutdown.



Location of NPPs in Japan

In Operation :54, Construction:02

Reactors affected by Earthquake in Japan

- Fukushima Daiichi
  - Unit -1- Automatic Shutdown
  - Unit-2- Automatic Shutdown
  - Unit-3 - Automatic Shutdown
  - Unit-4 - Maintenance Outage
  - Unit-5- Maintenance Outage
  - Unit-6 - Maintenance Outage
- Fukushima Daiini
  - Unit -1- Automatic Shutdown
  - Unit-2- Automatic Shutdown
  - Unit-3 - Automatic Shutdown
  - Unit-4 – Automatic Shutdown
- Onagawa
  - Unit -1- Automatic Shutdown
  - Unit-2- Automatic Shutdown
  - Unit-3 - Automatic Shutdown

1. Automatic reactor shutdown terminated the chain reaction- Nuclear fission stops within seconds
2. The only issue is to remove radioactive decay heat from fuel

Units at Fukushima-Daiichi

Unit	Capacity (MWe)	Construction Start	Commercial Operation start	Supplier
No.1	460	April, 1967	March, 1971	GE
No.2	784	Jan, 1969	July, 1974	GE/Toshiba
No.3	784	Aug, 1970	March, 1976	Toshiba
No.4	784	Sep, 1972	Oct, 1978	Hitachi
No.5	784	Dec, 1971	April, 1978	Toshiba
No.6	1100	May, 1973	Oct, 1979	GE/Toshiba
Total Power : 4696 MWe				

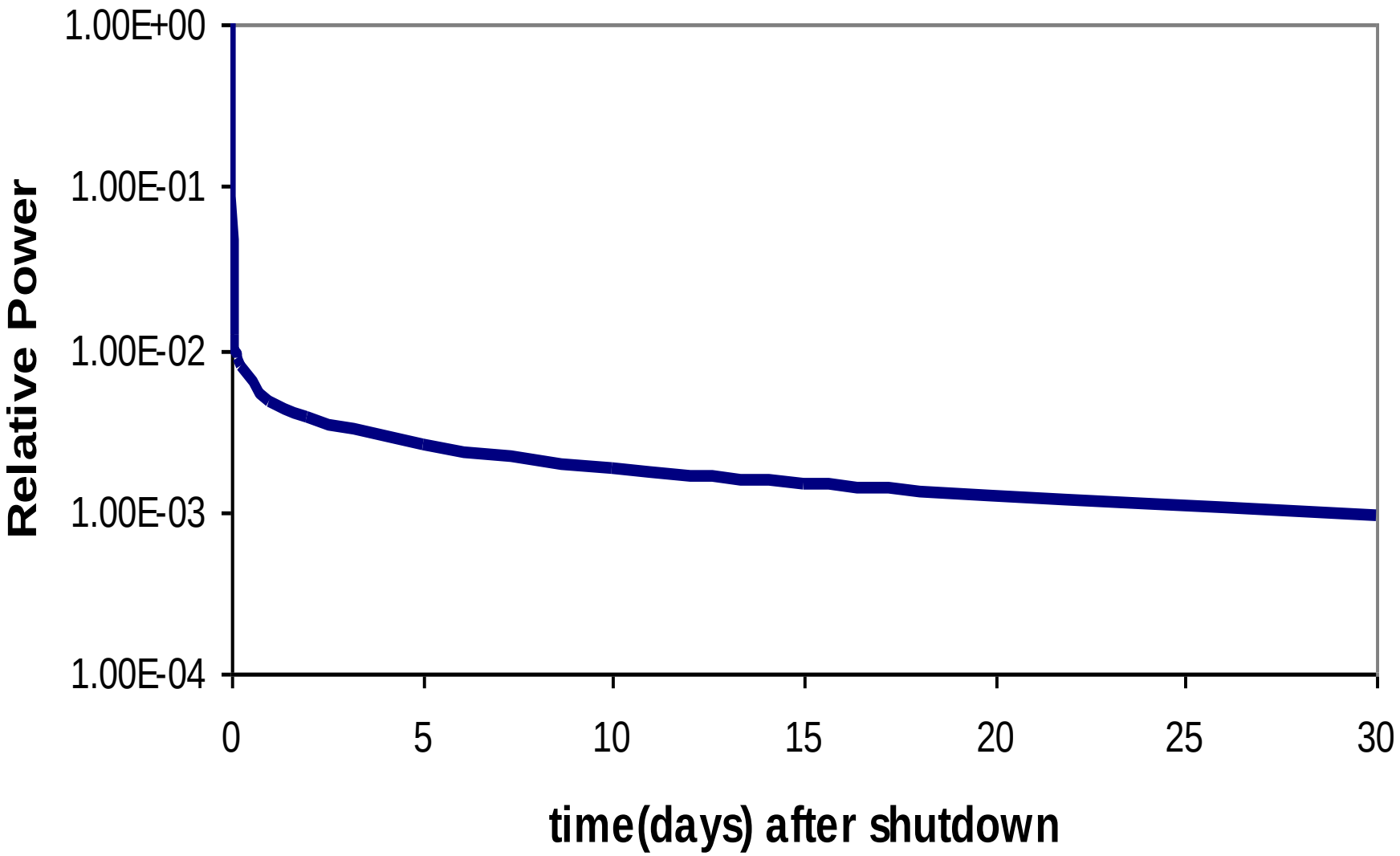
Events at Fukushima Dai-ichi NPP

- Earthquake of magnitude 9.0 on 11 March 2011 followed by Tsunami of 14 meter high waves - beyond the design basis.

- All operating plants at the affected area automatically shutdown - Terminating chain reaction.

Reactor core Cooling – Continued for one hour, got incapacitated after tsunami- caused fuel over heating-Metal Water Reaction - Hydrogen Generation- Explosion inside the outer Building. .

Decay heat curve



Incident Overview

Information sources

WANO

WORLD ASSOCIATION OF NUCLEAR OPERATORS

W A N O

NISA, Japan

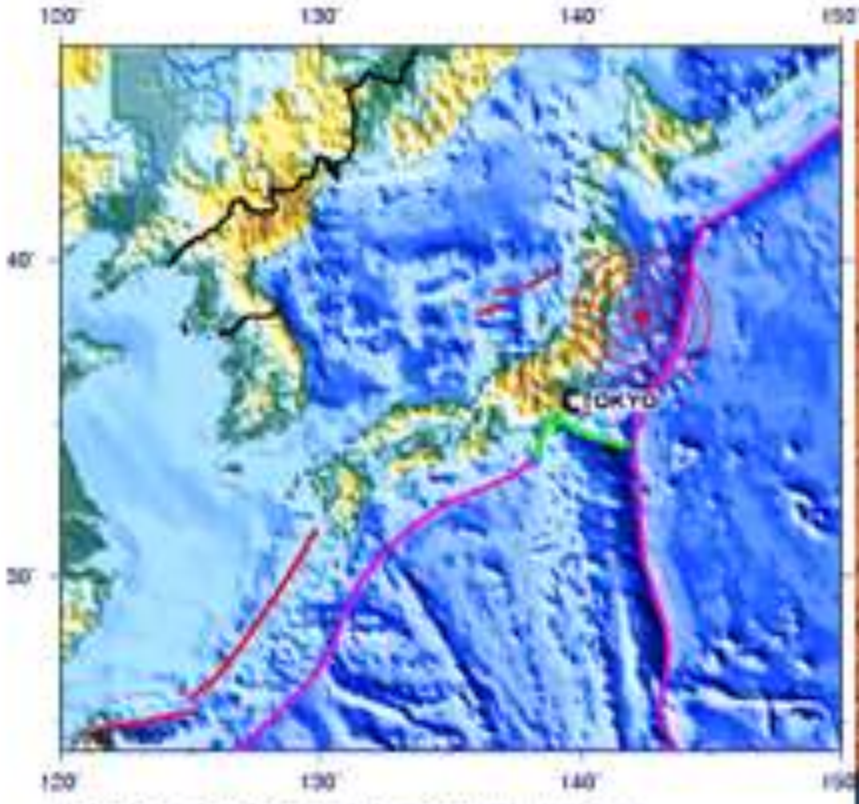
IAEA

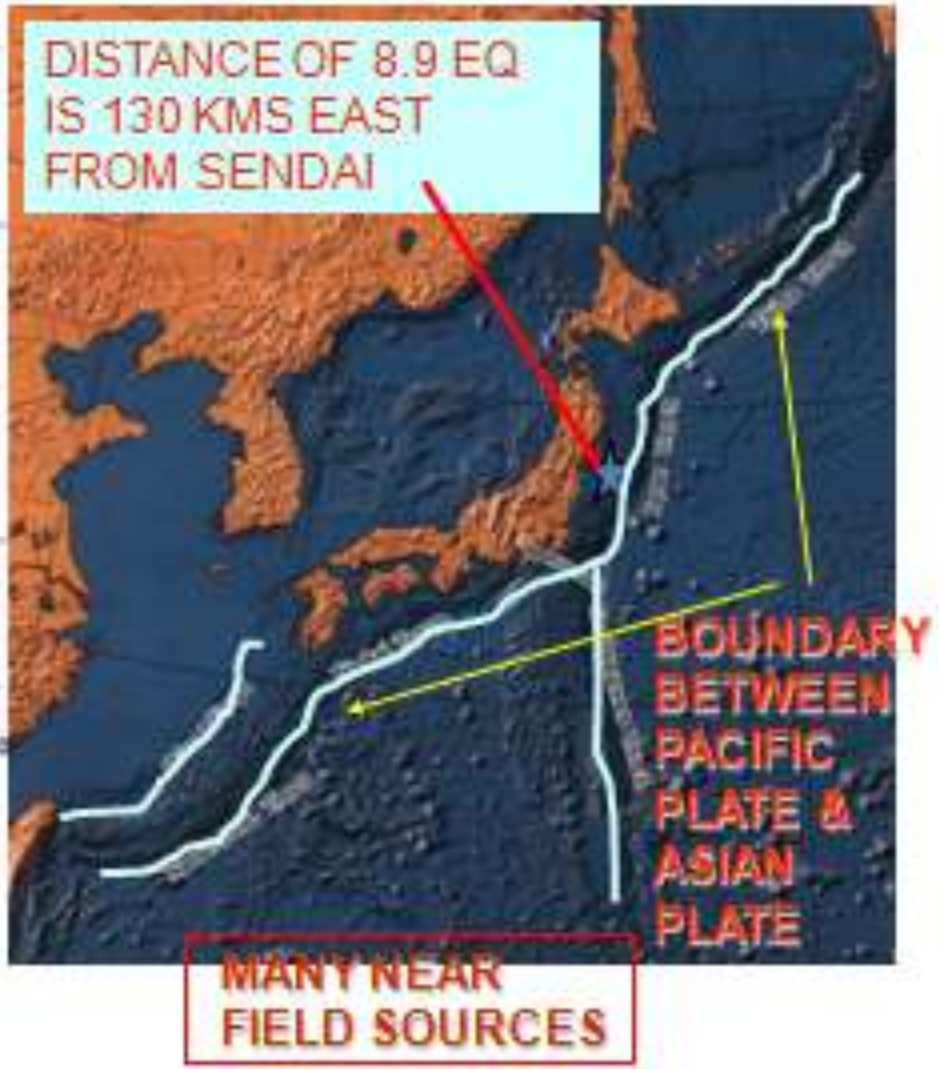
JAIF

World Nuclear Association

Energy For Sustainable Development

TSUNAMIGENIC LOCATIONS IN JAPAN





Events at Fukushima Dai-ichi NPP

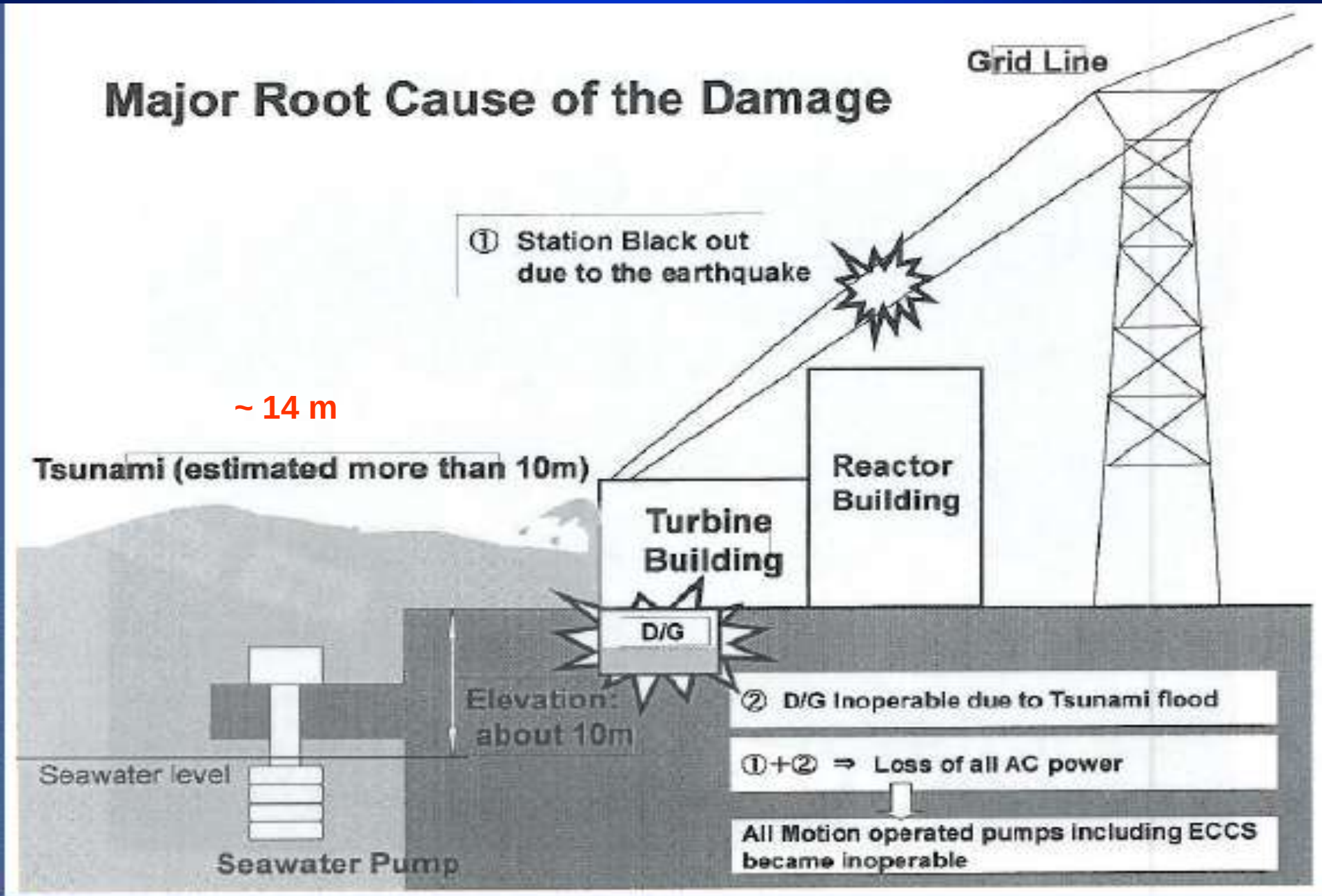
- No nuclear explosion.
- Hydrogen generated led to explosion damaging the outer concrete building .
- The reactor pressure vessels integrity unaffected.
- No death on account of radiation exposure.

FUKUSHMIMA Daai-ichi - Before

FUKUSHMIMA Dai-ichi - After

Possible scenario of progression of events

Root Cause


Major Root Cause of the Damage
Grid Line
① Station Black out due to the earthquake
~ 14 m
Tsunami (estimated more than 10m)
Reactor Building
Turbine Building
D/G
Elevation: about 10m
Seawater level
Seawater Pump
② D/G Inoperable due to Tsunami flood
①+② ⇒ Loss of all AC power
All Motion operated pumps including ECCS became inoperable

Developed scenario

Both off site and on site electrical power supply was not available (SBO condition).

In such case Two actions are needed:

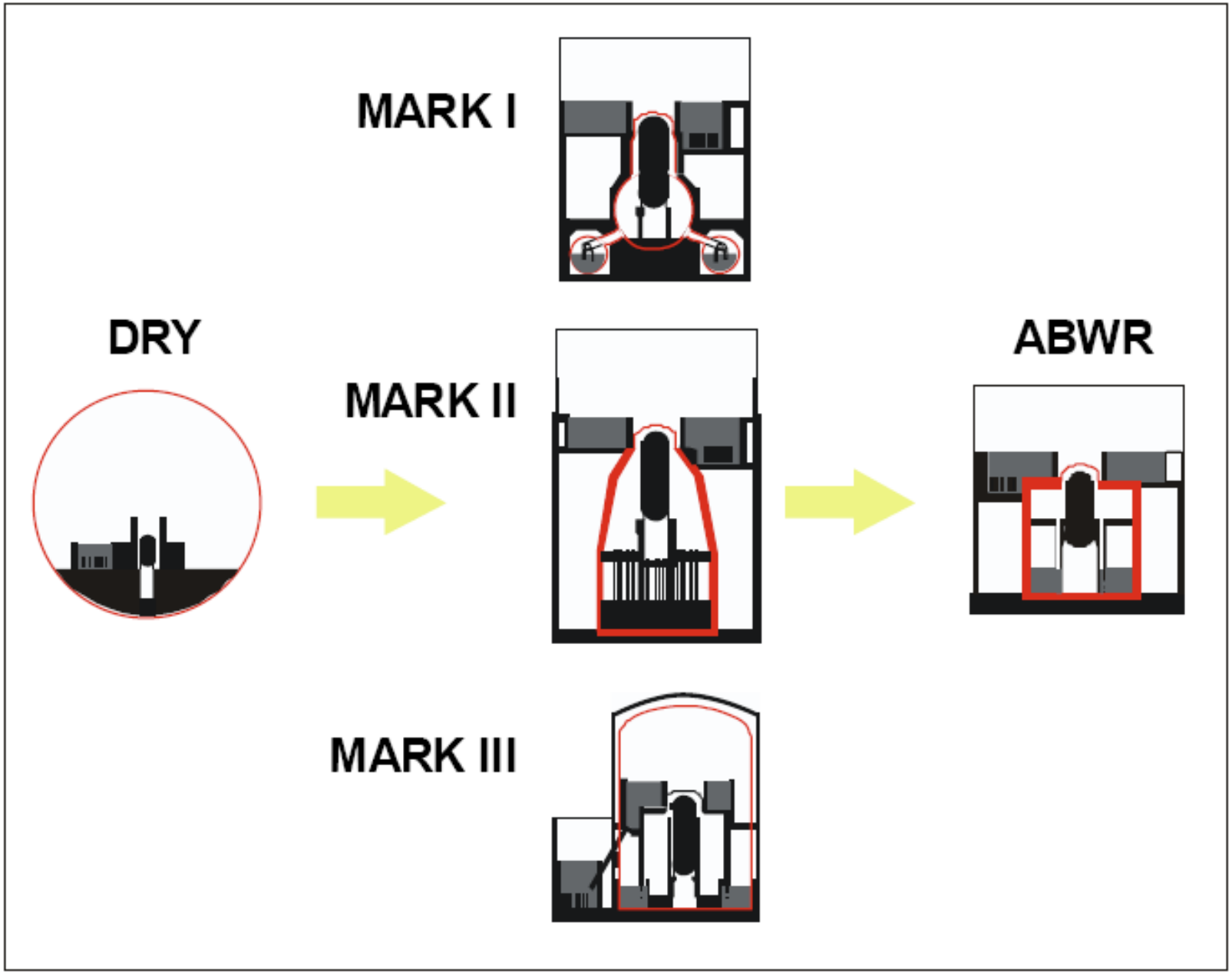
- **Residual heat removal by cooling and depressurization**
- **Emergency feed**

- **For lining up both the above systems valves are to be operated which are DC operated, but these were not available**

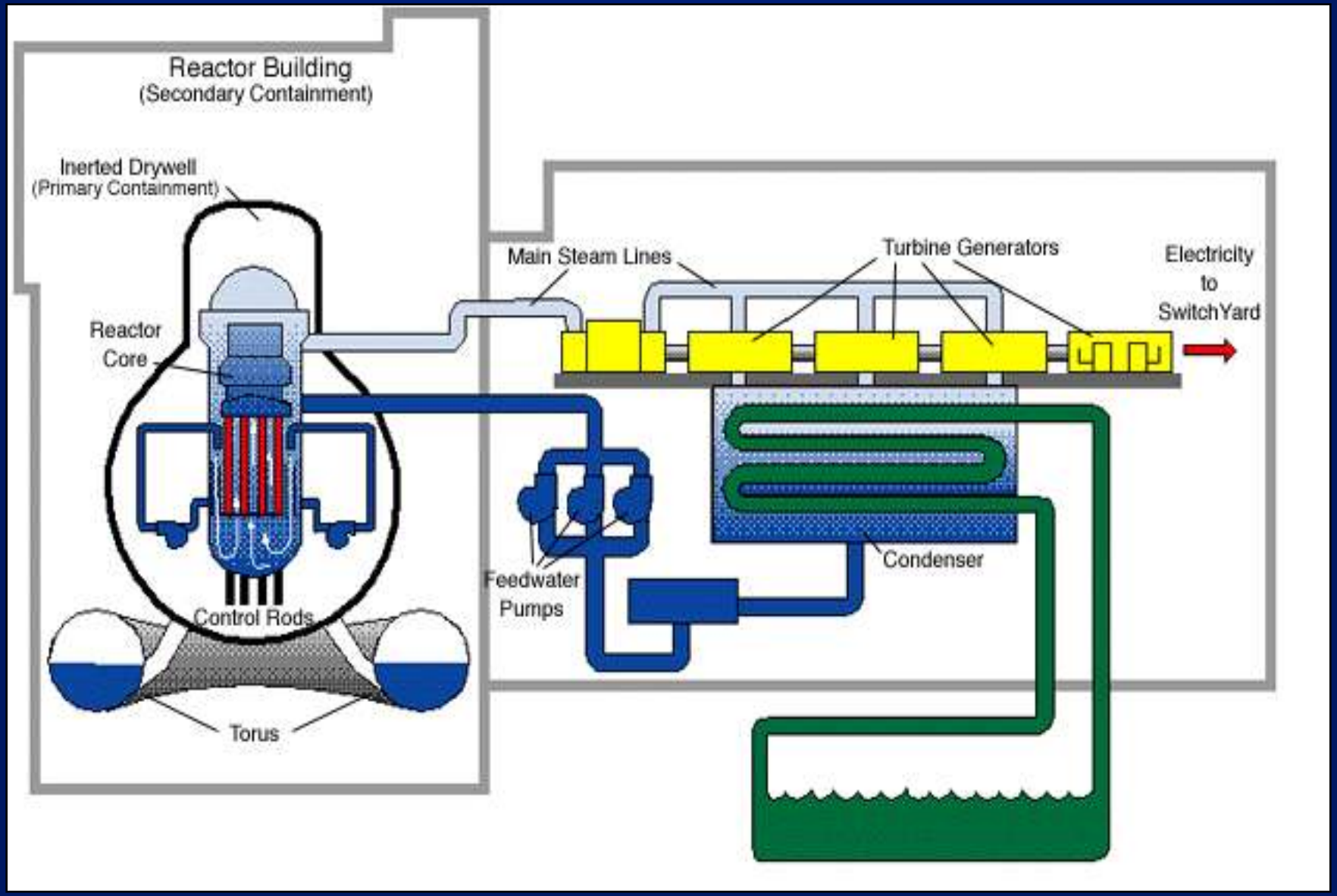
Developed scenario

- **Tsunami waves damaged**
  - **pump house equipment-the water overflowed the pumps for the cooling water system.**
  - **Suppression pool heat exchangers.**
  - **Cooling pumps that provide cooling water to DG sets-DG fuel oil tanks, located above ground, were carried away.**
  - **AC and DC switch gears - hampered operator response as all indications and plant lighting were lost**

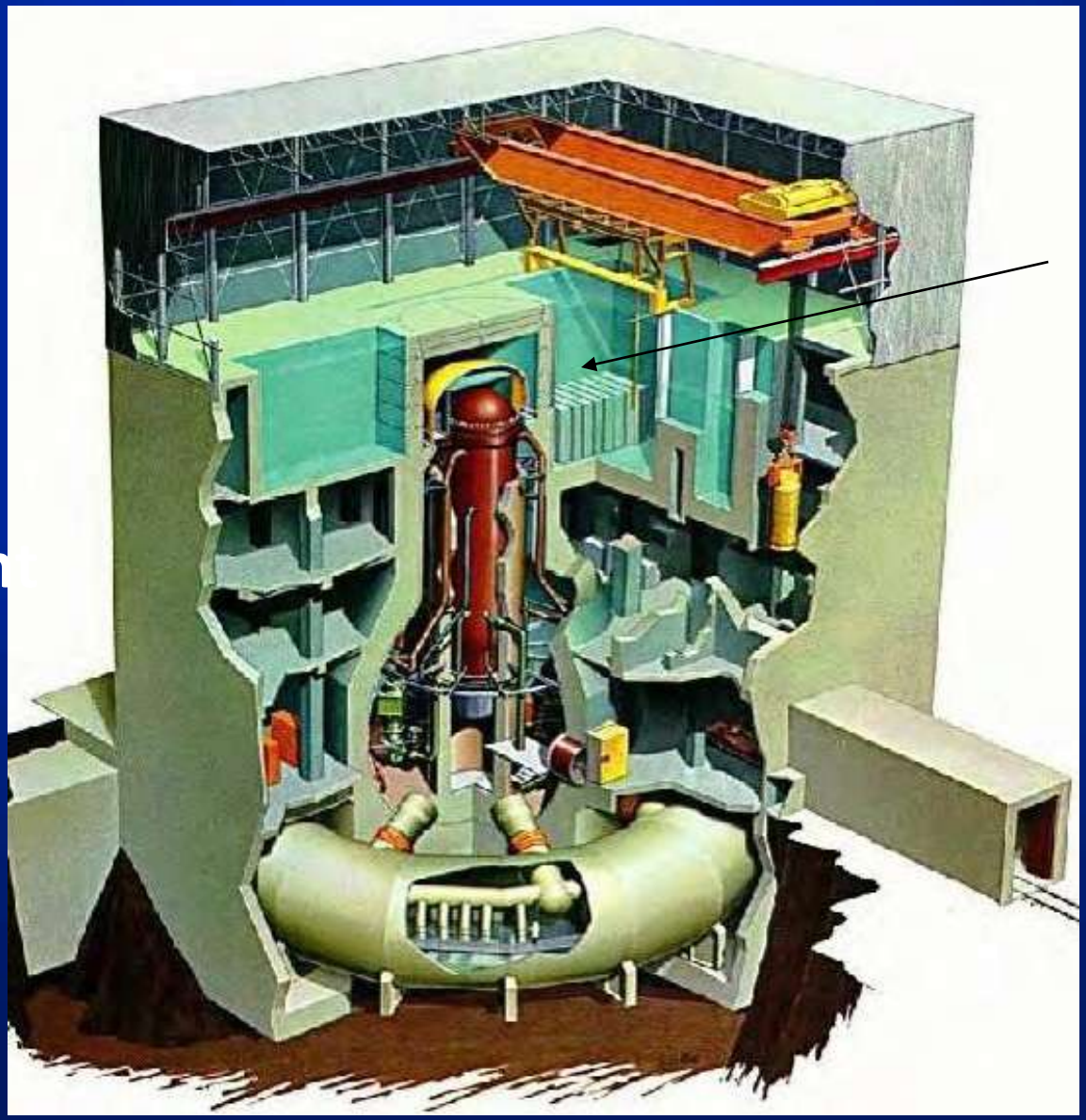
Primary Containment Evolution



BWR Schematic (Mark-1 type)

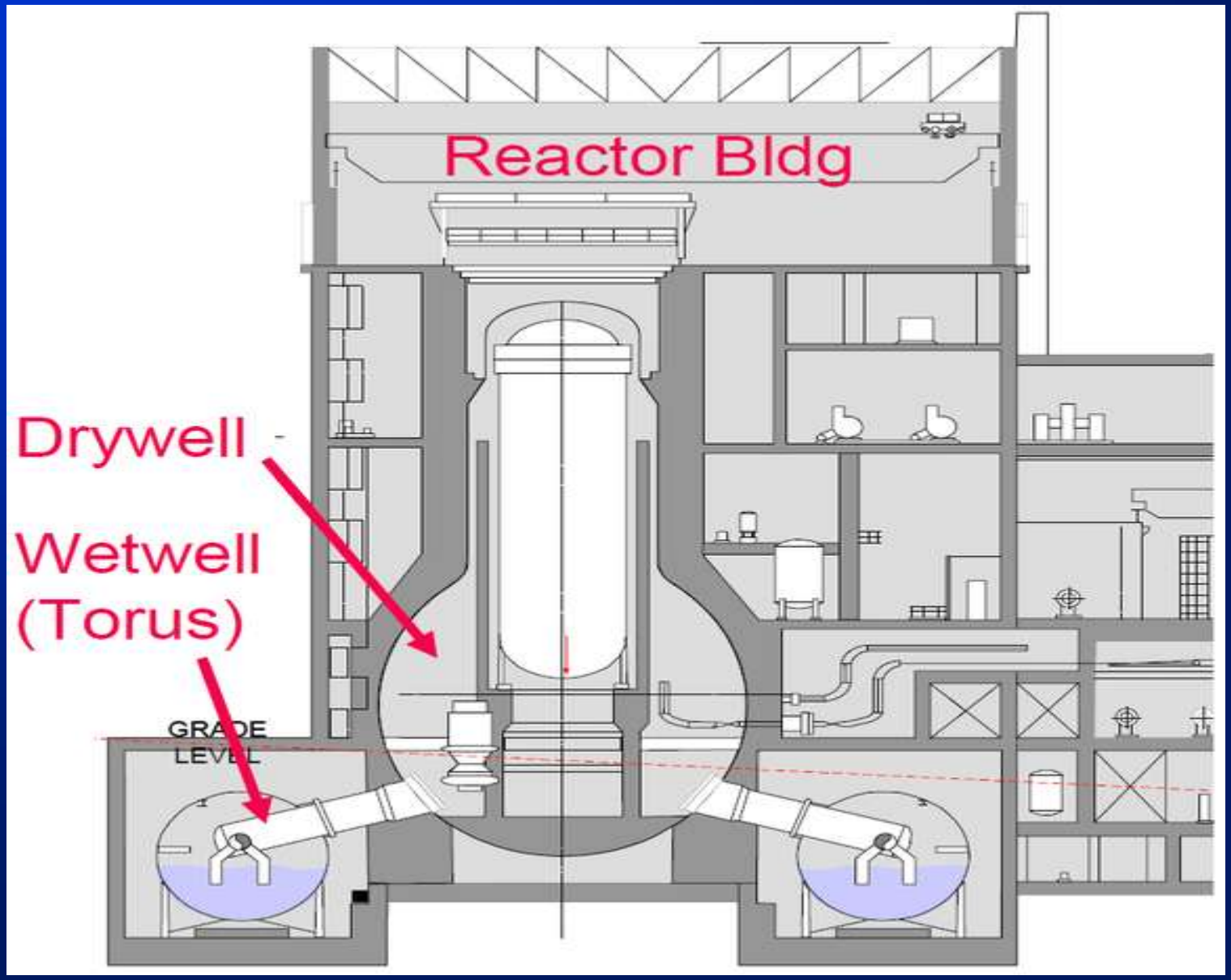


Fukushima Daiichi, Unit-1 Cross Section



Mark-1
containmen

Fukushima Daiichi-1, Unit-1 Cross Section



Developed scenario

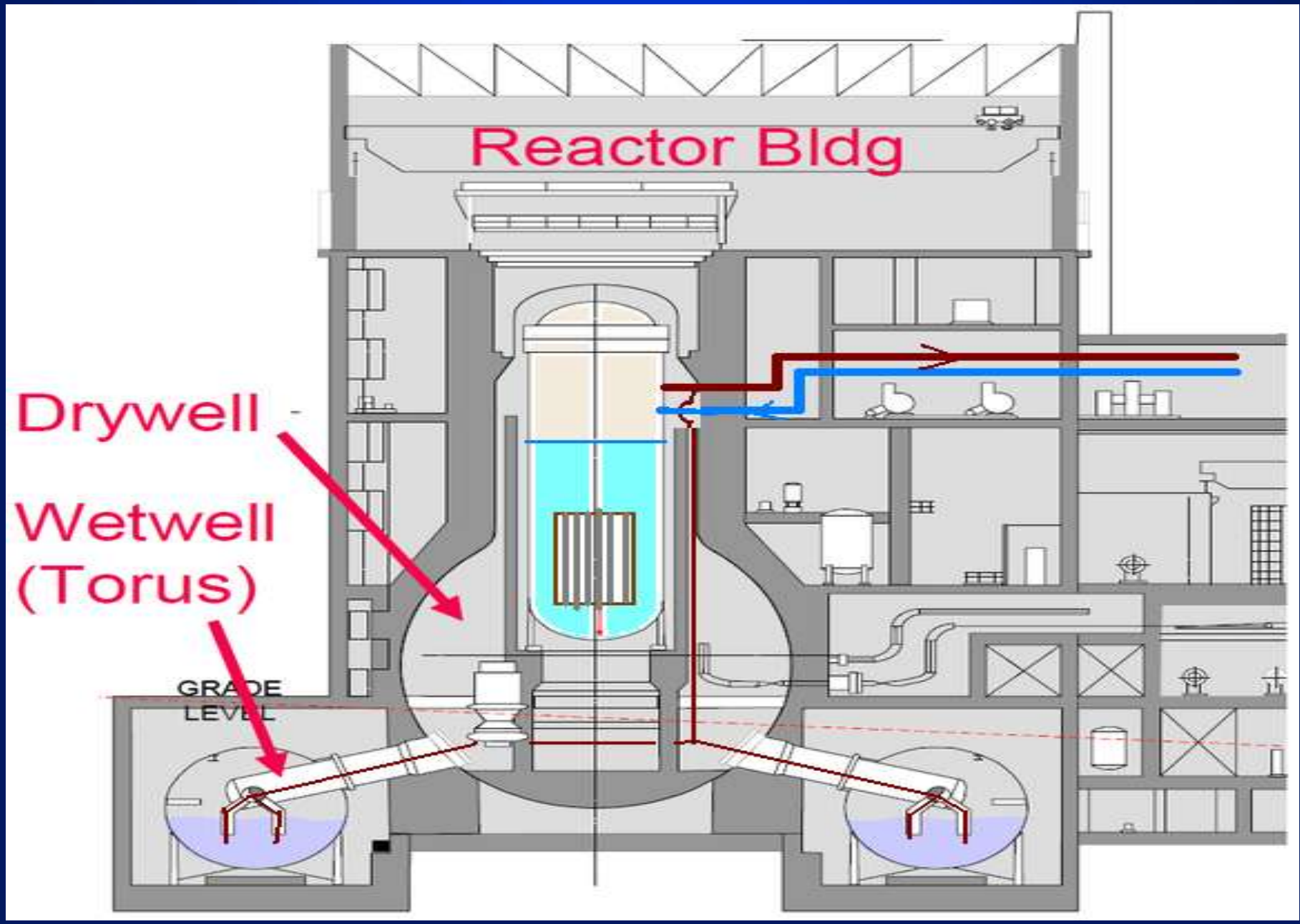
- The insufficient cooling ⇨ pressure inside RPV increases and relieves it to the suppression pool through auto blow down system through instrumented relief valves/ mechanical RVs.
- This steam gets quenched in the suppression pool partly (as per efficiency) and remaining steam and non condensable comes to drywell, the primary containment and results in pressure rise of drywell also.

Developed scenario

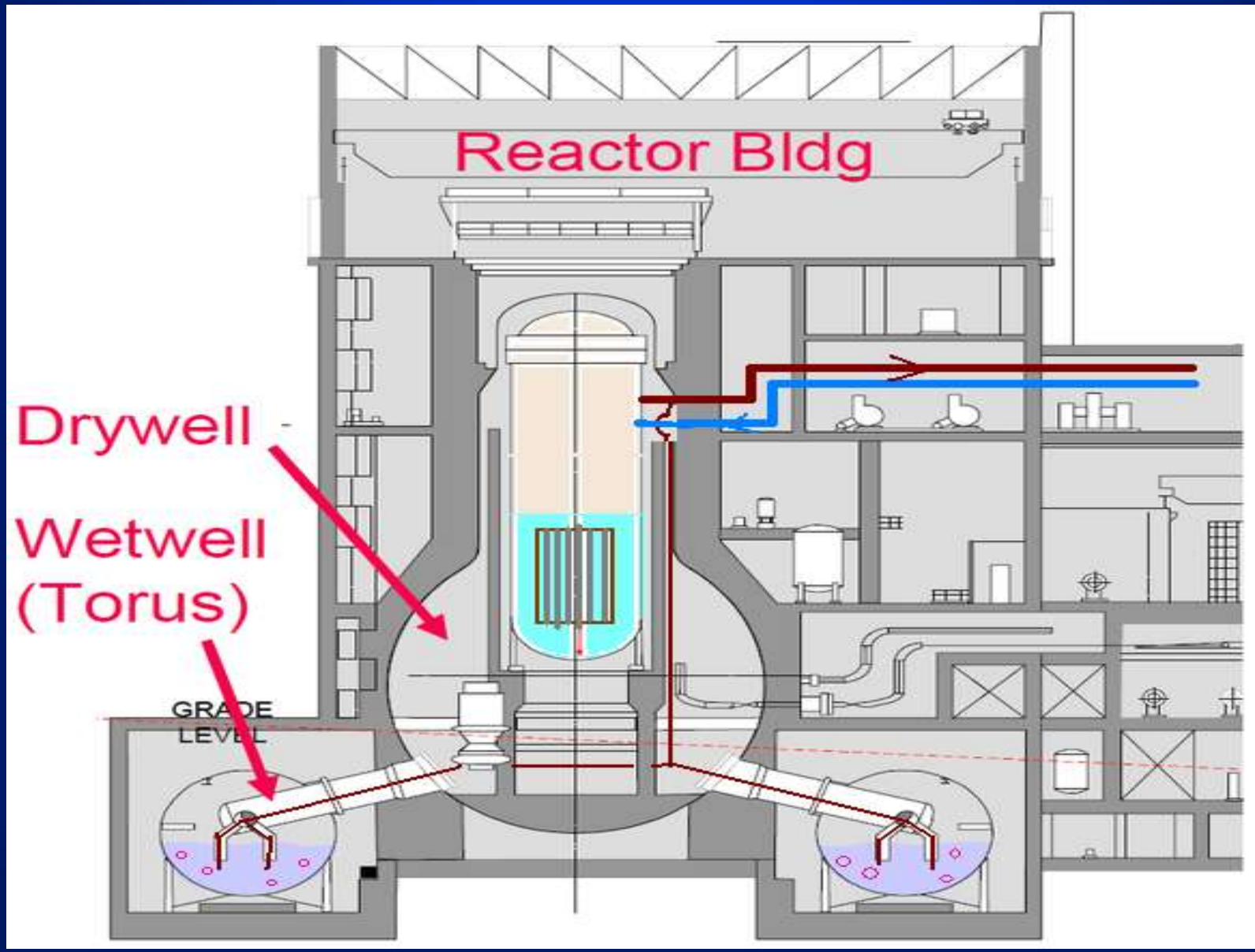
- Suppression pool recirculation pumps which are part of emergency cooling were not available so heat removal efficiency comes down and suppression pool temp increases, which further raises containment pressure.

- The pressure inside the reactor containment was allowed to increase as high as twice the design pressure in order to control the release the radioactivity.

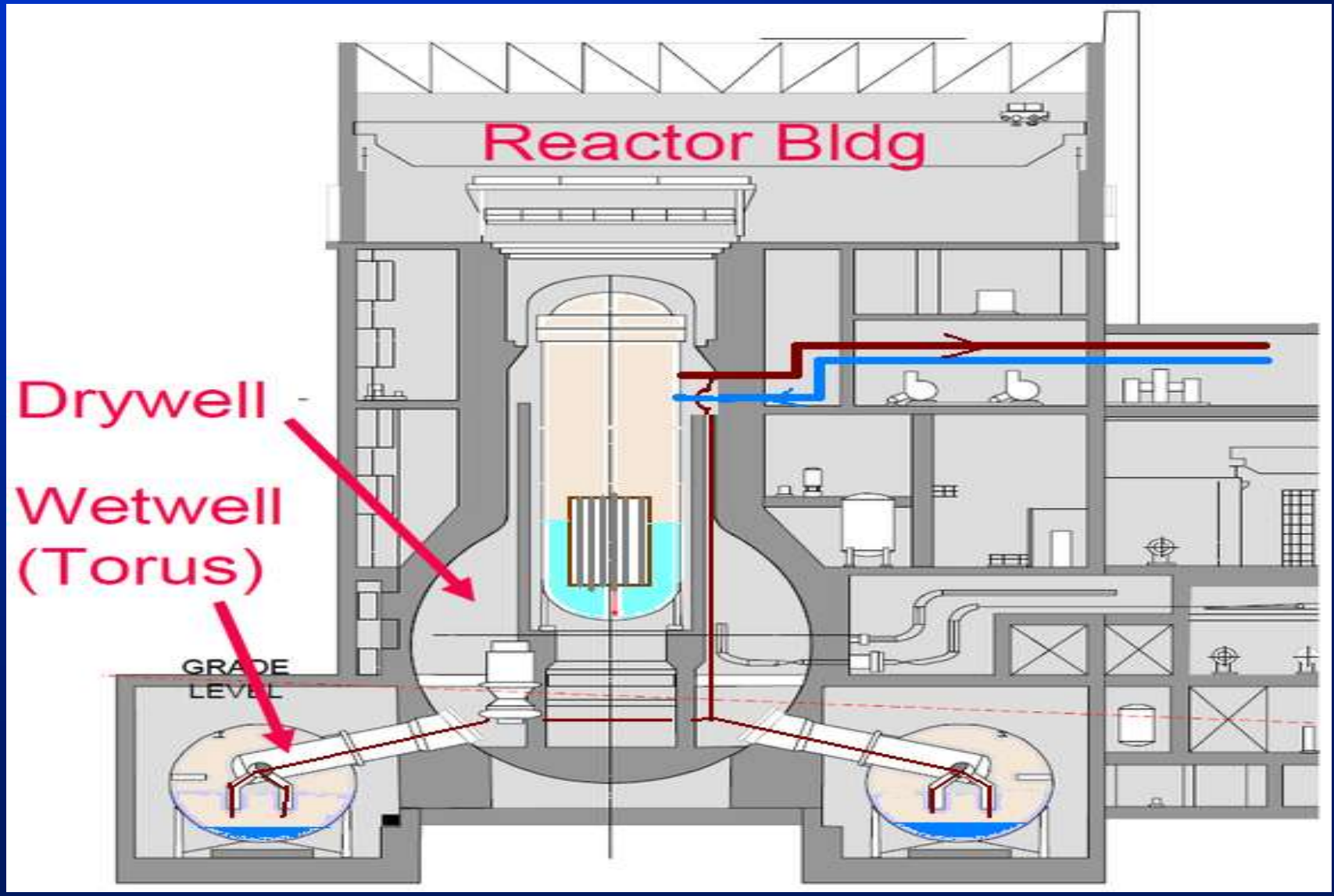
Normal operation



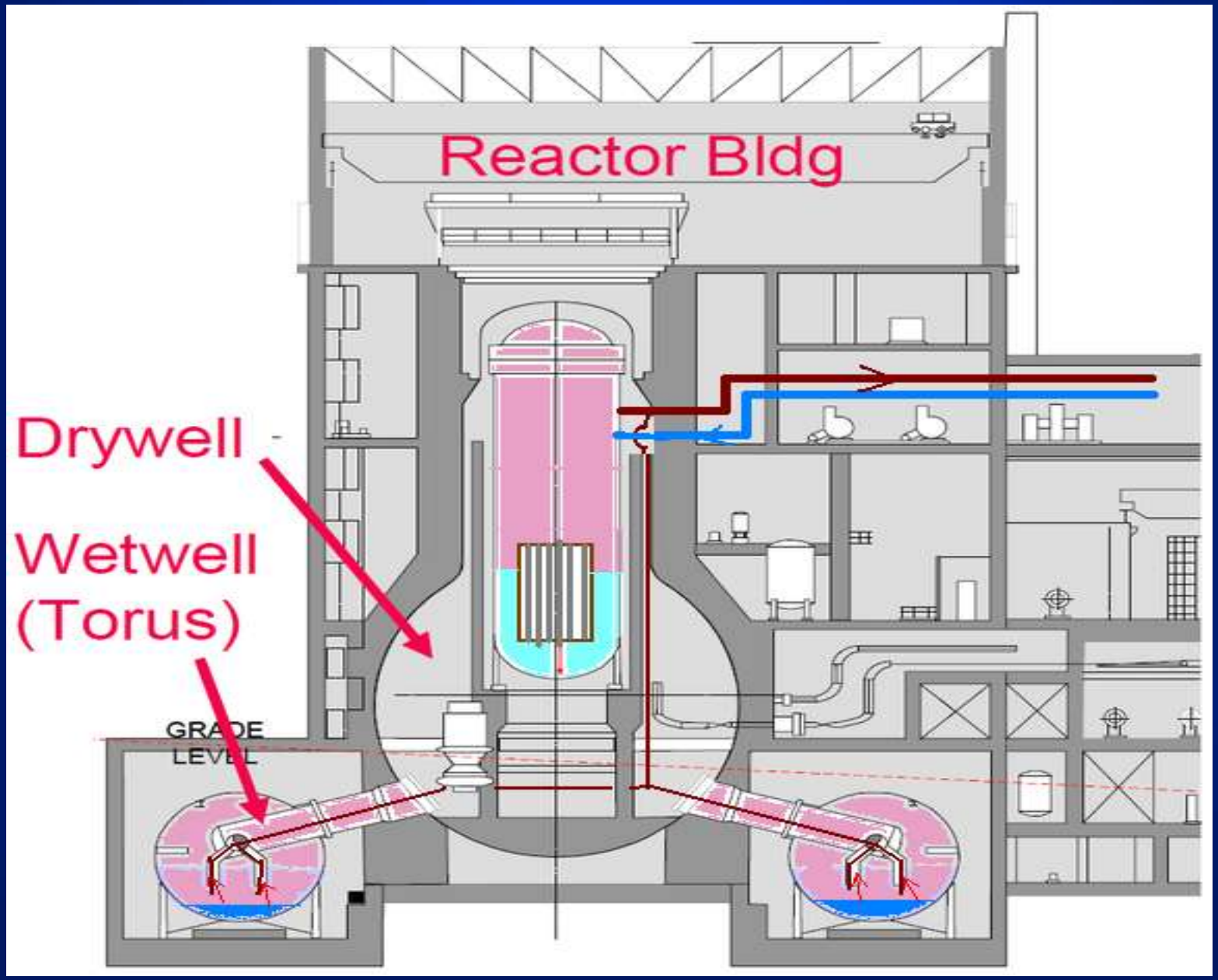
STAGE-1 : Steam relief to Wetwell



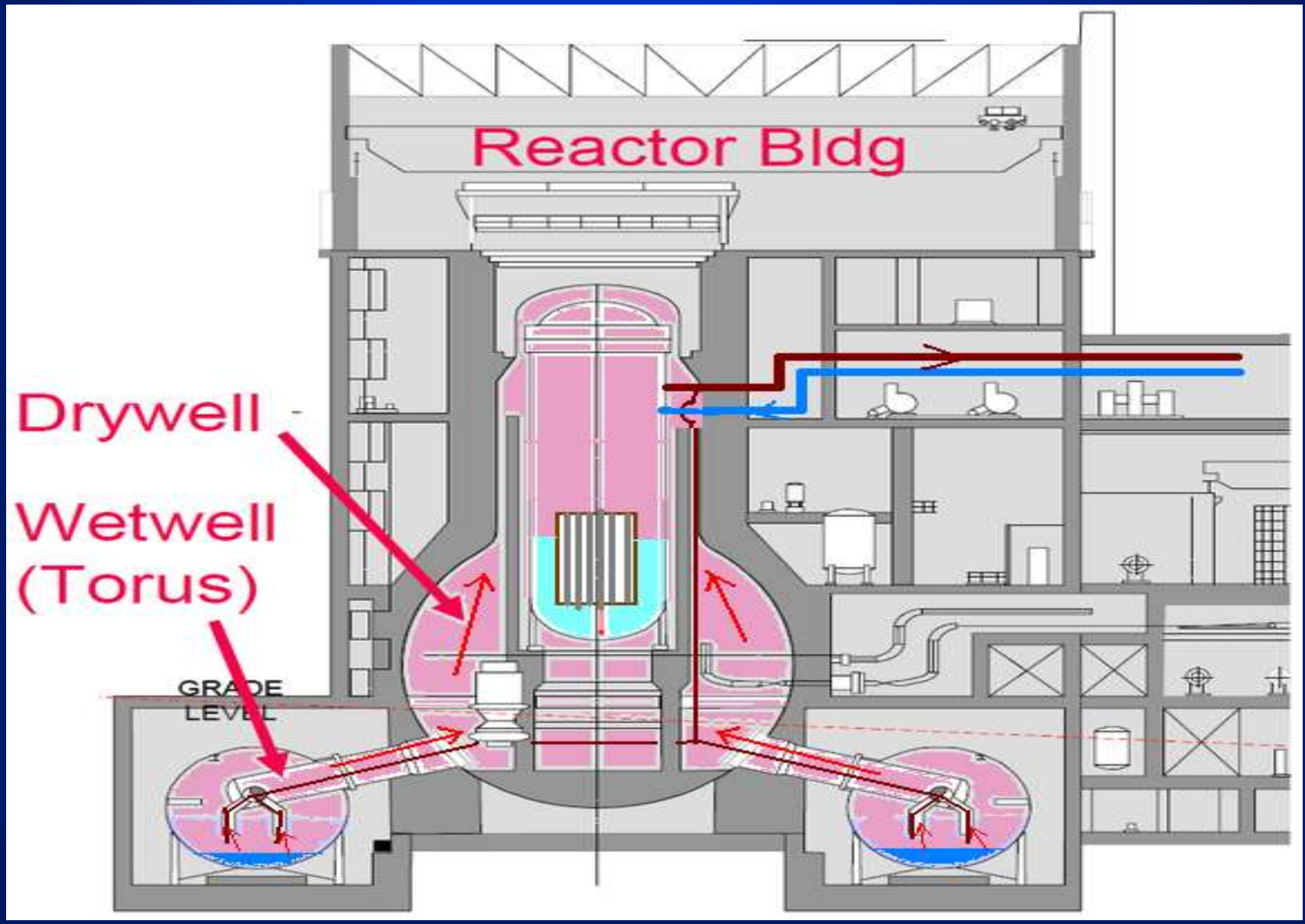
STAGE-2 : Pressurisation of Wetwell & Opening of drywell



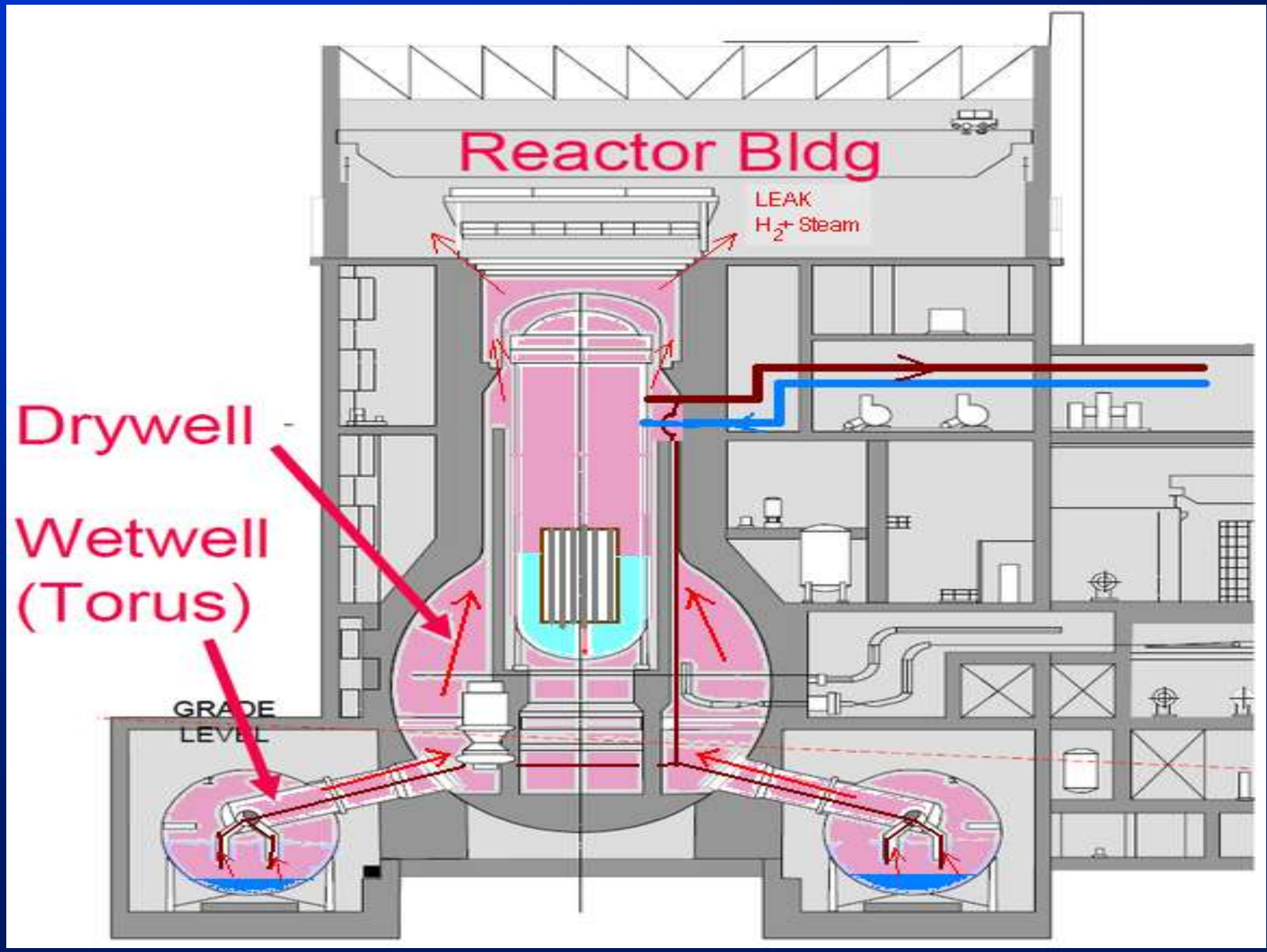
STAGE-3 : Steam carryover to Drywell



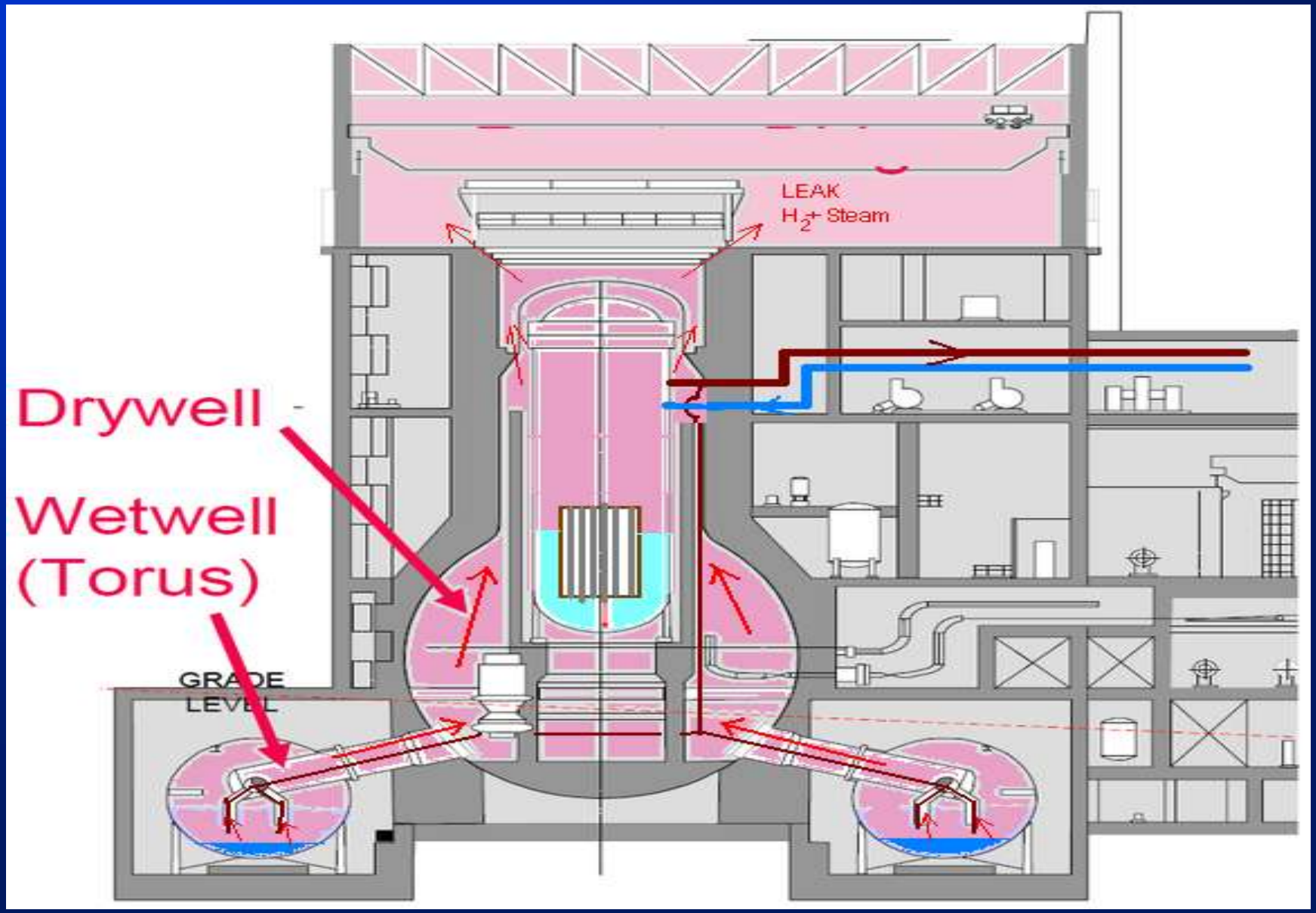
STAGE-4 : Drywell pressurisation



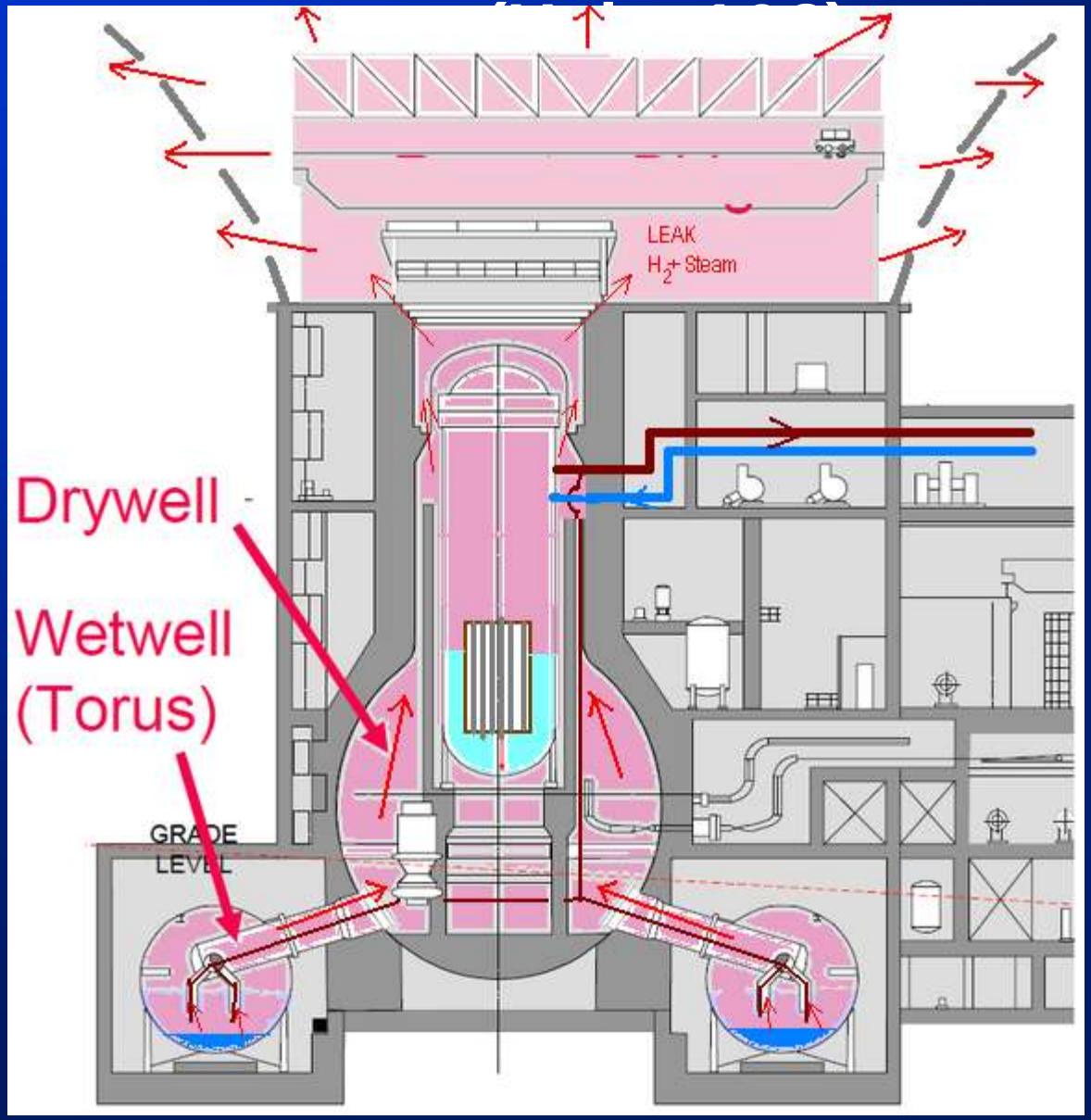
STAGE-5 : Leakage of steam, H_2 & non-condensables to secondary containment



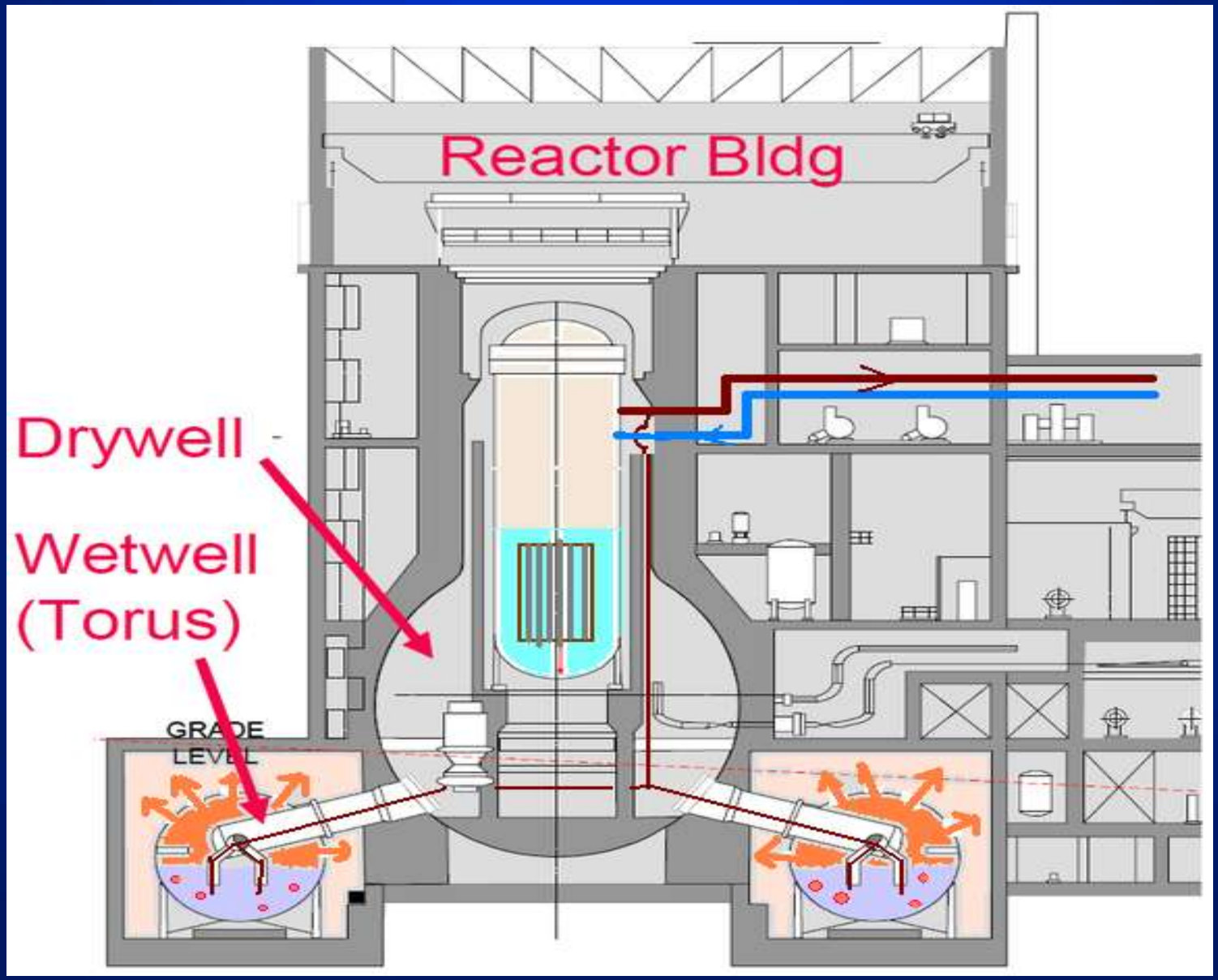
STAGE-6 : Accumulation of H_2 gas in secondary containment and pressure build-up



STAGE-7 : Attainment of explosive H_2 concentration in secondary containment – BURSTING & release

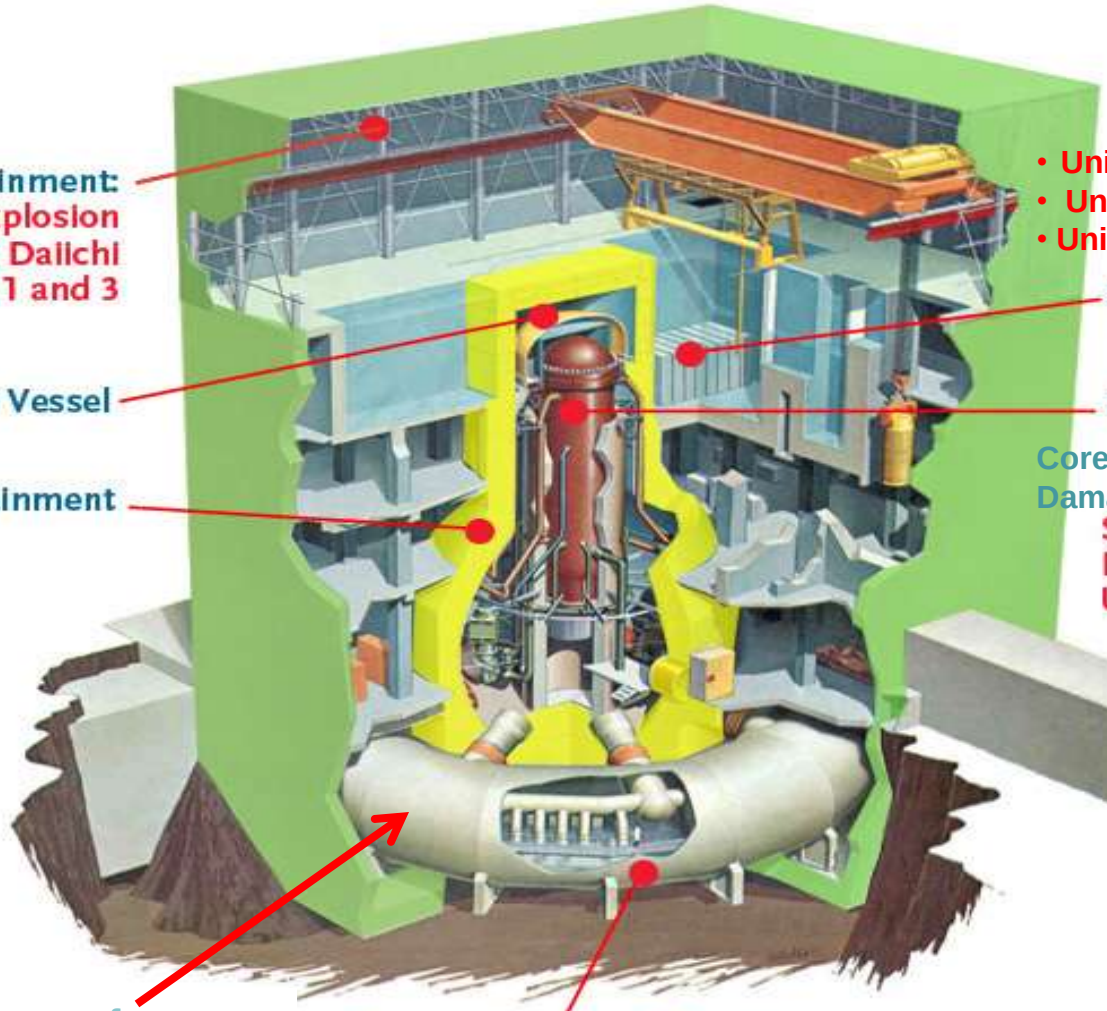


Attainment of explosive H_2 concentration in Wetwell – BURSTING & release (Unit-2)



Fukushima-1

Boiling Water Reactor Design At Fukushima Daiichi



Secondary Containment:
Area of Explosion
At Fukushima Daiichi
Units 1 and 3

Steel Containment Vessel

Primary Containment

Spent Fuel Pool

Reactor Vessel

Core and Fuel
Damaged in Unit- 1,2&3

Seawater Is Being Pumped
Into Reactor Vessels at
Units 1, 3 and 4

Possible area of
explosion at Fukushima
Daiichi 2

Suppression Pool (Torus)

Spent Fuel Pool Status

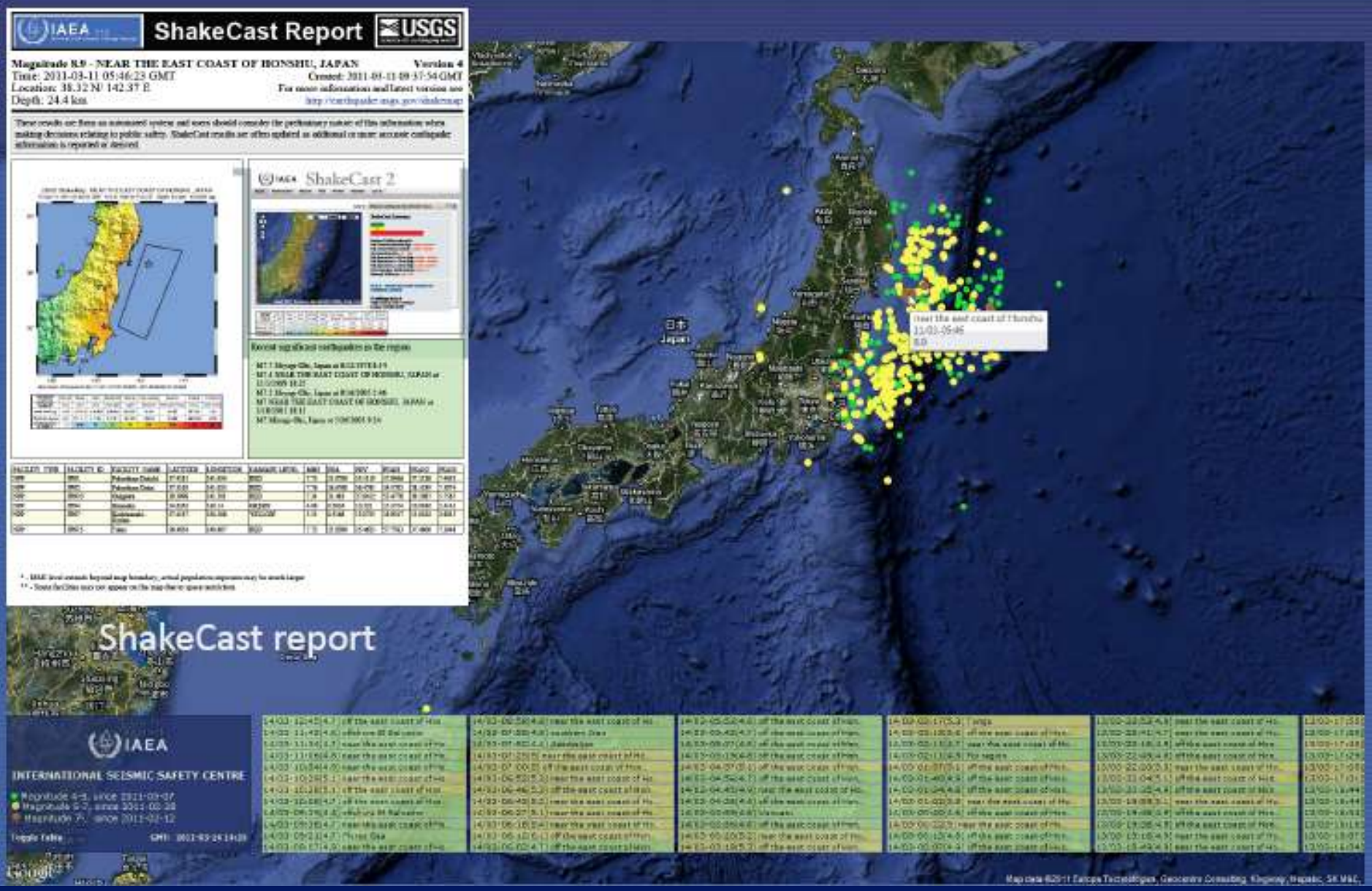
- **Unit- 3&4 :Low water level**
- **Unit- 3 :Fuel Rods Damaged**
- **Unit-5&6 : High Temperature**

Updated on 17-0-2011

Preliminary Analysis

Source :IAEA

Earthquake Details



Earthquake details

Characteristic of main shock (Japan Meteorological Agency: JMA)

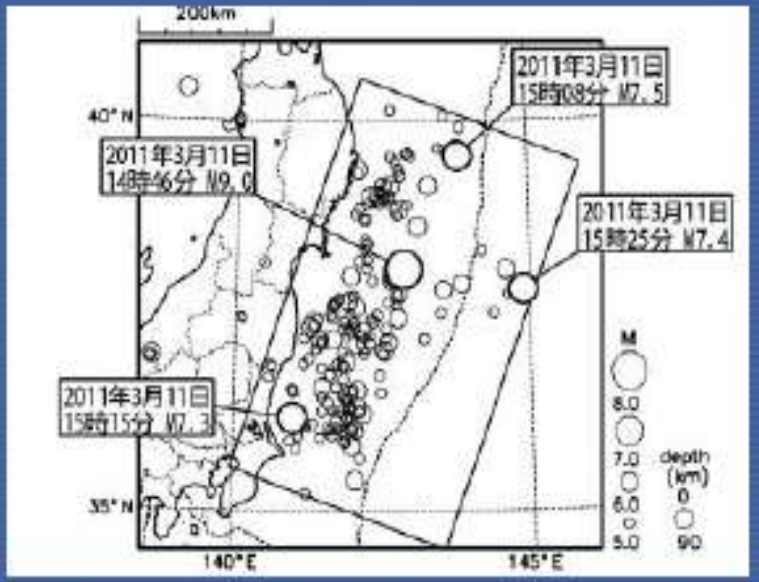
Date and Time:	11 March 2011 14:46 JST (05:46 UTC)	
Magnitude:	9.0 (interim value; the largest earthquake recorded in Japan)	
Hypocenter:	130km off the Pacific coast of Tohoku region, from Iwate to Ibaraki Prefectures, 24km depth	
Mechanism:	Reverse fault type with WNW-ESE compressional axis (by CMT analysis)	
JMA Seismic Intensity:	7 (Max)	Kurihara City of Miyagi Prefecture
	6+	28 cities and towns (including Wakuya Town, Tome City, Osaki City, Natori City) in Miyagi, Fukushima, Ibaraki, and Tochigi Prefectures
	6- or weaker	Observed nationwide from Hokkaido to Kyushu
Tsunami Warnings and Advisories:	Please refer to real-time information at http://www.jma.go.jp/en/tsunami/	

Main shock (M9.0):

- 11 Mar. 2011 14:46 (JST) M9.0

After shock (>M7.0):

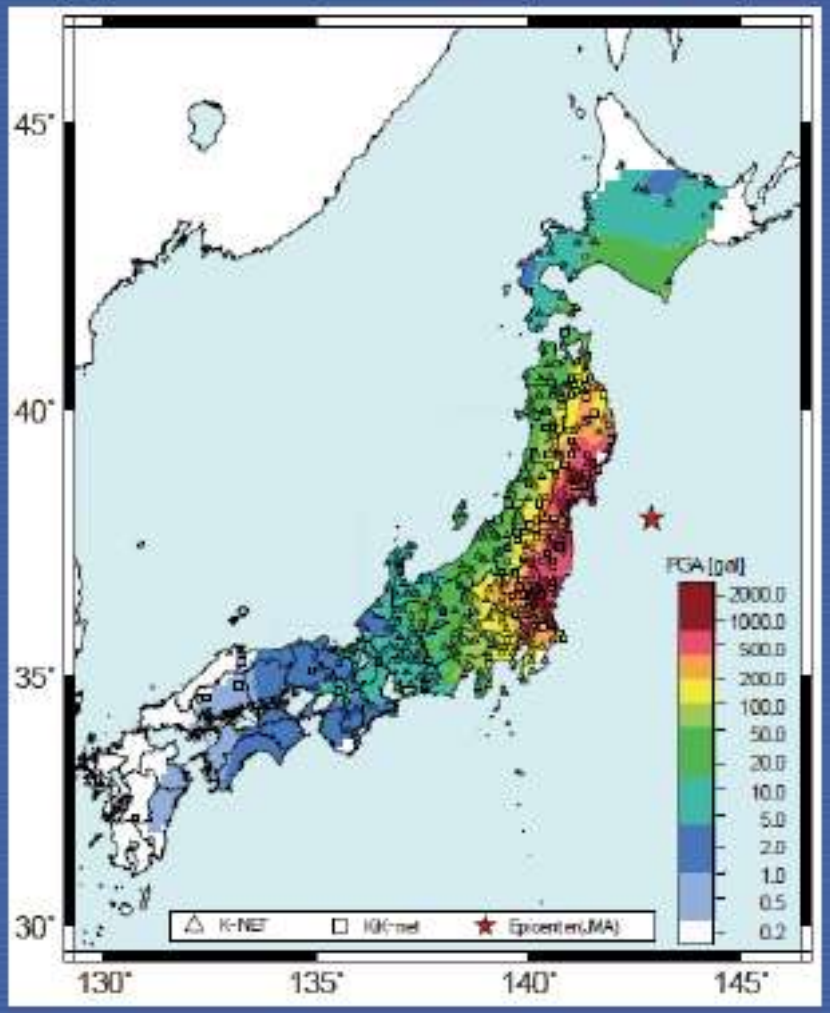
- 11 Mar. 2011 15:08 (JST) M7.5
- 11 Mar. 2011 15:15 (JST) M7.3
- 11 Mar. 2011 15:25 (JST) M7.4



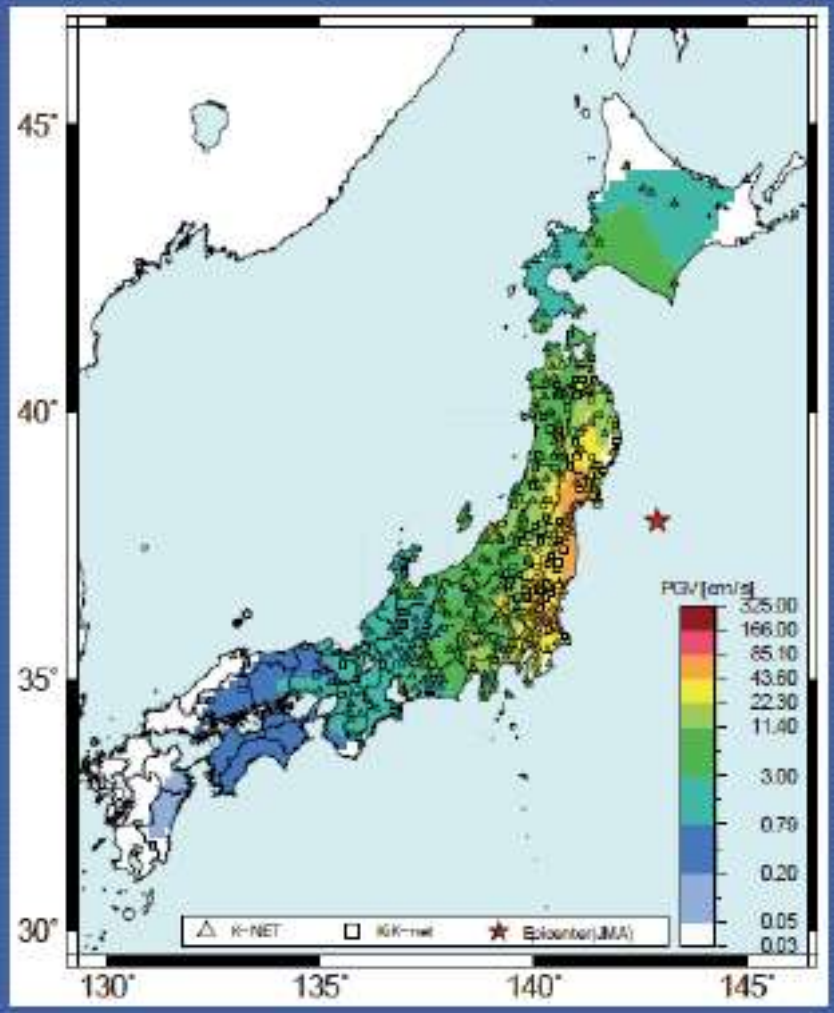
Distribution of main and after shock (JMA)

IAEA

Effects of Earthquake



PGA distribution

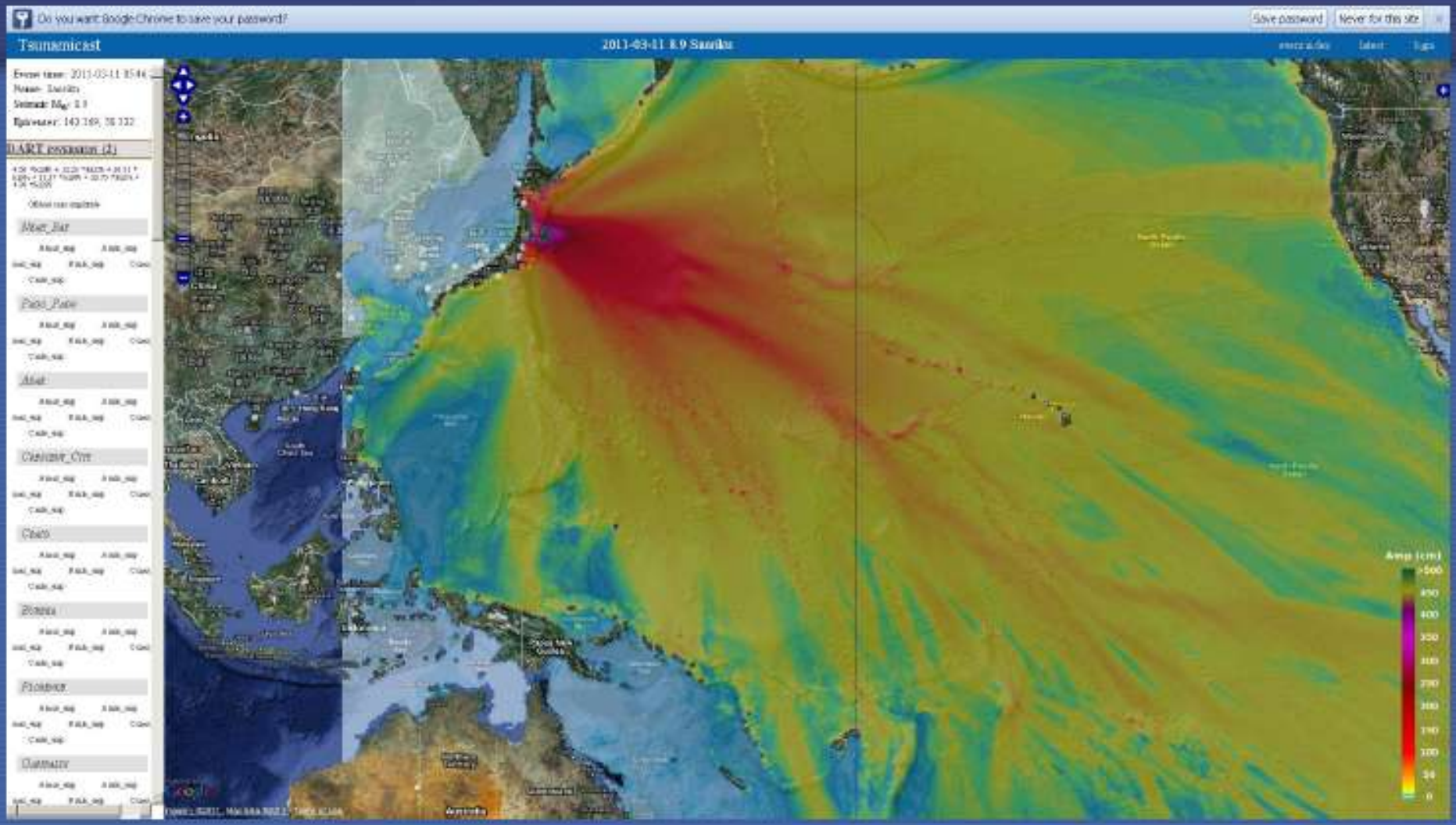


PGV distribution

IAEA

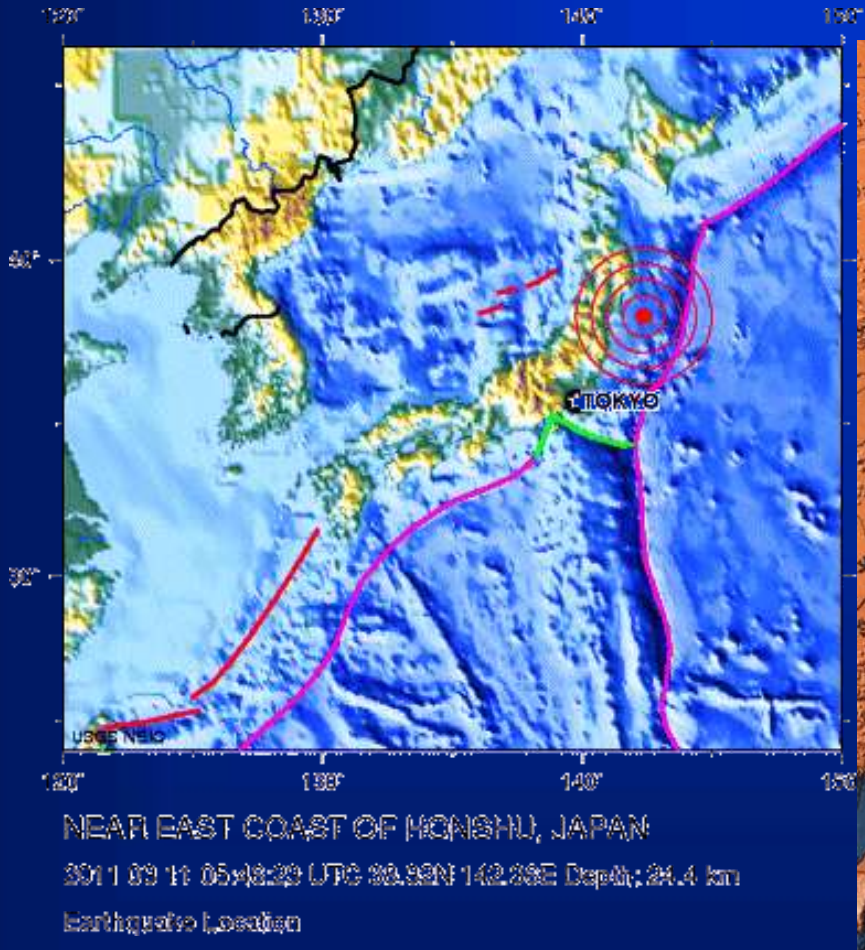
(National Research Institute for Earth Science and Disaster Prevention: NIED)

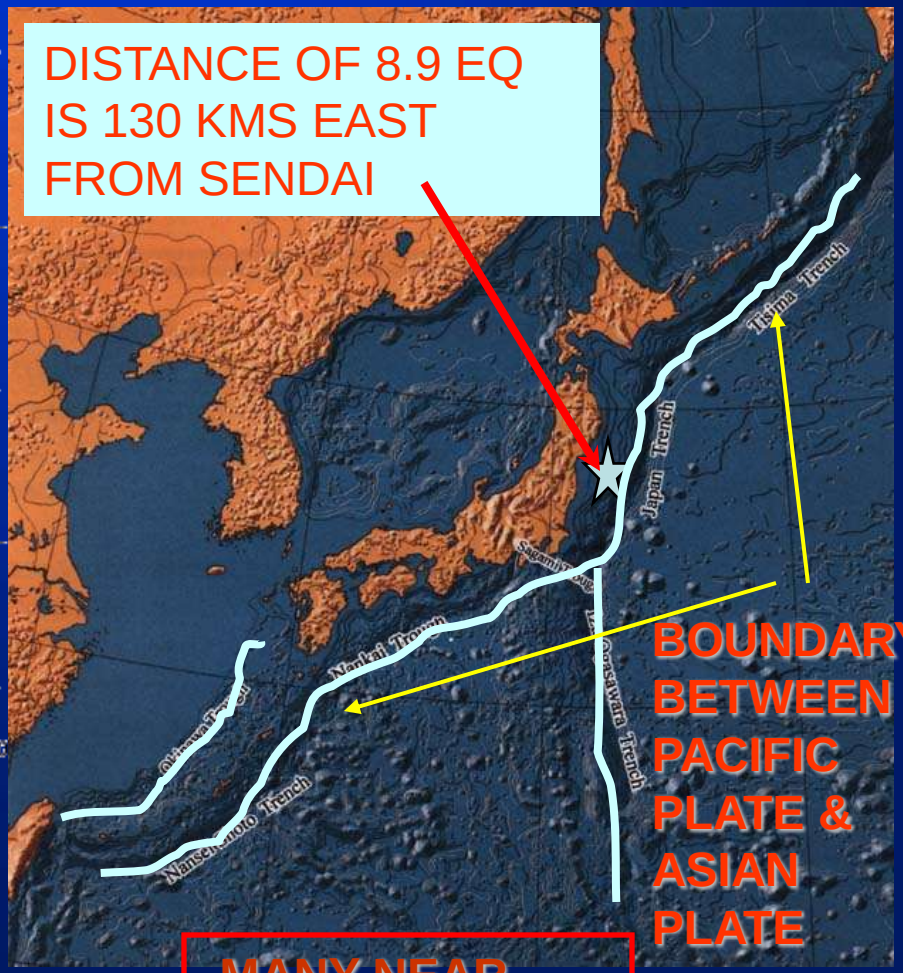
Tsunami Cast



Earthquake information from ISSC/EENS
(TsunamiCast)

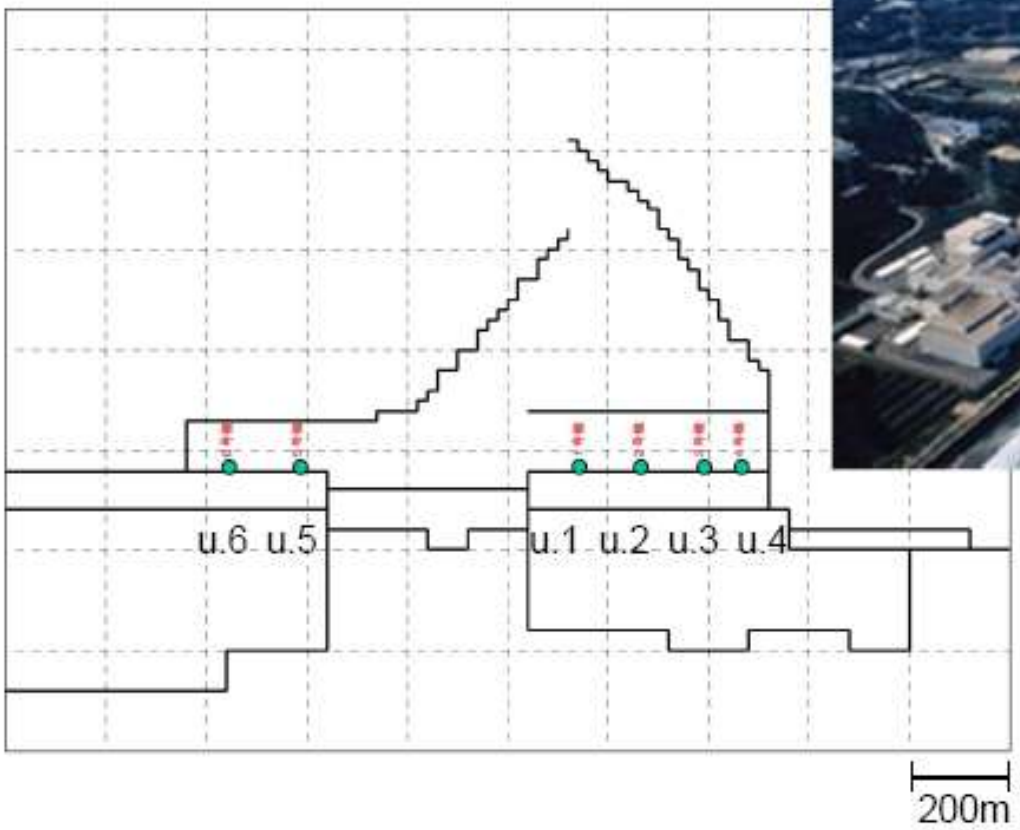
TSUNAMIGENIC LOCATIONS IN JAPAN





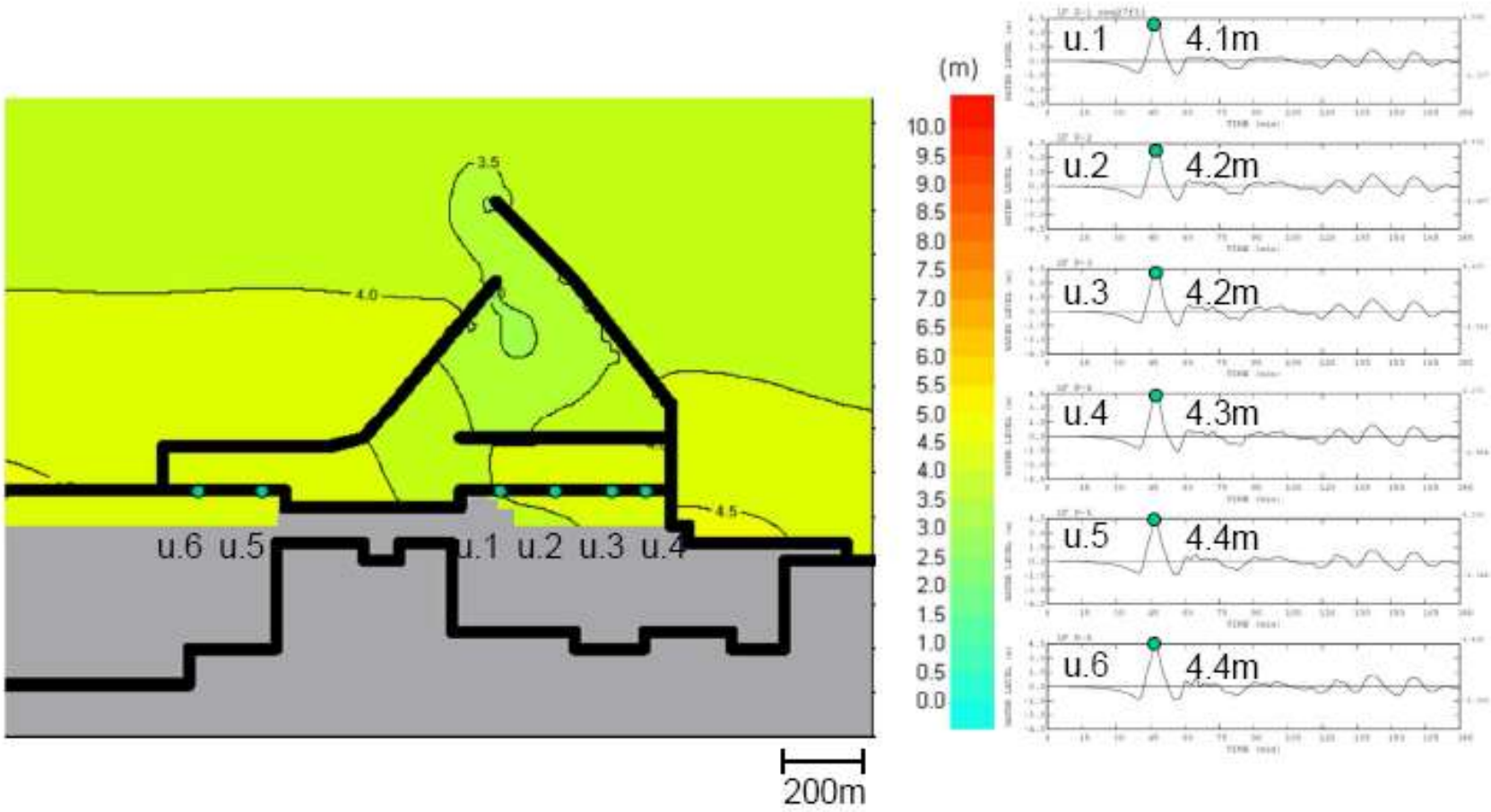
Design Basis

Location of Evaluation



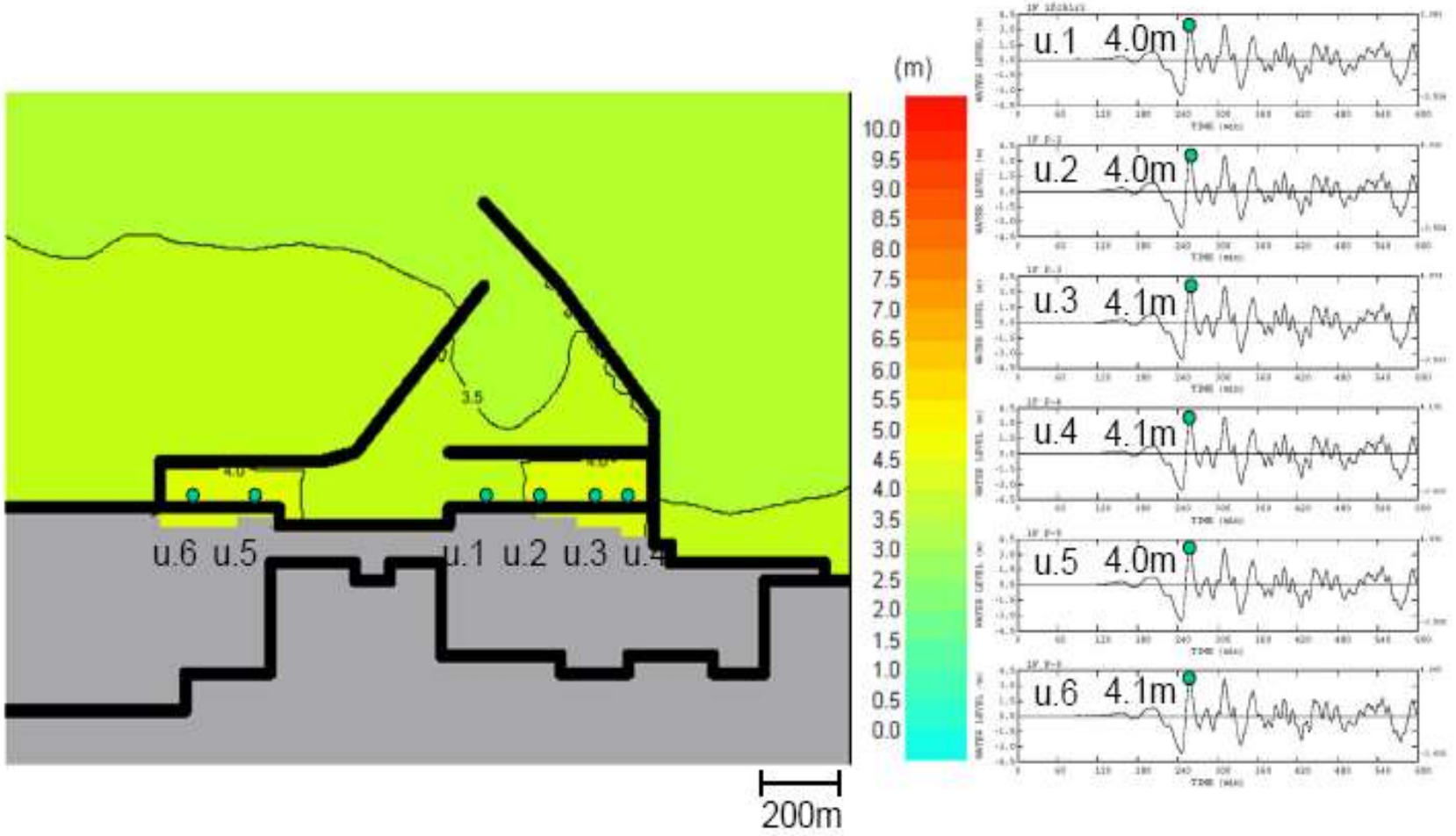
Design Basis

Maximum Water Level by Near Field Tsunami



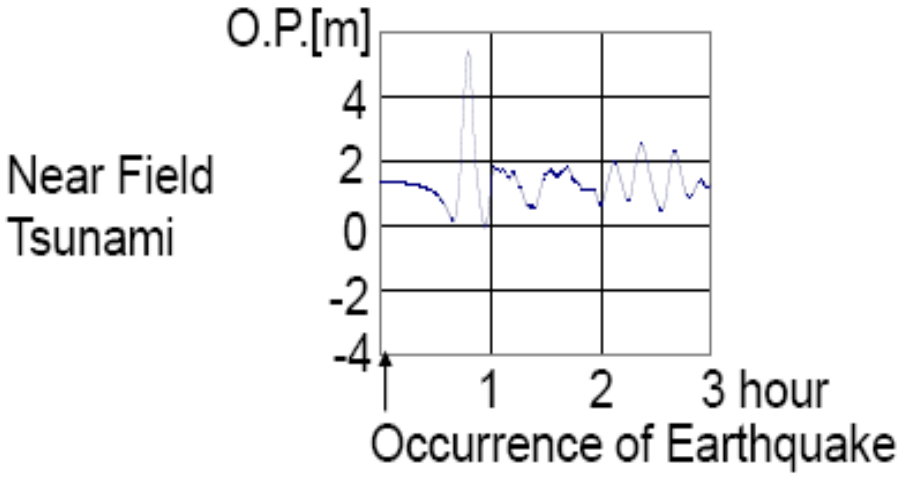
Design Basis

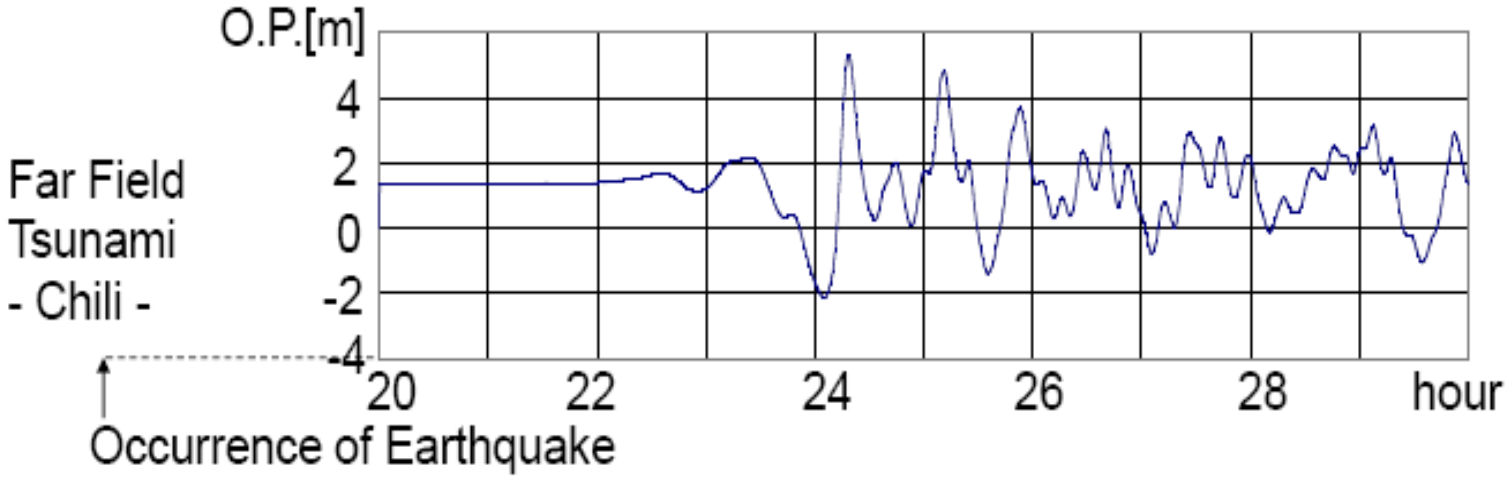
Maximum Water Level by Far Field Tsunami



Design Basis

Time History



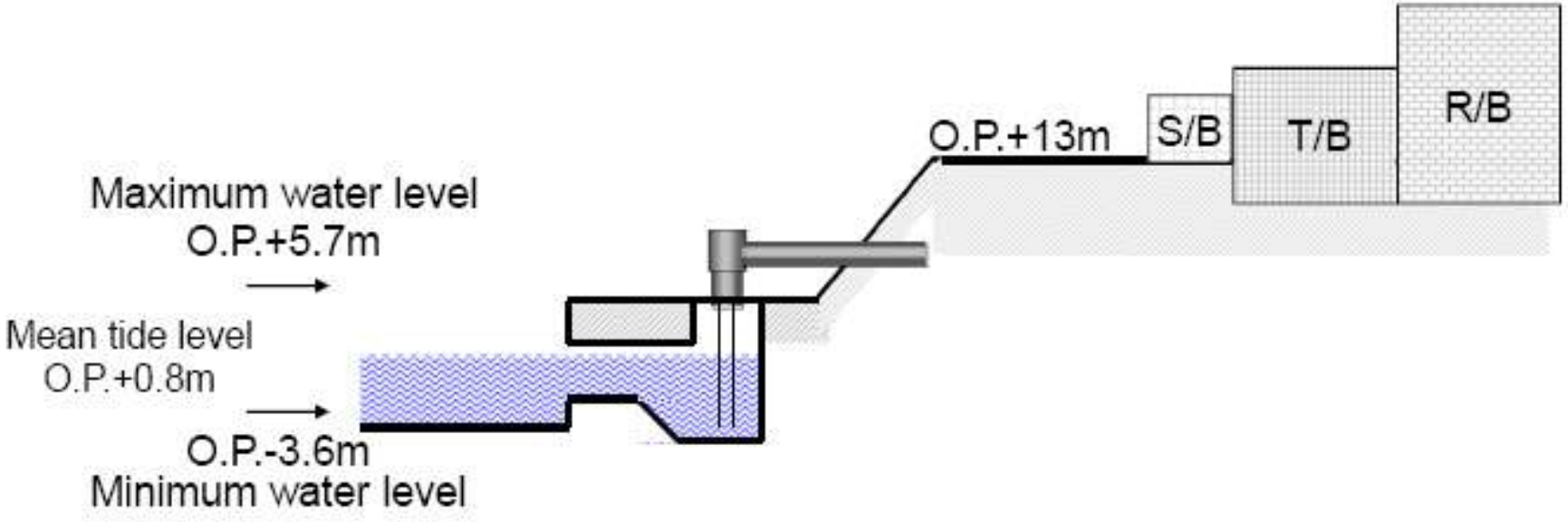


Design Basis

Summary of Evaluation

Maximum water level = 4.4 + O.P.+1.3 = O.P.+5.7m

Minimum water level = -3.6 – O.P.0.0 = O.P.-3.6m

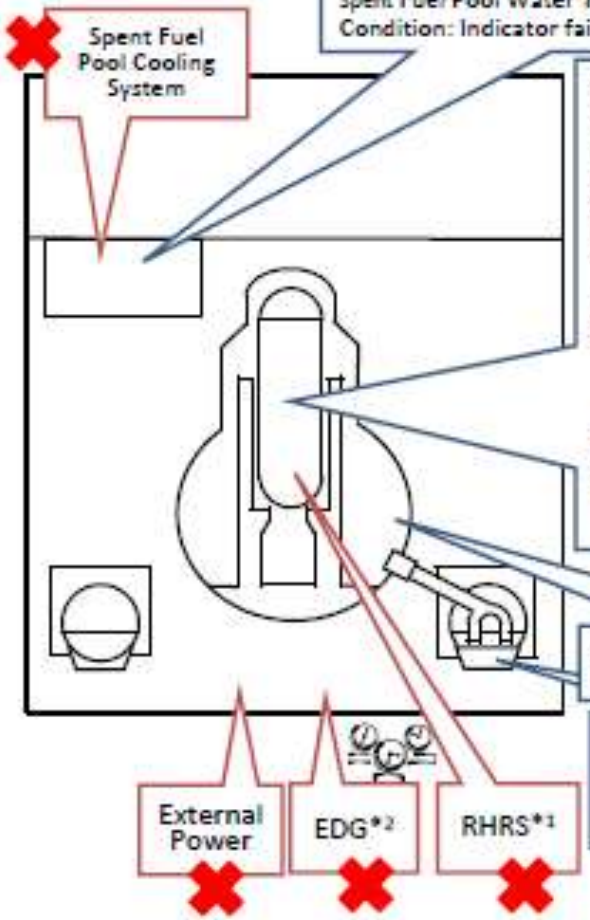


Major Events after Earthquake and Status at Fukushima reactors

AS Reported By NISA

Conditions of Fukushima Dai-ichi Nuclear Power Station Unit 1

(As of 13:00 April 3rd, 2011)



Spent Fuel Pool Water Temperature — ℃
Condition: Indicator failure

Reactor Pressure A 0.394MPa*
Reactor Pressure B 0.648MPa*
Condition : No large fluctuation
*converted to absolute pressure
Reactor Water Level A −1,650mm
Reactor Water Level B −1,650mm
Condition: No flooding of top of active fuel until the above level

Reactor Water Temperature — ℃
Condition: No data available

Reactor Pressure Vessel (RPV) Temperature:
Feedwater Nozzle Temperature :252.8℃
Temperature at the bottom head of RPV :116.7℃

PCV*3 Pressure 0.155MPa
Condition: No large fluctuation

S/P*4 Water Temperature — ℃
Condition : No data available
S/P*4 Pressure 0.155MPa
Condition : No large fluctuation

*1 Residual Heat Removal System
*2 Emergency Diesel Generator
*3 Primary Containment Vessel
*4 Suppression Pool

Major Events after the earthquake

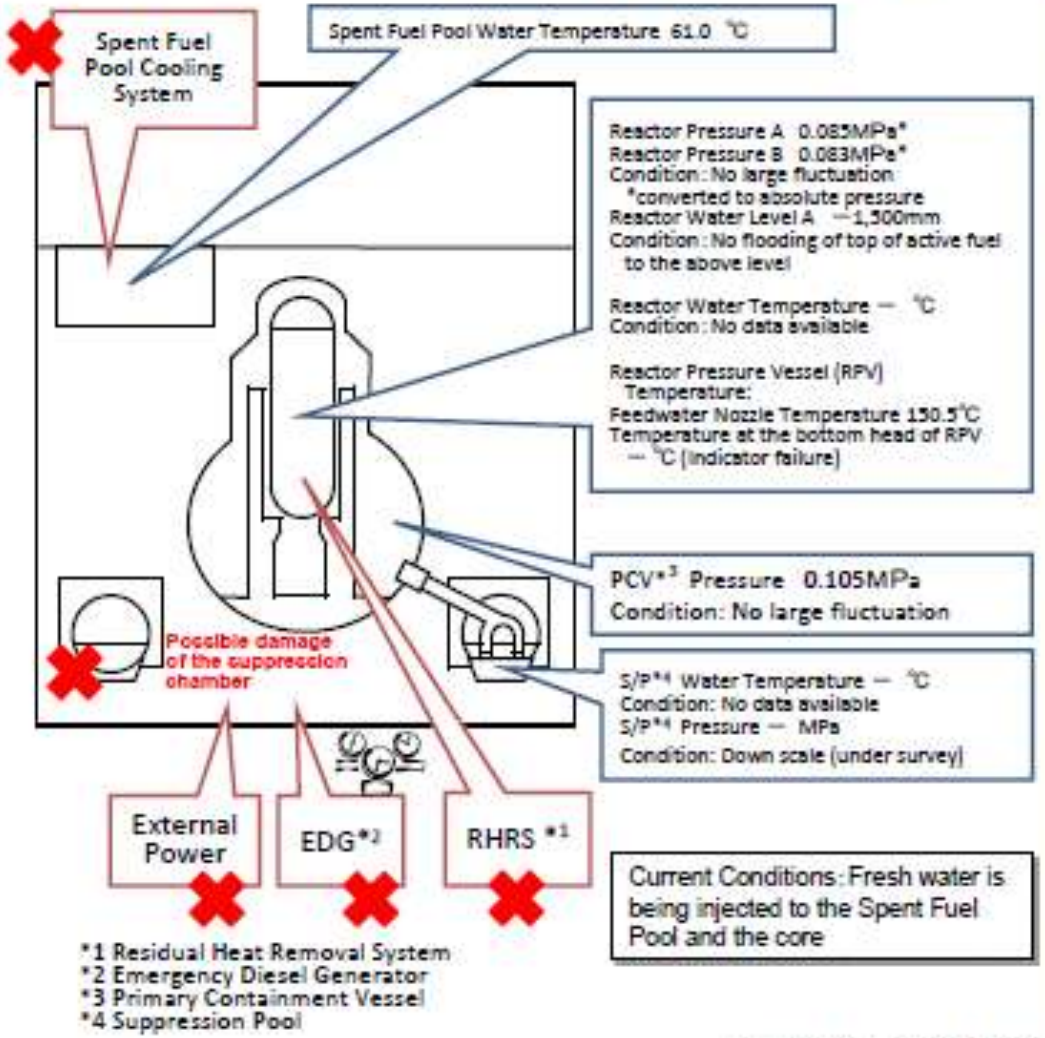
11th 14:46 Under operation, Automatic shutdown by the earthquake
11th 15:42 Report based on the Article 10 (Total loss of A/C power)
11th 16:36 Occurrence of the Article 15 event (Inability of water injection of the Emergency Core Cooling System)
12th 01:20 Occurrence of the Article 15 event (Unusual rise of the pressure in PCV)
12th 10:17 Started to vent.
12th 15:36 Sound of explosion
12th 20:20 Started to inject seawater and borated water to core.
23rd 02:33 The amount of injected water to the Rector Core was increased utilizing the Feedwater Line in addition to the Fire Extinguish Line. ($2m^3/h \rightarrow 18m^3/h$)
09:00 Switched to the Feedwater Line only.($18m^3/h \rightarrow 11m^3/h$)
24th 11:30 Lighting in the Central Control Room was recovered.
25th 15:37 Started fresh water injection.
29th 08:32 Switched to the water injection to the core using the temporary motor-driven pump.
31st 12:00 ~ 2nd 15:26 Started to transfer the stagnant water from the Condensate Storage Tank (CST) to the Surge Tank of Suppression Pool Water (SPT)
31st 13:03 ~ 16:04 Fresh water spray by Concrete Pump Truck (Fresh water)
3rd 12:02 The power supply to the temporary motor-driven pump was switched from the temporary power supply to the external power supply.

Current Conditions : Fresh water is being injected to the Spent Fuel Pool and the core

(Editorial committee for Nuclear Energy Handbook, Nuclear Energy Handbook)

Conditions of Fukushima Dai-ichi Nuclear Power Station Unit 2

(As of 13:00 April 3rd, 2011)



*1 Residual Heat Removal System
*2 Emergency Diesel Generator
*3 Primary Containment Vessel
*4 Suppression Pool

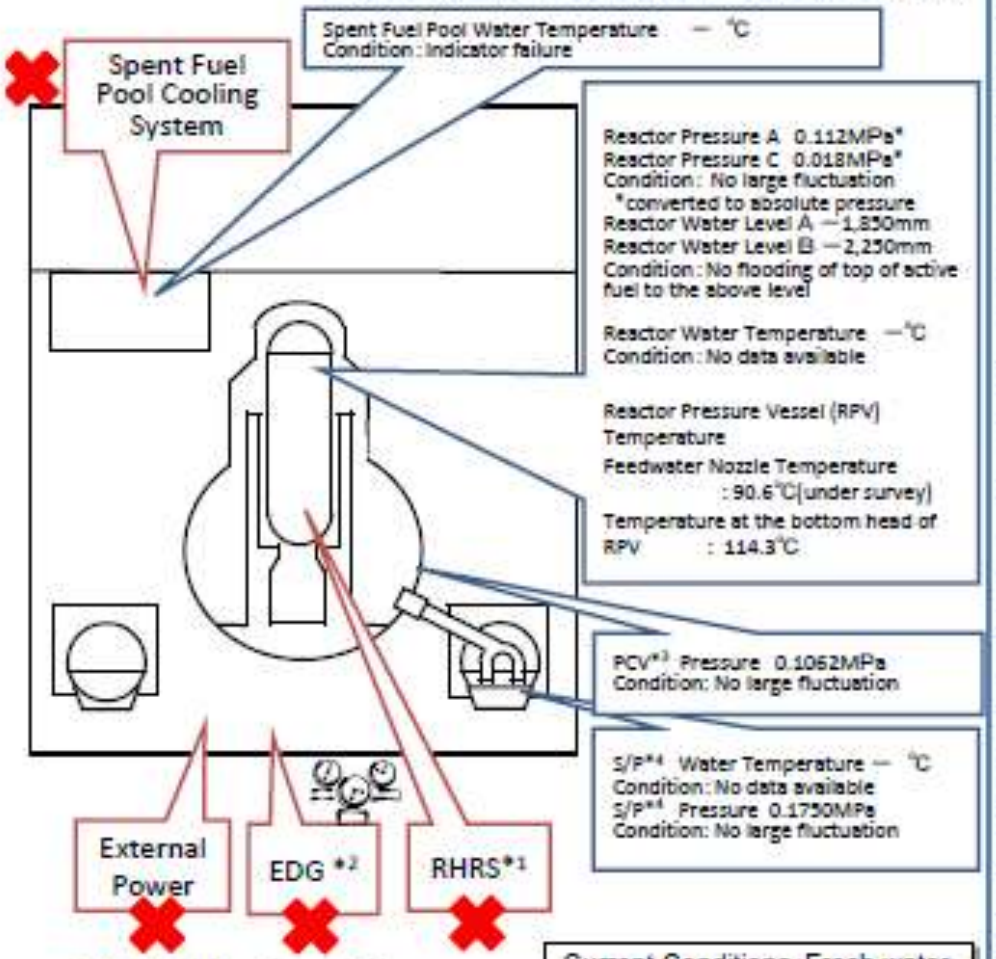
Major Events after the earthquake

- 11th 14:46 Under operation, Automatic shutdown by the earthquake
- 11th 15:42 Report based on the Article 10 (Total loss of A/C power)
- 11th 16:36 Occurrence of the Article 15 event (Inability of water injection of the Emergency Core Cooling System)
- 13th 11:00 Started to vent.
- 14th 13:25 Occurrence of the Article 15 event (Loss of reactor cooling functions)
- 14th 16:34 Started to inject seawater to the Reactor Core.
- 14th 22:50 Occurrence of the Article 15 event (Unusual rise of the pressure in PCV)
- 15th 00:02 Started to vent.
- 15th 06:10 Sound of explosion
- 15th around 06:20 Possible damage of the suppression chamber
- 20th 15:05～17:20 Approximately 40 ton seawater injection to the Spent Fuel Pool (SFP) via the Fuel Pool Cooling Line (FPC)
- 20th 15:46 Power Center received electricity.
- 21st 18:22 White smoke generated. The smoke died down and almost invisible at 07:11 March 22nd.
- 22nd 16:07 Injection of around 18 tons of seawater to SFP
- 25th 10:30～12:19 Sea water injection to SFP via FPC
- 26th 10:10 Started to inject fresh water to the Reactor Core.
- 26th 16:46 Lighting in the Central Control Room was recovered.
- 27th 18:31 Switched to the water injection to the core using the temporary motor-driven pump.
- 29th 16:30～18:25 Switched to the temporary motor-driven pump injecting fresh water to SFP.
- 29th 16:45～1st 11:50 Transferred the water from the Condensate Storage Tank (CST) to the Surge Tank of Suppression Pool Water (SPT)
- 30th 9:25～23:50 Confirmed malfunction of the temporary motor-driven pump injecting fresh water to SFP(9:45). Switched to the injection using the fire pump Truck, but suspended as cracks were confirmed in the hose. (12:47, 13:10) Resumed injection of fresh water(19:05)
- 1st 14:56～17:05 Injection of fresh water from FPC to SFP using the temporary motor-driven pump.
- 2nd 17:10 Started to transfer the water from the condenser to the Condensate Storage Tank (CST).
- 3rd 12:12 The power supply to the temporary motor-driven pump was switched from the temporary power supply to the external power supply.

(Editorial committee for Nuclear Energy Handbook, Nuclear Energy Handbook)

Conditions of Fukushima Dai-ichi Nuclear Power Station Unit 3

(As of 13:00 April 3rd, 2011)



*1 Residual Heat Removal System
*2 Emergency Diesel Generator
*3 Primary Containment Vessel
*4 Suppression Pool

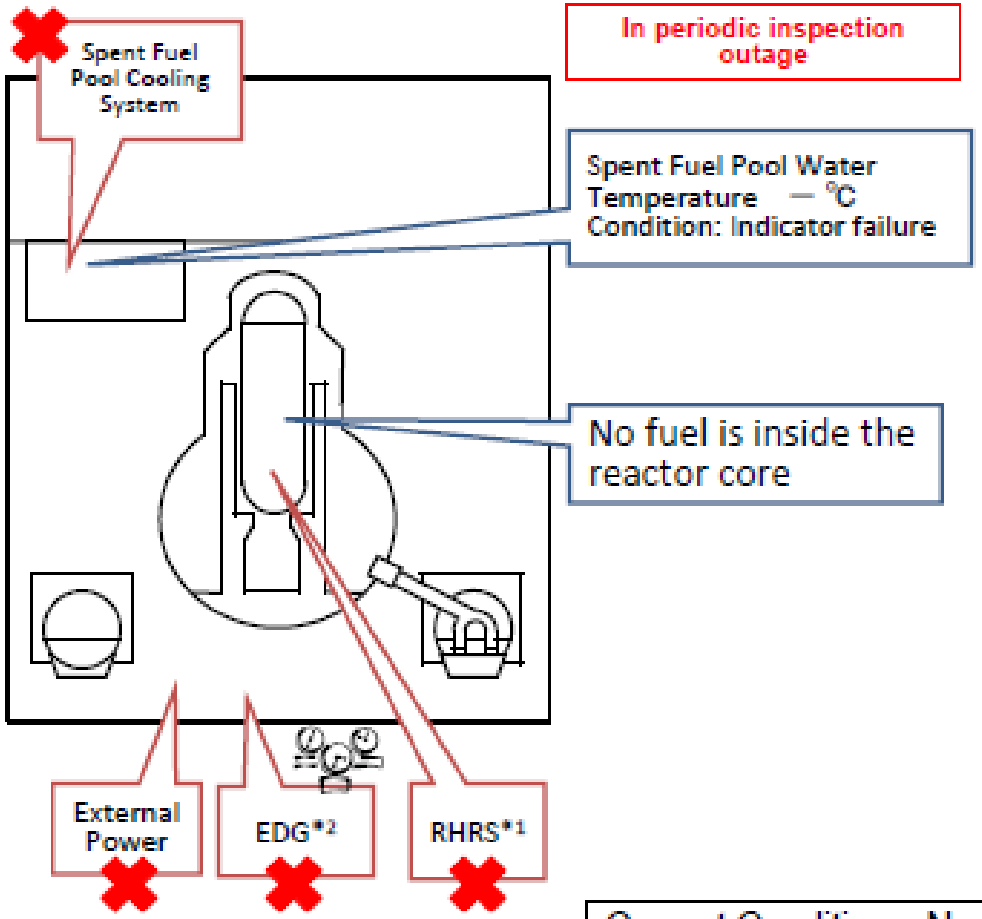
Current Conditions : Fresh water is being injected to the Spent Fuel Pool and the core

Major Events after the earthquake

11th 14:46 Under operation, Automatic shutdown by the earthquake
11th 15:42 Report based on the Article 10 (Total loss of A/C power)
13th 05:10 Occurrence of the Article 15 event (Inability of water injection of the Emergency Core Cooling System)
13th 08:41 Started to vent.
13th 13:12 Started to inject seawater and borated water to core.
14th 05:20 Started to vent.
14th 07:44 Occurrence of the Article 15 event (Unusual rise of the pressure in PCV)
14th 11:01 Sound of explosion
16th around 08:30 White smoke generated.
17th 09:48～10:01 Water discharge by the helicopters of Self-Defense Force
17th 19:05～19:15 Water spray from the ground by High pressure water-cannon trucks of Police
17th 19:35～20:09 Water spray from the ground by fire engines of Self-Defense Force
18th before 14:00～14:38 Water spray from the ground by 6 fire engines of Self-Defense Force
18th ～14:45 Water spray from the ground by a fire engine of the US Military
19th 00:30 ～01:10 Water spray by Hyper Rescue Unit of Tokyo Fire Department
19th 14:10 ～ 20th 03:40 Water spray by Hyper Rescue Unit of Tokyo Fire Department
20th 11:00 Pressure of PCV rose(320kPa).Afterward fell.
20th 21:36 ～ 21st 08:58 Water spray by Hyper Rescue Unit of Tokyo Fire Department
21st around 15:55 Grayish smoke generated and was confirmed to be died down at 17:55.
22nd 15:10 ～16:00 Water spray by Hyper Rescue Unit of Tokyo Fire Department and Osaka City Fire Bureau.
22nd 22:46 Lighting in the Central Control Room was recovered.
23rd 11:03 ～13:20 injection of about 35ton of sea water to the Spent Fuel Pool (SFP) via the Fuel Pool Cooling Line (FPC)
23rd around 16:20 Black smoke generated and was confirmed to died down at around 23:30 and 24th 04:50.
24th 05:35～16:05 Approximately 120 ton sea water injection to SFP via FPC
25th 13:28～16:00 Water spray by Kawasaki City Fire Bureau supported by Tokyo Fire Department
25th 18:02 Started fresh water injection to the core.
27th 12:34～14:36 Water spray by Concrete Pump Truck
28th 17:40～31st around 8:40 Transferring the water from the Condensate Storage Tank (CST) to the Surge Tank of Suppression Pool Water (SPT)
28th 20:30 Switched to the water injection to the core using a temporary motor-driven pump.
29th 14:17～18:18 Fresh water spray by Concrete Pump Truck
31st 16:30～19:33 Fresh water spray by Concrete Pump Truck
2nd 09:52～12:54 Fresh water spray by Concrete Pump Truck
3rd 12:18 The power supply to the temporary motor-driven pump was switched from the temporary power supply to the external power supply.

(Editorial committee for Nuclear Energy Handbook, Nuclear Energy Handbook)

Conditions of Fukushima Dai-ichi Nuclear Power Station Unit 4
(As of 13:00 April 3rd, 2011)



*1 Residual Heat Removal System

*2 Emergency Diesel Generator

*3 Reactor Pressure Vessel

Major events after the earthquake

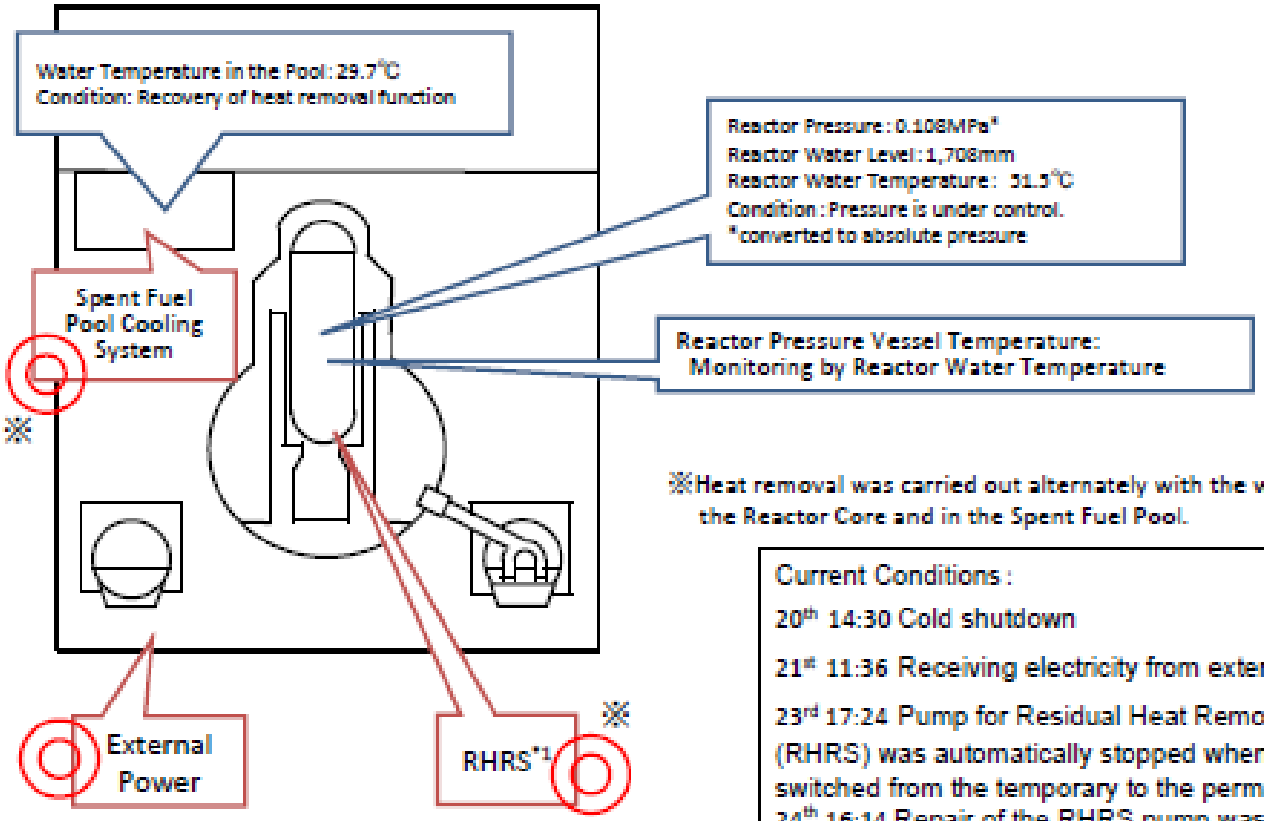
In periodic inspection outage when the earthquake occurred
14th 04:08 Water temperature in the Spent Fuel Pool (SFP), 84℃
15th 06:14 Confirmed the partial damage of wall in the 4th floor.
15th 09:38 Fire occurred in the 3rd floor. (12:25 extinguished)
16th 05:45 Fire occurred. TEPCO couldn't confirm any fire on the ground. (06:15)
20th 08:21～09:40 Water spray over SFP by Self-Defense Force
20th around 18:30～19:46 Water spray over SFP by Self-Defense Force
21st 06:37～08:41 Water spray over SFP by Self-Defense Force
21st around 15:00 Work for laying cable to Power Center was completed.
22nd 10:35 Power Center received electricity.
22nd 17:17～20:32 Water spray by Concrete Pump Truck
23rd 10:00～13:02 Water spray by Concrete Pump Truck
24th 14:36～17:30 Water spray by Concrete Pump Truck
25th 06:05～10:20 Sea water injection to SFP via the Fuel Pool Cooling Line (FPC)
25th 19:05～22:07 Water spray by Concrete Pump Truck
27th 16:55～19:25 Water spray by Concrete Pump Truck
29th 11:50 Lighting in the Central Control Room was recovered.
30th 14:04～18:33 Water spray by Concrete Pump Truck (Fresh water)
1st 8:28～14:14 Water spray by Concrete Pump Truck(Fresh water)

Current Conditions: No fuel is in RPV*3.
Fresh water is being injected to the Spent Fuel Pool.

(Editorial committee for Nuclear Energy Handbook, Nuclear Energy Handbook)

Conditions of Fukushima Dai-ichi Nuclear Power Station Unit 5
(As of 13:00 April 3rd, 2011)

In periodic inspection outage



※Heat removal was carried out alternately with the water in the Reactor Core and in the Spent Fuel Pool.

*1 Residual Heat Removal System

Current Conditions:

20th 14:30 Cold shutdown

21st 11:36 Receiving electricity from external power supply

23rd 17:24 Pump for Residual Heat Removal Seawater System (RHRS) was automatically stopped when the power supply was switched from the temporary to the permanent.

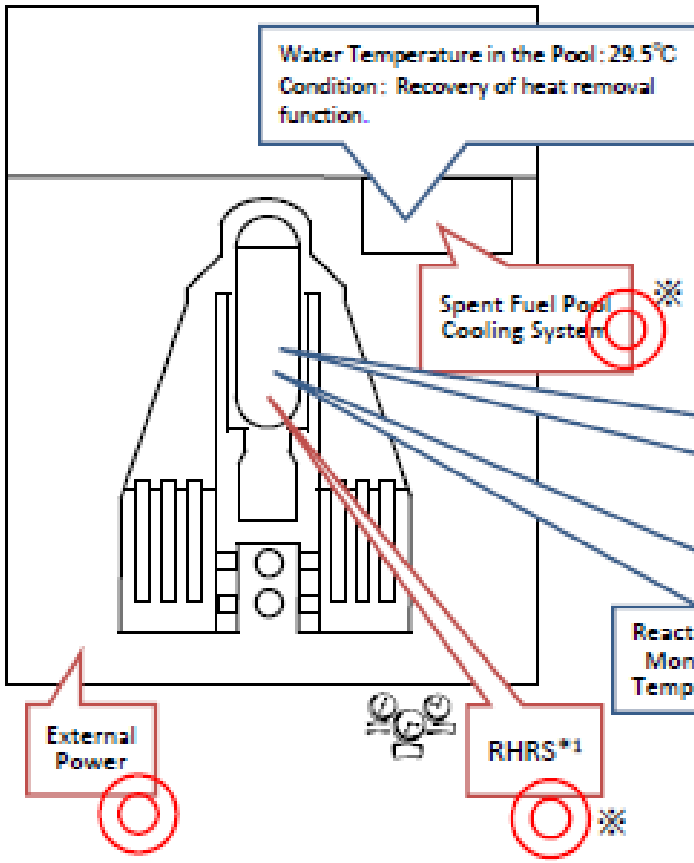
24th 16:14 Repair of the RHRS pump was completed.

24th 16:35 Started to cooling.

(Editorial committee for Nuclear Energy Handbook, Nuclear Energy Handbook)

Conditions of Fukushima Dai-ichi Nuclear Power Station Unit 6
(As of 13:00 April 3rd, 2011)

In periodic inspection outage



Current Conditions:
20th 19:27 Cold shutdown
22nd 19:17 Receiving electricity from external power supply

※Heat removal was carried out alternately with the water in the Reactor Core and in the Spent Fuel Pool.

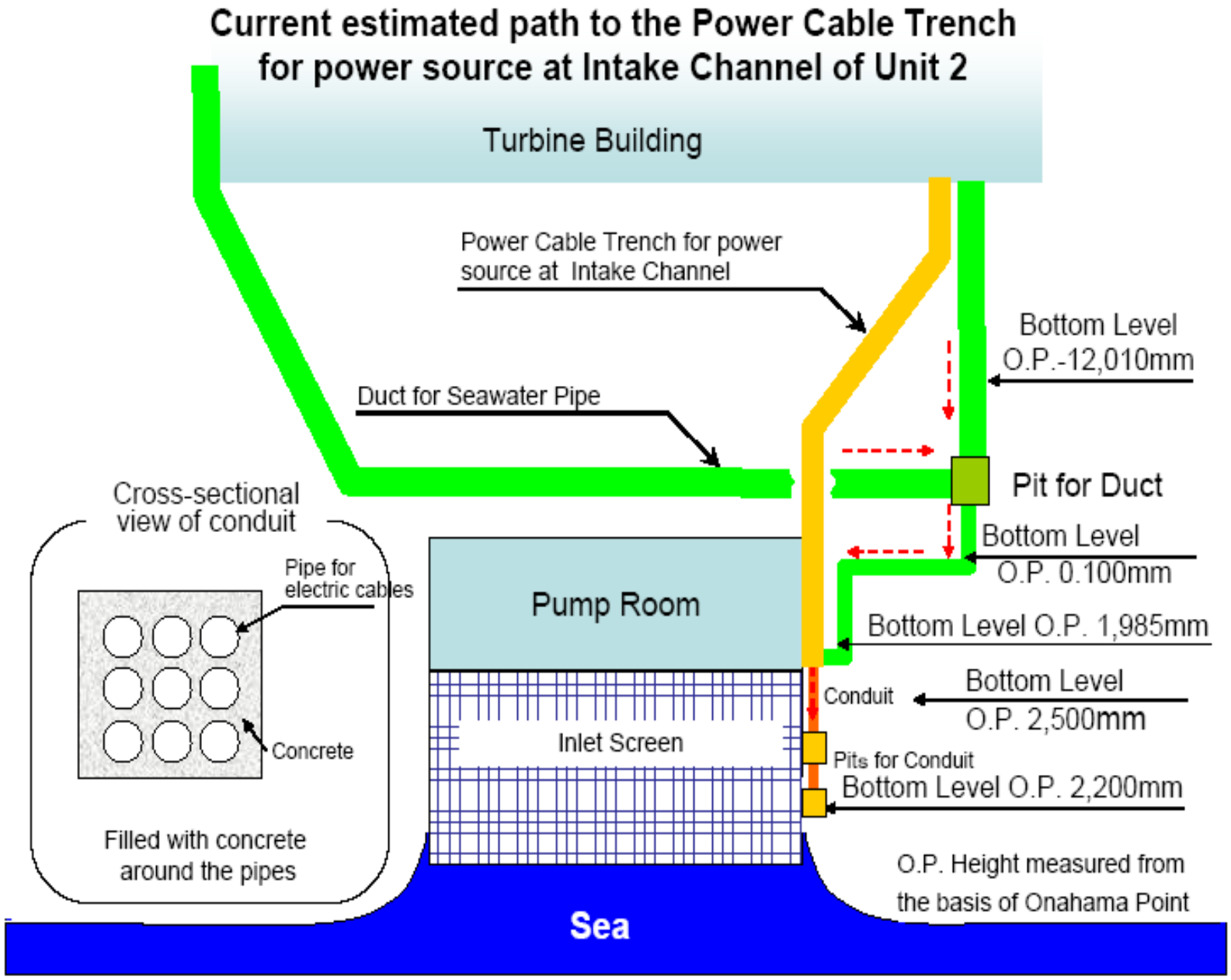
*1 Residual Heat Removal System

(Editorial committee for Nuclear Energy Handbook, Nuclear Energy Handbook)

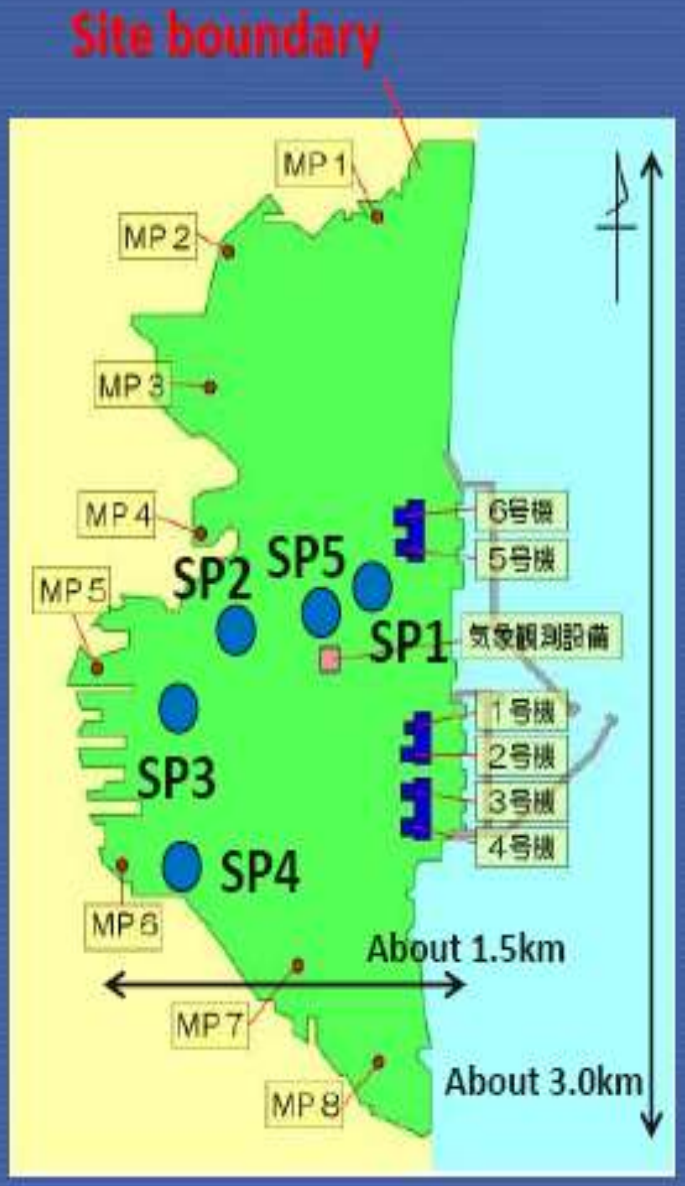
Around Units 1&2

Operation (Control) Rooms–Units 1&2

Current estimated path to the Power Cable Trench for power source at Intake Channel of Unit 2



Radiation Monitoring



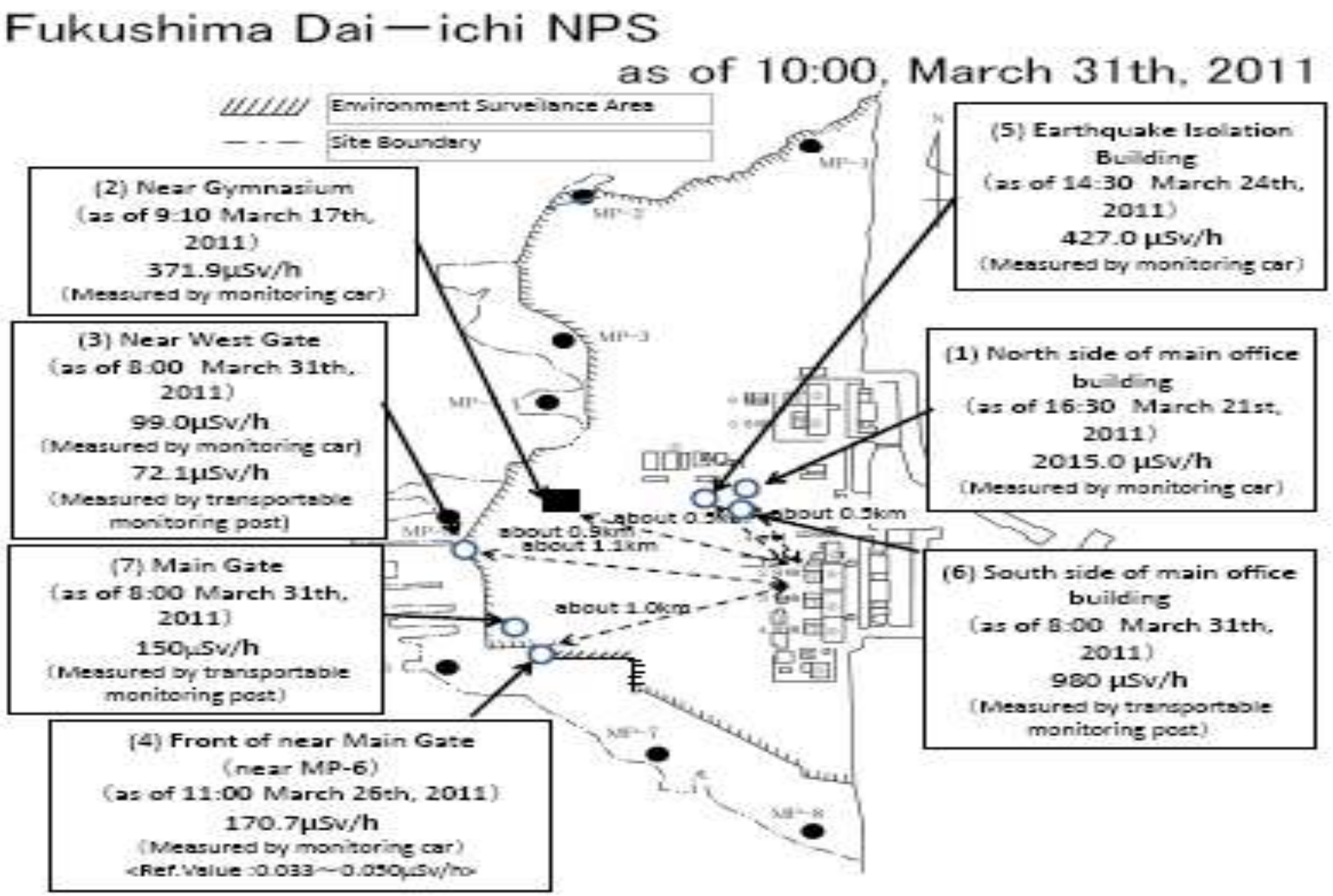
SP1~SP4 are additional monitoring post

- SP1: North main office building (0.5km)
- SP2: Side of the gym (0.9km)
- SP3: East gate (1.1km)
- SP4: Main gym (1.0km)
- SP5: In front of isolation building (0.5km)

(Distance between monitoring post and Reactor building of Unit1)

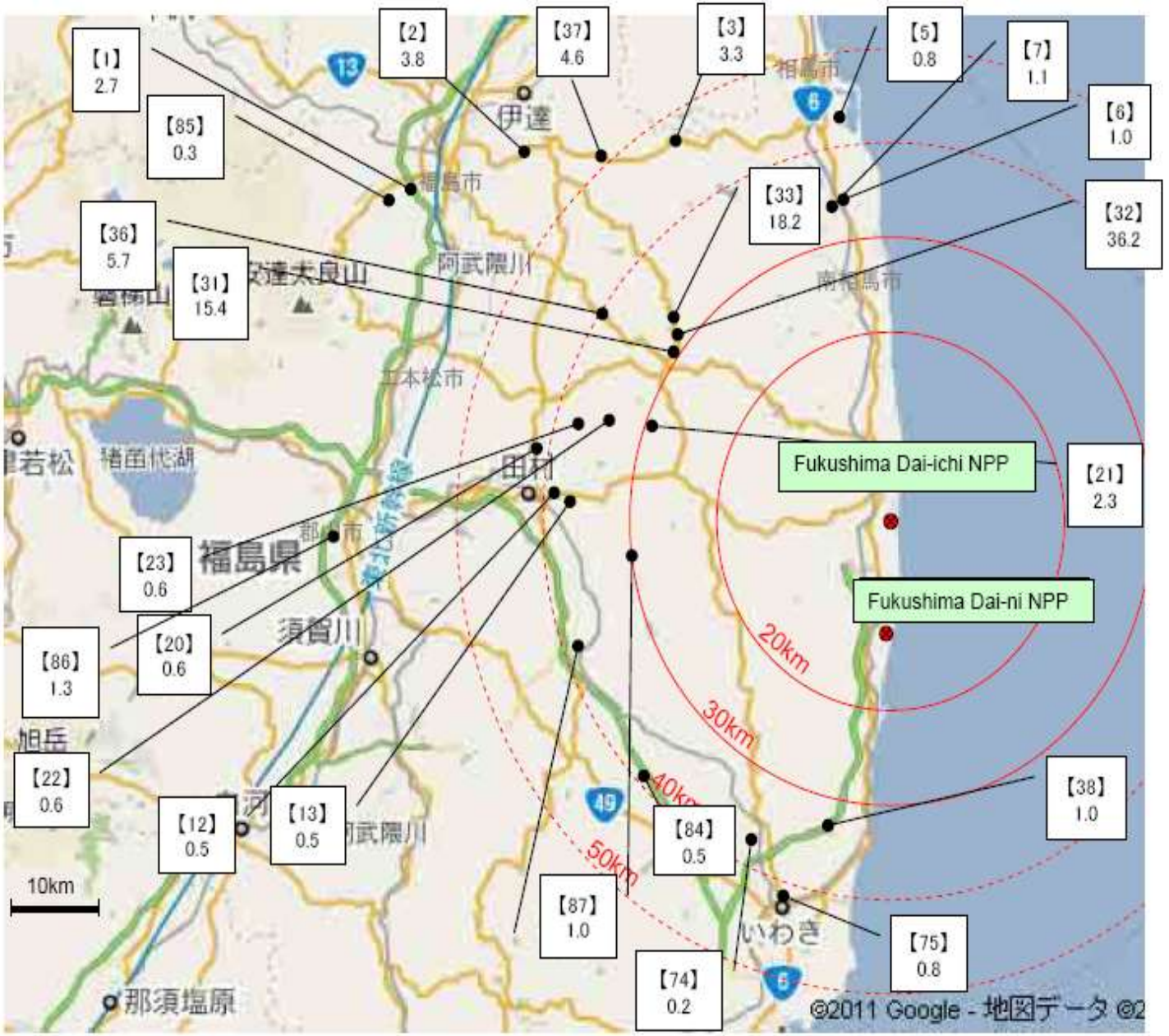
In Japan, EAB and LPZ are included in the site boundary area.

Radiation Levels in Plant Boundary



Radiation Levels in Fukushima Prefecture

Readings at Monitoring Post out of Fukushima Dai-ichi NPP



Monitoring Time
April 1,
6:00~12:00
● Monitoring Post

Unit : μSv per hour

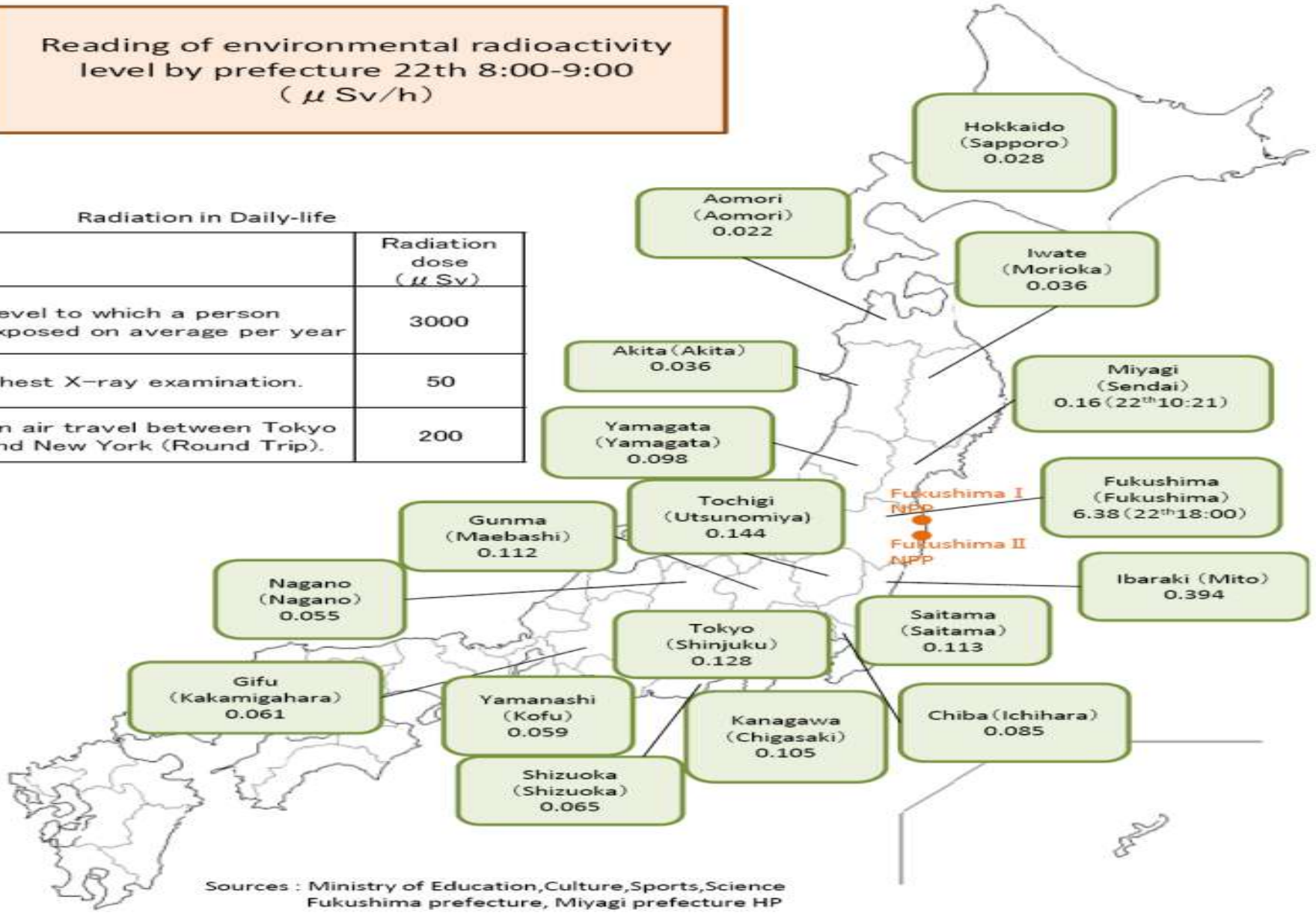
Circles indicate approximate range.

Radiation Levels in all Prefecture

Reading of environmental radioactivity level by prefecture 22th 8:00-9:00 (μ Sv/h)

Radiation in Daily-life

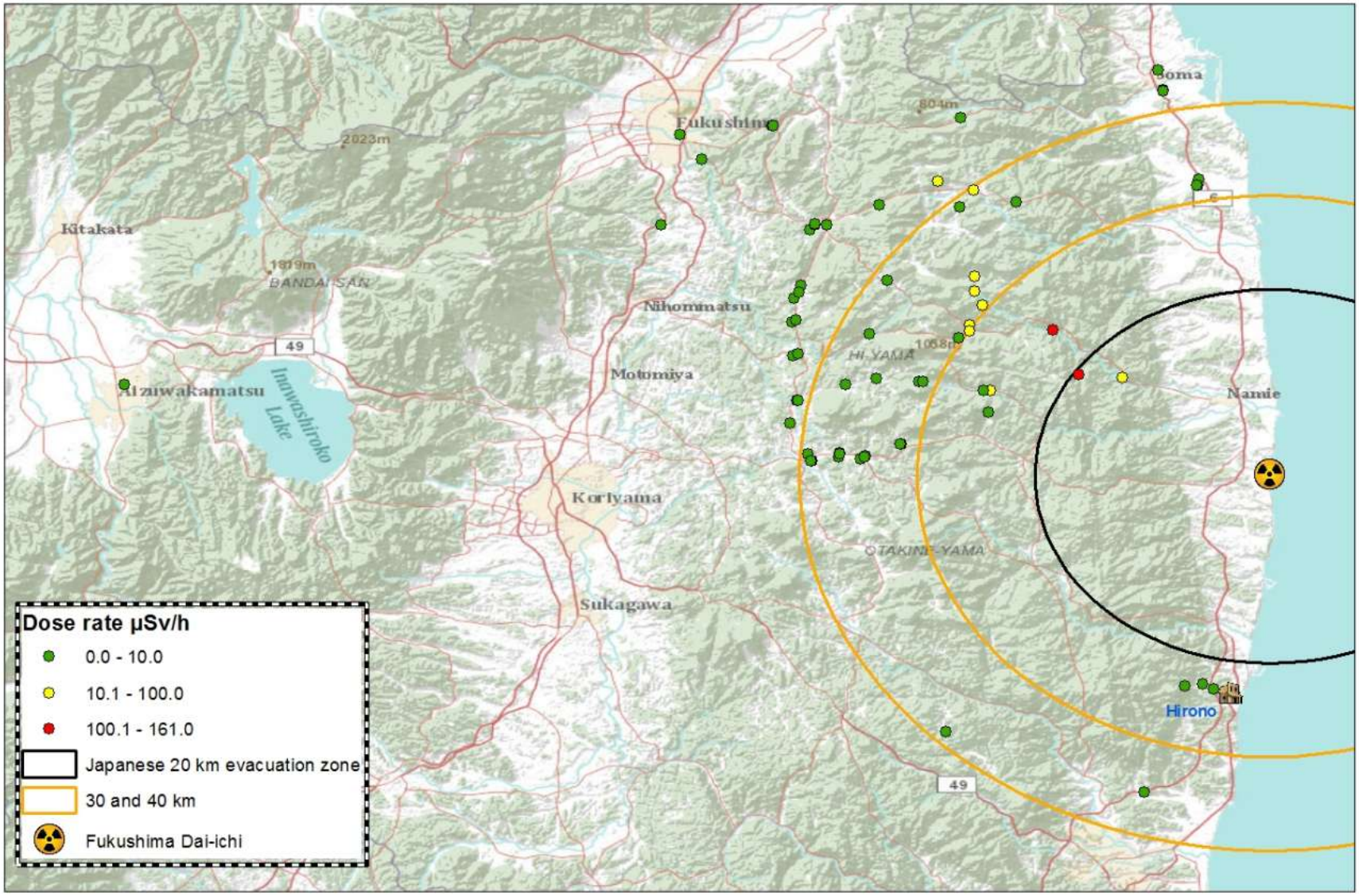
	Radiation dose (μ Sv)
Level to which a person exposed on average per year	3000
Chest X-ray examination.	50
An air travel between Tokyo and New York (Round Trip).	200

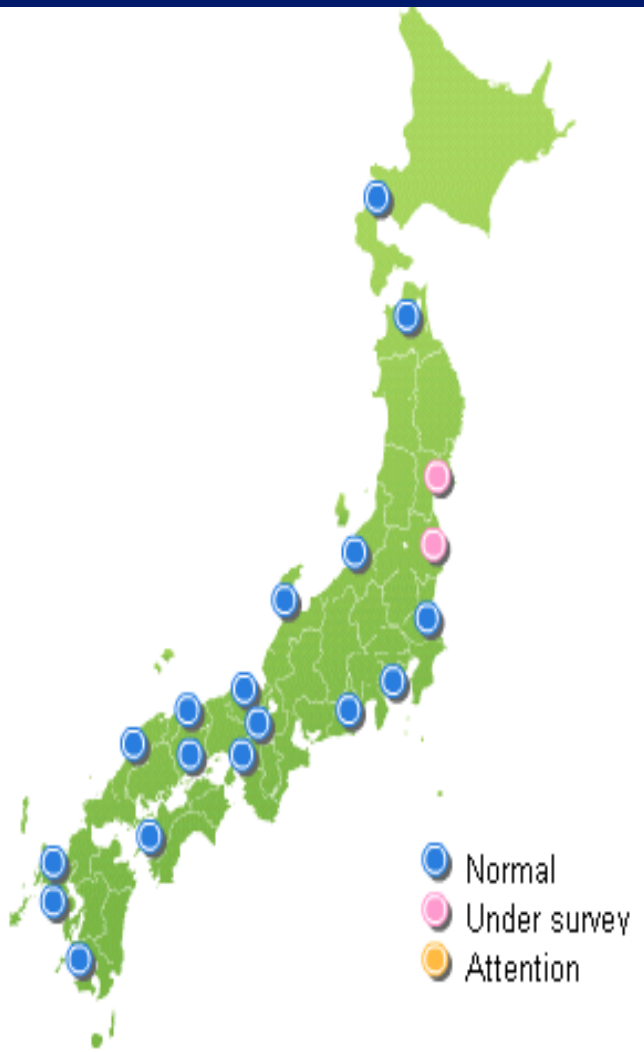


Sources : Ministry of Education,Culture,Sports,Science
Fukushima prefecture, Miyagi prefecture HP

IAEA Field Team Measurements up to 2011-03-31

Team Fukushima





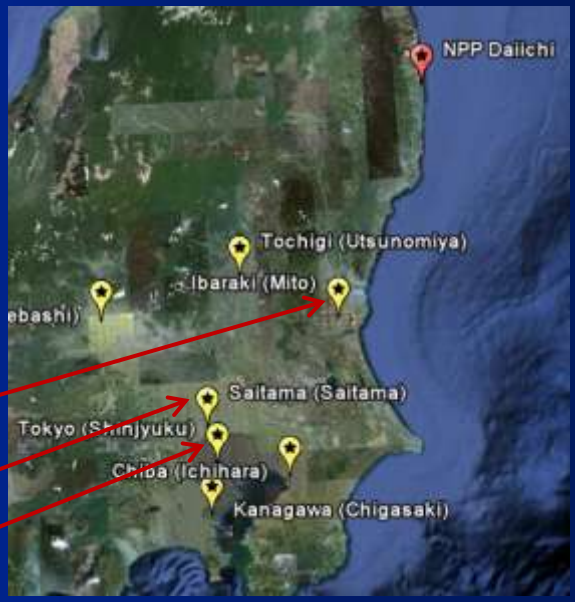
Latest updated time 2011/03/30 12:30

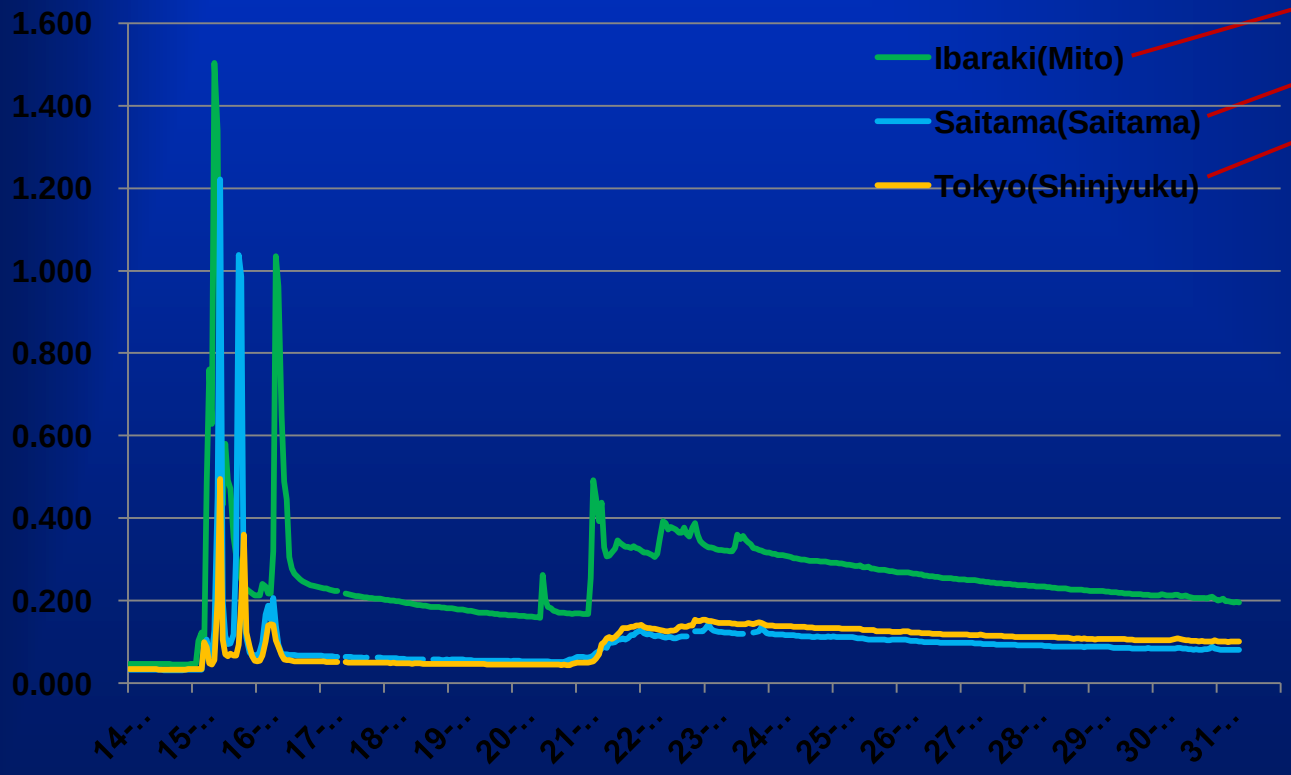
Radiation Maximum Data List

Prefecture	Maximum
Hokkaido	34nGy/h
Aomori	27nGy/h
Miyagi	Under survey
Fukushima	Under survey
Ibaraki	590nGy/h
Kanagawa	118nGy/h
Niigata	41nGy/h
Ishikawa	62nGy/h
Fukui/Kyoto	77nGy/h
Shizuoka	85nGy/h
Osaka	59nGy/h
Okayama/Tottori	39nGy/h
Shimane	46nGy/h
Ehime	24nGy/h
Saga/Nagasaki	33nGy/h
Kagoshima	44nGy/h

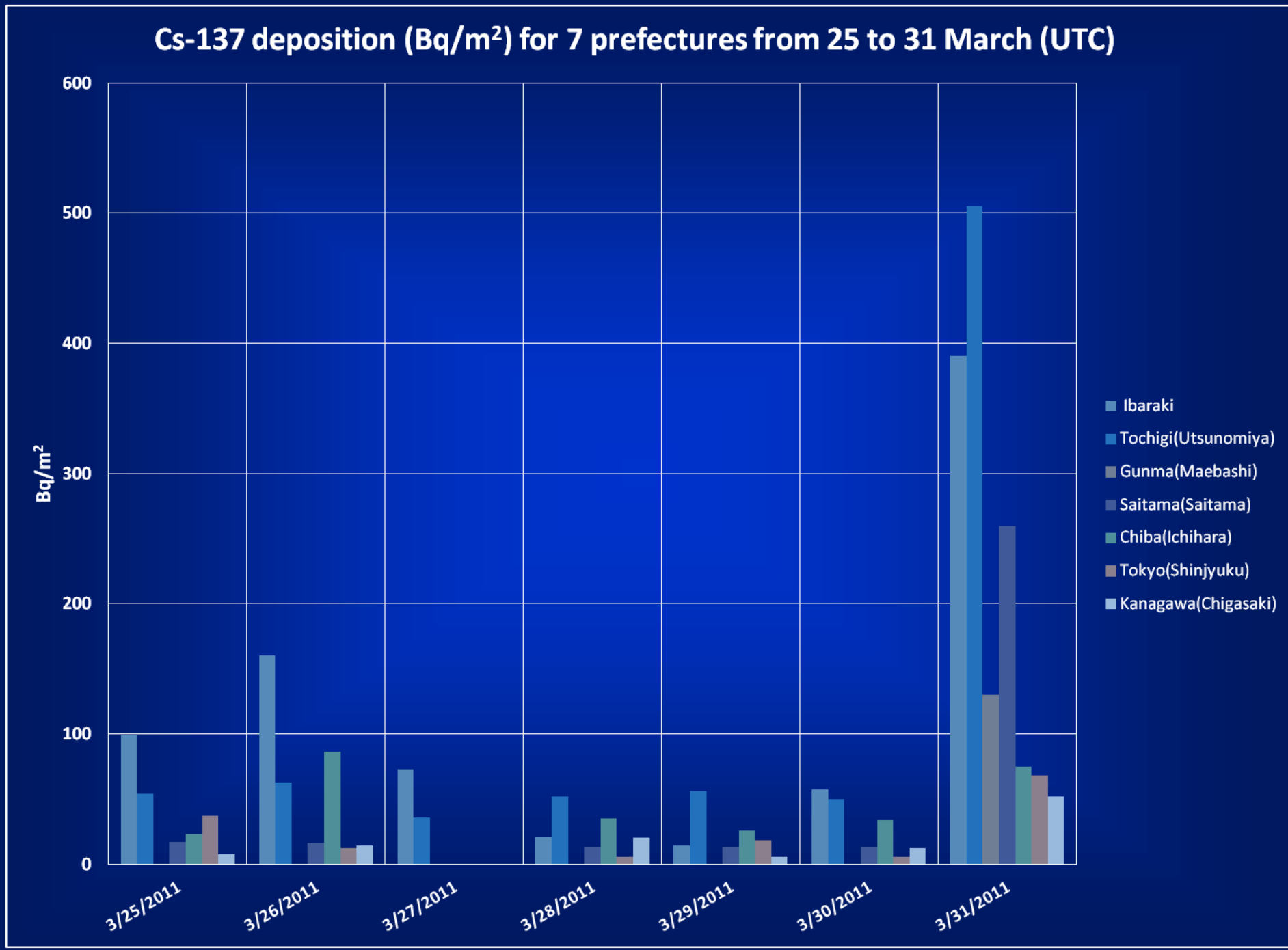
The above table is a list of the maximum values of the space dose rate distributions shown from local governments in the latest updated date and time.

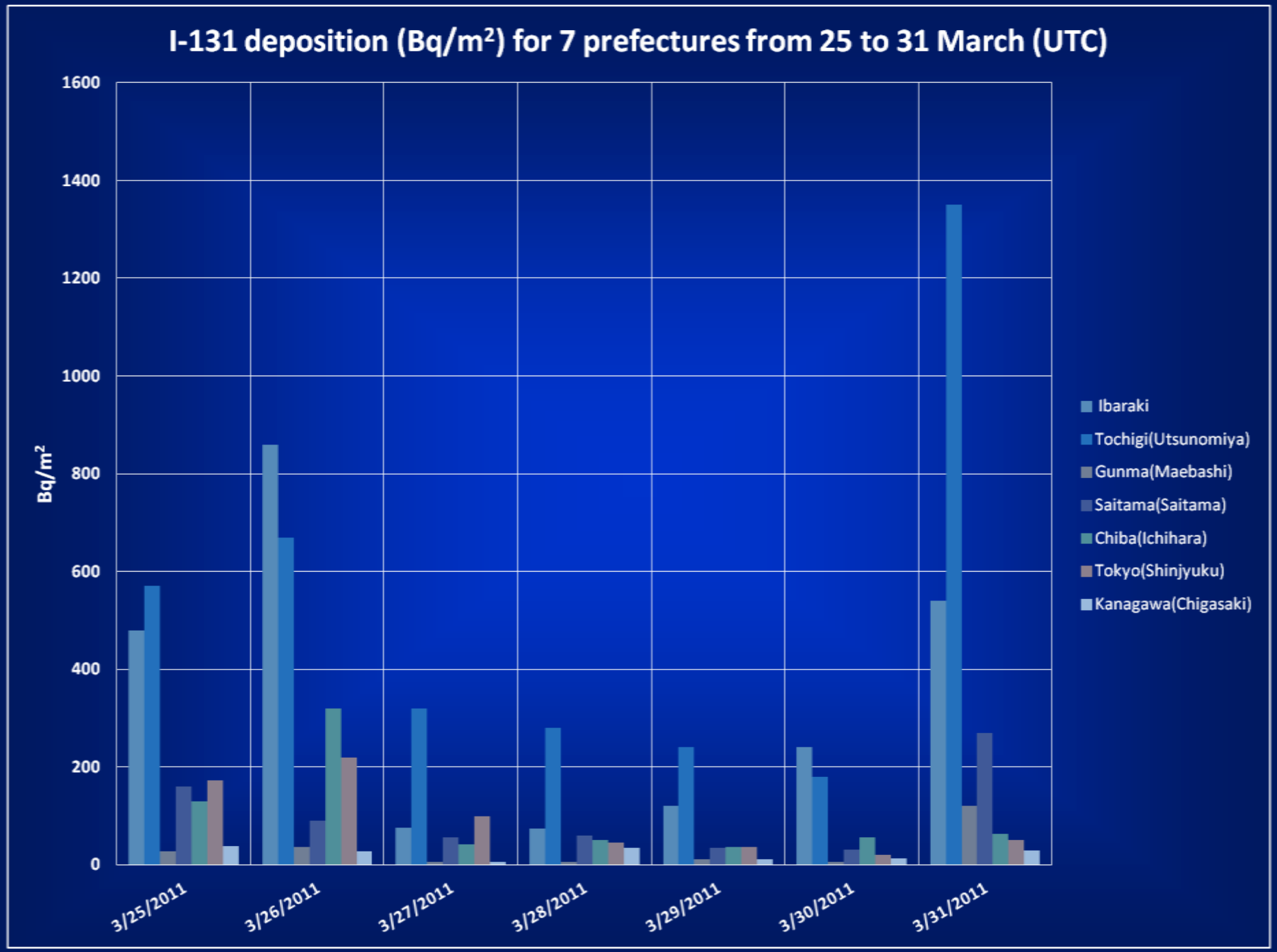
Gamma Dose Rates in µSv/hour
14-31 March



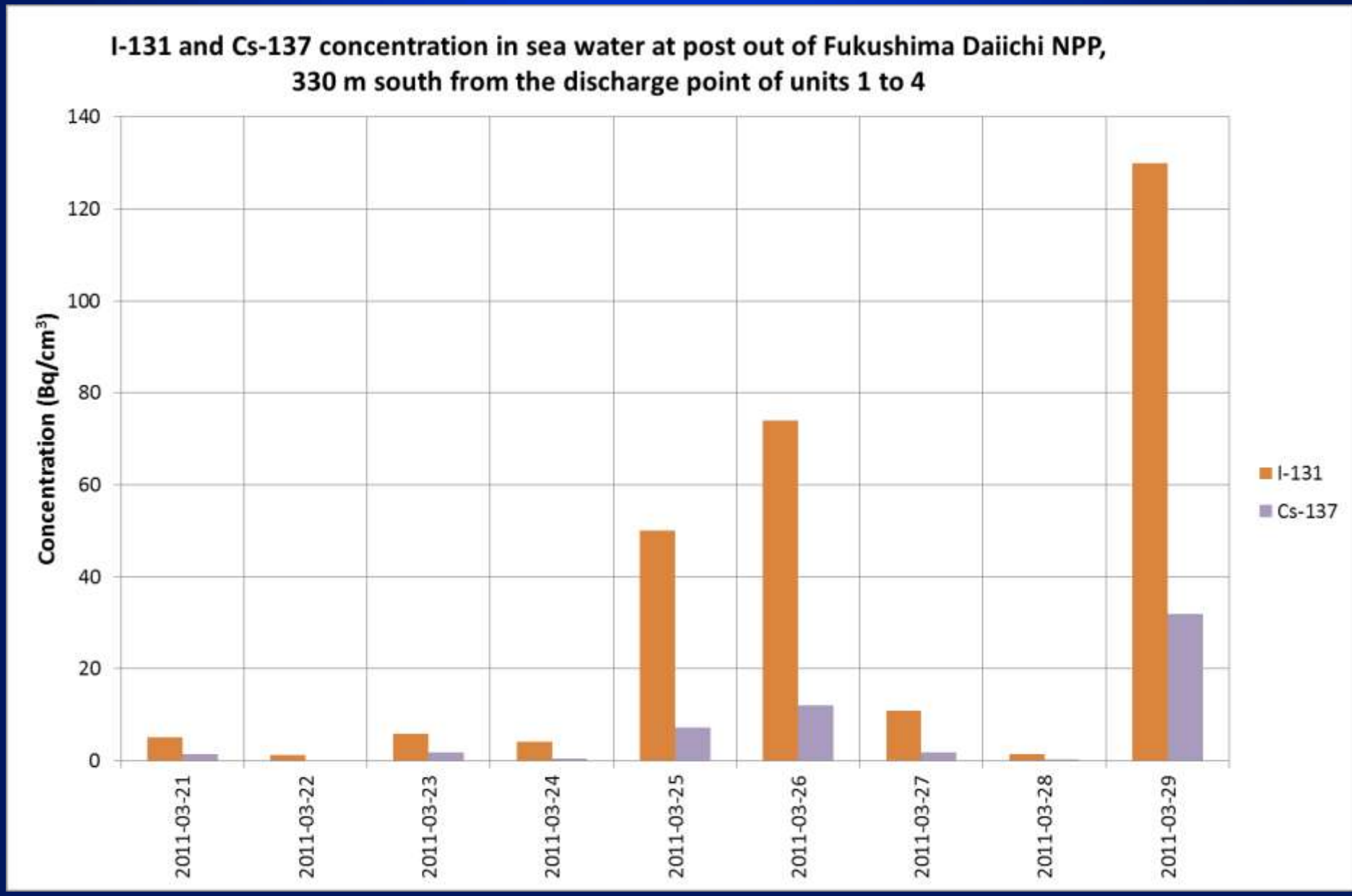


Natural Background: 0.1 µSv/hour: continue to decrease

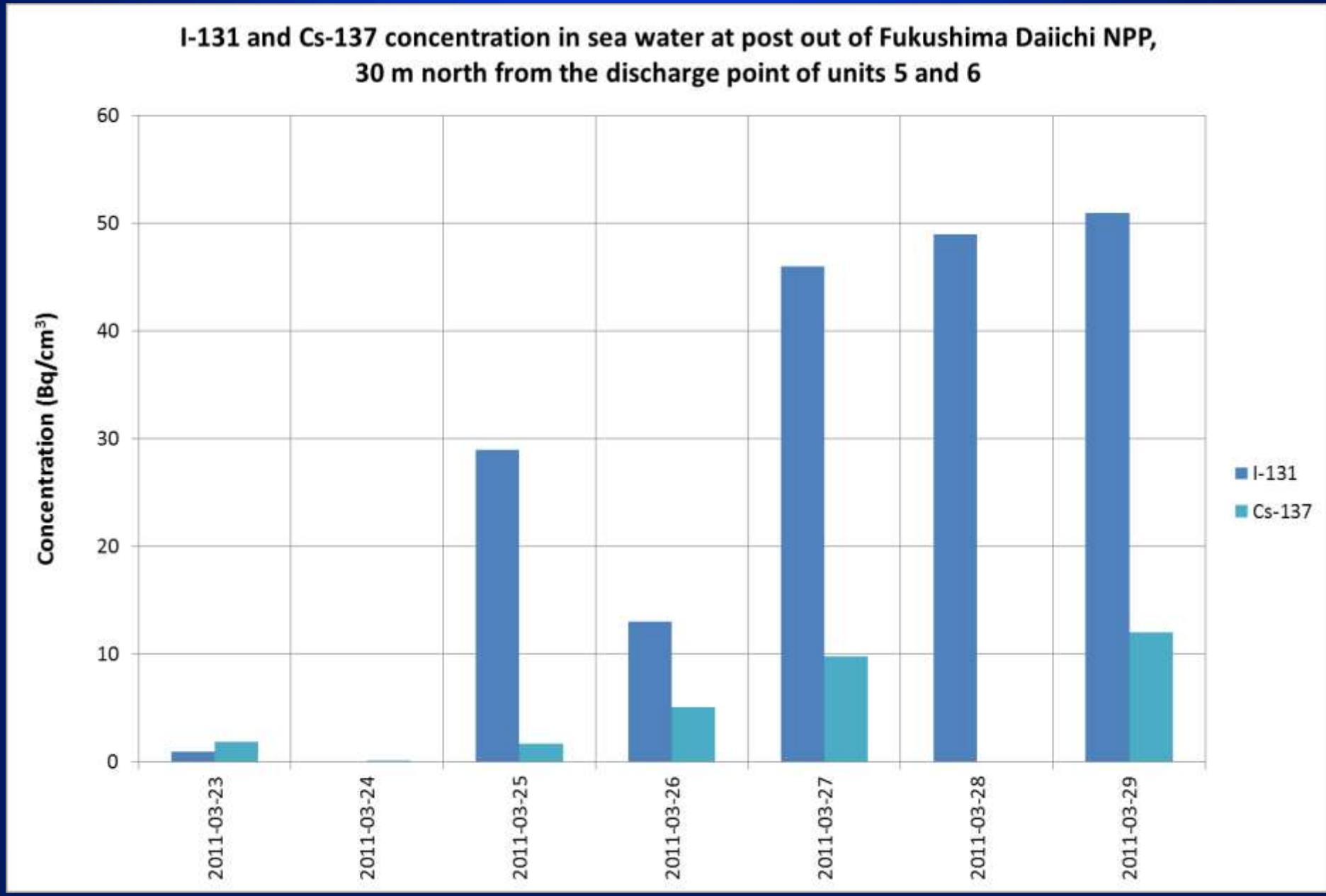

Cs-137 deposition (Bq/m²) for 7 prefectures from 25 to 31 March (UTC)
600
500
400
300
200
100
0
Bq/m²
3/25/2011
3/26/2011
3/27/2011
3/28/2011
3/29/2011
3/30/2011
3/31/2011
Ibaraki
Tochigi(Utsunomiya)
Gunma(Maebashi)
Saitama(Saitama)
Chiba(Ichihara)
Tokyo(Shinjyuku)
Kanagawa(Chigasaki)


I-131 deposition (Bq/m²) for 7 prefectures from 25 to 31 March (UTC)
Bq/m²
1600
1400
1200
1000
800
600
400
200
0
3/25/2011
3/26/2011
3/27/2011
3/28/2011
3/29/2011
3/30/2011
3/31/2011
Ibaraki
Tochigi(Utsunomiya)
Gunma(Maebashi)
Saitama(Saitama)
Chiba(Ichihara)
Tokyo(Shinjyuku)
Kanagawa(Chigasaki)

Seawater Contamination



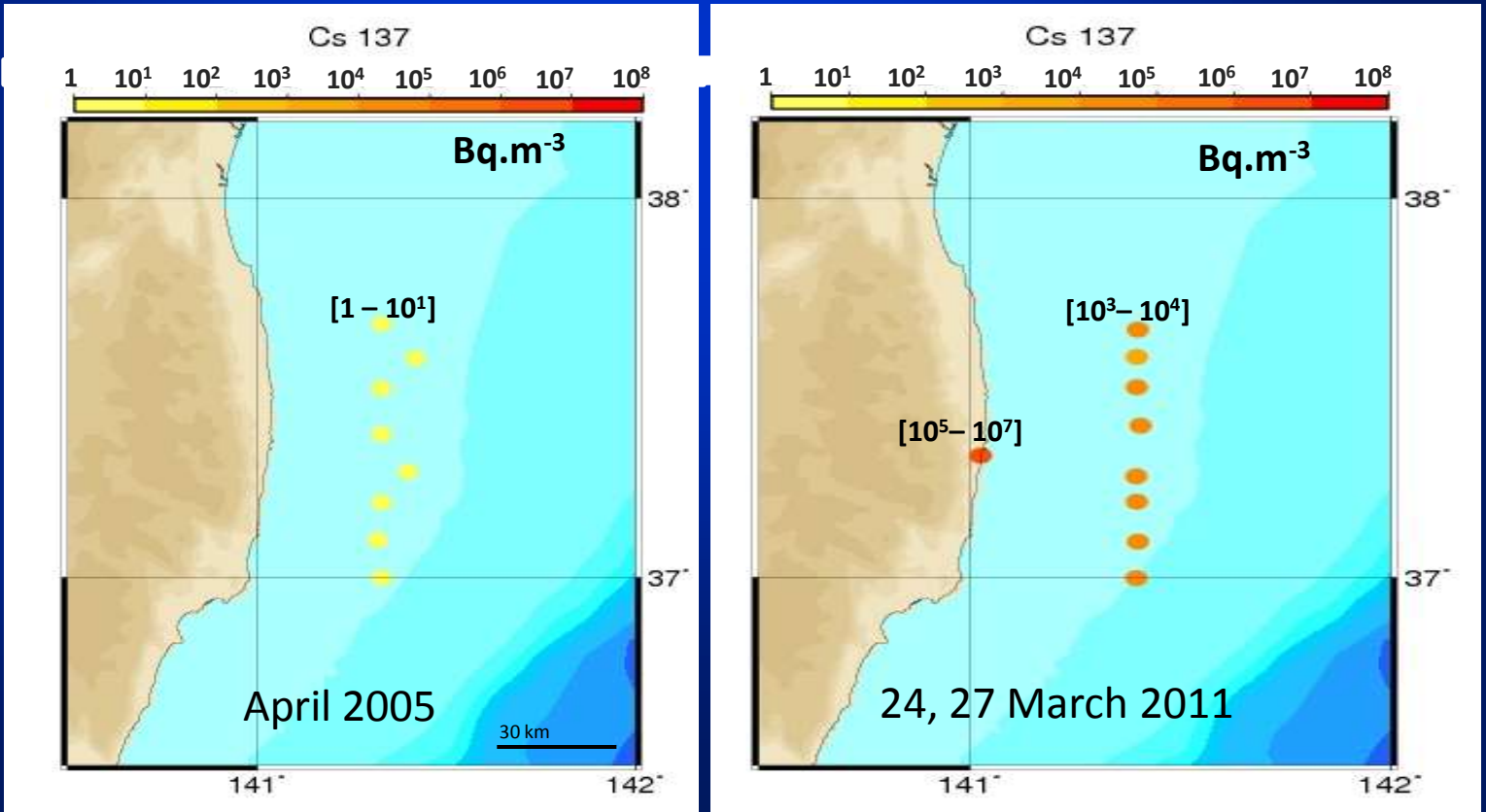
Seawater Contamination



Monitoring of the Marine environment

- Comparison of Cs-137 seawater concentrations with historical data- 30 km offshore surface water concentrations - 3-4 orders of magnitude as measured in 2005
- 330 m East of Fukushima Dai-ichi concentrations were -3 orders of magnitude higher values measured offshore, this showing the high dilution capacity of the marine environment

Cs-137 Bq.m^{-3}



Radioactivity in Foodstuffs(Absence)

- **Results reported March, 31 by the Japanese Ministry of Health, Labour and Welfare based on**

- **98 of the 111 samples for various food items**

  - **vegetables, fruit, seafood, various meats and unprocessed raw milk - in 8 prefectures namely**

  Chiba, Fukushima, Gunma, Ibaraki, Kanagawa, Niigata, Tochigi, and Tokyo.

- **I-131, Cs-134 and Cs-137 were either not detected or were below the regulation values set by the Japanese authorities.**

Radioactivity in Foodstuffs(presence)

- **13 of the 111 samples of :**

  Spinach and other leafy vegetables parsley and beef from Chiba, Fukushima, Ibaraki and Tochigi prefectures indicated that ,

  I-131 and/or Cs-134 and Cs-137 exceeded the regulation values set by the Japanese authorities.

Typical Background Radiation Levels of Indian Cities (IERMON

Place	Natural Background radiation level (microsievert per hour)
Manvalakurichi	0.456
Hyderabad	0.148
Shillong	0.125
Kolkata	0.105
New Delhi	0.075
Mumbai	0.061

Background Radiation Levels observed in Japanese Cities

Prefecture	Dose Rate (Microsievert per hour) on Mar 17 18:00 hrs JST	Normal (Max.) natural radiation (Microsievert per hour)
Chiba	**0.041**	**0.044**
Tokyo	**0.053**	**0.079**
Kanagawa	**0.056**	**0.069**
Niigata	**0.048**	**0.153**
Ibaraki	0.244	0.056
Tochigi	0.213	0.067
Gunmag	0.109	0.045
Saitamg	0.068	0.060

Radiation Exposure

- **A. Members of Public:**

  No cases of harmful influence on thyroid of children were detected.

  - **Of the 102,342 people screened (uptil Mar 28th) , only 101 people indicated the counts below 100,000cpm .There was no case which affects health.**

  B. Occupational Workers:

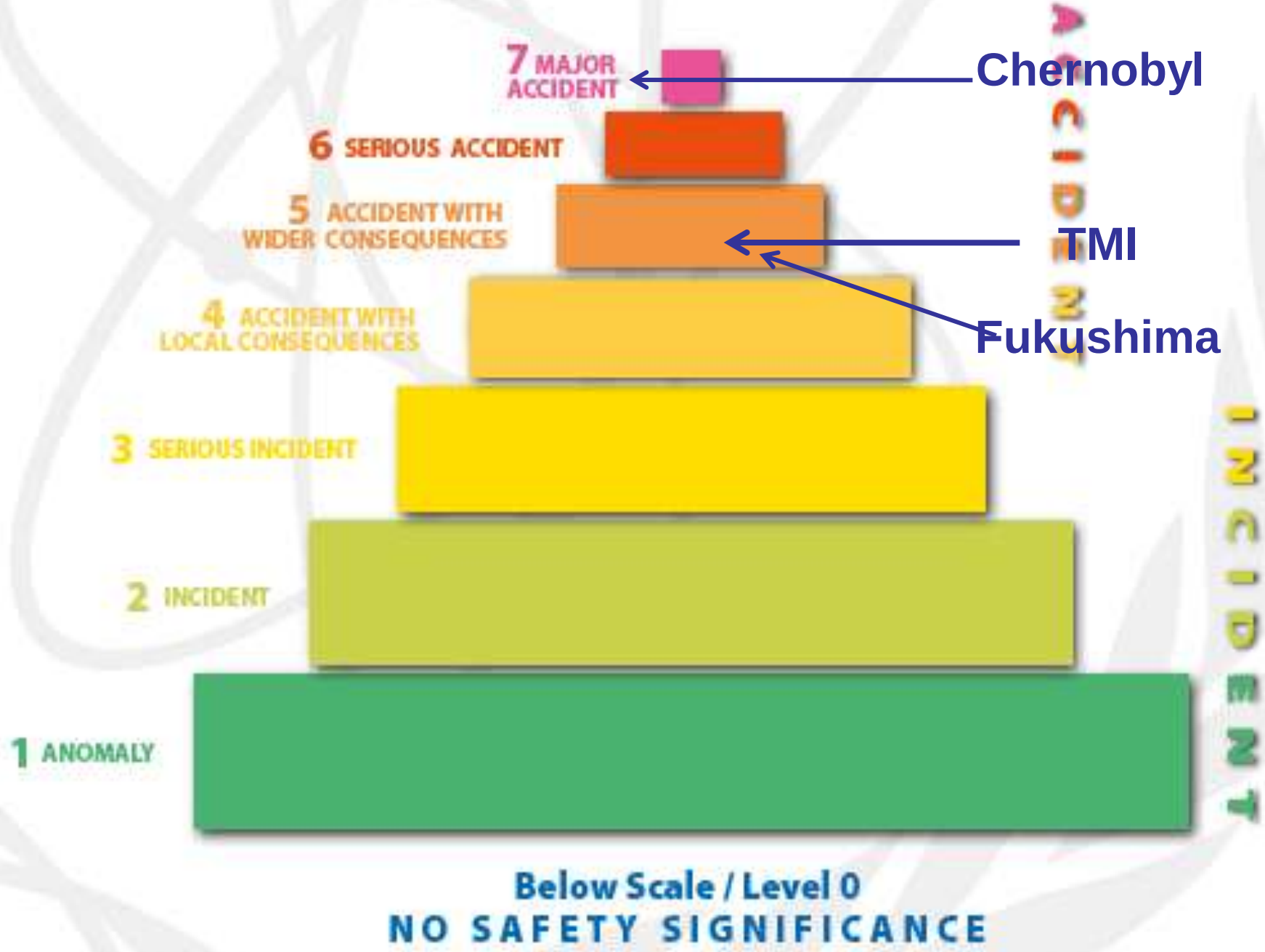
- **19 workers exceeded 100 mSv**
  - **3 workers exceeded 170 mSv**
  - **2 workers had radioactive material on their legs, estimated to be 2 to 3 Sv. Based on further monitoring (March 25 -28) were discharged.**

Fatalities / Injuries

- No Fatality .
- Earthquake (March 11)
  - 2 TEPCO employees, 2 subcontractors (fractures)
  - 2 employees missing
  - 2 injured employees return to work
- Explosion in Unit-1 (March 12)
  - 2 TEPCO employees (returned to work)
  - 2 Subcontractor employees
- Explosion in Unit-3 (March 14)
  - 4 TEPCO employees (returned to work)
  - 3 Sub contractor employees (returned to work)
  - 4 SDF Personnel.

Chernobyl and Fukushima

	Chernobyl	Fukushima
• Reactor	Operating	**Shutdown**
• Chain reaction of fission	Continuing	**Stopped**
• Explosion	Nuclear explosion	**Chemical explosion of Hydrogen**
• Moderator	Graphite – started burning	**Ordinary water-supported cooling**


7 MAJOR ACCIDENT
6 SERIOUS ACCIDENT
5 ACCIDENT WITH WIDER CONSEQUENCES
4 ACCIDENT WITH LOCAL CONSEQUENCES
3 SERIOUS INCIDENT
2 INCIDENT
1 ANOMALY
ACCIDENT
INCIDENT
Chernobyl
TMI
Fukushima
Below Scale / Level 0
NO SAFETY SIGNIFICANCE

Post event Actions - Public Safety

- Administration of Iodine tablets (0.01mSv/hr).
- Evacuation within 20 km radius- 3,20,000 people evacuated (1m Sv/hr)
- Sheltering in 20 to 30 km radius.
- Impounding of milk, water, grass, food, etc.

Responding to a Nuclear Emergency (contd.)

Q.3
If a nuclear emergency occurs, what will happen, what should we do?

A

The public is warned through a range of media.

A

Make sure you listen to instructions carefully.

Q.4
What should our response be when we hear of an accident occurring ?

A

Remain calm and follow instructions broadcast or transmitted by the competent authorities.

Q.5
What should we do in terms of contacting our family or children, etc?

A

You should following the various instructions in different places and wait until things settle down.

Responding to a Nuclear Emergency (contd.)

Q.6
About what kinds of thing must we watch out for?

A

Based on the correct information, you must act calmly.

Pay attention not to fall victim to rumors or Demonstrations.

Make sure to check information with neighbors!

Please be extra careful if you are in a big crowd

Q.7
If you are asked to take shelter indoors, what should you do?

A

You must go indoors – go to the nearest available building, house, public facility, etc.

Shut all doors and windows

Enter a nearby house, office or nearby public facility

Wash your hands and face well, if you were outside

Take a shower and shampoo your hair if asked to.

Stop ventilation fans and fan heaters

Put food into a container and wrap it

Remove the clothes you wore as they may have been exposed, put then into a plastic bag, and shut the mouth of the bag firmly, if asked to dispose of your clothes.

Secure drinking water in a sealable container.

Responding to a Nuclear Emergency (contd.)

Q.8
If we are asked to take refuge, what should we do?

A

Calmly prepare for evacuation/refuge and follow instructions.

Call in on neighbors

Turn the gas off and remove plugs from sockets

Close all doors

<Makes sure you keep basic equipment and Valuables with you>
i.e. a radio, flashlight/ cash, passbooks, seals a change of clothes masks, handkerchiefs emergency food drinkable water

Contact the local authorities about disabled and handicapped people to help them take refuge

Walk to a shelter- don't take your car

Provide pets with food and water and keep them inside

Follow directions of competent officials, i.e. police, rescue, fire brigade or local govt. officials

Q.9
What happens in the shelter/first-aid center?

A

First you should proceed with registration.

You will be checked for exposure to radiation and given first-aid as necessary

If you have been contaminated, you should wash and clean off as necessary.

A

If you have suffered exposure or contamination, this will be registered and you will receive a diagnosis.

Those requiring specialist care will be transported to the requisite medical facilities

Responding to a Nuclear Emergency

Q.1
What is a nuclear emergency?

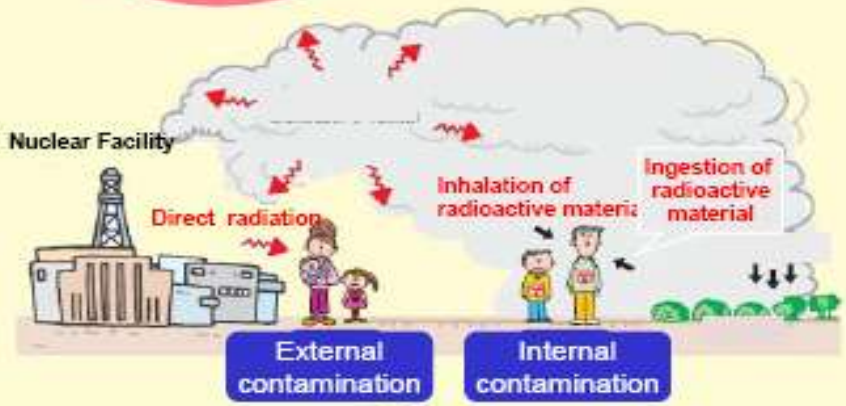
A

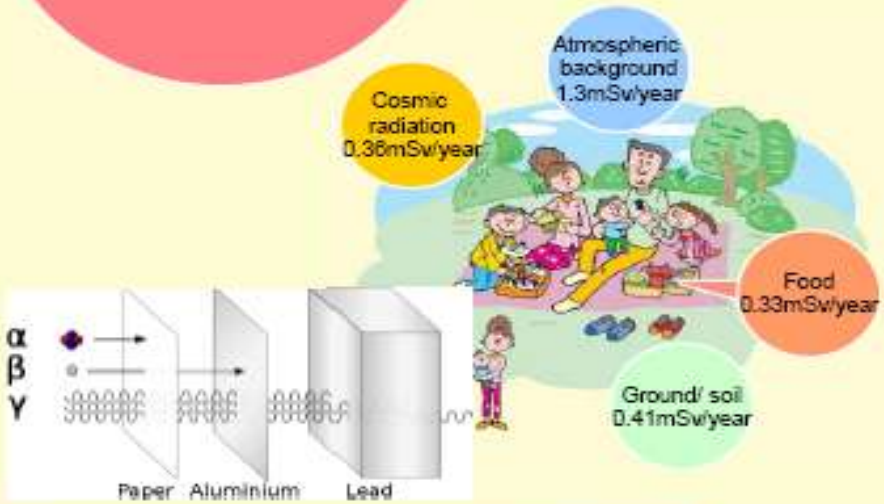
It is a radioactive leak from nuclear installation.

Q.2
How does radiation affect the human body?

A

Depending on the quantity, it might be detrimental to public health



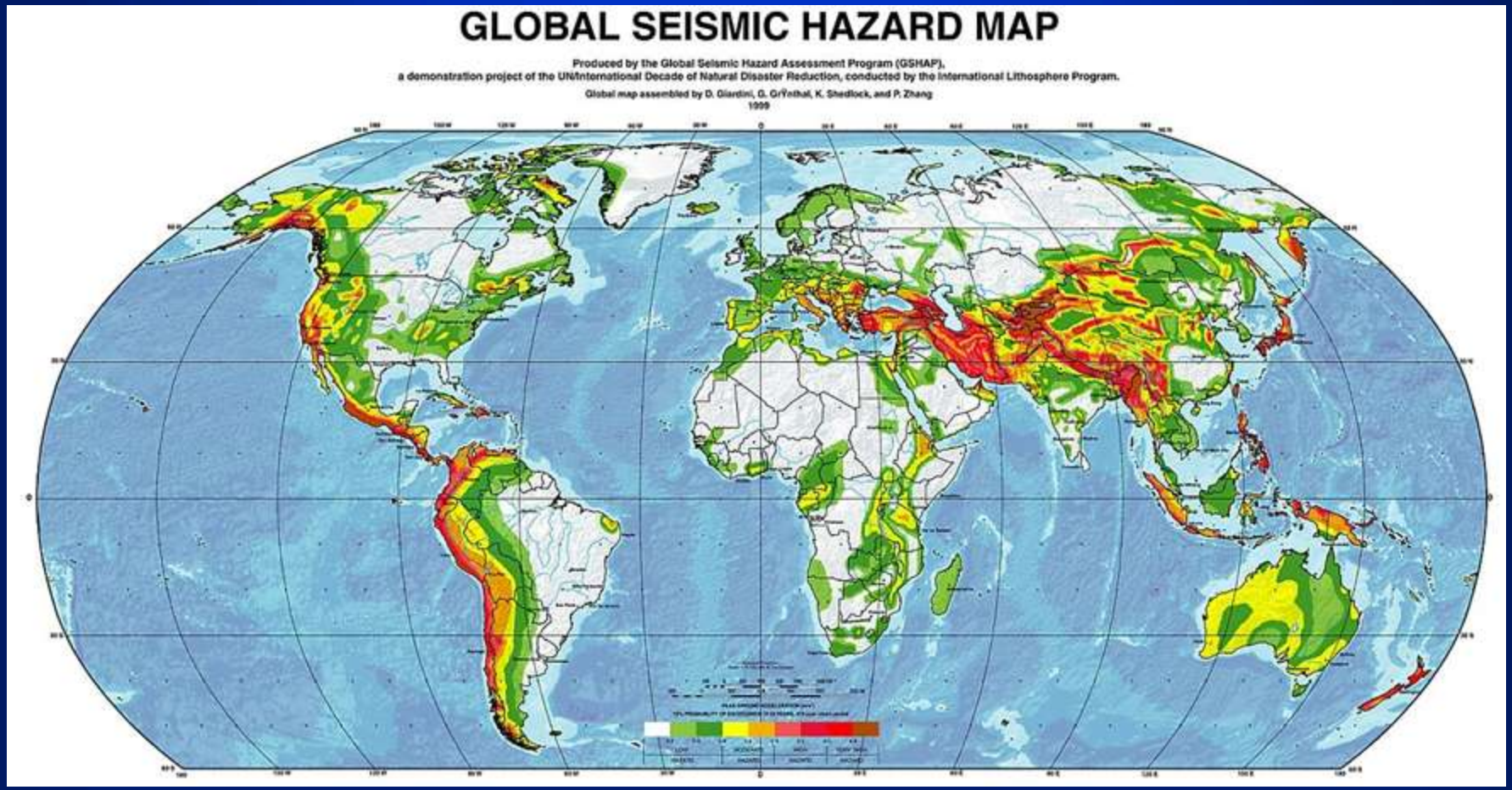


In order to protect the body from external contamination
(1) Protection by distance (leaving from the source of radiation as far as possible)
(2) Protection by time (receiving radiation for as short a time as possible)
(3) Protection by cover (entering into a building made from concrete)

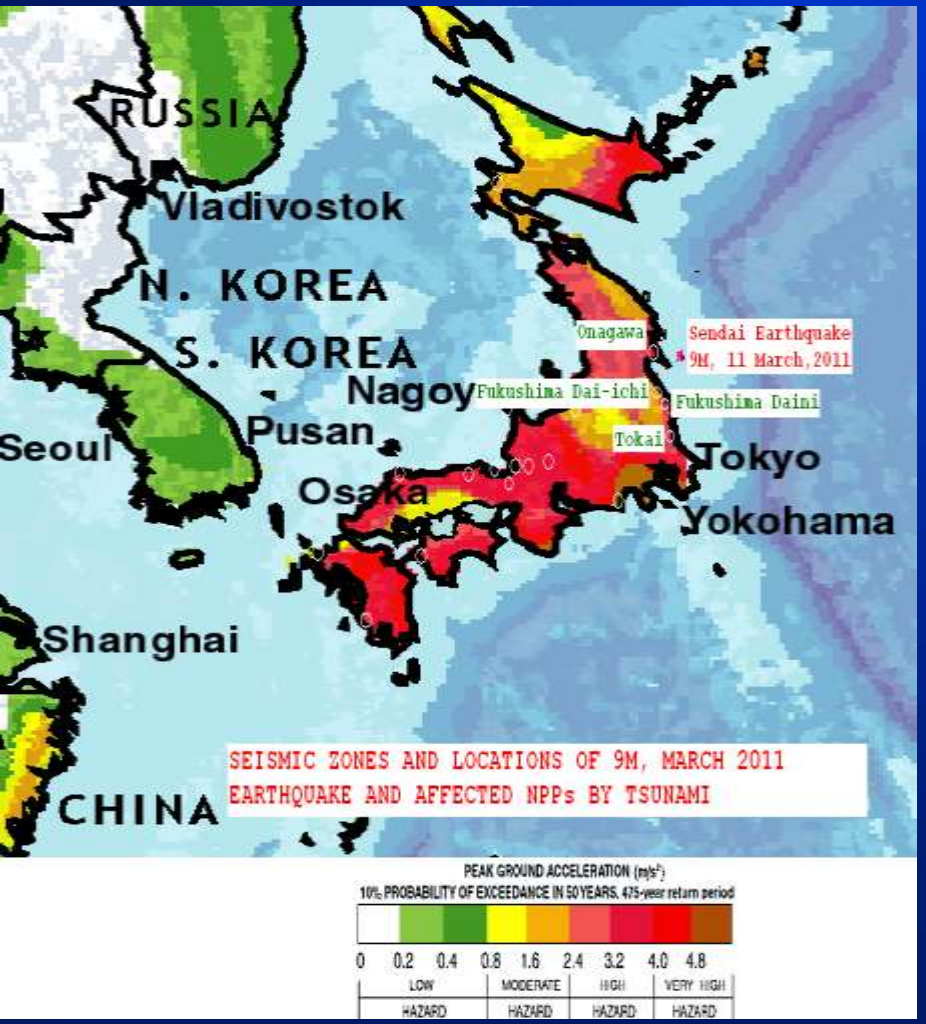
In order to protect the body from internal contamination
(1) Preventing inhalation (with a mask or a handkerchief)
(2) Preventing Ingestion (not eating polluted water or food)

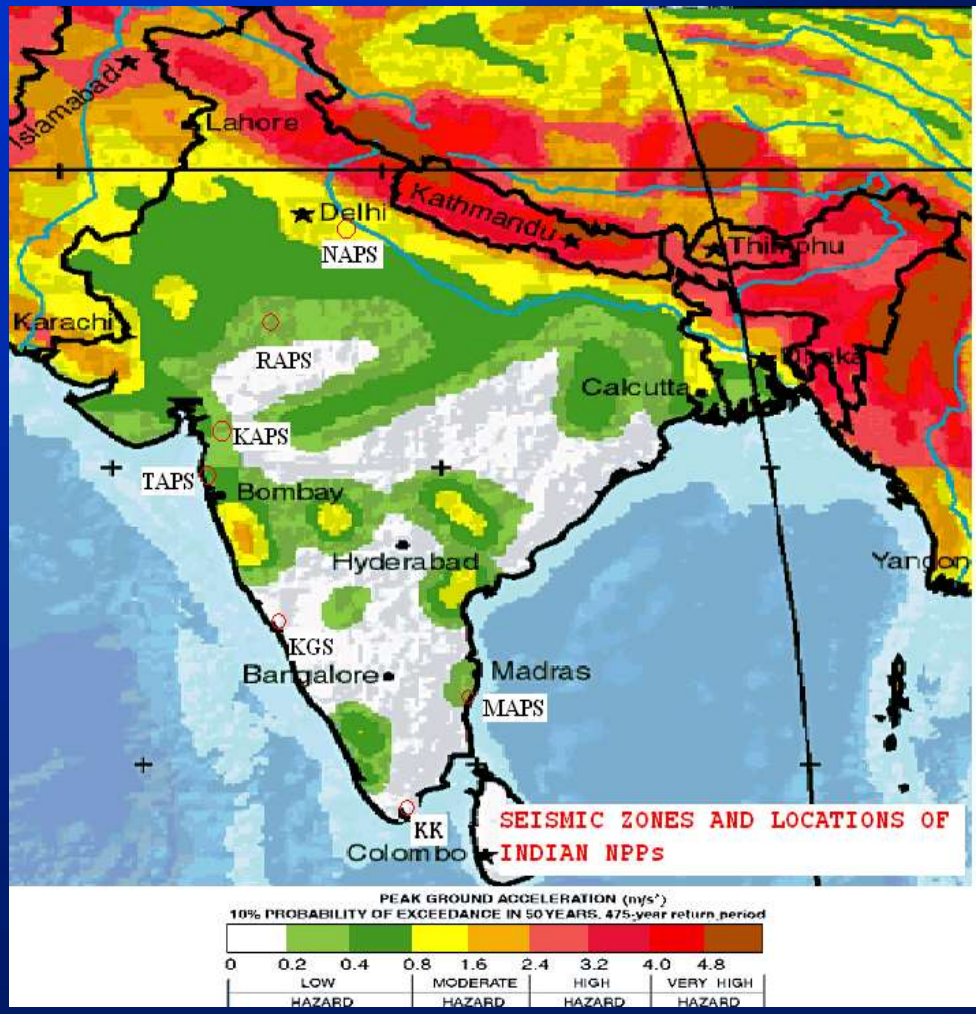
Safety Status
at
Indian NPPs in the context

Seismic Hazard



Comparative Seismic Hazard

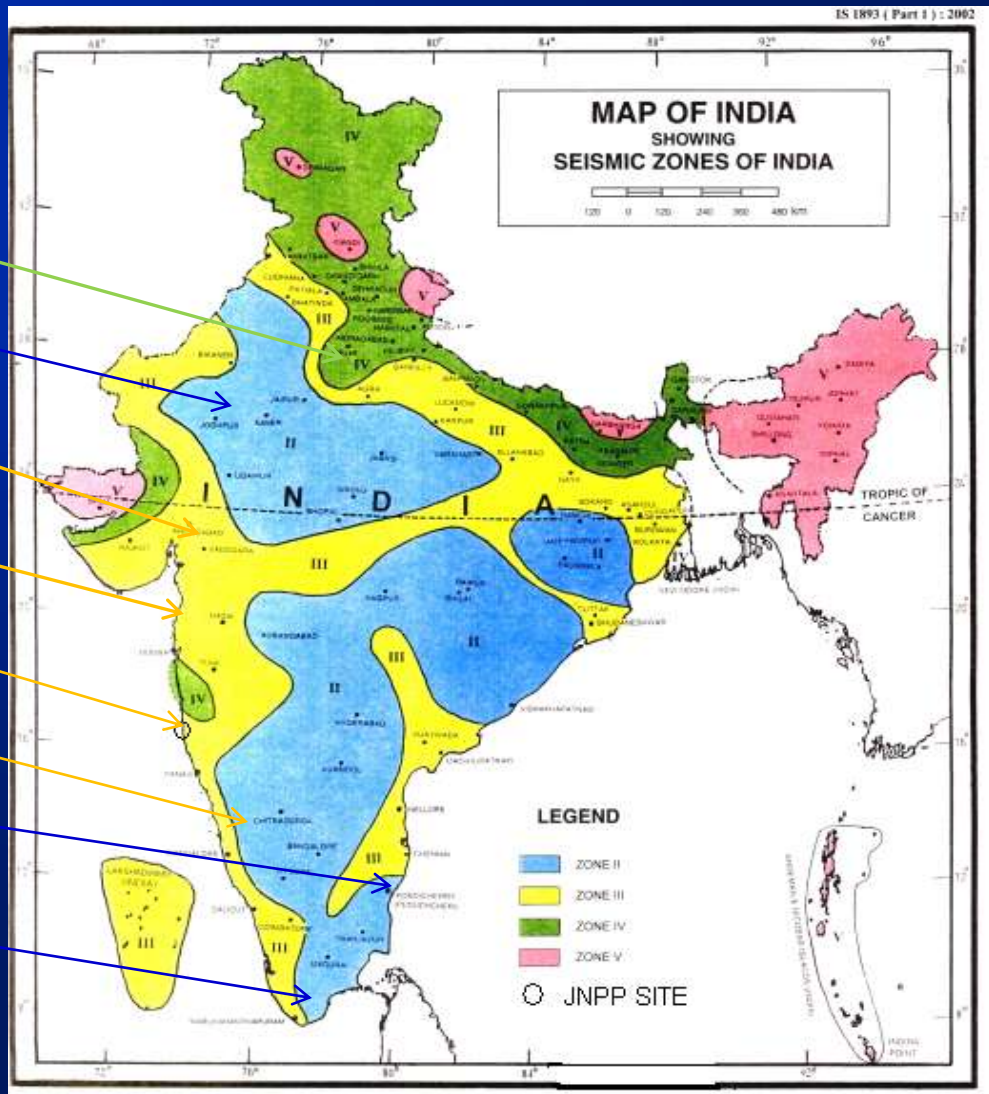




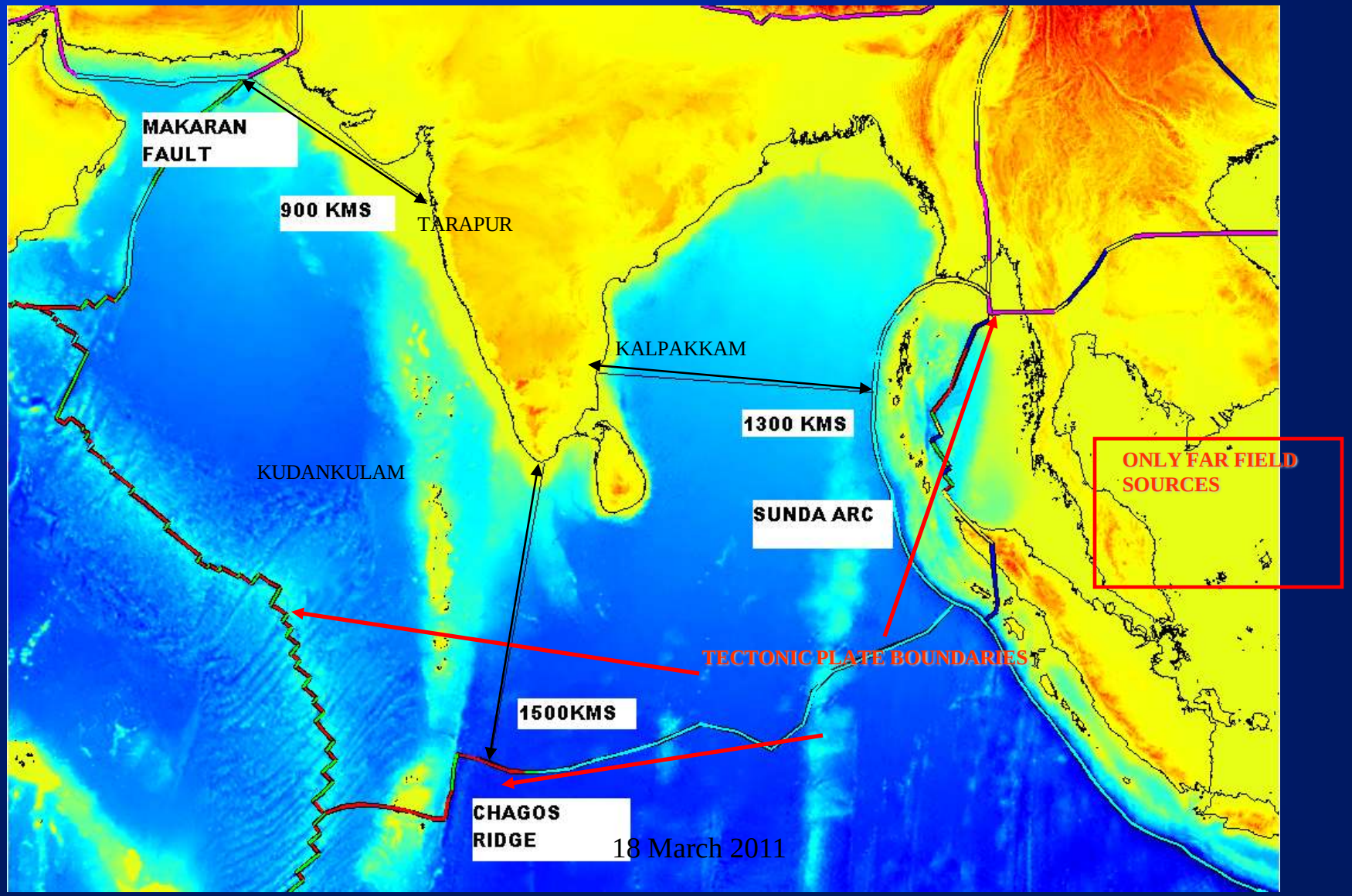
Status of Seismicity – Indian NPPs

- **Criteria - No Active fault within 5 km**

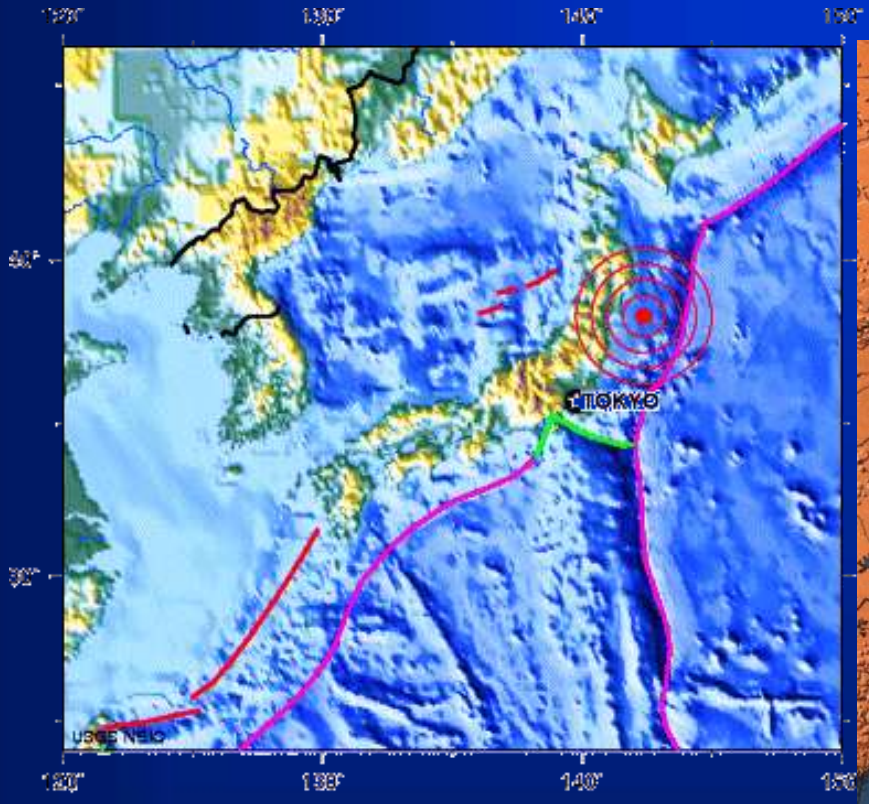
Site	Seismic Zone
Narora	IV
Rawatbhata	II
Kakrapar	III
Tarapur	III
Jaitapur	**III**
Kaiga	III
Kalpakkam	II
Kudankulam	II

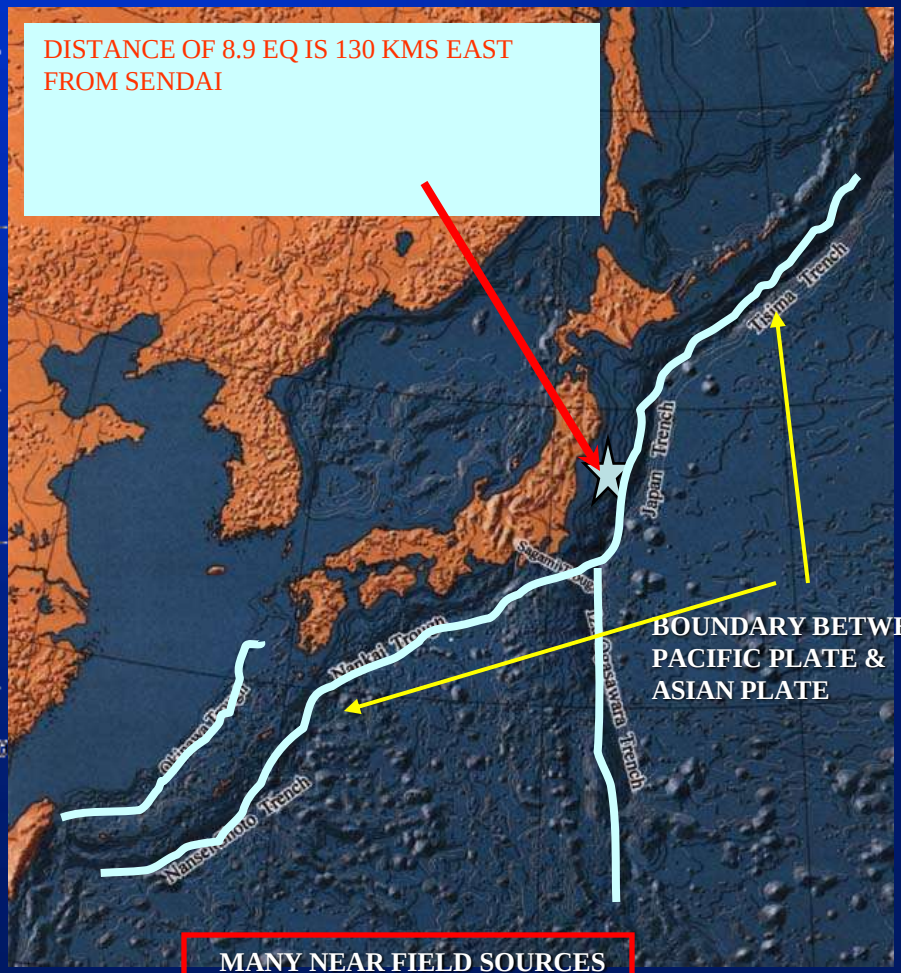


Tsunamigenic locations for Indian coast



TSUNAMIGENIC LOCATIONS IN JAPAN





Earthquake –magnitude, parameters used for seismic design of Indian nuclear power plants

Plant site	Magnitude (Richter scale)	Epicentral distance (KM)	Peak ground acceleration (g)
NAPS	6.7	12	0.3
RAPS	6.0	40	0.1
KAKRAPAR	6.5	30	0.2
KAIGA	5.7	12	0.2
TAPP	5.7	16	0.2
MAPS	6.0	20	0.156
KK	5.0	6	0.15

5.0 Mag.(Richter) =$2x10^{12}$ Joules energy, equivalent to Hiroshima atom bomb

5.0, 6.0, 7.0, 8.0, and 9.0 = $2x10^{12}$, $6.31x10^{13}$, $2x10^{15}$, $6.31x10^{15}$ and $2x10^{18}$ Joules

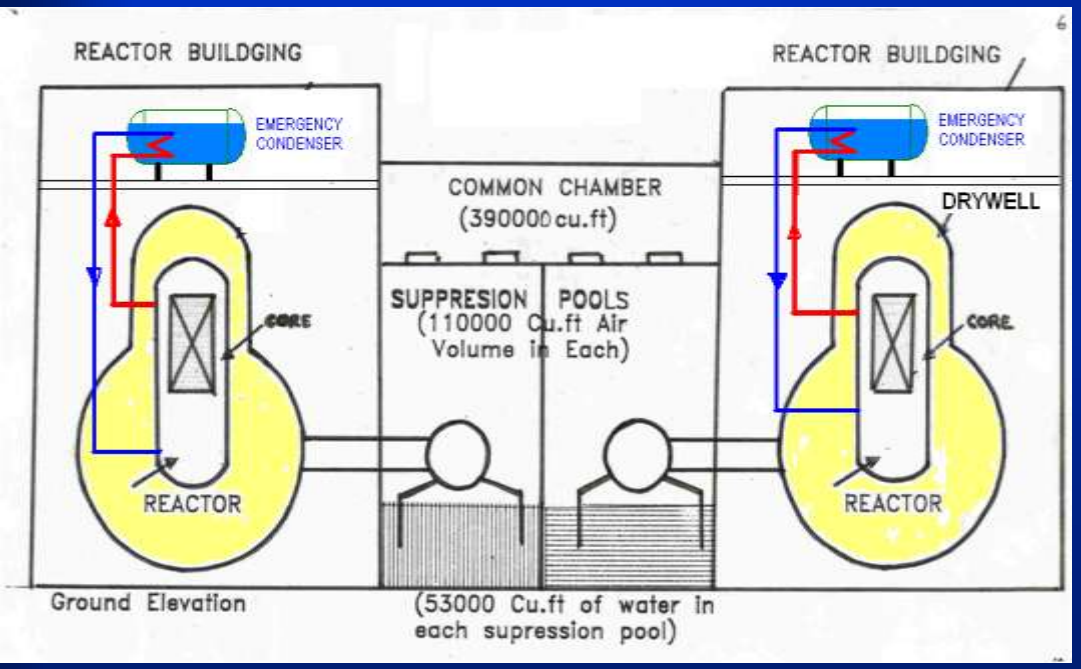
Seismic Margin Assignment (SMA) PGA's

Plant	Design PGA (g)	Seismic margin PGA	
		Based on analysis (Note-1)	Based on judgment (Note-2)
TAPS	0.2	0.337 to 1.83	
RAPS	0.1	0.233 to 2.26	
MAPS	0.2	0.233 to 2.26	
NAPS	0.3		0.6
KAPS	0.2		0.6
KAIGA	0.2		0.6
KK	0.15		0.6

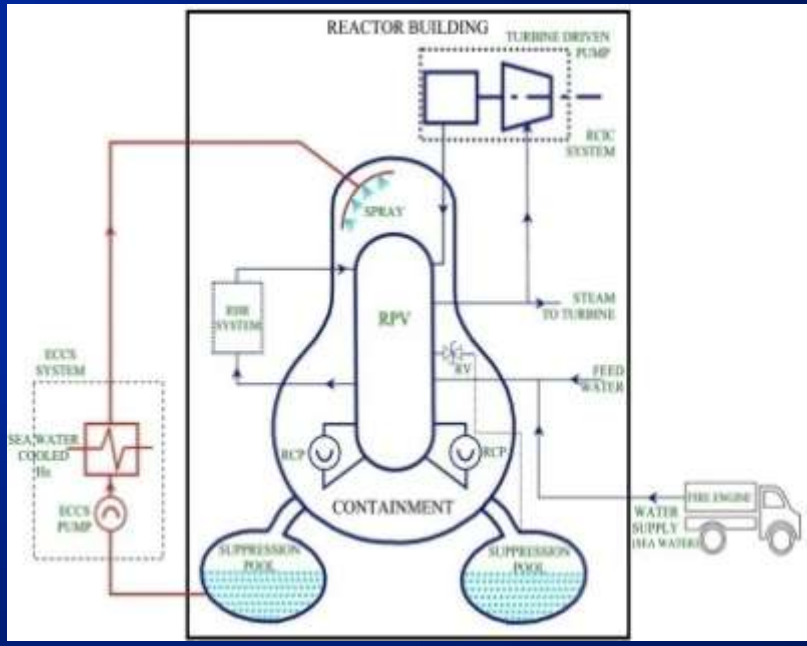
Note-1: These values are based on analysis conducted during the seismic re-evaluation of the plants based on permissible stress values. Very few components are close to the low PGA values, majority are close to 0.6g PGA.

Note-2: Design of new plants from NAPP onwards was done for allowable stress values However, the actual stress values are much less than the allowable values. The actual SMA PGA values are to be calculated referring to the analytical reports. But, based on the analytical values calculated for TAPP, RAPP and MAPP and performance of Kasiwaziki Kariwa and Shika NPP's in Japan, GSECL's plant at Jamnagar and Panendhro, IFFCO plant at Kandla, the SMA PGA will be about two to three times those of the analytical values.

Containment (TAPS-1&2)



Fukushima Reactor



TAPS-1&2 Safety vis-a-vis Fukushima

- TAPS 1&2- Primary Containment Volume to Power ratio,10 times than Fukushima NPP- Slow build up of pressure in containment .
- Passive systems for decay heat removal (Emergency Condenser) – Adequate to cool the core for 8 hours.
- Safety upgrades and renovation completed in year 2005.
- Detailed Evaluation and Review by AERB periodically.

Handling of Station Black Out in TAPS-1&2

Provisions of Reactor Safety Functions

➢ Reactor Shutdown/Scram

- Reactor Scram due to de-energization of Reactor Protection System (RPS) channels
- Reactor sub-critical within 5 sec.

➢ Reactor Core Cooling

- Primary Steam Isolation Valves (PSIVs) go close on
- de-energization of RPS channels.
  - Additionally, PSIVs go close automatically on
  - Reactor water low level
  - Primary steam line low pressure
  - Primary steam line high radiation
  - Dry well high pressure
  - Primary steam line high flow
  - Primary steam line area high temperature

Handling of Station Black Out in TAPS-1&2

Provisions of Reactor Safety Functions

- **Reactor Core Cooling**

- Emergency Condenser valved in on PSIV closure
  - Automatically –battery powered valve
  - **Manually operable from accessible area**

- **Emergency Condenser de-pressurizes the core and cools down RPV at the rate of 50°C/hr.**

- **RPV cooled and maintained up to 8 hours beyond which secondary side inventory of EC replenished.**

Handling of Station Black Out at TAPS-1&2

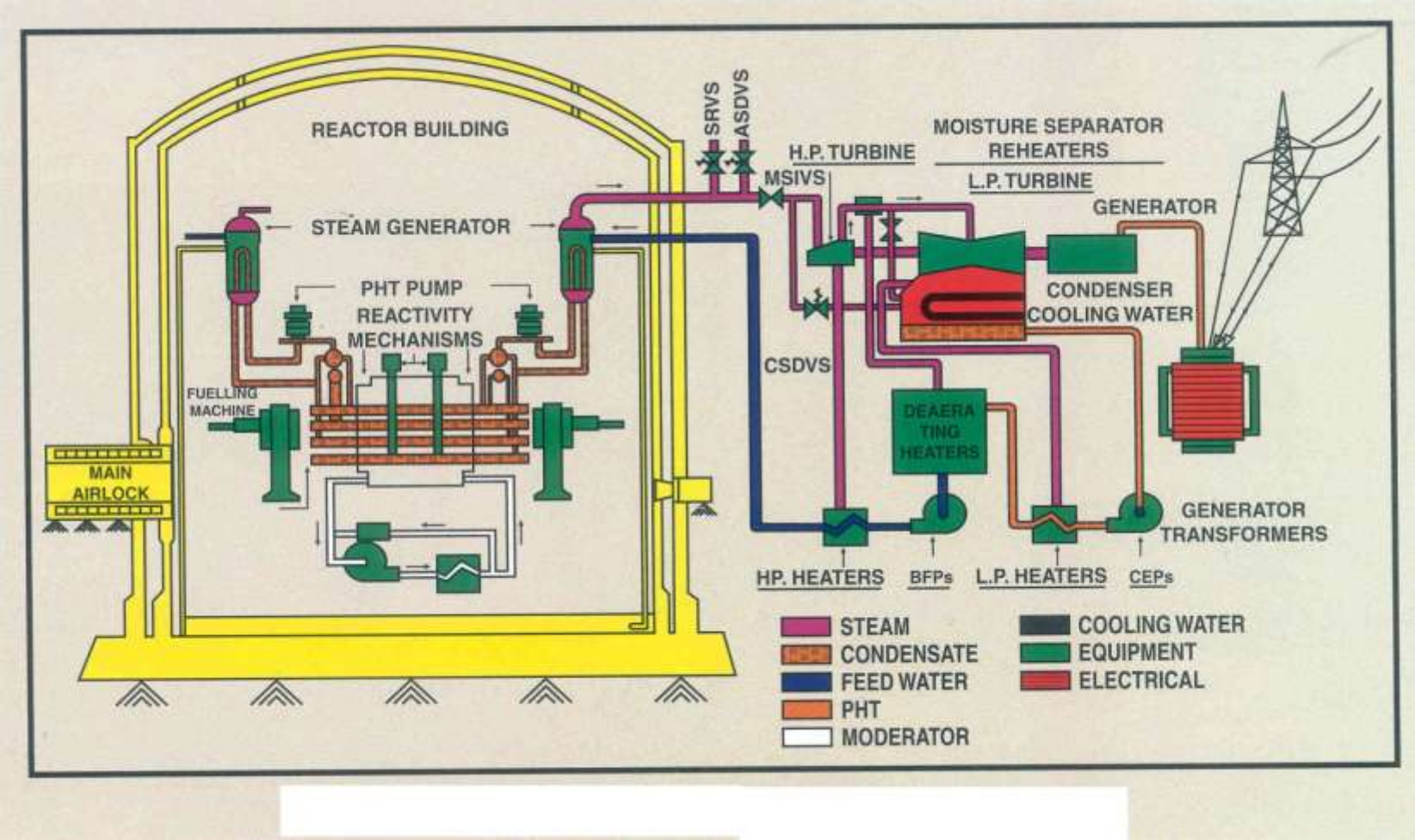
Provisions of Reactor Safety Functions

- **Reactor Containment Isolation**

- ❑ High steam flow in respective steam line (s)
- ❑ High temperature into pipe “tunnel area”
- ❑ Low pressure in steam lines
- ❑ Drywell high pressure

TAPS-1&2 would be maintained under sub-critical and cooled state due to the provisions.

PHWR Schematic



Safety in Indian PHWRs

Reactor Safety

Safe Shutdown

Systems & Features

- **Fast Acting**
- **Independent**
- **Passive**

(Control Rods, ALPAS/ LPIS Boron Injection for Long term shutdown)

Decay Heat Removal

Systems & Features

- **Active & Passive**
- **Backup Systems**

(ECCS, Suppression Pool, Inventory in Calandria & Calandria Vault, Fire water injection into SGs)

Containment

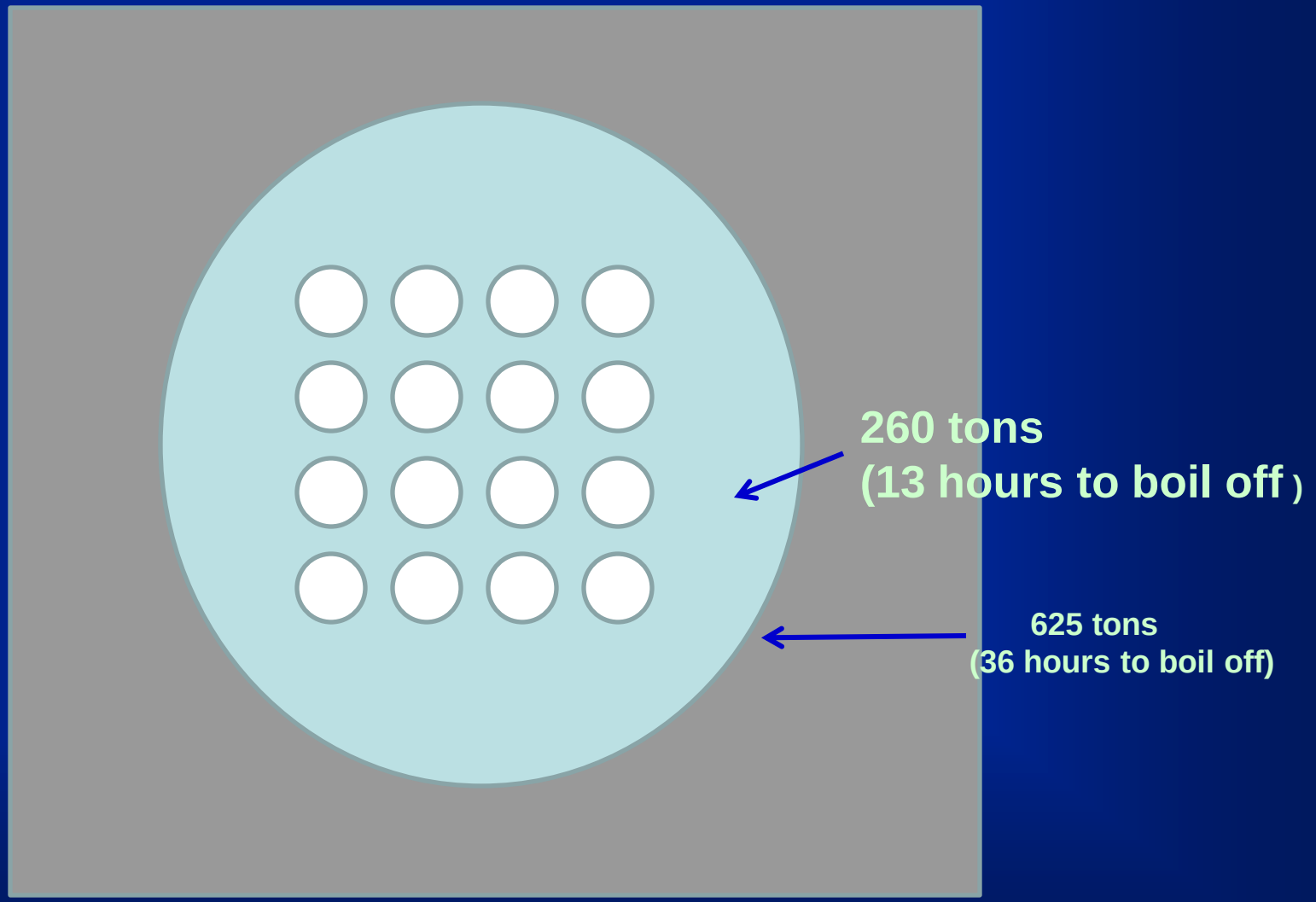
Systems & Features

- **Double Containment**
- **Inner Containment for design pressure IN DBA**
- **Secondary Containment under negative pressure**
- **ESFs**

TAPS-3&4 in light of Fukushima Event

In case all power supplies are lost ….

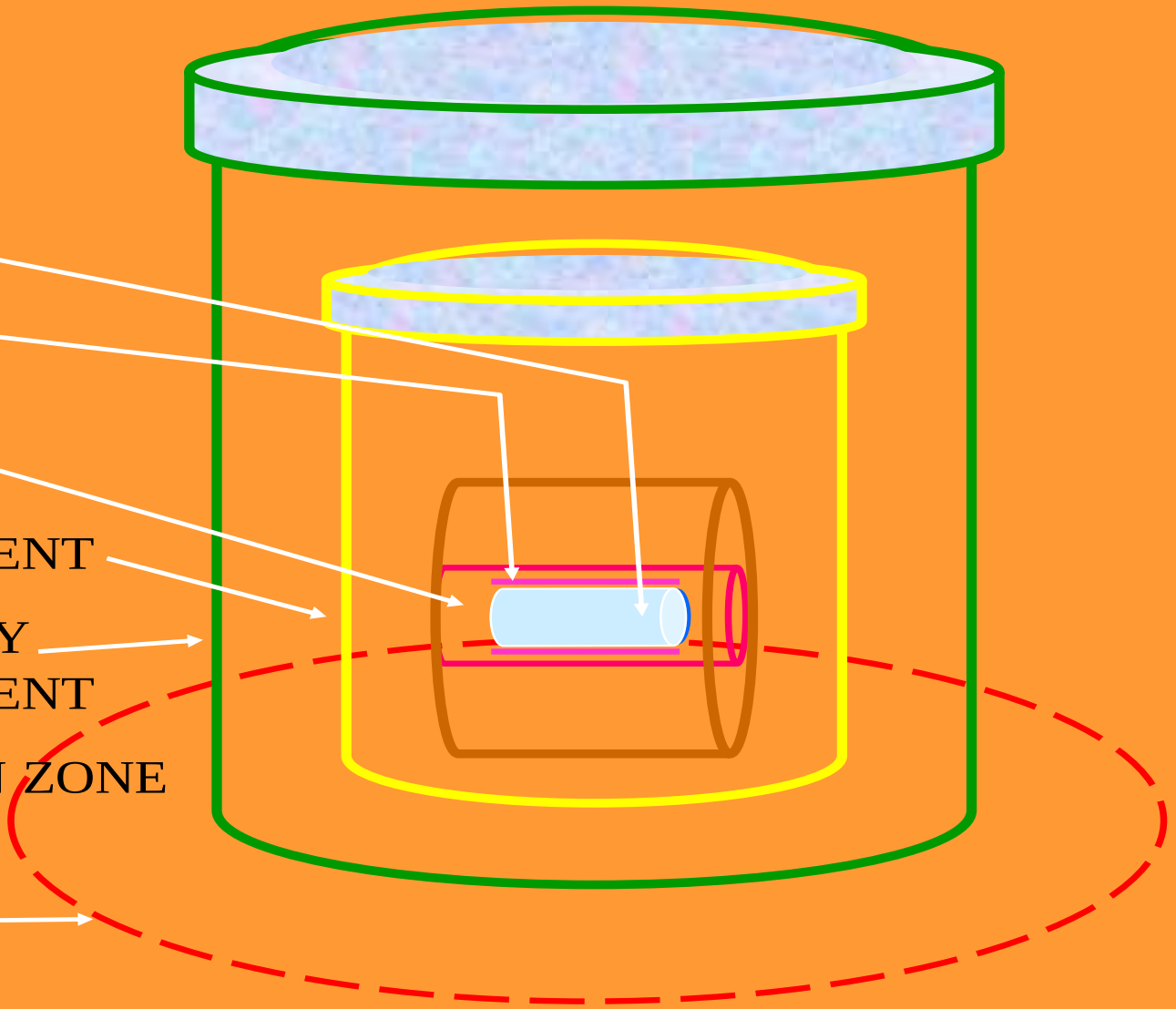
Time available to restore heat sinks



MULTIPLE BARRIERS TO PREVENT RADIOACTIVITY RELEASE

BARRIERS

1. PELLET
2. CLADDING
3. PHT
4. PRIMARY CONTAINMENT
5. SECONDARY CONTAINMENT
6. EXCLUSION ZONE



Safety Features – EPRs at JNPP

- Four independent safety trains- Housed in independent and Seismically qualified buildings.
- Provision of Hydrogen Re- combiners , Containment heat removal system.
- Emergency Feed Water System with two SBO DGs.
- Core Catcher –prevention of radioactivity releases.
- Double Containment- designed to withstand external air craft/ missile attack

Actions taken by NPCIL

- Emergency Control Centre at HQ activated on round o clock.
- Dissemination of Information to all sites & offices
- Quick Review of Events.
- Awareness to Public on Fukushima and Indian NPPs Safety aspects through,
  - Press & Media
  - Members of Parliament, State Assembly , Government officials
  - Posting of information on NPCIL and DAE Website
- Undertook Safety Reviews of Indian NPPs

Briefings

- **Prime minister of India , Minister of State briefings and keeping them posted regularly.**
- **Quick replies to the queries from various sections .**
- **Appraisal to the Parliament on Fukushima event and situation in India.**
- **Organized Number of press and media briefings at HQ , each NPP site.**

Review Committees

- **AERB has constituted high level committee for review**

- **NPCIL has setup four committees for review of safety in Indian NPPs to suggest improvements, if any**
  - **TAPS 1&2 (BWRs)**
  - **RAPS 1&2 (First PHWRs)**
  - **MAPS 1&2 (First generation Indigenous PHWRs)**
  - **NAPS 1&2 and onwards (Standard Indian PHWRs)**

The four committees have submitted their preliminary reports and will continue for detailed review

Recommendations - TAPS 1&2

- **Short Term**
  - **Regular Training for EOPs, mockup drills, disaster management training, Provisions for self sufficiency for 7 days without any external help.**
- **Long Term**
  - **Provision of Reliable Power – Raising tsunami resistant wall around EDGs and tanks, Mobile DGs inside plant, CNG/ Gas generators outside plant through overhead cables, relocating existing SBO DG at higher elevation**
  - **Core Cooling – provision of water sources, suction from intake canal, underground raw water tank, overhead tank away from site**
  - **Coolant Injection – into feed water lines, RPV using ACWS pumps, into dry well and suppression pool, replenishment of secondary side inventory**
  - **Containment Venting, Hydrogen Management –passive recombiners**
  - **Spent Fuel Pool Management**
  - **Alternate Communications Systems and Passive Instrumentation**

Recommendations- RAPS 1&2

- Augmentation of - Water Sources and Feed / make up capability
- Extension of Power Sources
- Systems Improvement – Automatic reactor trip on very high intensity earthquake, bypass switch for ECCS Injection, alternate pumping arrangements for pumping water, Portable Instruments etc.
- Augmentation of long term resources – Up gradation of Class II Electrical System, Hydrogen Management, bund at out fall retaining emergency feed in the event of break in RPS dam

Recommendations -MAPS 1&2

- **Short Term**
  - Procurement of medium size air cooled power packs,
  - Engineering to delink process water emergency storage tanks from process water system.
  - Procurement of small pumps with requisite head from power packs to pump water into SGs
  - Pump for Deaerator water transfer to SGs and Strengthening Feed water line
  - Helium purging from Calandria and hydrogen purging from generator
- **Long Term**
  - Underground concrete tank of 750 cum including pumps, liquid nitrogen and power pack-100 cu m tank at HP heater floor
  - Solar power lighting
  - Hydrogen management devices
  - Provision of Lub. oil reservoir on top of TG bearings

Recommendations NAPS onwards

- **Short Term**
  - Reactor trip on seismic event
  - Additional batteries and emergency lights in SBO kits
  - Surveillance of fire water lines, inclusion in ISI programme
  - EOPs strengthening
  - Provision of hand pumps for transferring diesel from Underground tanks
  - Leak tightness of all JBs,
- **Long Term**
  - Suppression pool inventory with power pack operated pumps
  - Instrumentation scheme in the event of extended power failure
  - Injection of water in BDBAs/Severe accidents
  - SSE qualified reservoirs of 5000 cu.m to be provided at NAPS, KApS and TAPS 3&4
  - Supply of water to SFSBs
  - Construction of tsunami wall / mangroves at TAPP 3&4
  - Solar batteries , emergency lighting etc.

International cooperation

- WANO governing board meeting was held on March, 15 on audio conference- CMD NPCIL along with top 20 world nuclear industry officials participated
- WANO officials from other 3 regional centers camping at Tokyo for support
- IAEA governing board meeting held on 21 March 11, NISA official briefed governors, Indian ambassador briefs about Indian situation
- IAEA deputes officials at Japan
- US, France sends experts to Japan.

Significant Operating Experience Report
WANO SOER 2011-2

Fukushima Daiichi Nuclear Station Fuel Damage Caused by Earthquake and Tsunami

March 2011

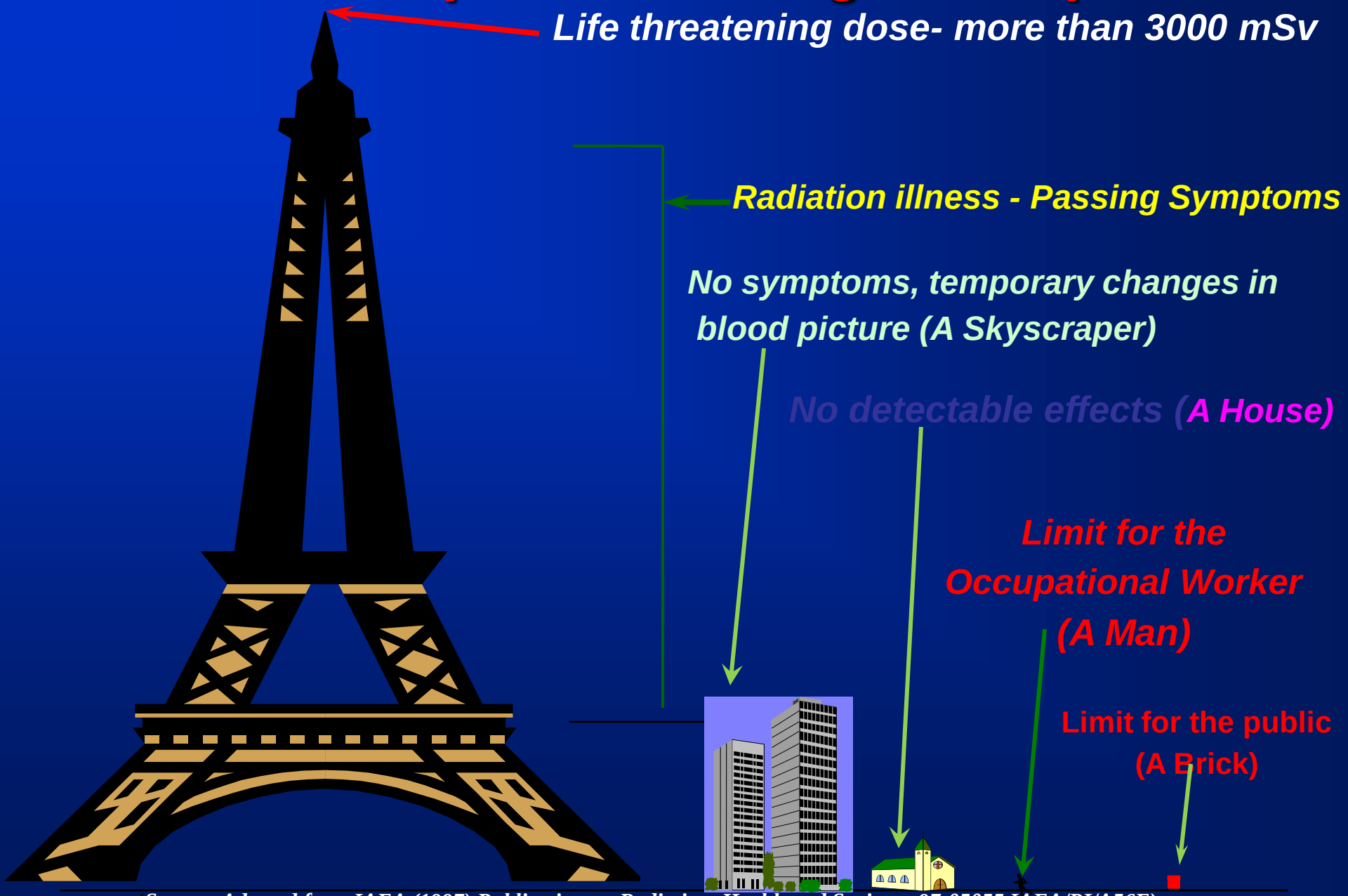
WANO Global Meet

- WANO meeting later this year to discuss lessons learnt from Fukushima event.

- High level commission to restructure WANO organisation and approach to further strengthen safety and reliability in NPPs world over.

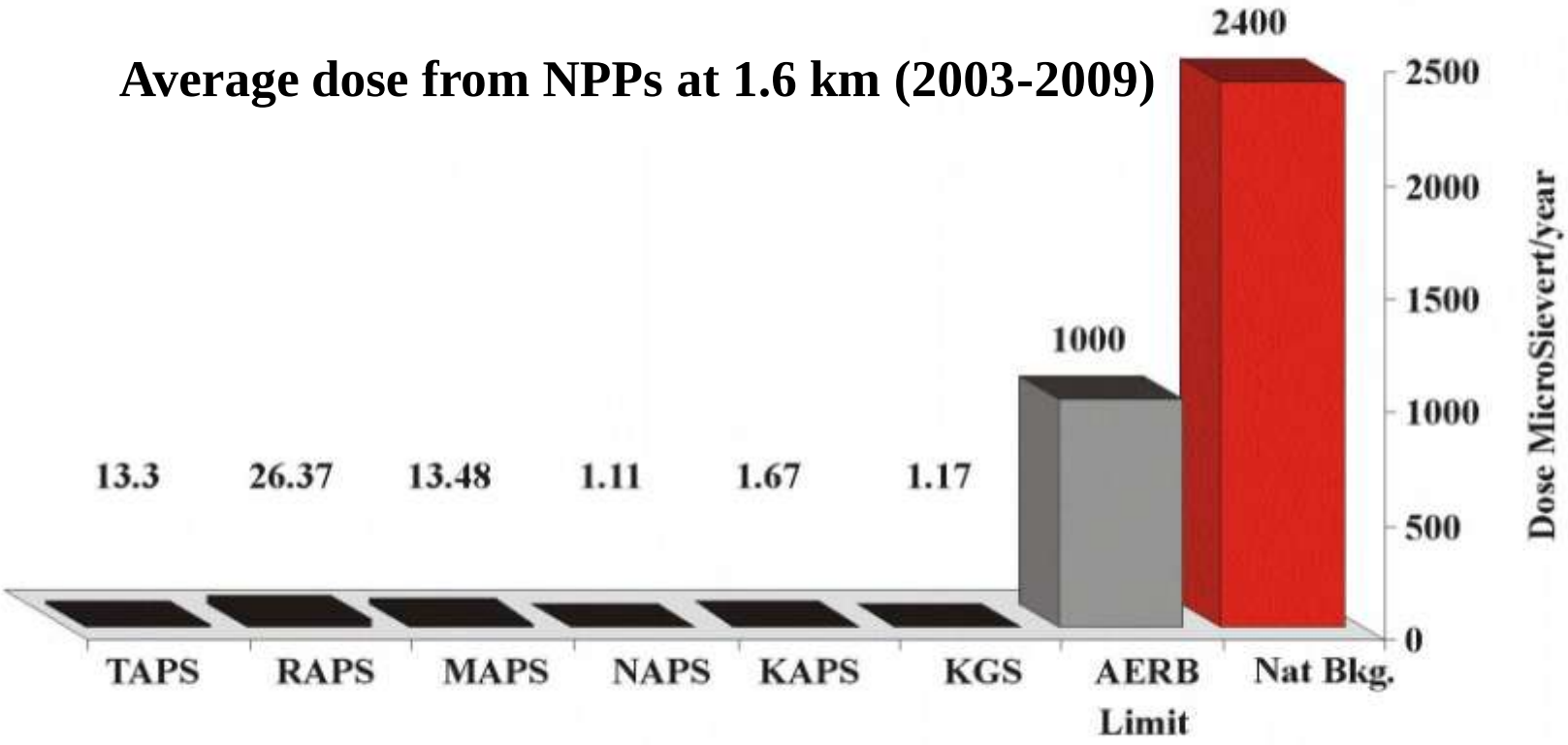
Thank You

Radiation Exposure-The right Perspective



(Source: Adapted from IAEA (1997) Publication on Radiation, Health and Society - 97-05055 IAEA/PI/A56E)

Radiation Dose to Public is insignificantly small fraction of natural background and the Regulatory limit



Radiation - Basic Terms Used

- Becquerel (Bq) refers to one disintegration of a radioactive element per second
- When radiation interacts with human body it deposits energy in the body.
- The effect on human body will depend on the energy deposited per Kg and the type of radiation
- Sievert (Sv) refers to an effective dose of one Joule of energy per Kg of the body weight

Radiation –a Fact of Life

- Radiation is always present around us and inside our body.

- An average effective dose of 2.4 milli Sievert/ Year is received by us from natural radiation background

Radiation in Daily-life

※Unit : μSv

Radiation dose (microsievert: μSv)

250,000

50,000

10,000

1,000

100

10

Upper limit of radiation dose permitted for people who engage in emergency work.
[250,000 μSv/year]

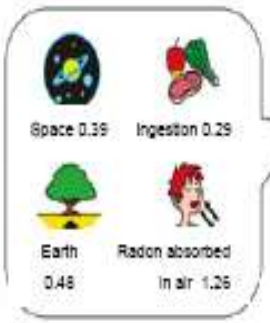
Upper limit of radiation dose permitted for radiation workers, police , and firefighters who engage in disaster prevention.
[50,000 μSv/year]

[~10,000 μSv/year]

Radiation dose in Guarapari(Brazil) per year.

Chest CT scan
[6,900 μSv/each time]

[~2,400 μSv/year]



Global average

Natural radiation dose per year.

Dose limit for public per year (except for medical care).

[1,000 μSv/year]

Gifu ⟷ Kanagawa

Maximum difference of the average of natural radiation dose in each prefecture.
[~400 μSv/year]

gastrointestinal X-ray examination.
[600 μSv/each time]

An air travel between Tokyo and New York (RT).
(Increased cosmic radiation at high altitude.)
[~200 μSv/round trip]

[50 μSv/each time]
Chest X-ray examination.

[22 μSv/year]
Evaluated dose of radiation from radioactive substance emitted from the nuclear fuel reprocessing plant per year.

[50 μSv/year]
Standard dose of radiation around a nuclear plant (light water reactor).
(Actual result is far below the value.)

[10 μSv/year]
Standard radiation dose from Clearance level.