The Fukushima Nuclear Accident

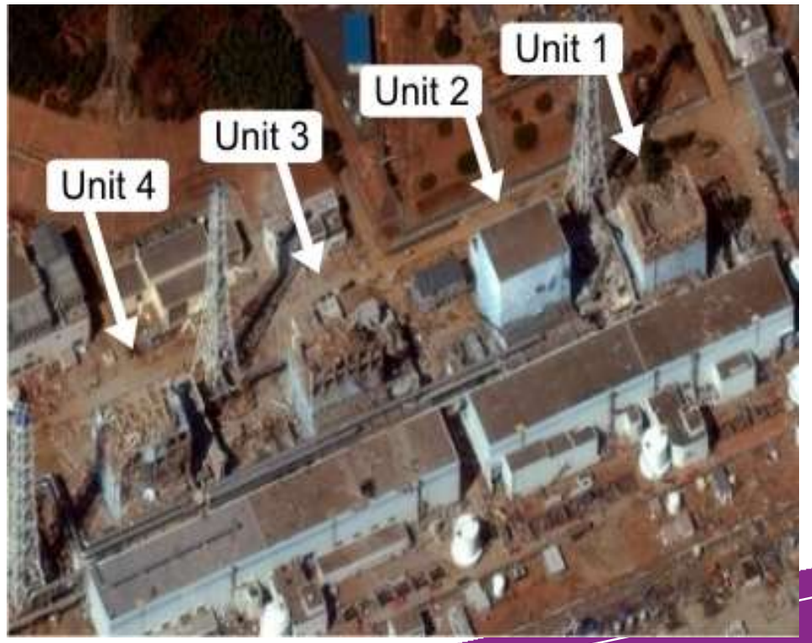
Professor Tom Mazour

The Fukushima Nuclear Accident:

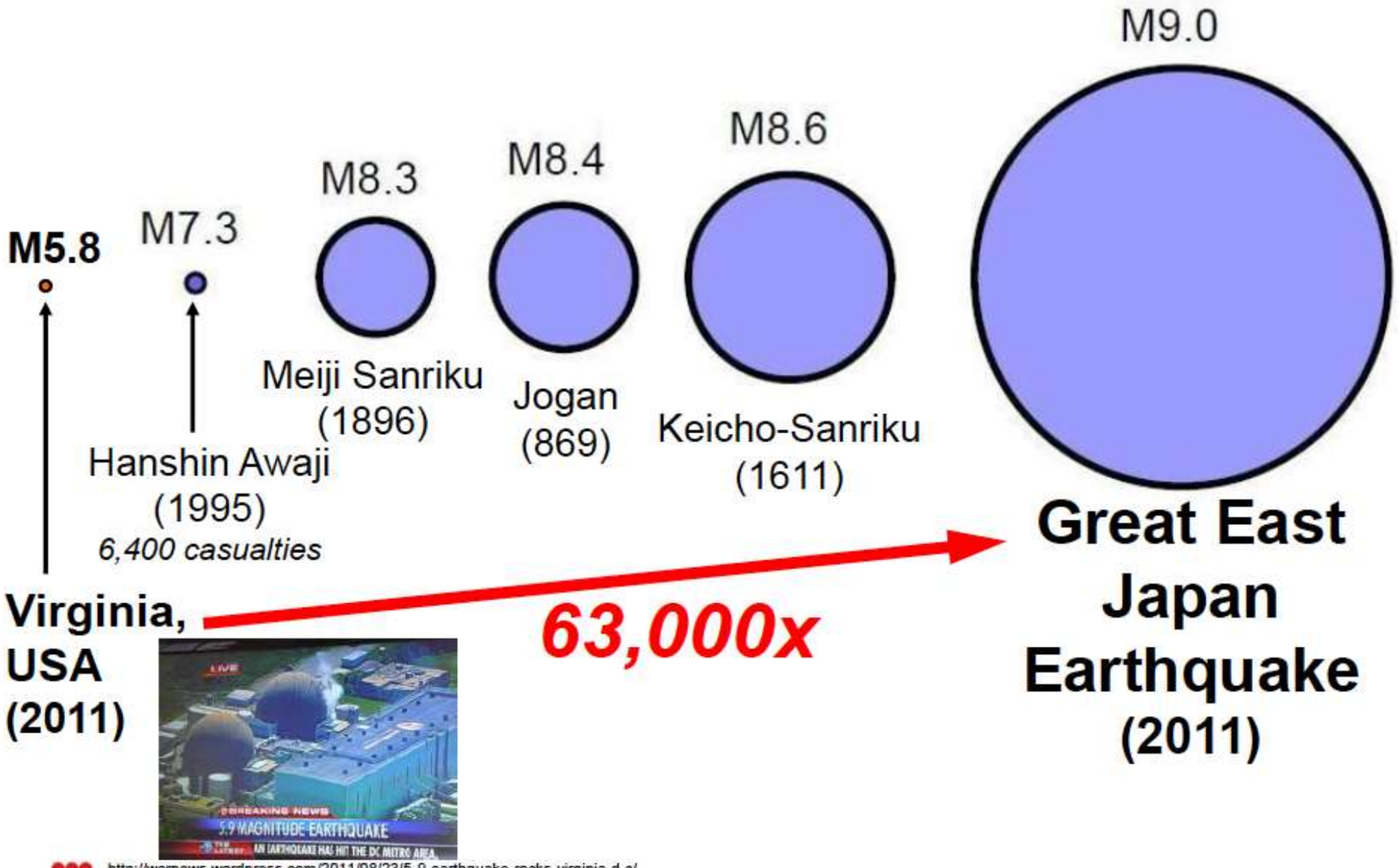
How did it happen?

What have been the consequences?

Tom Mazour



Comparison of Seismic Energy (Magnitude)



http://wcmews.wordpress.com/2011/08/23/5-9-earthquake-rocks-virginia-d-c/

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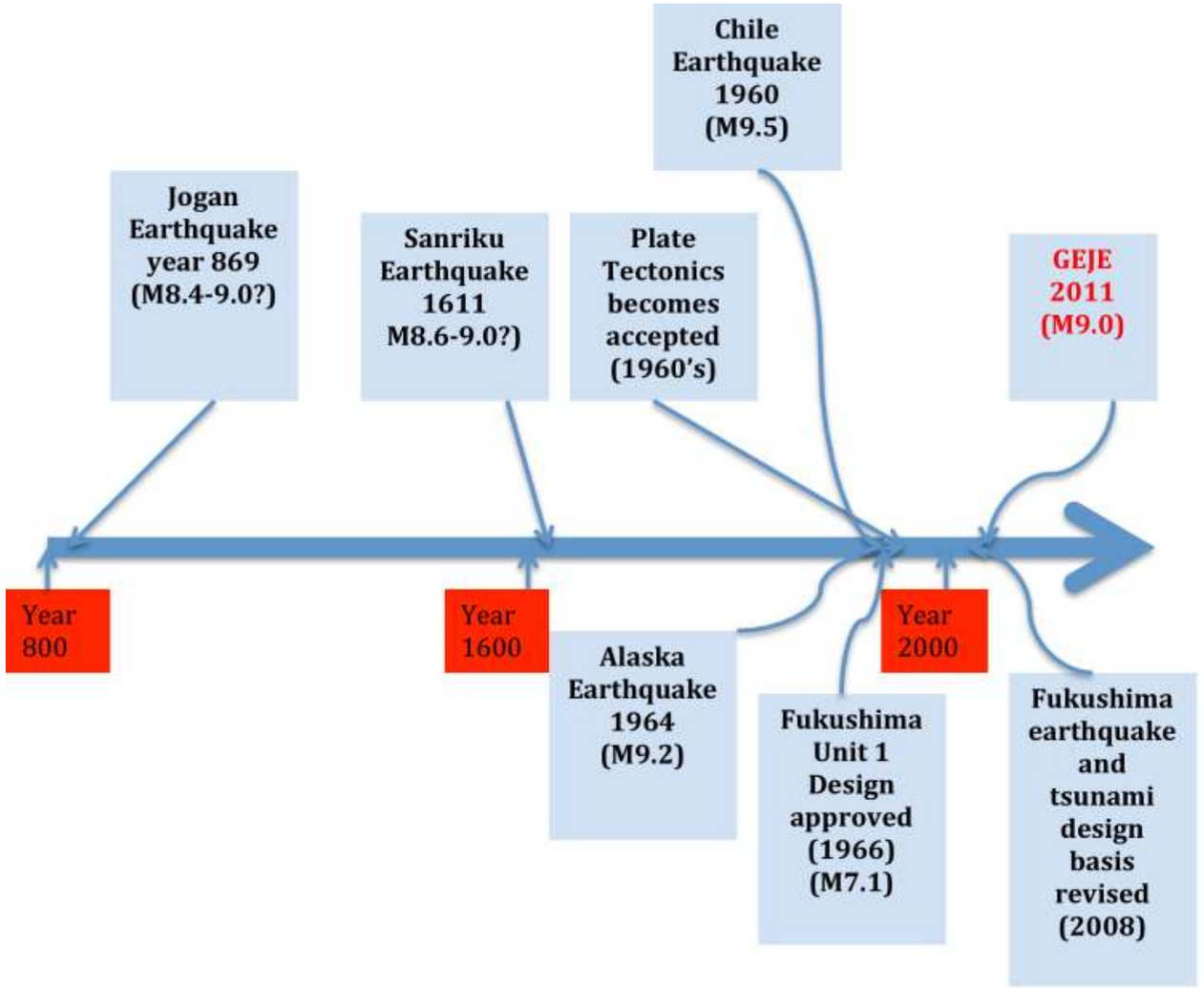
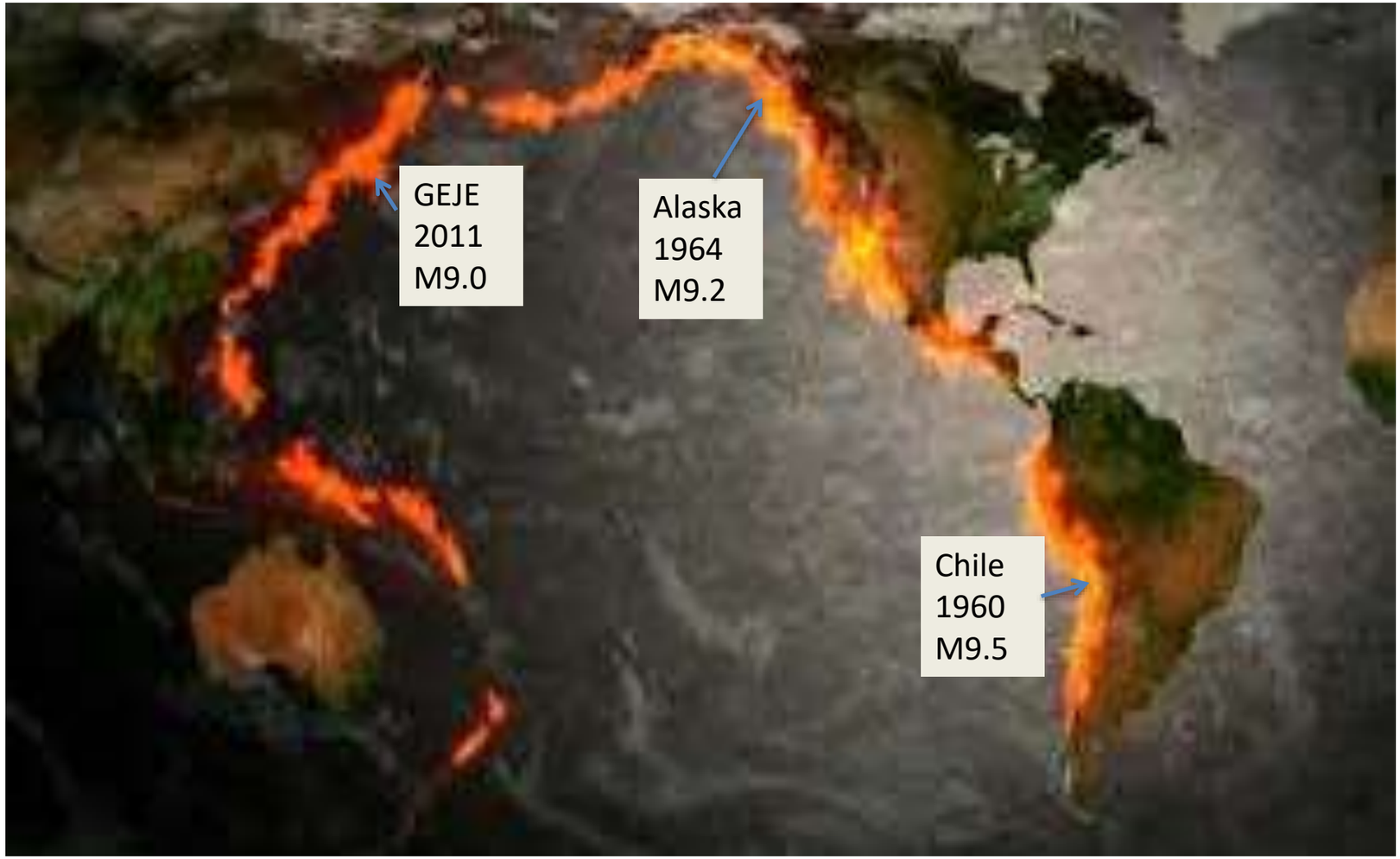
1000+ Year Timeline - Fukushima



The Ring of Fire



Causes of the Fukushima Accident:

1. An earthquake of magnitude 9.0 near Japan wasn't considered credible
2. ?
3. ?
4. ?


N
0
200 km
Higashidori NPP
Epicentre
Onagawa NPP
Fukushima Daiichi NPP
Fukushima Daini NPP
Tokai Daini NPP
JAPAN
Tokyo
Japan Trench
Osaka
Izu-Bonin Trench
Source: Esri, NASA

Consequences of the GEJE for Fukushima?

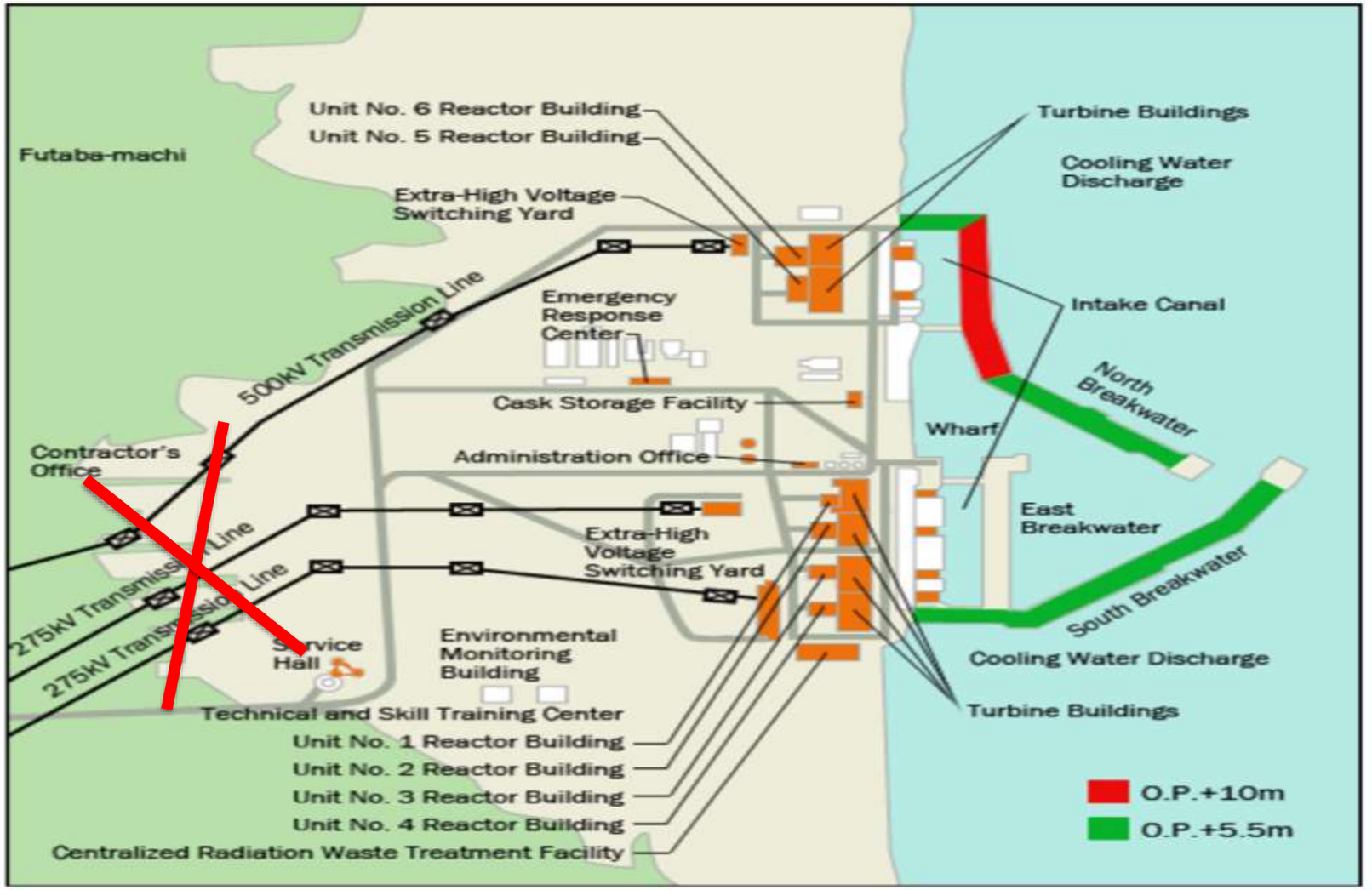
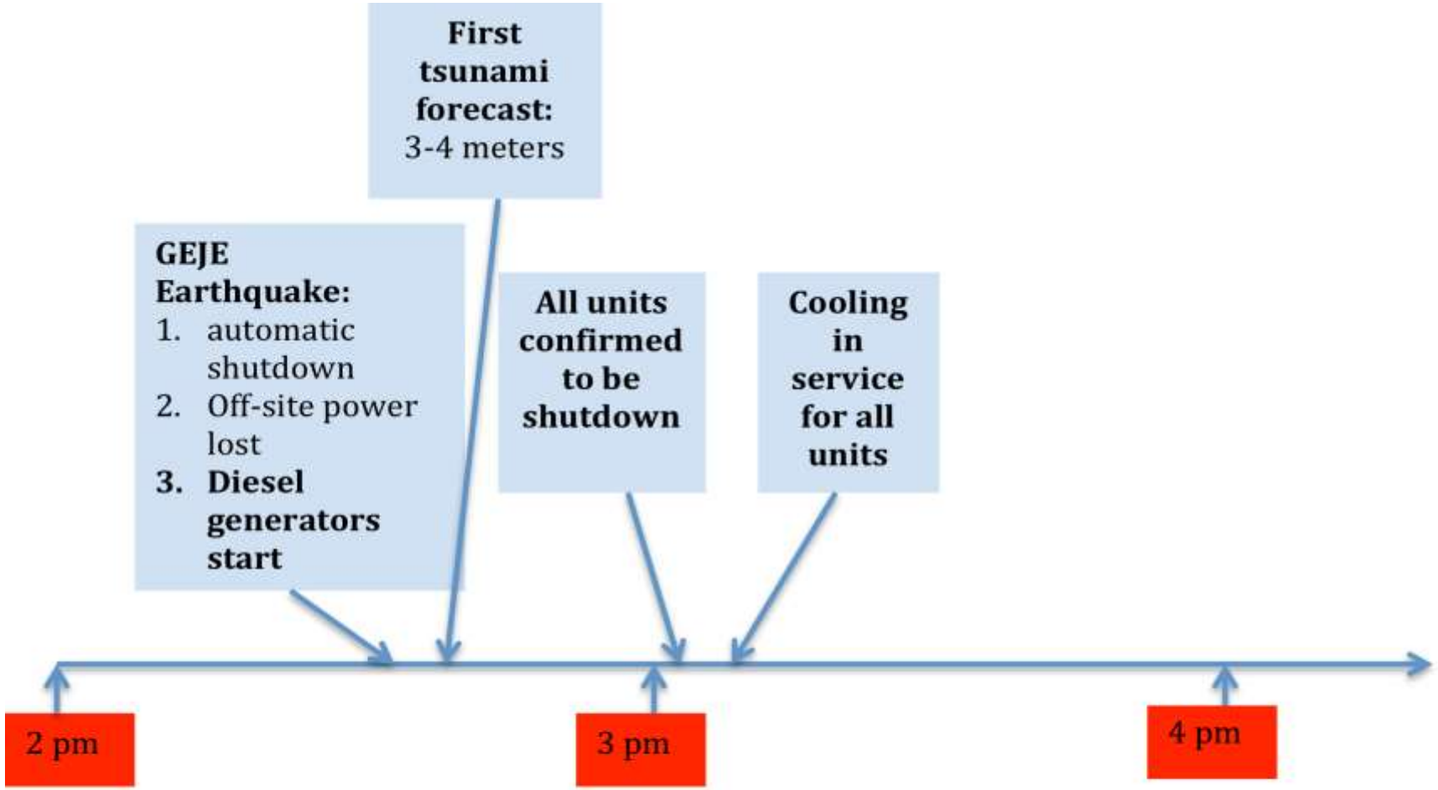


FIG 7 – Fukushima Site Layout and Seawall Height, INPO (2011) (1)

Timeline: 11 March 2011



Timeline: 11 March 2011

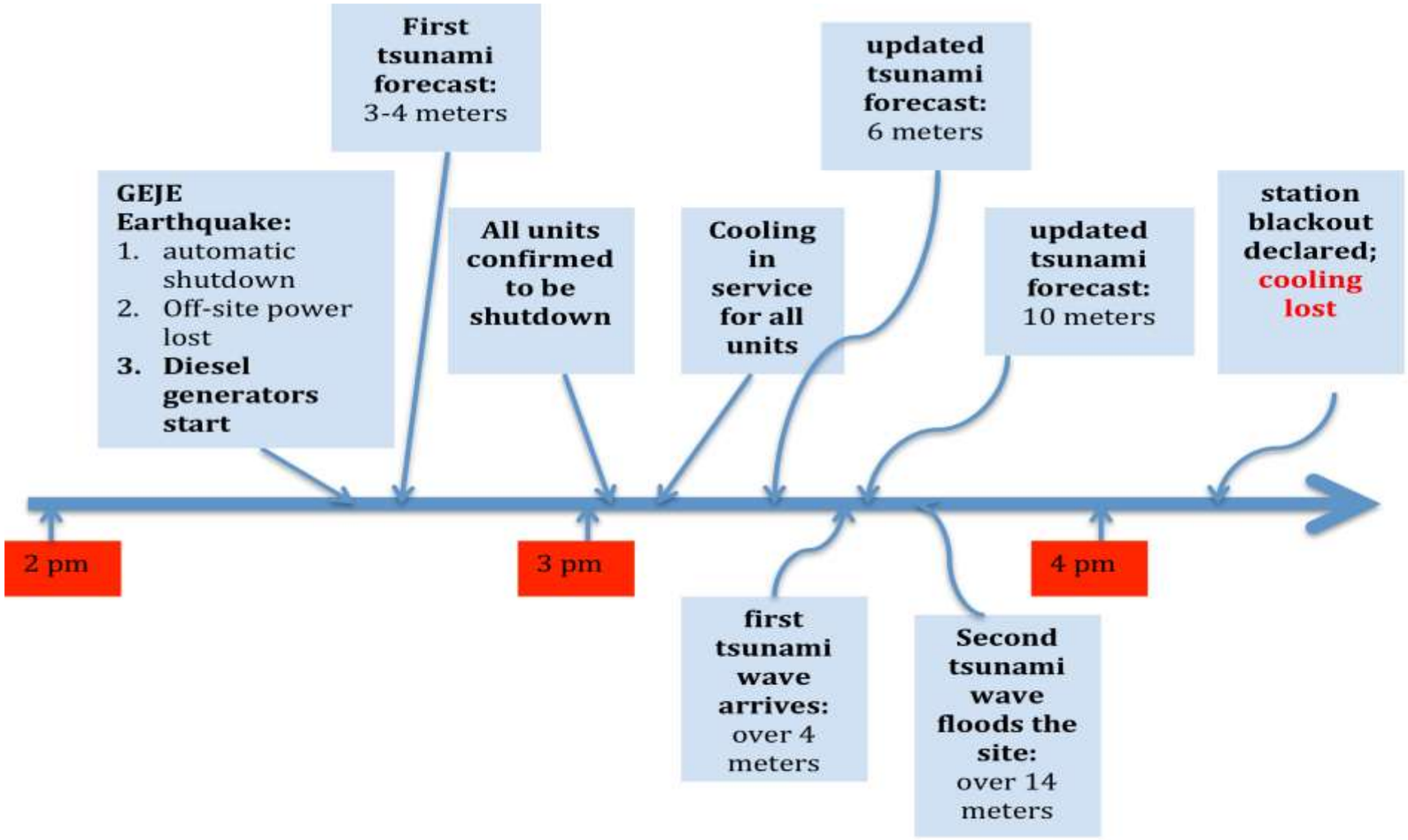



Photo by City of Sendai

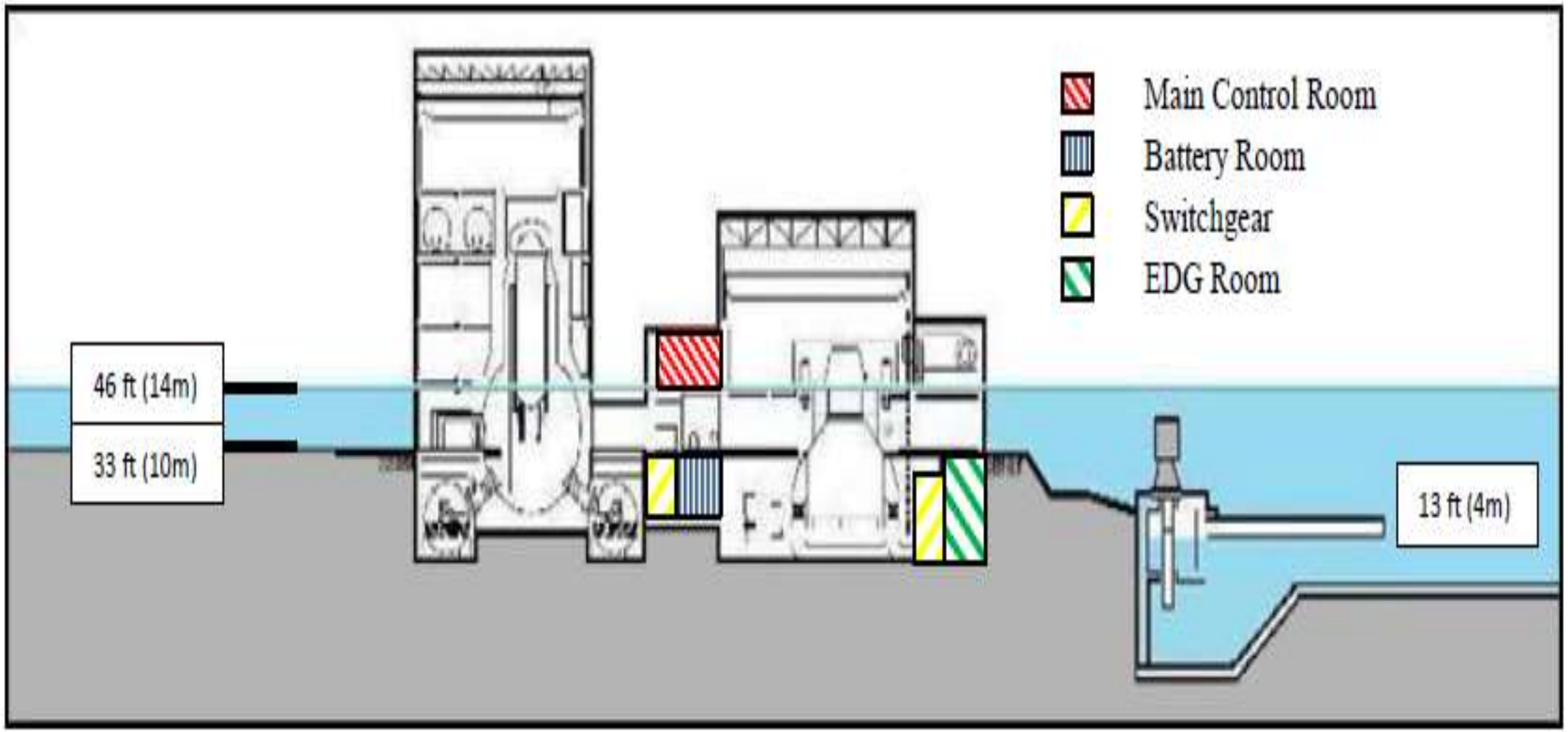


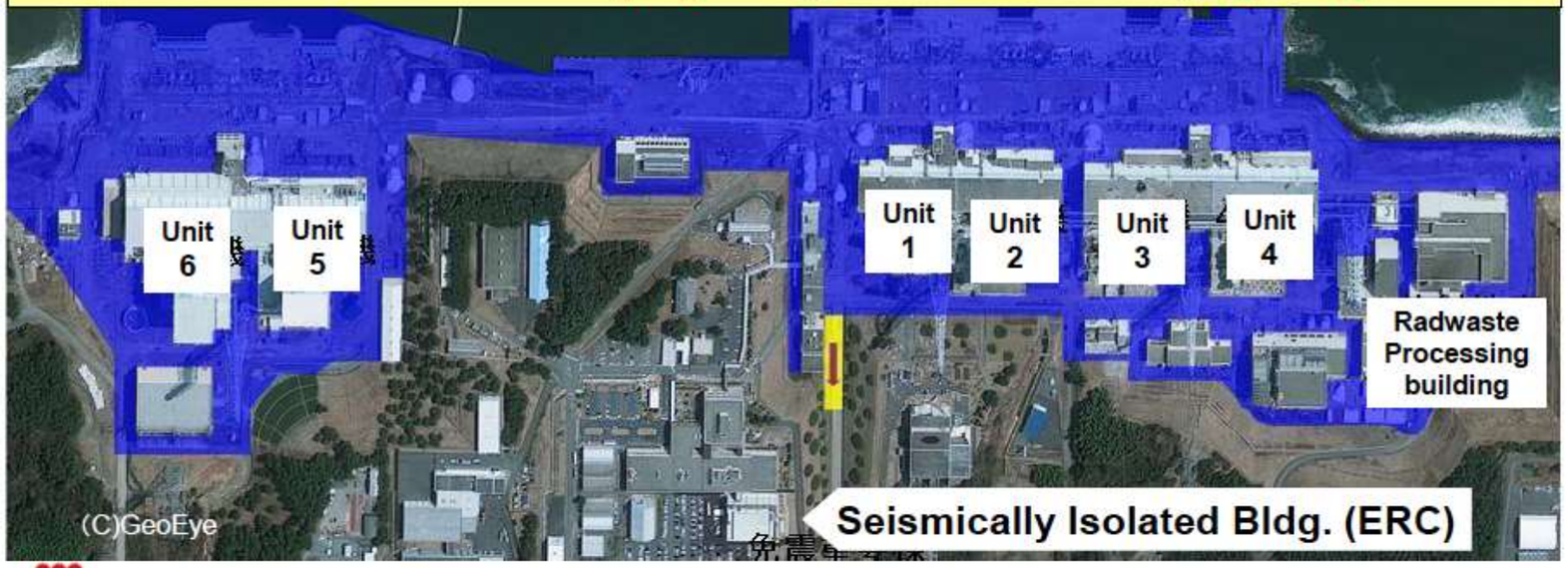
FIG 3 – General Elevations and Inundation Level, INPO (2011) (2

Causes of the Fukushima Accident:

1. An earthquake of magnitude 9.0 wasn't considered as credible
2. **A tsunami of the magnitude that arrived on March 11, 2011 wasn't a design requirement**
3. **?**
4. **?**

Impact of Earthquake/Tsunami at 1F

- **After the Earthquake** (near design-basis):
  - ✓**Loss of all off-site power**
  - ✓**Plant responded as designed** (automatic shutdown of operating units/startup of EDGs)
- **After the Tsunami** (beyond design-basis):
  - ✓**Station Black Out** (SBO) for 5 out of 6 units
  - ✓**Loss of almost all safety system, instrumentation, lighting**, etc.



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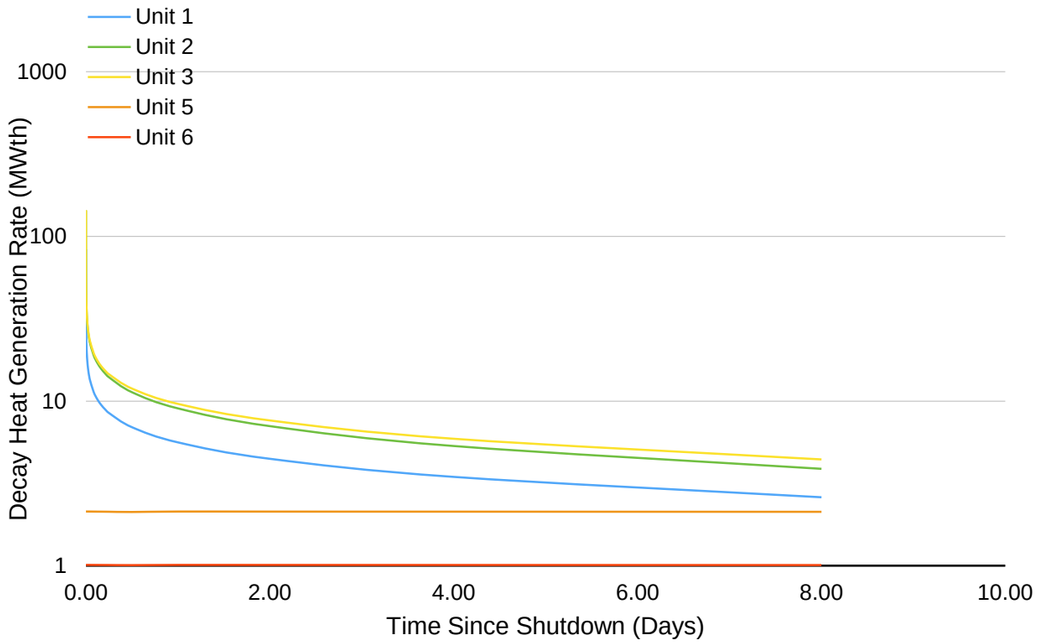
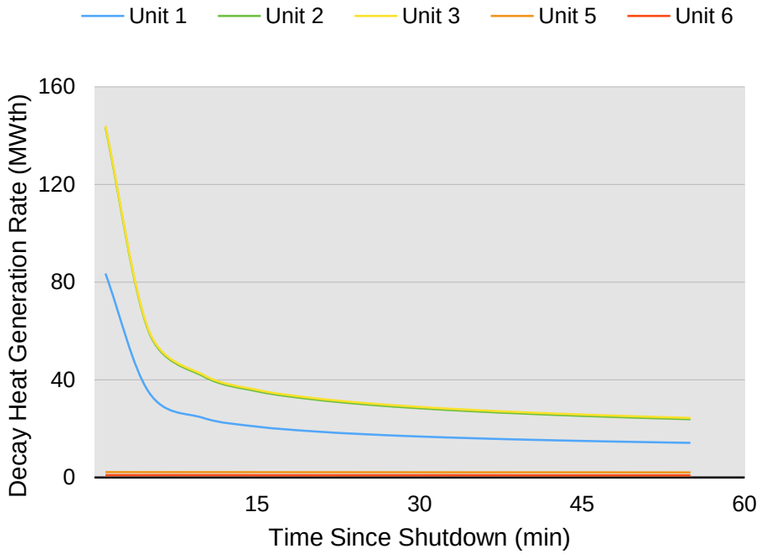
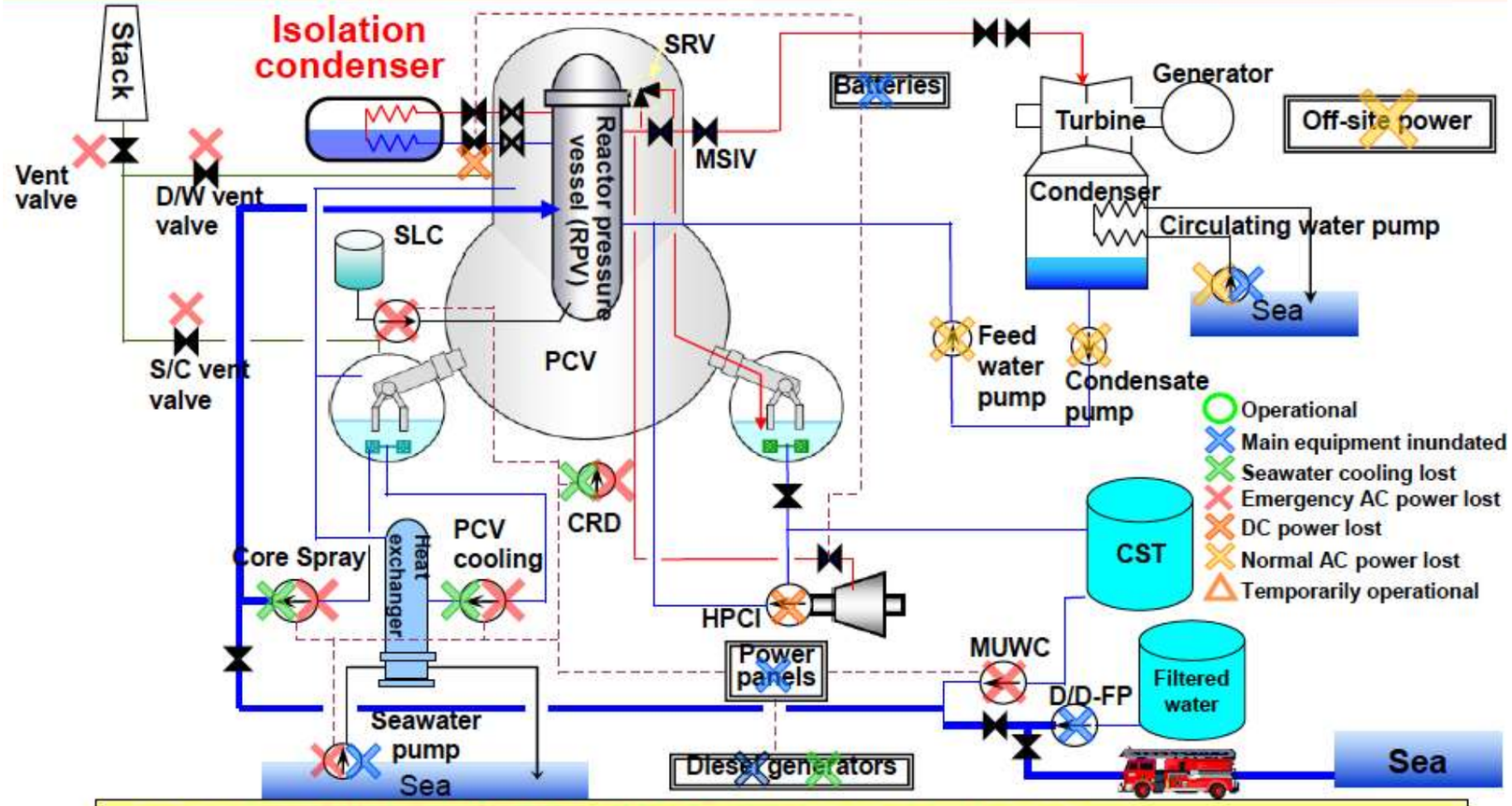
Decay heat rates





Plant Status After Tsunami (1F Unit 1: BWR-3/Mk-I)

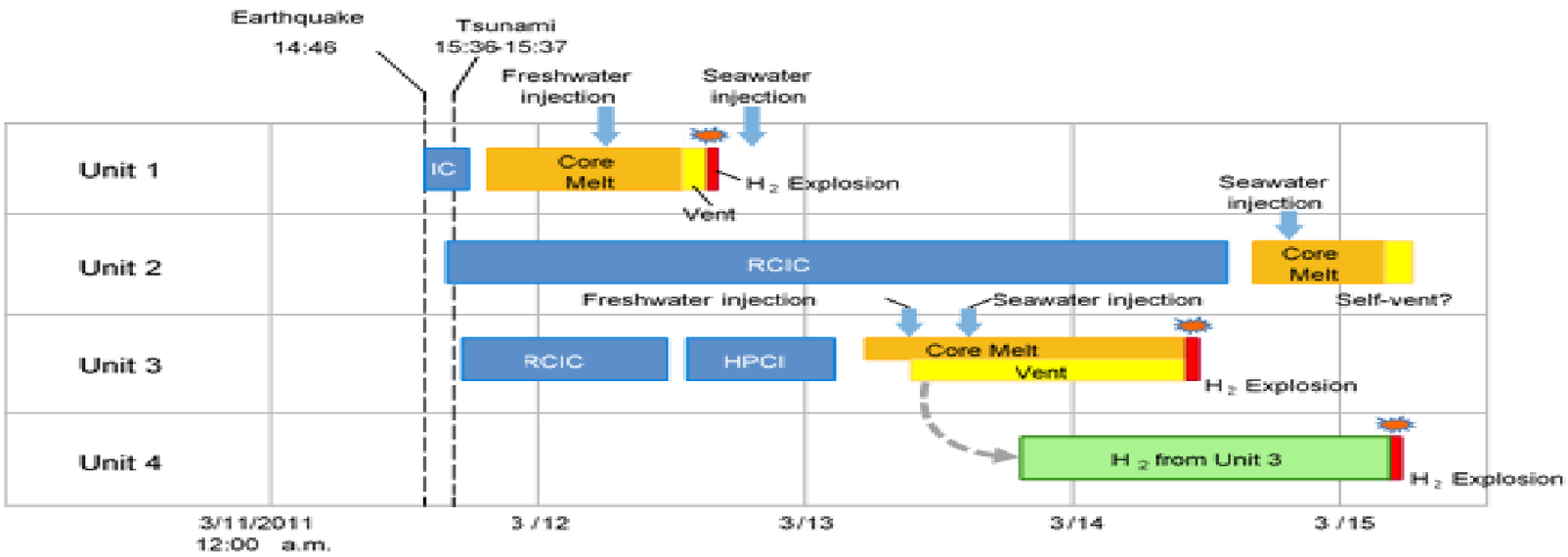


- Reactor **automatically shutdown** after earthquake
- **Loss of all AC/DC power** + core cooling capability due to tsunami
- Core melt and Zr-water reaction led to **H2 explosion** in R/B
- Stabilization by sea water injection via **fire trucks**

Causes of the Fukushima Accident:

1. An earthquake of magnitude 9.0 wasn't considered credible
2. A tsunami of the magnitude that arrived on March 11, 2011 wasn't a design requirement
3. **Due to the plant design the tsunami led to a loss of cooling for the reactors**

Timeline of Core damage



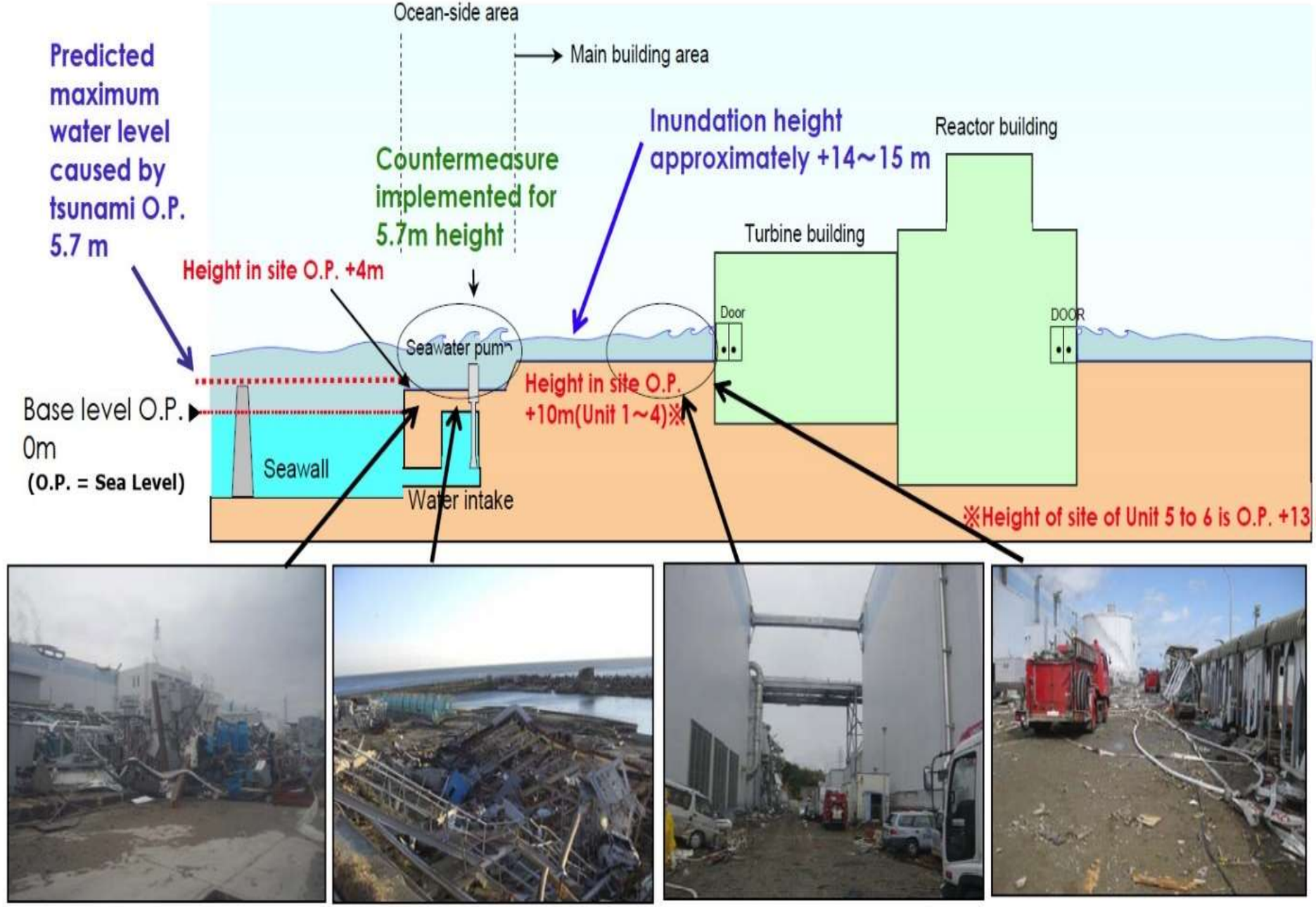
RCIC = Reactor Core Isolation Cooling

HPCI = High-Pressure Coolant Injection

IC = Isolation Condenser

- Cooling system active
- Containment venting
- Core melting
- Hydrogen backflow into unit
- Hydrogen explosion

Length of bar indicates duration


Ocean-side area
Main building area
Predicted maximum water level caused by tsunami O.P. 5.7 m
Countermeasure implemented for 5.7m height
Inundation height approximately +14~15 m
Reactor building
Turbine building
Height in site O.P. +4m
Door
DOOR
Seawater pump
Height in site O.P. +10m(Unit 1~4)※
Base level O.P. 0m
(O.P. = Sea Level)
Seawall
Water intake
※Height of site of Unit 5 to 6 is O.P. +13 m

Accident Response at 1F: In the Main Control Room

Checked instrumentation in near-complete darkness

Supervised operation wearing full-face mask

Brought in heavy batteries to restore instrumentations

Lack of: instrumentation, communication means, lighting, food, water, sleep, ...

Increase in: radiation level, fatigue, fear, despair, ...

→*Yet, operators stayed behind to carry through their duties*

Infrastructure was devastated

Emergency Responders had MANY challenges!

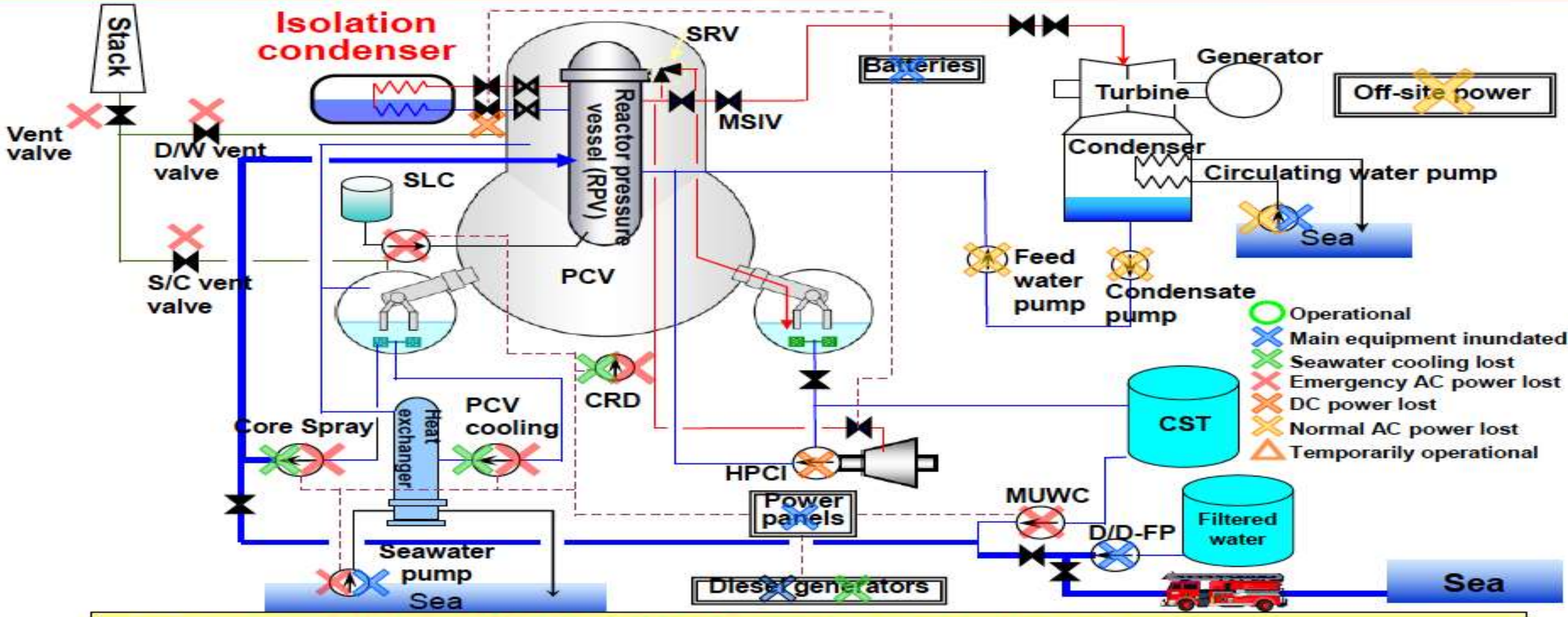
Accident Response at 1F: In the Field

Roads damaged by earthquake

Roads blocked by tsunami debris

Continual aftershocks, tsunami alerts, open manholes, etc. exacerbated the situation

Plant Status After Tsunami (1F Unit 1: BWR-3/Mk-I)



- Reactor automatically shutdown after earthquake
- Loss of all AC/DC power + core cooling capability due to tsunami
- Core melt and Zr-water reaction led to H2 explosion in R/B
- Stabilization by sea water injection via fire trucks

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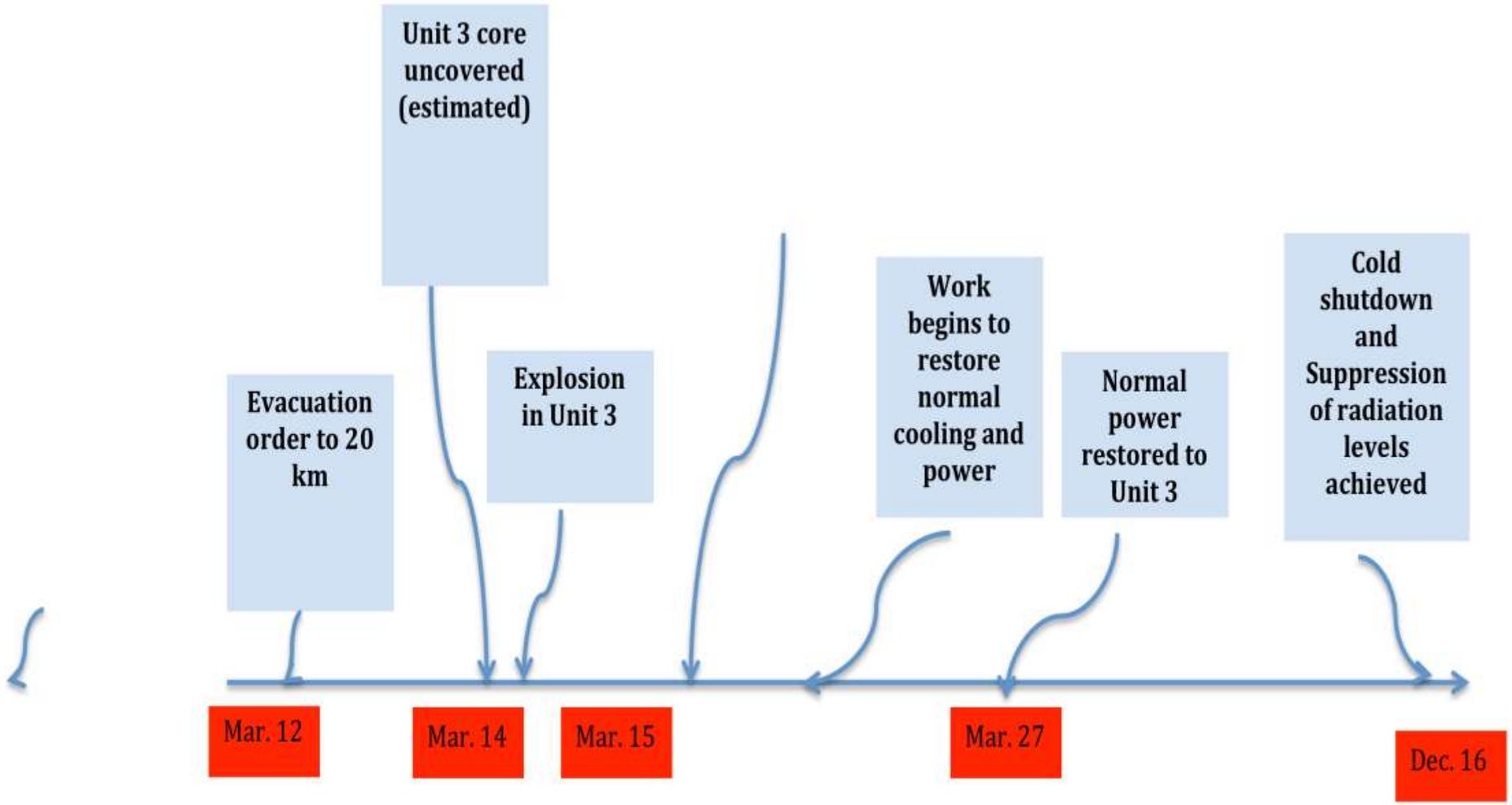
Timeline: 2011



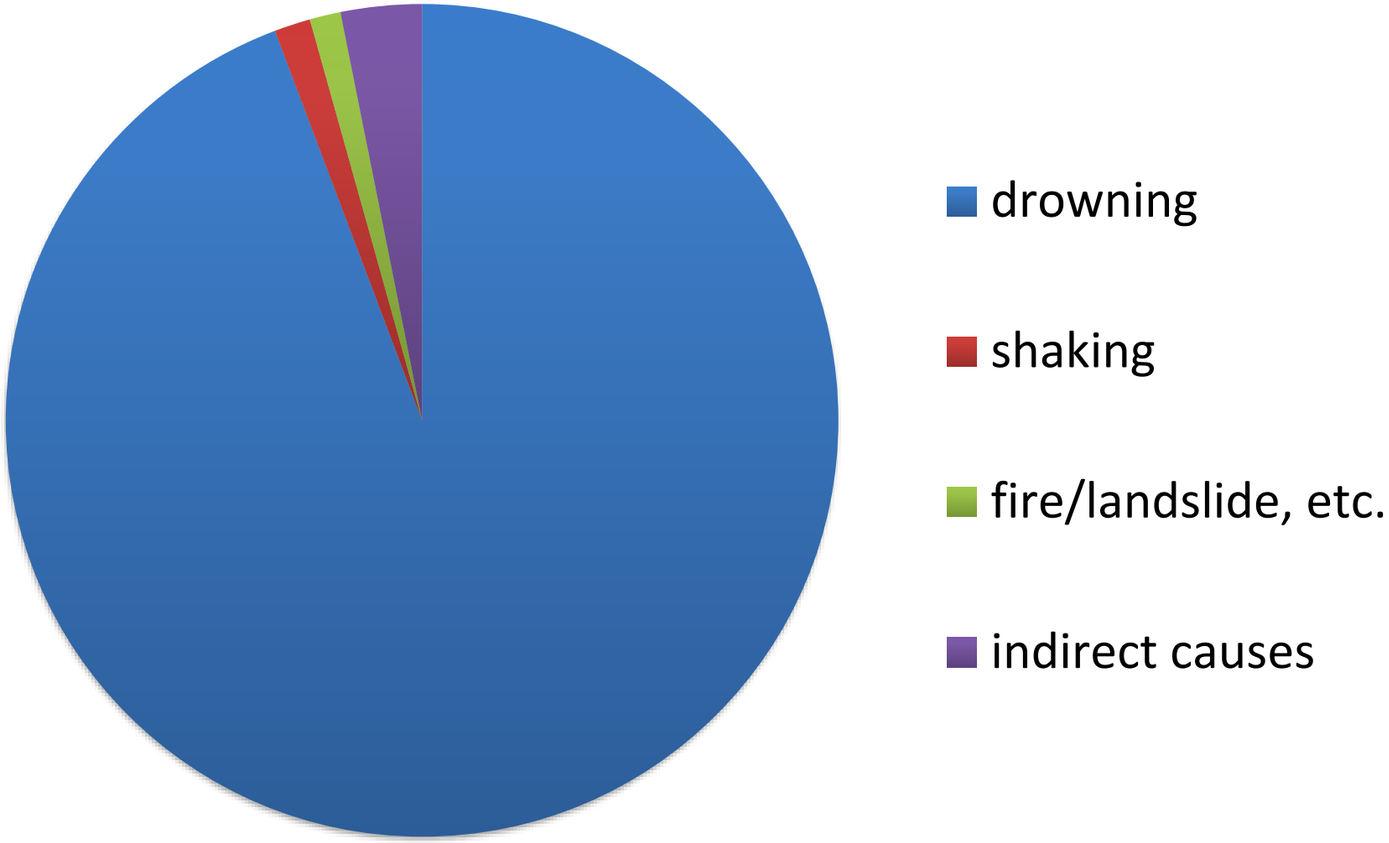
Causes of the Fukushima Accident:

1. An earthquake of magnitude 9.0 wasn't considered credible
2. A tsunami of the magnitude that arrived on March 11, 2011 wasn't a design requirement
3. Due to the plant design these combined to cause a loss of cooling for the reactors
4. **The mindset was that such an event couldn't happen; responses were delayed**

Consequences of GEJE/Fukushima

- Deaths
- Costs
- Impact on society

About 19,000 Dead/Missing from GEJE



How Many Radiation-Related Deaths from Fukushima?

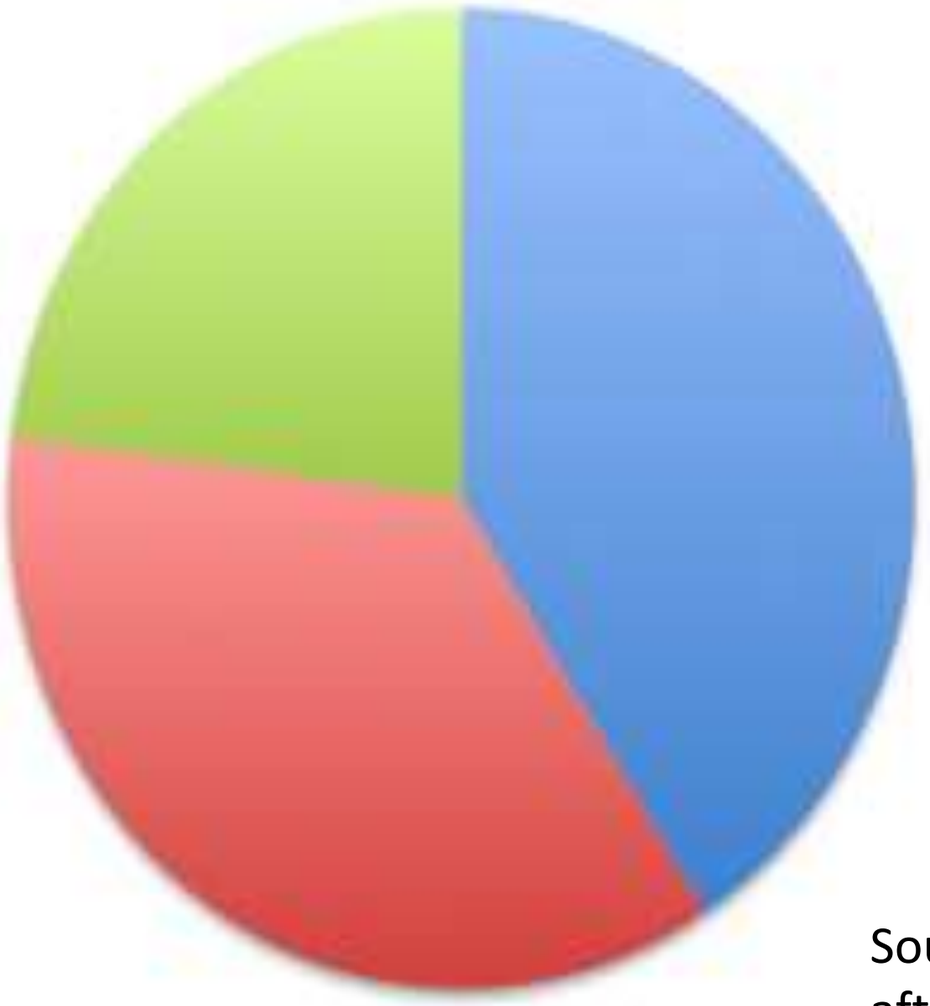
- Workers or those living nearby:
  0 (zero)
- Expected deaths in the long term:
  - “No discernible increased incidence of radiation-related health effects are expected among exposed members of the public or their descendants” (UNSCEAR)

Biggest Health Effect of Fukushima?

- “The most important health effect is on mental and social well-being, related to the enormous impact of the earthquake, tsunami and nuclear accident, and the fear and stigma related to the perceived risk of exposure to ionizing radiation. Effects such as depression and post-traumatic stress symptoms have already been reported.” (UNSCEAR)

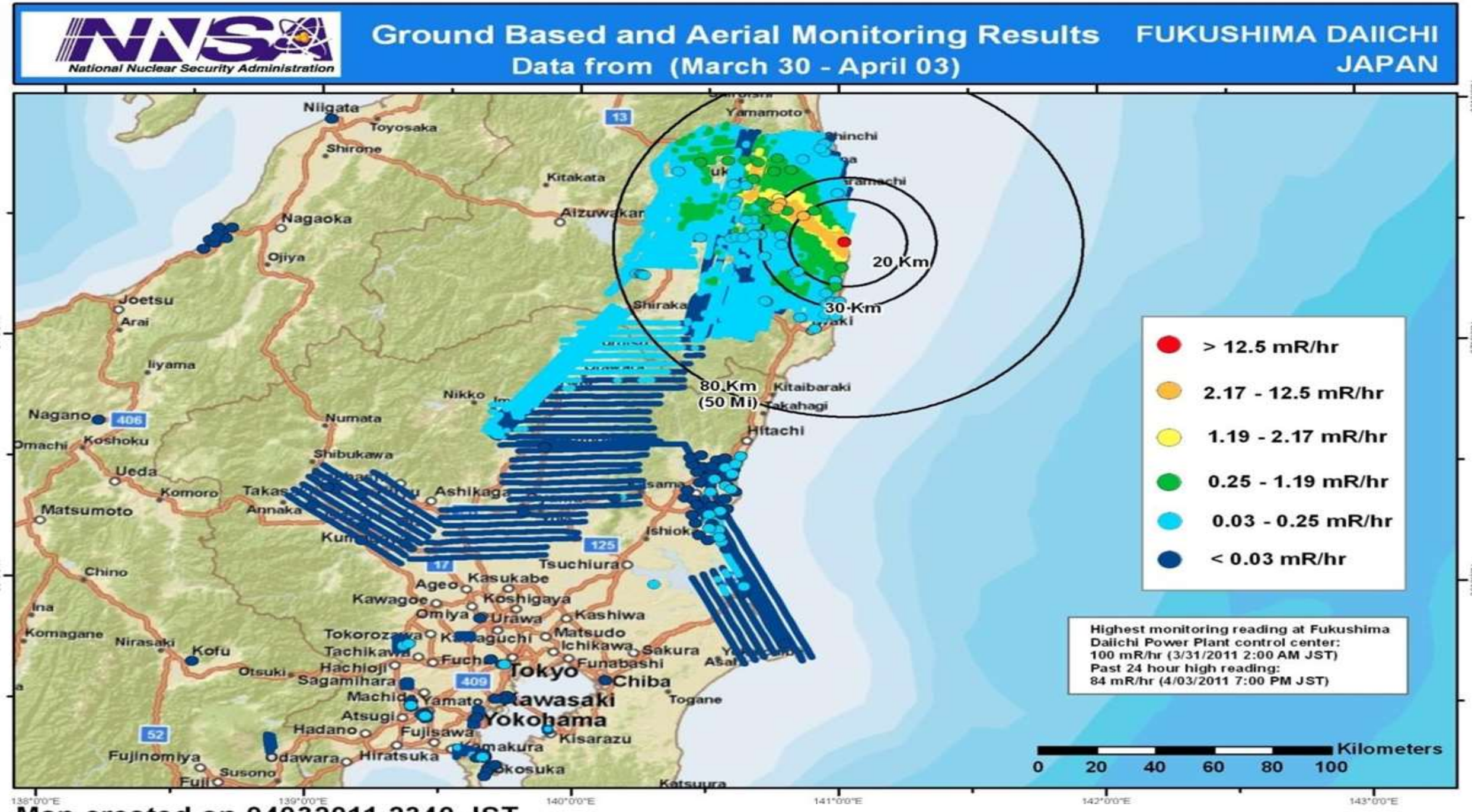
More than 100,00 people were evacuated; many of them still haven’t returned!

Economic Losses (%)



The most costly natural disaster in history: US$250-600 billion

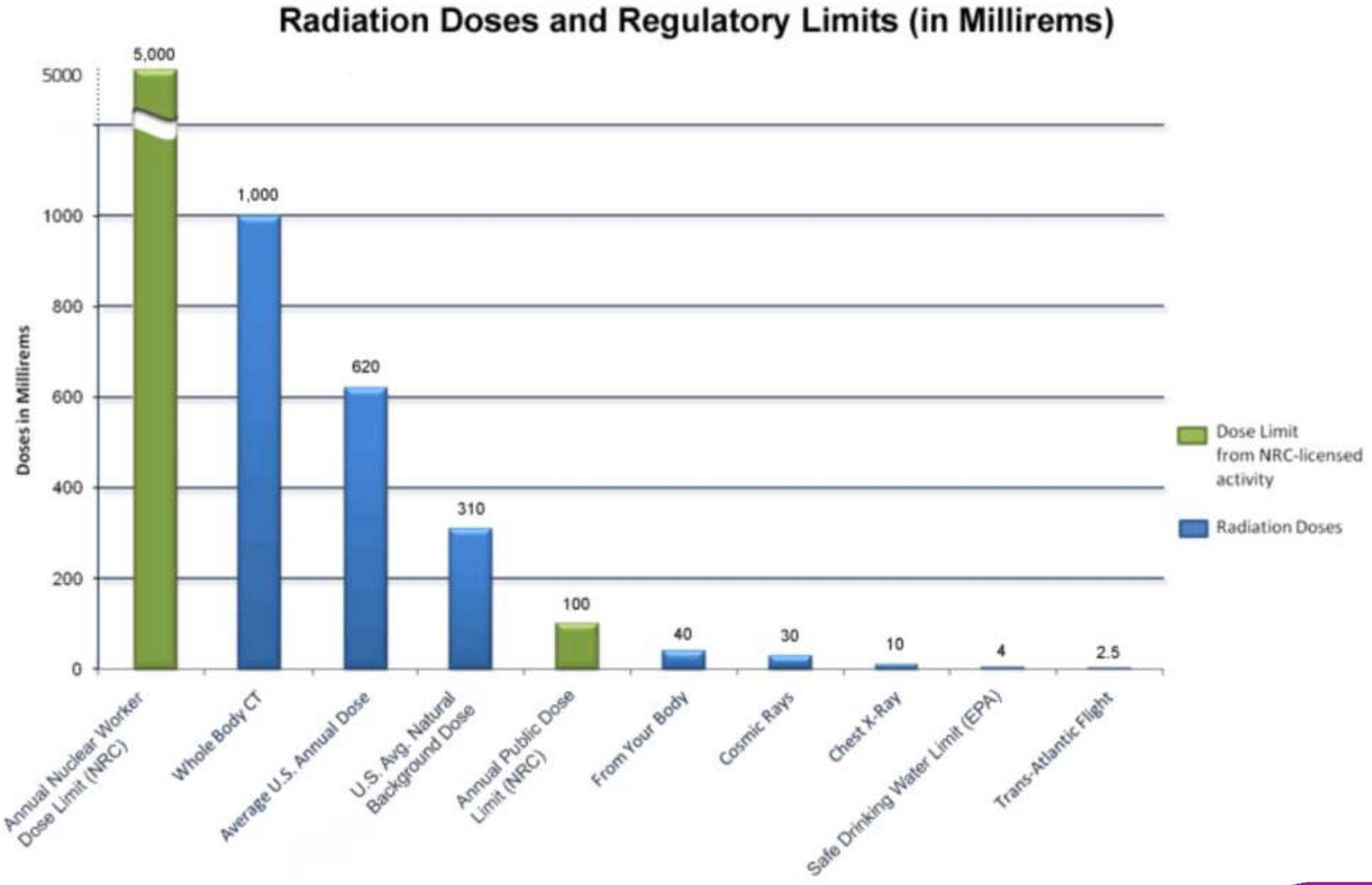
Source: Japan 366 Days after; Vervaeck and Daneill



Map created on 04032011 2340 JST

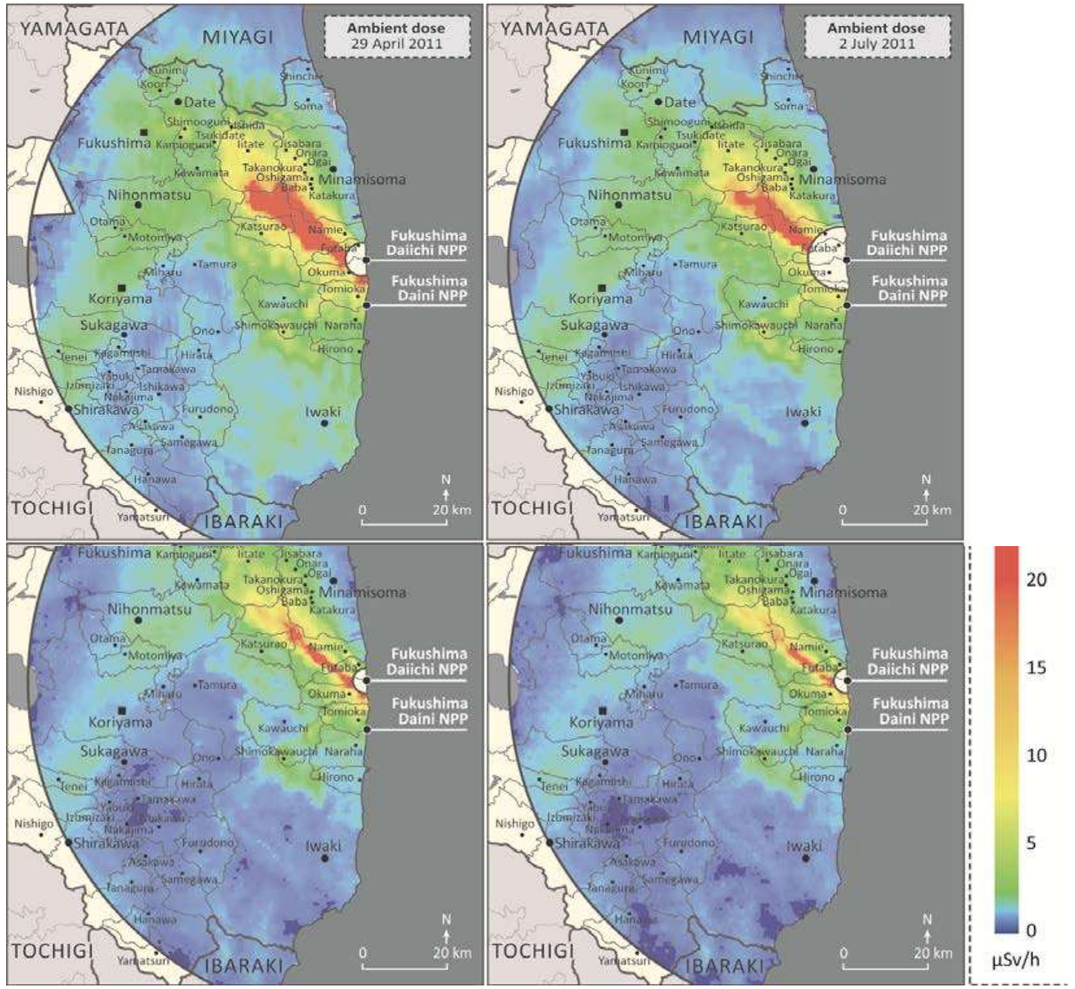
Name: NIT Combined Flights Ground Measurements 30Mar_03Apr2011 Results

Putting Things in Perspective



What about Conditions Today?

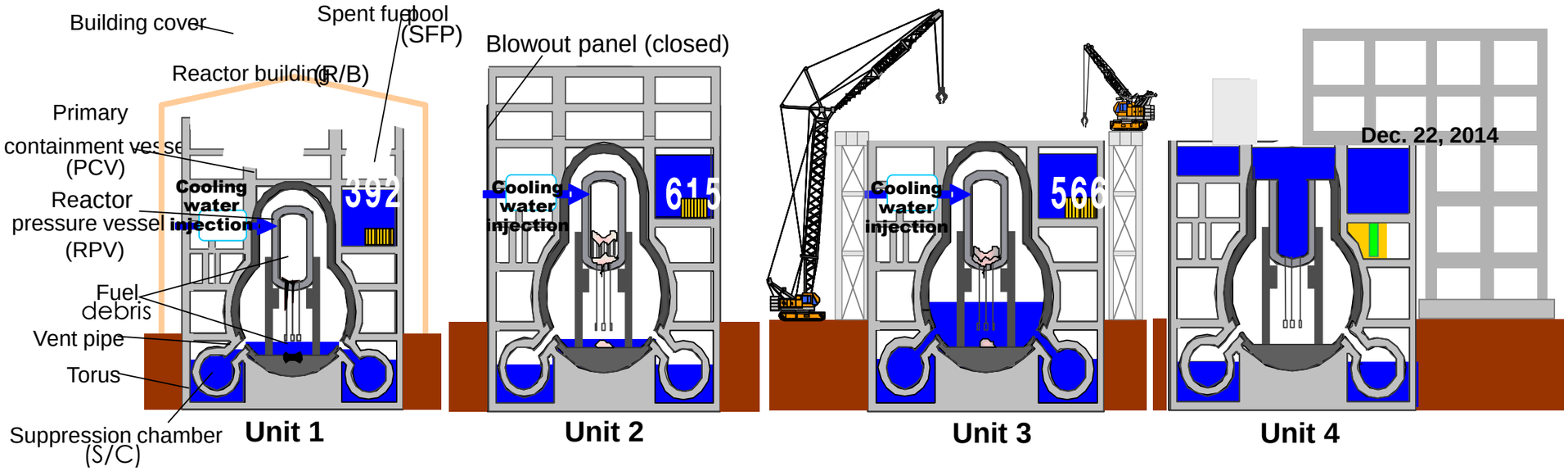
29 April 2011



Would you want to live here?

Fukushima Plant Status

■ **All units maintained in cold shutdown state**



RPV bottom temp.	
Unit 1	24℃
Unit 2	30℃
Unit 3	27℃

PCV internal temp.	
Unit 1	24℃
Unit 2	31℃
Unit 3	27℃

Spent Fuel Pool temp.	
Unit 1	25.5℃
Unit 2	25.1℃
Unit 3	22.8℃

Amount of Water injection to reactor	
Unit 1	4.2㎥/h
Unit 2	4.4㎥/h
Unit 3	4.3㎥/h

Values as of 11:00 on June 24th 2015

Take-Aways regarding the Fukushima Accident

- The Fukushima nuclear accident was more a man-made than a natural disaster- it was preventable
- Fear and social stigma related to radiation were its biggest health consequences
- The Fukushima Accident was part of the costliest natural disaster in history

Questions??