cfms
COMITÉ FRANÇAIS DE MÉCANIQUE
DES SOLS ET DE GÉOTECHNIQUE

LA CONGÉLATION _
ARTIFICIAL FREEZING OF SOILS, *IN CIVIL ENGINEERING*

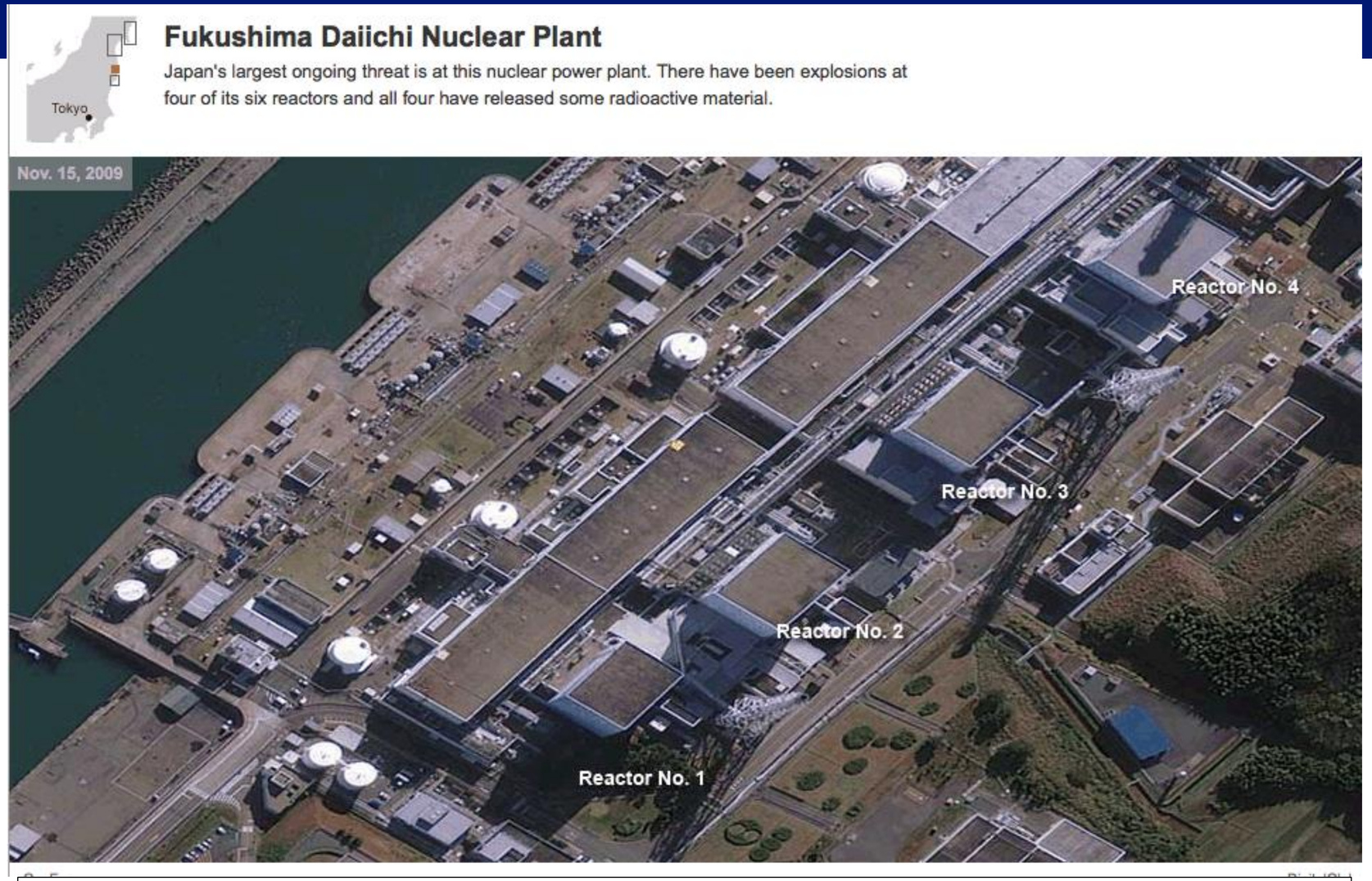
Le Mur de glace de Fukushima

P. Ackerer – DR CNRS

Institut Terre & Environnement de Strasbourg | ITES | UMR 7063 de l'Université de Strasbourg & CNRS & ENGEES

CFMS SCIENTIFIC AND TECHNICAL DAY _ NOVEMBER 17TH 2023

Le mur de glace de Fukushima



The facility, operated by the Tokyo Electric and Power Company (TEPCO), was made up of six boiling-water reactors constructed between 1971 and 1979. At the time of the accident, only reactors 1–3 were operational, and reactor 4 served as temporary storage for spent fuel rods.

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Friday, march 11th,2011
14:46 Earthquake of magnitude 9.

14:46 + 1min: Reactors 1,2 and 3 are stopped.

15:30 **Wave of 15m reaches the nuclear power** plant located 6.5 to 10m above sea level. **A wall of height 5.7m was build to protect the NP**.
The cooling system of the three reactors are stopped due to lack of electricity. The generators have been destroyed by the tsunami.

Saturday, march 12th
5:50 (+14h20) Injection of water in reactor 1 whose temperature is over **2800 °C.**

6:50 (+15h20) Melted material fell to the bottom of the containment vessels in reactors 1 and bored sizable holes in the floor.

15:36 (+24h06) **Explosion of reactor 1** due to high hydrogen pressure resulting from the absence of cooling.

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Monday, march 14th
11:11 **Explosion of reactor** 3.

16:58 Official announcement of the melting of the 3 reactor hearts.

Tuesday, march 15th
6:02 **Explosion of reactor 2**.

9:38 **Explosion and fire in the storage area of reactor 4**.

11:01 Explosion of the building around the storage area.

11:35 People in less than 30km from the NP has to stay home or at work.

19:22: **400 mSv/h close to reactor 3, 100 mSv/h close to reactor 4 (remember: 1 mSv/y)**

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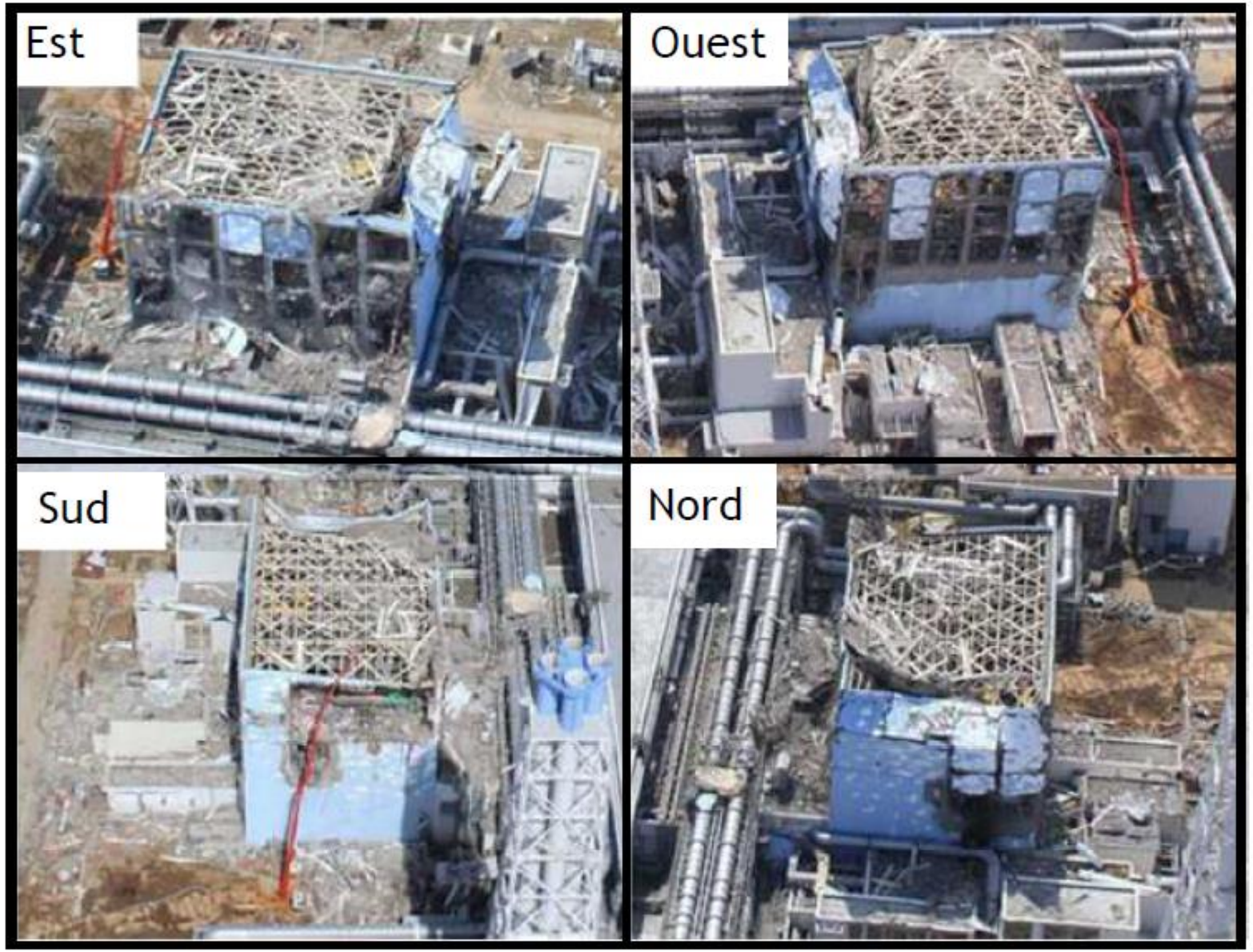

Figure 5-15 - Bâtiment du réacteur n°4 suite aux incendies et explosion survenues le 15 mars

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Wednesday , march 16th
5:45 Fire in reactor 4.

Wednesday , march 30th
Radiactive level equal to 2 times the allowed maximum is measured **40 km from the NP.**

Monday , April 11th
Contaminated zone is extended.

As the pattern of the deposition of radioactive materials became better understood, an additional corridor of land covering roughly **207 square km** and stretching away from the initial 20-km zone was also designated for evacuation in the months following the disaster.

Months later, radiation levels remained high in the evacuation zone, and government officials remarked that **the area might be uninhabitable for decades**.

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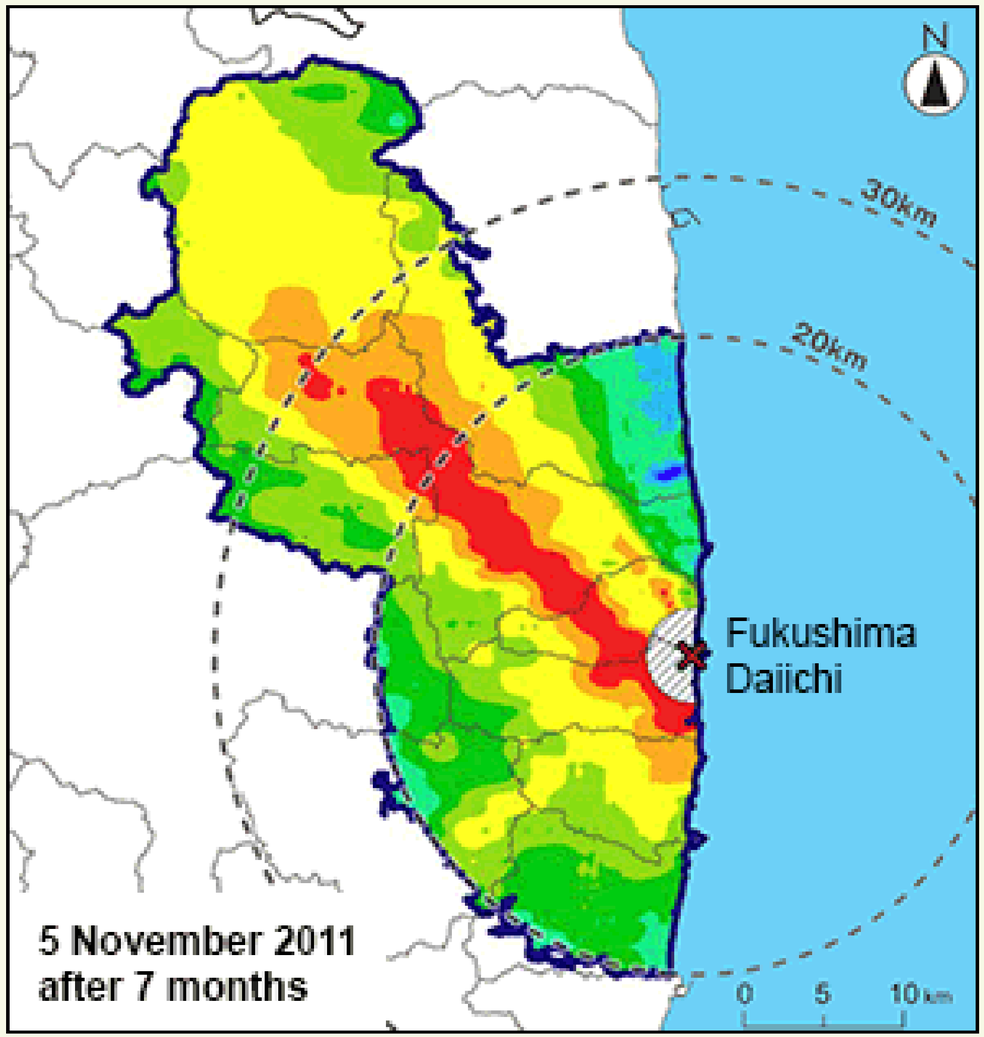
Radiation Decline in Evacuation Area



Key

Radiation level 1m above ground, including background (μSv/h)

- 19.0 <
- 9.5 - 19.0
- 3.8 - 9.5
- 1.9 - 3.8
- 1.0 - 1.9
- 0.5 - 1.0
- 0.2 - 0.5
- 0.1 - 0.2
- ≦ 0.1

Not measured

X 8.76 mS/y

Source: Nuclear Regulation Authority
Animation and translation: World Nuclear Association

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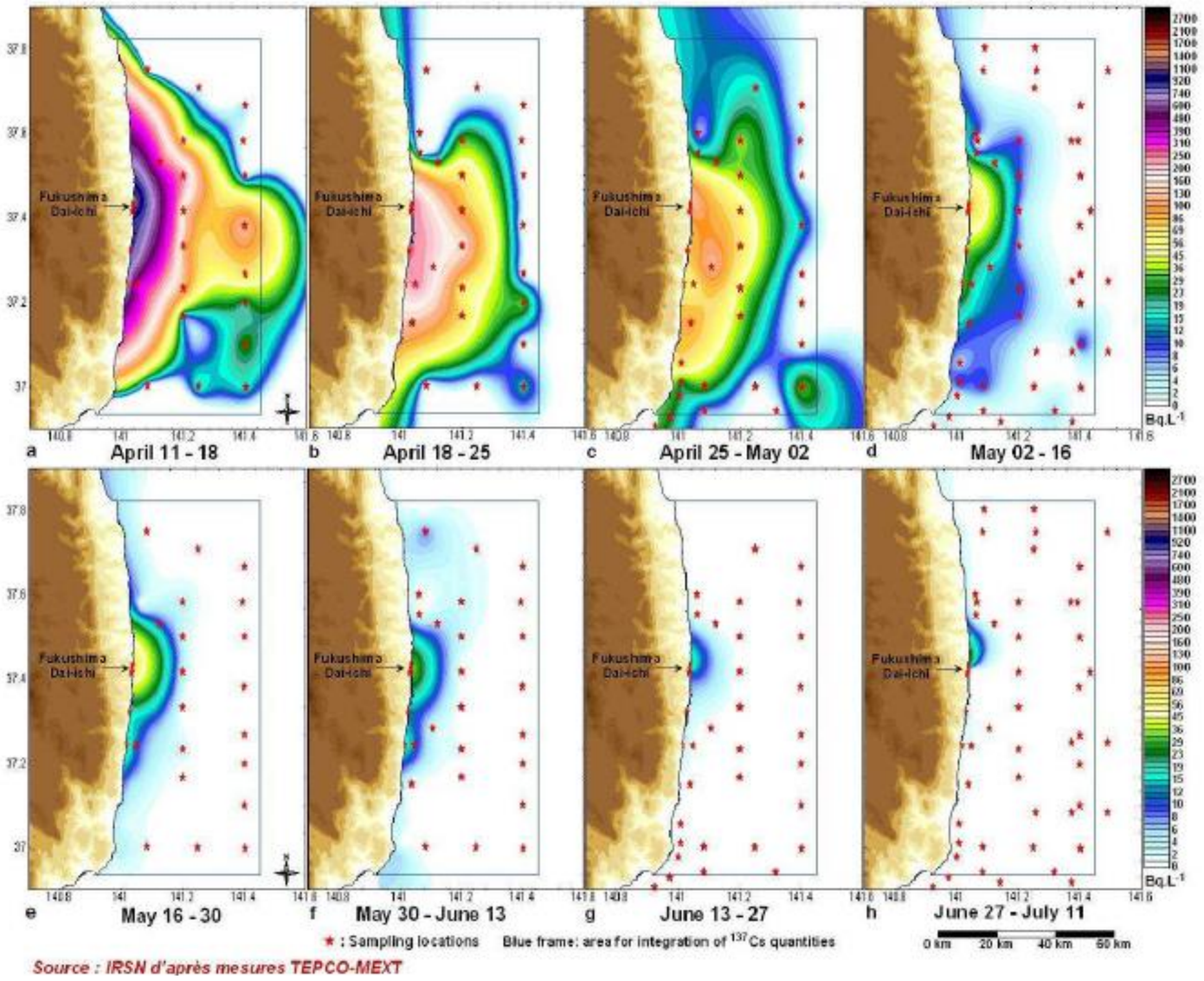
160 000 citizens have to leave this area and are not willing to come back. They receive 810 euros/months compensation…
(810x160000x12x10=15.5 billions euros?)

Ocean contamination.



^{137} Cesium concentration in the ocean from April 2011 to July 2011.

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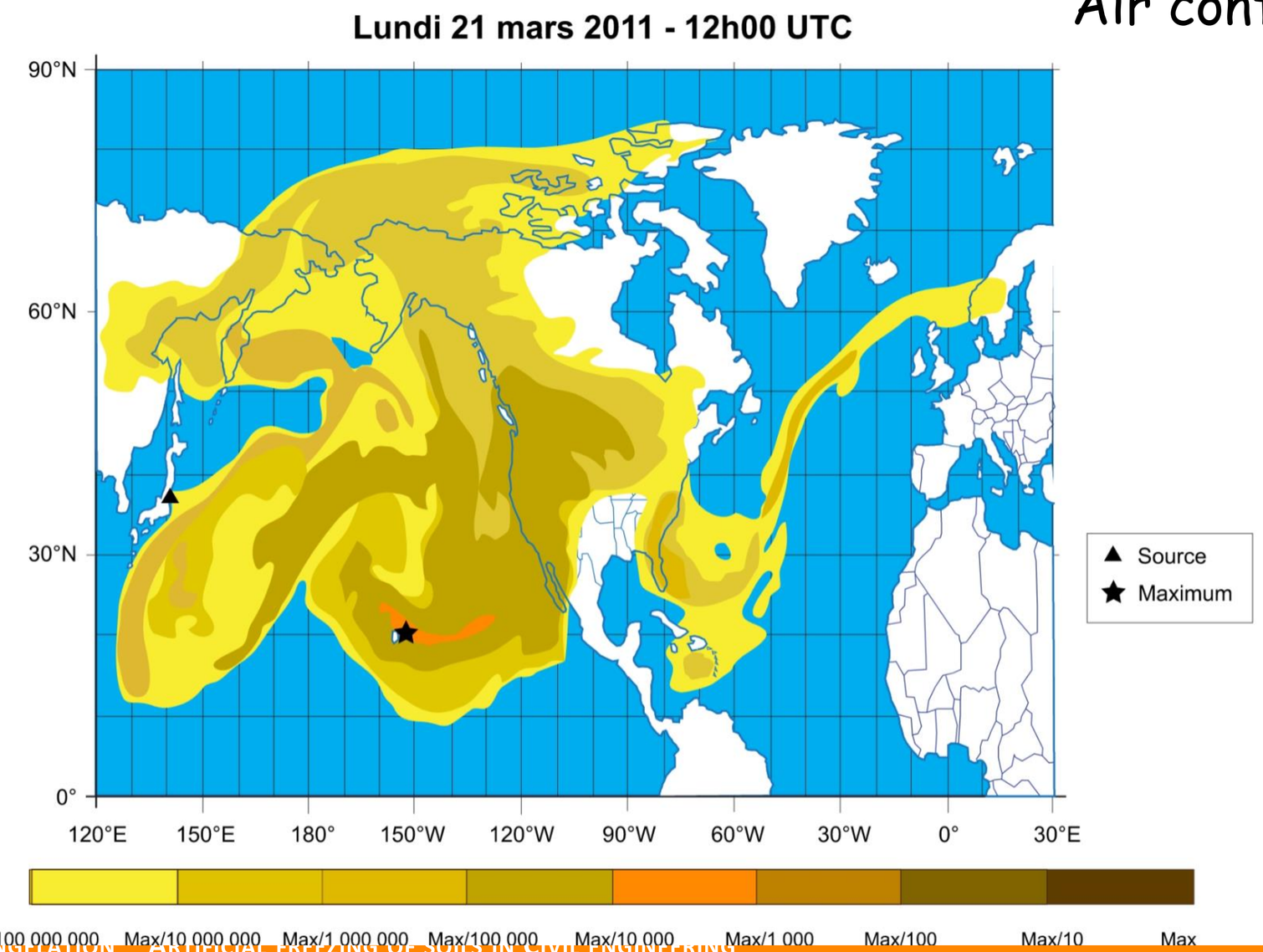
Air contamination.



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Soil contamination.

Started in 2013 and completed in 2019, the work cost 24 billion euros: 16,000 people excavated over 20 million cubic meters of land, which will be stored for several decades.

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Groundwater contamination

Tepco estimates that **1,000 tons of groundwater** enters the area around reactors 1 to 4 at each day;
400 tons per day is believed to reach the reactor building basement levels.

This water is heavily contaminated by radioactive compounds. These compounds can be removed from the water **except tritium.**

Consequences: this water is stored in tanks ….

Today, about 1 200 00 tons (or cubic meters) of water, about 500 Olympic swimming pools are stored in the area of the nuclear power plant.

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The maximum storage capacity was reached in 2022.

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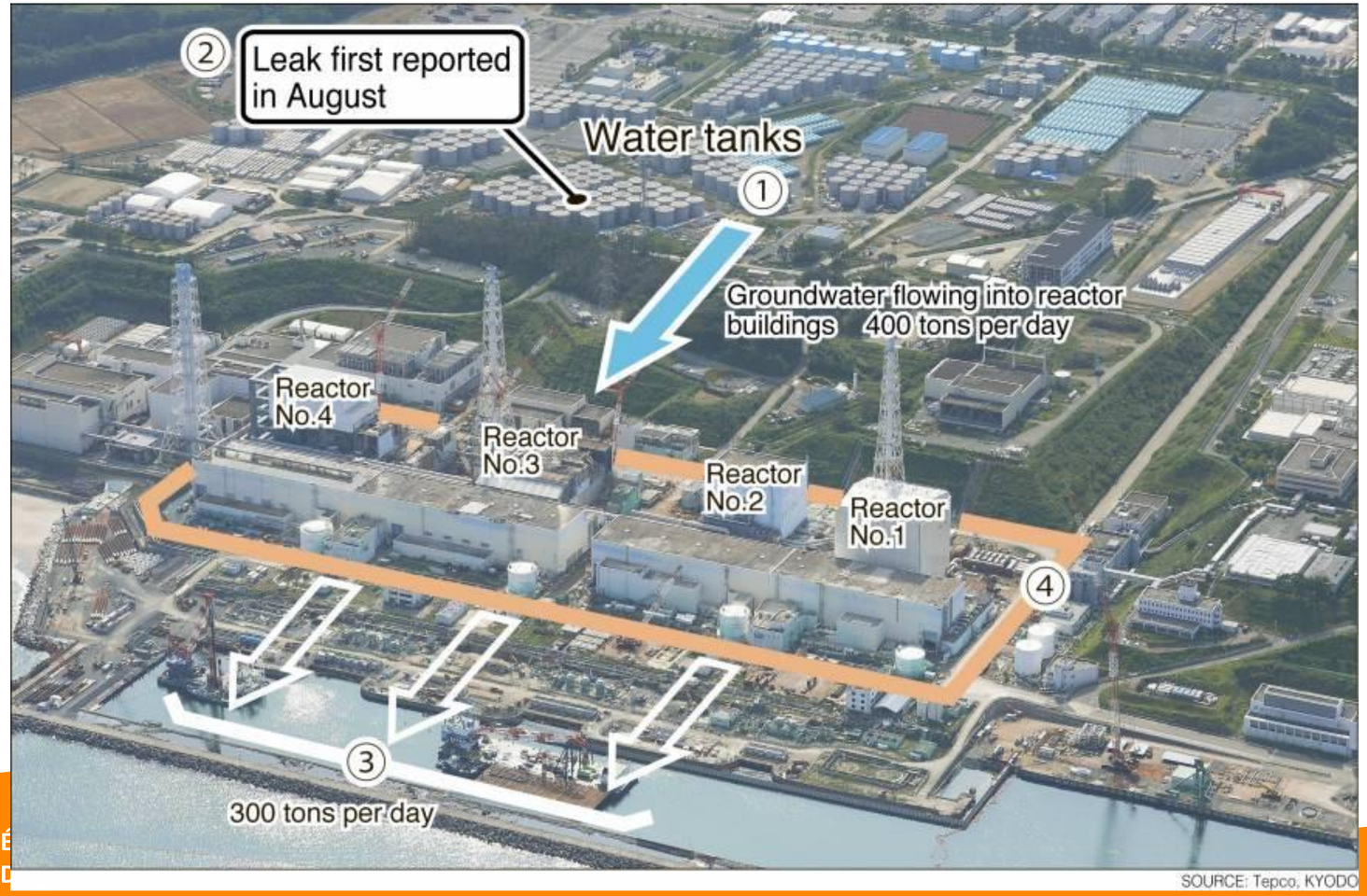
On Aug. 19, 2013, Tepco found 300 tons contaminated water had leaked from tanks in this area. Of about 1,060 water tanks there, 350 are similar flange-type tanks, which are less durable than welded ones.

Tepco believes a maximum of 300 tons of contaminated water is seeping into the sea every day.



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No.	Countermeasure items		Countermeasures	Status and plans of efforts
12	Isolate water from contamination source	Existing countermeasures	Installing land-side frozen soil impermeable walls around buildings.	A demonstration project for land-side impermeable walls will be started and completed within the current fiscal year. The operation will be started within FY 2014.
13		Existing countermeasures	Pumping up groundwater from wells near building (sub-drain)	Restoration work for sub-drain pits is in operation. The sub-drain purification facility will be completed in September 2014.
14		Existing countermeasures	Pumping up groundwater on the mountain side of the buildings (Groundwater bypassing)	Installation work of groundwater bypassing will be completed in March this year. To commerce operations as early as possible.
15		Existing countermeasures	Paving the ground surface in the contaminated area on the sea-side of the building (with asphalt etc.)	The paving work will be completed in March 2014.
16		Multi-layered measures	Installing gutters at top of tanks	Installing tanks in highly-dosed area will be completed in December in this year. Installing tanks in other areas will be completed in March next year.
17		Multi-layered measures	Additional countermeasures for suppressing inflow of groundwater (“Wide-are facing (surface water shut-off)” or “Additional water shut-off and its inside facing”)	The method of this countermeasure should be determined as soon as possible, as multi-layered measures added to land-side impermeable walls, sub-drain, etc. The approaches with consideration given to work environment improvement by reducing the dose (through surface decontamination, etc.) as well as the proper treatment method for waste generated with decontamination will be examined when executing countermeasures.

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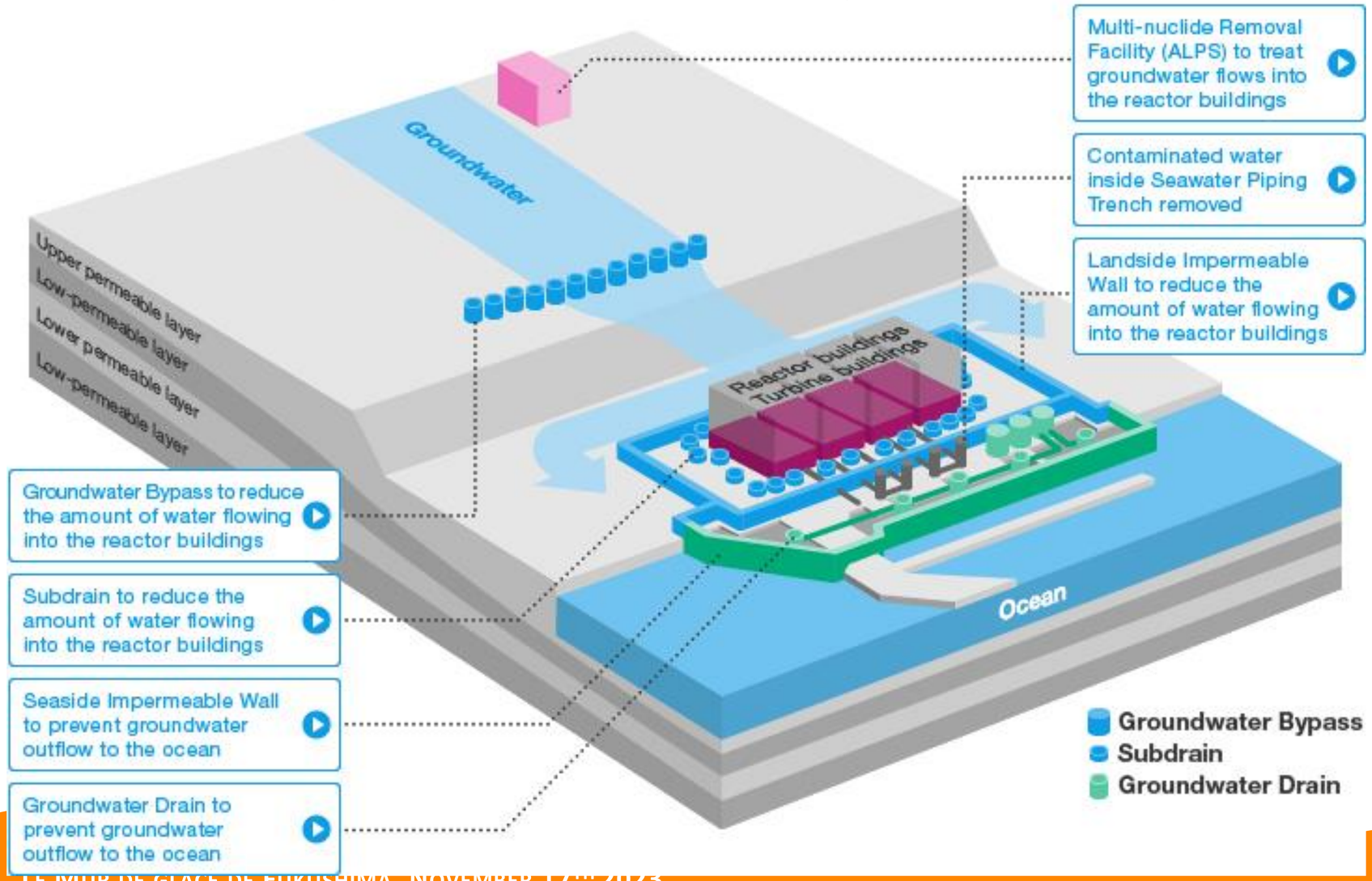
The Ice Wall: the aim is to freeze the soil into a solid mass that blocks groundwater flowing from the hills west of the plant to the coast.



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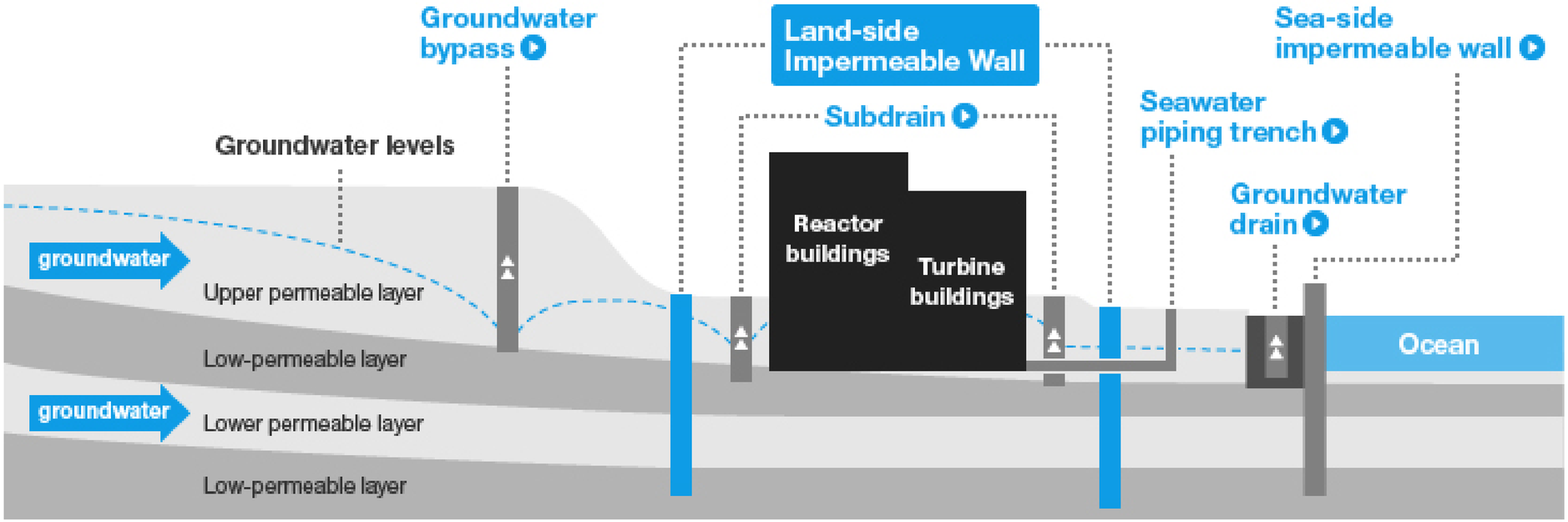
Measures being taken at the F1NPS for the processing and control of the contaminated water.



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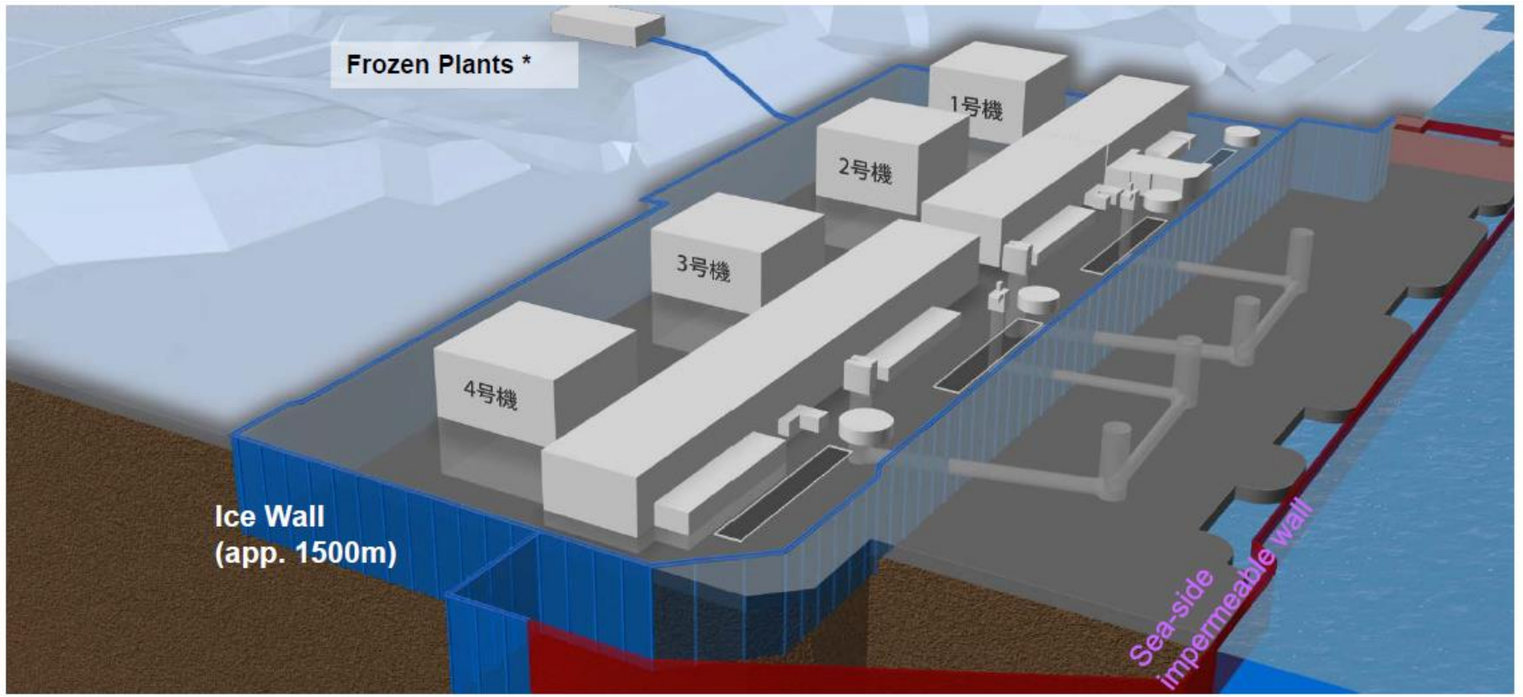

About 1,500 tubes filled with brine to a depth of 30 meters in a 1.5 kilometre perimeter around four of the plant's reactors. It cools the brine to minus 30 degrees Celsius.

Costs for building : **290 millions €** in public funds.

Costs to maintain and operate: about **80 millions € per year**

The ice wall needs an estimated 44 million kilowatt hours of electricity a year to run, enough to power about **15,000 typical Japanese homes**.

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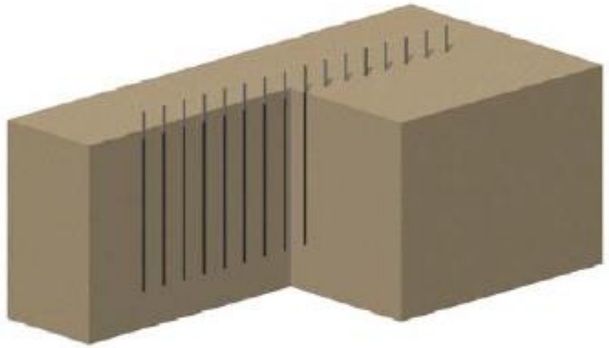
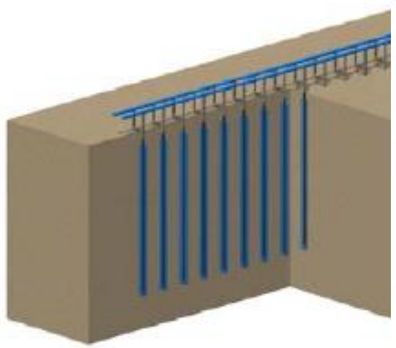
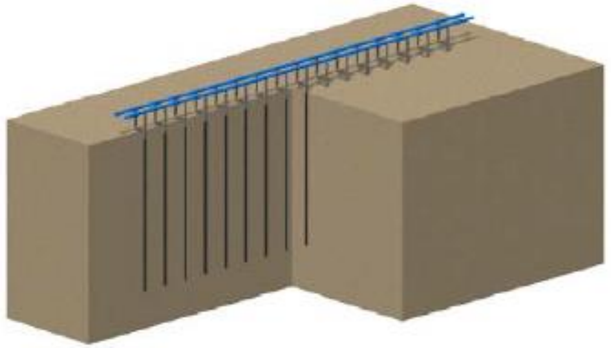
Process



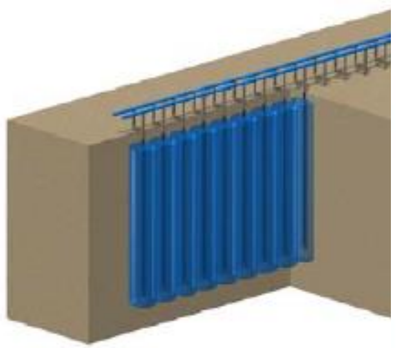
(1)Boring and standing frozen pipes



(3)Frozen Wall construc



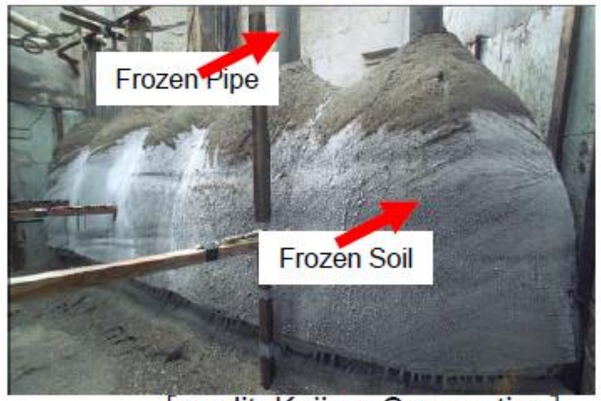
(2)Connect freezing pipes



(4)Frozen Wall c

Construction site

Drilling with rotary boring machine used in well boring and pile driving (versatile)



[credit: Kajima Corporation]

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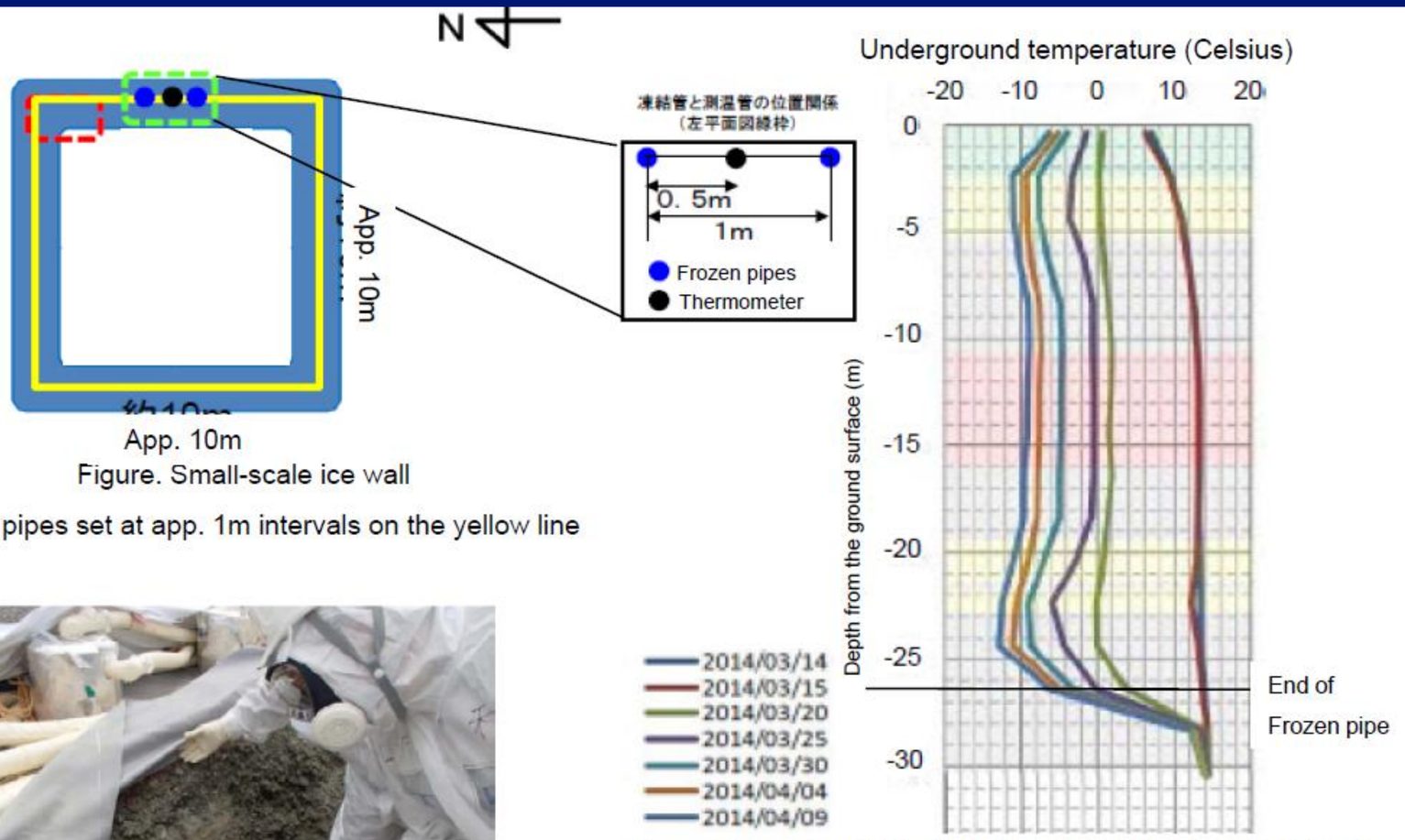

Figure. Small-scale ice wall

*frozen pipes set at app. 1m intervals on the yellow line

Figure: Temperature distribution between frozen pipes (app. 1m interval)

Frozen Soil (red rectangular area in above figure)

Verified by ground temperature that the ground got frozen about one month after starting to freeze.

Ice Wall efficiency

According to the latest figures released by the plant's operator Tokyo Electric Power Co. (TEPCO), the ice wall is reducing the amount of contaminated water inside the reactor's buildings to **95 tons per day**.

The water inflows often fluctuate with rainfall. The dry month of January averaged **83 tons a day**, Tepco data showed. But when a typhoon struck during the last week of October 2017, **866 tons a day poured into the reactors.**

Since the ice wall became fully operational at the end of August 2017, an **average of 141 metric tons** a day of water has seeped into the reactor and turbine areas.

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In 2017, radioactivity in the containment surrounding reactor number 2 reaches 650 Sieverts per hour, with a possible margin of error of 30%. At such doses, a human would die in only 30 seconds.

According to the Japanese government's latest estimate (2018), the cost of the Fukushima nuclear disaster in Japan will probably reach 188.5 billion euros: this is twice as much as the previous estimate.

Contaminated water started to be released in the Pacific Ocean, August 24th, 2023.

A total of 1.33 tons of contaminated water plus maximum 500 m3/year at least until 2050.

The impact is expected to be negligible at 10km from the injection due to dilution and mixing.

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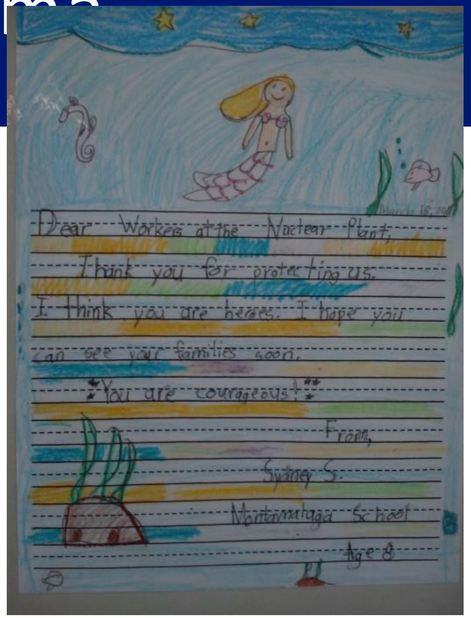

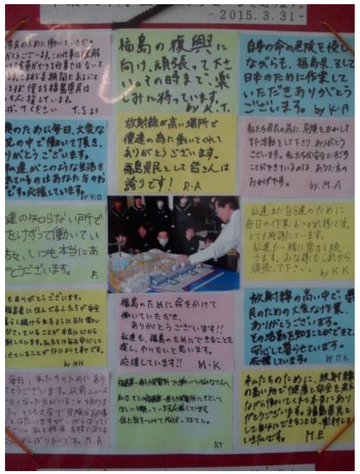

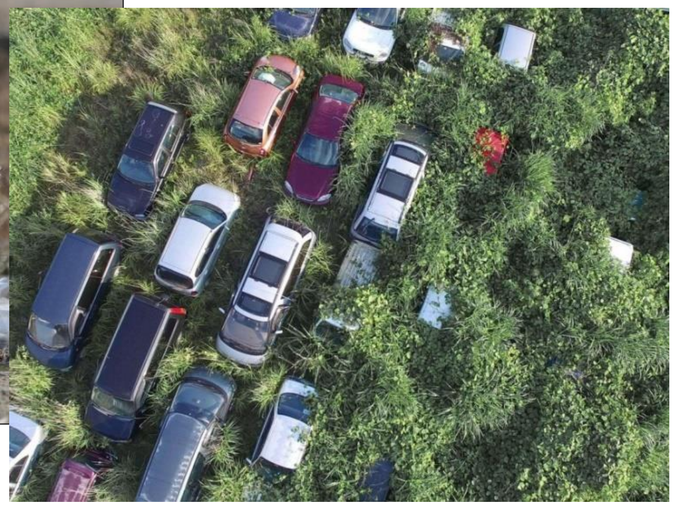

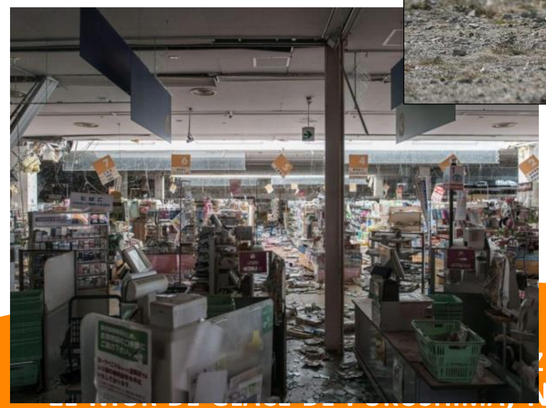

Sources: Rep. IRSN, TECPO, IAEA, perso.

Thank You

Questions ?

….@….