The Effects of Multilayered Contaminated Water Countermeasures

March 1, 2018

TEPCO

Tokyo Electric Power Company Holdings, Inc.

Overview

- The continually increasing amount of contaminated water generated by groundwater/rainwater flowing into buildings has been a serious obstacle in the way of decommissioning, so the decision was made to implement multilayered countermeasures, such as the land-side impermeable wall.

- It's been approximately six months since the land-side impermeable wall was completely closed on August 22, 2017, and the ground temperature in almost all areas remains below 0° C. On the mountain side of the site this has created a difference in water levels inside and outside the wall of approximately 4 to 5 m, and this land-side impermeable wall has been completely formed, with the exception of only some very deep parts. Therefore, we have provided details on the current state of multilayered contaminated water countermeasures as well as the role and impact that this land-side impermeable wall has had.

- In the course of compiling this information we have determined that these multilayered contaminated water countermeasures, such as the land-side impermeable wall and sub-drains, etc., now comprise a water management system that enables us to keep groundwater levels at stable levels and prevent groundwater from coming close to buildings.

- Furthermore, during periods of heavy rainfall, such as during an approaching typhoon, the levels of groundwater would increase and ground water would seep from an expansive region to the area around the buildings as well as the T.P.+2.5m foundation prior to formation of the land-side impermeable wall. This caused groundwater levels to quickly rise and it took much time for the groundwater levels to decrease after these periods of heavy rainfall. However, at current time this flow of groundwater is cut off by the land-side impermeable wall thereby enabling increases in groundwater levels to be reduced and requiring less time for these groundwater levels to decrease.

- However, we must be persistent with these contaminated water countermeasures, so going forward we will continue with our efforts to reduce the levels of accumulated water in buildings as well as the water level at which sub-drains operate, and implement rain countermeasures, such as fixing building roofs and paving ground surfaces, as we strive to further reduce the amount of contaminated water being generated.

Overview of the effects of multilayered contaminated water countermeasures

The amount of contaminated water being generated has been greatly reduced in conjunction with the progress of multilayered contaminated water countermeasures.

- As progress has been made with multilayered contaminated water countermeasures, such as the land-side impermeable wall and sub-drains, etc., the amount of contaminated water being generated by rainwater and groundwater has been reduced to 110 m^3/day with the closure of the impermeable wall; less than one fourth of what it was prior to closure of the land-side impermeable wall (490 m^3/day). (Slide 10)

- As a result, the amount of contaminated water generated has decreased, and even though this data is from the dry season, it still falls well below the Mid/Long-Term Roadmap goal for the year 2020 of 150m^3/day. (Slide 11)

- The effect of the land-side impermeable wall as part of multilayered contaminated water countermeasures has been analyzed and calculated, and results have shown that it is reducing the amount of contaminated water being generated. Furthermore, we have determined that the impermeable wall has also contributed to decreasing groundwater levels around buildings and enabled the stable control of sub-drains by reducing the amount of water pumped up by sub-drains and the amount of water pumped up at the T.P.+2.5m foundation. (Slide 13)

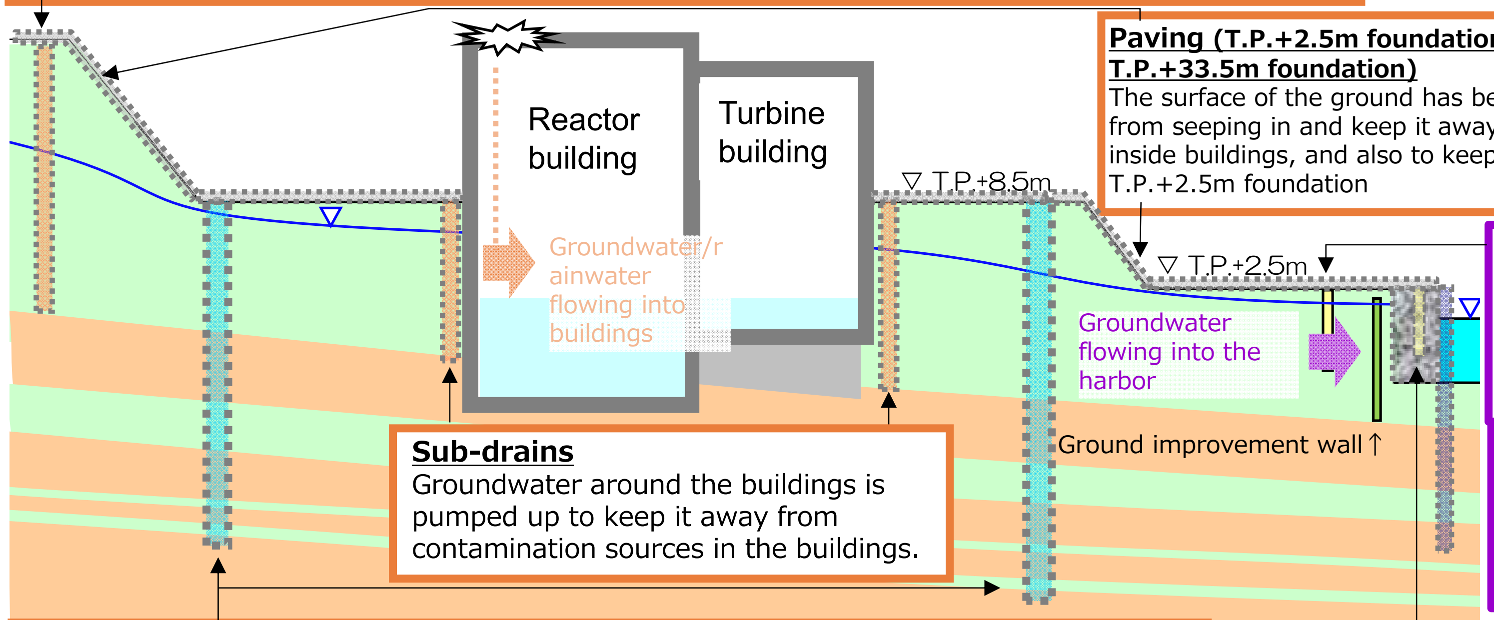
Overview of multilayered contaminated water countermeasures around buildings

【Prior to multilayered countermeasures】

- Some of the groundwater flowing down from the mountains to where the buildings are located was seeping into buildings and then flowing out into the harbor.
- The contaminated water countermeasures shown in the following diagram were considered in order to reduce the amount of water flowing into buildings and prevent contaminated water from being generated, as well as prevent groundwater from leaking into the harbor.
- When considering these countermeasures it was decided to take a multilayered approach that combines each of these measures in order to ensure that countermeasures for contaminated water were put in place amidst the various restrictions that existed, such as site work restrictions stemming from the high air dose rates around buildings, and the possibility of not being able to restore existing facilities to the state they were in prior to the disaster.

Groundwater bypass
Groundwater at the T.P.+33.5m foundation away from the building is pumped up to keep it away from contamination sources in the buildings.

: Measures for keeping water away from contamination sources
: Measures for preventing leaks of contaminated water



Paving (T.P.+2.5m foundation, T.P.+8.5m foundation, T.P.+33.5m foundation)
The surface of the ground has been paved to prevent rainwater from seeping in and keep it away from contamination sources inside buildings, and also to keep rainwater from seeping into the T.P.+2.5m foundation

Well points
Located inside the ground improvement wall built at the T.P.+2.5m foundation, water is pumped up from these wells to prevent it from leaking

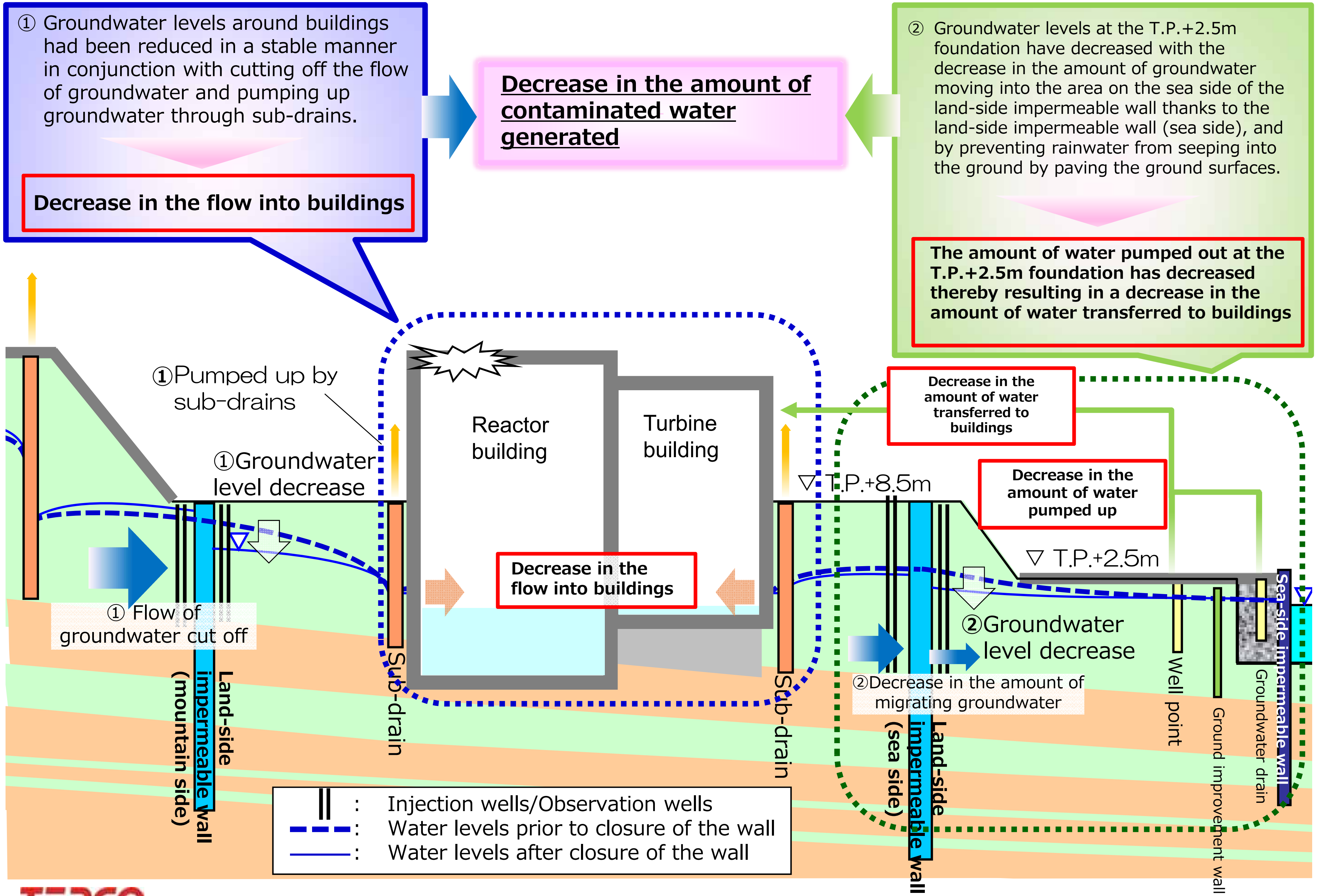
Sub-drains
Groundwater around the buildings is pumped up to keep it away from contamination sources in the buildings.

Sea-side impermeable wall
Prevents groundwater flowing from the site into the harbor from leaking

Land-side impermeable wall
A frozen soil wall has been built to surround the buildings and suppress groundwater flowing down from the mountains thereby keeping the water away from contamination sources in the buildings and the T.P.+2.5m foundation

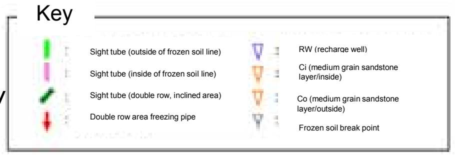
Groundwater drain
Used to pump up water that builds up inside the sea-side impermeable wall to prevent it from leaking

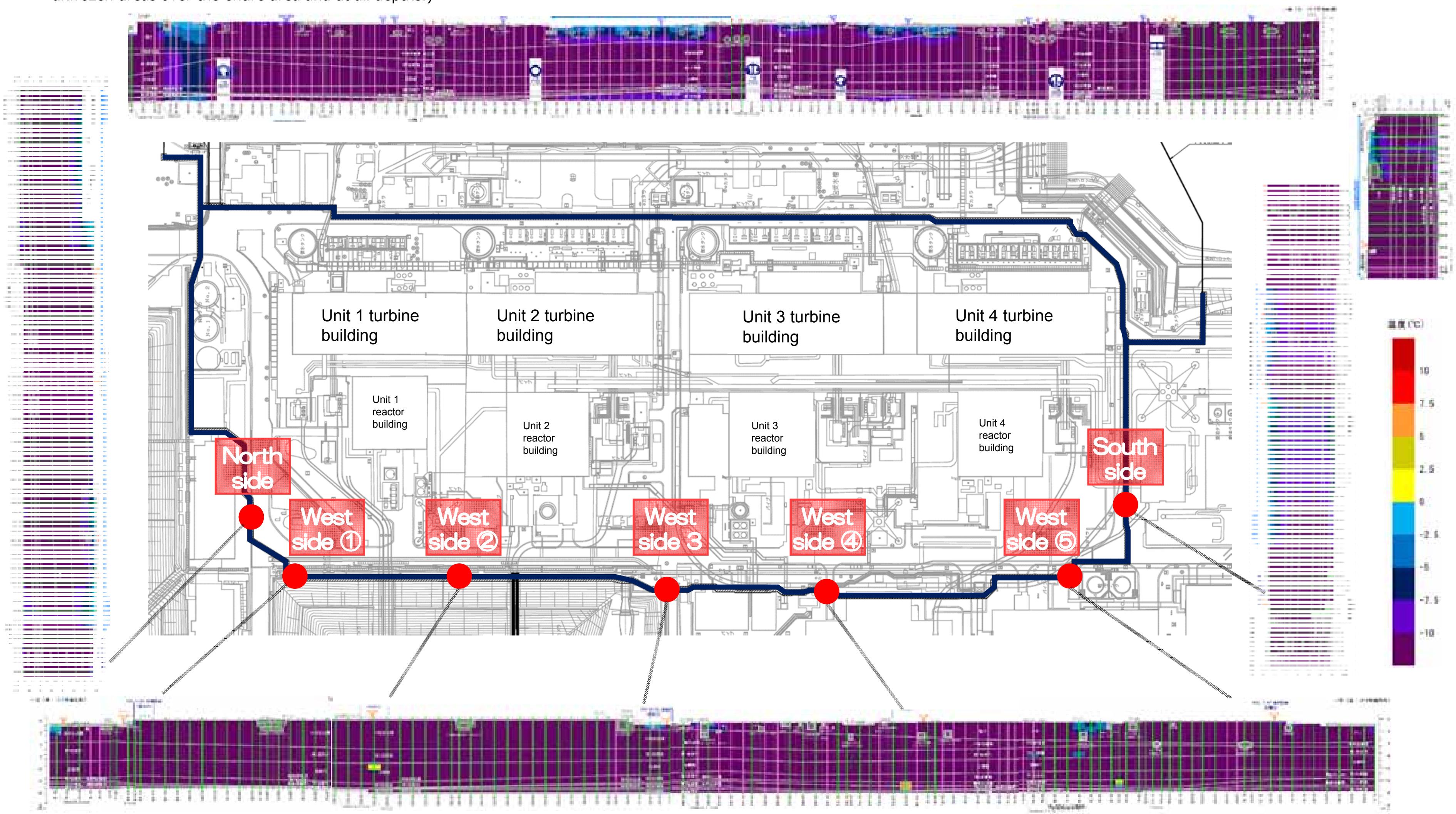
The effect of multilayered contaminated water countermeasures (mechanism)



Status of freezing of the frozen soil wall

- It's been approximately six months since commencement of freezing (August 22, 2017) of the last section of the wall (West ③)
- With the exception of shallow areas above groundwater levels near the surface, deep stratified areas and some parts of medium/small-grain sandstone layers the temperature measured at sight tubes 85cm away from freezing lines is below 0°C. (※Sight tubes have been placed at 5m intervals in order to detect changes in temperature caused by unfrozen areas over the entire area and at all depths.)

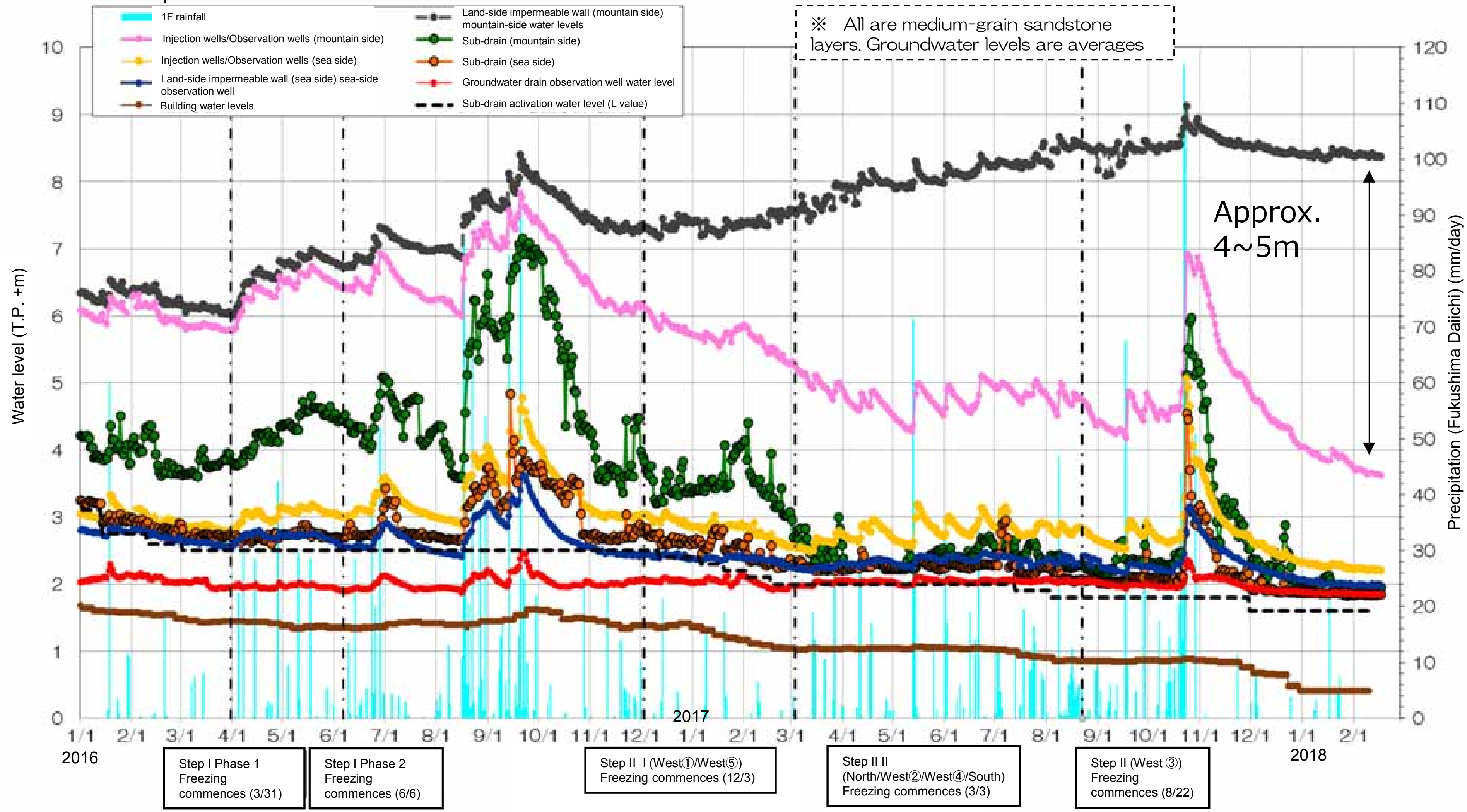




(Temperature data as of 7:00am on Feb. 26, 2018)

Changes over time in groundwater levels inside and outside the land-side impermeable wall

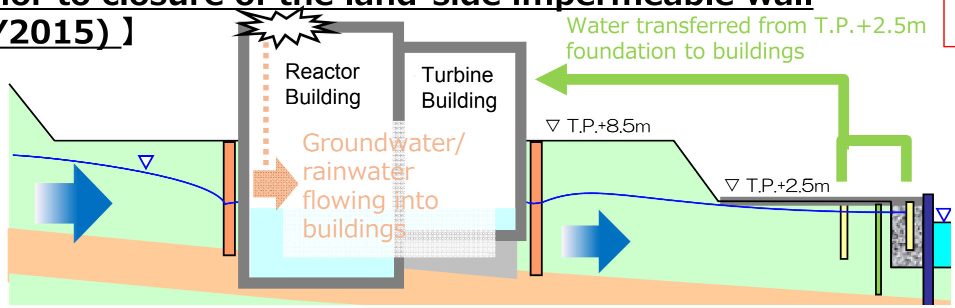
- By gradually closing the land-side impermeable wall and operating sub-drains in a stable manner groundwater levels inside the land-side impermeable wall have been decreasing, with the exception of during heavy rainfall, and the difference between the water levels inside and outside the land-side impermeable wall is approximately 4~5 meters.
- Since the typhoon in October 2017 there has been little rainfall. This mixed with the lowering of sub-drain activation water levels on November 30 （T.P.+1.8m→1.6m） has resulted in the lowest average groundwater levels to date for the area inside the land-side impermeable wall.



Trends in Average Water Levels inside and outside of Land-Side Impermeable Wall

Current state and future of multilayered countermeasures for contaminated water

【Prior to closure of the land-side impermeable wall (FY2015)】

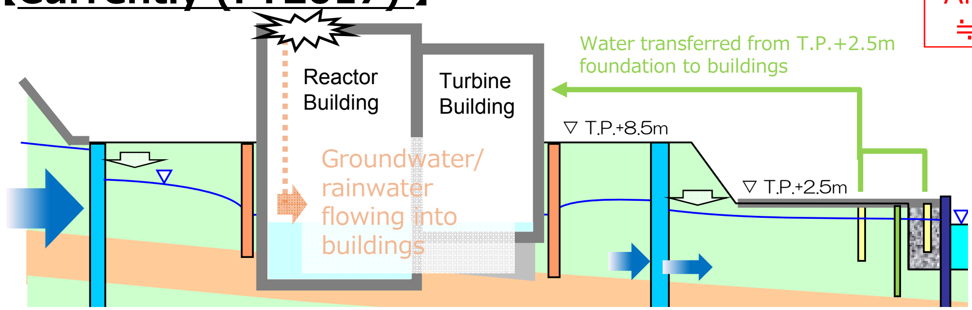


Amount of contaminated water generated※1
≒ 520m³/day (during the dry season)

- Sub-drains were in operation to decrease groundwater flow into buildings. But, sub-drain groundwater levels were not being reduced.
- Temporarily the amount of contaminated water generated increased because in addition to pumping out water from well points inside the ground improvement wall, groundwater that was shut off by closure of the sea-side impermeable wall was being pumped up through groundwater drains, and some of that water was being transferred to the buildings.

Closure of land-side impermeable wall, T.P.+2.5m foundation paving, reduction in water levels of accumulated water in buildings and sub-drains, etc.

【Currently (FY2017)】

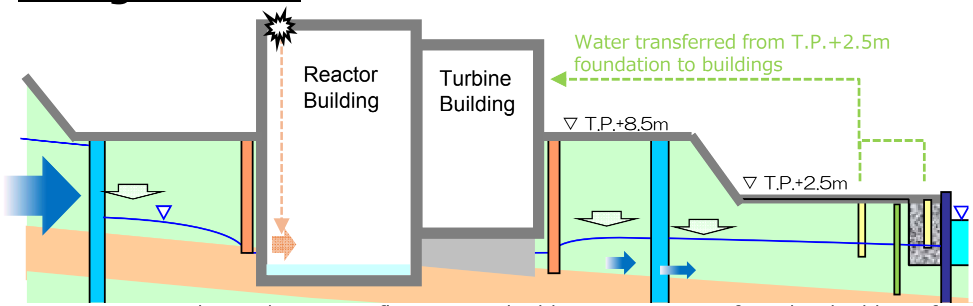


Amount of contaminated water generated※1
≒ 140m³/day (during the dry season), 170m³/day (corresponds to average precipitation)

- In conjunction with the closure of the land-side impermeable wall and measures to improve the reliability of sub-drains, the water level in sub-drains was reduced to around the level at which the sub-drains are set to activate, and the flow of groundwater into buildings was reduced along with the amount of water being pumped up at the T.P.+2.5m foundation.
- As a result of multilayered contaminated water countermeasures, such as the land-side impermeable wall and the sub-drains, groundwater levels are being kept under control in a stable manner and a water level management system that prevents groundwater from getting close to buildings was constructed.

Roof leak countermeasures, T.P.+8.5m foundation paving, reduction in water levels of accumulated water in buildings and sub-drains, etc.

【Going forward】



Amount of contaminated water generated※1
≦ 150m³/day (corresponds to average precipitation)

- Some of the water flowing into buildings will be allowed to a certain extent in order to maintain water level differences inside and outside the reactor buildings even after 2020.
- Going forward we will continue to reduce the levels of accumulated water in buildings as well as water in sub-drains while at the same time continuing multilayered contaminated water countermeasures, including additional countermeasures, such as measures to prevent rain leaking in through the roofs, in an attempt to reduce the amount of contaminated water generated to as close to zero as possible.

※1 Groundwater/rainwater flowing into buildings, water transferred to buildings from T.P.+2.5m foundation, ALPS chemical injections, etc.

Effect of multilayered countermeasures for contaminated water (T.P.+8.5m foundation)

【Conditions at the T.P.+8.5m foundation prior to formation of the land-side impermeable wall】

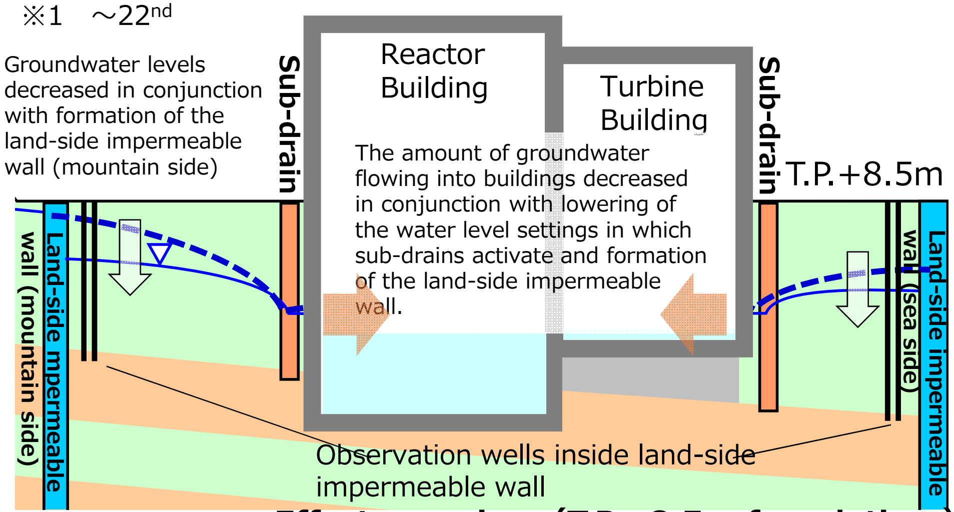
- Groundwater around the buildings was flowing into the buildings and becoming contaminated, so sub-drains were used to pump up the groundwater from around the buildings to reduce the flow of water into buildings.

【The effect of multilayered contaminated water countermeasures】

- In conjunction with formation of the land-side impermeable wall (mountain side), the flow of groundwater inside the land-side impermeable wall was cut off. Coupled with measures to improve the reliability of sub-drains, this enabled sub-drains to be operated in a stable manner under normal circumstances.
- Multilayered contaminated water countermeasures enabled the level of groundwater around buildings to be reduced from T.P.+4.9m before formation of the land-side impermeable wall to T.P.+3.3m after (An approx. 1.6m decrease).
- As a result, the flow of groundwater in the buildings was reduced from approximately 190m³/day to approx. 90m³/day

Avg. water level of observation wells inside land-side impermeable wall	
Prior to closure of the land-side impermeable wall (Avg. from Dec. 2015 to Feb. 2016)	T.P.+4.9m (Set water level for sub-drain activation: T.P.+3.5m→2.5m)
During the dry season last FY (Avg. from Dec. 2016 to Feb. 2017)	T.P.+4.5m (Set water level for sub-drain activation: T.P.+2.4m→2.0m)
(Avg. for Dec. 2017 to Feb. 2018※)	T.P.+3.3m (Set water level for sub-drain activation: T.P.+1.6m)

※1 ～22nd



Effect overview (T.P.+8.5m foundation)

Amount of groundwater/rainwater etc. flowing into buildings	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	**Approx. 190m³/day**
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※1)	**Approx. 90m³/day**
(Reference) Past minimum	51m³/day(weekly average) (Dec. 22~28, 2017)

Amount of groundwater/rainwater flowing into buildings was reduced by more than ½ after formation of the land-side impermeable wall was closed compared to before.

The effect of multilayered contaminated water countermeasures（T.P.+2.5m foundation ）

【Conditions at the T.P.+2.5m foundation prior to formation of the land-side impermeable wall】

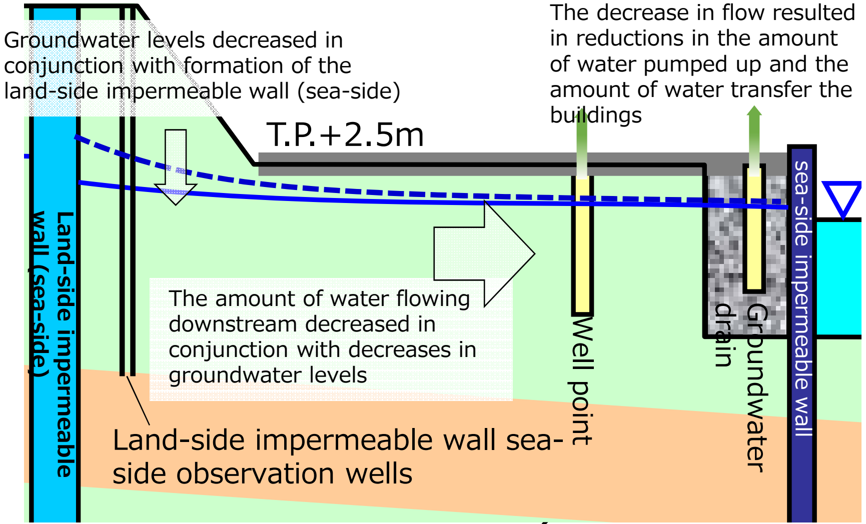
- At the T.P.+2.5m foundation, the sea-side impermeable wall prevents groundwater from leaking into the harbor, and groundwater is pumped up to prevent groundwater upstream from seeping to the surface.
- Some of the water pumped up at the T.P.+2.5m foundation is transferred to the turbine building and becomes contaminated water.

【The effect of multilayered contaminated water countermeasures】

- In conjunction with formation of the land-side impermeable wall (sea-side), groundwater flow to T.P.+ 2.5m foundation was reduced and the level of groundwater on the sea-side of the land-side impermeable wall decreased from T.P.+2.8m to T.P.+2.0m.
- In conjunction with the decrease in groundwater levels, the amount of water pumped up at the T.P.+2.5m foundation decreased thereby enabling a reduction of the amount of pumped water transferred to the buildings from approx. 300m³/day to approx. 20m³/day, less than 1/10 what it was.

Avg. water level of observation wells inside sea-side impermeable wall	
Prior to closure of the land-side impermeable wall (Avg. from Dec. 2015 to Feb. 2016)	T.P.+2.8m
During the dry season last FY (Avg. from Dec. 2016 to Feb. 2017)	T.P.+2.4m
Average from Dec. 2017 ~Feb. 2018※	T.P.+2.0m

Approx. 80cm reduction compared to prior to closure



Effect overview（T.P.+8.5m foundation ）

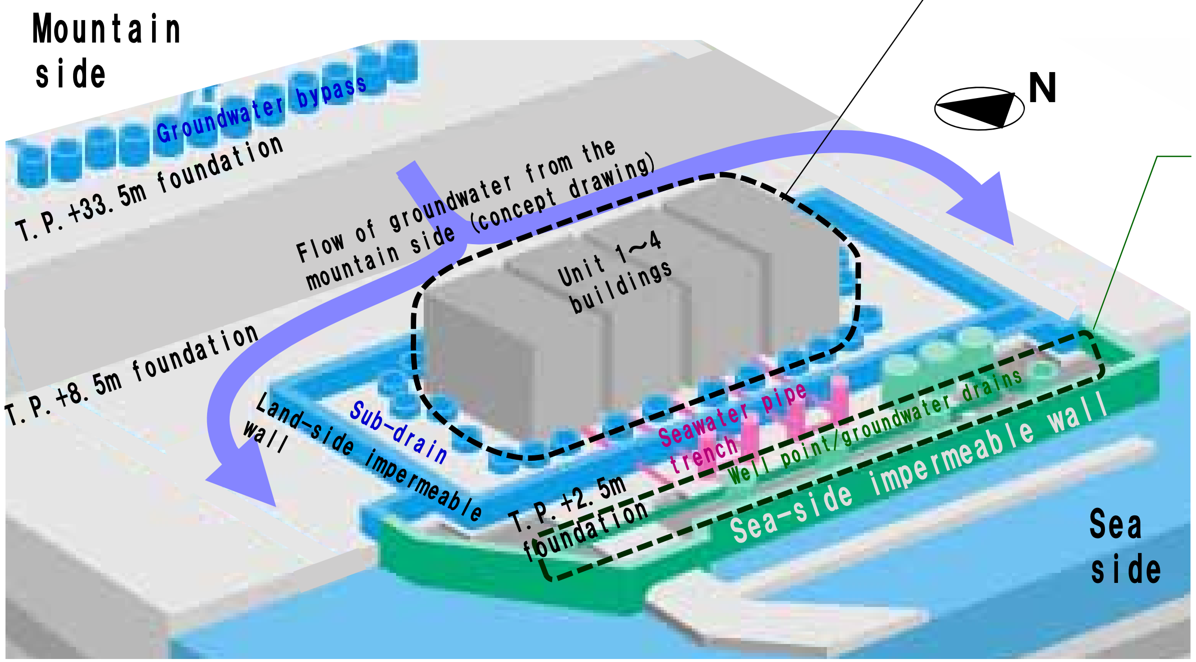
Amount of water transferred from the T.P.+2.5m foundation to buildings (Total amount of water pumped up at the T.P.+2.5m foundation (groundwater drain/well points))	
Prior to closure of the land-side impermeable wall (Avg. from Dec. 2015 to Feb. 2016)	Approx. 300m³/day (Approx. 370m³/day)
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※1)	Approx. 20m³/day (Approx. 60m³/day)
(Reference) Past minimum	7m³/day(Jan. 1, 2018) (19m³/day(Feb. 20, 2018))

The amount of water transferred from the T.P.+2.5m foundation to buildings has been reduced to less than 1/10 what it was before closure of the land-side impermeable wall

※1 ～22nd

The effect of multilayered contaminated water countermeasures
(Decreases in the amount of contaminated water generated by rainwater/groundwater)

Groundwater flowing from the mountains has been stopped in conjunction with closure of the land-side impermeable wall, and the groundwater is diverted around the buildings to the sea side of the site.



In order to perform the assessment with a small degree of estimated error caused by rainfall, data from similar periods of drought with the approximate same amount of rainfall were compared

(Reference) Precipitation	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 1.8mm/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※1)	Approx. 0.7mm/day

① Amount of rainwater/groundwater etc. flowing into buildings	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 190 m^3/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 90 m^3/day

② Water transferred from the T.P.+2.5m foundation to buildings	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 300 m^3/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 20 m^3/day

Amount of contaminated water generated from rainwater and groundwater※2	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 490 m^3/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 110 m^3/day

※1 ～22nd
※2 Does not include water injected into ALPS with chemical agents and other transferred water

The amount of contaminated water generated from rainwater and groundwater has been reduced to less than ¼ what it was prior to closure of the land-side impermeable wall

Reduction in the amount of contaminated water generated in conjunction with multilayered contaminated water countermeasures

The amount of contaminated water generated (contaminated water generated by rainwater and groundwater in addition to other transferred amount of water※1) has decreased to an average of approx. 140m³/day for the period from Dec. 2017 to Feb. 2018 ※2, and even though this data is from the dry season, it still falls well below the Mid-and-Long-Term Roadmap goal for the year 2020 of 150m³/day.

① Amount of rainwater/groundwater etc. flowing into buildings	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 190 m³/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 90 m³/day

② Water transferred from the T.P.+2.5m foundation to buildings	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 300 m³/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 20 m³/day

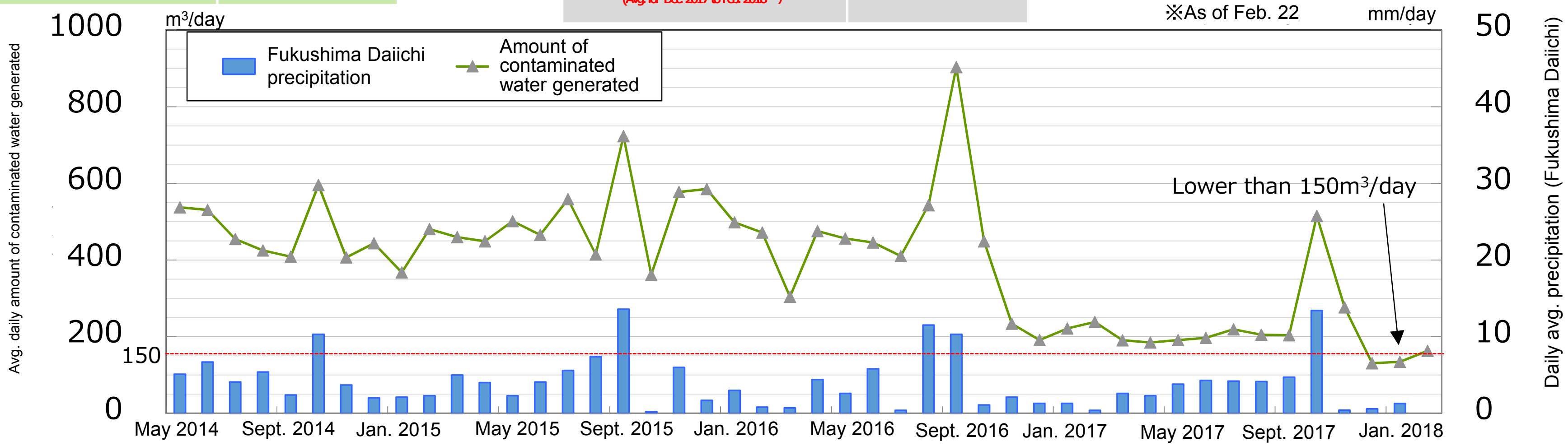
③=①+② Amount of contaminated water generated from rainwater and groundwater	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 490 m³/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 110 m³/day

④ Other transferred water※1	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 30 m³/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 30 m³/day

⑤=③+④ Amount of contaminated water generated	
Prior to closure of the land-side impermeable wall (Avg. for Dec. 2015 to Feb. 2016)	Approx. 520 m³/day
After closure of the land-side impermeable wall (Avg. for Dec. 2017 to Feb. 2018※2)	Approx. 140 m³/day

※1 Water transferred in conjunction with decommissioning; includes water sprayed on the operating floor, residual water transferred from trenches and water injected into ALPS with chemical agents

※2 ～22nd



Reductions in the amount of contaminated water generated

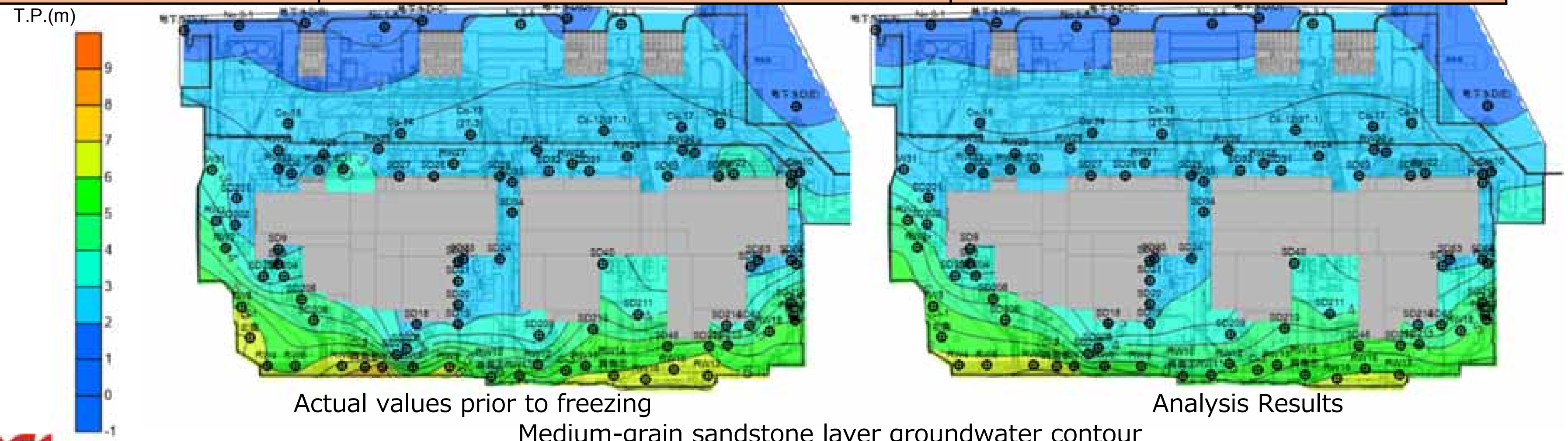
【Reference】How the land-side impermeable wall suppresses the amount of water flowing into buildings and the amount of water being pumped up (overview)

- Since the formation of the land-side impermeable wall, enhancement of sub-drains, and sub-drain water level activation setting reductions have all been implemented simultaneously as part of multilayered contaminated water countermeasures, we used three-dimensional seepage flow analysis to assess the effect that the land-side impermeable wall has had.
- Additional information was added to the model created by the Contaminated Water Treatment Countermeasures Committee in 2013 in order to model the area from the land-side impermeable wall (mountain side)～sea-side impermeable wall.
- Calculations were made for the dry period prior to the commencement of freezing (February 16 through March 21, 2016), and it was confirmed that the amount of groundwater flow in the buildings, the amount of water being pumped up, and the groundwater distribution have been reproduced.
- The effect of the land-side impermeable wall was confirmed by using the levels of water in sub-drains and of accumulated water in buildings for the dry period after closure of the land-side impermeable wall (December 1, 2017 through February 8, 2018 ※) represented in the model to compare the amount of groundwater flowing into buildings and the amount of water that would be pumped up if there was no land-side impermeable wall.

※ Period until an increase in water flow into buildings was seen in conjunction with works

Unit: (m³/day)

	Actual values prior to freezing	Analysis Results
Amount of groundwater/rainwater flooded buildings	140	130
Amount pumped up at T.P.+2.5m foundation	310	240
Amount pumped up by sub-drains	430	410



Actual values prior to freezing　　　　Analysis Results

Medium-grain sandstone layer groundwater contour

【Reference】 How the land-side impermeable wall suppresses the amount of water flowing into buildings and the amount of water being pumped up

- The land-side impermeable wall has contributed to reducing the amount of contaminated water generated by rainfall and groundwater by 95m³/day. This is half of what it would be if there were as no land-side impermeable wall (189m³/day).

< Amount of contaminated water generated by rainwater and groundwater>

	Without land-side impermeable wall	With land-side impermeable wall (actual data) [2017.12.1～2018.2.8※]	Effect
Amount of groundwater/rainwater flowing into buildings	95m³/day	78m³/day	17m³/day reduction
Amount of water transferred to buildings from T.P.+2.5m foundation	94m³/day	16m³/day	78m³/day reduction
Total amount of contaminated water generated by rainwater and groundwater	189m³/day	93m³/day	95m³/day reduction

- Furthermore, groundwater flowing from the mountains is cut off by the land-side impermeable wall and diverted around the buildings thereby reducing the total amount of water pumped up by sub-drains and at the T.P.+2.5m foundation by 549m³/day and contributing to the decrease in groundwater levels around buildings and the stable control of sub-drains.

<Amount of water pumped up by sub-drains and at the T.P.+2.5m foundation>

	Without land-side impermeable wall	With land-side impermeable wall (actual data) [2017.12.1～2018.2.8※]	Effect
Amount pumped up by sub-drains	826m³/day	353m³/day	473m³/day reduction
Amount pumped up at T.P.+2.5m foundation	141m³/day	65m³/day	76m³/day reduction

(Chart totals may not match due to rounding)

※ Period until an increase in water flow into buildings was see in conjunction with works