Disaster Prevention
(KIX Disaster Resilience Enhancement Project)

May 31st, 2019





Shaping a New Journey

KANSAI AIRPORTS

Project overview

1. Typhoon damage

- Although the tidal level of 2.5 meters (CDL) recorded on Typhoon Jebi's approach was lower than the record high of 3.2 meters observed when Typhoon Nancy hit Japan, the storm's strong winds created waves over 5 meters high, significantly higher than the previous height of 3.4 meters, resulting in seawall overtopping.
- Phase I Island was extensively flooded (90% of the total flood volume of 2.3 to 2.7 million m^3) mainly due to high waves overtopping east and south seawalls.
- Resultant damage includes flooded Runway A and other facilities making flight operations impossible; a power outage resulting from damage to 3 high-voltage electrical facilities in the basement of T1; and a loss of drainage functions at three locations due to damaged power distribution panels in drainage pump systems.

2. Details of the project

(i) Basic concept

- In preparation for massive natural disasters in the future, comprehensive and systematic measures to enhance KIX's disaster preparedness will be implemented in a prompt and steady manner with the focus on the following three pillars: prevent high waves from overtopping seawalls and flooding airport islands; protect electrical facilities and other key infrastructure from future flooding of the airport island caused by torrential rain or high waves that are greater than the necessary height of a seawall; and keep drainage systems functioning to allow for speedy recovery of airport functions.
- The project takes into account basic visions of the final report by the "committee to assess measures against large-scale natural disasters implemented at nation's major airports"[1] and "three-year emergency plan for disaster prevention, mitigation and national resilience enhancement"[2] along with recent changes in climate and an influx of foreign passengers.

[1] Civil Aviation Bureau, Ministry of Land, Infrastructure and Transport, April 10, 2019
[2] Cabinet decision, December 14, 2018

Project overview

(ii) Details of disaster defense

<table>
<tr><th></th><th colspan="2">Description</th></tr>
<tr><td>(1) Wave overtopping prevention measures</td><td colspan="2">● The design waves (or the 50-year stochastic wave) for south, east and north seawalls on Phase I Island were revised given recent changes in climate, data from Typhoon Jebi, and other factors in order to identify the necessary height of seawalls to block storm surge and high waves keeping also in mind placement of blocks on the seaward side of seawalls to dissipate waves
● Desirable seawall construction heights were determined given the amount of future settlement and sufficient elevation of Runway A and others
● Based on the above, raise the south, east and north seawalls followed by Runway A and place blocks on the seaward side of south and east seawalls</td></tr>
<tr><td>(2) Anti-flooding measures</td><td rowspan="2">Protect the airport against flooding due to torrential rain or high waves overtopping the necessary height of a seawall</td><td>● In order to maintain and secure crucial airport functions, relocate electrical facilities above ground in T1, install water barriers, watertight doors and others</td></tr>
<tr><td>(3) Measures to secure drainage functions</td><td>● In order to quickly restore airport functions, deploy large pump trucks and mobile generator trucks and shelter electrical facilities for drainage pumps</td></tr>
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Project overview

(iii) Project cost: Approx. 54.1 billion yen

(iv) Schedule

- By the end of June 2019 (short-term measures):
  Deployment of large pump trucks and installation of water barriers as well as watertight doors at electrical rooms, etc.,

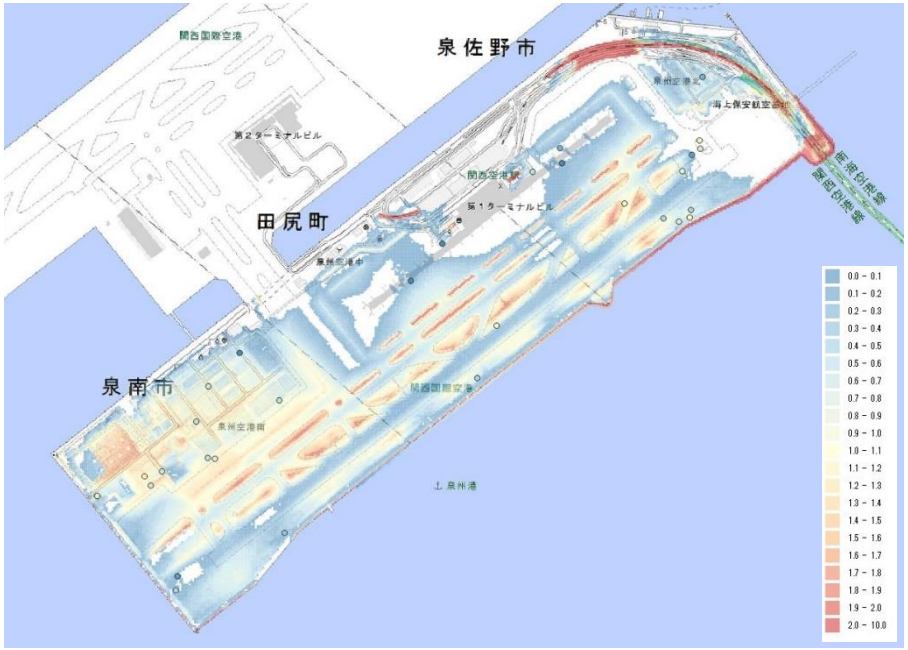
- By the end of FY2020:
  Elevation of control panels and south, east and north seawalls and relocation of electrical facilities for Terminal 1, KAP bldg. and AL bldgs. above ground, as well as sheltering of control and power distribution panels for drainage pumps

- By the end of FY2022 (long-term measures):
  Elevation of Runway A and taxiways following the east seawall elevation, placement of blocks on the seaward side of south and east seawalls and elevation and extension of concrete walls around Terminal 1, etc.

Reference

Typhoon Jebi floodwater volume

- Total floodwater on the airport premises estimated based on possible flood factors was 2.3 to 2.7 million m^3
- This result is by and large consistent with the estimation made based on the actual measurements of flood height (2.7 million m^3)

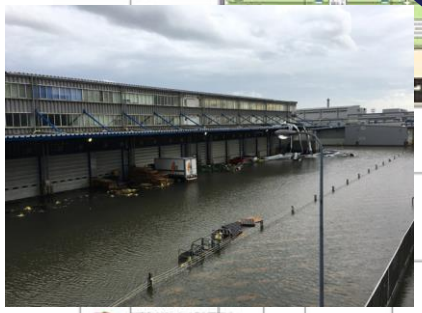


*The flood factors include: waves overtopping seawall; overflow water from collapsed seawall nearby VOR/DME; backflow from drainage pipes due to inoperable pumps; and rainfall.

* VOR/DME: navigational aids providing aircraft position and distance information

Damage from Typhoon Jebi

[Runway & apron]
• Flooding throughout entire area



[Cargo warehouse]
• Roofs blown off, shutters damaged
• Utilities (power, AC) partially or totally offline in nearly all buildings due to flooding
• Damage to some goods in warehouse

[Ground handling]
• Flooding submerged 90% of 600 vehicles (i.e. towing cars) and 2,200 pieces of equipment

[Seawall]
Seawall partially damaged

[Aeroplaza (commercial complex)]
• Broken glass in Level 2 lobby, one pax injured

[Pax handling systems]
• Partially offline due to power outage and flooding (check-in, BHS, etc.)

[T1]
• Flooding of electrical equipment, AC, pax/cargo handling facilities and disaster prevention facilities
• Power offline in north and central areas of main terminal building

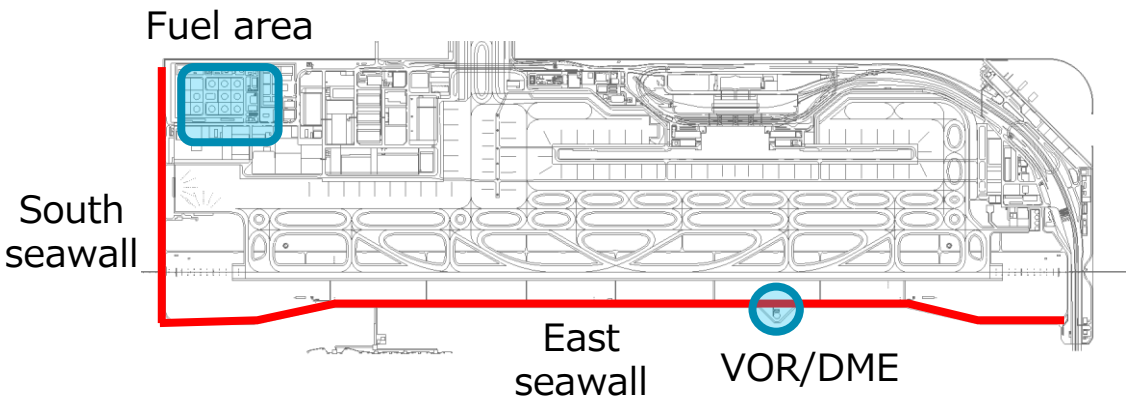
[Railway trench]
• Flooded

[Access bridge]
• Heavy damage from tanker collision
• Gas leaks from damaged areas
• Roads blocked
• Rail service halted

Runway B
Terminal 2
Cargo warehouse
Terminal 1
Runway A
Access bridge

Seawall overtopping

- Of all flood waters, about 60% came over the east seawall and 30% over the south seawall
- Key airport facilities such as Runway A and aprons were flooded
- The fuel area was flooded
- The seawall right beside VOR/DME collapsed due to unexpected wave pressure

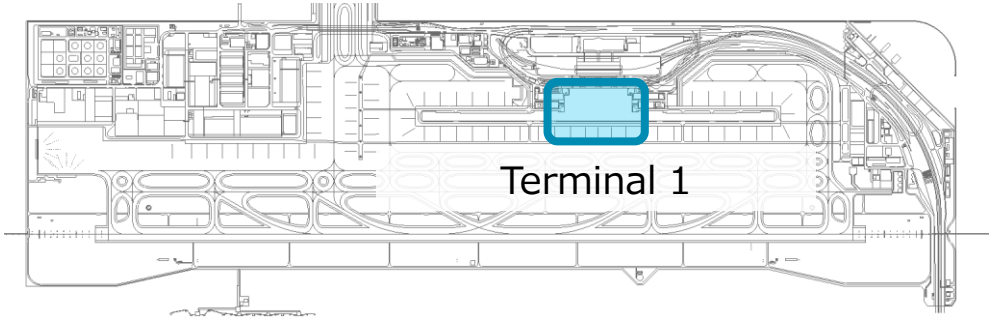


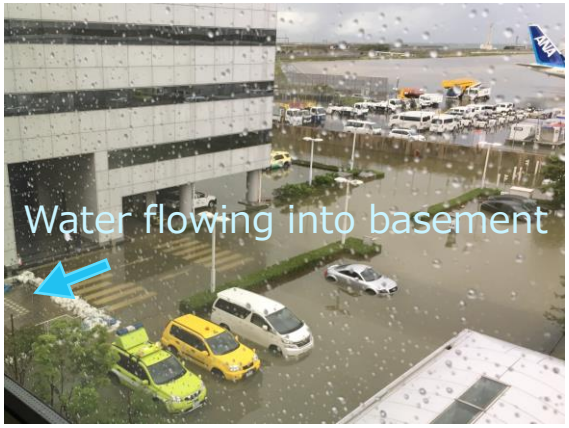
Fuel area flooded

Seawall nearby VOR/DME collapsed

Facilities failure including power outage

- Sea water flooded into the basement of the Terminal 1 building through a slope
- Three high-voltage facilities installed on the basement floor were damaged by flooded water, reducing the power supply to the building to half
- Disaster prevention and monitoring facilities installed on the basement floor were damaged by flood water and rendered inoperable
- Control panels for the baggage handling system were rendered inoperable due to flooding





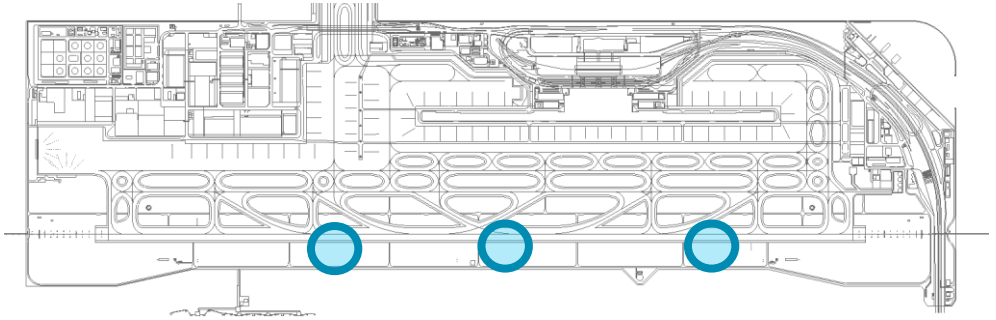
Slope leading to T1 basement

T1 basement ER

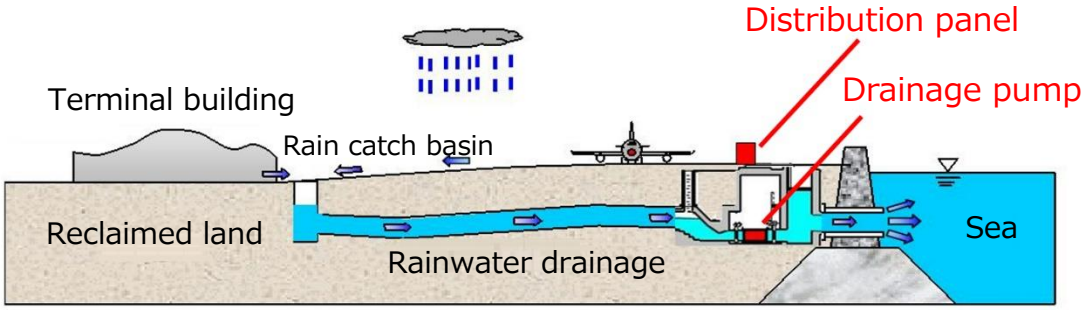
Drainage function impaired

- Power distribution panels for drainage pumps installed at three locations near the east seawall were damaged by wave overtopping and powerful winds

- Of the total drainage capacity of 200,000 m^3/hour for the entire Phase I Island, 110,000 m^3/hour were lost due to inoperable pump systems at the three locations



3 locations of affected power distribution panels

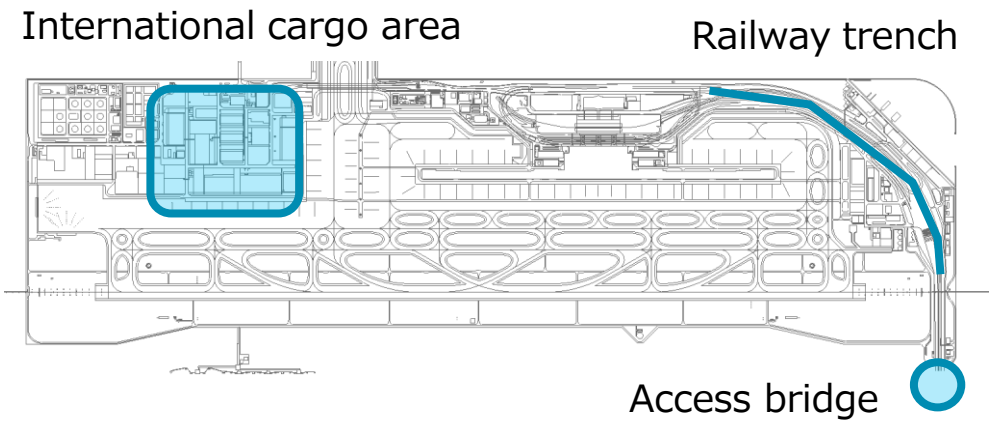


Rainwater and drainage pump

Distribution panels for drainage pumps

Other facilities damaged

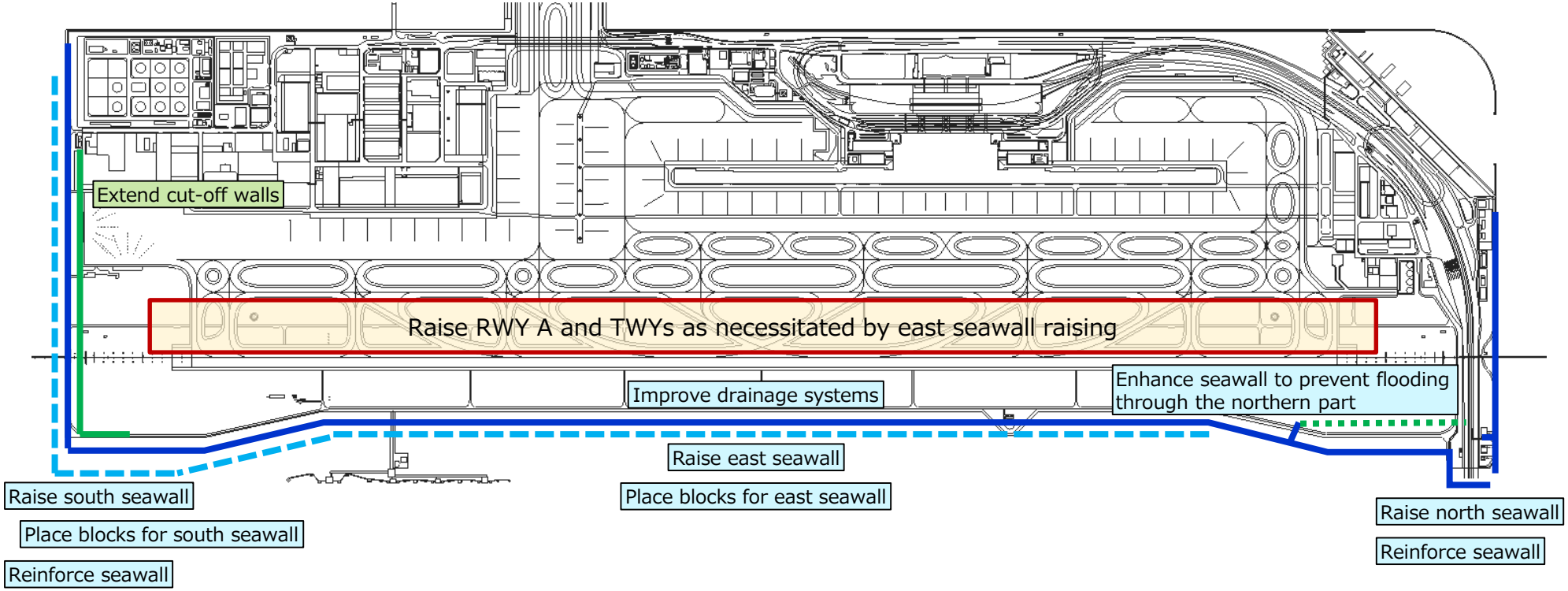
- Cargo goods, electrical equipment, warehouses and vehicles were damaged by flooding and powerful winds
- The railway trench was flooded with sea water from overtopping waves
- A tanker adrift by powerful winds dragging anchor collided with the access bridge, damaging road lanes and railway track
- Boarding bridges, ground handling vehicles and warehouses were damaged by flooding and powerful winds



International cargo area

Railway trench

(1) Overview of wave overtopping prevention: Seawall raising and tetrapod placement

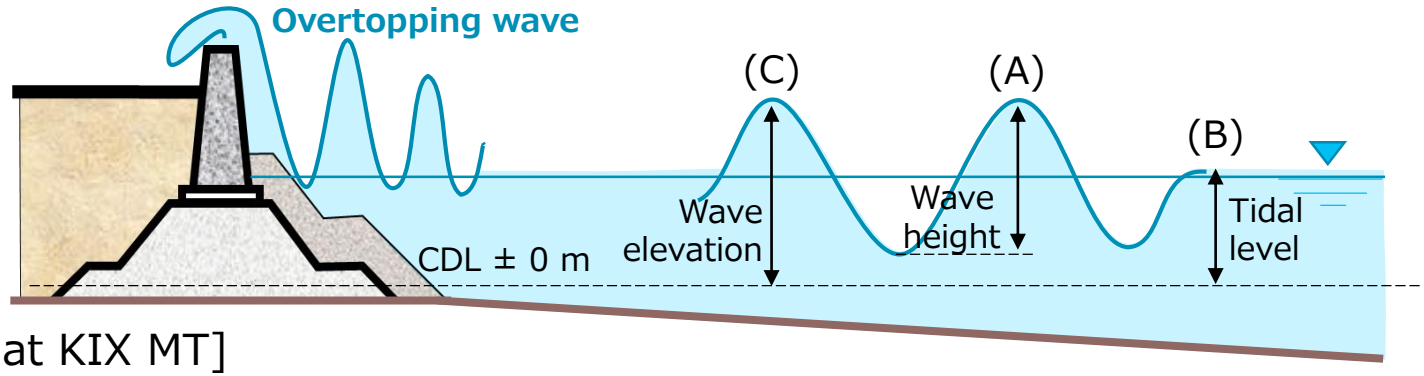


＊ Seawall reinforcement
The design criteria for the strength of the seawalls have been revised from the current ones aimed at withstanding the external force (wave power) of the 50-year stochastic waves to those aimed at withstanding the external force of high waves of a similar magnitude of Typhoon Jebi in 2018 (equivalent to the external force of the 100-year stochastic waves). Additional reinforcing steels will be embedded in the upper part of the north and south seawalls

＊ Cut-off wall extension (overflow retention wall)
The existing cut-off wall in the green zone behind the south seawall will be raised by about 1.5 m in order to prevent floods from reaching closer to the center of the airport island even if waves should overtop the necessary height of the south seawall. Waves in the vast ocean on the south side of the airport island are usually higher than those in the eastern waters of about 4 km between the airport island and the mainland

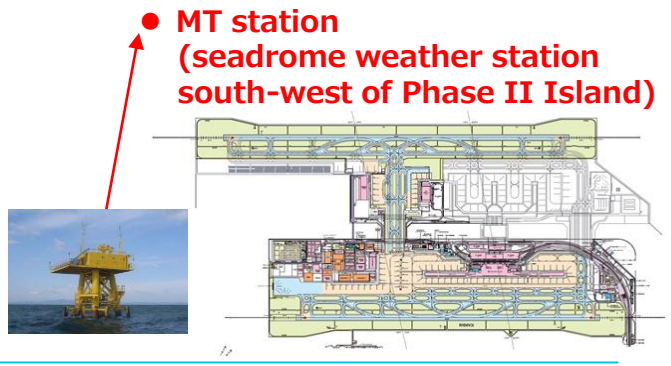
Revision of the design wave (50-year stochastic wave)

- The design waves (50-year stochastic wave) used for calculation of the seawalls' necessary heights have been revised based on the wave heights of the recent typhoons, etc. including Typhoon Jebi
- The current record-high tidal level used for calculation of the seawalls' necessary height will remain unrevised since the tidal level during Typhoon Jebi was below the current record-high tidal level (during Typhoon Nancy)

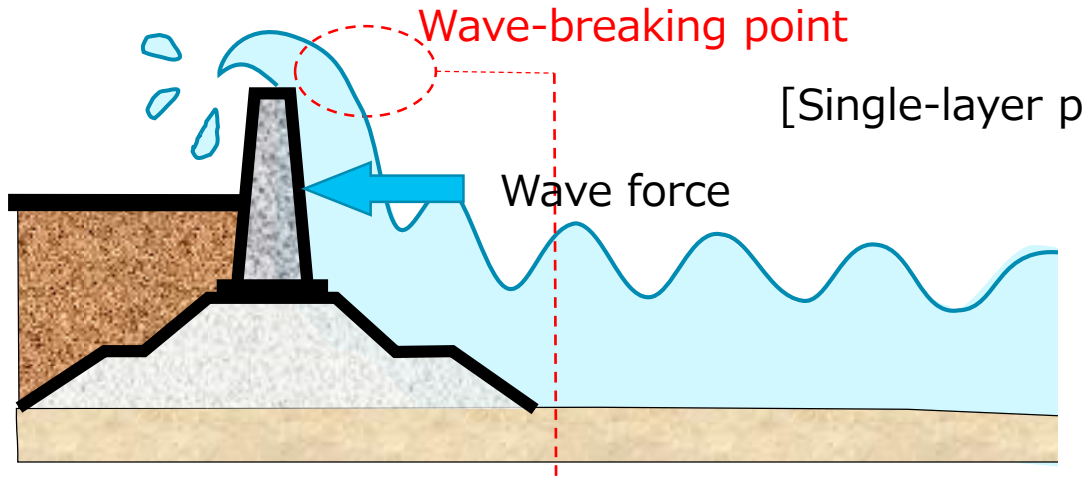


[Waves observed at KIX MT]

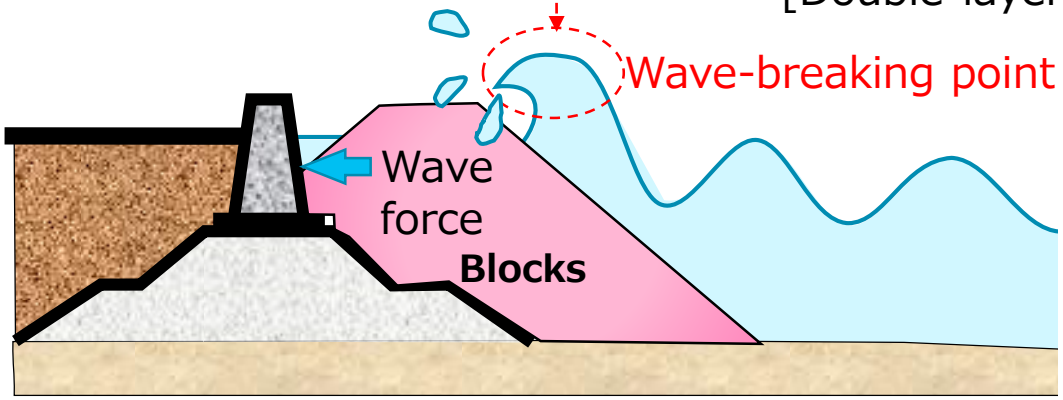
	Typhoon Jebi	Existing design requirement	New design requirement
Wave height (A)	5.2 m	3.7 m (Former design wave)	4.3 m (New design wave)
Tidal level (B)	CDL + 2.5 m	CDL + 3.2 m (Typhoon Nancy)	CDL + 3.2 m (Typhoon Nancy)
Wave elevation (C)=(A)/2 + (B)	CDL + 5.1 m	CDL + 5.05 m	CDL + 5.35 m



Effects of tetrapods



[Single-layer protection with seawalls]



[Double-layer protection with seawalls and blocks]

Blocks can;

- keep wave-breaking points further away from the seawalls, and
- diminish the wave force imposed on the upper part of the seawalls

Review of necessary heights of seawalls in light of revised design waves

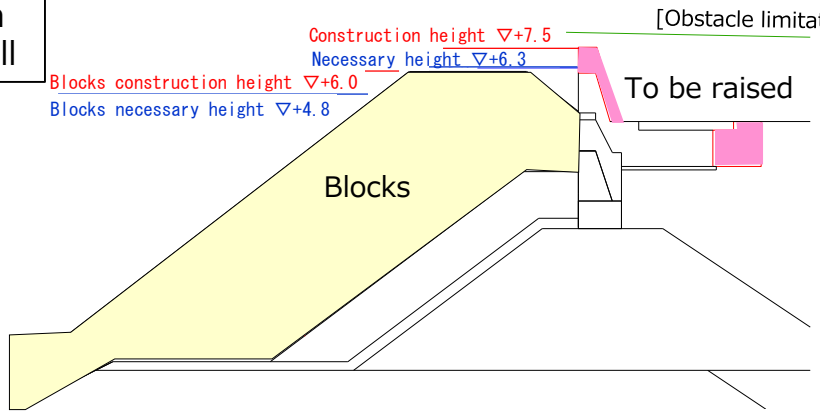
- A review of the necessary heights of the seawalls has revealed that not only the south and east seawalls, overtopped by waves during Typhoon Jebi, but also the north seawall need to be raised, taking into account the revised design heights of the south, east and north seawalls of Phase I Island (from the 50-year stochastic wave) and the plan to place blocks with expected effects of breaking waves before the seawalls
- The appropriate construction heights have been determined with consideration for anticipated future ground settlement, etc.
- The necessary height of each seawall has been confirmed to be sufficient to withstand high waves of the tidal level and wave height similar to those during Typhoon Jebi

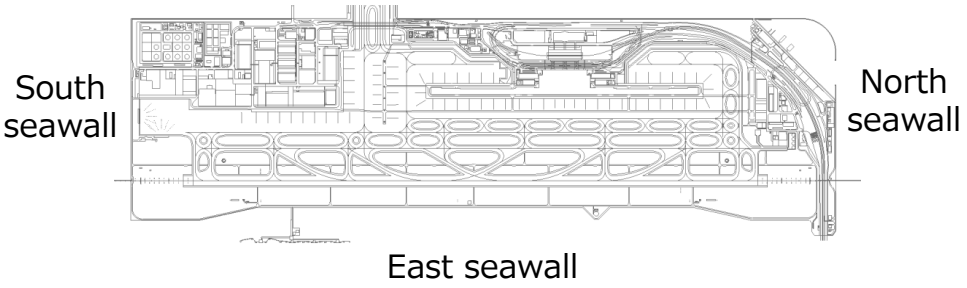
	South seawall		East seawall			North seawall	
	Before review	After review	Before review	After review		Before review	After review
	W/o blocks	W/ blocks	W/o blocks	W/o blocks*1	W/ blocks	W/o blocks	W/o blocks*1
Design wave (50-year stochastic wave)	3.6 m	3.9 m	1.7 m		2.2 m	2.8 m	3.4 m
Seawalls' necessary height CDL*2	+6.0 m	+6.3 m	+4.5 m	+5.6 m	+4.6 m	+5.0 m	+7.6 m
Seawalls' construction height CDL*3	-	+7.5 m	-	+6.6 m	+5.4 m	-	+8.0 m
Elevation of seawalls	-	1.5 m	-	2.7 m	1.7 m	-	2.7 m
Blocks' necessary height CDL	-	+4.8 m	-	-	+3.4 m	-	-
Blocks' construction height CDL*3	-	+6.0 m	-	-	+4.3 m	-	-

*1: Blocks will not be placed seaward of the northern part of the east seawall as well as the north seawall since these seawalls are perpendicular to the sea bottom; thus, placing a large number of blocks may trigger significant ground settlement around the foot of the access bridge
*2: The anticipated rise in the sea level of 0.1 m is factored into the seawalls' necessary heights under the new requirement
*3: The seawalls' heights upon completion of the construction
(Seawall raising and tetrapot placement will be completed in FY2020 and FY2022 respectively)

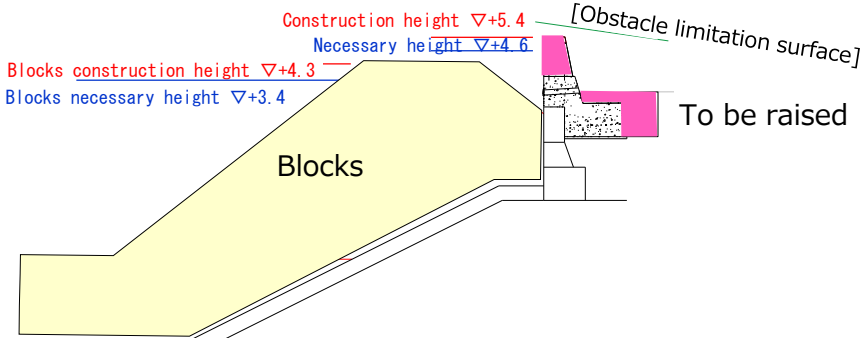
Raising south, east and north seawalls

South seawall

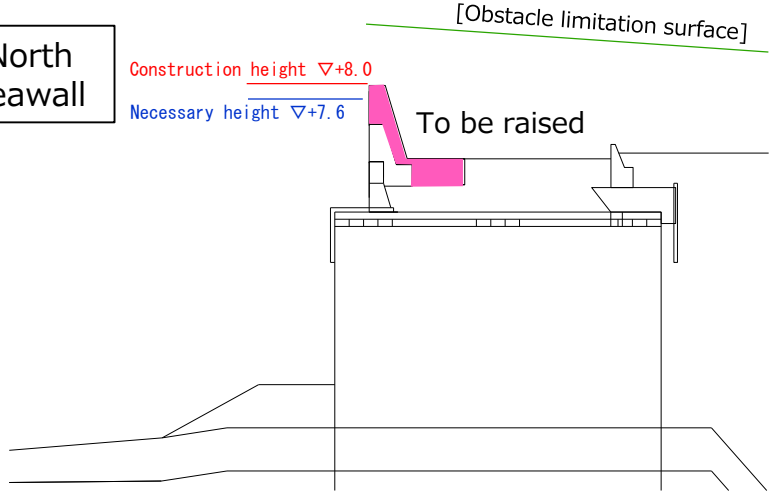




East seawall



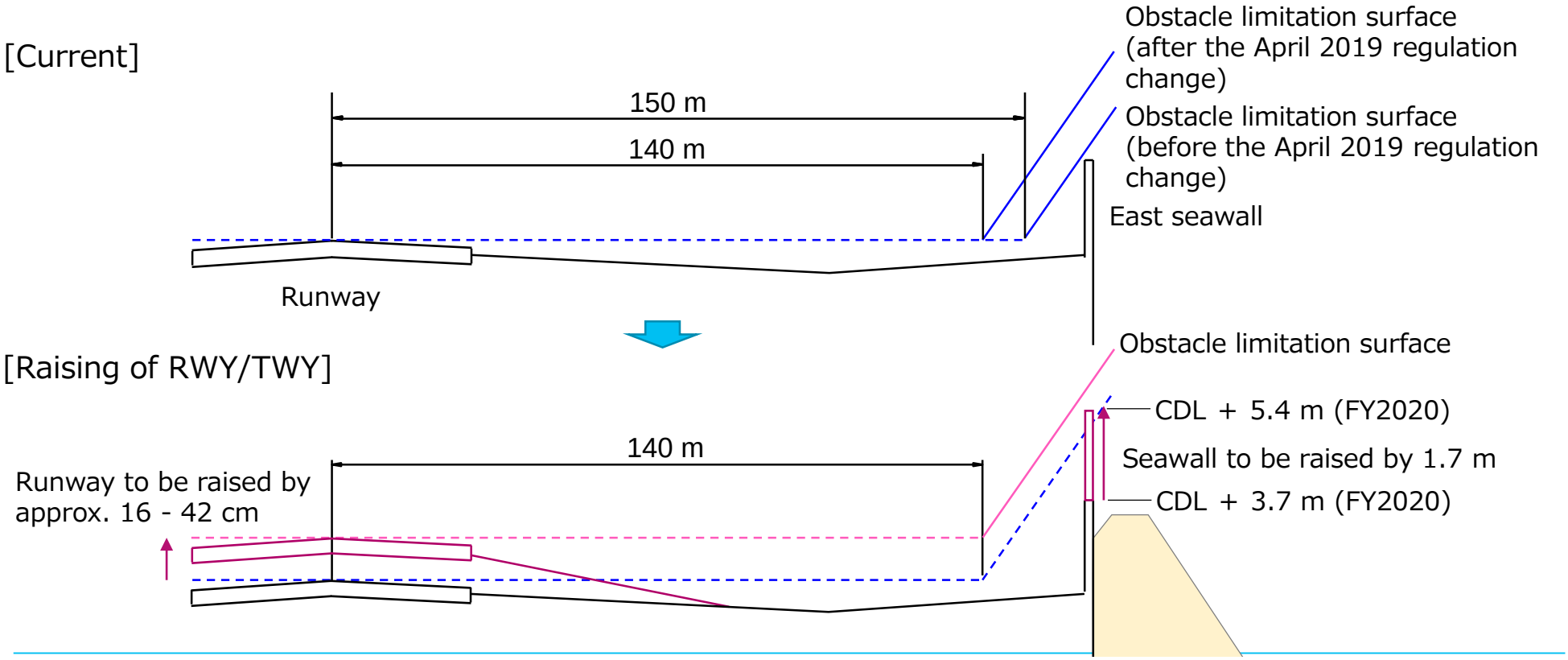
North seawall



Raising RWY A and TWYs as required by raised south seawall

- Runway A and taxiways will be raised in order to prevent the top of the raised east seawall from conflicting with the obstacle limitation surface* of the runway, thereby securing safe flight operation

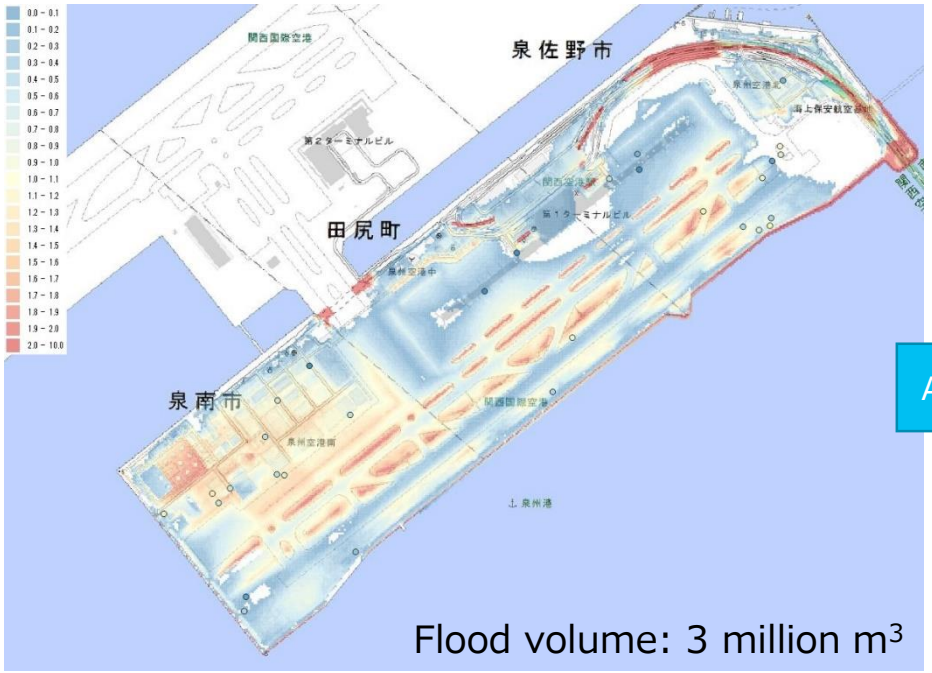
*A restriction on the height of buildings in and around an airport to ensure safe landing/taking-off of aircraft



Effects of wave overtopping prevention measures

Verification of the effects of the wave overtopping prevention measures shows:

- The volume of wave overtopping will be kept down significantly for Typhoon Jebi class in 2018



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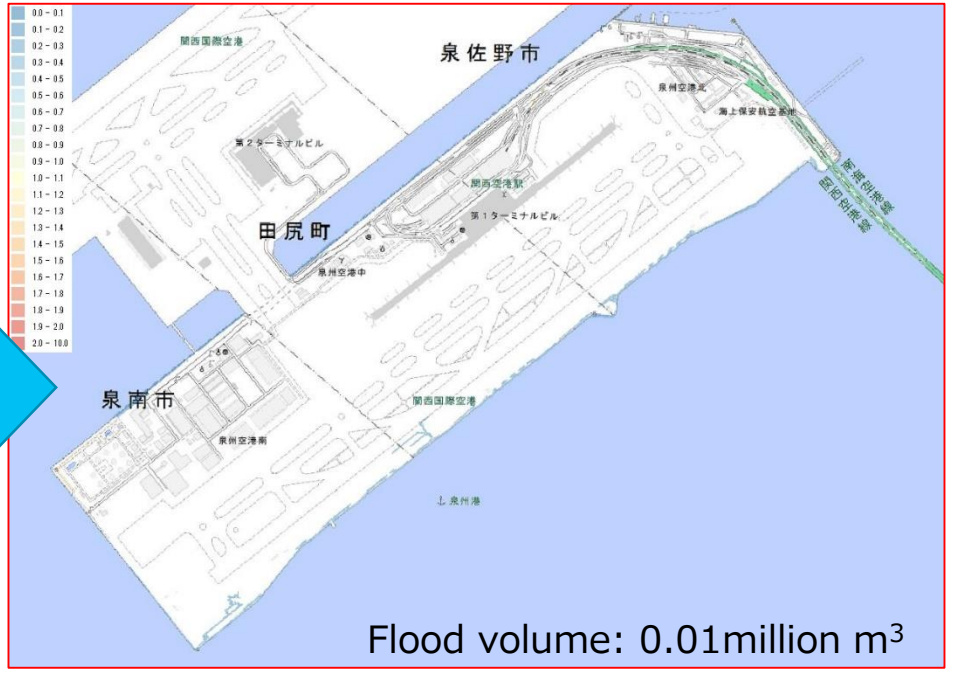
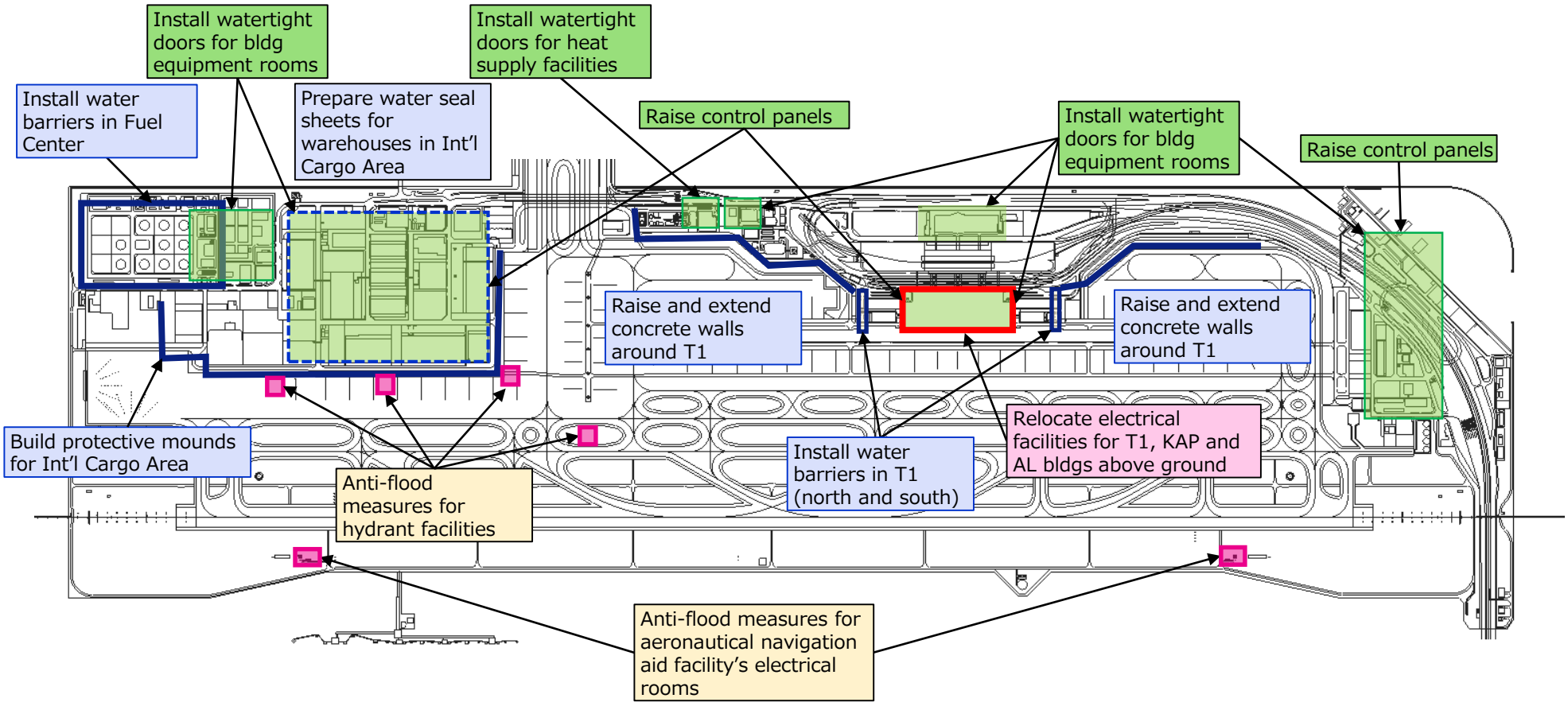


*The above illustrates the results of a flood simulation with waves overtopping the east and south seawalls in the same way as Typhoon Jebi in 2018, using the same tidal level and waves (Typhoon Jebi).

(2) Overview of anti-flood measures: Relocation of electrical facilities above ground, installation of water barriers and raising of control panels

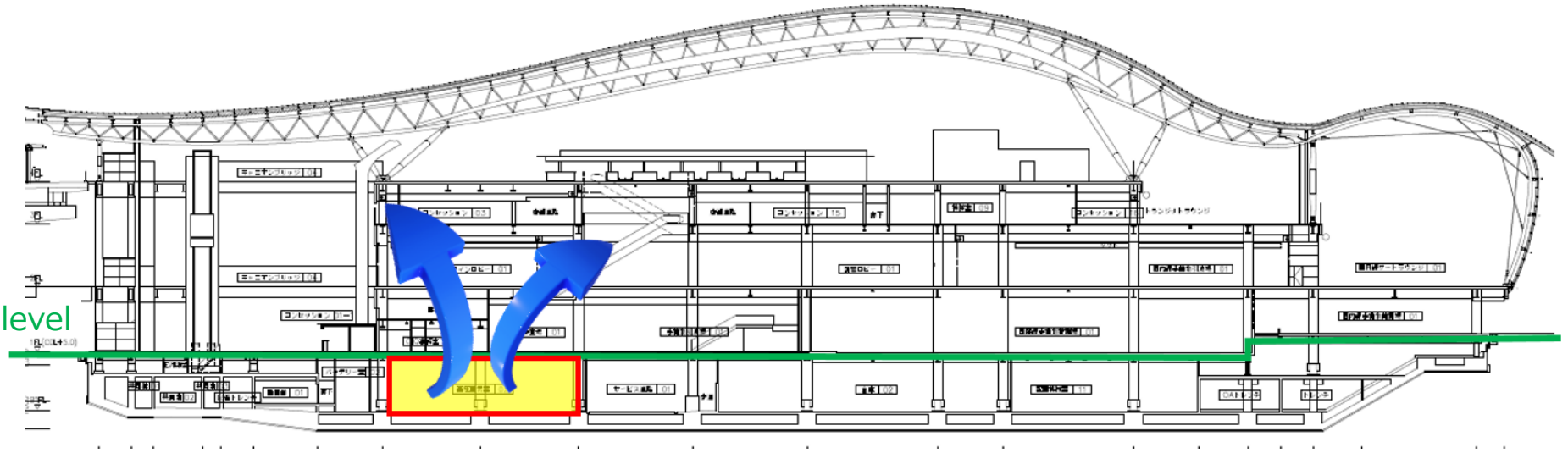


*Anti-flooding measures for common utility tunnel: The common utility tunnel's openings for access and ventilation will be raised or enclosed by concrete walls

Relocating electrical facilities for T1, KAP & AL bldgs above ground

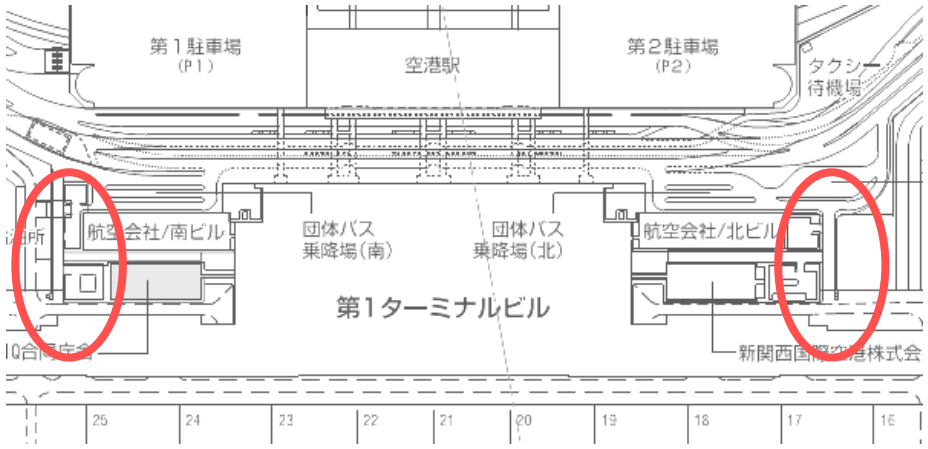
- A drastic anti-flood measure will be taken for electrical facilities for T1, KAP bldg and AL bldgs; we will relocate extra high & high voltage electrical rooms, central monitoring room, disaster prevention center, and public address systems above ground

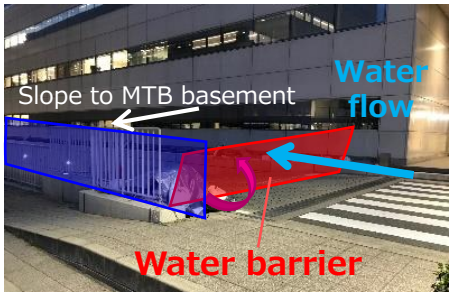
T1 MTB section view

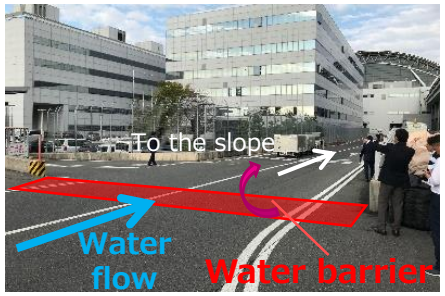


Installing water barriers in T1 (north and south)

- We will install water barriers as well as raise and extend the concrete walls around T1 Main Terminal Building (MTB) in order to prevent water from flooding into the basement of T1 MTB. Further, double-layer protection for the areas in and around T1 MTB home to important facilities will be established by installing watertight doors and raising control panels





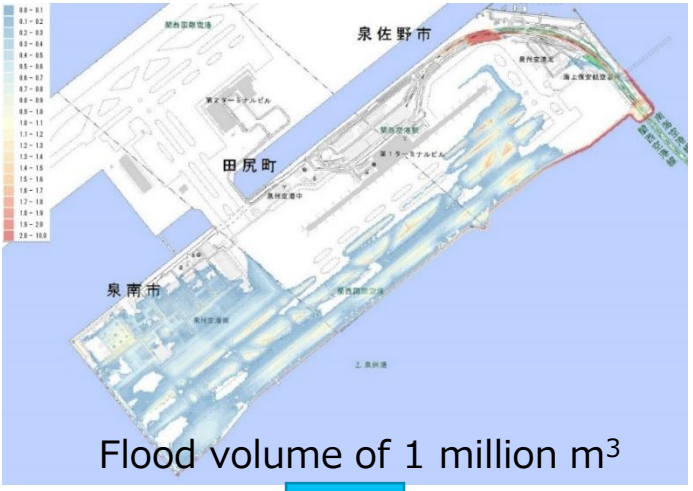


Install water barriers on the path of water flow into T1 basement

Building protective mounds in Int'l Cargo Area
Preparing water seal sheets for warehouses

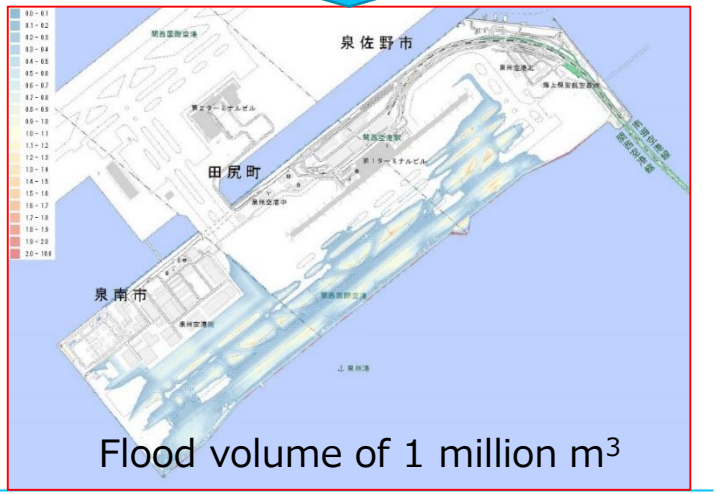
- GSE passages will be raised by 20 cm to protect Int'l Cargo Area from a flood of one million m^3
- When a typhoon is approaching, entrances will be covered with water seal sheets prepared in advance so as to prevent water from flooding into the warehouses

Water seal sheets



Flood volume of 1 million m^3

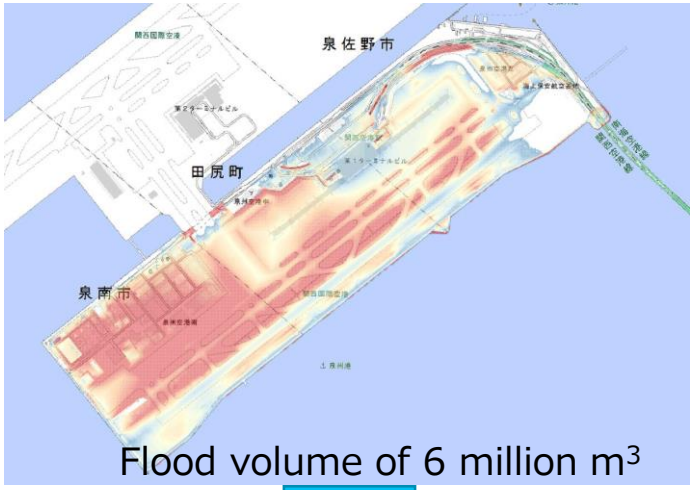
After



Flood volume of 1 million m^3

Raising and extending concrete walls around T1

- Approx. 2-m high concrete walls will be erected in order to prevent flooding of the terminal area
- The walls can protect the T1 MTB area from a flood of six million m^3



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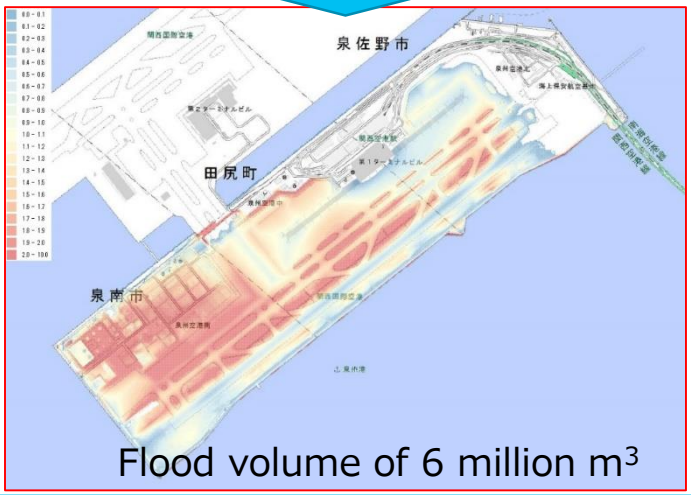
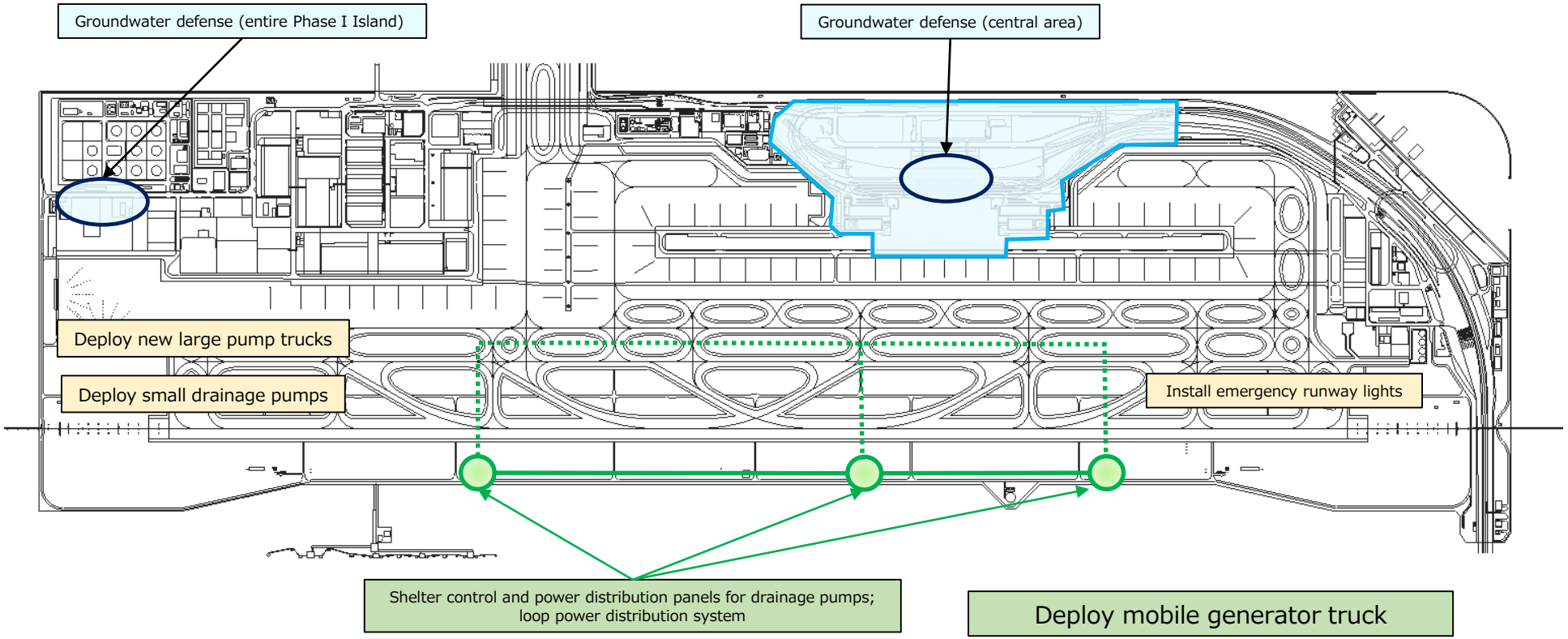


(3) Overview of measures to secure drainage functions: Protection of drainage pumps from flooding, deployment of large pump trucks



* Groundwater defense
  Enhance functions necessary to keep groundwater levels low
* Installation of emergency runway edge lights
  Introduce portable emergency runway edge lights with built-in battery to ensure speedy recovery of runways even in the event that the airport island is flooded rendering runway edge lights inoperable due to a power loss and damaged facilities

Sheltering control and power distribution panels for drainage pumps; adopting a loop power distribution system; deploying mobile generator trucks

- In order to ensure continuous operation of drainage pumps even in times of emergencies, shelter electrical facilities, adopt a loop power distribution system and deploy 3 mobile generator trucks for drainage pumps in preparation for damage to electrical facilities

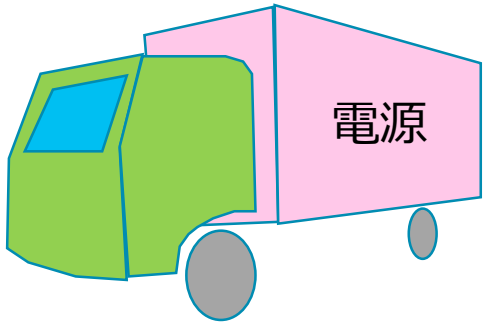
Control & power distribution panels for drainage pumps

Current

After

For illustrative purposes only

Mobile generator truck



※ 500kVA x 3 trucks

Deploying large pump trucks and small drainage pumps

To enhance drainage functions and facilitate speedy recovery of airport functions in times of flooding:

- Deploy 4 large pump trucks
- Introduce 17 small portable pumps

Large pump trucks

Small drainage pumps

Schedule

Emergency measures (To complete by the end of June 2019)	Install water barriers in T1 (north and south) and watertight doors at basement equipment rooms in T1, raise control panels in the basement of T1, prepare water seal sheets for cargo warehouse in Int'l Cargo Area, introduce large pump trucks, small drainage pumps, and emergency runway edge lights