Measures for Earthquake-Resistance Enhancement of Industrial Complexes around The Tokyo Bay

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3. Measures and challenges for earthquake and tsunami-resistance enhancement of industrial complexes

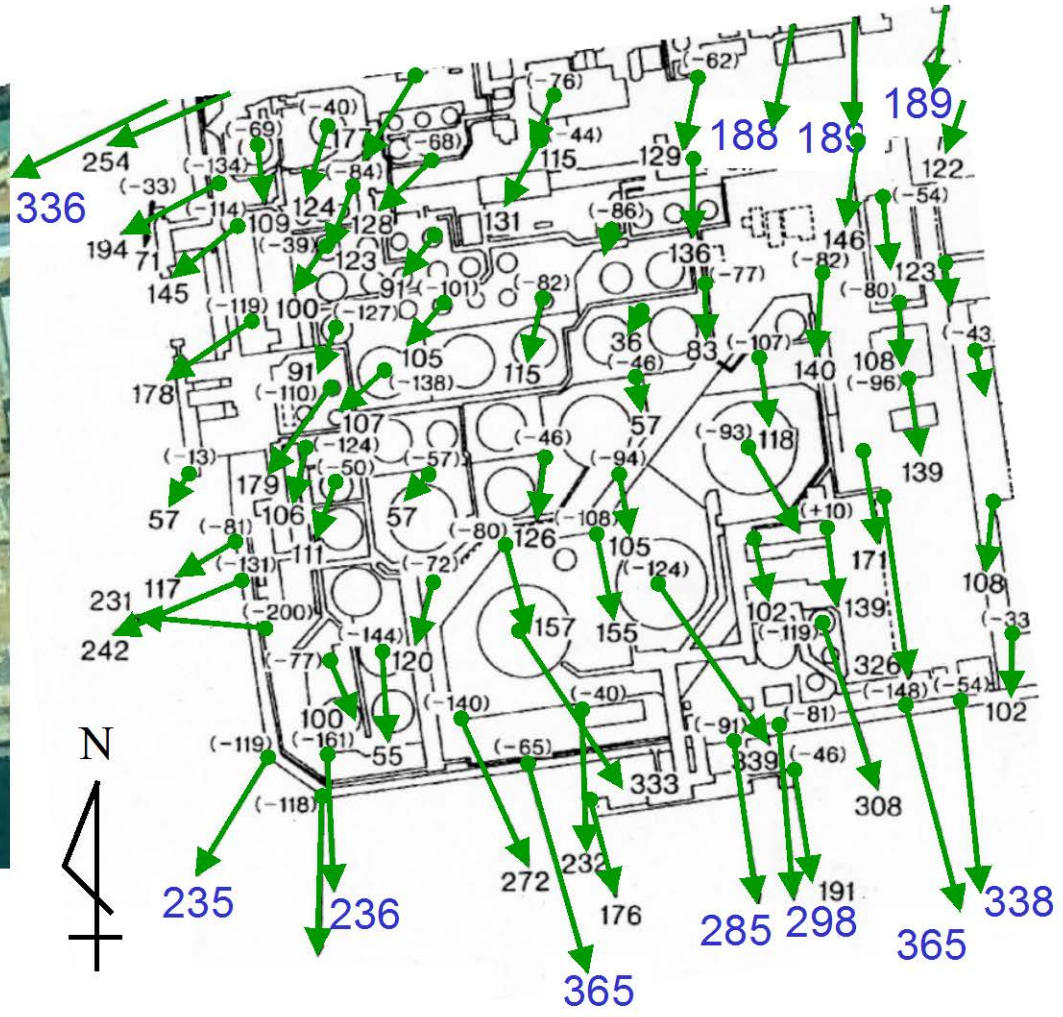
1. Damage to Industrial Facilities Caused by Past Earthquakes and Tsunamis

- Damage by soil liquefaction in soft reclaimed lands
- Fires of oil tanks caused by long-period components of earthquake ground motion
- Damage caused by tsunamis

Inclination and Subsidence of Tanks caused by Soil Liquefaction (The 1995 Kobe Earthquake)

Ground Displacements of An Artificial Island in Kobe Caused by Soil Liquefaction (The 1995 Kobe Earthquake)

Tank yard in Kobe



(Aerial photo taken two days after the earthquake)

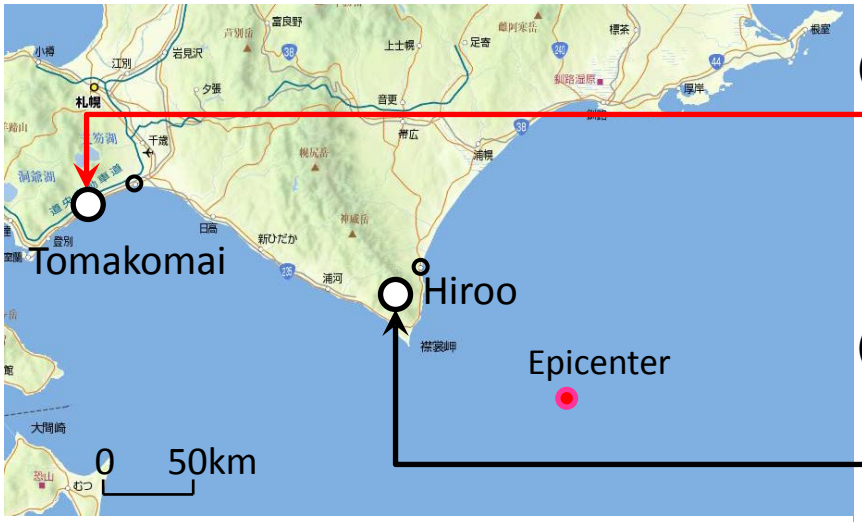
Ground displacements（cm）

Liquefaction-Caused Damage to Oil Protection Wall

（The 2011 Great East Japan Earthquake）

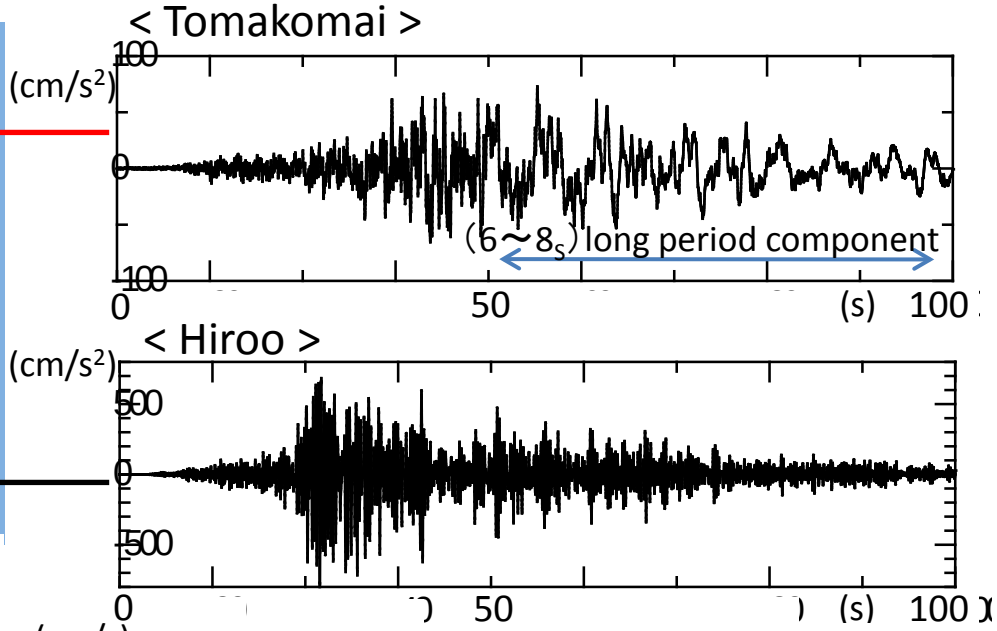
Fires of Oil Tanks Caused by Long-Period Components of Earthquake Ground Motion(1)

（The 2003 Tokachi-Oki Earthquake）

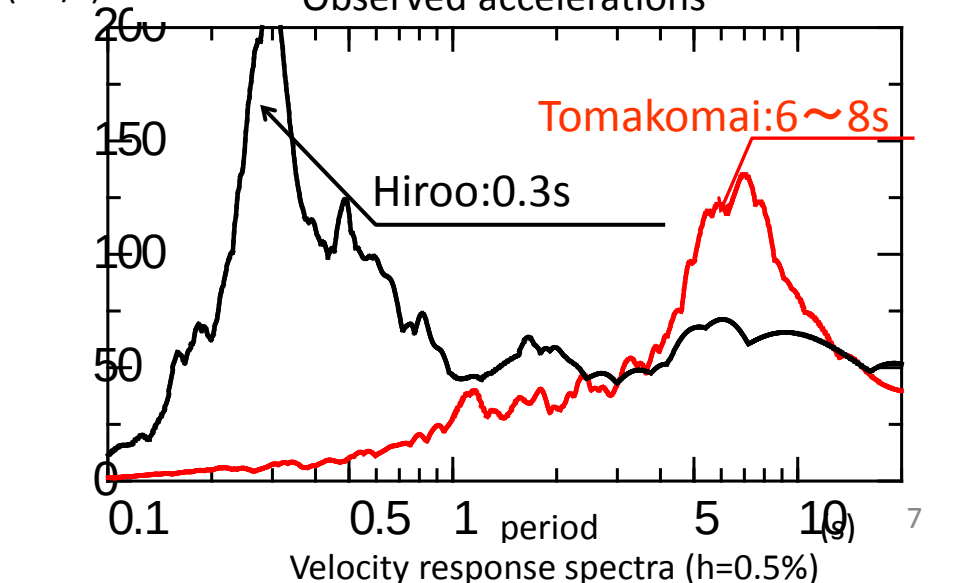


Epicenter of the earthquake and observation points of earthquake ground motion

Fires of oil tanks



Observed accelerations



Velocity response spectra (h=0.5%)

Fire of Oil Tanks Caused by Long-Period Components of Earthquake Ground Motion(2)

The 1964 Niigata earthquake

The 1999 Kocaeli earthquake, Turkey

Measures Recommended by the Fire Defense Agency to Prevent Oil Tank Fire

(i) Lowering oil surface to avoid the overflow

(ii) Preparation of emergent fire fighting to prevent large fires

(iii) Reinforcement of floating roofs to avoid sinking into the oil

(iv) Reinforcement of oil protection wall

Damage to Oil Refinery and Fires on Sea Surface Caused by Tsunami（The 2011 Great East Japan Earthquake）


Fire of oil refinery


Drift of fuel tanks

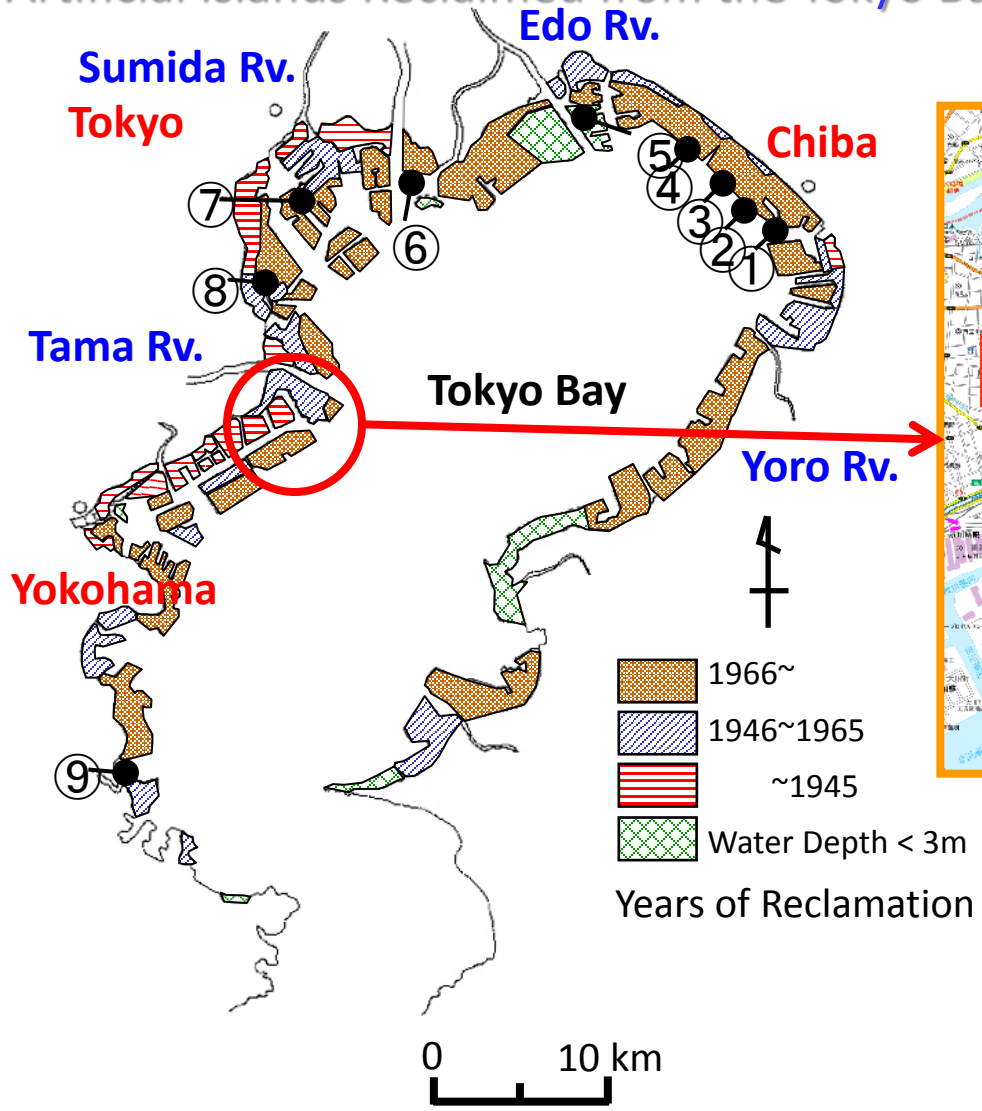

Fires on sea surface

Horizontal Movement of Oil Tanks
（The 2004 Sumatra offshore earthquake, Indonesia）

Three oil tanks were floated by floodwater and transported about 300m from their original locations (Banda Ache, Sumatra, Indonesia)

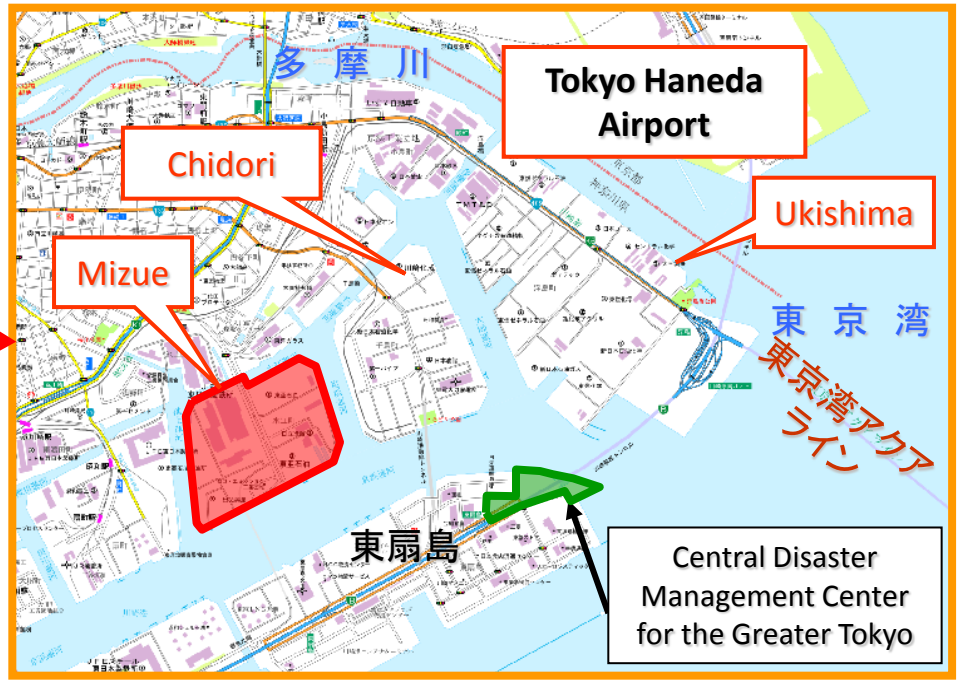
2.Earthquake and Tsunami Risk of Industrial Complexes Around the Tokyo Bay

Artificial Islands Reclaimed from the Tokyo Bay



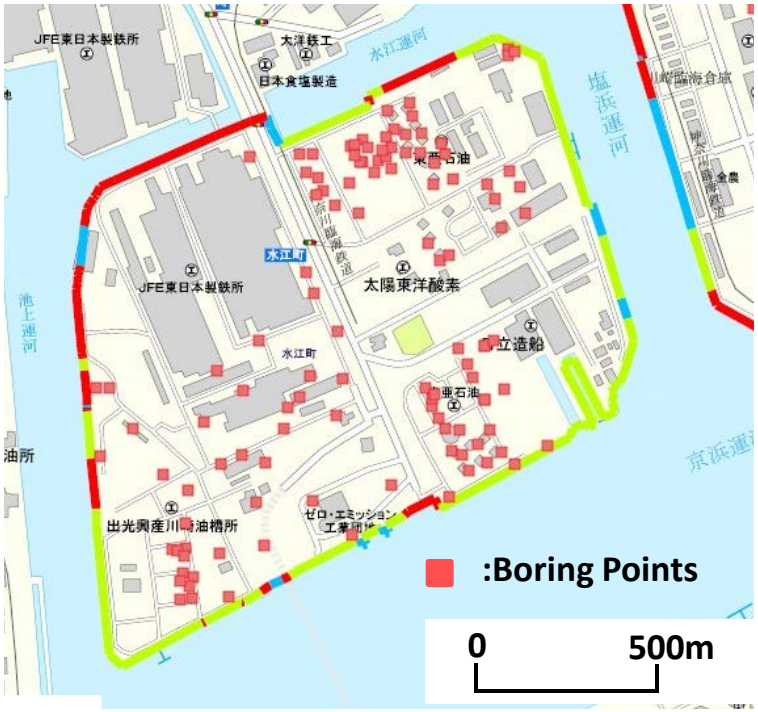
(Source) After S. Kaizuka

Artificial Islands in Kawasaki City

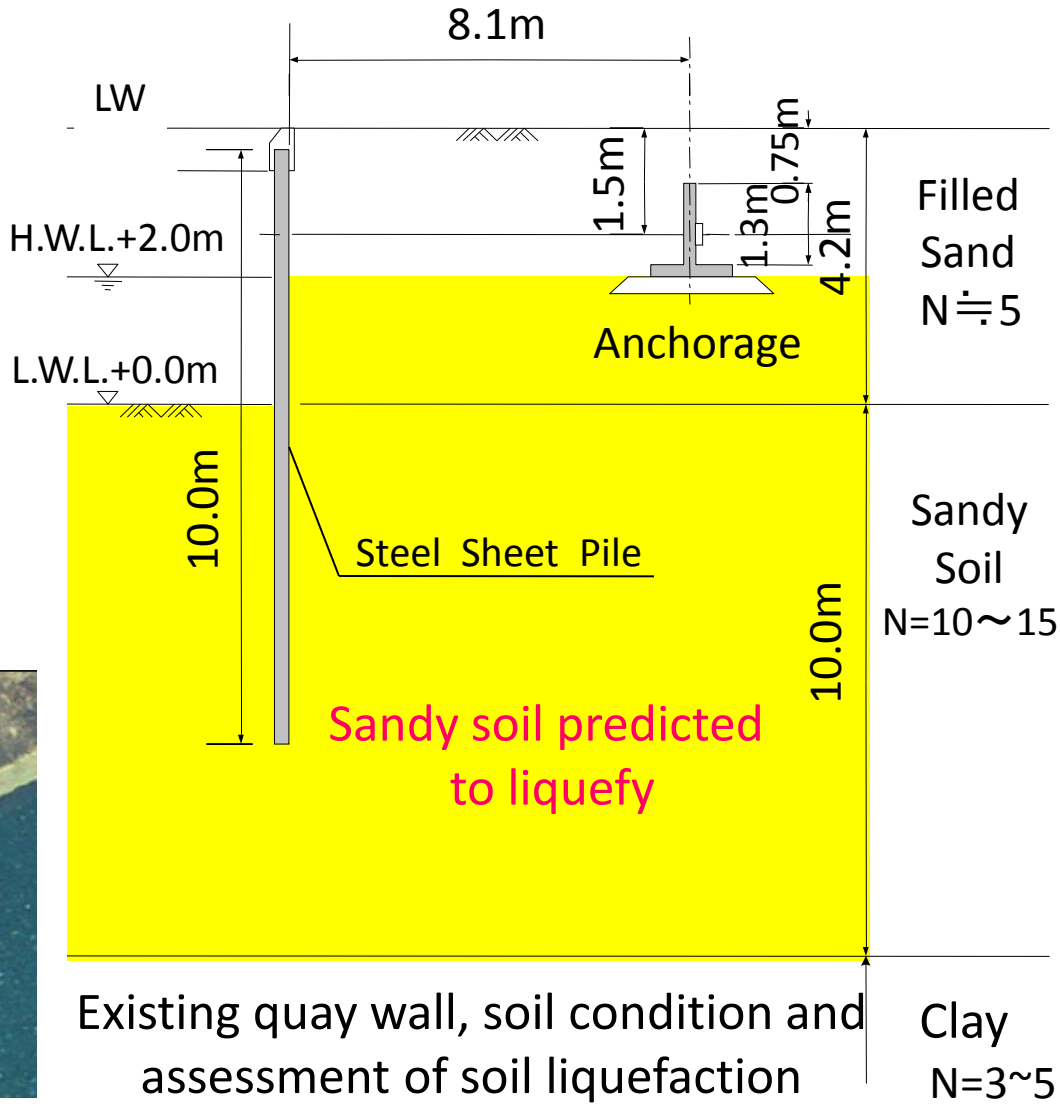


Mizue & Chidori area were reclaimed before1945.
Ukishima area was reclaimed from 1946 to1965.

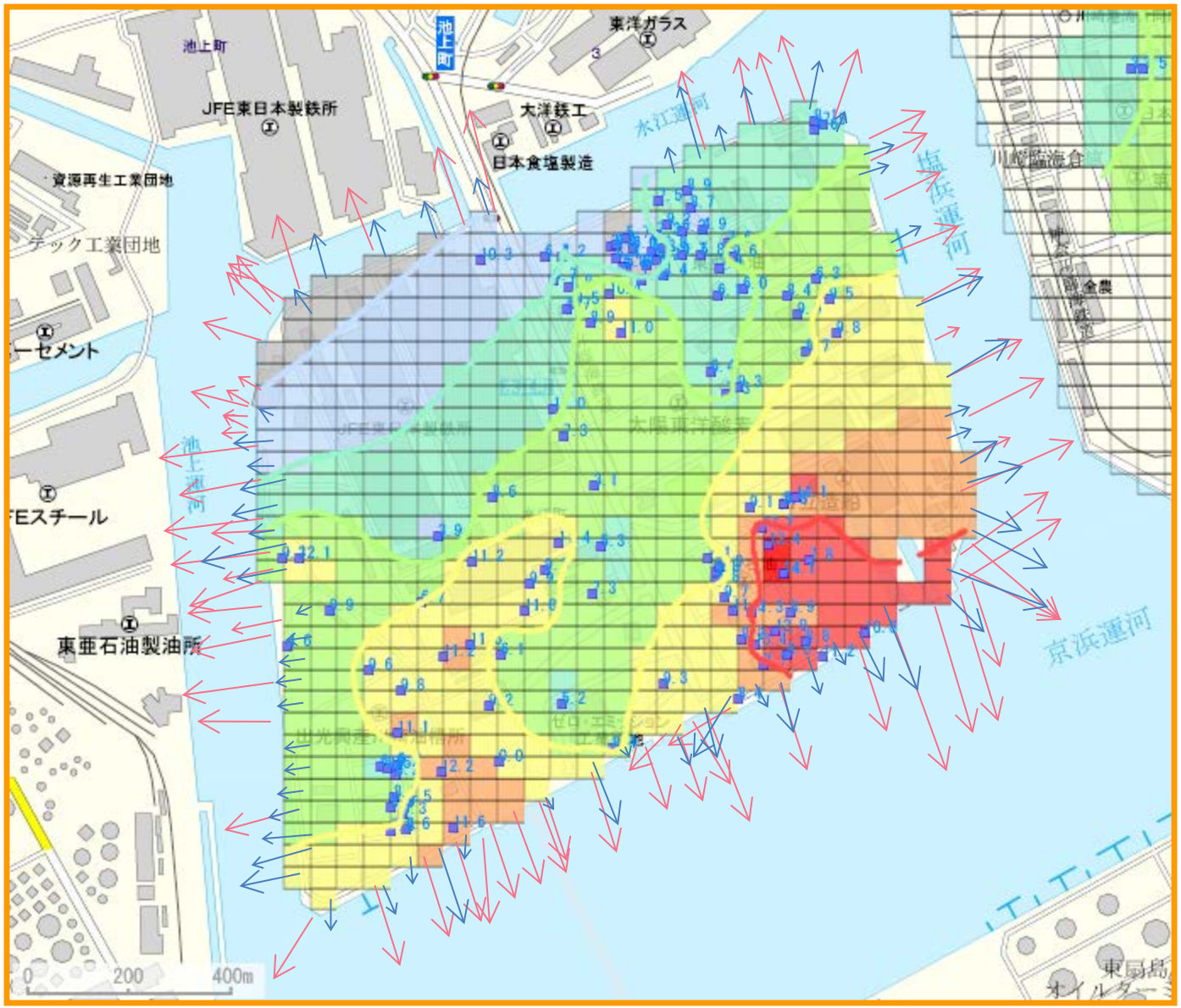
An Artificial Island in The Tokyo Bay, Seawall Structure, Soil Condition and Assessment of Soil Liquefaction



An Artificial island in Tokyo Bay



Assessment of Soil Liquefaction and Its Induced Ground Displacements



Thickness of liquefied soil

- 5～
- 6～
- 7～
- 8～
- 9～
- 10～11m
- 11～12m
- 12～13m

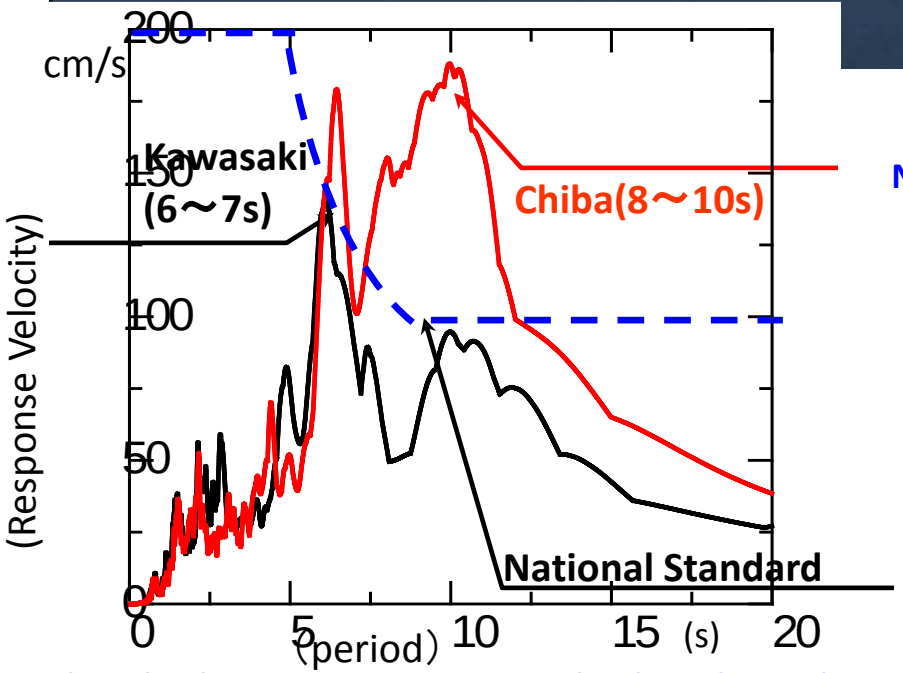
4m **Horizontal Displacement of Seawalls**

4m **Horizontal Displacement of Ground**

Assessment of Overflow of Oil from Floating Roof Tanks

(By the Tokai and Tonankai Earthquakes)

Industrial Complex around The Tokyo Bay



Predicted Velocity-Response Spectra by the Tokai and Tonankai Earthquakes

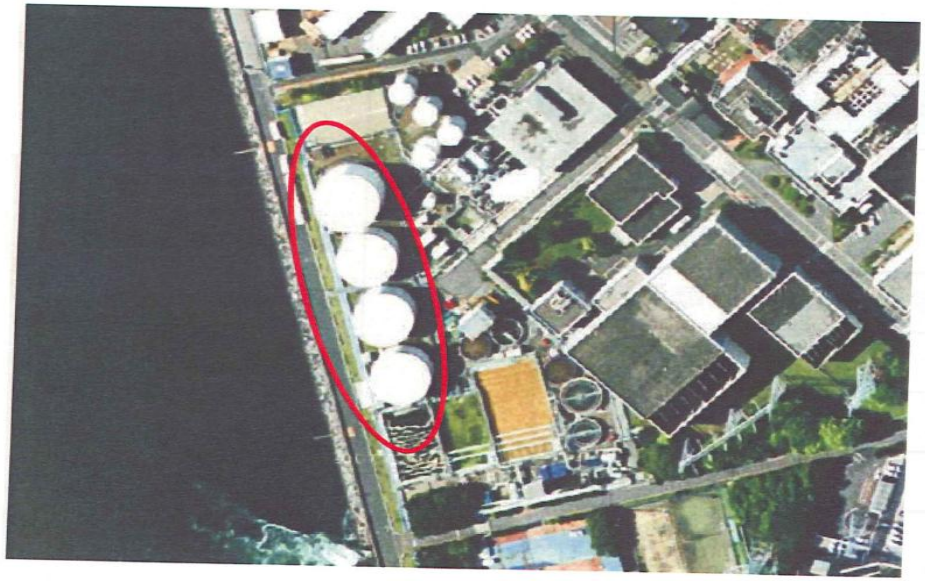
Number of Tanks and Oil-Overflowing Tanks in The Tokyo Bay

Diameter of tanks	Number of tanks	Number of tanks (overflowing)
～24m	203	13(6.4%)
24～34m	136	27(19.9%)
34m～60m	118	18(15.3%)
60m～	159	6(3.8%)
	616	64(10.4%)

Tanks for Oils, Chemical Products and Poisons around the Tokyo Bay

Yokohama

Kawasaki

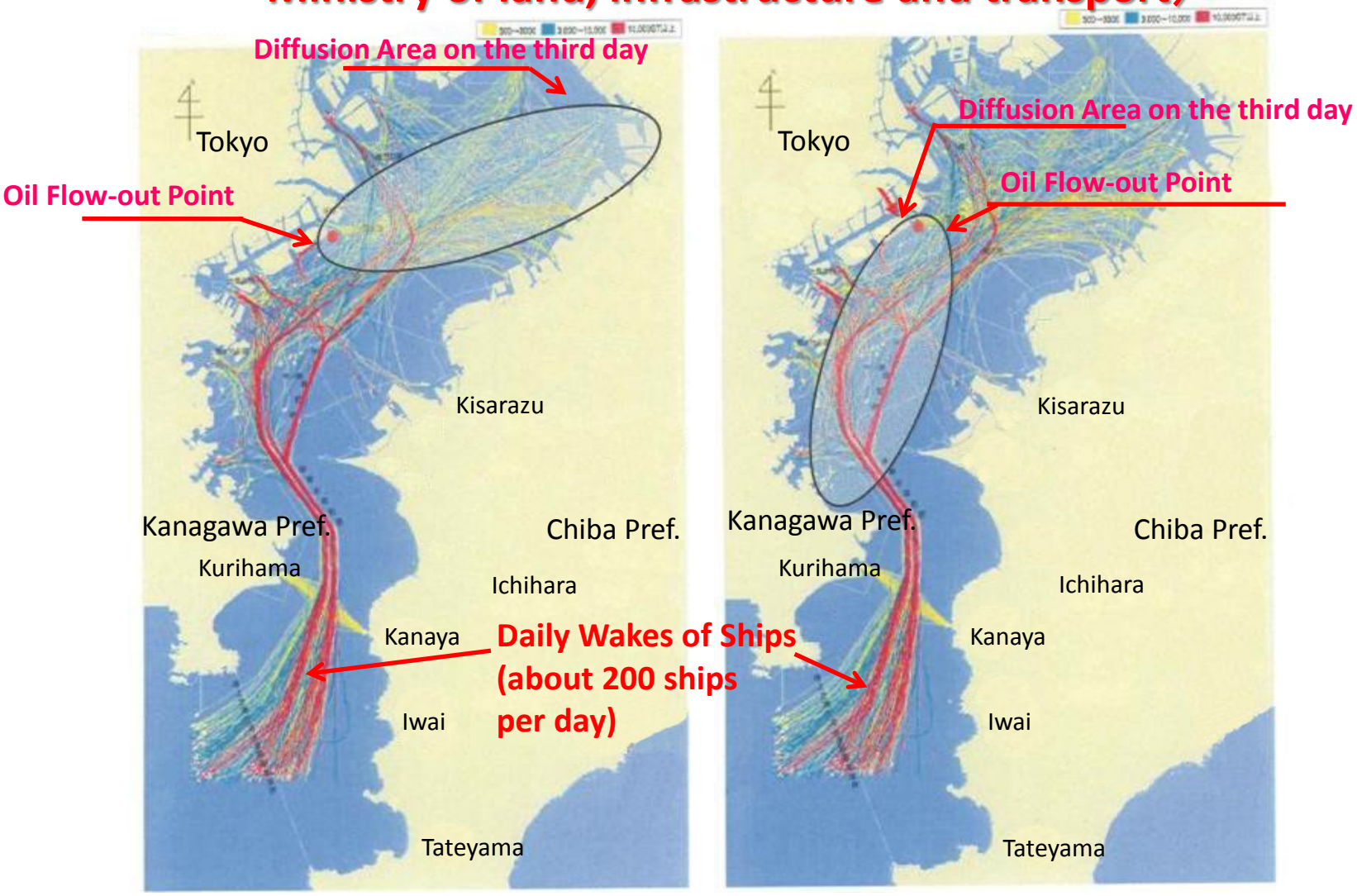


Chiba

Tank for storage of poison

Diffusion of Crude Oil in The Tokyo Bay

(Committee for assessment of earthquake damage in the Tokyo Bay area, Ministry of land, infrastructure and transport)



(a) Summer season

(b) Winter season

Flow-out Point ; Keihin Canal Volume of Crude Oil ; 12,000kl

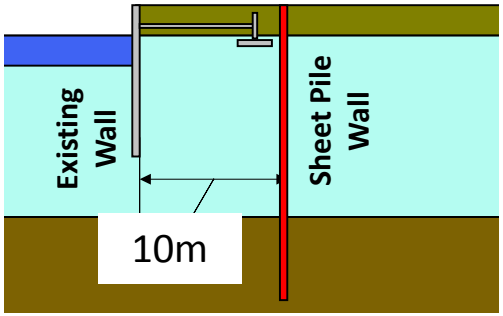
Wind Velocity ; 5m/s

12 LNG and Oil Power Plants around The Tokyo Bay

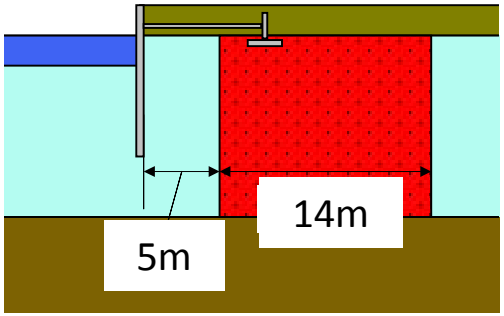
3.Measures and Challenges for Earthquake and Tsunami-Resistance Enhancement of Industrial Complexes

Reinforcement of Seawalls against soil liquefaction and its caused ground displacement

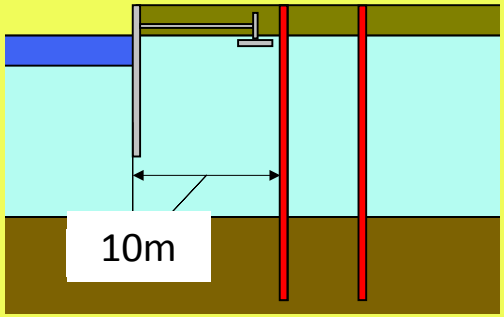
Continuous Wall

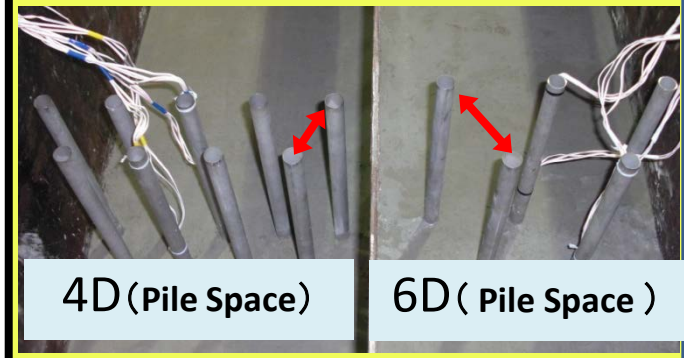


Soil Improvement



Pile Group

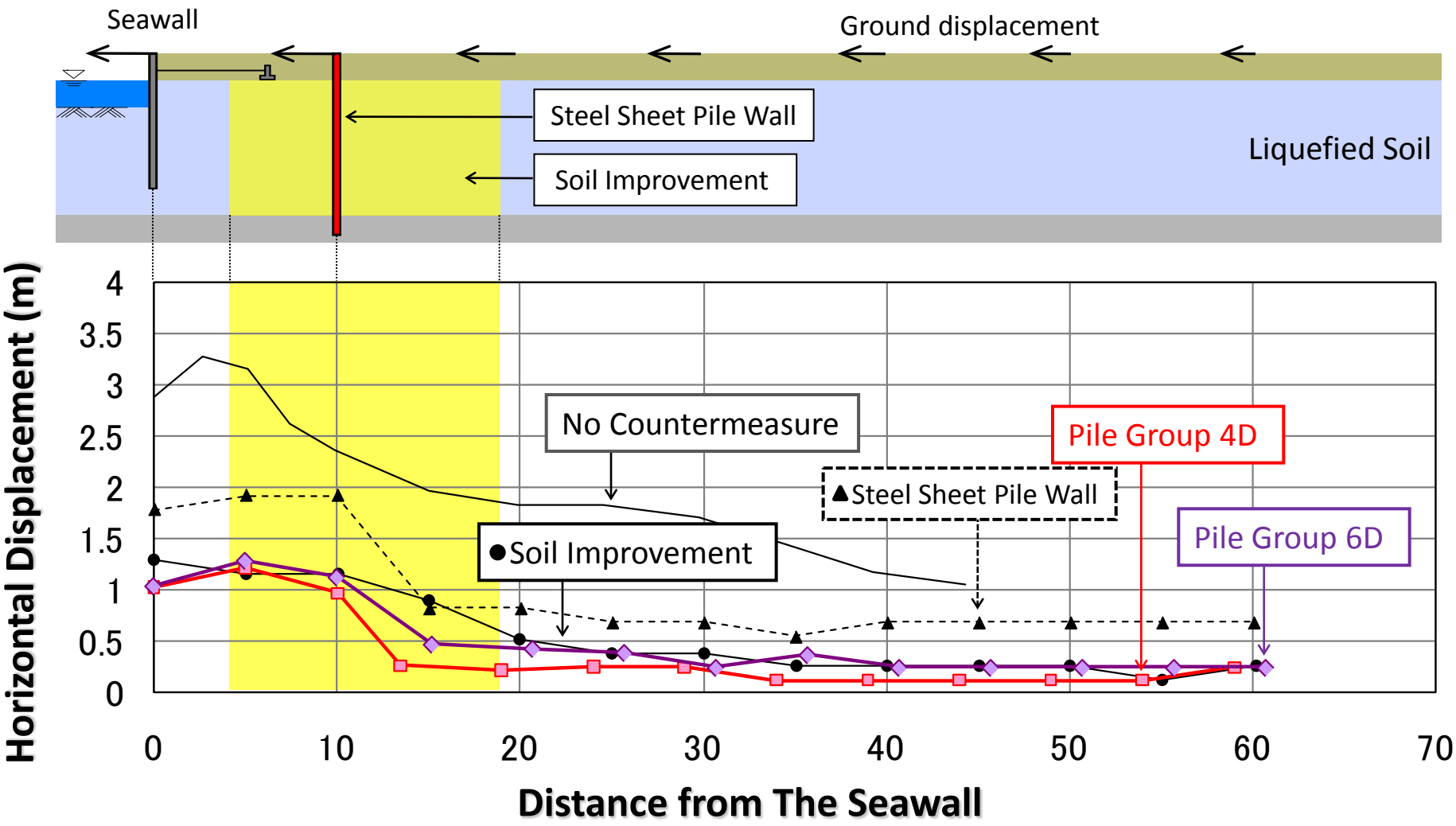




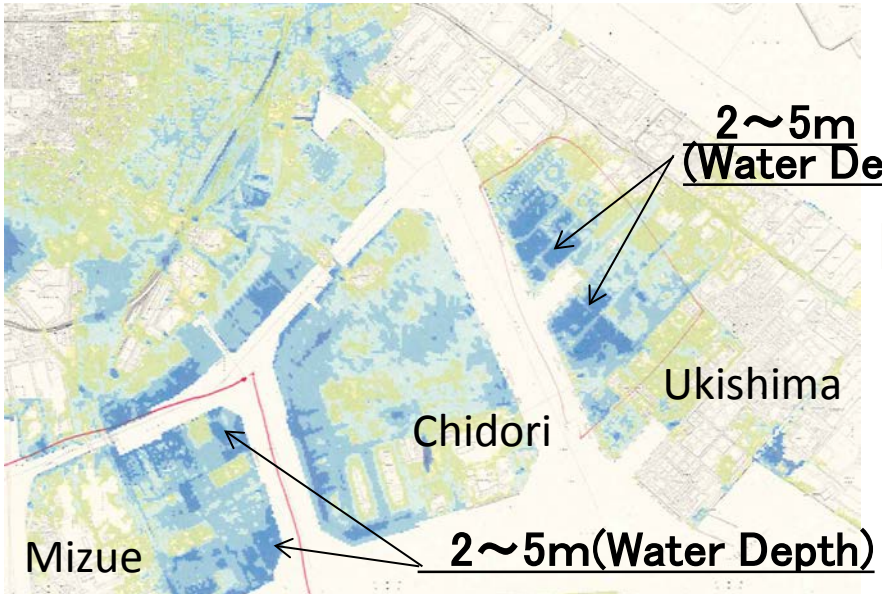
* D: Diameter of Pile

(Model for Experiment)

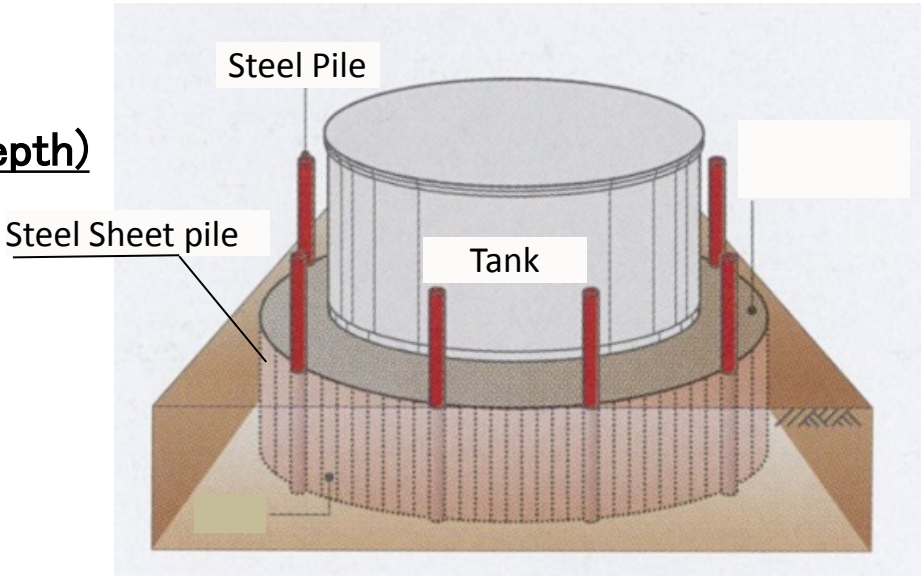
Reduction of Horizontal Displacements of Seawall and Ground by The Reinforcements



Protections for Industrial Facilities against Tsunami

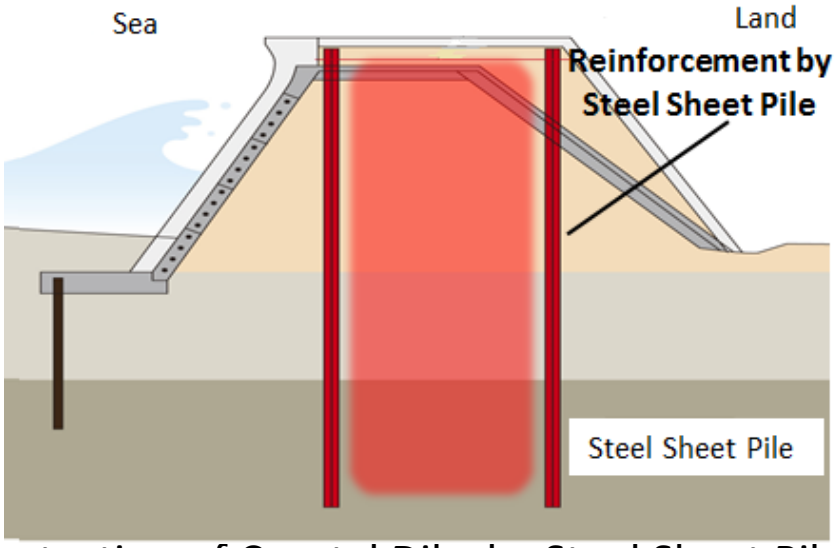


Assessment of Floodwater Depth at Keihin Industrial Complex



Measure of Protection against Floating Objects and Prevention of Lift-up by Floodwater

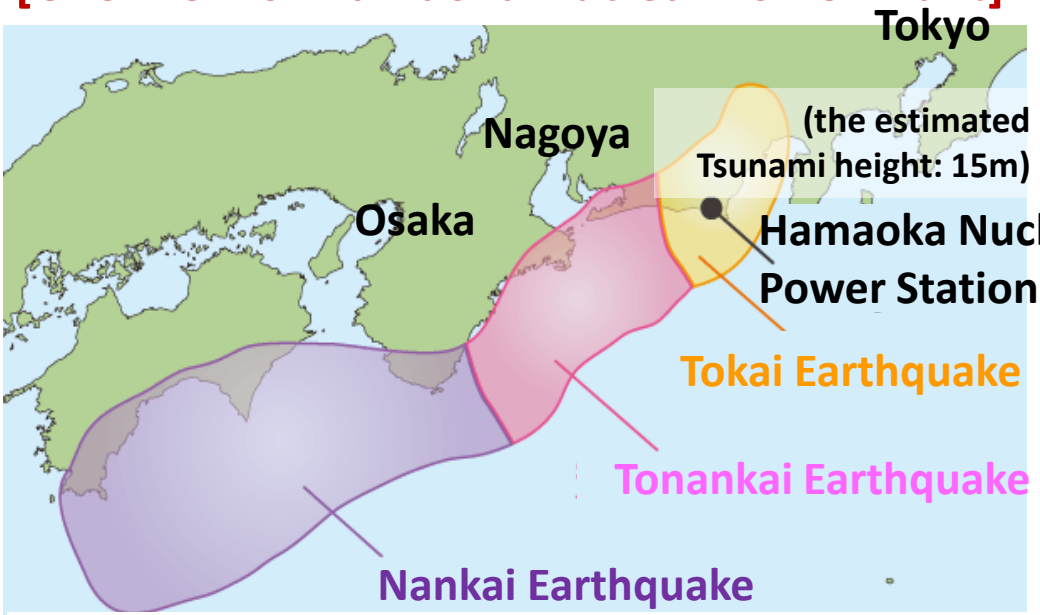
Protection of Coastal Dike by Steel Sheet Pile



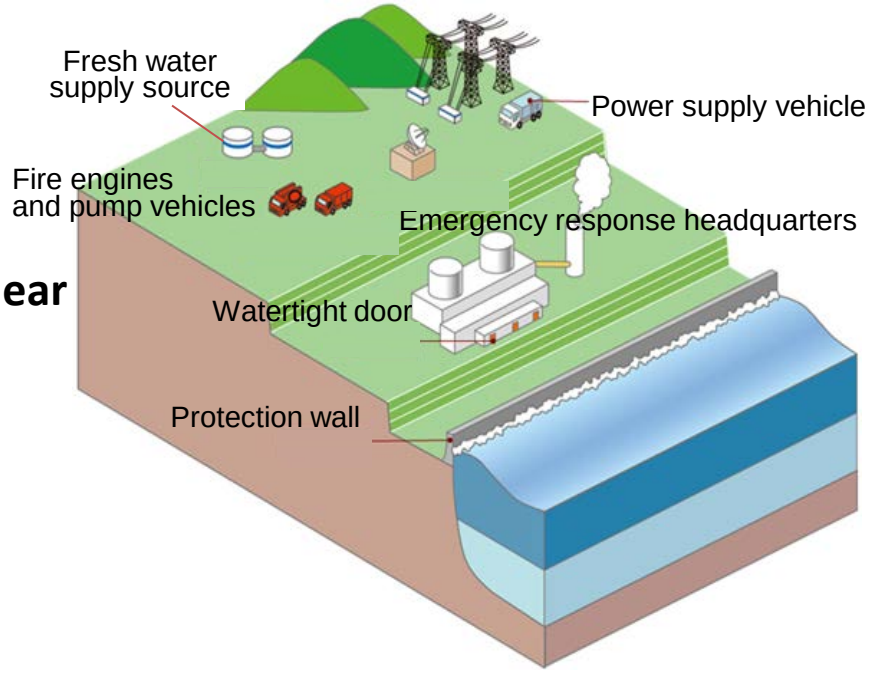
Protection of Coastal Dike by Steel Sheet Pile

Measures of Tsunami Protections for Nuclear Facilities

[Overview of Hamaoka Nuclear Power Plant]



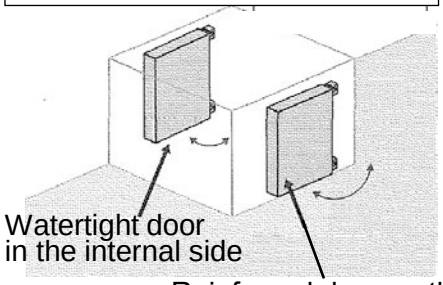
Hamaoka Nuclear Power Plant and Earthquake Sources along Nankai Trough



Tsunami Protection Measures of Hamaoka Nuclear Power Plant

Steel Frame Wall (with 18 m height)

A double-door configuration for doors attached to the external walls of buildings (conceptual illustration)



Watertight Door Attached to External Wall of Buildings

Basic Principles of The Fundamental Law for National Land Resilience

1. Save Human Life

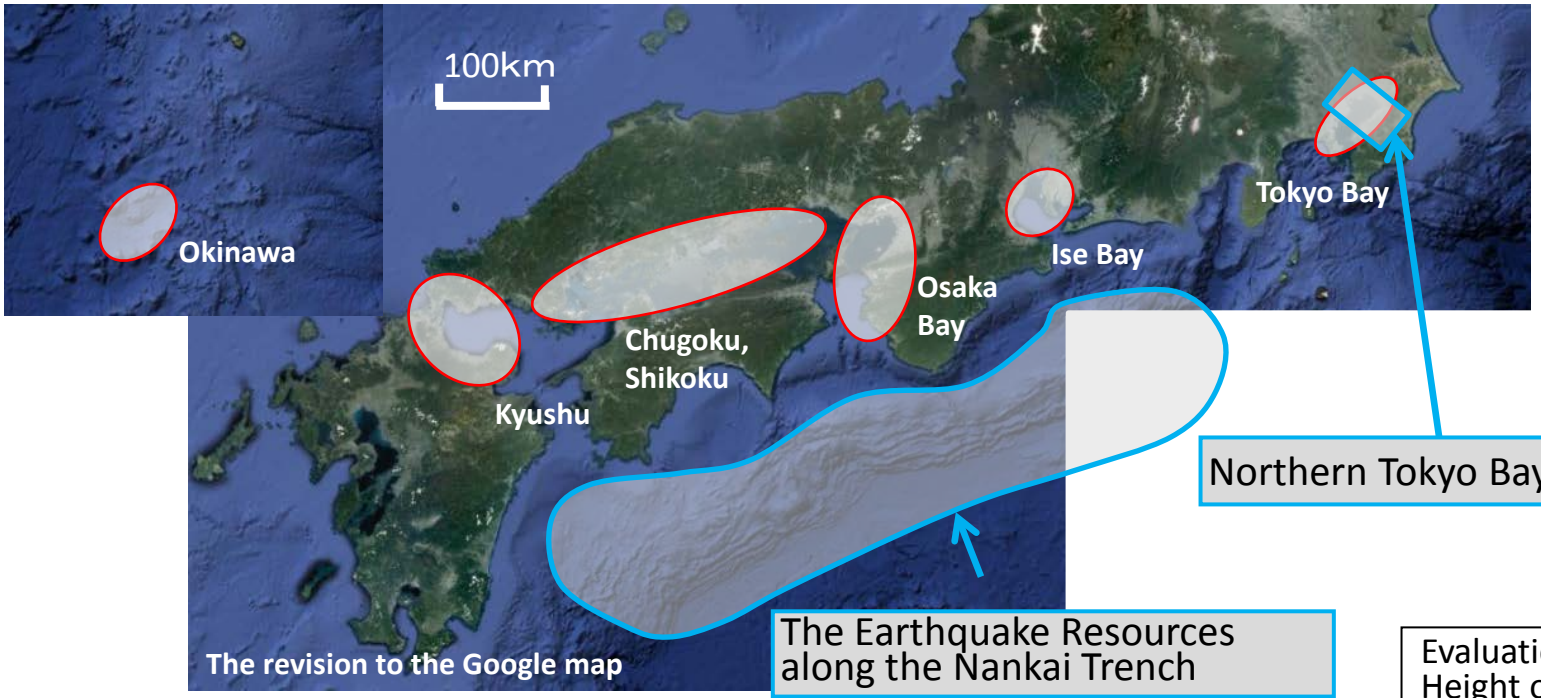
2. Prevent Critical Damage to Functions of The Nation and Local Communities

3. Minimize Loss of People's Property and Public Infrastructures

4. Smooth Recovery and Reconstruction

Policy by Ministry of Economy, Trade and Industry（2013～）

Northern Tokyo Bay Earthquake, Earthquake Resources along the Nankai Trench, and Locations od Petroleum Complexes



Evaluation of Tsunami Height of Flood

Flow of Assessment of Damage to Petroleum Complexes by Future Earthquakes

Soil Condition Survey for Assessment of Soil Liquefaction → Assessment of Soil liquefaction of Artificial Islands → Assessment of Stability and Deformation of Quaywalls → Assessment of Ground Displacement → Assessment of Damage to Petroleum Complexes due to Earthquake Motion, Soil Liquefaction, Ground Displacement and Tsunami

Recommendations for Earthquake-Resistance Enhancement of Industrial Complexes

1. Earthquake-resistance enhancement in larger areas（Whole areas of man-made islands and bay areas ）
2. Strong leadership by the national and local governments
3. Public investment for private industrial facilities
4. Share of disaster risk information among industries and local communities
5. Assessment of the impact of damage to industrial complexes on the national economy and societies

Private and public dikes along the Keihin canal