Management of the Impact of Earthquake on Sewerage Services

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1. Earthquake and Sewerage

Many earthquakes have so far attacked Japan where citizens in urban areas have difficulties in their daily lives due to the deterioration of urban infrastructures.

Since the sewerage system is indispensable for urban lives, it is crucial to predict and prepare for the seismic damage of the sewerage system. Two types of measures are discussed against earthquakes; one is the construction of earthquake-proof facilities and the other is the mitigation of the seismic damages. This paper deals with the methods to assess the vulnerability of the sewerage facilities and to predict the social impact of the failure in the sewerage functions. These methods are needed for local governments to establish the action plan against earthquakes.

2. Vulnerability Assessment

The seismic damages are predicted on the basis of the model earthquake, soil condition, material/structure of the facilities and so on. Seismic intensity-damage analysis is conducted by utilizing the statistical data collected in the earthquakes Japan experienced recently.

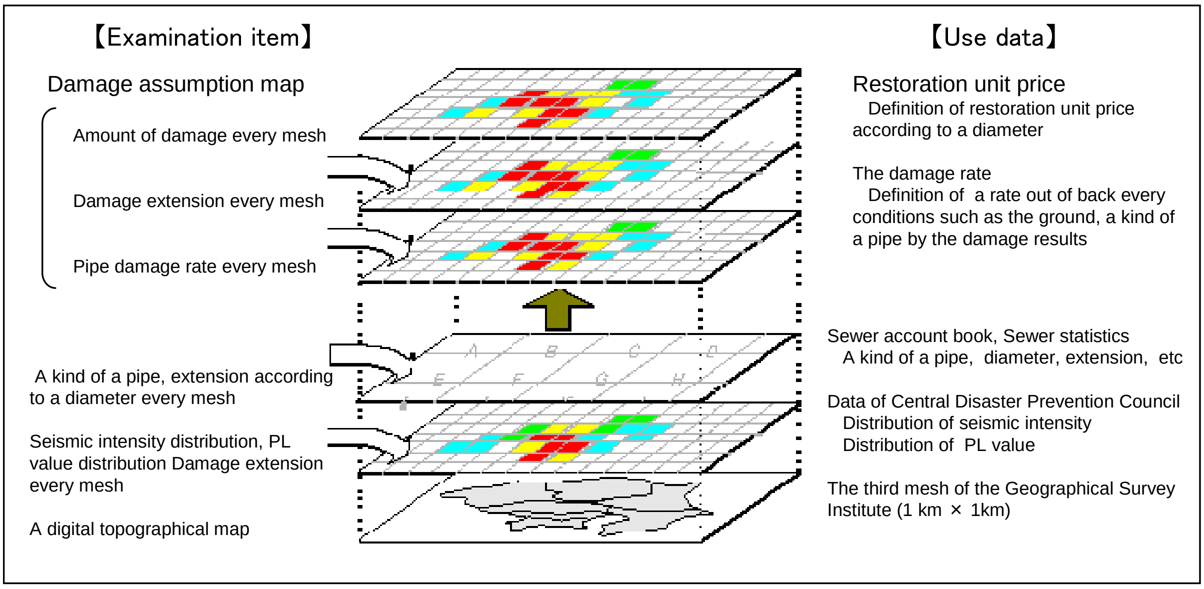


Figure 1 Damage Estimation Map of Sewer Networks

Vulnerability of the sewerage system is displayed on the digital topography that facilitates the formulation of the action plan.

3. Impact Analysis

Scenarios of the social impact of earthquakes are studied, paying attention to the interactive relationship between sewerage and other infrastructures in supporting both of daily lives and industrial/commercial activities. Typical risks related to the sewerage and water supply are shown in Figure 2.

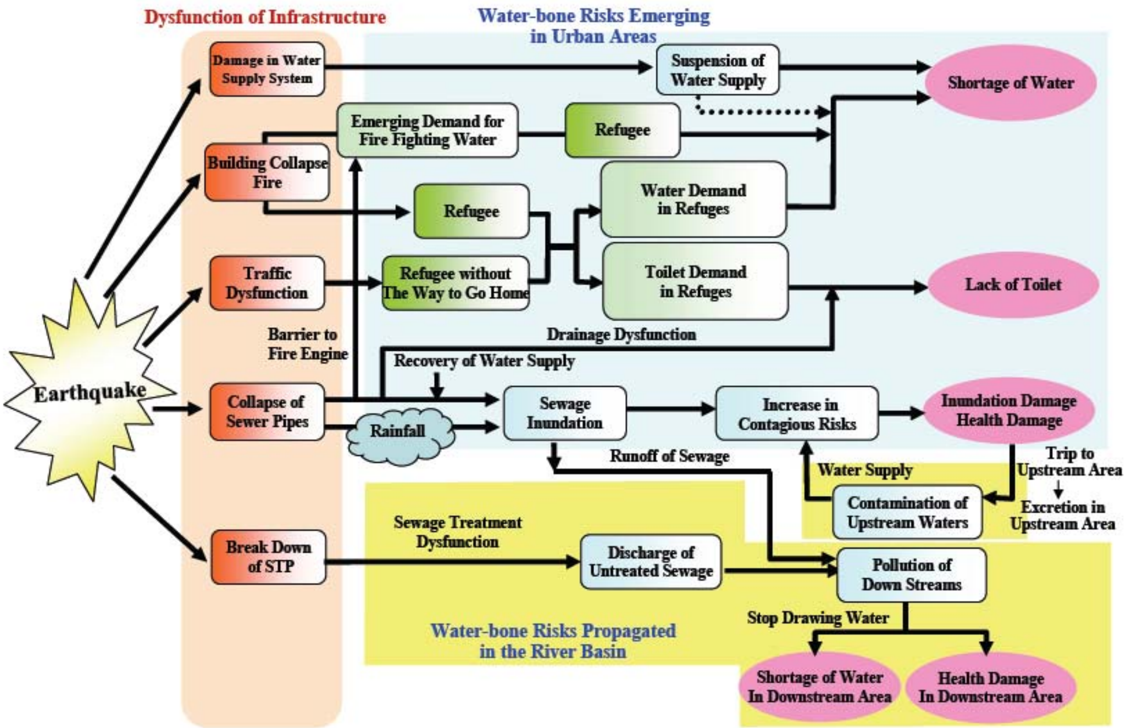


Figure 2 Scenario Analysis of Dysfunction of Sewerage and Water Supply System

There are two types of waterborne risks: one is emerging in urban areas and the other is propagated downstream in the river basin.

Quantitative evaluation was tried based on the following scenarios.

(1) Impact of the deteriorated sanitation on daily lives

One of the main difficulties is the lack of flush toilet service due to the cut-off of water supply. The behavior of business persons without toilet service was analyzed on the basis of the questionnaire survey in the central business district around Tokyo station which is expected to be mostly crowded with hundreds of thousand people after a huge earthquake. The result suggests the necessity of water-free toilet such as “manhole toilet” as well as of the installation of earthquake-proof toilet facilities on the commuters’ main routes for home in the suburbs.

(2) Epidemic risk propagation through water recycles in a river basin

A case study was conducted for Lake Biwako - Yodogawa River water system which 14 million people depend upon. Water is recycled through repeated water intake from and discharge into the river. Discharge of raw sewage and leakage of toxic chemicals from seismically damaged facilities of sewerage and other industries can cause suspension of water supply in large areas downstream.

4. Action Plan against Earthquake

Measures against the targeted earthquake are prioritized on the basis of the vulnerability assessment and impact analysis in the formulation of the action plan. An example of the actions for earthquake-proof reinforcement in a wastewater treatment plant is shown in Figure 3.

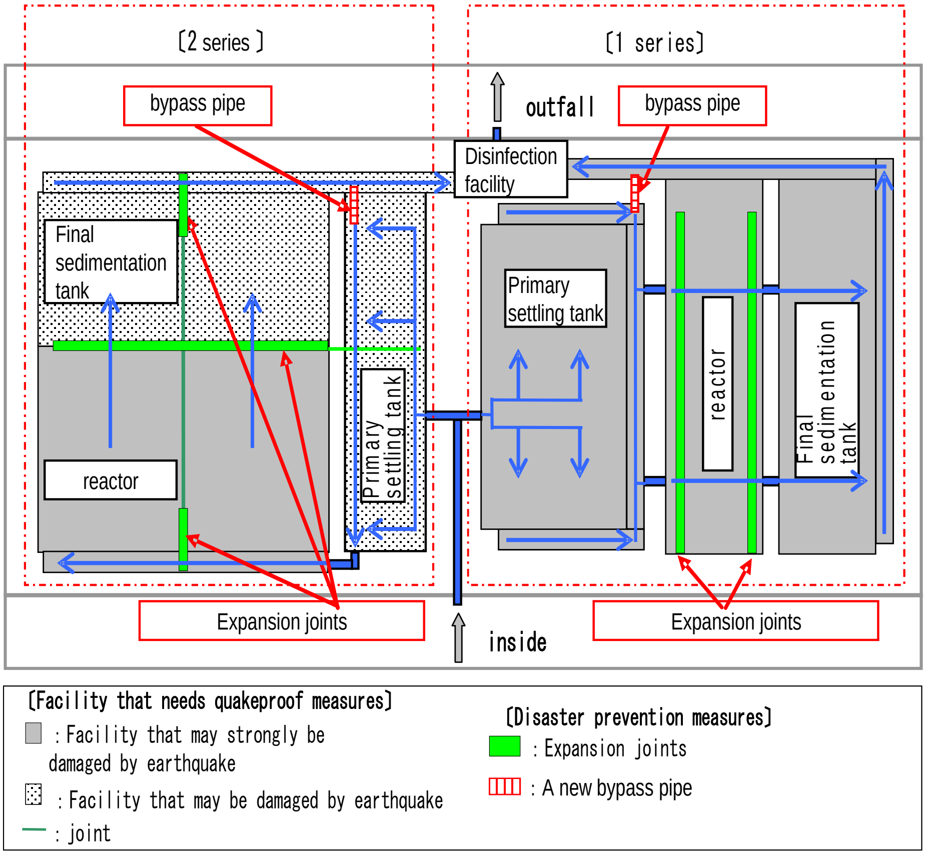
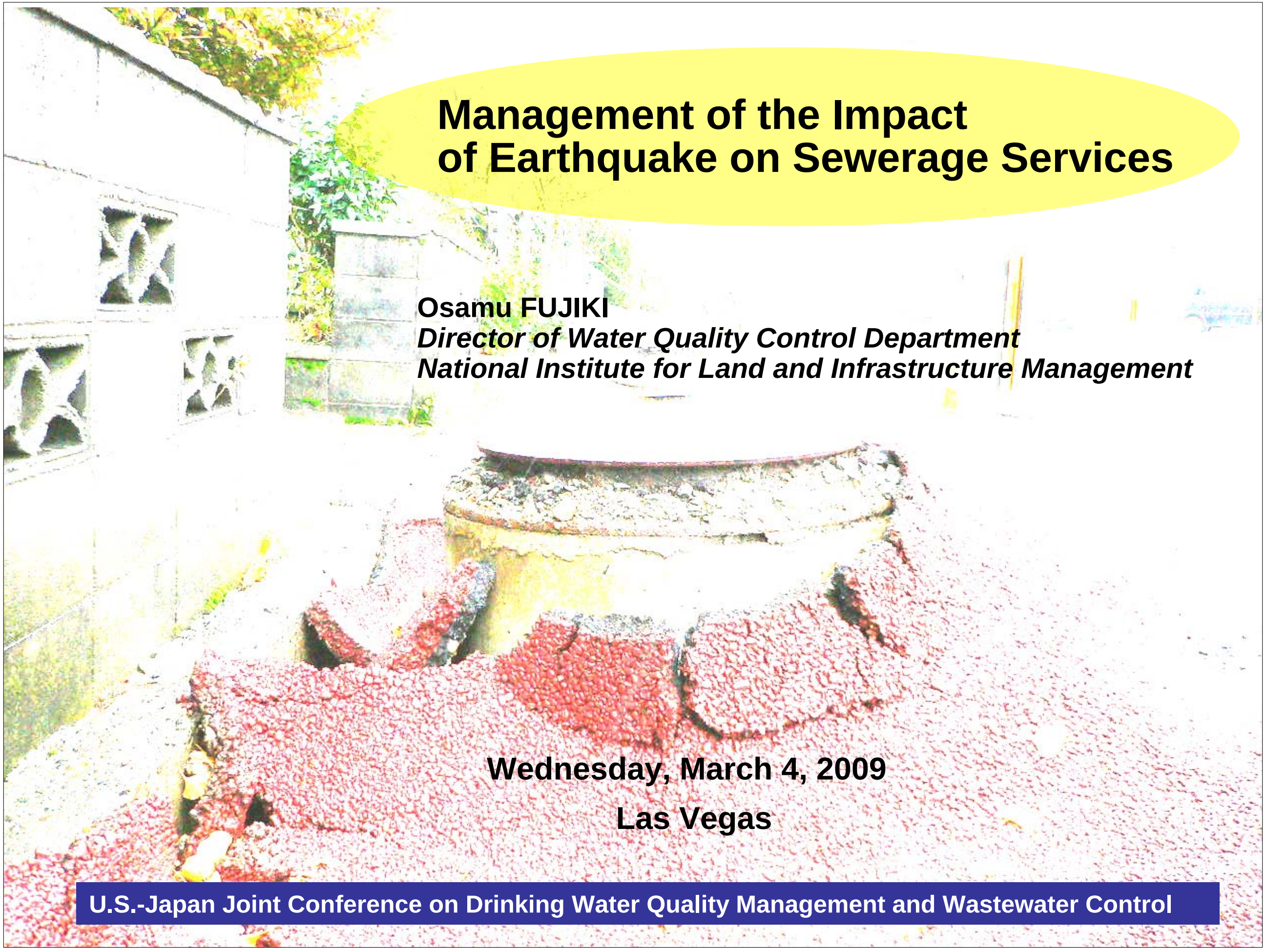


Figure 3 Example of the Earthquake-proof Reinforcement in a Wastewater Treatment Plant



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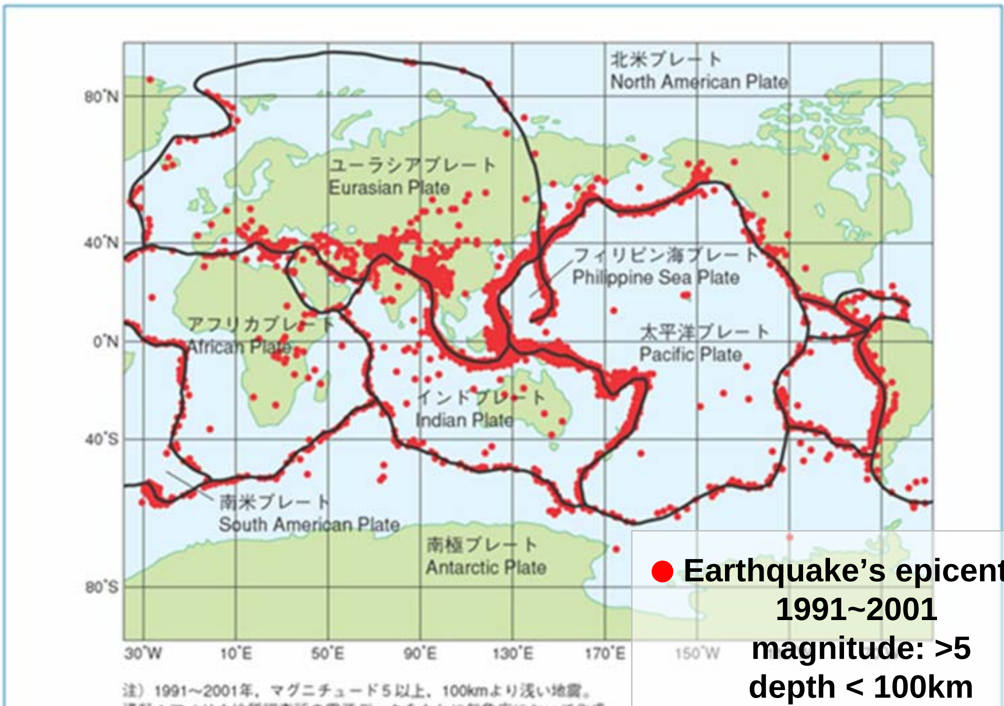
Distribution map of earthquake's epicenter



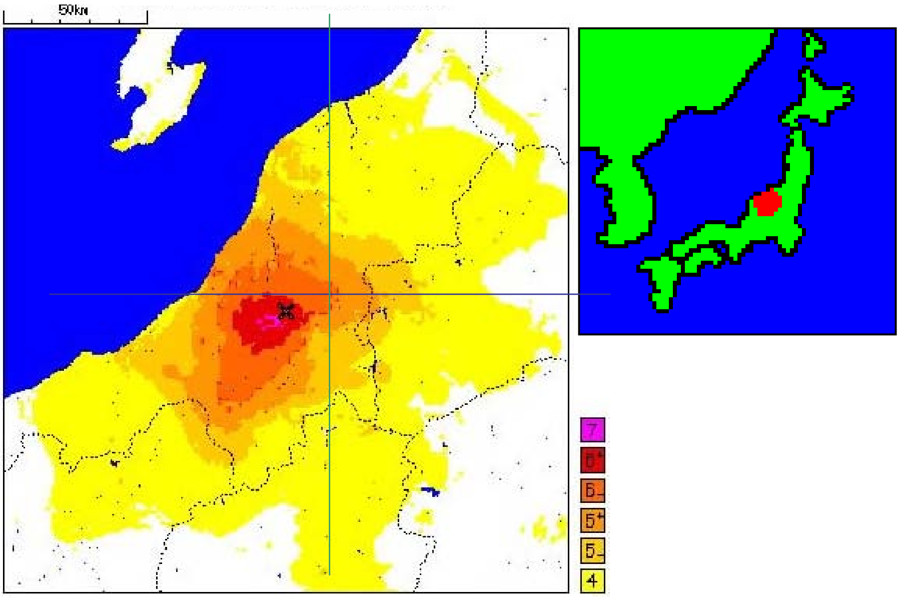
● **Earthquake's epicenter**
1991~2001
magnitude: >5
depth < 100km

Source : the Japan Meteorological Agency

The Niigata-Ken Chuetsu Earthquake

(2004.Oct.23) **M6.8**

Seismic Intensity Distribution



37.3 degrees north latitude, 138.9 degrees of east longitude, depth 13km M6.8

Source: Japan Meteorological Agency

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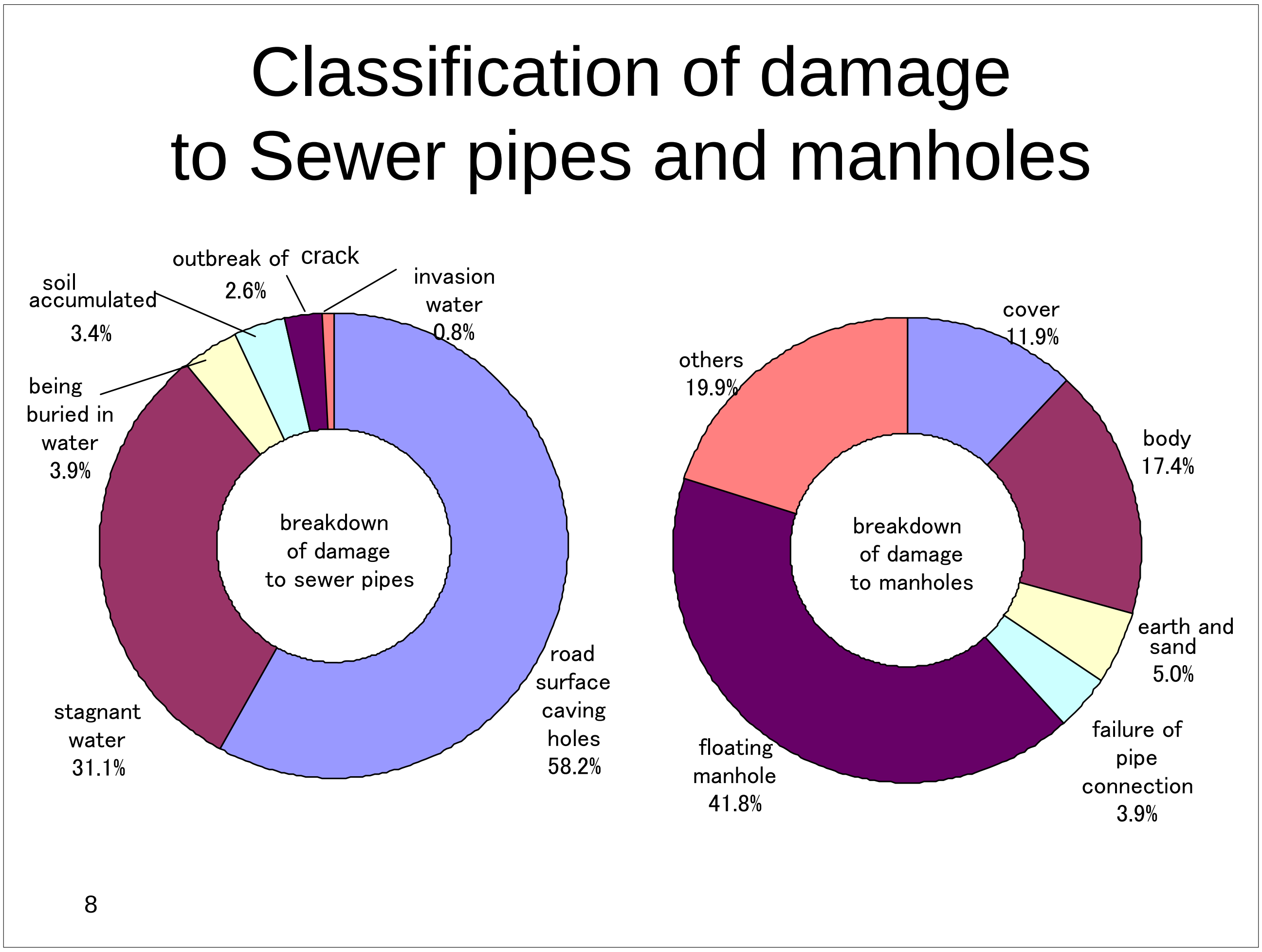
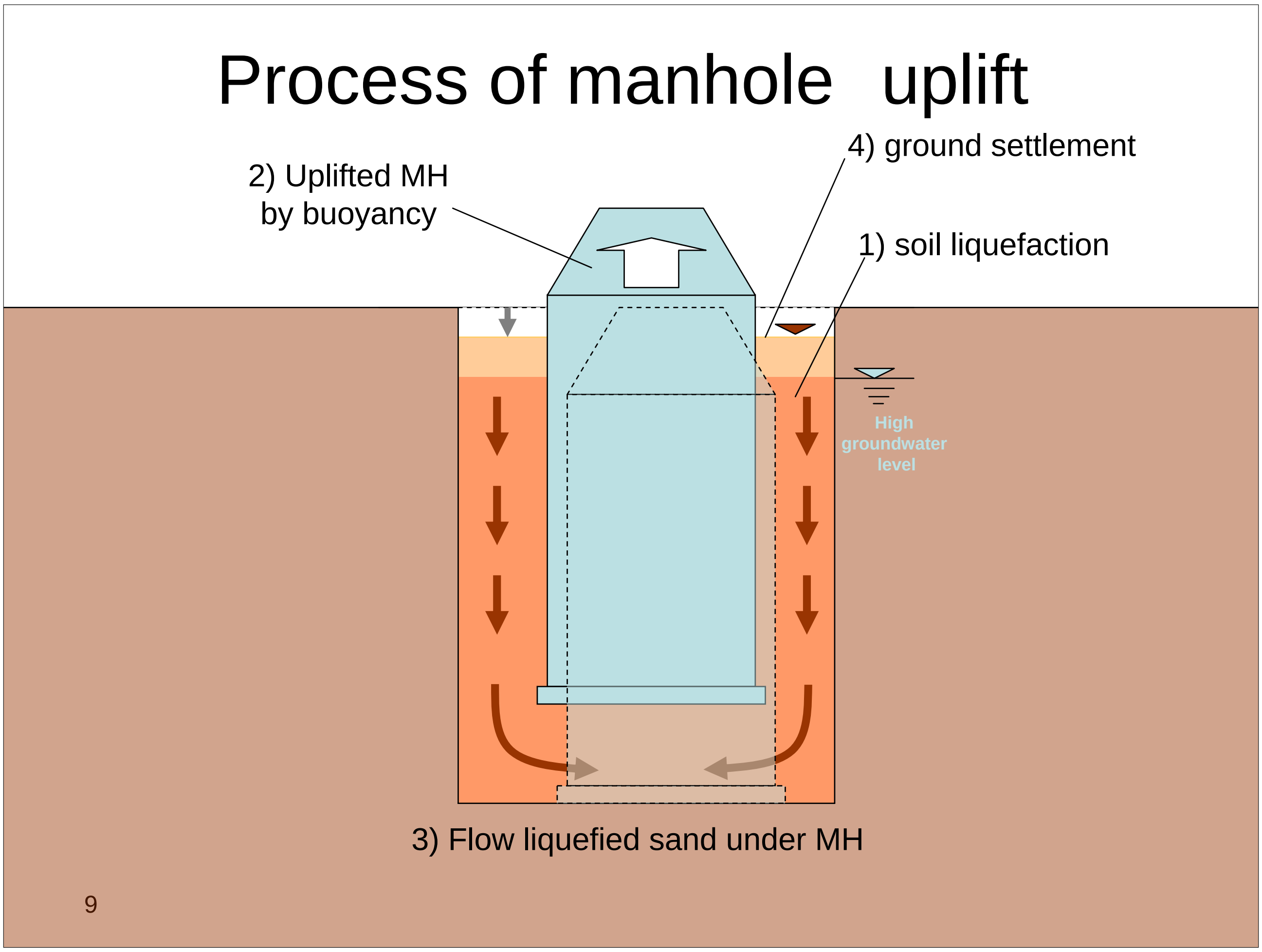

Classification of damage
to Sewer pipes and manholes
soil accumulated 3.4%
outbreak of crack 2.6%
invasion water 0.8%
being buried in water 3.9%
breakdown of damage to sewer pipes
stagnant water 31.1%
road surface caving holes 58.2%
others 19.9%
cover 11.9%
body 17.4%
breakdown of damage to manholes
earth and sand 5.0%
failure of pipe connection 3.9%
floating manhole 41.8%
8

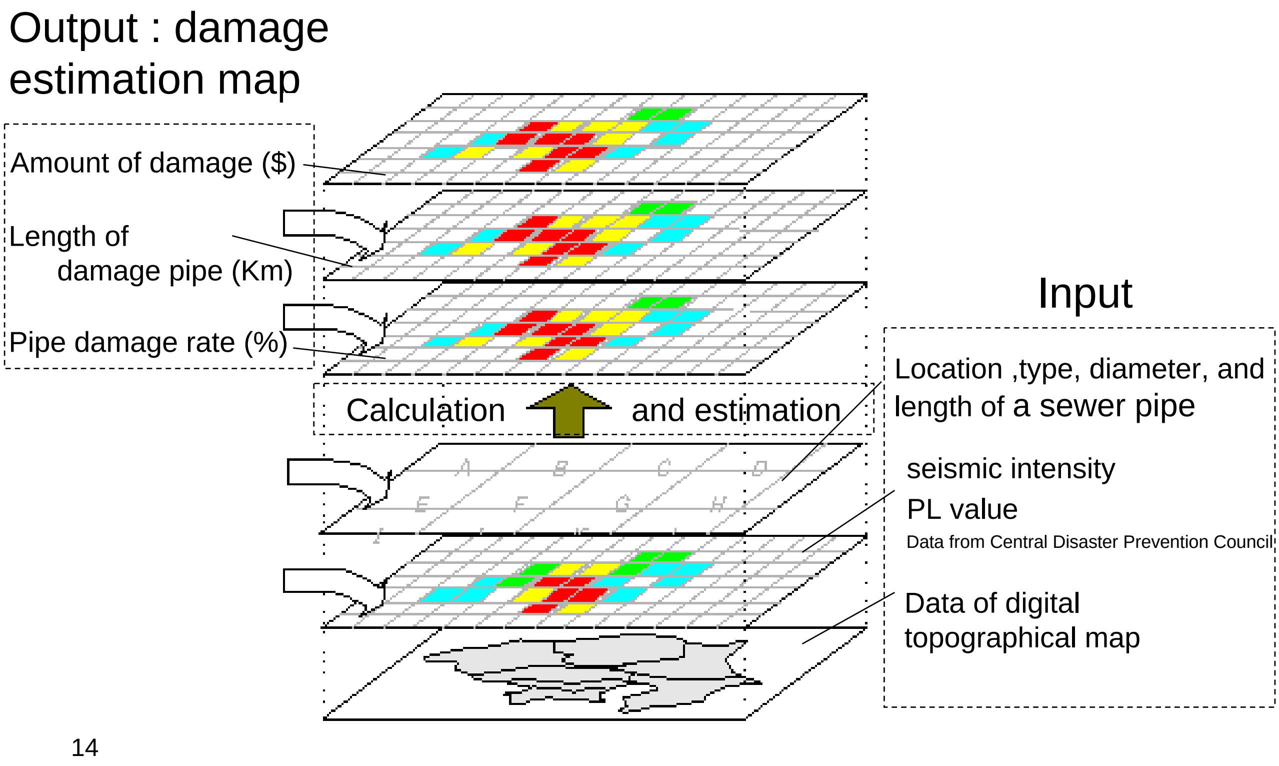

Process of manhole uplift
2) Uplifted MH
by buoyancy
4) ground settlement
1) soil liquefaction
High
groundwater
level
3) Flow liquefied sand under MH
9


10


11


12

Concept of damage estimation method for sewer pipes



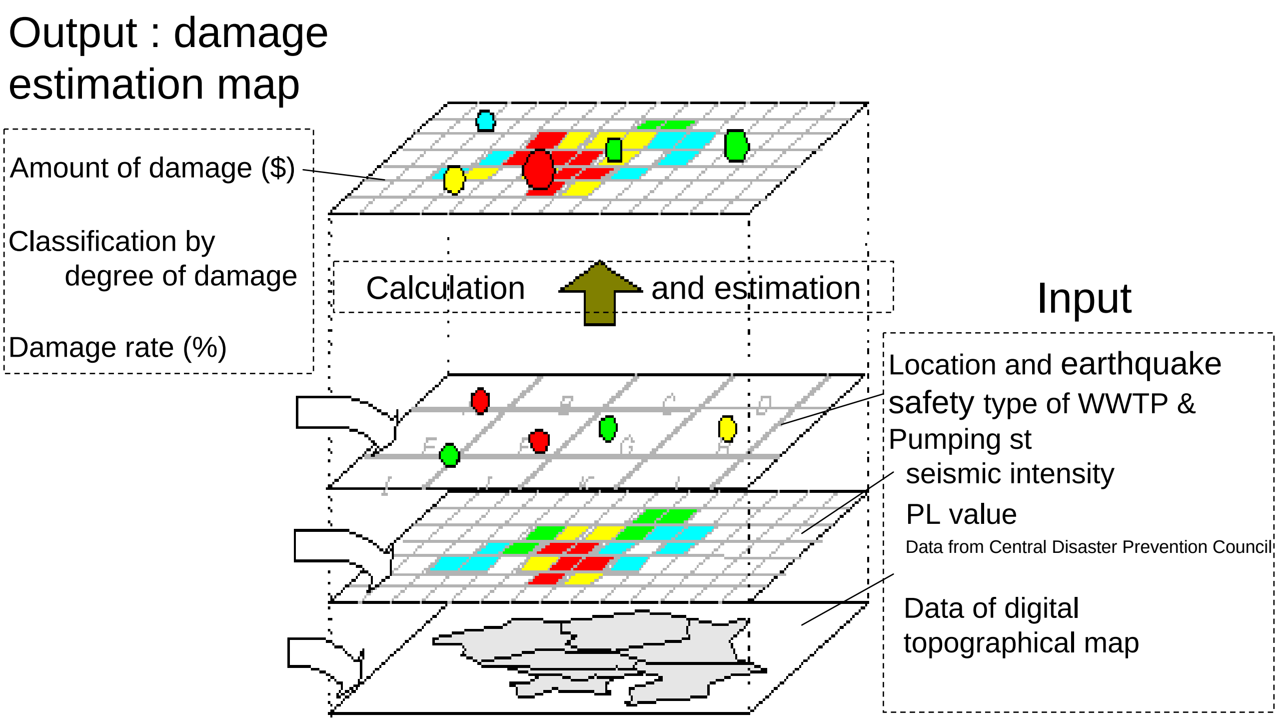
Potential of Liquefaction (PL)

- PL is the weighted sum of the strength against the sharing stress toward depth at the ground in question.
- PL is used as an indicator of liquefaction.

value	potential of liquefaction
0	very low
0<PL<=5	low
5<PL<=15	medium
15<PL	high

15

Concept of damage estimation method for WWTP & Pumping Station



16

Target：
Expected North Tokyo Bay Earthquake

simulated by Central Disaster Prevention Council

- Estimated earth quake center
  Northern Tokyo Bay (located immediately below Tokyo Metropolitan Area)
- Target **magnitude 7.3** based on earthquake record in Japan since 1600

- According to earthquake record in Japan since 1600,

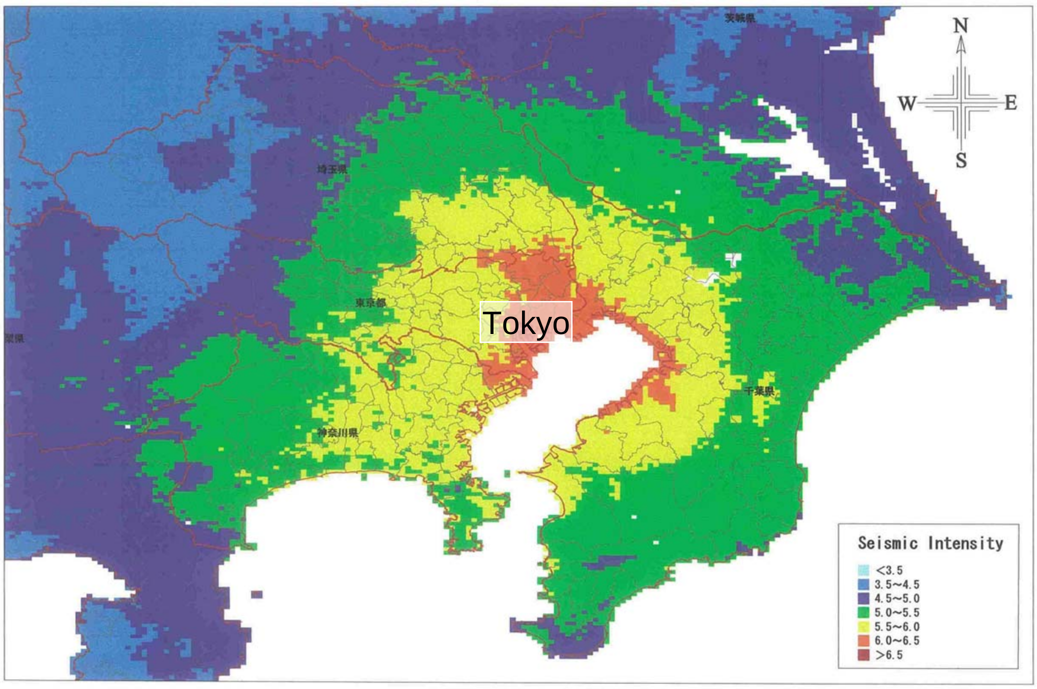
→ Over Magnitude 8.0 : 2 earthquakes in 1703 and 1922
→ Over Magnitude **8.0** : **Low- frequency** in next 100 years

→ Magnitude 7.0-8.0 : 10++ earthquakes since 1600
→ Magnitude 7.0-8.0 : a couple of earthquakes in last 200 years
→ Magnitude **7.0-8.0** : **High possibility** in next 100 years

17

(Source: Central Disaster Prevention Council)

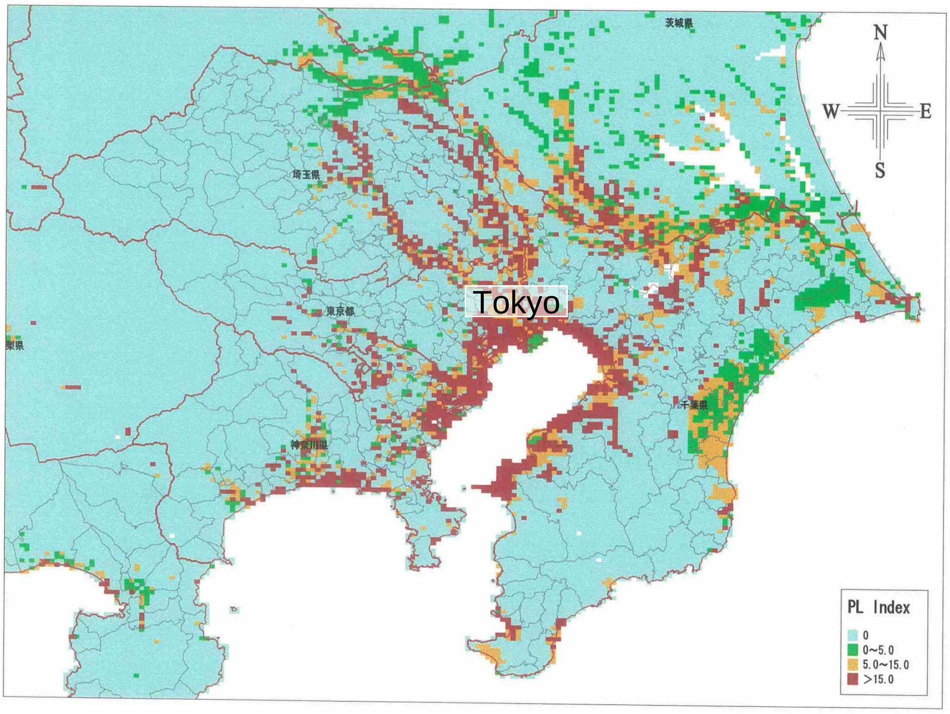
Seismic Intensity Distribution Map of the North Tokyo Bay Earthquake



18

Source : the Central Disaster Prevention Council

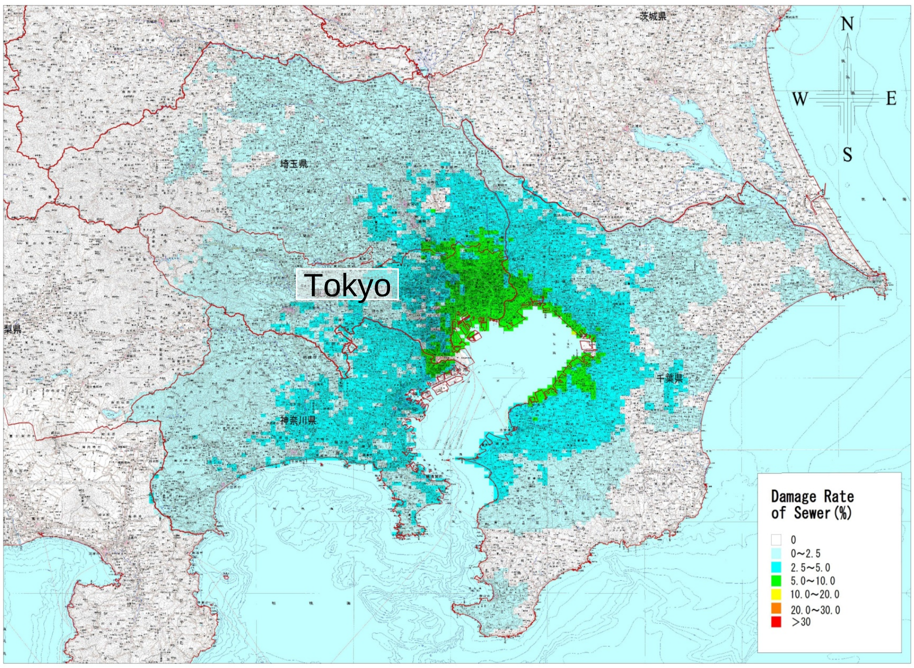
PL Value Distribution Map of the North Tokyo Bay Earthquake



19

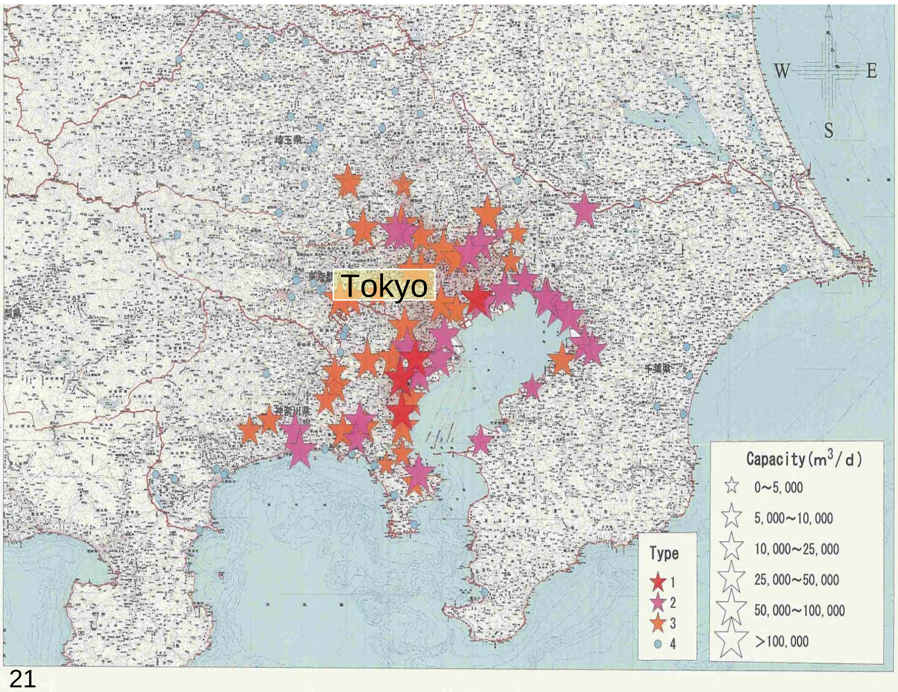
Source : the Central Disaster Prevention Council

Damage Rate Estimation Map of Sewer Pipes under the North Tokyo Bay Earthquake



20

Classification Map of WWTP damage under the North Tokyo Bay Earthquake



Type-1
Damage by ground lateral flow
Type-2
Damage by liquefaction
Type-3
Damage by seismic force
Type-4
Slight damage

21

Estimation of Damage to Pipe

	Average	Max
$\frac{\text{Km of damaged pipe}}{\text{Km of current pipe}}$ (%)	2.9%	22.0%
Amount of damage (million US $)	5,343 million	38,888 million

1 US $ = 100 JPN

Area: Saitama pref, Chiba pref ,Tokyo metropolitan area ,Kanagawa pref

22

Estimation of Damage to WWTP & Pumping station

	Average	Max
Amount of damage (million US $)	1,590 million	4,056 million

1 US $ = 100 JPN

Area: Saitama pref, Chiba pref ,Tokyo metropolitan area ,Kanagawa pref
122 WWTPs and 537 Pumping stations

23

Estimation of the Number of people who can’t access sewage system

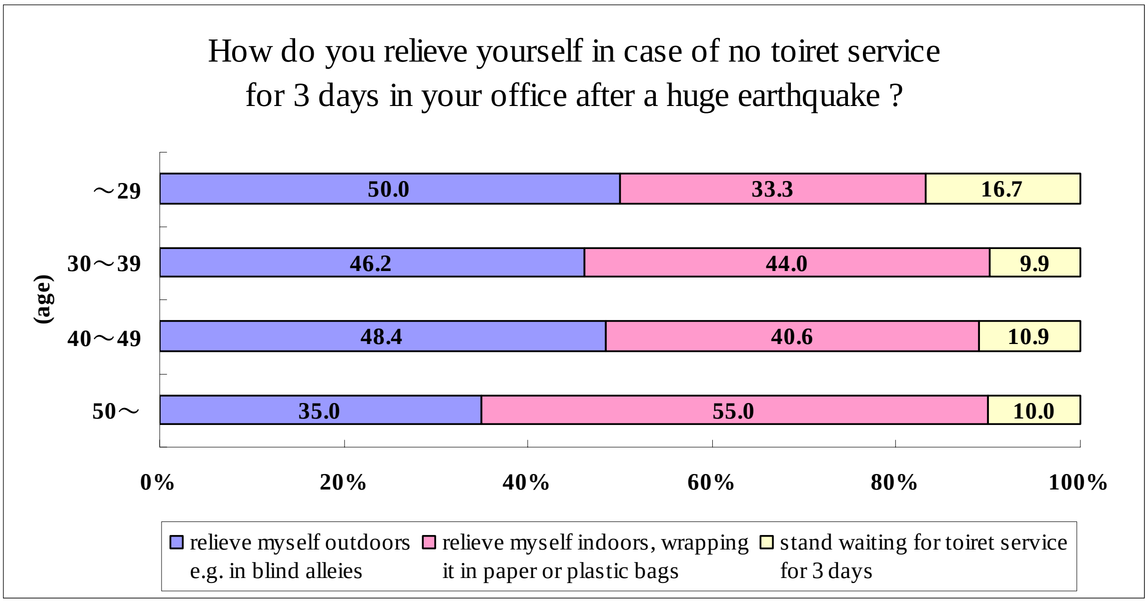
	Average	Max
Number of people As daytime population	961,000	6,431,000

Area: Saitama pref, Chiba pref ,Tokyo metropolitan area ,Kanagawa pref
122 WWTPs and 537 Pumping stations

24

Answer to the Questionnaire on the Survival after a Huge Earthquake

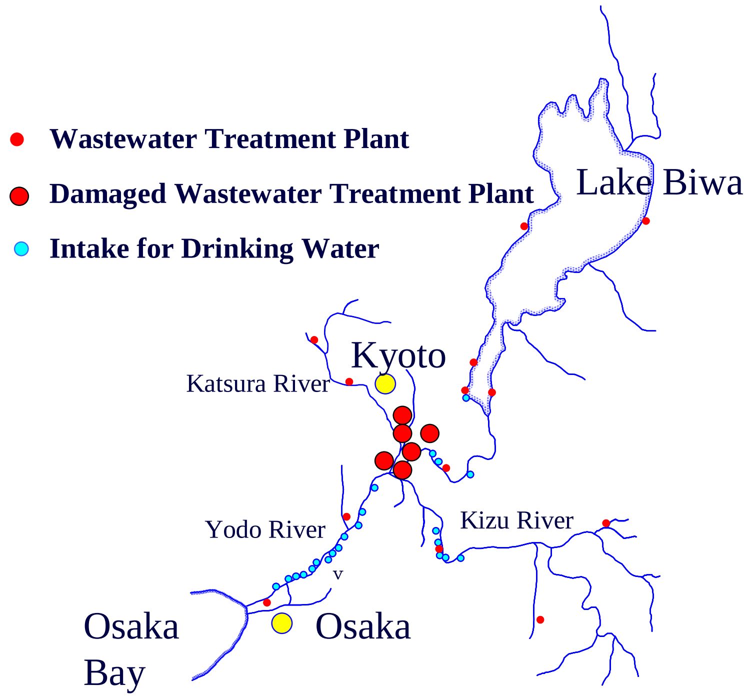
225 (male:89, female:136) out of 700 nominated office workers replied to the questions on the supposition that they have to stay at office without water supply for flush toilet for 3 days after a huge earthquake



25

Survey field : Central Business District around Tokyo Station

Scenario Analysis for Biwako-Yodogawa River water system



Suppositions

Large scale earthquake of maximum seismic intensity six-odd on the Japanese scale attacks upriver area of the Yodogawa River basin in winter when the river flow is relatively small.

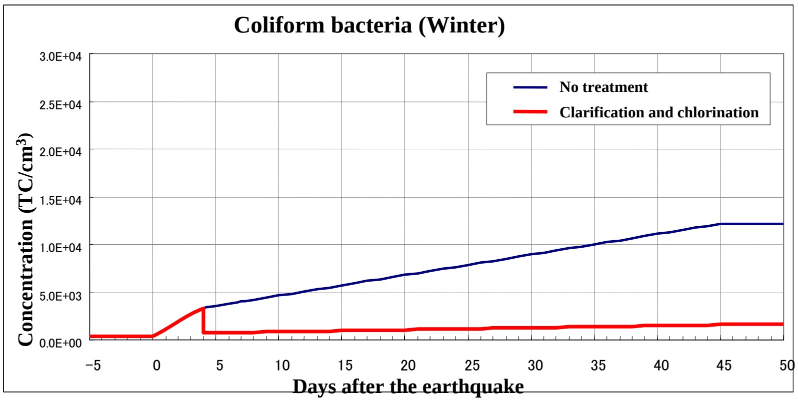
6 WWTPs are damaged and cease to work. The influent raw sewage is discharges into the Yodogawa River without treatment but simple clarifier and chlorination facility resume their functions on the 5th day after the earthquake.

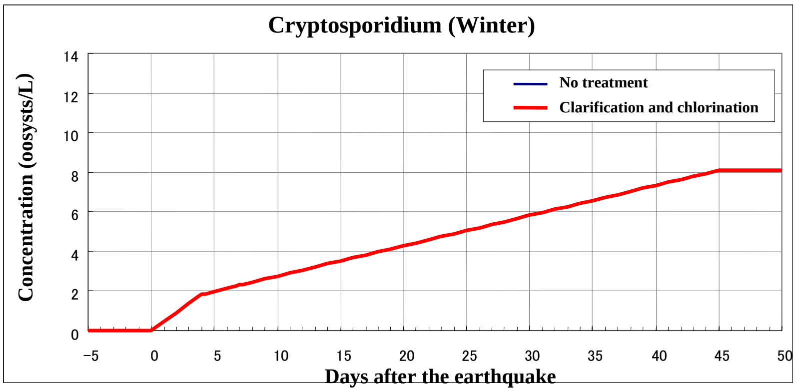
Water supply is cut off just after the earthquake. But 25 % of the capacity is restored on the 5th day after the earthquake and total capacity is completely restored on the 46th day.

26

Estimated Change in the Concentrations of Coliform Bacteria and Cryptosporidium

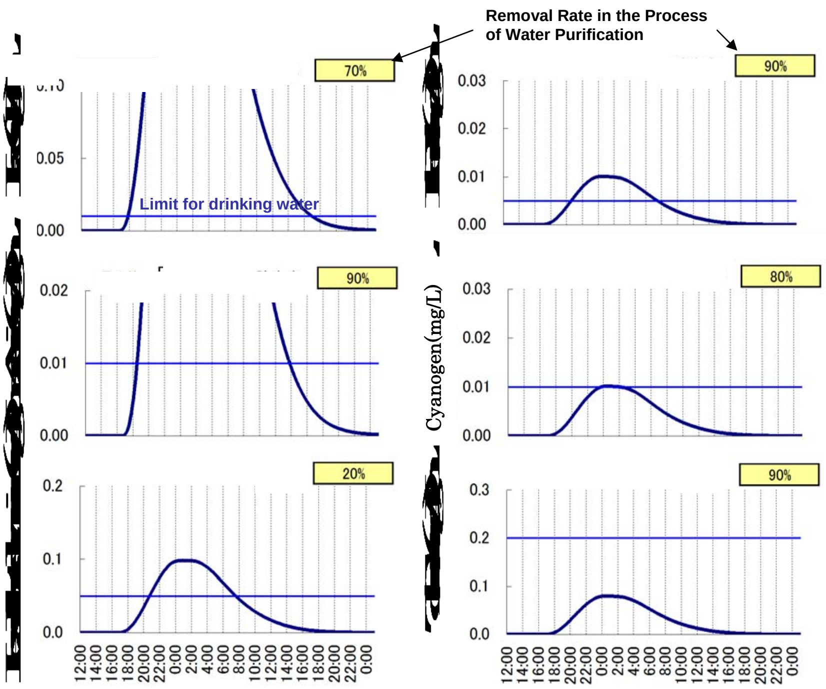
at the water intake point of 26 km upstream from the river mouth





27

Estimated Variation in the Concentration of Toxic Substances in Drinking Water



Targeted Toxic Substances

(1) Lead and its compounds (as the concentration of lead) (2) Arsenic and its compounds (as the concentration of arsenic) (3) Hexavalent chromium and its compounds (as the concentration of hexavalent chromium) (4) Phenols (as the concentration of phenol) (5) Cyanide ion and cyanogen chloride (as the concentration of cyanogen) (6) Toluene

Suppositions

Damaged area is caught in a shower of 25mm in total for 6 hours.

The storm water washes toxic substances out of the damaged factories and other business facilities and conveys them into the Yodogawa River.

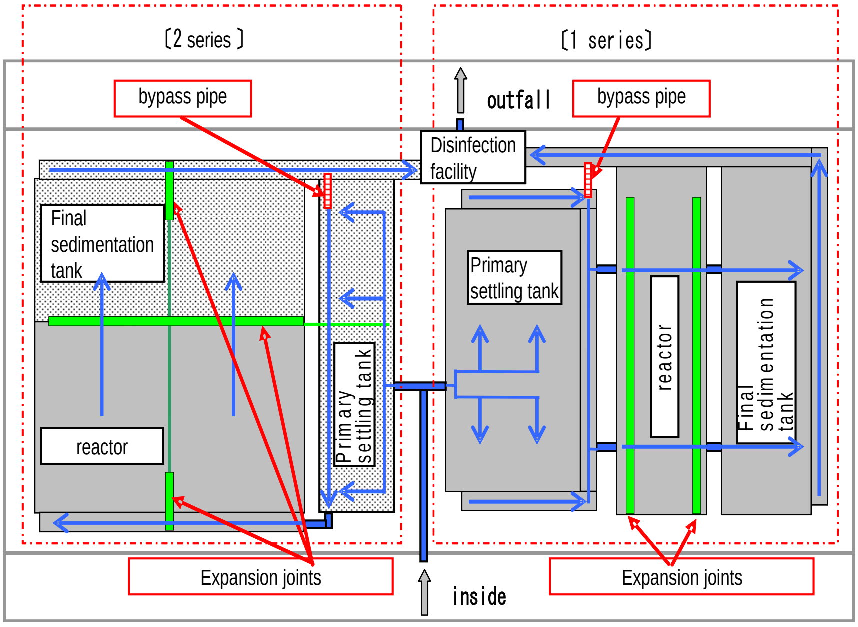
The damage ratio is set at 0.23.

Half amount of every stored toxic substance in damaged facilities is assumed to be washed out into the river.

The storage amount is set at 2weeks / 52 weeks (a year) of the annual dealing amount which is estimated from the data registered in the PRTR (Pollutant Release and Transfer Register) System.

28

Example of the Earthquake-proof Reinforcement in a Wastewater Treatment Plant



〔Facility that needs quakeproof measures〕

: Facility that may strongly be damaged by earthquake

: Facility that may be damaged by earthquake

: joint

〔Disaster prevention measures〕

: Expansion joints

: A new bypass pipe

29

Road surface caving by broken pipe

Failure of pipe connection

Disasters occur because they come too late to remember.

Thank you for your attention !

Floating of manhole

The car which collided with floating manhole

30

Procedures of the Vulnerability Assessment

（1）The predicted distribution of seismic intensity of large earthquake level in the Tokyo area is prepared.

（2）The sewer facility damage may be caused by liquefaction of soil and sand sedimentation. The trunk sewer does not have damage of flow function since the tractive force is large enough to sweep the soil and sand sediments which flow in at the damaged parts. On the other hand, the branch sewer might have damages related to flow function i.e. blockage of sewer.

(3) As an indicator of liquefaction, PL value was used. PL value is the weighted sum of the strength toward depth direction against the shearing stress. The relation between PL value and sediment deposit damage rate due to liquefaction is shown below.

Relation between PL Value and sediment deposited rate

PL	Sediment deposited rate
PL=0	0.000
0<PL≦5	0.008
5<PL≦15	0.019
15<PL	0.068

(4) The damage of sewer per unit length is estimated using data of the past records. The total amount of the sewer damage in the Capital area (Tokyo Bay North area) is estimated to be 30 billion yen.