Japanese experience and lessons learned from the Great East Japan Earthquake

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Outline of Presentation

0. Outline of the Great East Japan Earthquake

1. Experience and Lessons learned from the Great East Japan Earthquake

2. Our challenge after the disaster

3. Conclusion

4. Way forward

Chapter 0.
Outline of the Great East Japan Earthquake

(Source:JICA)

Comparison with other Catastrophic Disasters

Historical Earthquake	Kanto	Hanshin	Sumatra	Chile	East Japan
Date	1923/9/1	1995/1/17	2004/12/26	2010/2/27	2011/3/11
Earthquake Magnitude	7.9	7.3	9.1	8.8	9.0
Japanese Intensity Scale	7	7	5～6	(4～5)	7
Casualties	105,835	6,400	220,000	802	15,600
Undiscovered Casualties	-	3	77,000		4,800
Cause of Casualties	Earthquake & Fire	Earthquake	Tsunami	Tsunami	Tsunami
Fully Collapsed Houses	109,713	104,000	139,000 Aceh	150,000	115,000
Burned-out Houses	212,353	7,483	-	-	-

Chapter 1.
Experience and lessons learned from the Great East Japan

Japanese Experience
~Road Network~

People-oriented

Multifunction/Multilayer

Multidisciplinary approach

Resilient Road Network enables us to rehabilitate as soon as possible

1. Construction of High-spec roads
2. Quick Recovery with assistance provided by local constructors
3. Quick Reconstruction with support of in-land constructors

(Source: MLIT)

Reliable Road Network makes it possible that emergency relief are smoothly provided.

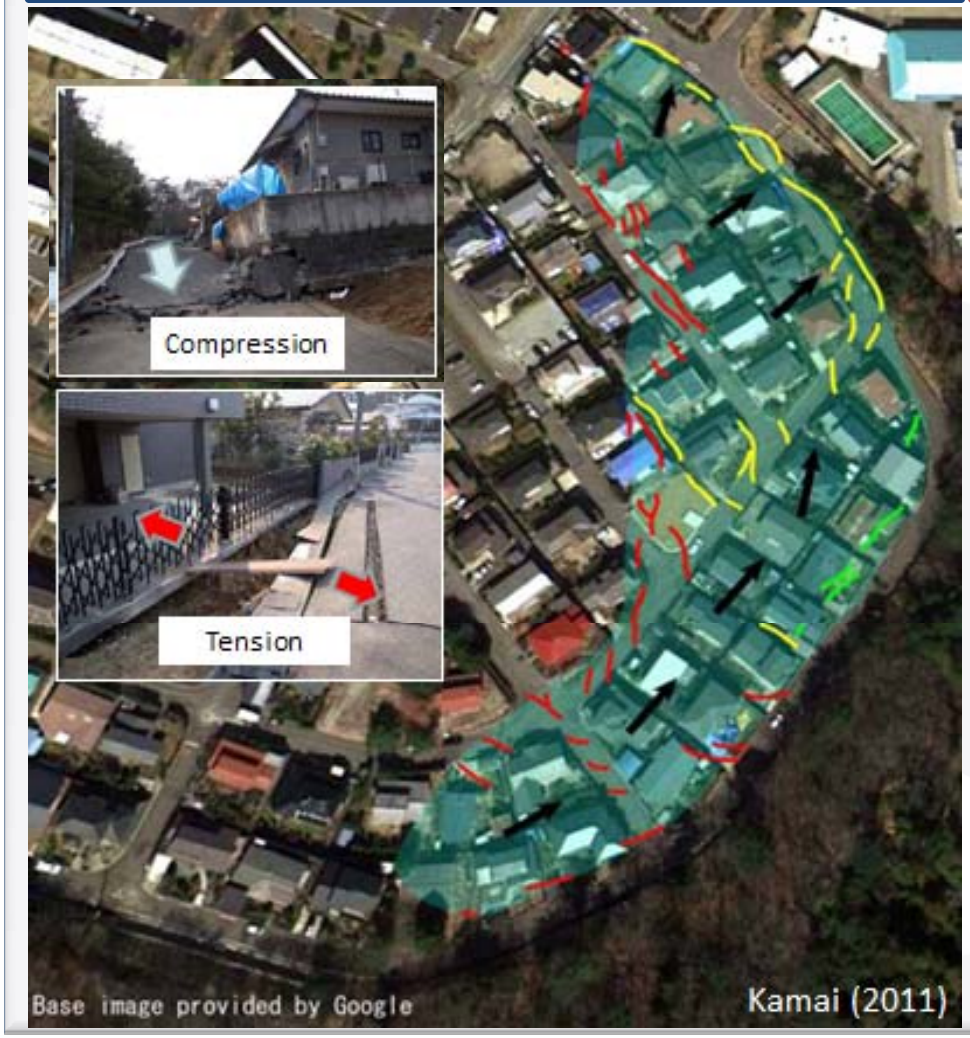
Urban Planning

Smooth Response

Multi-functioned Road

“Multidisciplinary approach” may reduce economic loss and realize resilient society.

Earthquake-induced Landslide at newly developed area



Torrent coming downstream from a collapsed reservoir

What Giant Dykes told us

~ Case of Taro Village ~

(Photo: Asahi.com)

Name of disaster	Casualty
Meiji-sanriku Eq.	1867/2248(83%)
Syowa-sanriku Eq.	911/2773(33%)
Great East Japan Eq.	146/2466(5%)

Misunderstanding might invite tragedy.

Chapter 2.
Our challenge after the disaster

(Source:MLIT)

Keyword 1 : People-oriented

WHY WERE THE REAGION HEAVILY AFFECTED?

Insufficient understanding of function of measure

Anticipated risk
or
Estimated disaster scale

Target

Evacuation plan/Response
(Non-structure)

Disaster Education
(Non-structure)

Sea wall
(Structure)

Coastal Dike
(Structure)

Level to which society
should be protected

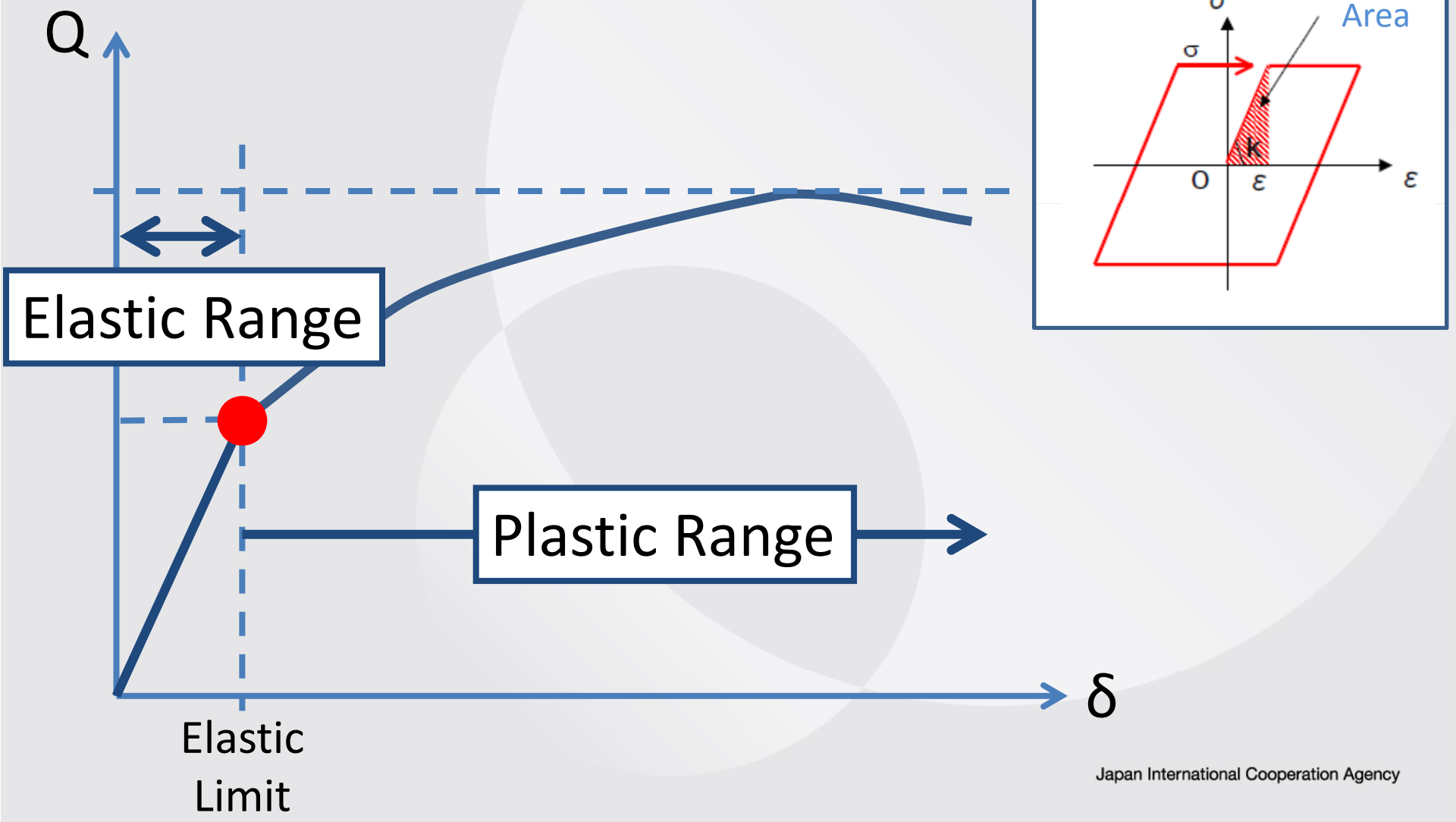
No perfect one single measure against any disaster

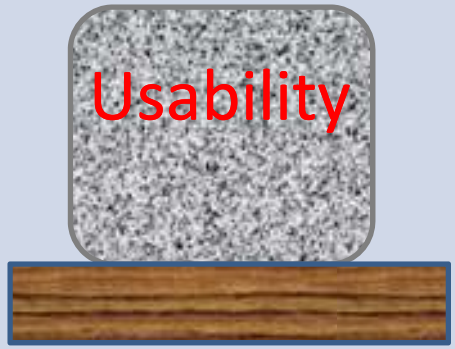
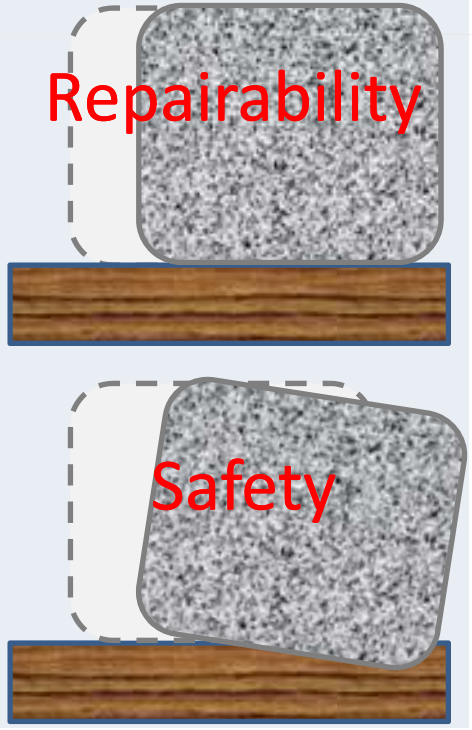
Redundant design basis event

☐Great Hanshin-Awaji Earthquake (Mw=7.2)(17 January, 1995)

Category	Earthquake ground motion	Tsunami
Level 1	having a high possibility of occurrence within the design working life of the facilities concerned (1-2 times within its life)	having a high possibility of occurrence within the design working life of the facilities concerned (100 year interval)
Level 2	having an intensity of the maximum scale among those expected to occur	having an intensity of the maximum scale among those expected to occur (100 year interval)

Fracture mechanism



Category	Targeted Tsunami	Functions to be required	Performance requirements
Level 1	100 year interval	(1)To save human lives (2)To protect assets (3)To maintain economic activities	
Level 2	1000 year interval	(1)To save human lives, combining with non-structure measures (2)To minimize economic damage (3)To prevent huge secondary disaster (4)To make it possible to quickly recover	

Success Story on Bullet Trains

5 out of 27 trains operated at the highest speed of 169mi/hr.

No Casualty and No derailed Train car
No damaged elevated tracks and tunnels

Why?

Disaster Risk Management of Bullet Train

Risk Literacy	Redundancy	Kaizen

（UrEDAS)
I.Function maintenance for inland quakes
II.Creation and Introduction of Redundant system
III.Relentless revision, taking account for advance in seismology

(Anti-derailed device)
I. Development and deployment of devices

(Elevated Tracks)
I.Redundant Building standards established
II.Retrofitting to structures and facility

Anti-derailed device

Seismic Retrofitting

Concept of Reconstruction

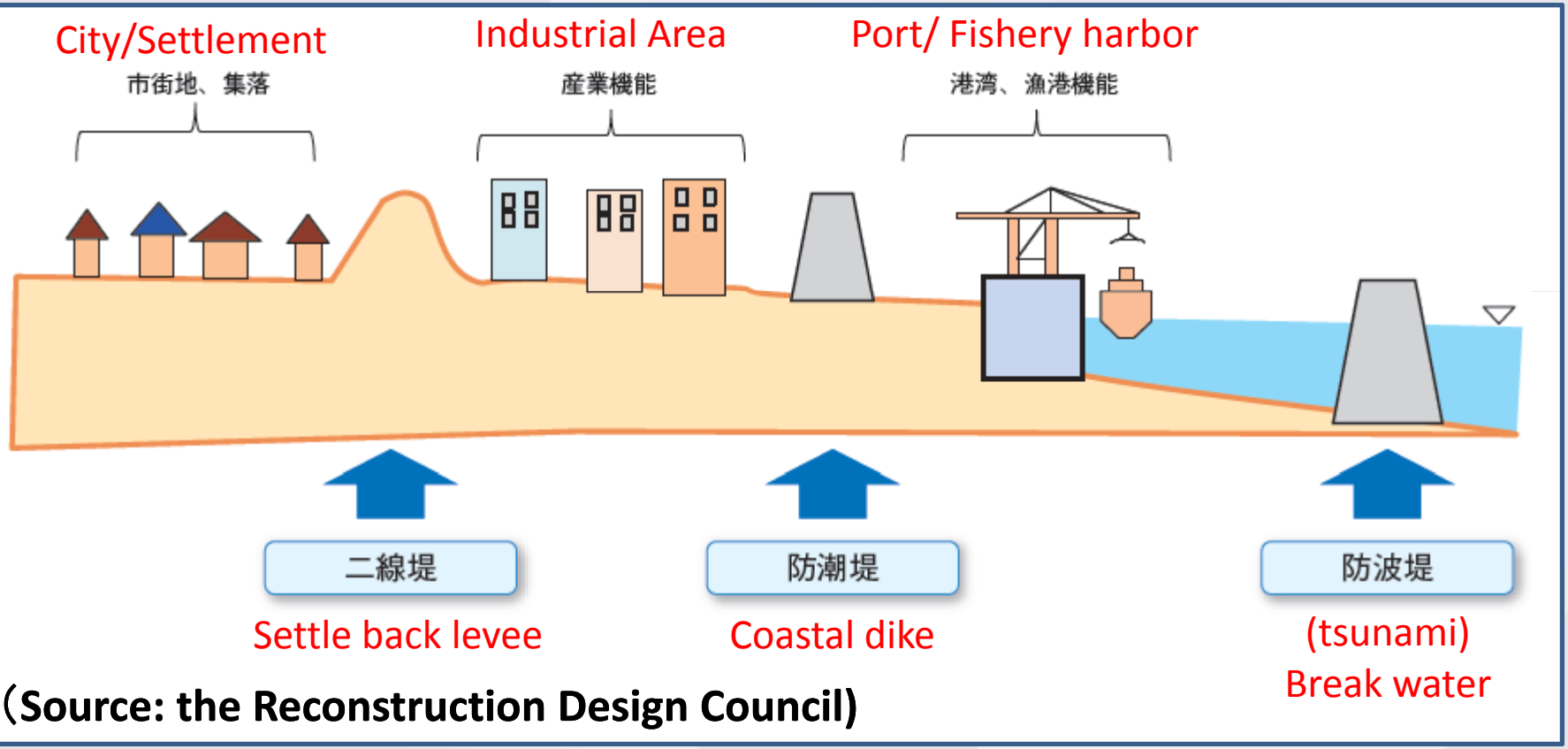
Realizing of Safe and Resilient Society

1. Reconsideration of people-oriented measures (design scenarios and regulations/codes) (Dispelling of misunderstandings in structure measures)
2. Urban Planning taking into consideration for multi-layer defense
3. Designing and construction of multi-purpose/ -function countermeasure

Keyword 2 : Multifunction/Multilayer

Keyword 3 : Multidisciplinary

Urban Planning with a concept of multi-layer defense



（Source: the Reconstruction Design Council)

Concept of "Disaster Reduction" ,not "Disaster Prevention"

①From Structure measures to People-oriented measures

②From "Linear-base planning" to "Area-based planning"

Elevated highway blocked tsunami and reduced damage

A professor advised to build higher embankment than its design for the aim of helping reduce damage as a second line levee.

3. Conclusion

Risk includes uncertainty and anticipation.

“Stopped thinking” may bring tremendous damage

Every infrastructures shall contribute to effective Disaster risk management (DRM).

- People-oriented
- Multifunction/Multilayer
- Multidisciplinary approach

4. Way forward

Toward unexpected disaster……

A) Preparation of materials to convince policymakers to accept the new concept

B) Preparation of materials to show incentive to additionally implement DRM on routine works by including other sectors

Thank you for your attention

JICA must endeavor to effectively shear the valuable experience and lessons with the international community.

Reference

Main damage of infrastructure

Items	Number
Casualty/Missing Evacuee	15,365 / 8,206 468,653 (Peak)
Building Damage	Completely Destroyed 111,044 houses Partly Destroyed 71,936 houses Partially Damaged 320,118 houses Burned Houses 261 houses
Port Damage	International and Key ports : 18 ports Local ports: 18 ports
Coastal Dyke Damage	190km out of 300km
Rode Infrastructure Damage	15 Highways, 69 national road 641 local roads
Inundation Damage	521 km^2

How to determine horizontal seismic coefficient

$$k_h = c_z \cdot c_s \cdot k_{h0}$$

Category	Area A	Area **B**	Area C
Compensation Coefficient	1.00	0.85	0.70

Category	Compensation Coefficient
Very important facility	1.0
General facility	0.7～0.8
Huge rigid structure	
Earth structure	0.5～0.7

Category	Category I	Category II	Category III
k_{h0}	0.16	0.20	0.24

Engineering effort to reduce any risk by eliciting misunderstanding

How to minimize limitation in structures' function

Thorough redundancy

Safe and Resilient Society

Earthquake ground motion (Level 1)

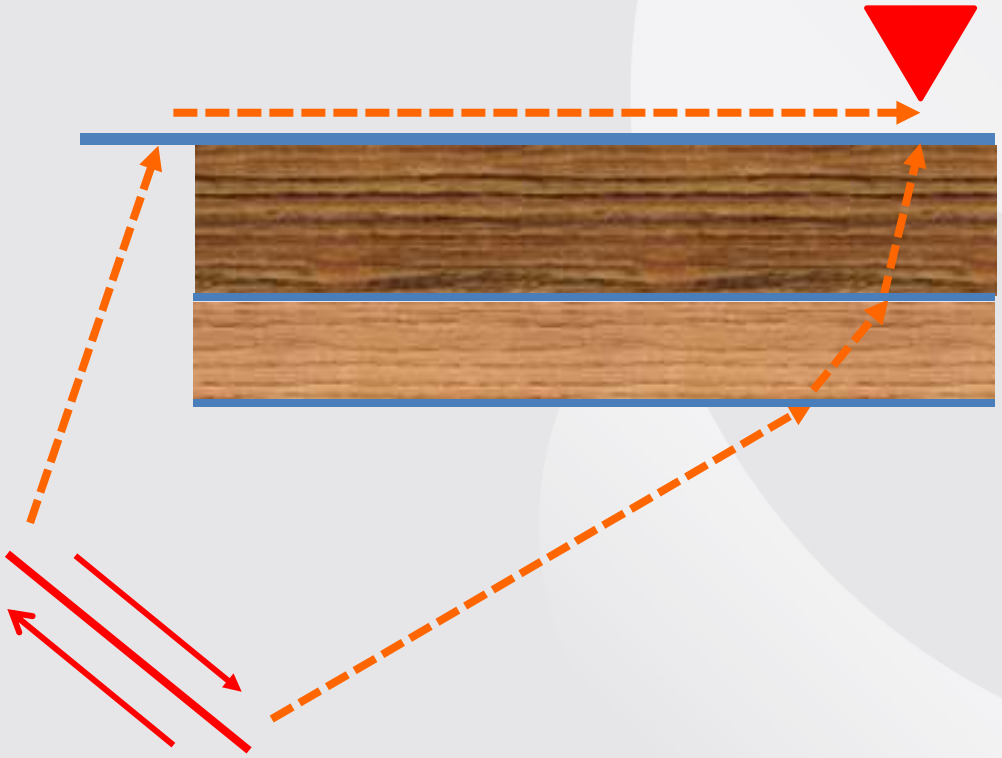
Probability of exceedance within a design working life of a structure concerned

0.5
(Twice within its life)

CASE A (Design working life: 50years)

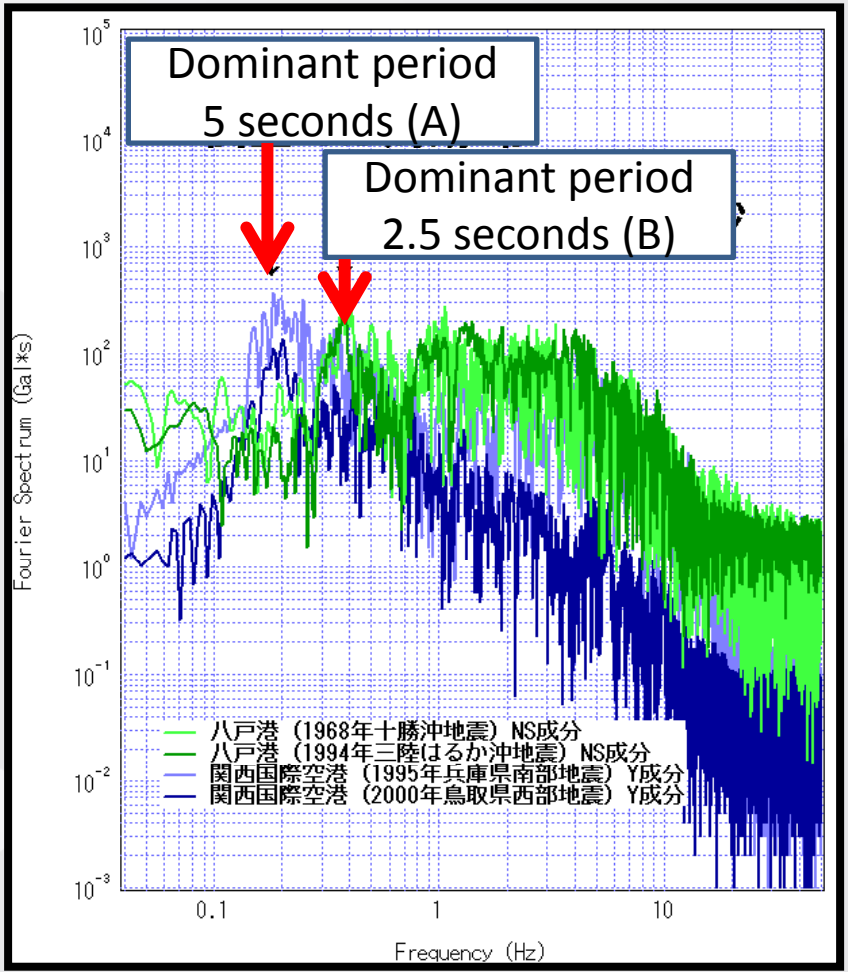
$$(1-\frac{1}{x})^{50} = 0.5 \Rightarrow$$ X = 75 years

How to determine levels of earthquake ground motion

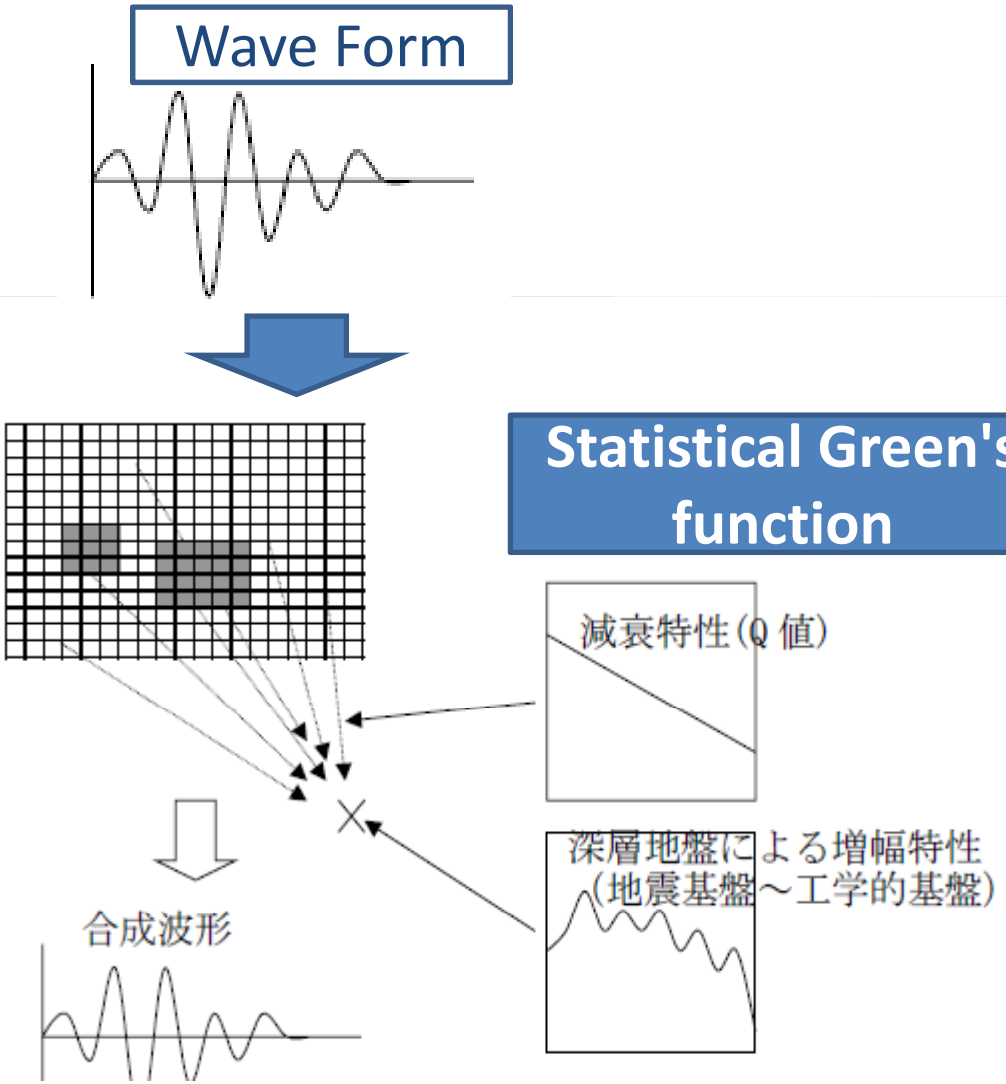


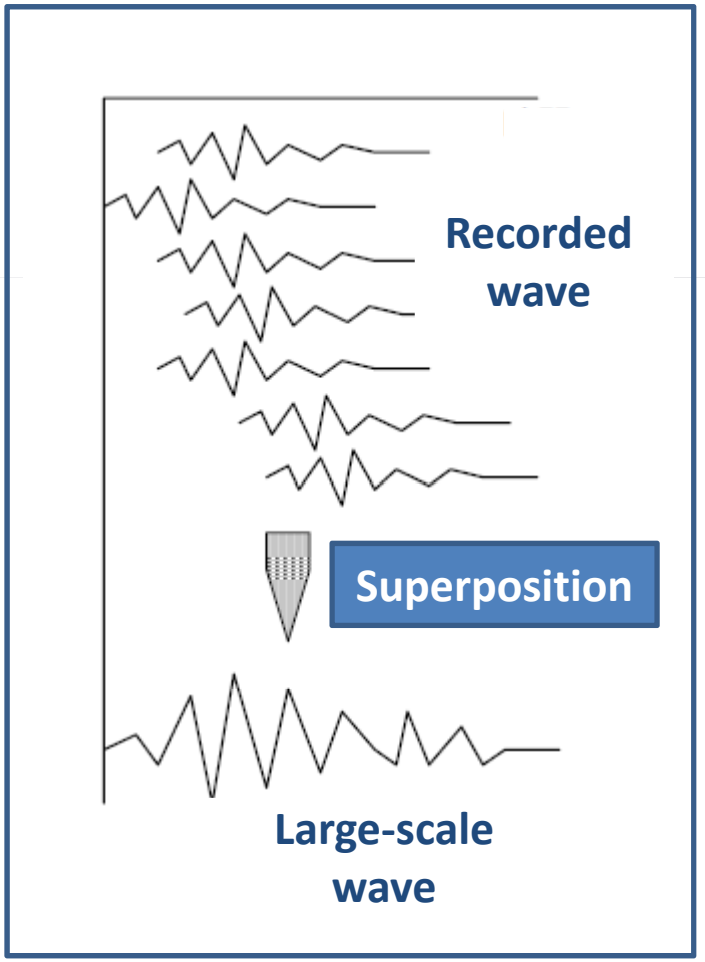
$$O(f)=S(f)P(f)G(f)$$

Fourier amplitude spectrum

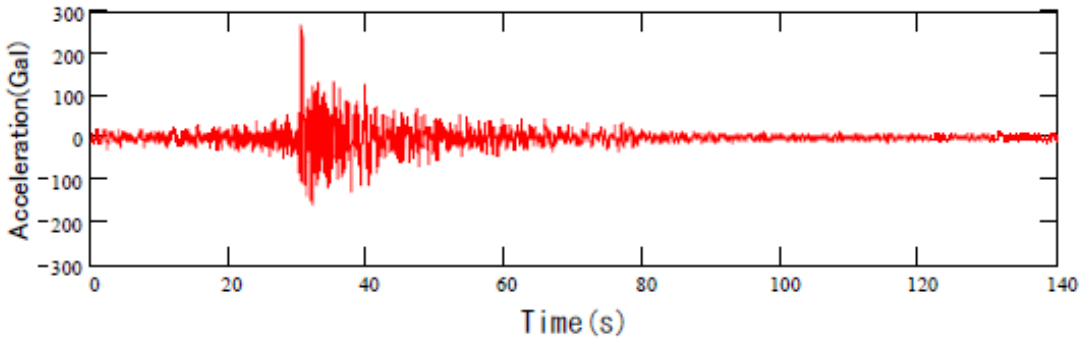


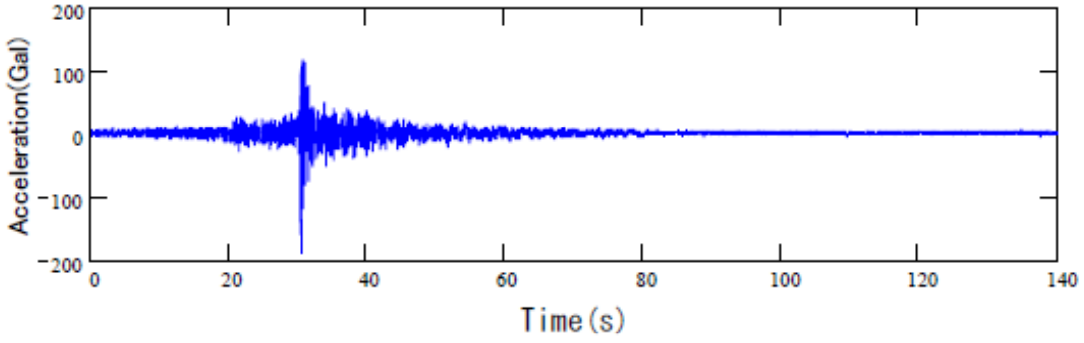
Statistical Green's Function

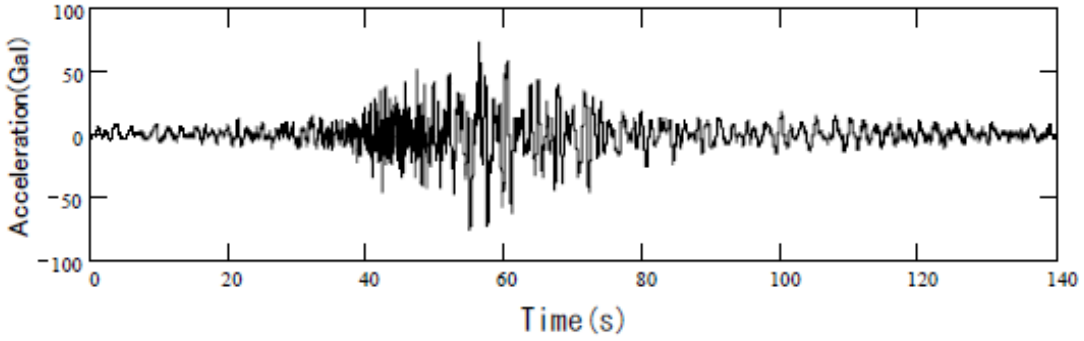


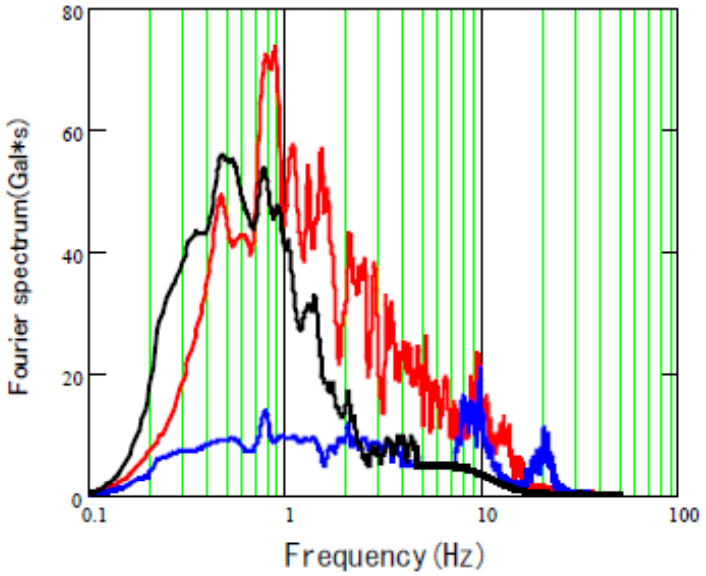


Fourier Spectrum





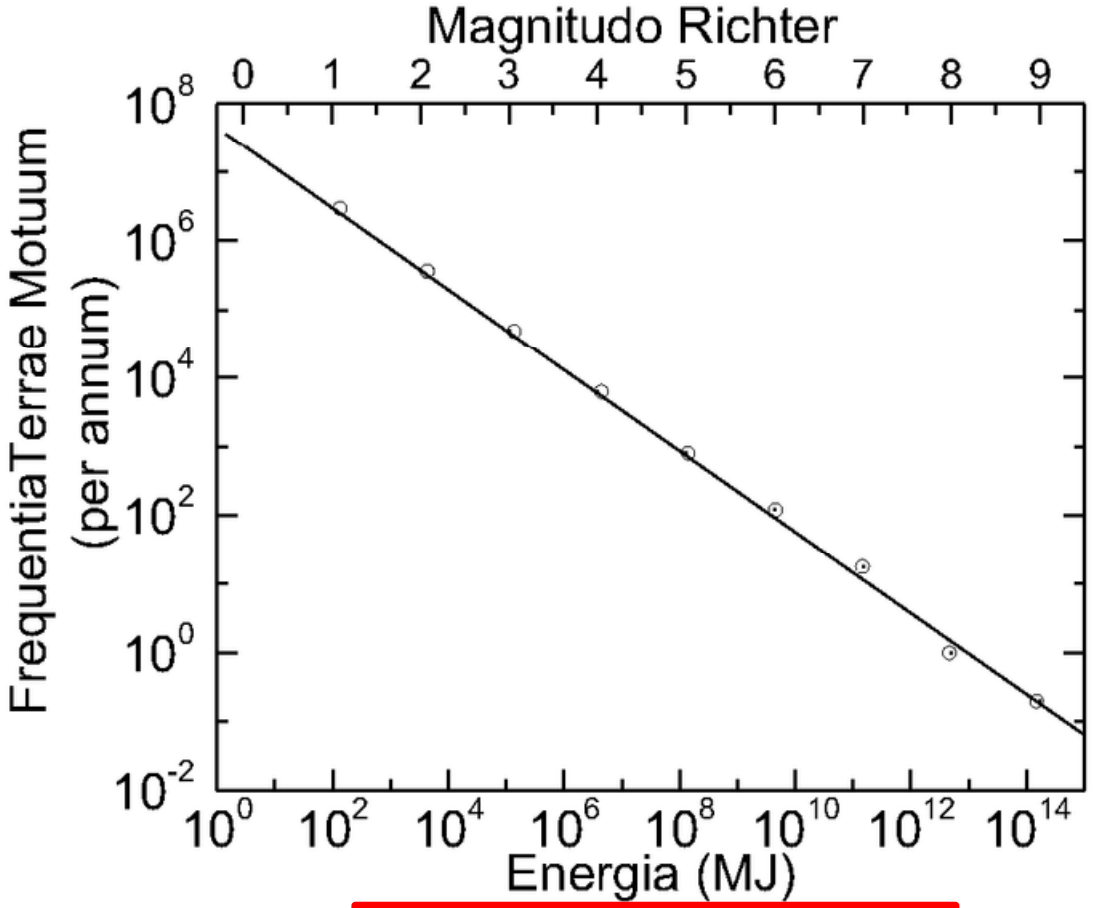




$$S_A(\omega) = \frac{R_{\phi\theta}}{4\pi\rho\beta^3} Mo \cdot \frac{\omega^2}{1+(\omega/\omega_c)^2} \cdot \frac{1}{1+(\omega/\omega_{\max})^2} \frac{e^{-\omega R/2Q\beta}}{R}$$

$$\omega_c = 2\pi f_c, \qquad f_c = 4.9\times10^6\,\beta(\Delta\sigma/Mo)^{1/3}$$

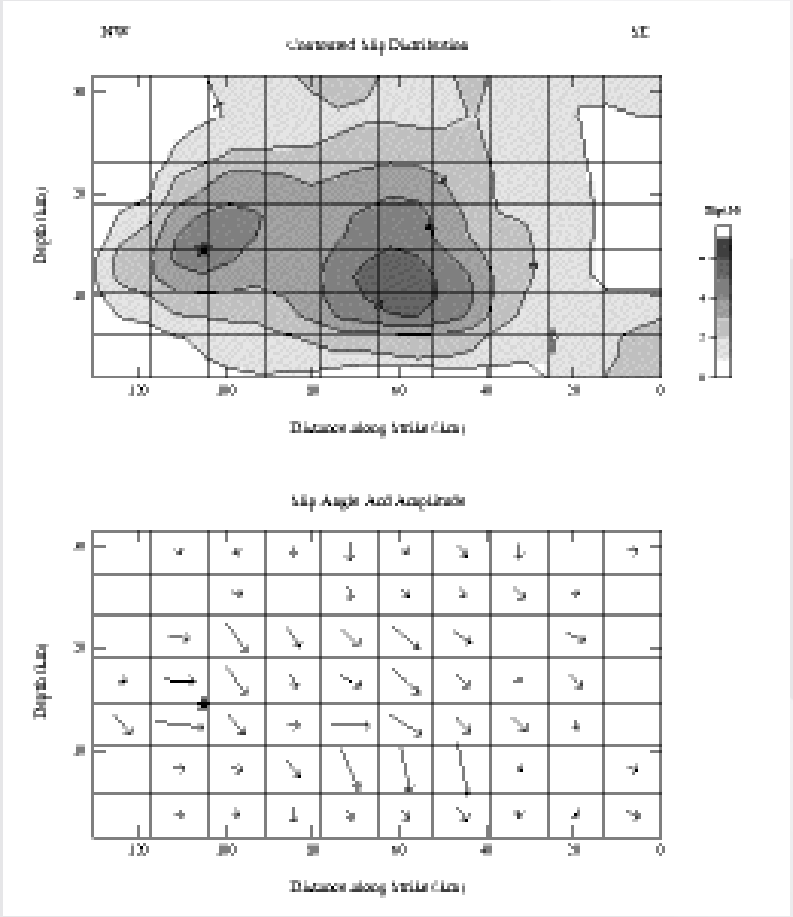
Gutenberg-Richter Law



$$\log_{10}N=a-bM$$

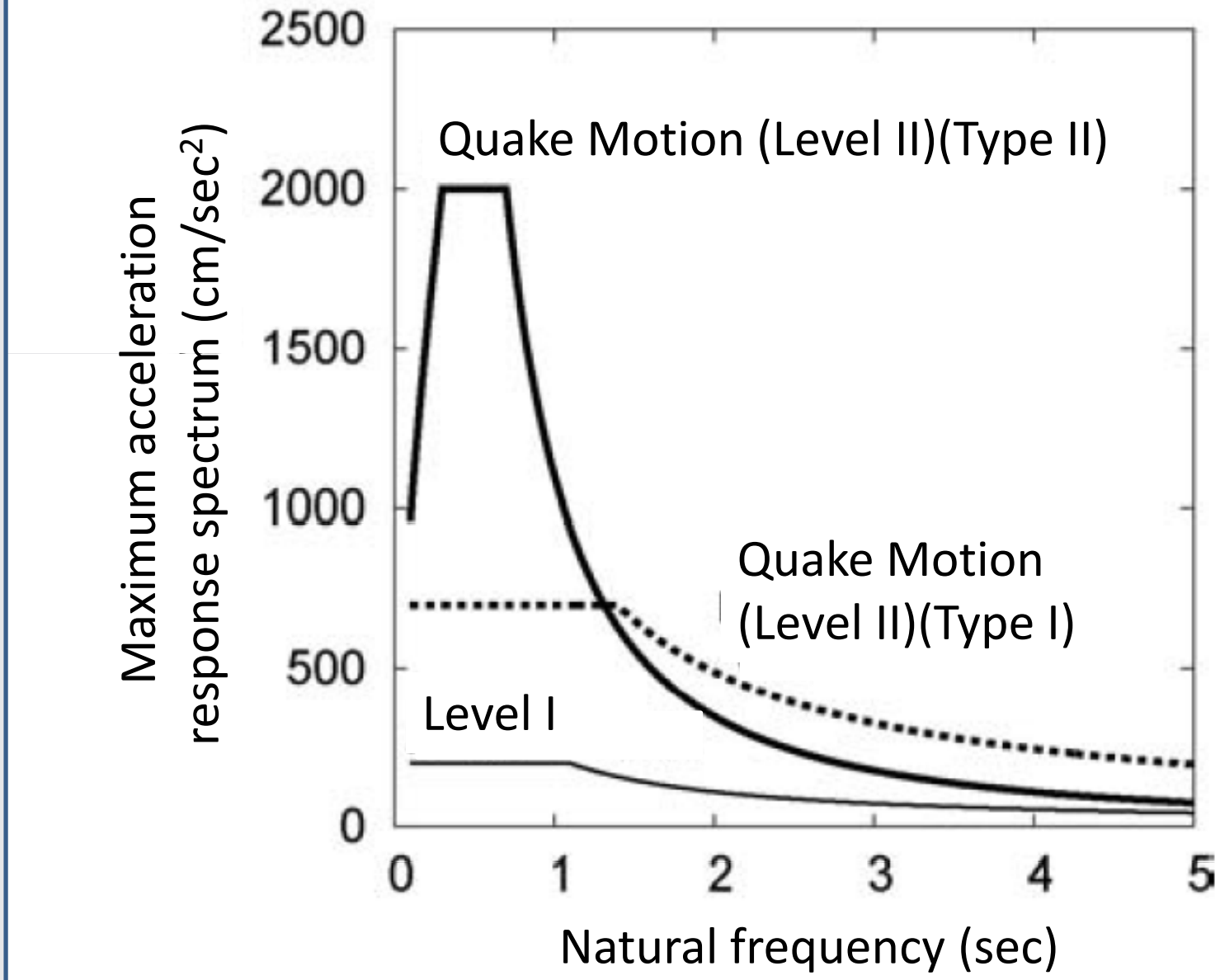
Earthquake Ground Motion (Level 2)

Distribution of Asperity



Historically-worst disaster

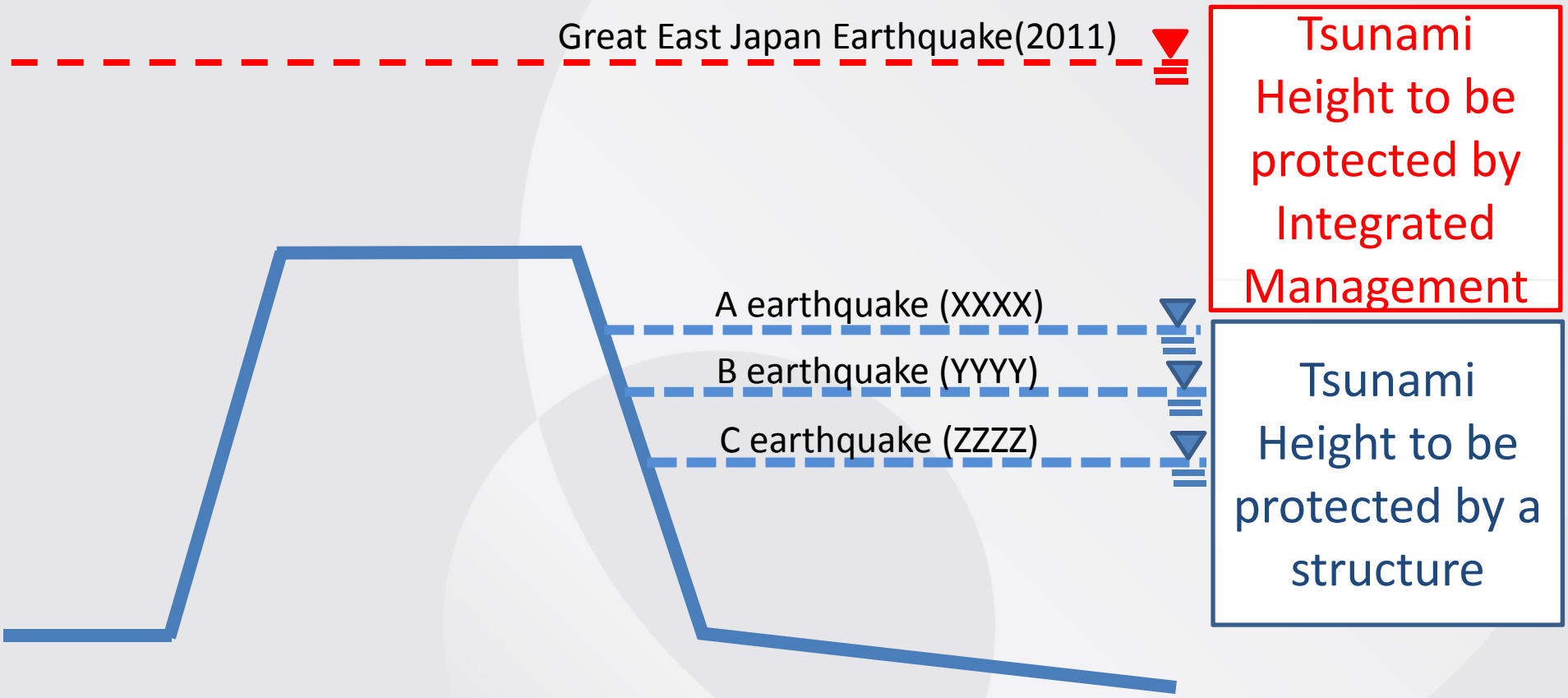
Larger than M6.5 in-land earthquake


Maximum acceleration response spectrum (cm/sec²)
2500
2000
1500
1000
500
0
0
1
2
3
4
5
Natural frequency (sec)
Quake Motion (Level II)(Type II)
Quake Motion (Level II)(Type I)
Level I

Design seismic coefficient for infrastructure types

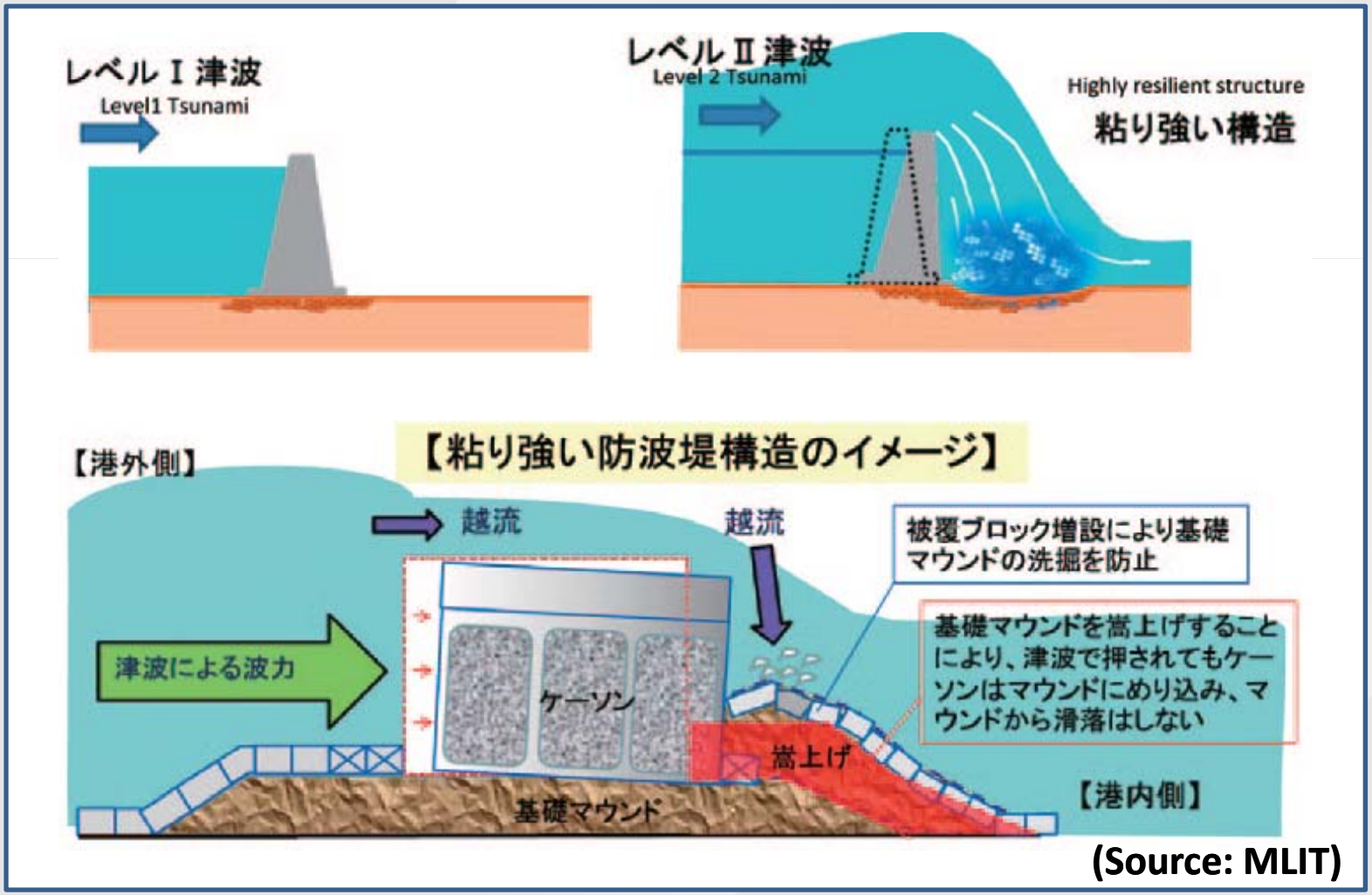
	Level 1	Level 2
Building	0.2 (196 gal)	1.0 (980 gal)
Rode (Class I)	0.08 (78.4 gal)	0.16 (156.8 gal)
Rode (Class III)	0.12 (117.6 gal)	0.24 (235.2 gal)
Bridge	0.2 (196gal)	2.0 (1960 gal)
Gas Reservoir Facility	0.3 (294 gal)	0.6 (588 gal)

Points not to encounter a pitfall



- Psychologically-based Information delivery to community

Image of Tsunami Levels and of resilient structure



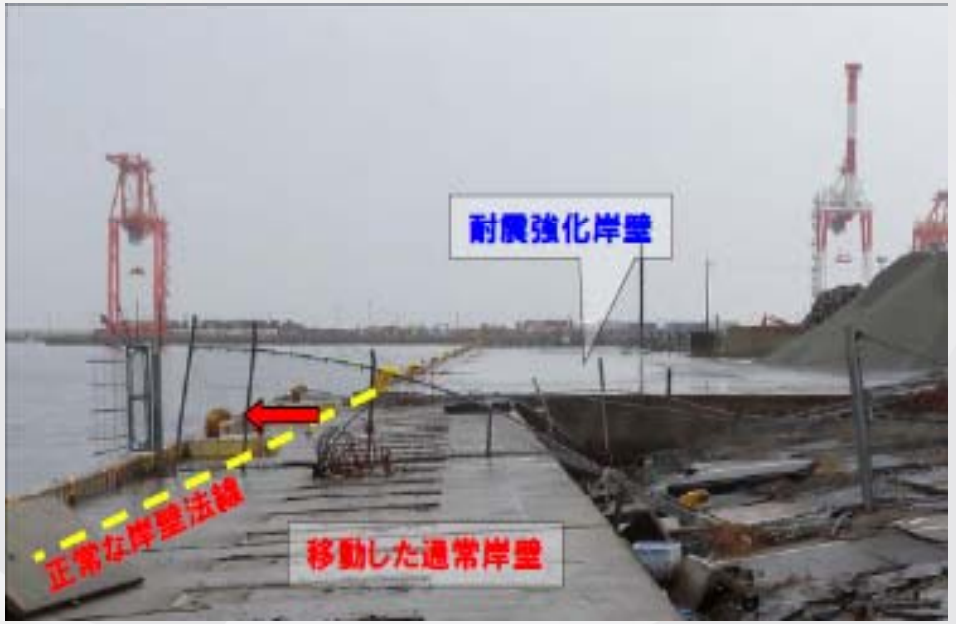
(Source: MLIT)

Pre-Improved infrastructures avoid tremendous damage from the disaster

Effect of reinforcement

JMA Intensity: X

JMA Intensity: IX



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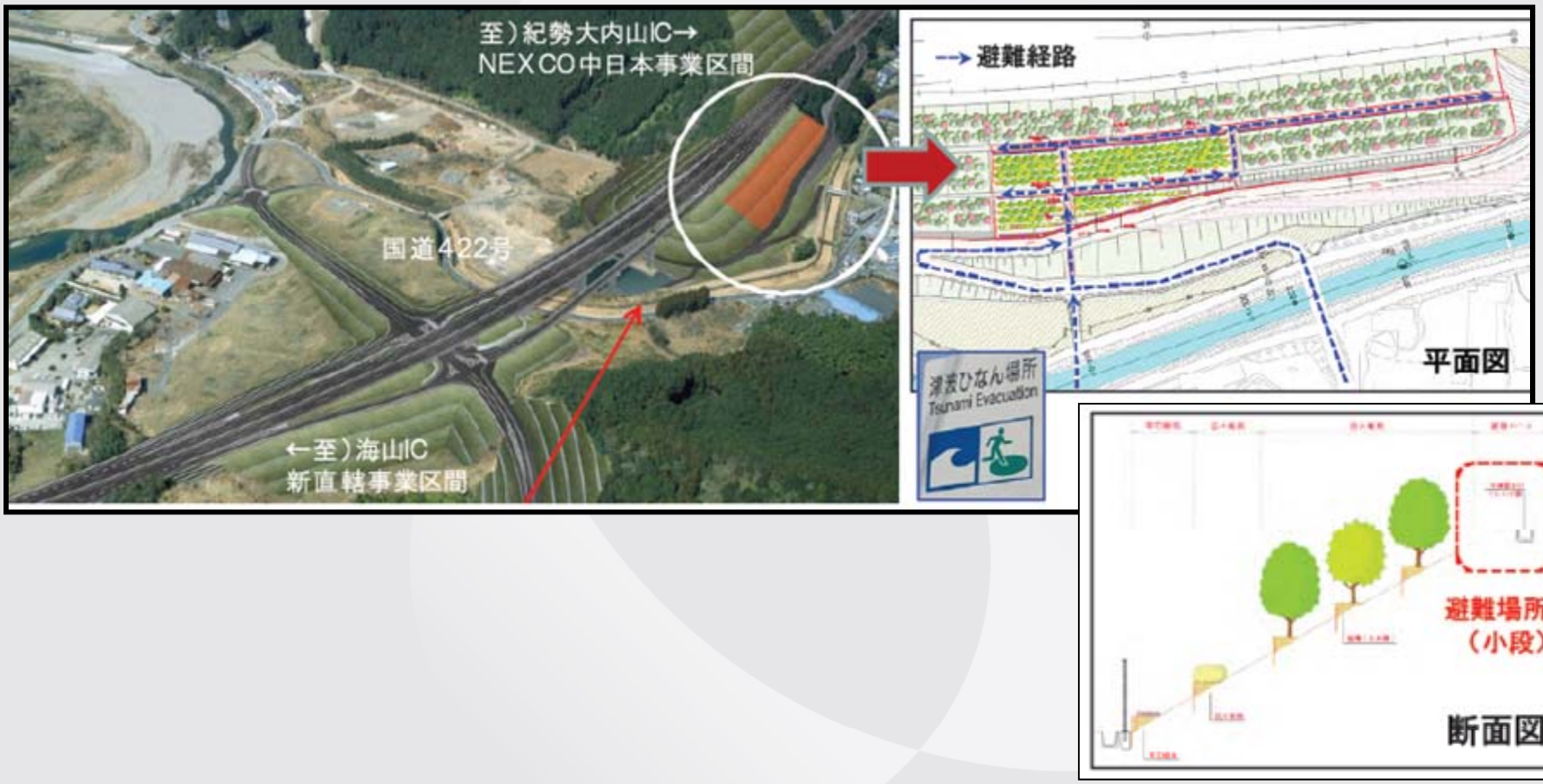
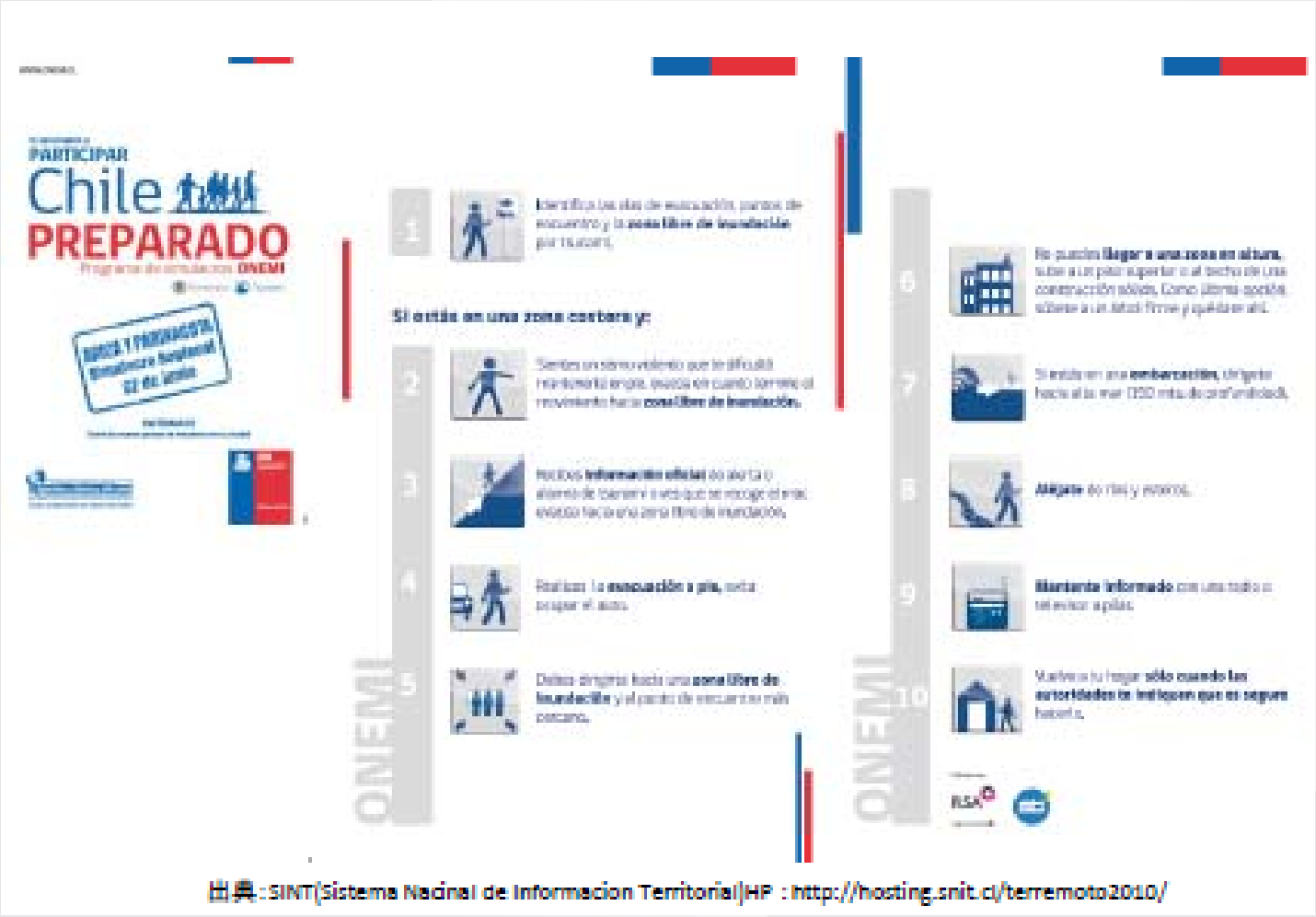
Designing and construction of multi-purpose/ -function measure

(1) Highway to be used as evacuation space

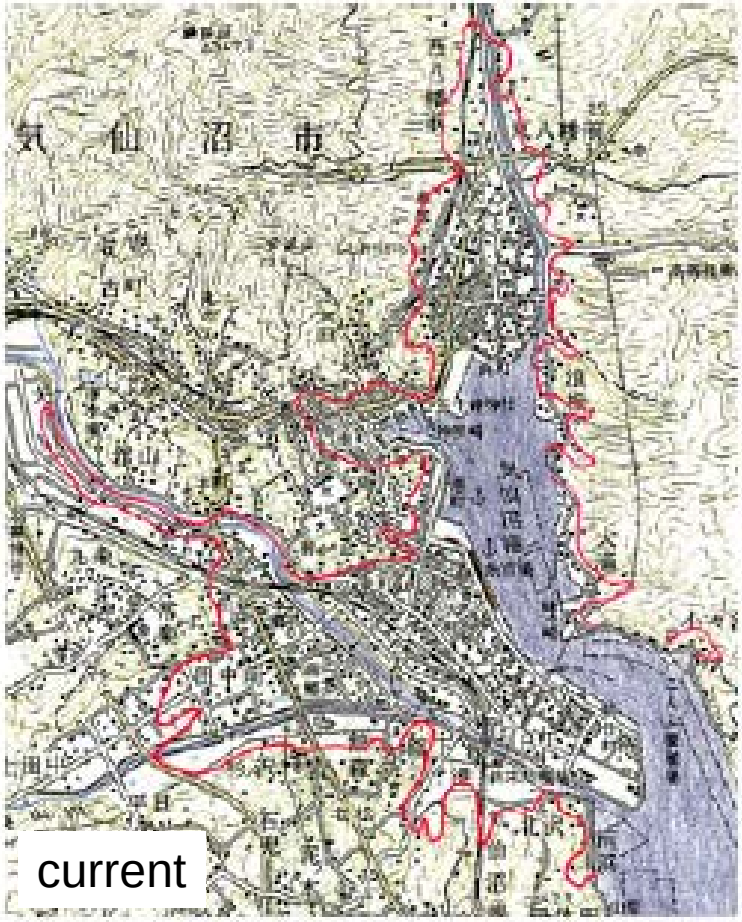


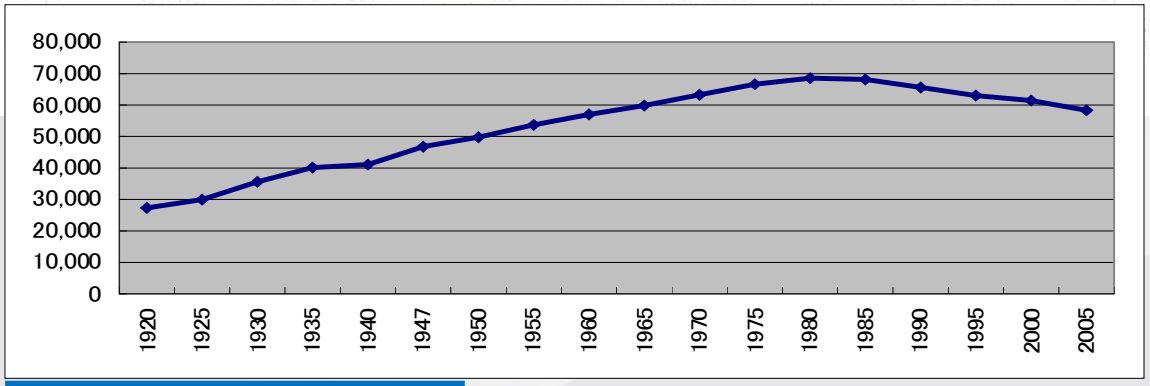

三陸大津波
Tidal wave Warning
ここまで
Ending Here
昭和8年(1933年)

Chilean preparedness



出典：SINT(Sistema Nacinal de Informacion Territorial)HP：http://hosting.snit.cl/terremoto2010/





水谷(2011)

Population Growth

3. Conclusion

Importance to take effective countermeasures

- Recognize of limitation in function, taking account for the worst scenario
- Continuous identification of risks possible due to changes in scientific and social aspect
- Secure of Redundancy (Multi-function measure/Multi-defense) for reducing risks

Importance to constantly continue improving any measures in an appropriate manner.

Importance to balance finance and technique in realizing effective DRM through mainstreaming