Underground Space Inundation and Evacuation

T. Ishigaki and T. Ozaki (Kansai Univ.)
K. Toda and Y. Baba (Kyoto Univ.)

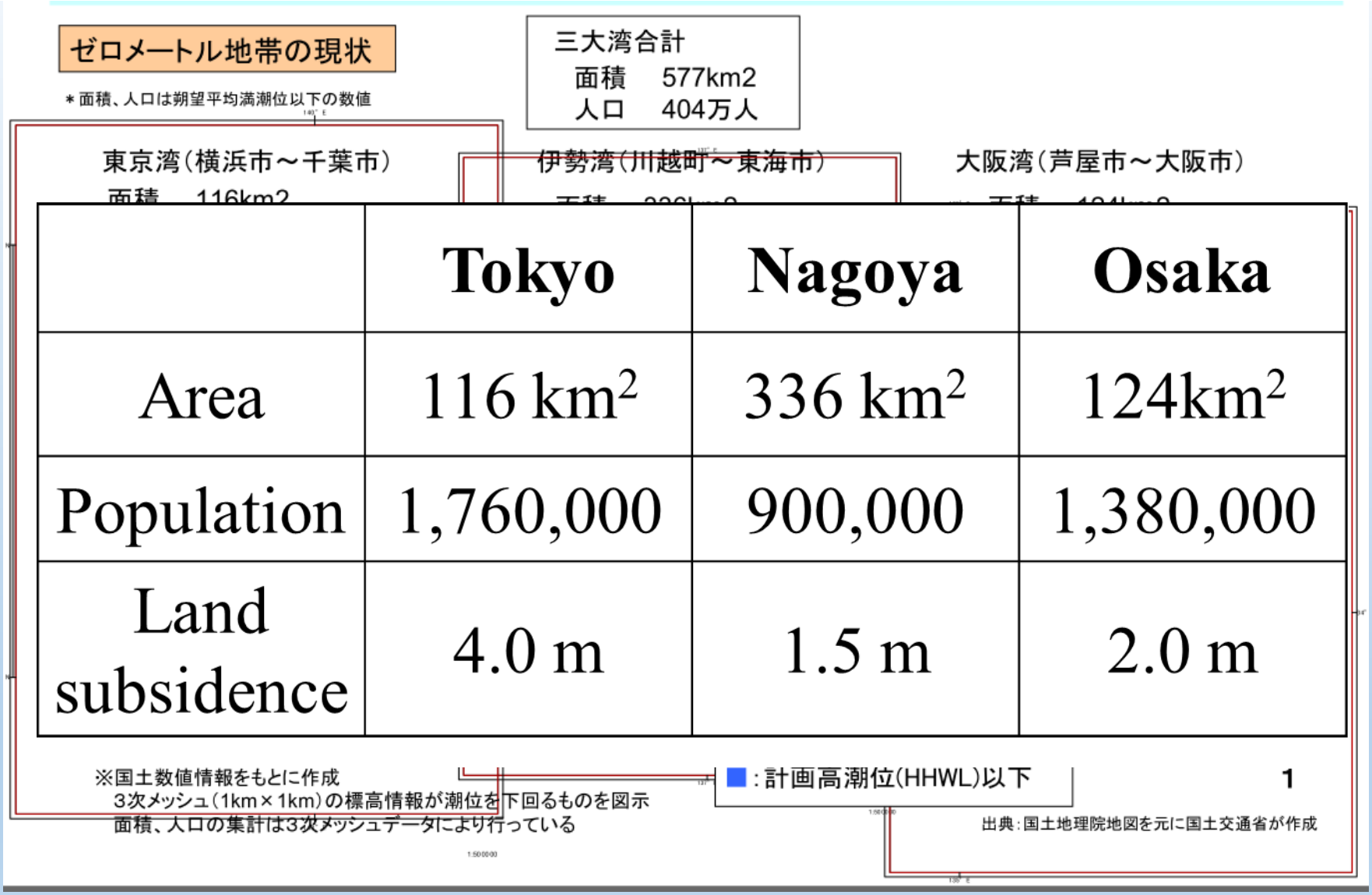
Contents

Underground space in Japan

Scale	**Underground space**	**Numbers**
large	Subway	642 stations
	Shopping mall	78 malls
	Parking	many
	Underpass	many
small	Basement	many

Japanese Underground Space

Under sea level area in Japanese mega cities, Tokyo, Nagoya, Osaka



	Tokyo	Nagoya	Osaka
Area	116 km^2	336 km^2	124km^2
Population	1,760,000	900,000	1,380,000
Land subsidence	4.0 m	1.5 m	2.0 m

（「わが国におけるゼロメートル地帯の高潮対策と現状」より）

Floods

➢Force

- Typhoon or Heavy Rainfall > Pluvial or Fluvial floods
- Typhoon > Storm surge, Earthquake > Tsunami

➢Type of flood

- Static flooding :U<1m/s, hydrostatic pressure
- Dynamic flooding: U>1m/s, hydrostatic & hydrodynamic force
- River bank erosion: flow velocity or loss of stability
- Rise of ground water: hydrostatic pressure

➢Impact parameters of flood

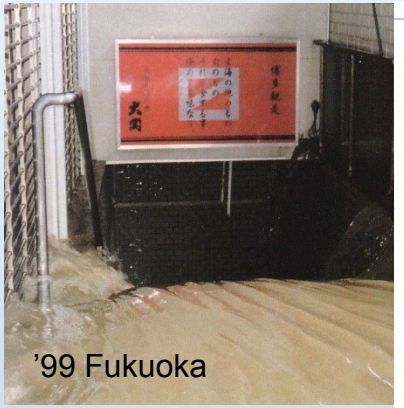
- Flood depth: 0.5m, 2m
- Duration of flood: some hours, several days, weeks
- Flow velocity: 1m/s, 2m/s, 3-5m/s
- Velocity of water rise:

(after Non Structural Flood Plain Management, ICPR)

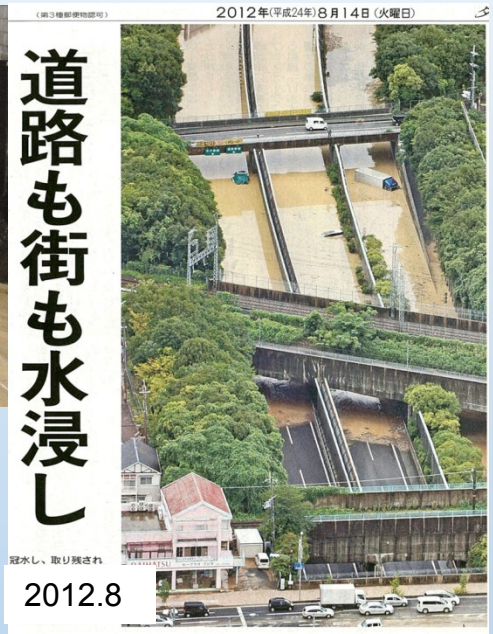
Underground inundation

東京、赤坂見附　1993(日本河川協会)

'99 Fukuoka



'99 Fukuoka



2012.8

2000.9.11-12, 名古屋

2008.7

New York 2012.10.29

Underground inundation in Japan & World

Year	Site	Underground space	Flooding
1999 June	Fukuoka	subway, basement, mall	pluvial, fluvial
1999 July	Tokyo	basement	pluvial
2000 Sep.	Nagoya	subway	pluvial, fluvial
2003 July	Fukuoka	subway, basement, mall	pluvial, fluvial
2008 July	Kyoto	underpass	pluvial
2011 Mar.	Natori	railway tunnel	tsunami
2011 Aug.	Osaka	underground mall	pluvial
2011 Sep.	Kasugai	underpass	pluvial
2013 Sep.	Kyoto	subway	fluvial

Year	Site	Nation	Underground space	Flooding
2001 July	Seoul	Korea	subway	pluvial
2002 Aug.	Europe	Germany etc.	subway	fluvial
2003 Sep.	Busan, Masan	Korea	basement, parking	storm surge
2012 Oct.	New York	USA	subway, tunnel	storm surge

1999 Fukuoka
(NHK-TV News)

Fluvial flooding

2003 Fukuoka
(NHK-TV News)

Pluvial flooding

27.8.2011 Osaka, Japan
77.5 mm/hr.
22.5mm/10min.

出典：You Tube

Tsunami flooding

11.3.2011 Tohoku

NHK News

Tsunami flooding

Railway tunnel near Sendai Airport

Railway underpass in Ofunato City

Ofunato

Storm surge flooding

Hurricane Sandy（29,10,2012）

Strom surge disasters

	Tokyo	**Nagoya**	**Osaka**
Typhoon	30.9.**1917**	26.9.**1959**	21.9.**1934**
Death	1127	4697	2702
Missing	177	401	334
Injured	2022	38921	14994

Contents

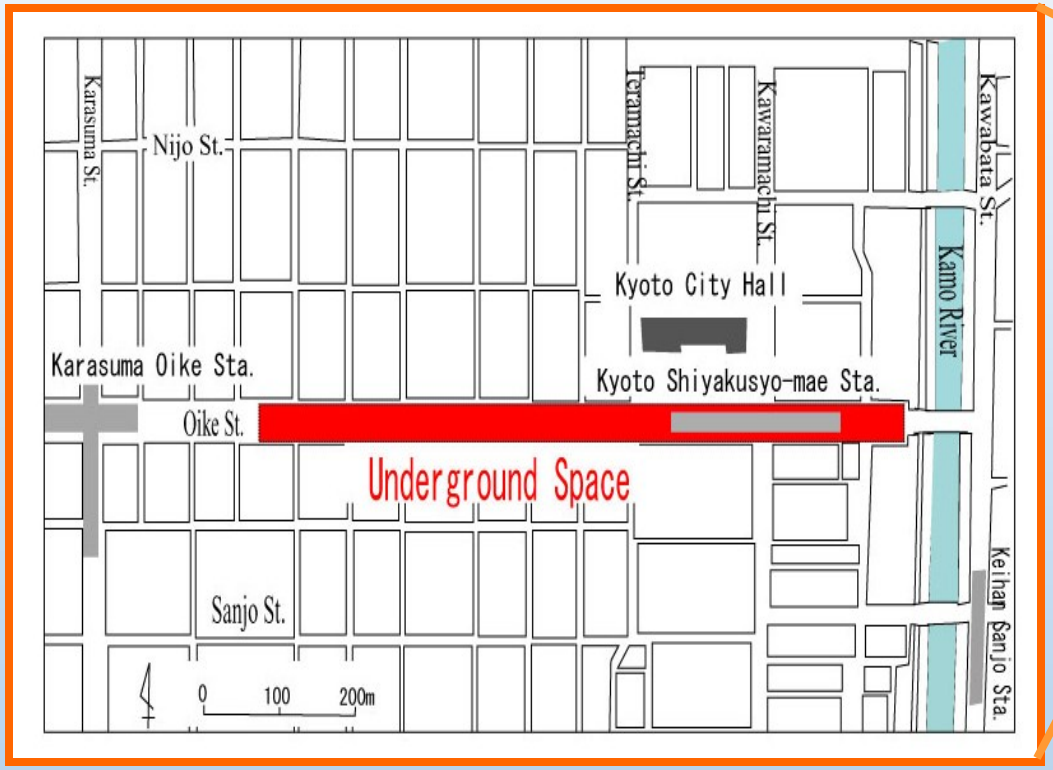
Underground Space Inundation

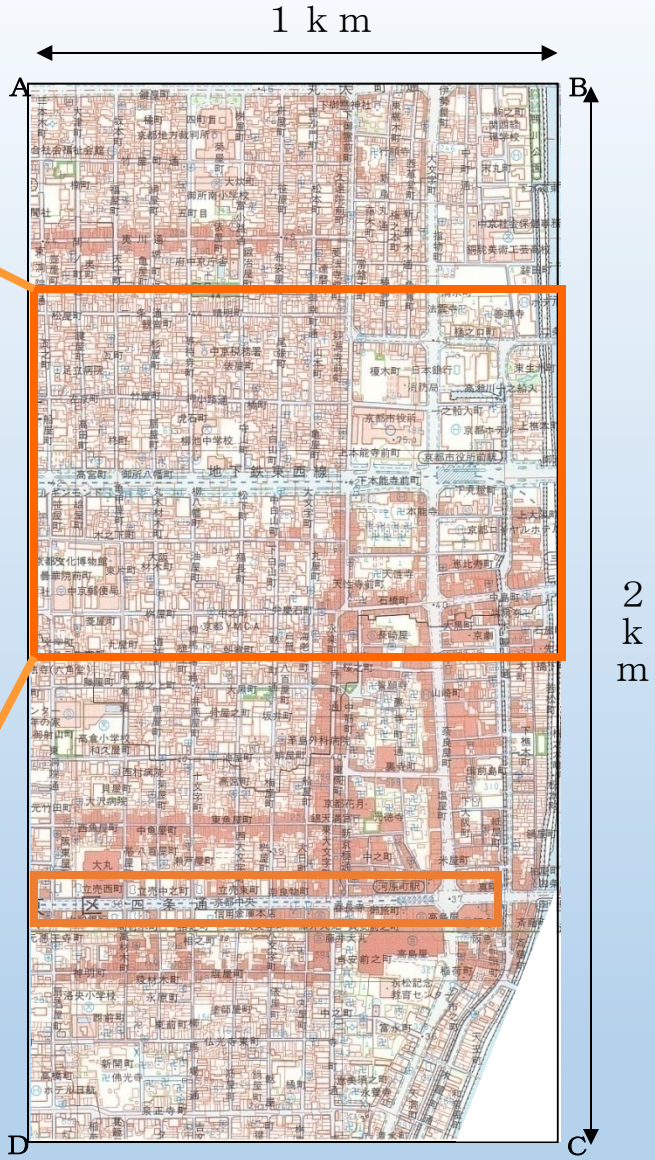
- What happened?
- What will happen?

Evacuation from Underground Space

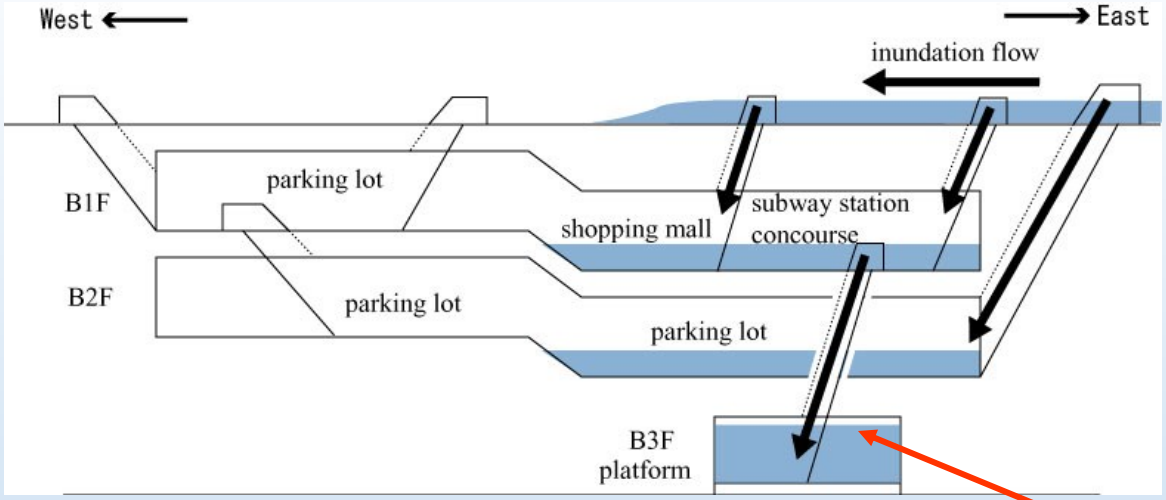
- Static flooding (hydrostatic pressure)
- Dynamic flooding (hydrostatic and hydrodynamic force)

Location





- Under Oike St. in the center area of Kyoto
- Longitudinal distance : 650m, Width : 40m
- The east end is close to The Kamo River

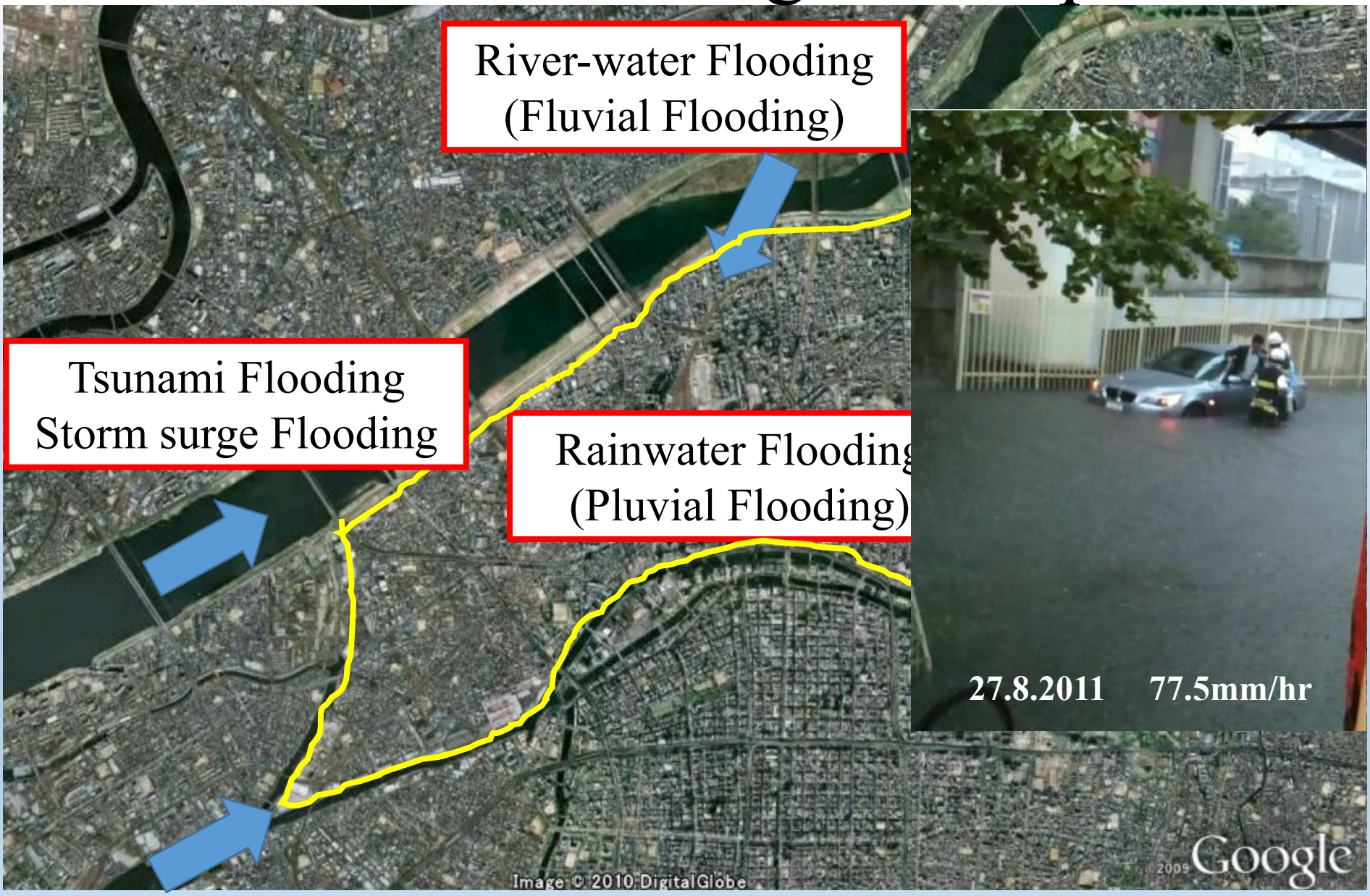


Prototype

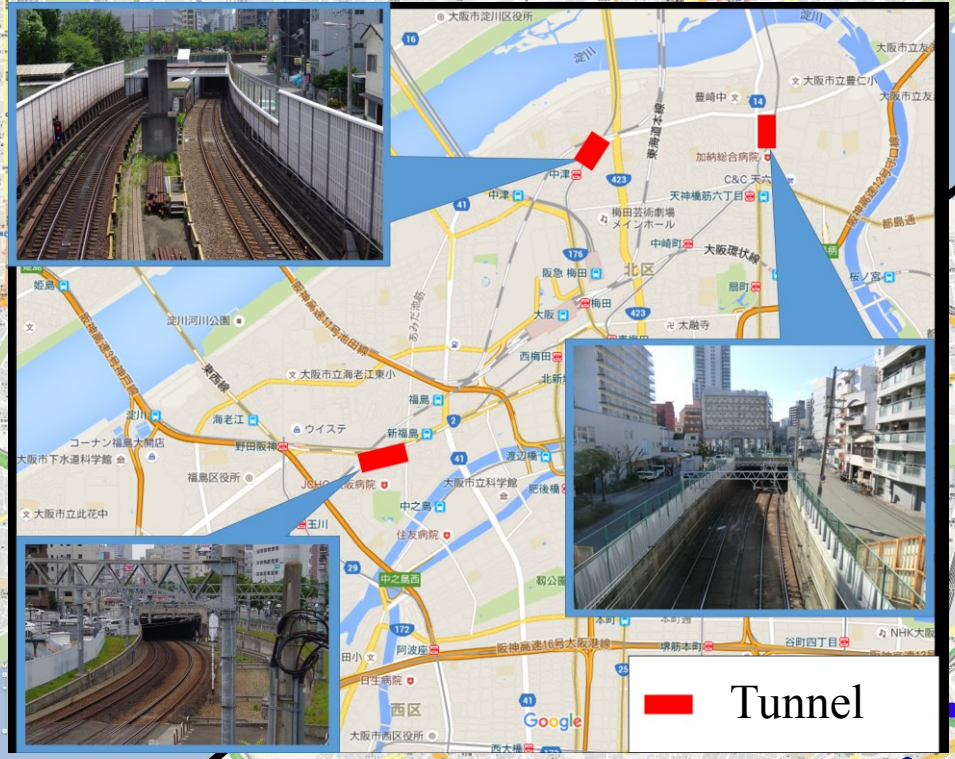
Model(s=1/30)

Japanese Underground Space

Hazards for underground space

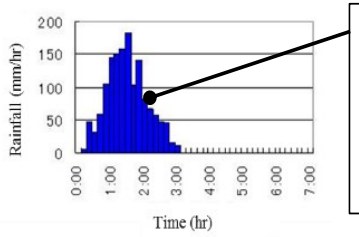
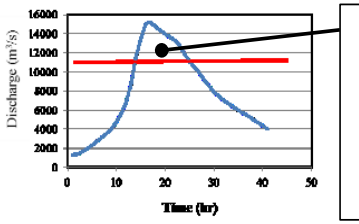
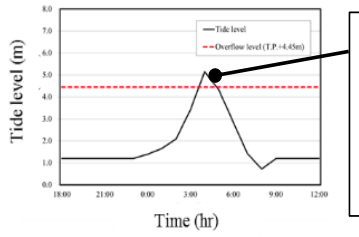
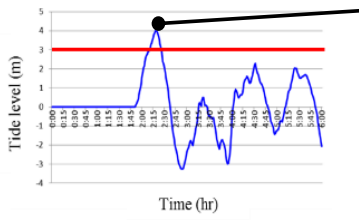


Mega-underground space in Osaka



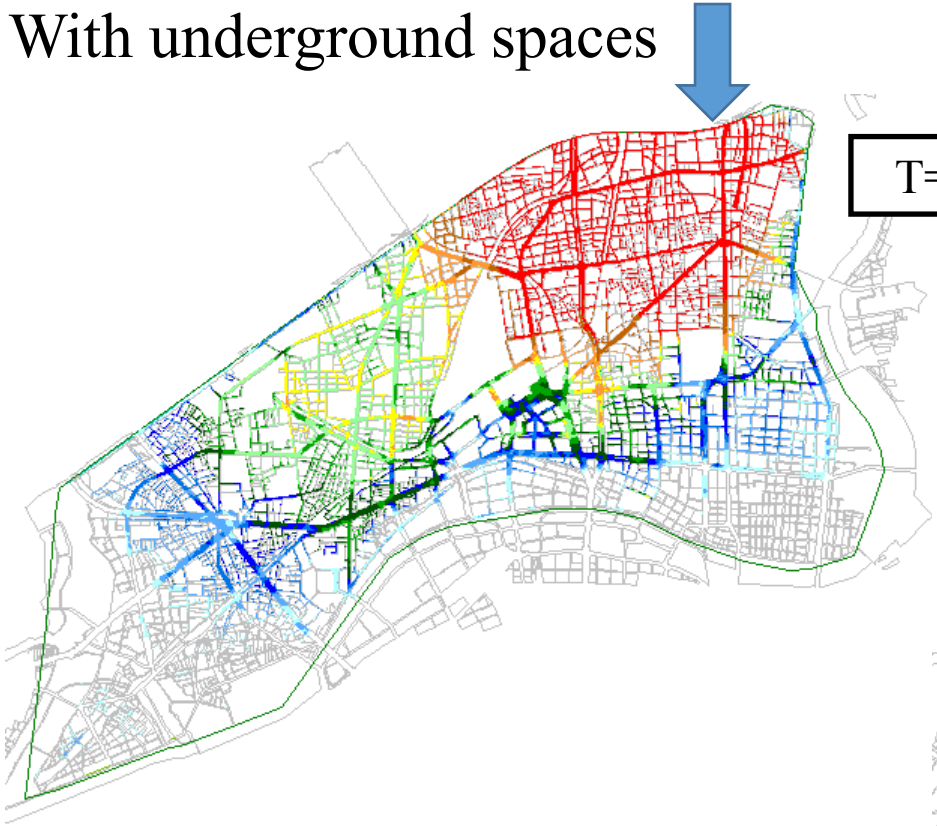
Entrances to underground spaces

Extreme flood conditions

Flooding	Extreme flood condition	Inflow condition of calculation
Pluvial	Rainfall in Okazaki, Japan Date: 29.8.2008 Total: 242mm/3hr Max. per 1hr : 146.5 mm (2.5 times of design rainfall, 60mm)	 Rainfall intensity per 10 min. T=3 hr $Q_{total}=2.97x10^6$ m^3
Fluvial	Two times of the design runoff discharge Date: 25.9.1953 Total: 500mm/2days(=2 times data) (released by Japanese government)	 Overflow discharge T=10.9 hr $Q_{total}=9.32x10^7$ m^3
Storm surge	Super typhoon model Magnitude: 900 hPa (released by Japanese government)	 Overflow depth T=1.5 hr $Q_{total}=9.18x10^6$ m^3
Tsunami	Tsunami caused by the Nankai Trough Great Earthquake Magnitude: 9.0 (released by Japanese government)	 Overflow depth T=0.37 hr $Q_{total}=5.83x10^6$ m^3

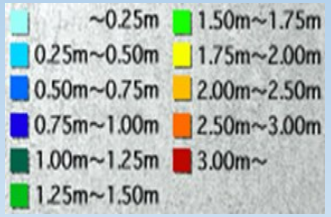
Fluvial flooding

With underground spaces

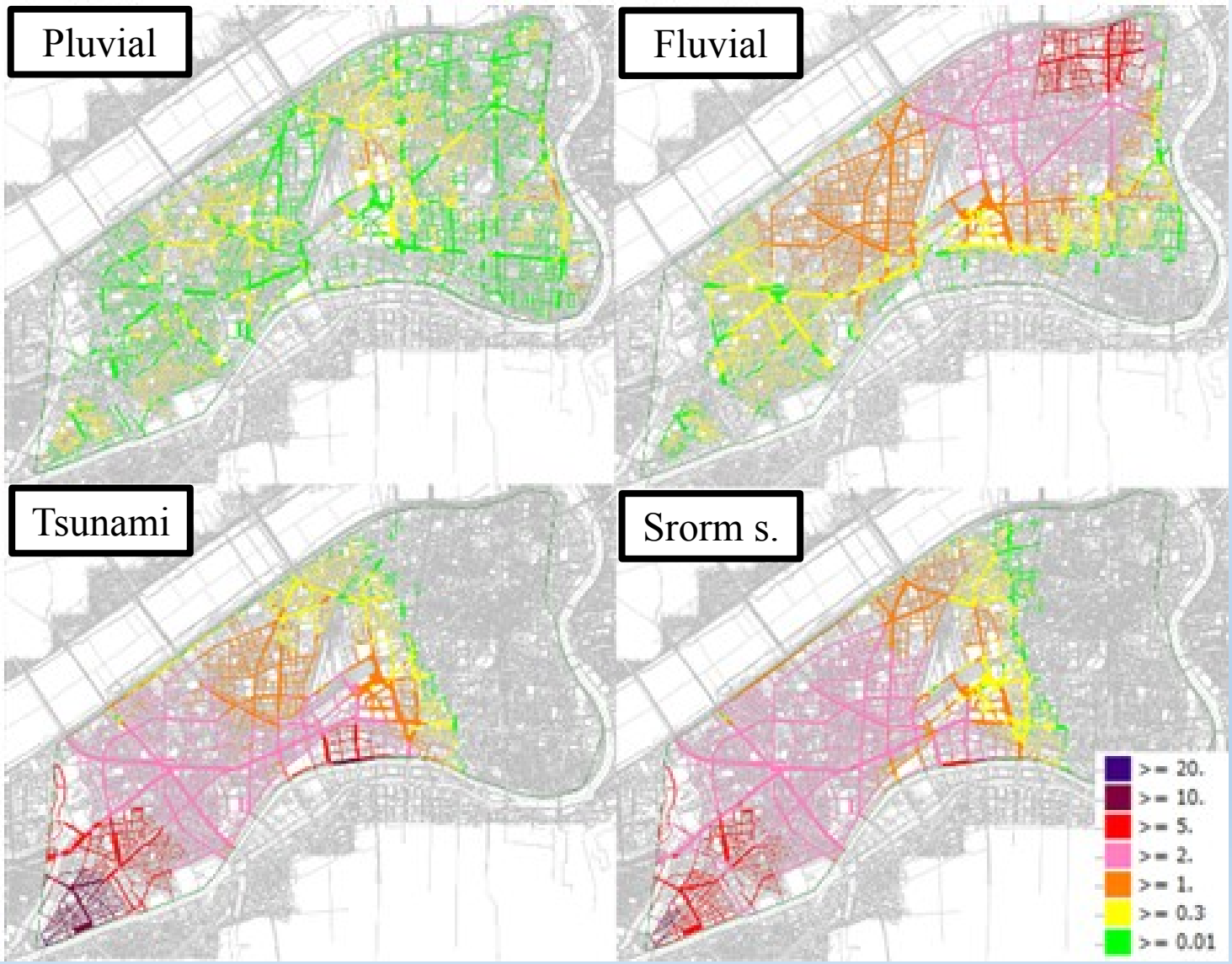


T=4hours

Without underground spaces



Calculation results

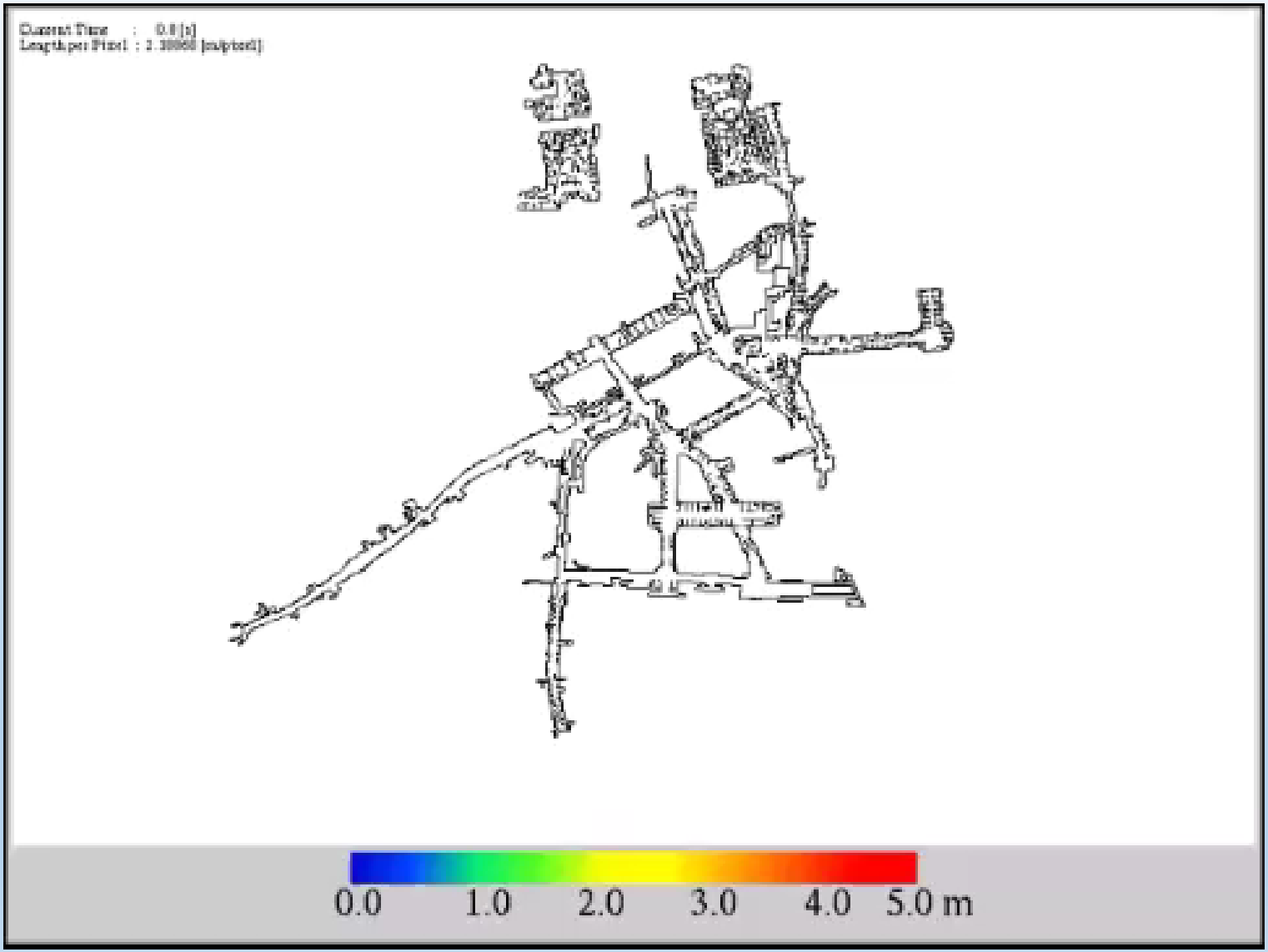


Inflow discharge into underground spaces without counter measures

Extreme flood	**Duration (hr)**	**Flood volume ($x10^4m^3$)**	**Inflow discharge ($x10^4m^3$)**	**Inflow rate (%)**
Pluvial flood (146.5mm/hr)	3.0	297	37(21)	**13(7)**
Fluvial flood (Q_p=4000 m^3/s)	10.9	9300	6760(2880)	**73(31)**
Tsunami flood (M=9.0)	0.35	583	292(117)	**50(20)**
Storm surge (super typhoon)	1.5	960	538(211)	**56(22)**

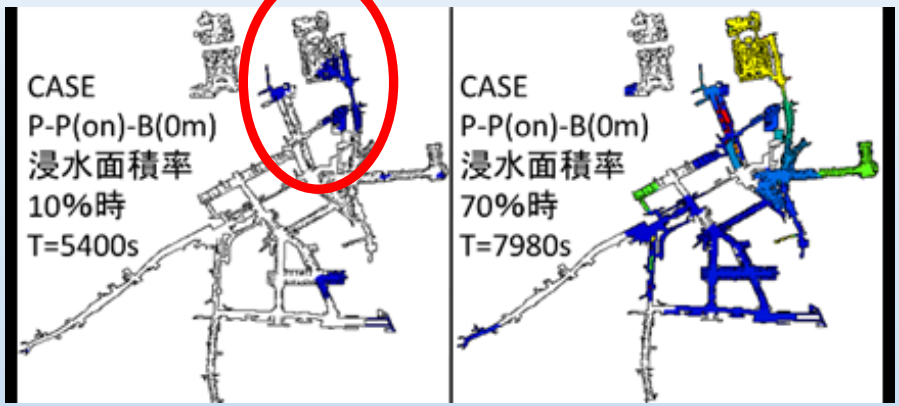
Pluvial flooding

通路・店舗・地下駅を考慮

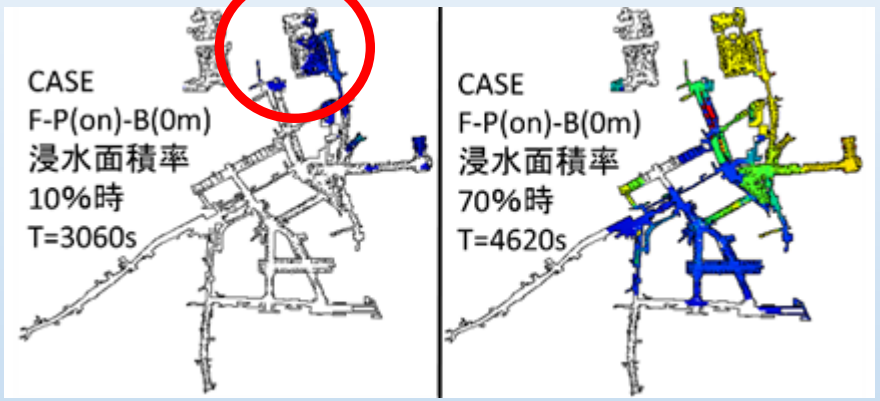


Calculation results

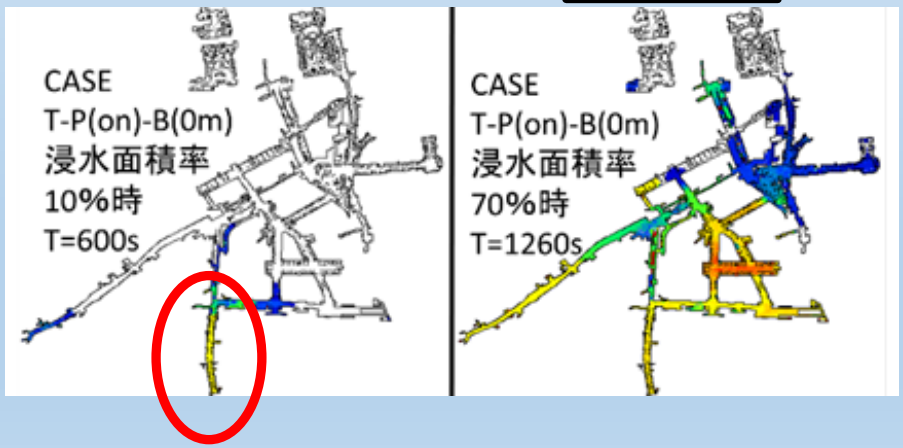
Pluvial



Fluvial



Tsunami

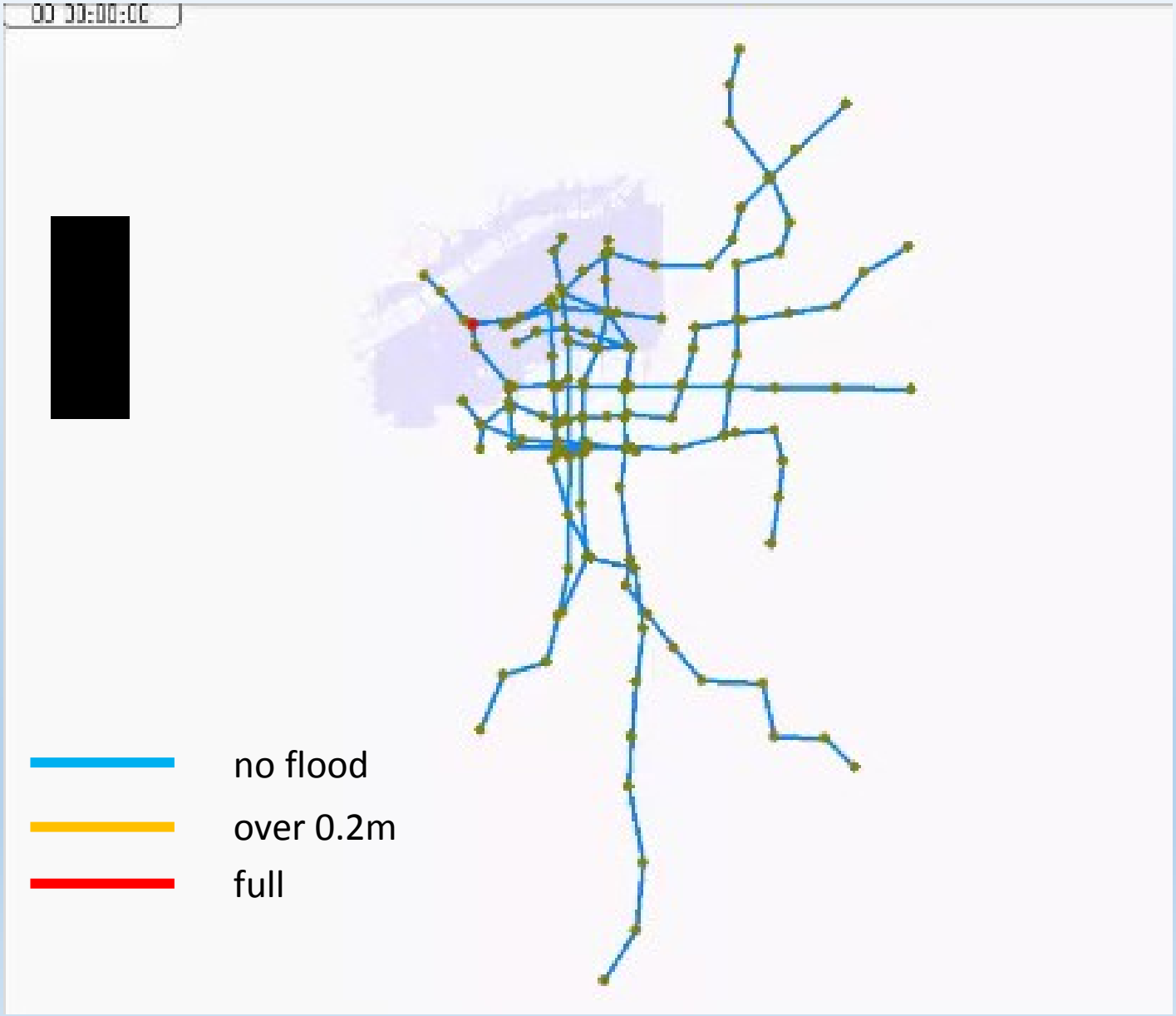


Srorm s.


御堂筋線
四ツ橋線
谷町線
千日前線
中央線
堺筋線
JR東西線
阪神本線
対象路線（8路線）64駅
下新庄
東淡川
淡路
守口市
城北公園
守口市役所
柴島
滝井
千林
都島区
大阪市城東区役所
鶴見区
大阪
福島区
城東区
徳庵
放出
大阪市役所
中央区
西区
玉造
今里
今里
布施
なんば
浪速区
桃谷
俊徳道
大阪市大正区役所
生野区
長瀬
天王寺

Fluvial flooding

Flooding through subway tunnels



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Floods

➢Causes

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- Typhoon > Storm surge, Earthquake > Tsunami

➢Type of flood

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- Dynamic flooding: U>1m/s, hydrostatic & hydrodynamic force
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➢Impact parameters of flood

- Flood depth: 0.5m, 2m
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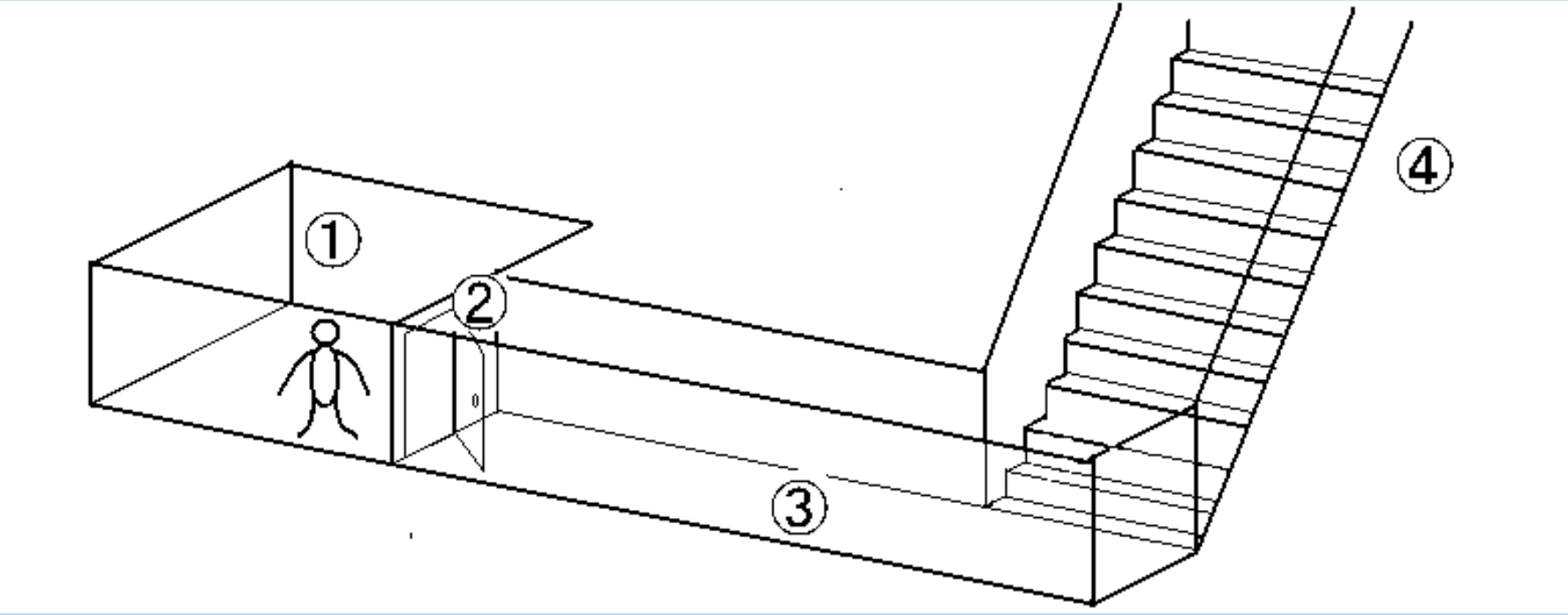
- Flow velocity: 1m/s, 2m/s, 3-5m/s
- Velocity of water rise:

(after Non Structural Flood Plain Management, ICPR)

Evacuation from Underground

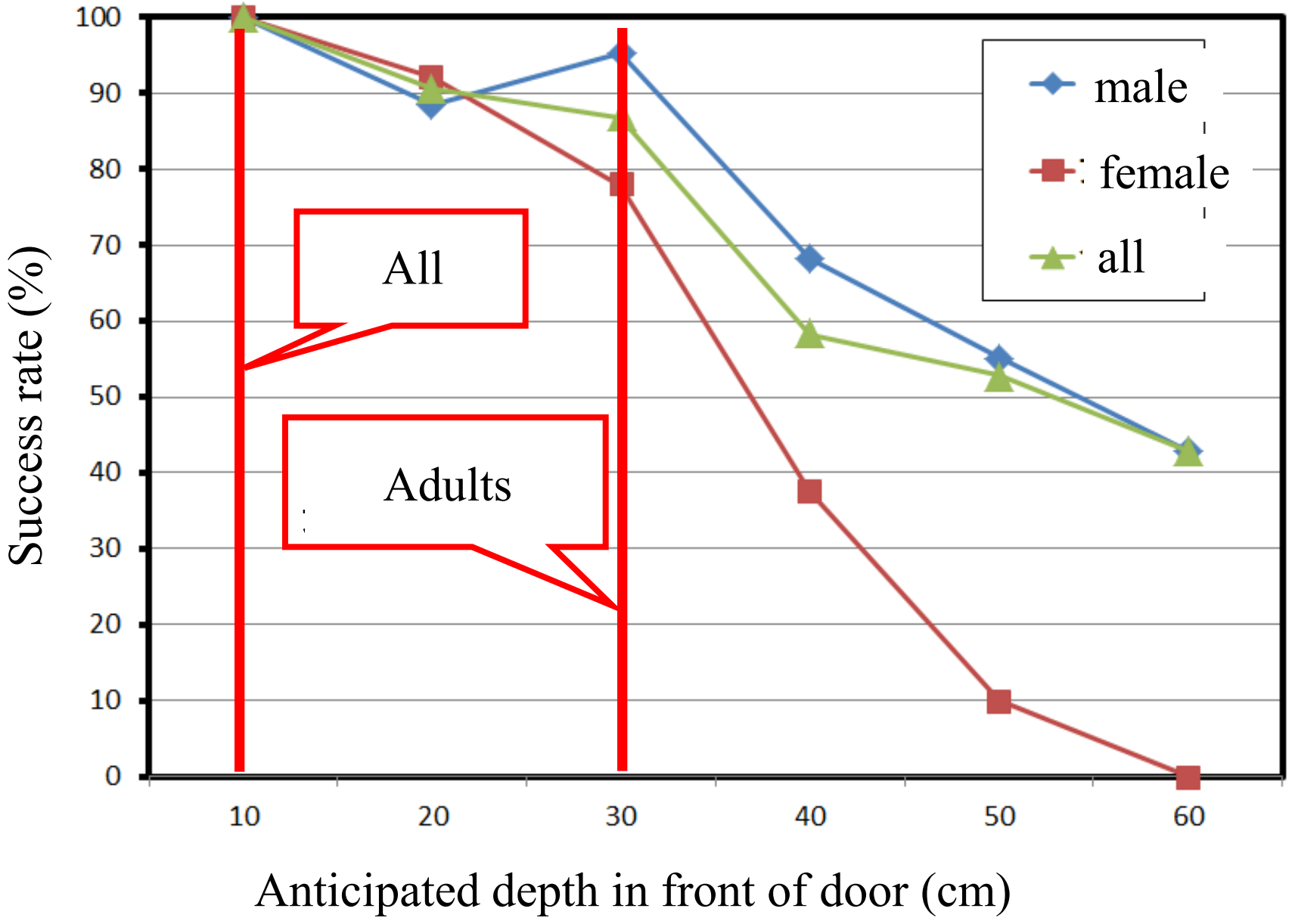
①Notice flood
②Open the door

③Walk the corridor
④Climb the stairs



Mobile door equipment

Male : 561 persons
Female : 298
Total : 859


Success rate (%)
100
90
80
70
60
50
40
30
20
10
0
10
20
30
40
50
60
Anticipated depth in front of door (cm)
male
female
all
All
Adults

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Evacuation tests cooperated with Kyoto Univ.

Examinees : 314

47 females (30.2years), 157 males (25.8years)

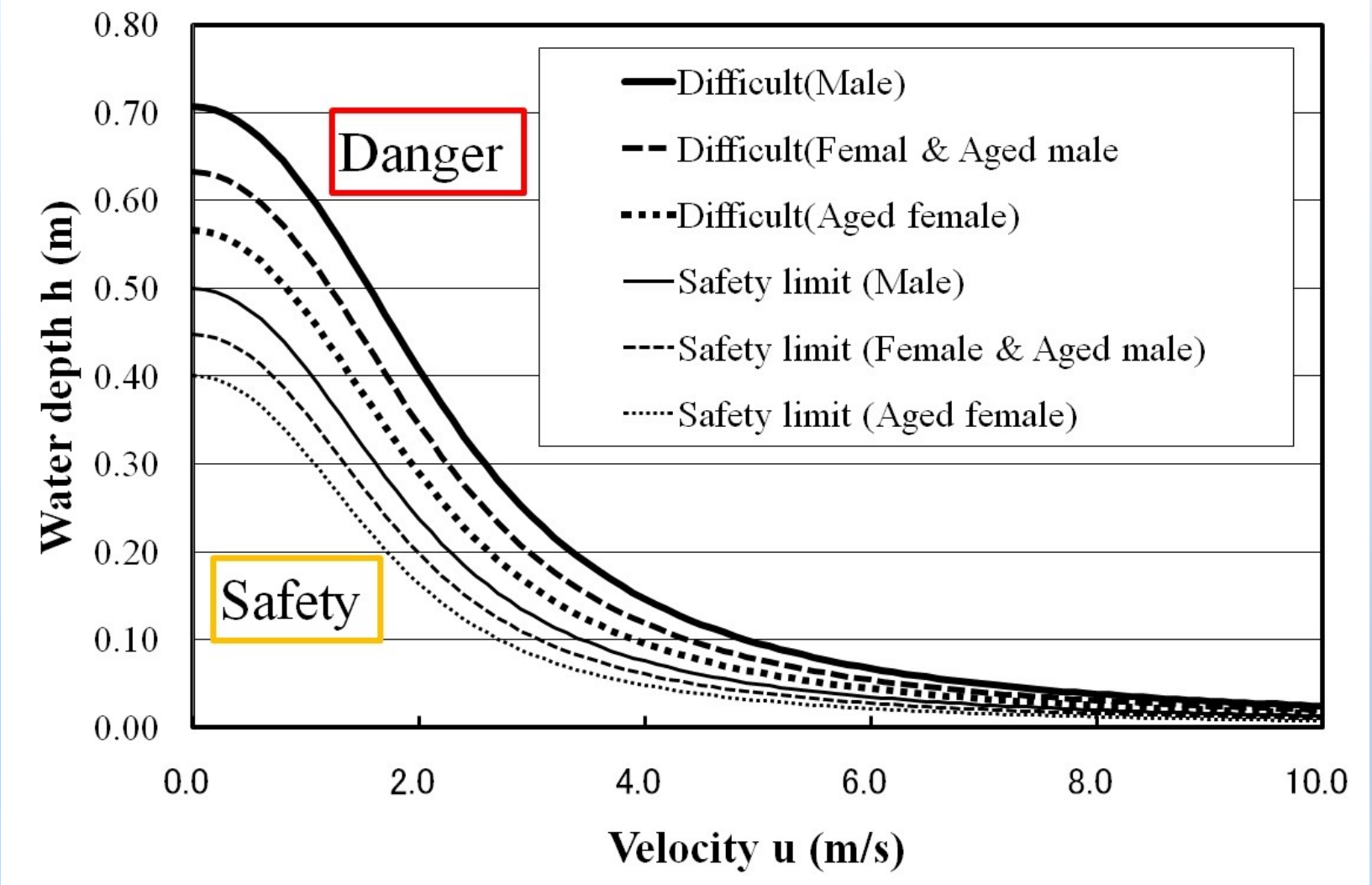
11 children (8years), 3 children (12years)

Criteria for safe evacuation

Specific force per unit width : $u^2h/g+h^2/2$

	Safety limit	Difficult
Male	0. 125	0. 250
Elderly male	0. 100	0. 200
Female	0. 100	0. 200
Elderly female	0. 080	0. 160

Criteria for safe evacuation



$H=50cm\ U^2h/g+h^2/2>0.250$

If it's over the Limit value!

Underground space is useful?

地震で電車が止まり、改札口のコンコースで運転の再開を待つ人たち（11日午後５時６分、京王線新宿駅で）＝吉岡毅撮影

Questions

- What is problem to be solved?

We have already pointed out.

- How to make underground space management?

We have to prepare an appropriate plan for underground space management.

It is good to have a shelter against every storm.

Thank you for your attention