Urban Floods and Tokyo Storm Runoff Model

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Representative Papers

- Jinno, K., Kawamura, A.,Berndtsson, R, Larson, M., and Niemczynowicz, J. (May 1993) Real-time rainfall prediction at small space-time scales using a two-dimensional stochastic advection-diffusion model. Water Resources Research, Vol.29, No.5, pp.1489-1504.
- Jinno, K., Xu, S., Berndtsson, R., Kawamura, A. and Matsumoto, M. (August 1995) Prediction of sunspots using reconstructed chaotic system equations. Journal of Geophysical Research - Space Physics, Vol.100, No.8, pp.14,773-14,781.
- Kawamura A., Jinno, K., Berndtsson, R. and Furukawa, T. (December 1997) Real time tracking of convective rainfall properties using a two-dimensional advective-diffusion model. Journal of Hydrology, No.203, pp.109-118.
- Kawamura, A., McKerchar, A.I., Spigel, R. H. and Jinno, K. (January 1998) Chaotic characteristics of the Southern Oscillation Index time series. Journal of Hydrology, No.204, pp.168-181.

Representative Papers

- Xu, Z., Jinno, K., Kawamura, A., et al. (February 1998) Performance risk analysis for Fukuoka water supply system. Water Resources Management, Vol.12, I.1, pp.13-30.
- Merabtene, T., Kawamura, A., et al. (August 2002) Risk assessment for optimal drought management of integrated water resources system using genetic algorithm. Hydrological Processes, No.16, pp.2189-2208.
- Jin, Y.H., Kawamura, A., et al. (January 2005) Quantitative relationship between SOI and observed precipitation in southern Korea and Japan by nonparametric approaches. Journal of Hydrology, No.301, pp.54-65.
- Hentati, A., Kawamura, A., et al. (June 2010) Evaluation of sedimentation vulnerability at small hillside reservoirs in the semi-arid region of Tunisia using the Self-Organizing Map. Geomorphology, No.122, pp.56-64.

Representative Papers

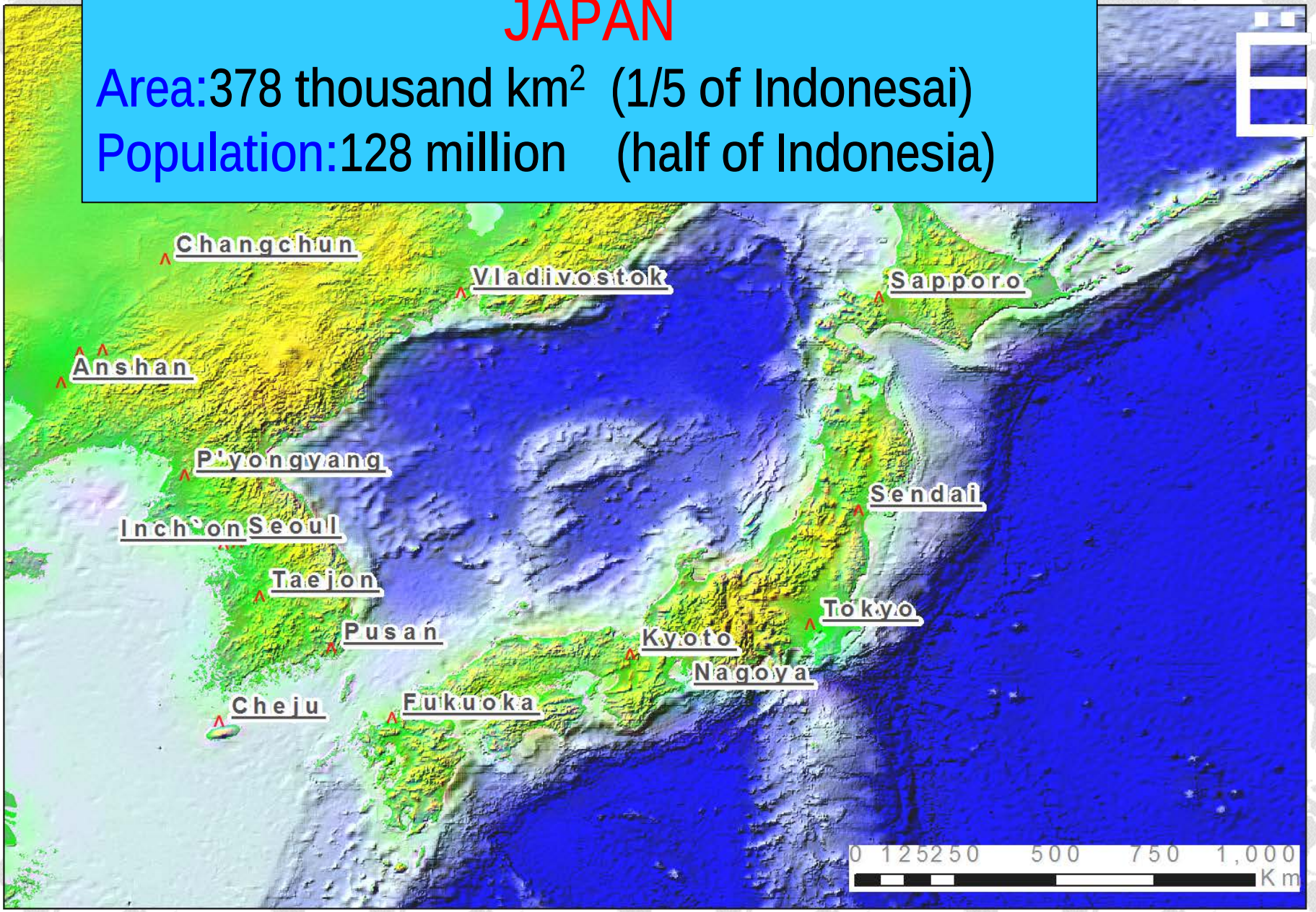
- Jin, Y.-H., Kawamura, A., et al. (October 2011) Spatiotemporal classification of environmental monitoring data in the Yeongsan River basin, Korea, using self-organizing maps. Journal of Environmental Monitoring, No.13, pp.2886-2894.
- Amaguchi, H., Kawamura, A., Olsson, J. and Takasaki, T. (February 2012) Development and testing of a distributed urban storm runoff event model with a vector-based catchment delineation. Journal of Hydrology, No.420-421, pp.205-215.
- Bui, D.D., Kawamura, A., et al. (March 2012) Aquifer system characterization for potential groundwater resources in Hanoi, Vietnam. Hydrological processes, Vol.26, No.6, pp.932-946.
- Olsson, J. Amaguchi, H., Kawamura, A. et al. (May 2012) Adaptation to climate change impacts on urban storm water: a case study in Arvika, Sweden. Climatic Change (on line)

http://www.comp.tmu.ac.jp/akira/

JAPAN

Area:378 thousand km^2 (1/5 of Indonesai)

Population:128 million (half of Indonesia)



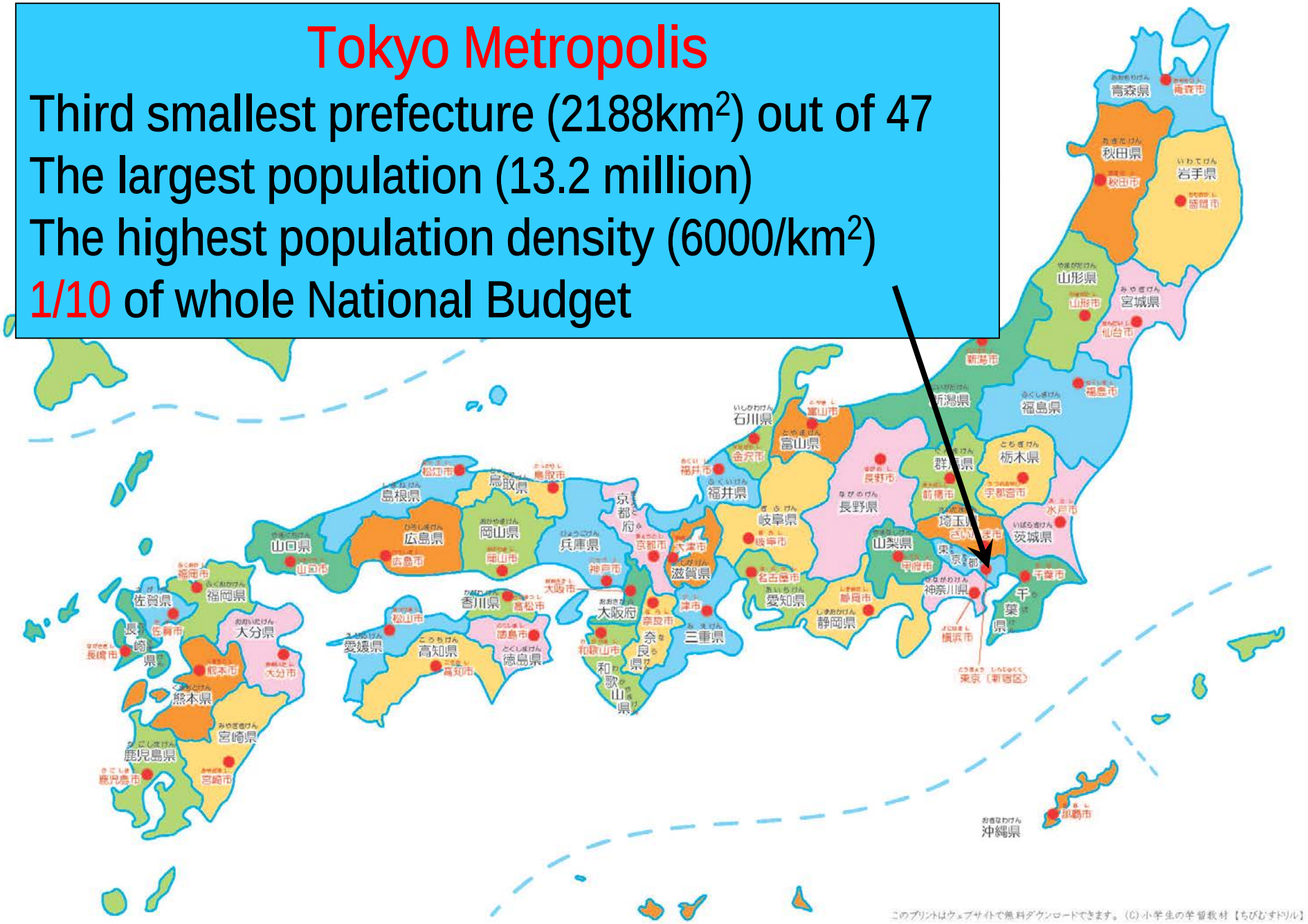
Tokyo Metropolis

Third smallest prefecture (2188km^2) out of 47

The largest population (13.2 million)

The highest population density (6000/km^2)

1/10 of whole National Budget

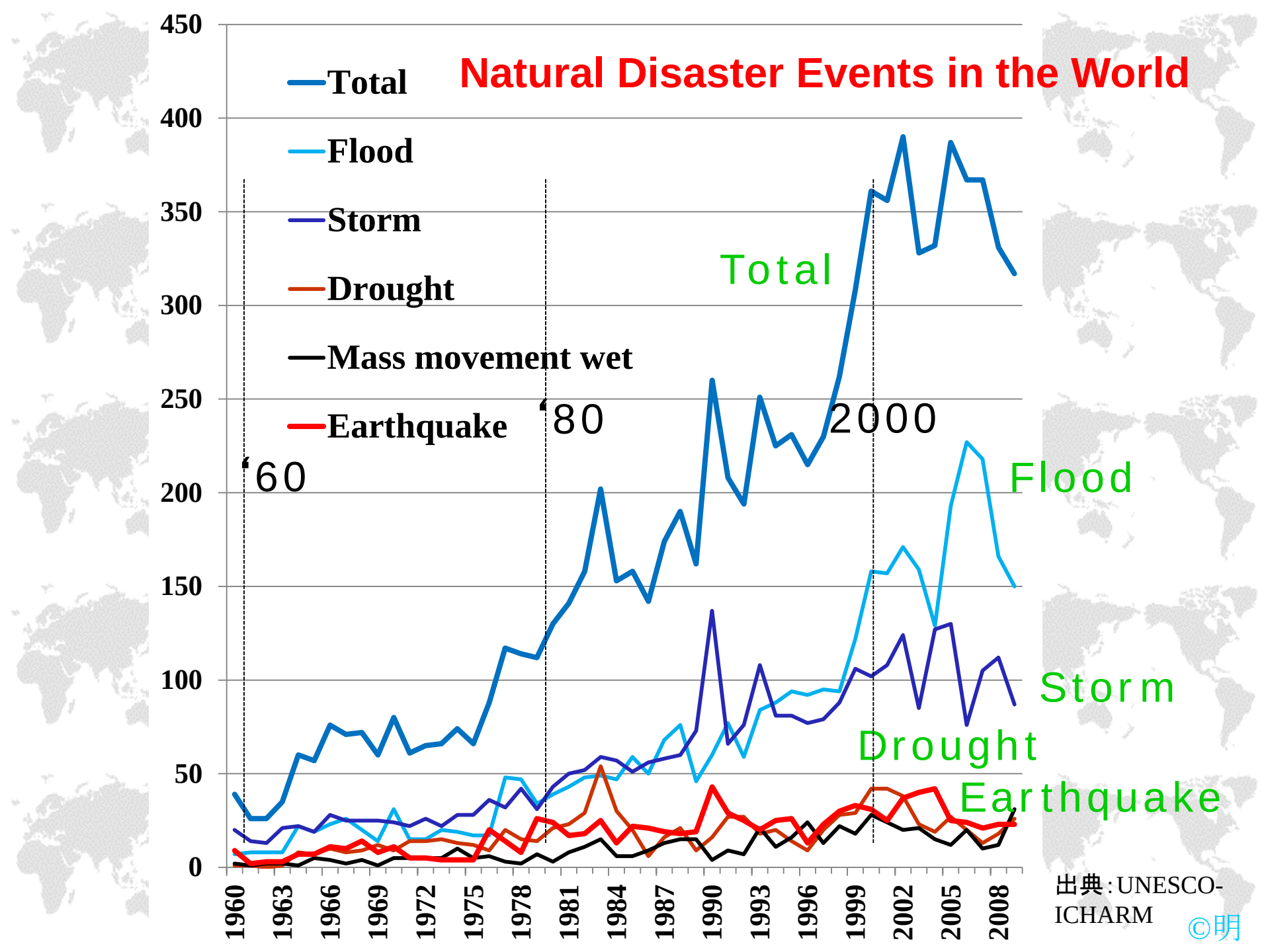



Tokyo Metropolitan University (Established in 1949)
Only one Tokyo Metropolitan Governmental University
Staff : about 1,000 members (700 faculty members)
Students: about 10,000 students (3000 graduate students)
TOKYO METROPOLITAN UNIVERSITY

Times Higher Education's 2011-2012 World University Ranking

DR	WR	University	Overall Ranking Score	Teaching	Research	Citations	Industry Income	International Outlook
1	30	**The University of Tokyo**	74.3%	86.1%	80.3%	69.1%	76.6%	23.0%
2	52	**Kyoto University**	64.8%	76.4%	72.0%	56.3%	71.7%	21.1%
3	108	**Tokyo Institute of Technology**	52.8%	56.0%	58.9%	49.5%	66.3%	24.9%
4	119	**Osaka University**	51.0%	61.8%	56.5%	40.0%	75.0%	21.1%
5	120	**Tohoku University**	50.8%	57.7%	55.7%	42.9%	78.9%	25.6%
6	202	**Nagoya University**	41.0%	45.5%	39.2%	43.8%	33.1%	21.2%
7	237	**Tokyo Metropolitan University**	36.1%	19.0%	10.3%	84.3%	27.6%	17.8%
8	261	**University of Tsukuba**	34.3%	37.2%	26.2%	41.4%	32.0%	27.2%
9	271	**Kyushu University**	33.5%	46.8%	30.7%	23.2%	75.1%	19.5%
10	284	**Tokyo Medical and Dental University**	33.0%	42.8%	22.6%	36.7%	40.8%	18.0%

Natural Disasters


Natural Disaster Events in the World
Total
Flood
Storm
Drought
Mass movement wet
Earthquake
'60
'80
2000
Total
Flood
Storm
Drought
Earthquake
450
400
350
300
250
200
150
100
50
0
1960
1963
1966
1969
1972
1975
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
出典：UNESCO-ICHARM
©明

The Facts of Death Toll in the World

- The total numbers of death toll by earthquake for 108 years during 1900-2007 is
- 2 million 144 thousand

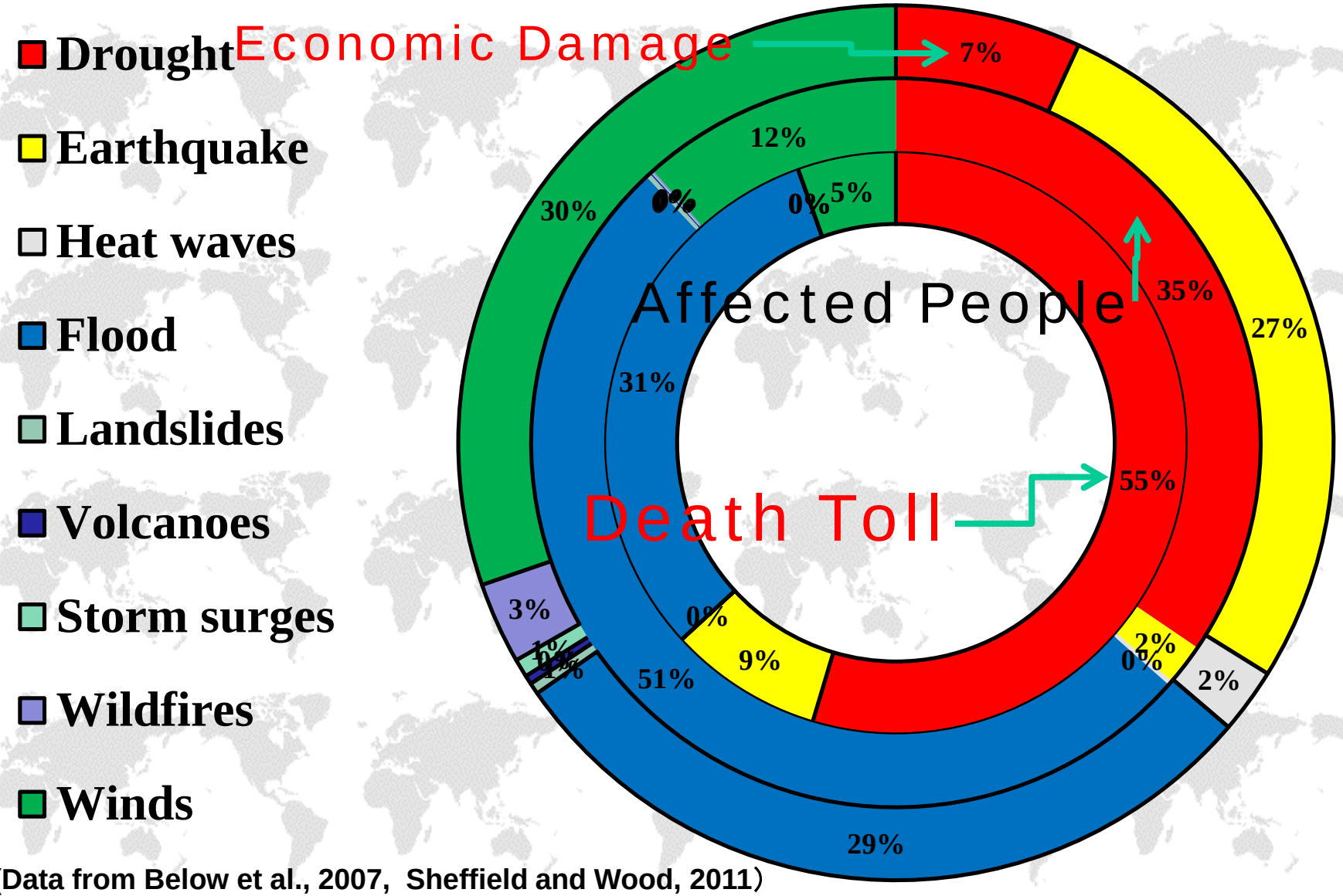
- The number of death toll by one flood event occurred in Yellow River in China in 1931 is
- About 3 million 700 thousand (including infectious disease, die of starvation)

- Very high death toll by Drought

Death Toll by Major Natural Disasters

Year	Disaster Type	Country	Death Toll	Remarks
1900	Drought	India	1,250,000	
1920	Drought	China	500,000	
1921	Drought	USSR	1,200,000	
1928	Drought	China	3,000,000	
1931.July	Flood	China	3,700,000	
1939.July	Flood	China	500,000	
1942	Drought	India	1,500,000	
1943	Drought	Bangladesh	1,900,000	
1959.July	Flood	China	2,000,000	
1965	Drought	India	1,500,000	
1970. Nov 12	Cyclone	Bangladesh	300,000	High Tide 9 m
1983. Apr-May	Drought	Chad, Ethiopia, Djibouti, Sudan	453,000	
1991. Apr 29	Cyclone	Bangladesh	138,868	High Tide 6 m
2004. Dec 26	Earthquake/Tsunami	13 Countries of Indian Ocean	283,100	M9.0
2008. May 2	Cyclone	Myanmar	138,366	
2010.J an12	Earthquake	Haiti	220,000	M7.0

Natural Disaster Damages 1900-2004



(Data from Below et al., 2007, Sheffield and Wood, 2011)

The Facts of Death Toll in the World

- The death toll by Spanish influenza occurred during 1918-1920 is
- More than 20 million

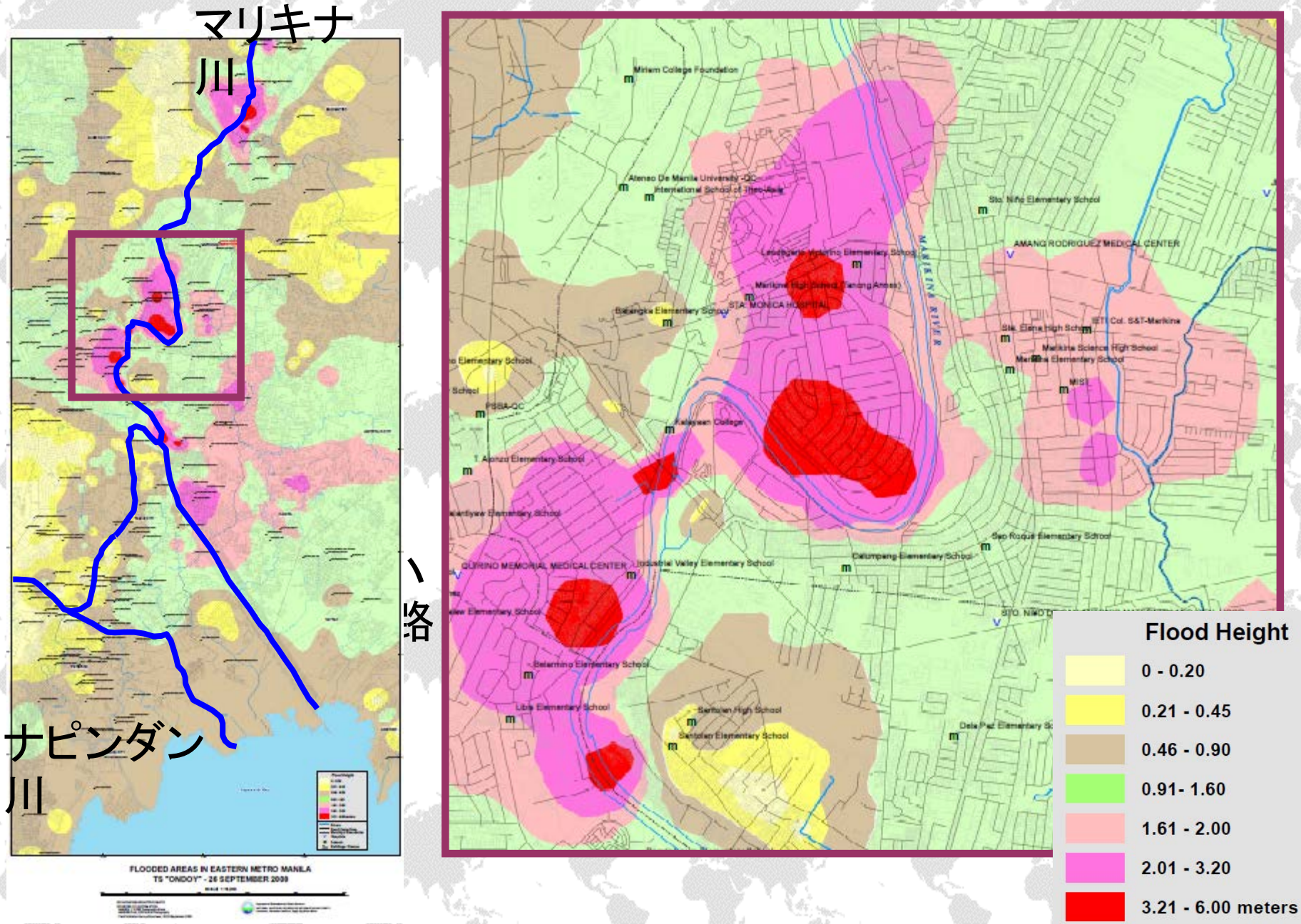
- The death toll by World War II during 1939-1945
- About 55 million

Urban Flood in Metro Manila, Philippines in 2009

Urban Flood in Metro Manila, Philippines on 26 September, 2009

Urban Flood in Metro Manila, Philippines on 26 September, 2009

Urban Flood in Metro Manila, Philippines on 26 September, 2009


マリキナ川
ナピンダン川
FLOODED AREAS IN EASTERN METRO MANILA
TS "ONDOY" - 26 SEPTEMBER 2009
Miriam College Foundation
Ateneo De Manila University -QC
International School of Theology
Sto. Niño Elementary School
AMANG RODRIGUEZ MEDICAL CENTER
Leandro Locsin Memorial Elementary School
Marikina High School (Tanong Annex)
STA. MONICA HOSPITAL
Balanga Elementary School
MARIKINA RIVER
Sta. Elena High School
IETI Col. S&T-Marikina
Marikina Science High School
Marikina Elementary School
MISI
PSBA-QC
Kalayaan College
T. Alonzo Elementary School
Sto Roque Elementary School
Calumpang Elementary School
QUIRINO MEMORIAL MEDICAL CENTER
Industrial Valley Elementary School
Concepcion Elementary School
Libis Elementary School
Santolan High School
Santolan Elementary School
Flood Height
0 - 0.20
0.21 - 0.45
0.46 - 0.90
0.91- 1.60
1.61 - 2.00
2.01 - 3.20
3.21 - 6.00 meters

Cristine Reyes, Filipina Famous Actress

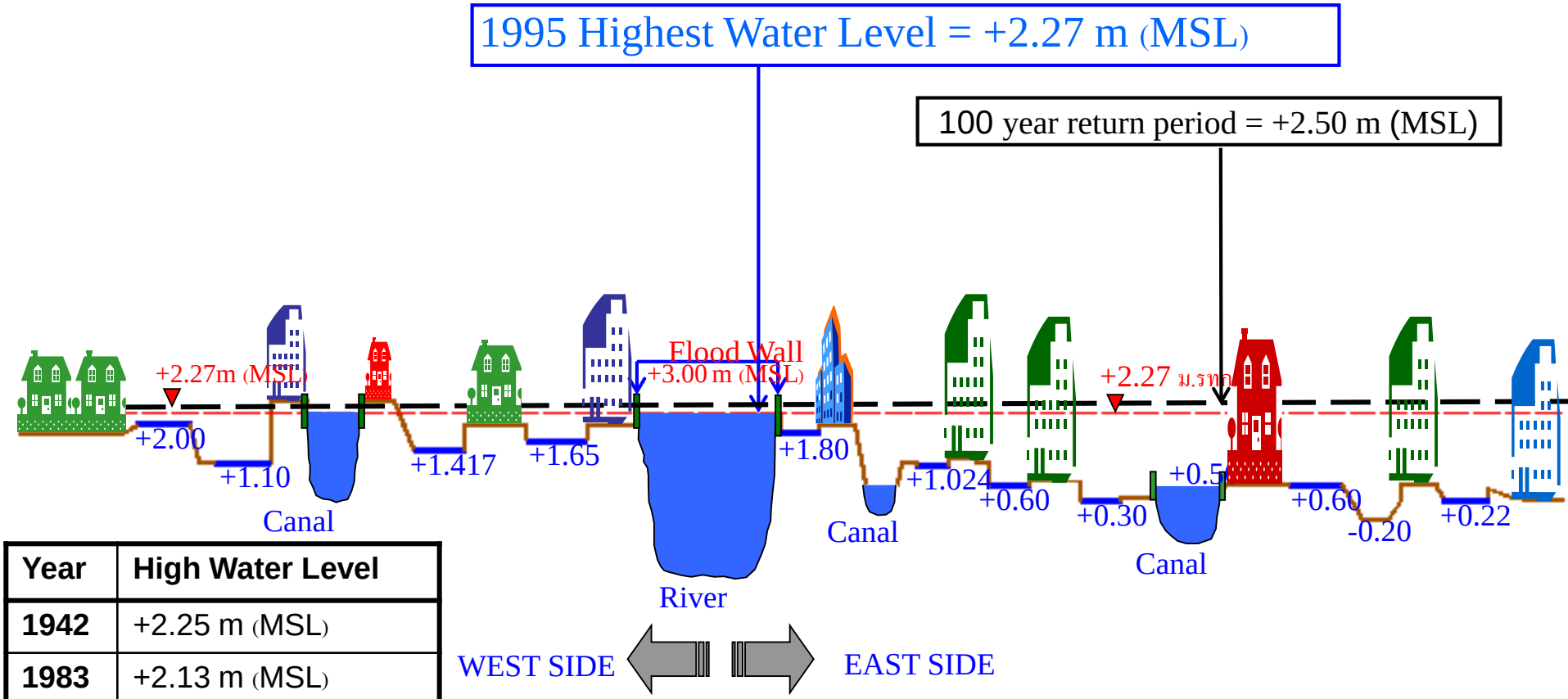
Evacuated on the roof at Provident Village in the Marikina River basin

Cristine Reyes' House

Mangahan Floodway
By Kawamura
Nov. 29, 2009

Urban Flood in Bangkok, Thailand in 2011

Cross Section of Bangkok Area



Year	High Water Level
1942	+2.25 m (MSL)
1983	+2.13 m (MSL)
1995	+2.27 m (MSL)
1996	+2.14 m (MSL)
2002	+2.10 m (MSL)
2006	+2.22 m (MSL)
2008	+2.17 m (MSL)
2010	+2.10 m (MSL)
2011	**+2.53 m (MSL)**

High Water Level in 100 year return periods
= +2.50 m (MSL)

Cause of flood

(MSL) = mean sea level

- Large Runoff from upstream
- Heavy Rainfall
- Tidal Effect

Inundated Ayutthaya Remains

洪水災害調査報告会 2011年12月9日JICA竹谷公男客員専門員

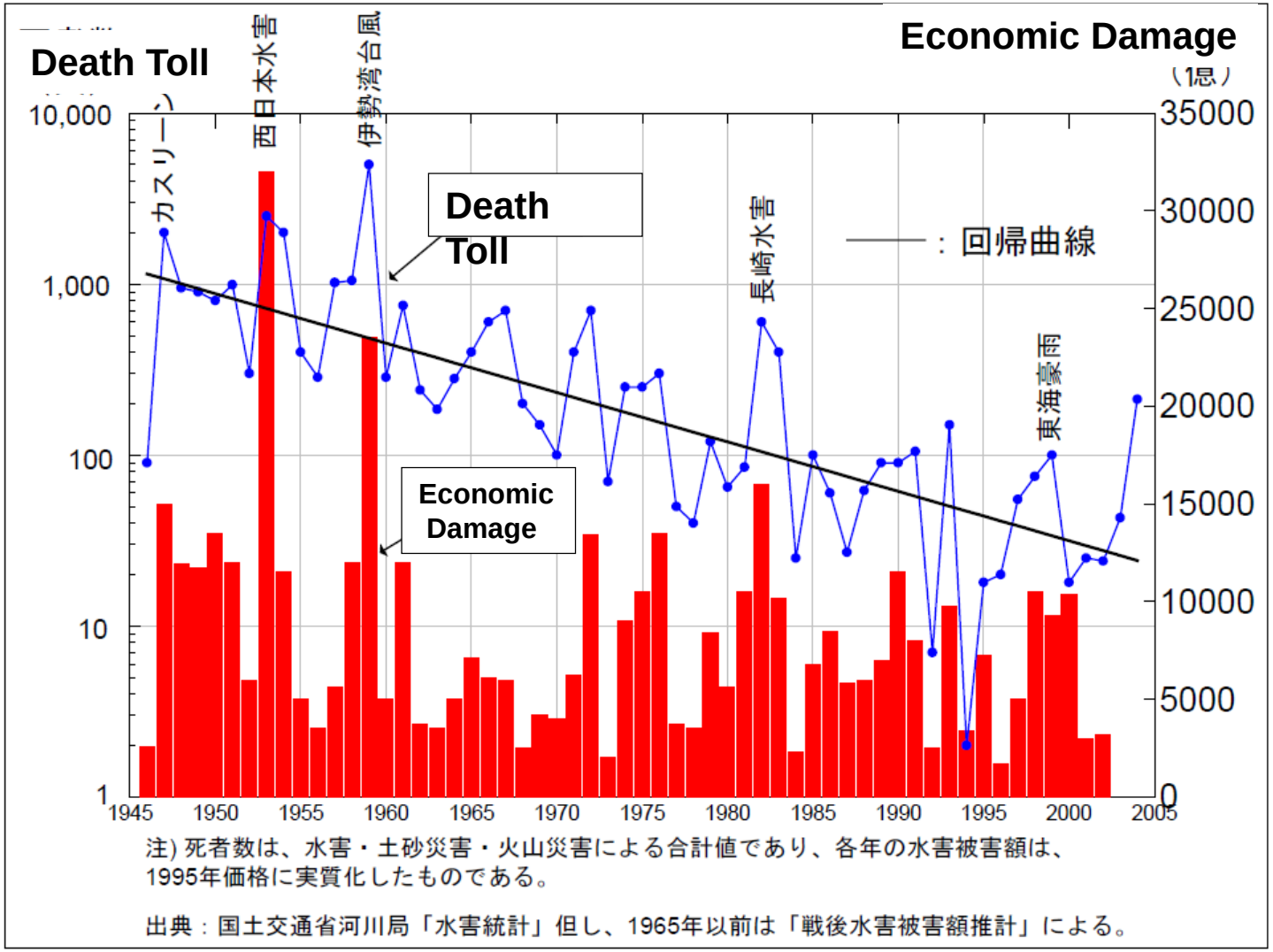
Inundated Industrial Park

HONDA工場：洪水災害調査報告会 2011年12月9日JICA竹谷公男客員専門員

Inundated Don Mueang Airport

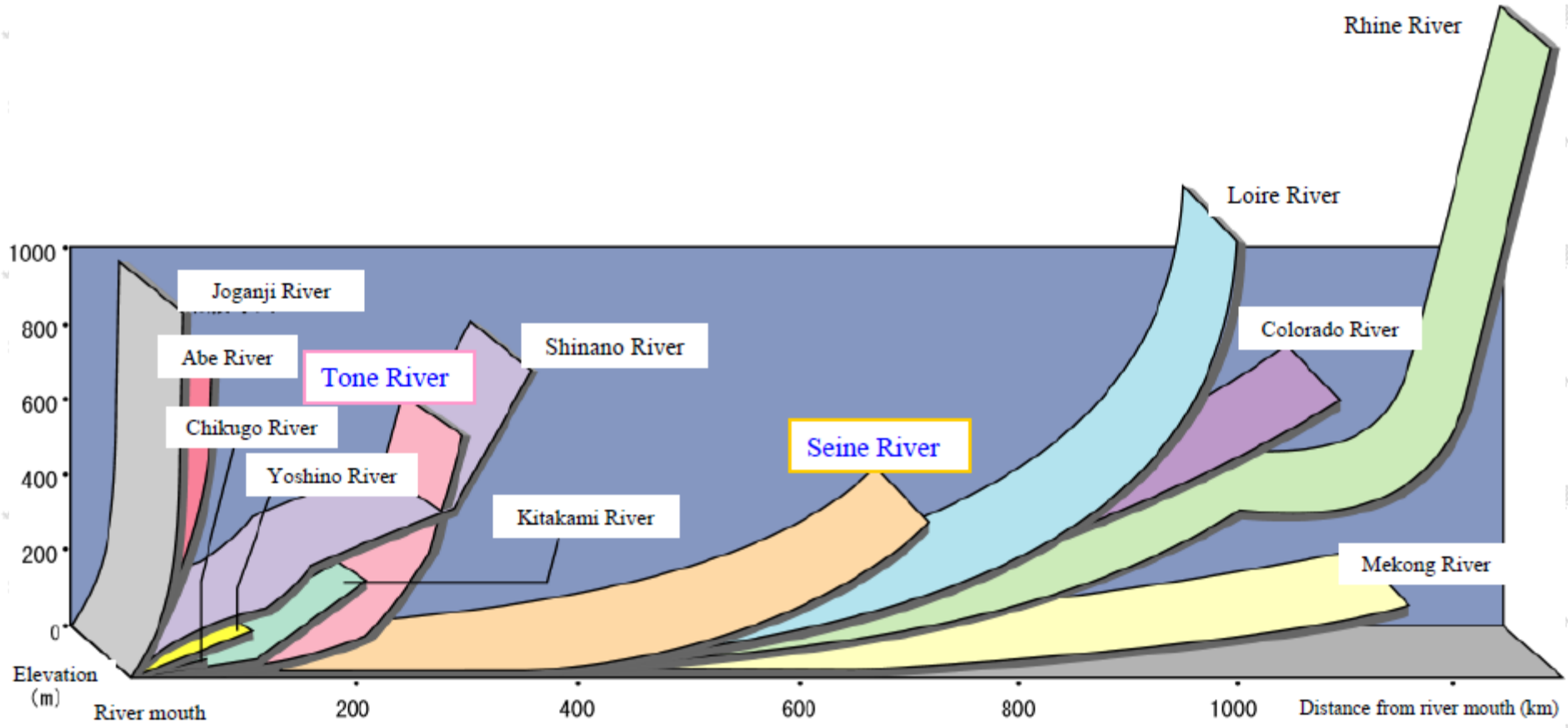
Urban Flood in Jakarta, January 17, 2013

Flood Situation in Japan



Death toll is constantly decreasing by the flood control after World War II

Rivers in Japan tend to be steep, short and rapid flowing.



Comparison of the longitudinal profiles of rivers in Japan and other countries

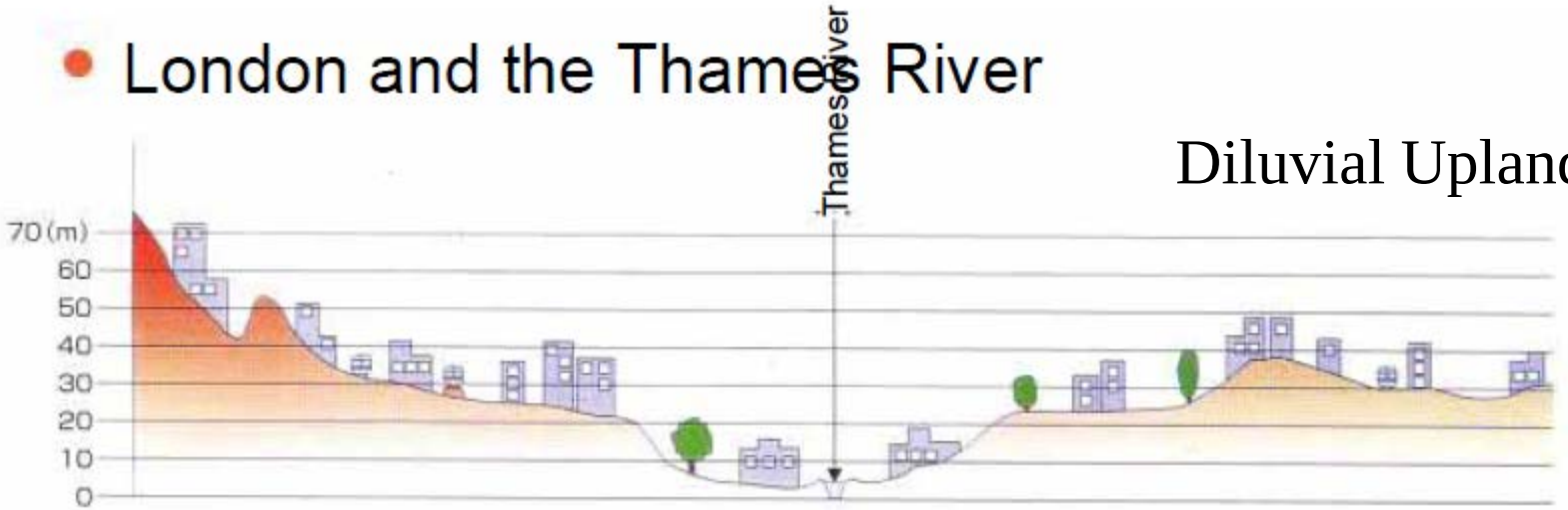
Scene of the Thames River

Scene of the Sumida River in Tokyo

Cross Section of London and Tokyo

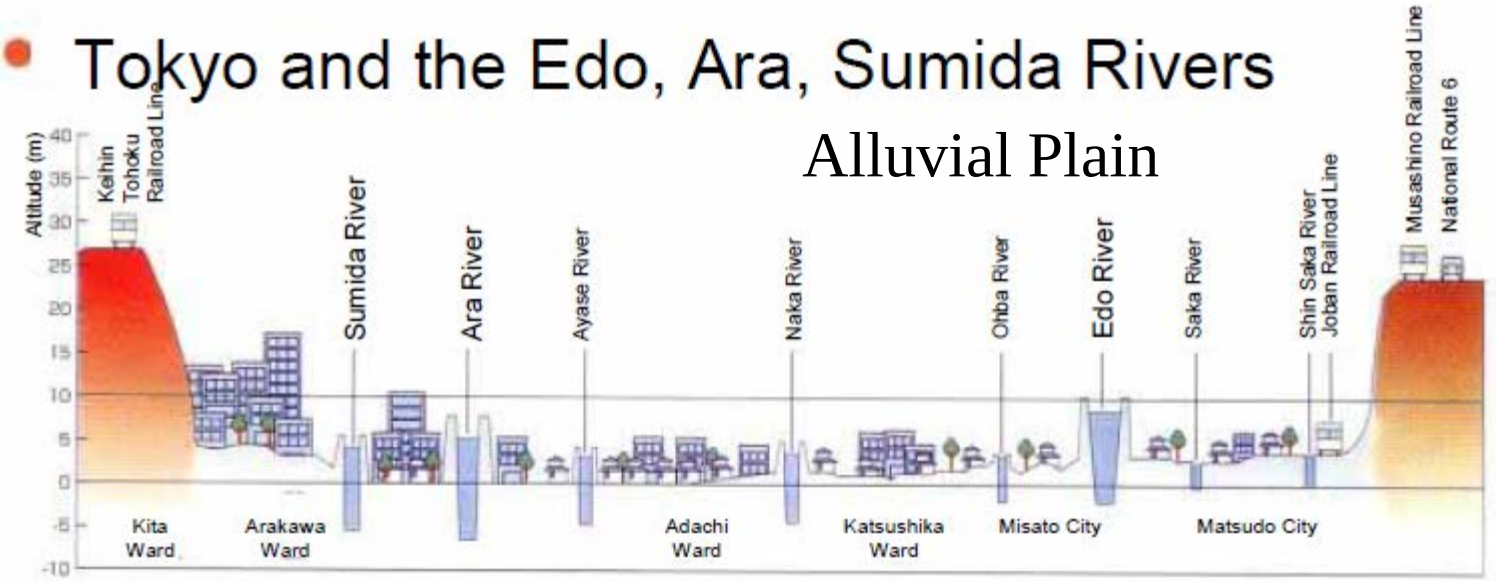
- London and the Thames River

Diluvial Upland

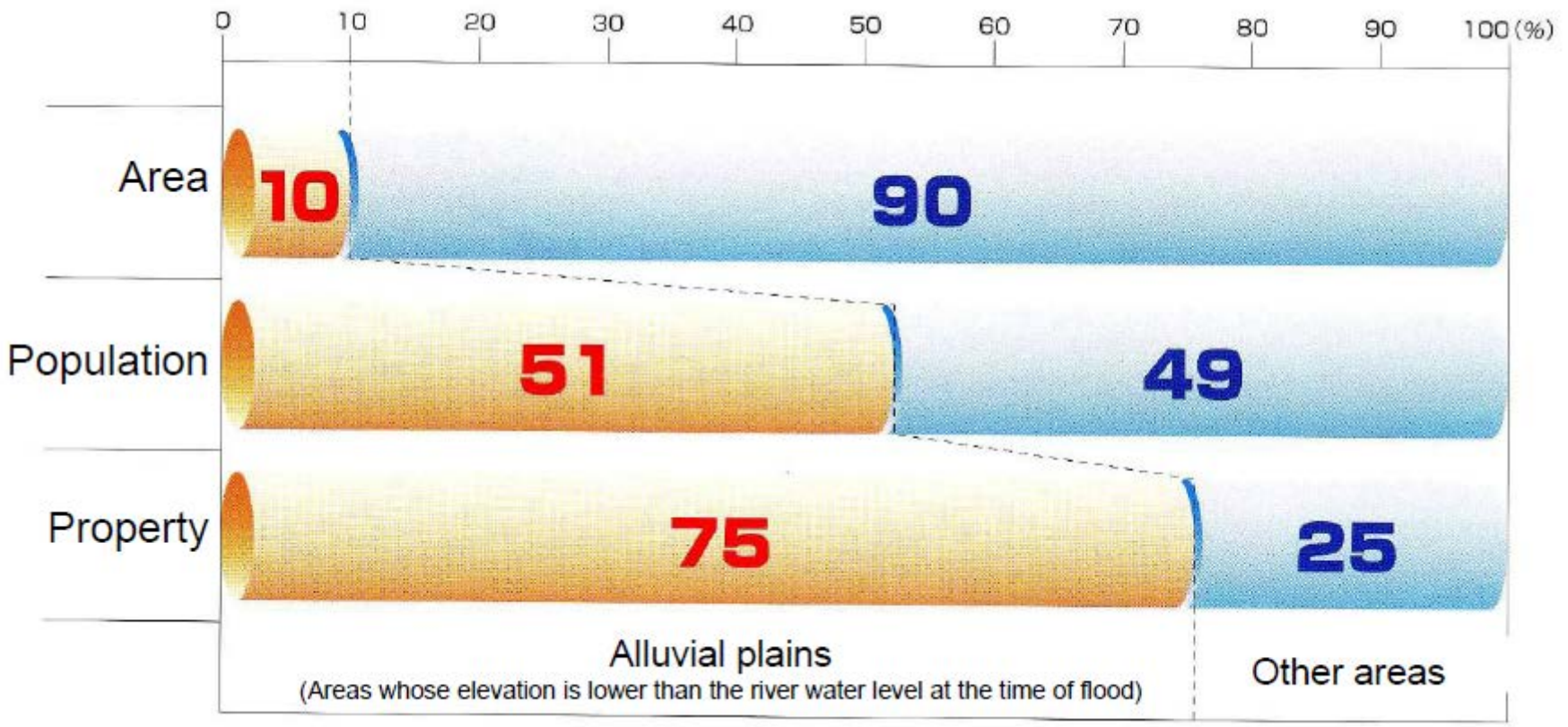


- Tokyo and the Edo, Ara, Sumida Rivers

Alluvial Plain

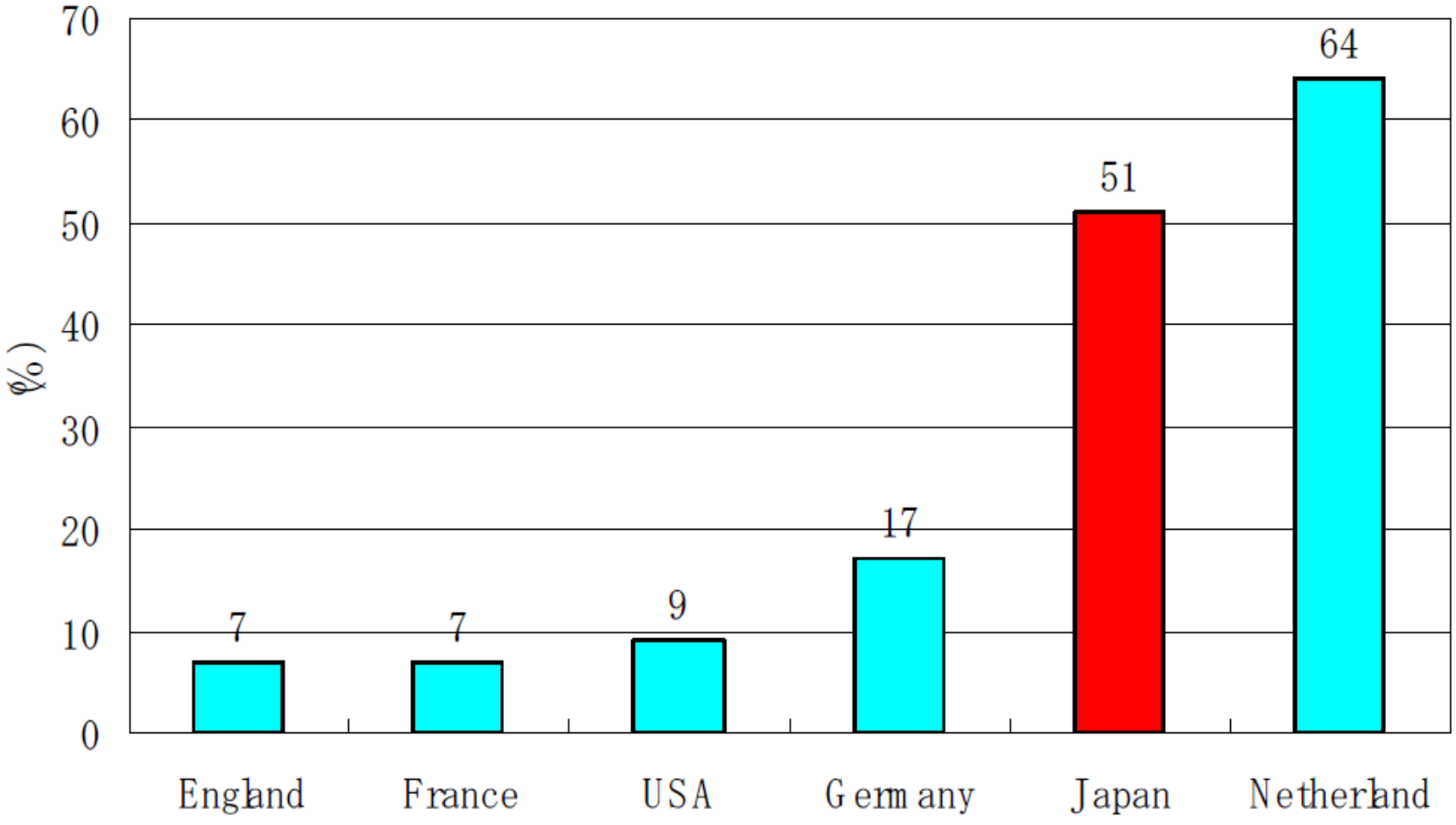


Situation of the alluvial flood plains in Japan

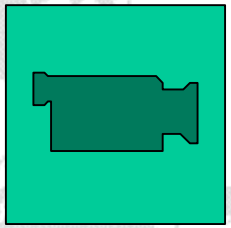


51 percent of population and 75% of property are concentrated in floodplains accounting for only 10% of total land area.

Population in flood plain / Total population



Urban Floods in Tokyo



Example of Urban Flood

Kanda River in ordinary times (Tokyo)

Kanda River in flood during Typhoon No. 11 in 1993

Example of Urban Flood

Localized Torrential Rain
(Sept. 4, 2005)

Subway Hakata Station during localized heavy rain in July 2003

Inundation of basement in Shinjuku in July 1999

豪雨 地下室を襲う

点検の65歳が水死

階段から雨水、脱出できず

天井近くまで濁水し家具などが散乱した地下1階の倉庫＝東京都新宿区西落合で21日午後6時すぎ、竹内紳写す

雨水が流れ込んだ地下1階への階段＝東京都新宿区西落合で21日午後6時すぎ、竹内紳写す

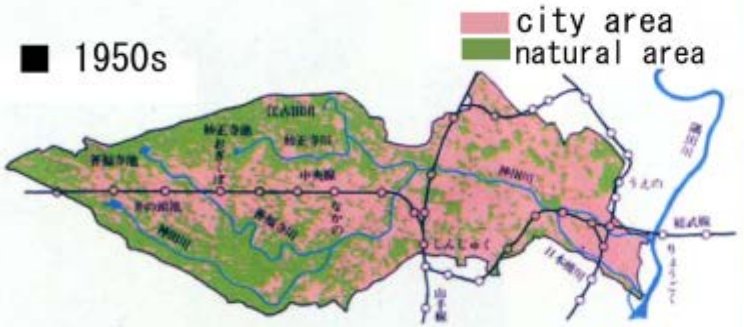
Subway Azabu-juban Station during Typhoon No. 22 in October 2004

Inundation of basement during Fukuoka Flood of June 1999

Urbanization

■ Before Urbanization

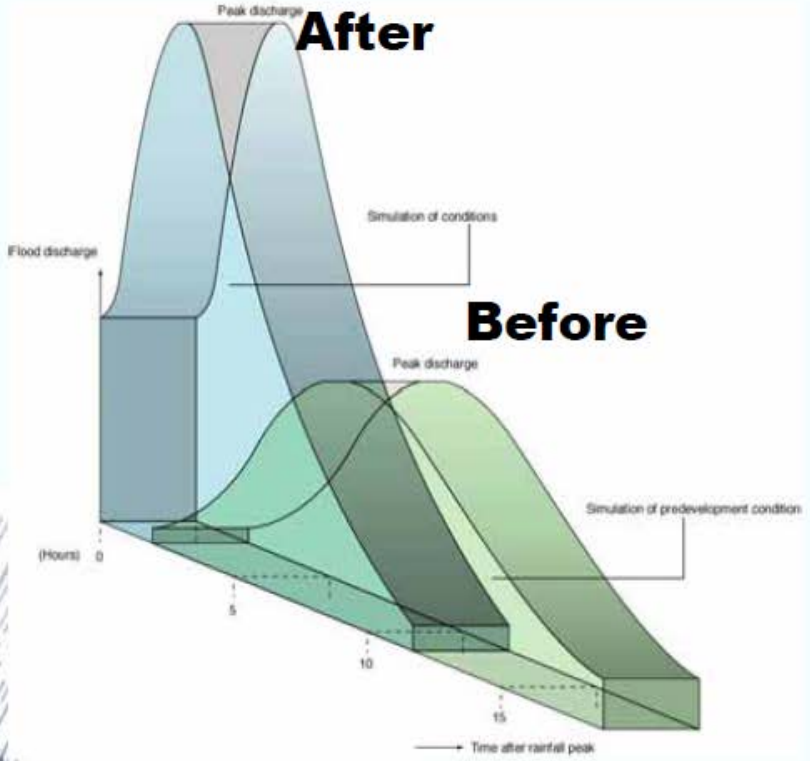
■ 1950s



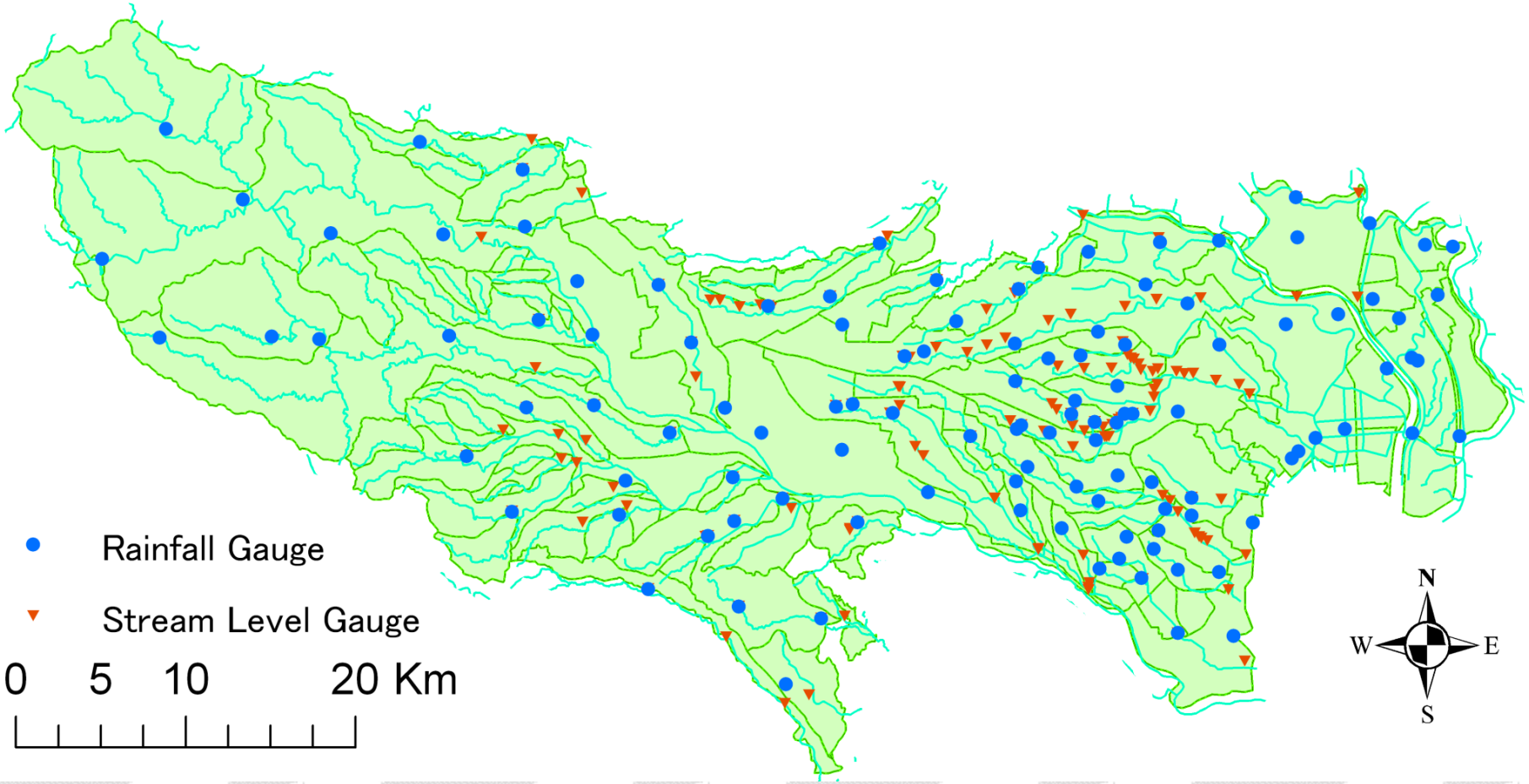
■ After Urbanization

■ 1990s

Urbanization Effect on Hydrograph

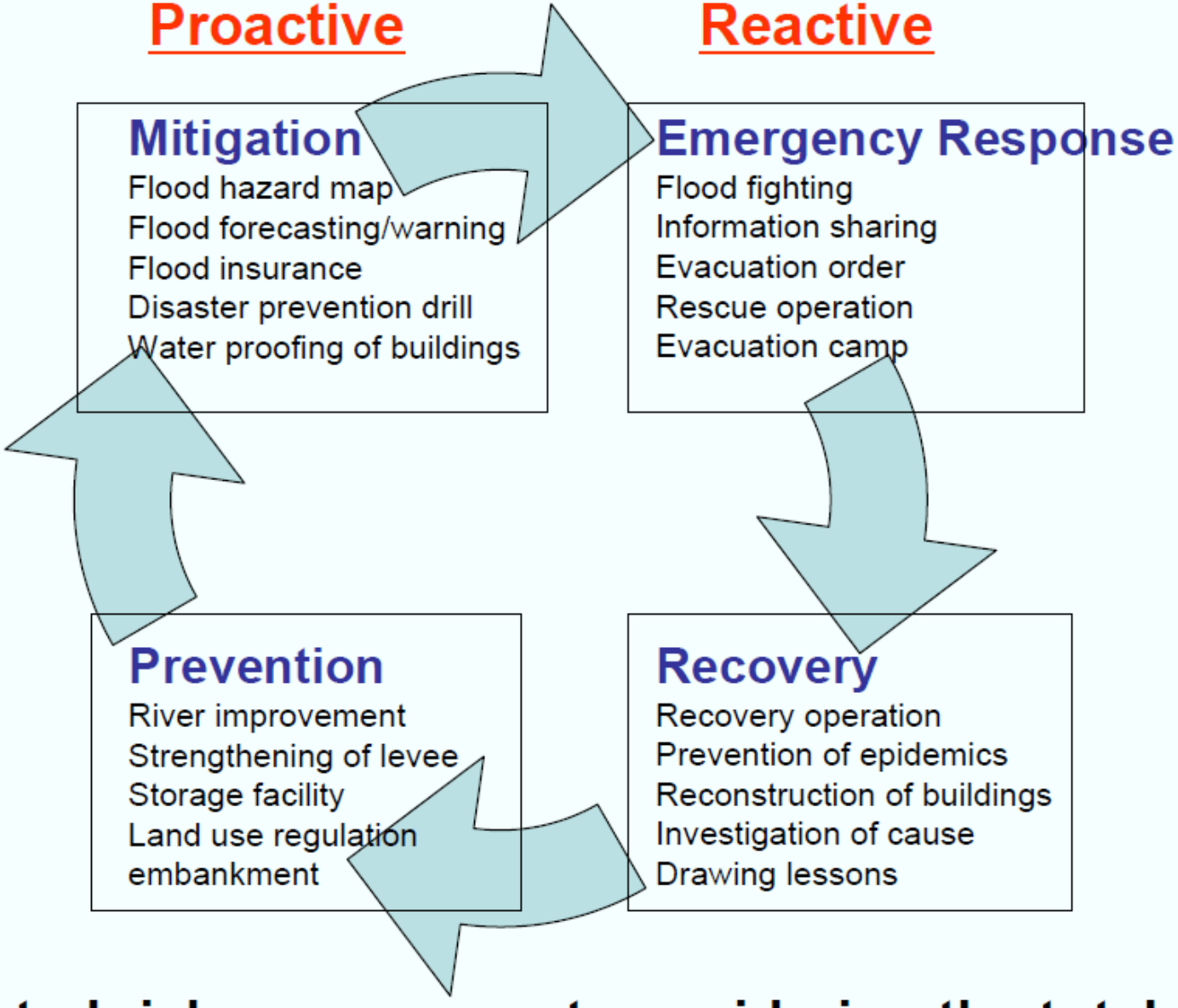


Tokyo Hydrological Data Acquisition System



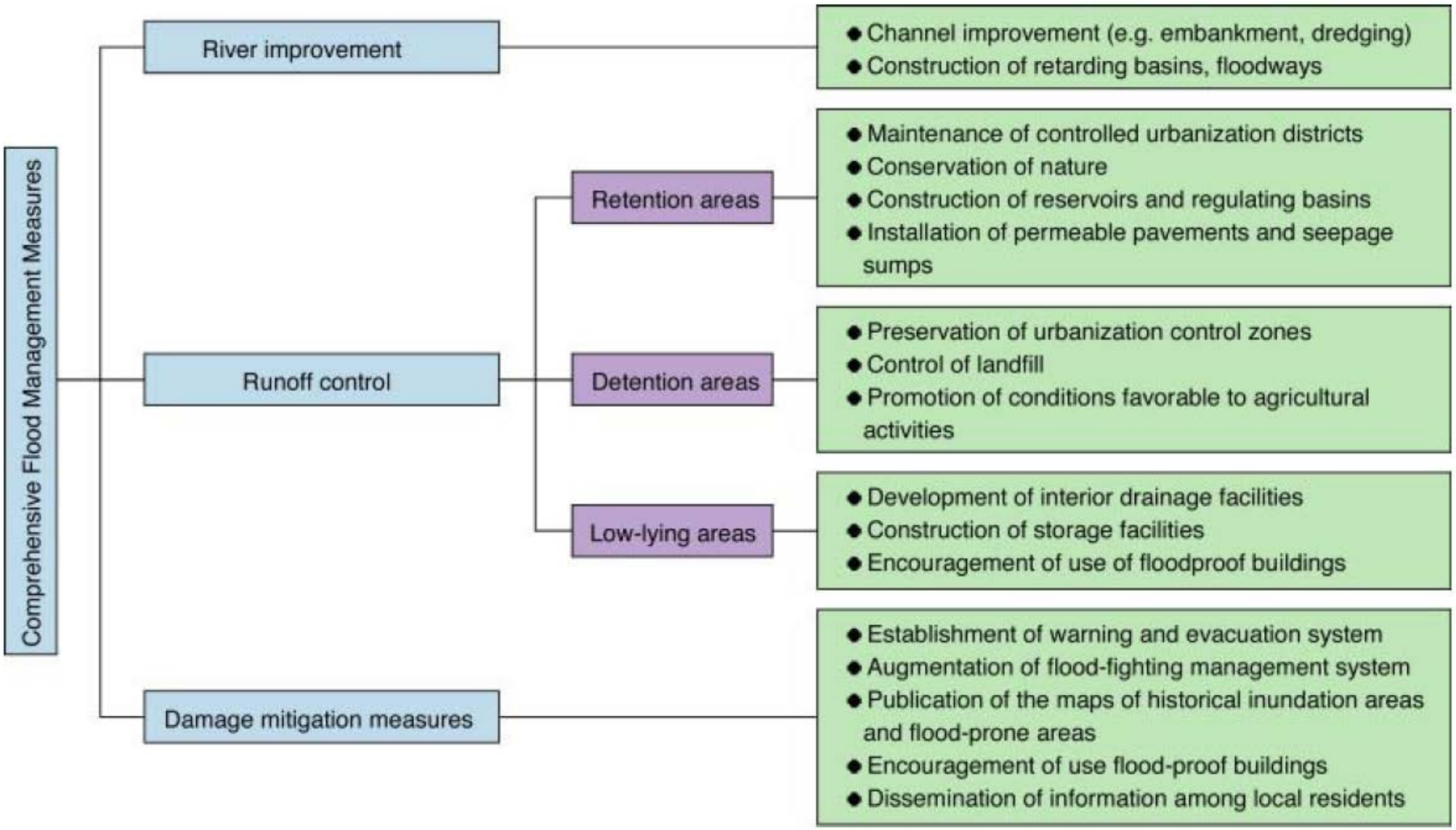
Flood Record of Nerima Ward

Month Day, Year	Total Rainfall (mm)	Maximum Hourly Rainfall (mm/hour)	Number of Inundated Houses
July 7, 1994	65	34	6
Aug. 2, 1995	18	18	24
July 21, 1999	151	131	285
Aug. 7, 2000	47	44	11
Sept. 12, 2000	91	24	5
July 18, 2001	61	53	142
June 25, 2003	56	24	9
Sept. 4, 2005	231	120	687



Integrated risk management considering the total balance of proactive and reactive measures is important

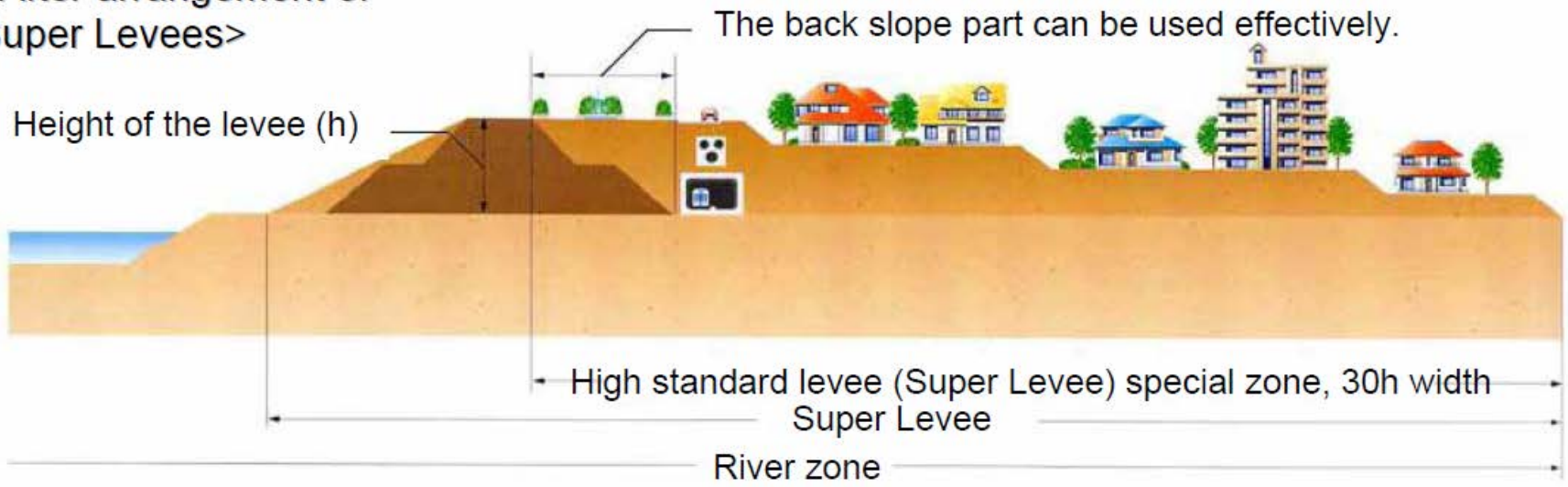
Comprehensive Flood Control Measures in Tokyo



Super Levees

<Before arrangement of Super Levees>

<After arrangement of Super Levees>



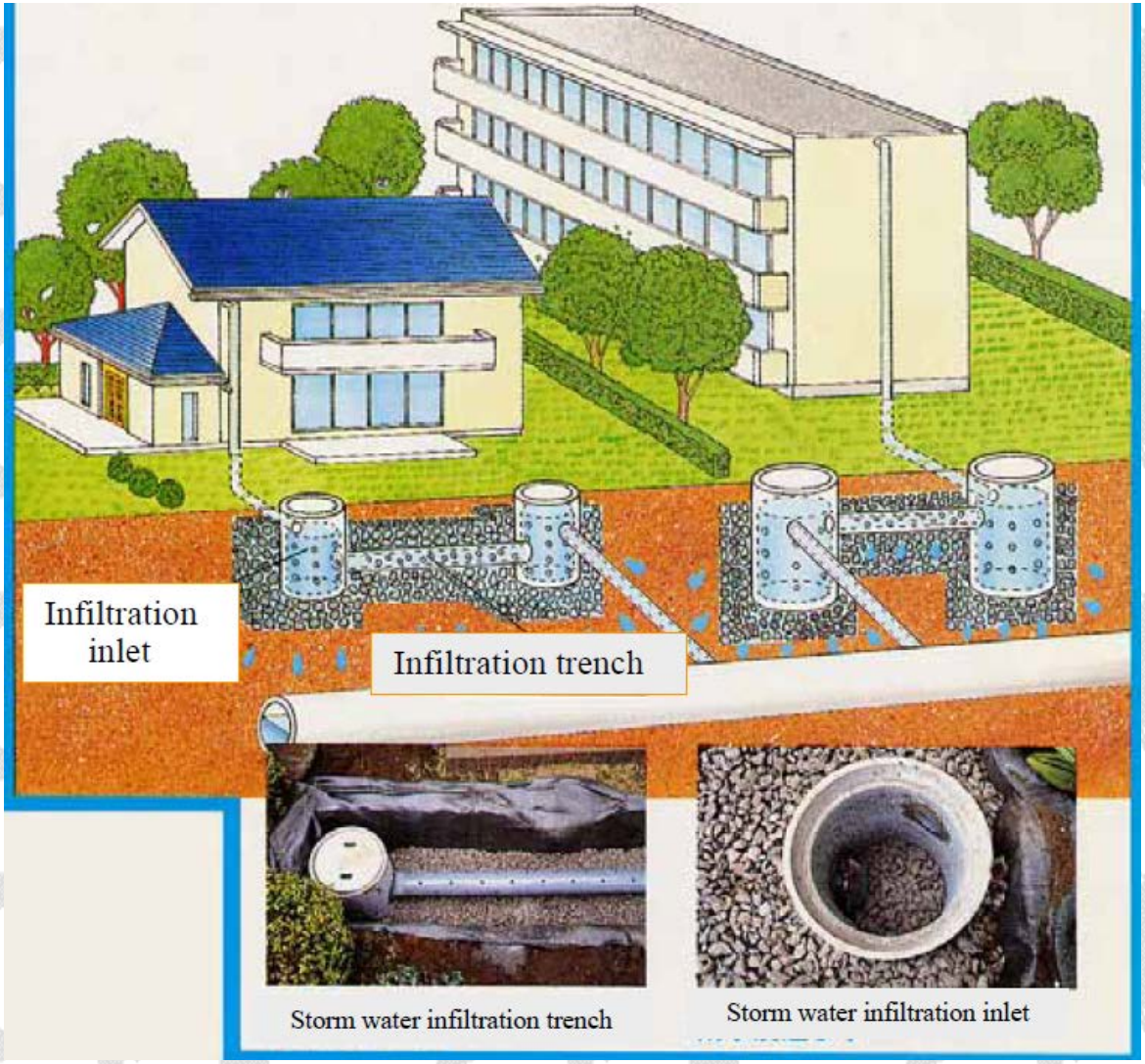
Runoff Control Measures

Permeable pavement

Permeable tile pavement

Tokyo Metropolis

Storm Water Infiltration Facilities



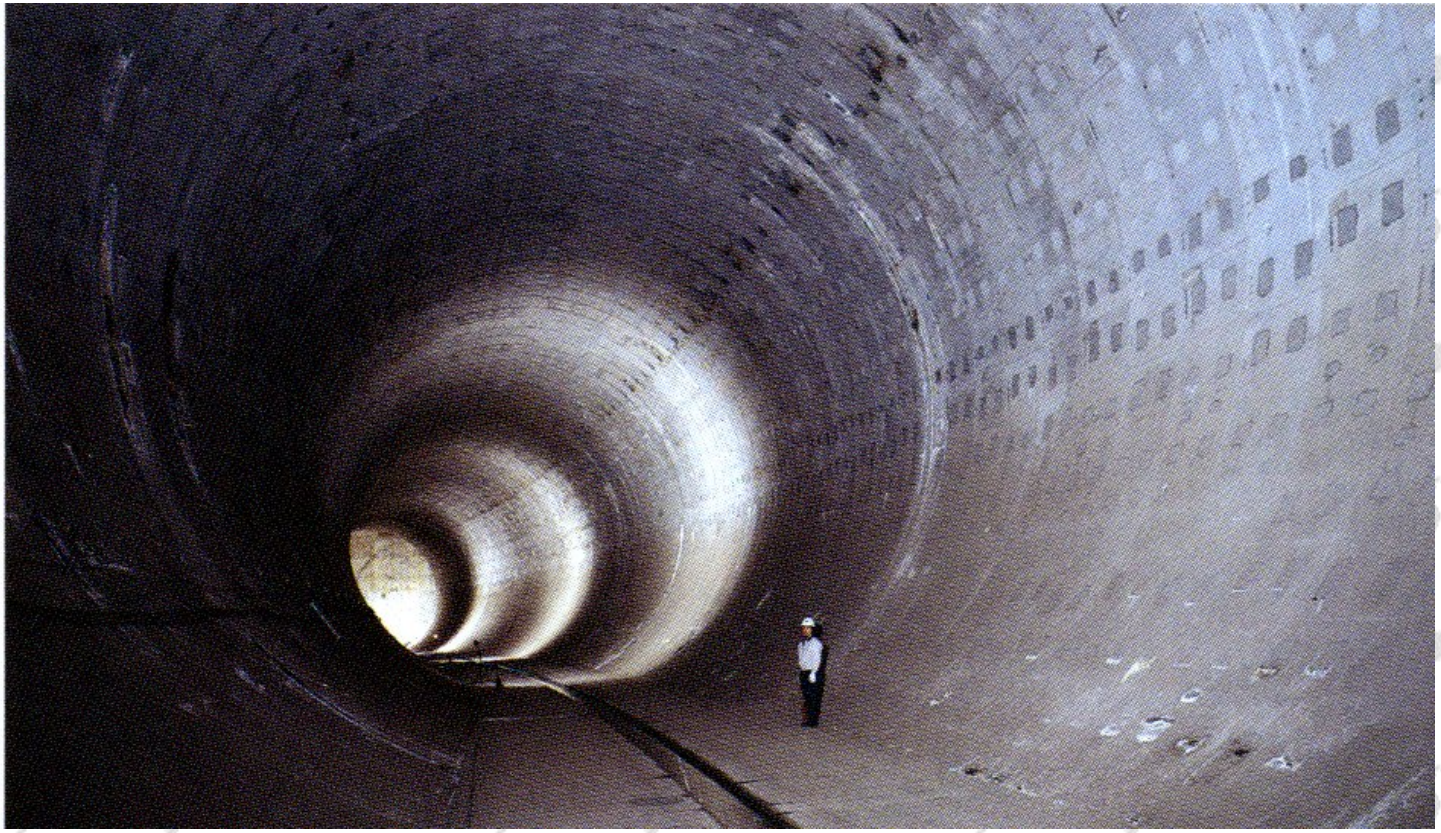
Construction of Rainwater Storage Facilities

Multipurpose Retarding basin

Piloti Style (Elevated-Floor) Construction

The piloti method (elevated-floor style) is used to minimize damage even if the building is inundated.

Underground Flood Retarding Reservoir



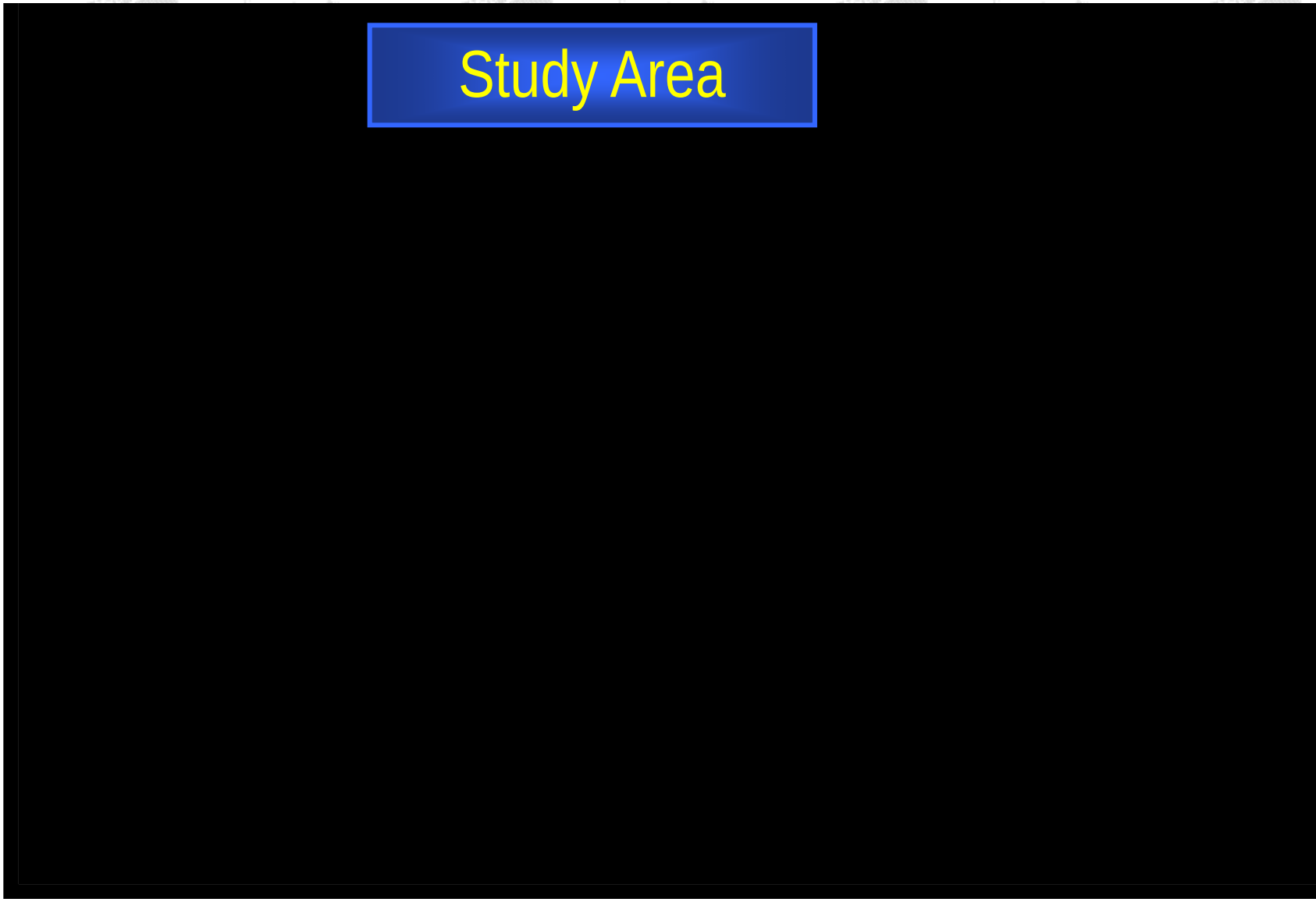
4.5km long tunnel with inside diameter of 12.5m (540 thousand m^3)
Planned as part of the larger underground river (floodway) project

Tokyo Storm Runoff (TSR) Model Based on Precise GIS Delineation

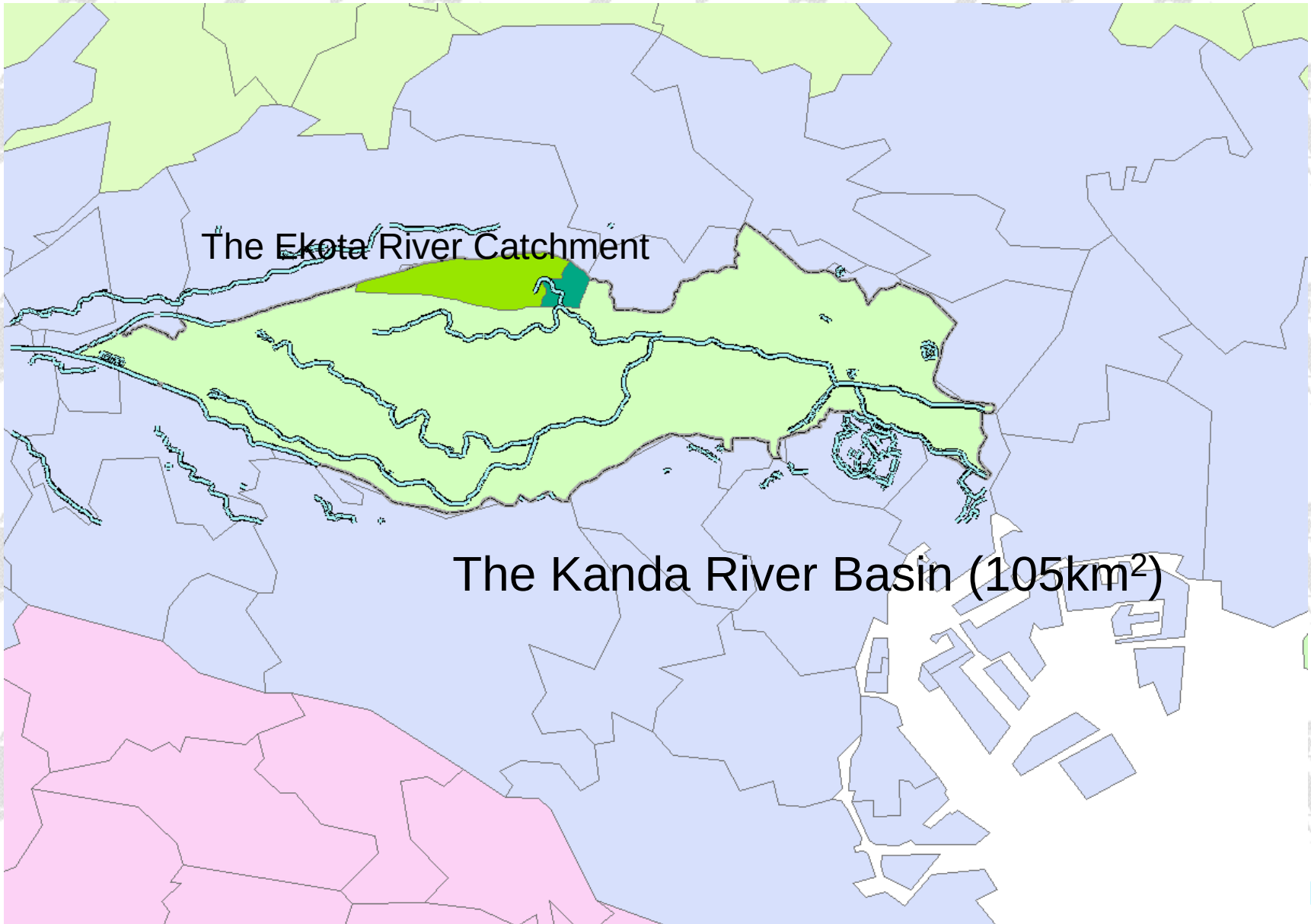
Amaguch, H., Kawamura A. and Takasaki T. (2007) Physically based distributed flood runoff model for an urban catchment using polygon feature GIS data.” ***J. Japan Society of Civil Engineers B*****, Vol.63, No.3, pp.206–223, (in Japanese).**

Amaguchi, H., Kawamura, A., Olsson, J. and Takasaki, T. (February 2012) Development and testing of a distributed urban storm runoff event model with a vector-based catchment delineation. Journal of Hydrology, No.420-421, pp.205-215.

Study Area



Study Area



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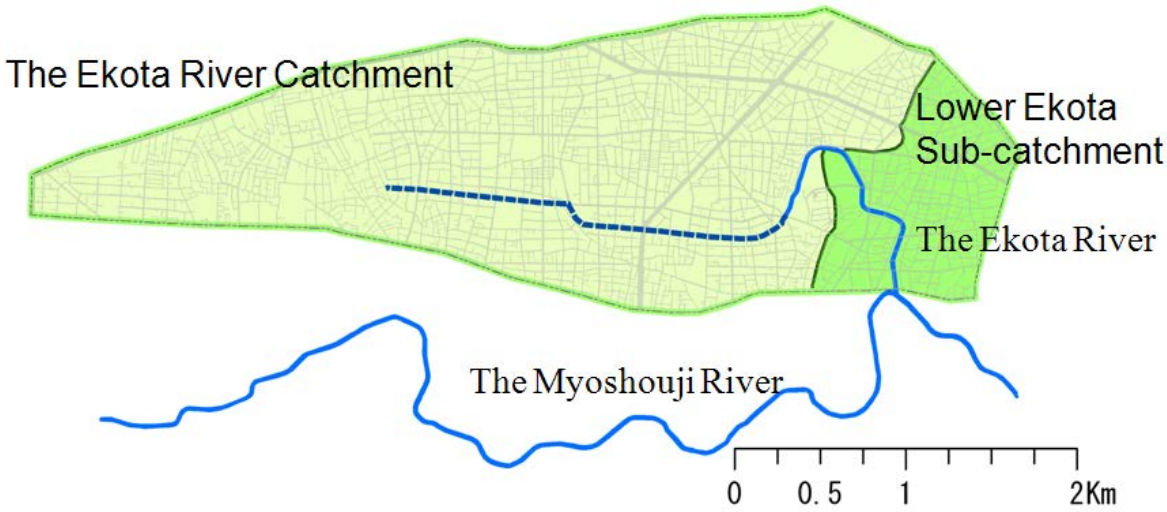
Study Area



Lower Ekota Sub-catchment (1.1km^2)

Characteristic of Urban Catchment

Rural catchments

Urban Catchments

Surface

Buildings, Roads, Parking lots, Playgrounds, Parks, etc.

＋

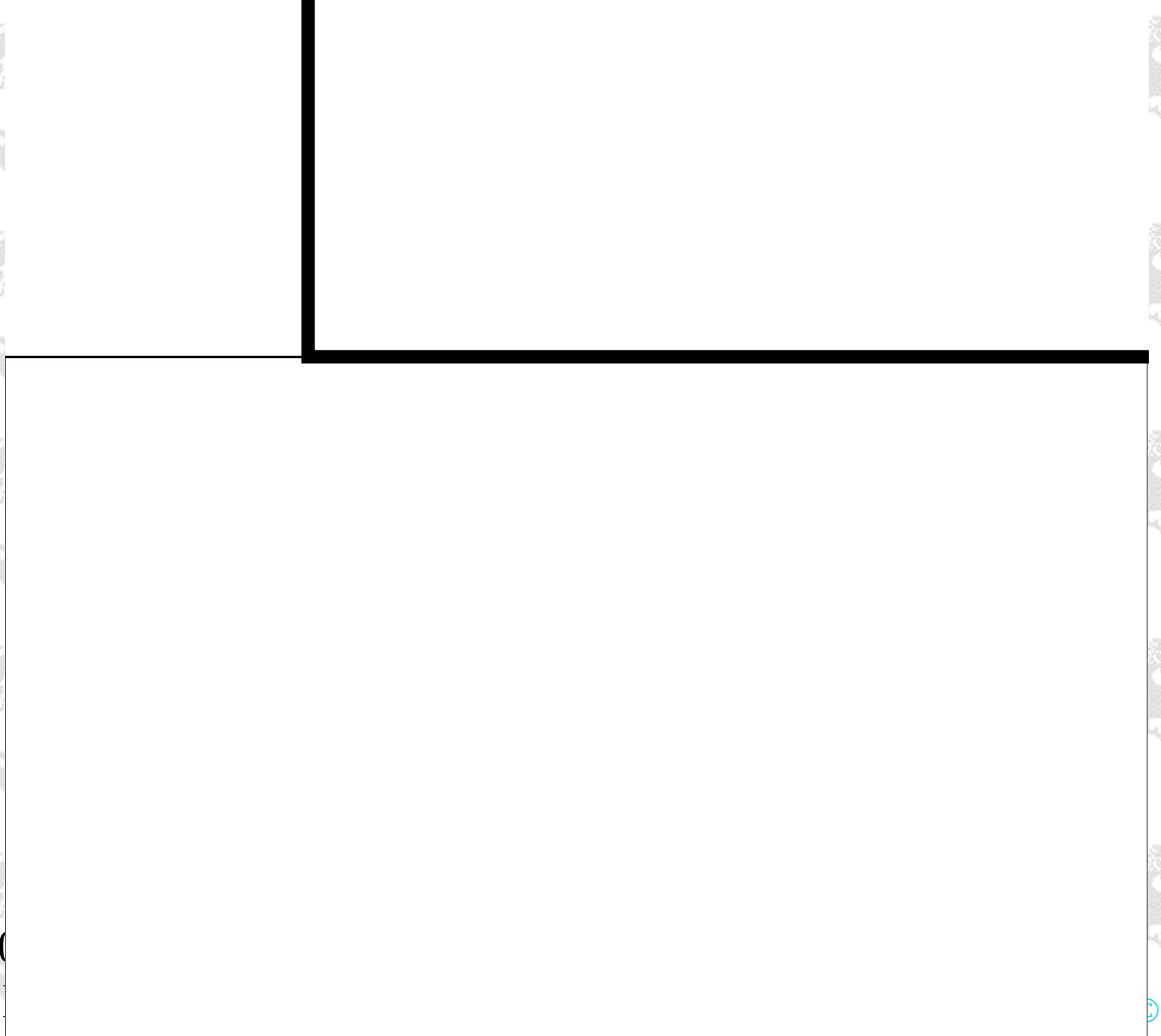
Underground

Sewer System

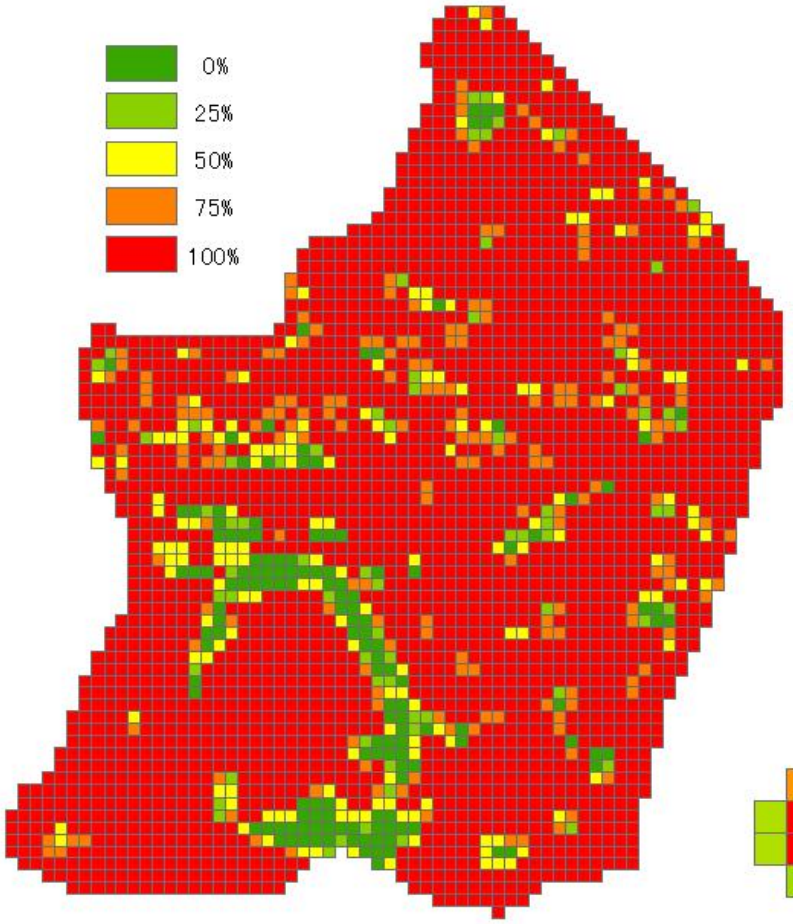
Leakage from water pipes

Conventional Distributed Runoff Model

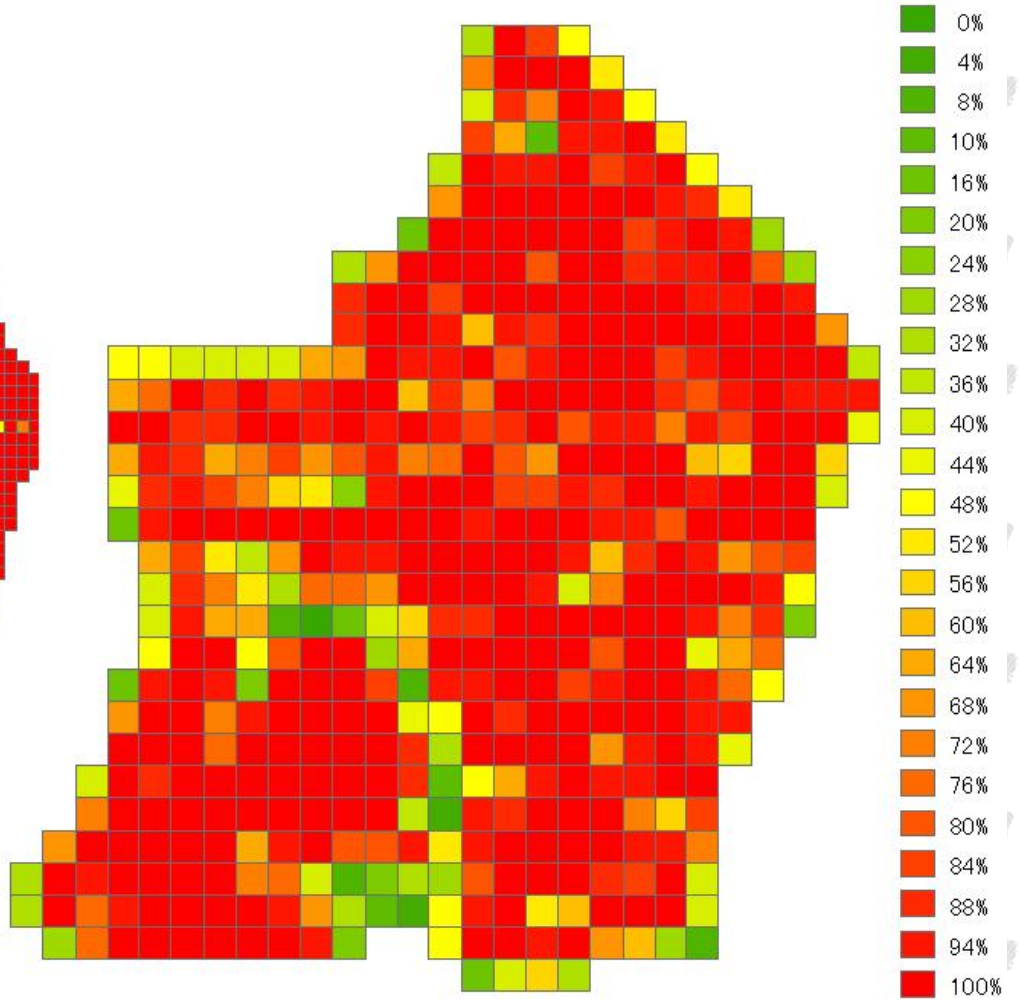
- **Grid based distributed models are used as rainfall-runoff models not only in mountainous and rural catchments, but also in urban catchments due to their simplicity and the limitation of available information of the catchments.**
- **Grid based models, however, are not appropriate for urban catchment modeling, because those models greatly average the land use property into each grid cell ignoring individual land structure property of the urban catchment.**



Grid Based Distributed Model



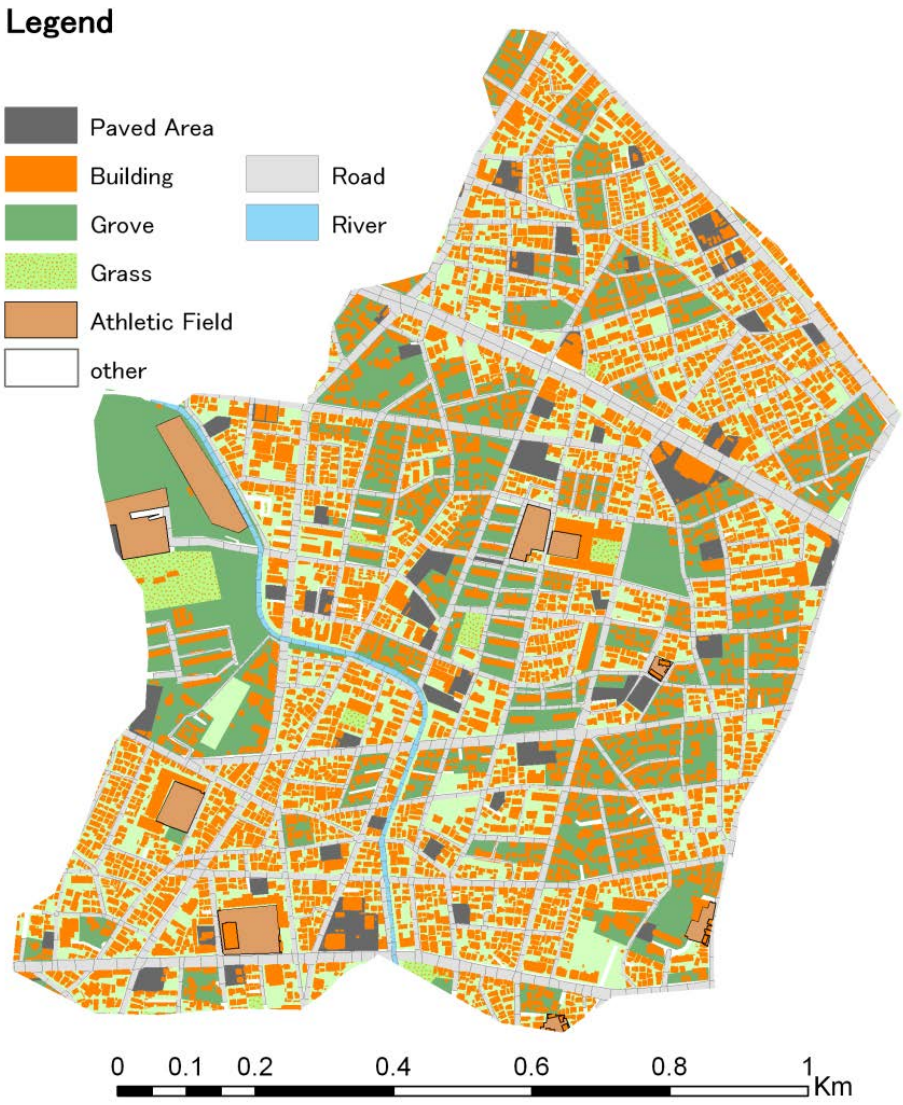
(a) 20m Grid



(a) 50m Grid

Impervious Area Rate (%)

Tokyo Storm Runoff (TSR) Model



Element name		Number	Total area (m^2)
Inside Block	Paved area	58	44,542
	Building	4,558	348,056
	Groove	174	205,088
	Athletic field	8	32,679
	Others	383	207,500
Block		1467	837,865
Road		1688	274,061
River		53	8,063
total		5,181	837,865

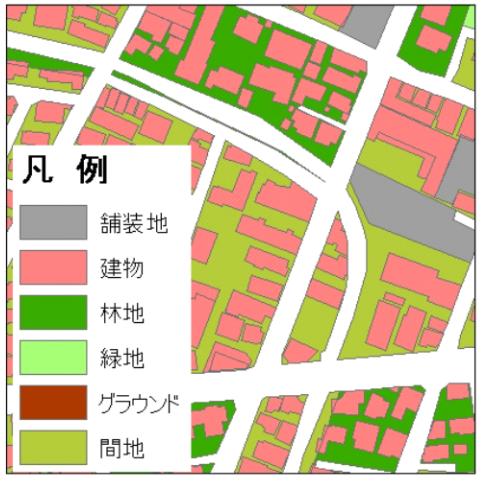
Building up Advanced GIS Manually

Basic GIS Data

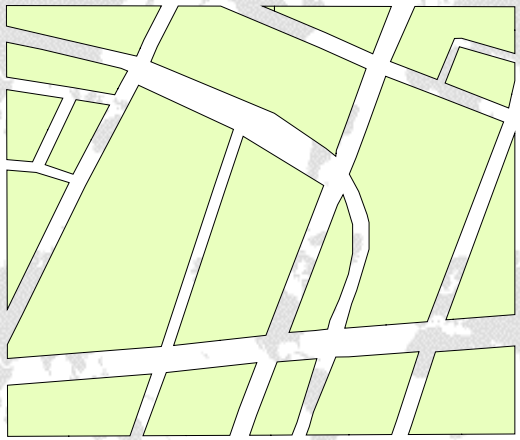
Building, River,
Residential Block

Advance GIS Data

Land Use Element

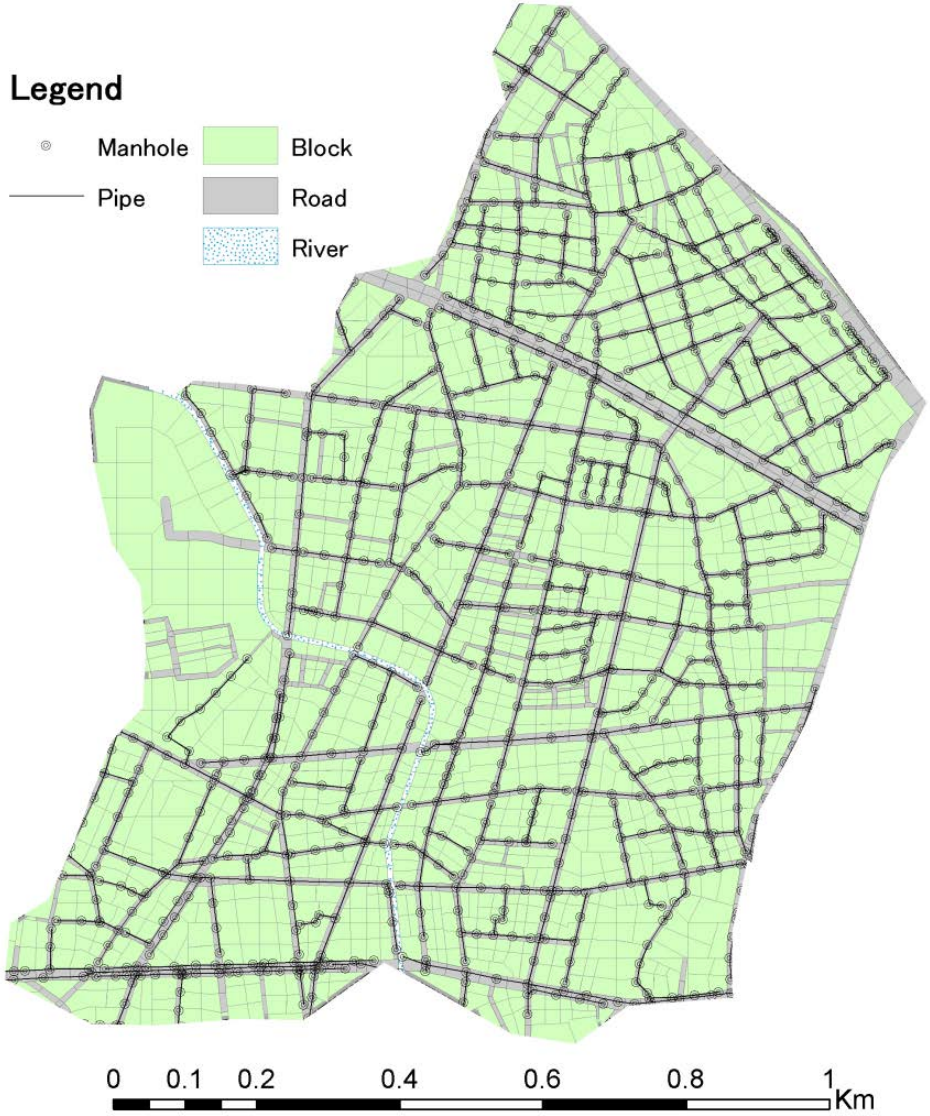


Extract
Residential Block



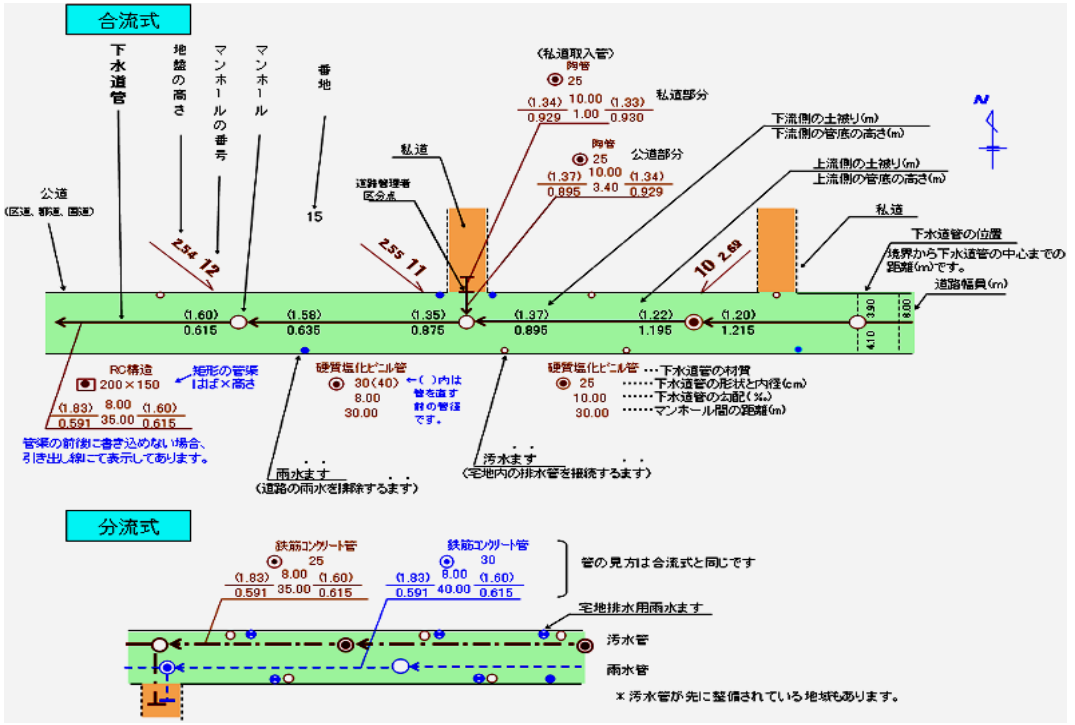
1/2500 Topographical Map

Tokyo Storm Runoff (TSR) Model

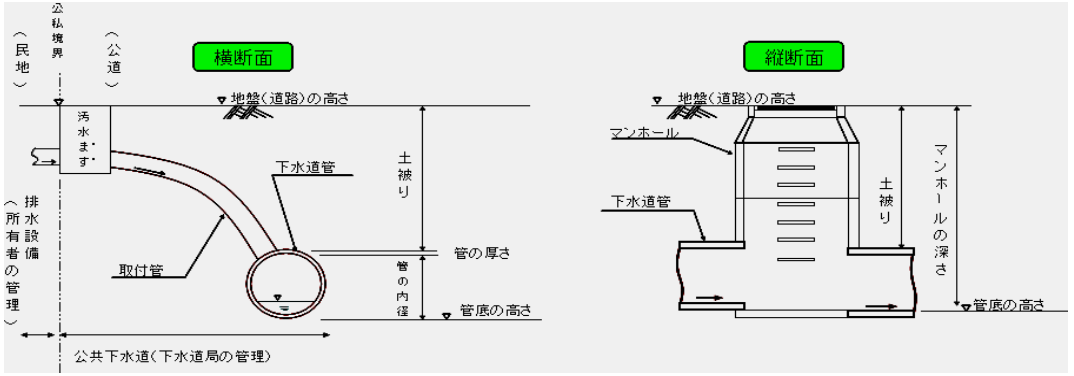


Element name	Number
Manhole	1,039
Pipe	1,053

Ledger of Sewer Pipe System



合流管・・・汚水(雑排水を含む)と雨水の両方を流している管
汚水管・・・汚水(雑排水を含む)のみを流している管
雨水管・・・雨水のみを流している管

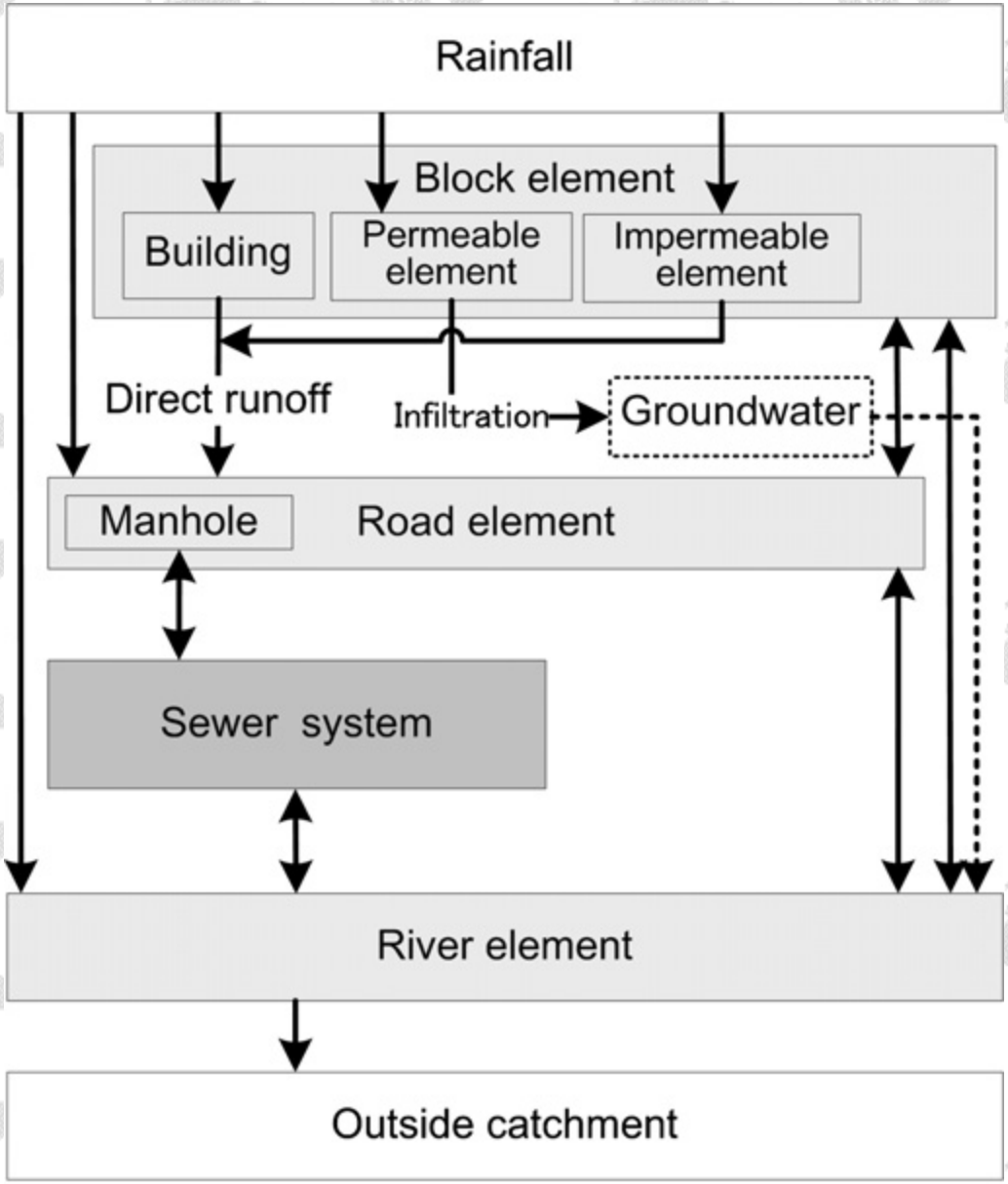


・地盤と管底の高さは，東京湾平均海面(T.P.)からの高さ
・土被りとは，地表面から下水道管の上端までの深さ

図4-7　下水道台帳解説図

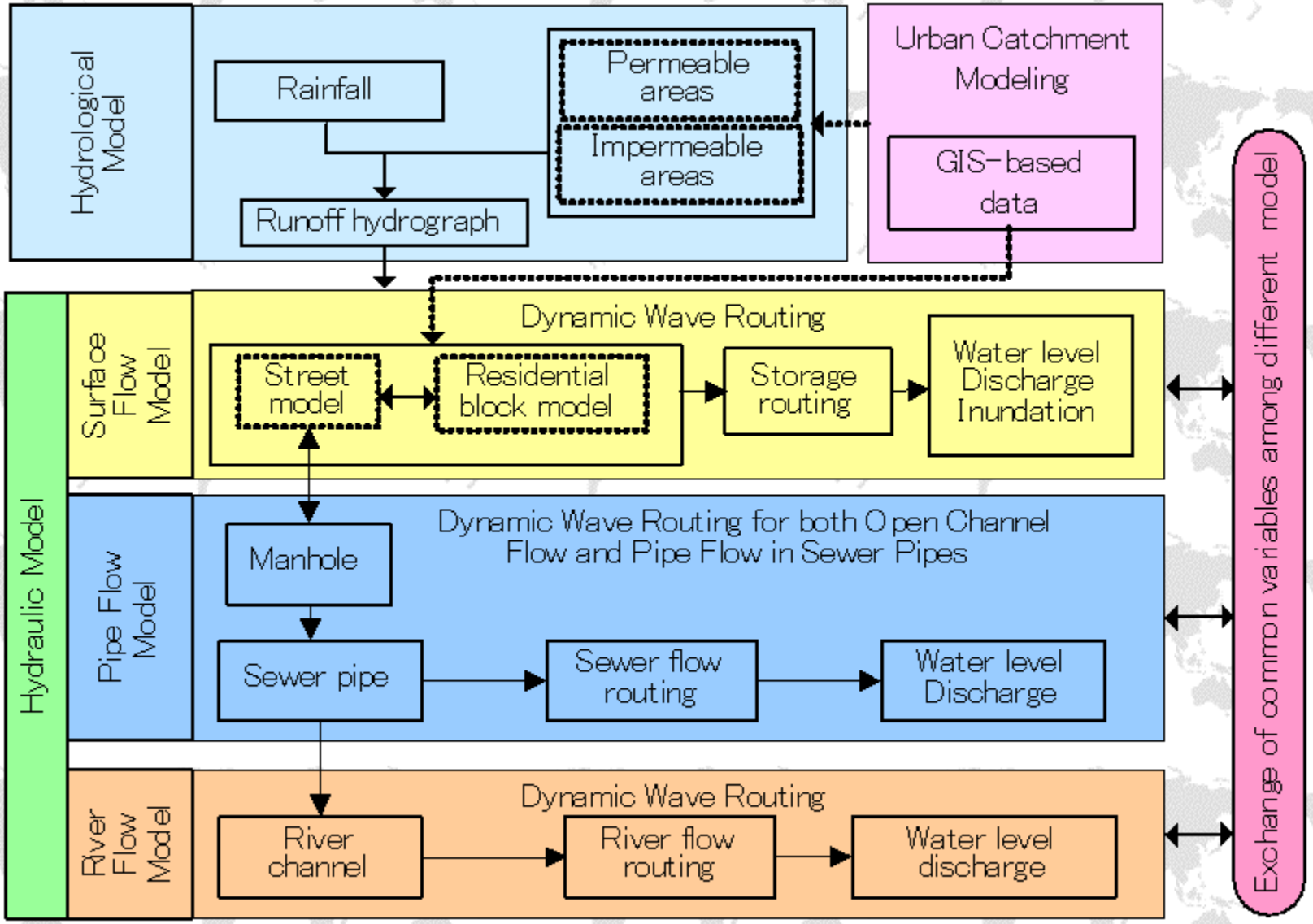
Advantages of TSR model

- The main novelty of TSR model is that GIS is used to divide the urban environment into its smallest, perfectly homogeneous, elements which are hydraulically connected and finally integrated to form a complete catchment-based rainfall–runoff model.
- One key advantage of the detailed delineation is that flow tracking is possible on an element-to-element basis.
- Another advantage is that small, individual facilities that may strongly affect flow locally, such as infiltration areas or rainwater collection tanks of single buildings, may be reproduced.
- Thus detailed what-if scenarios of the consequences of some flow-preventive measure may be evaluated, both widespread implementation of some small-scale structure (e.g. local infiltration or green roofs) and single implementation of some large-scale construction (e.g. retention pond).



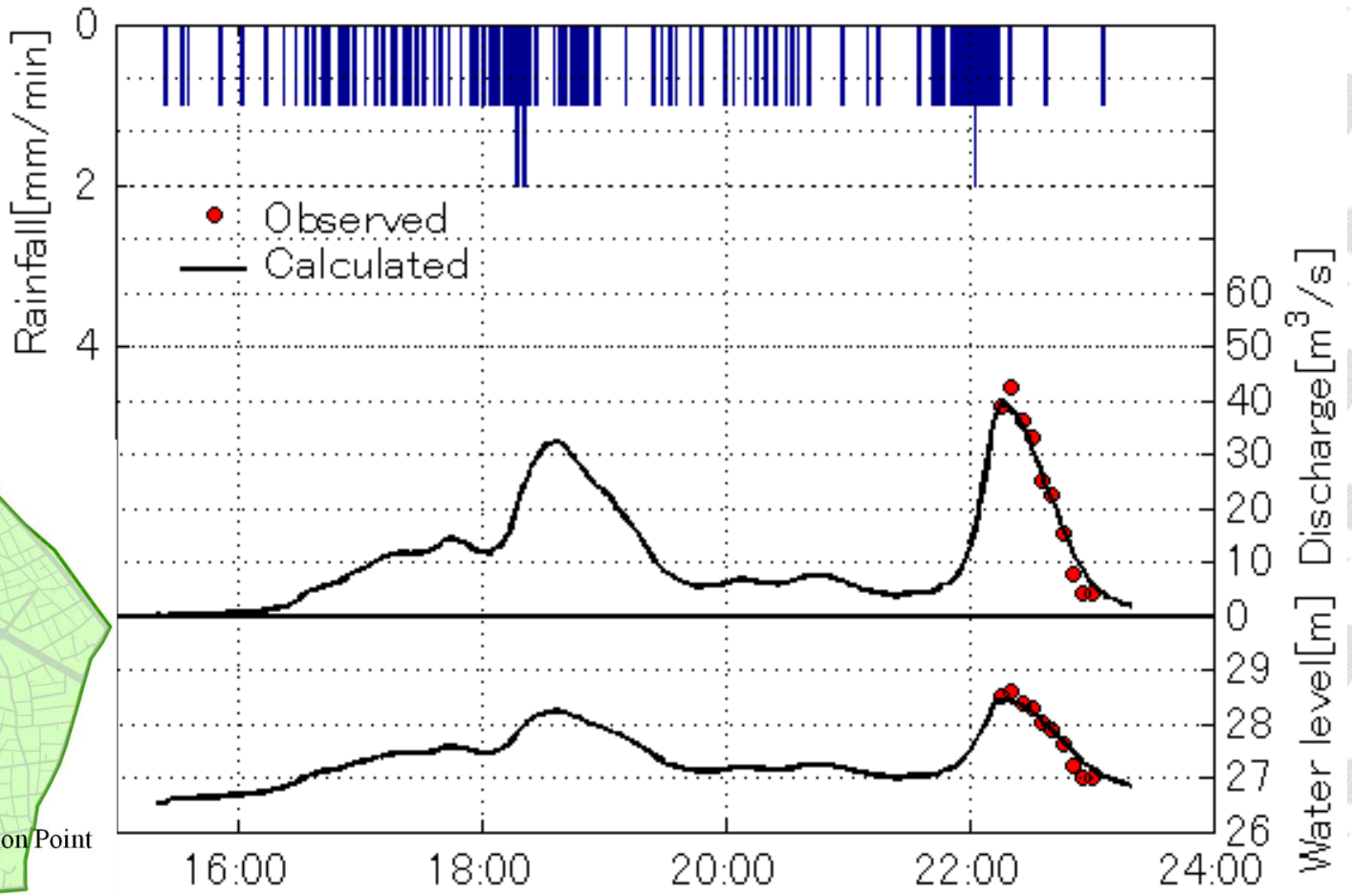
Schematic of the rainfall–runoff process of the TSR model

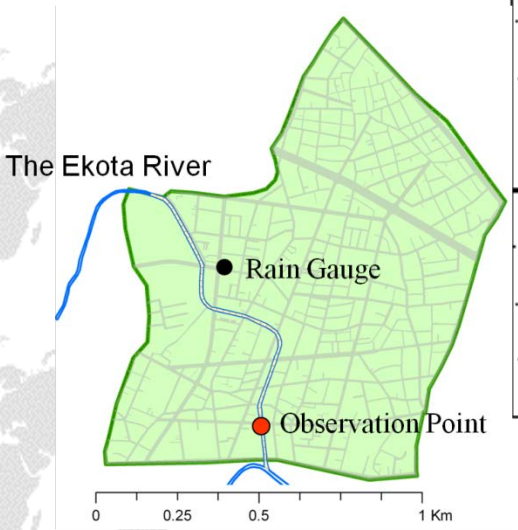
Urban Runoff Modeling using Advanced GIS Data



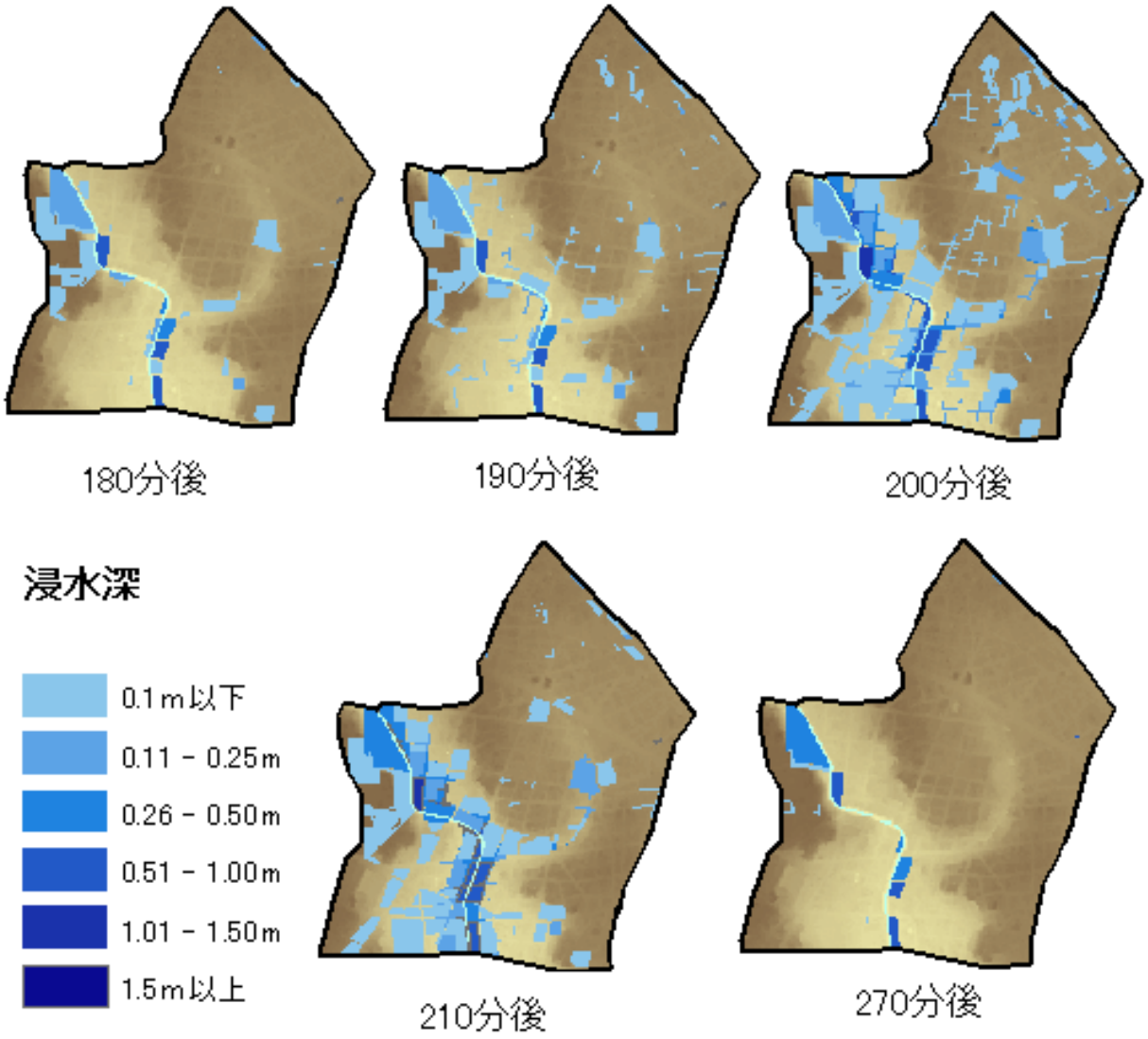
Example of Rainfall Runoff Analysis by the proposed model

Storm event on October 20, 2004 caused by Typhoon no.23





Change of inundation depth for hypothetical storm



TSR Model

- TSR model precisely describes spatial characteristics of an urban catchment. By this GIS delineation, rainfall runoff process including inundation process can be exactly traced.
- The model can precisely simulate the effect of stormwater retarding facilities installed even in one building.
- At the present time, it requires a great deal of labor to build up the advanced GIS data. In the near future, however, these data will be built and opened to the public.


Thank you for your kind attention!