



筑波大学  
*University of Tsukuba*

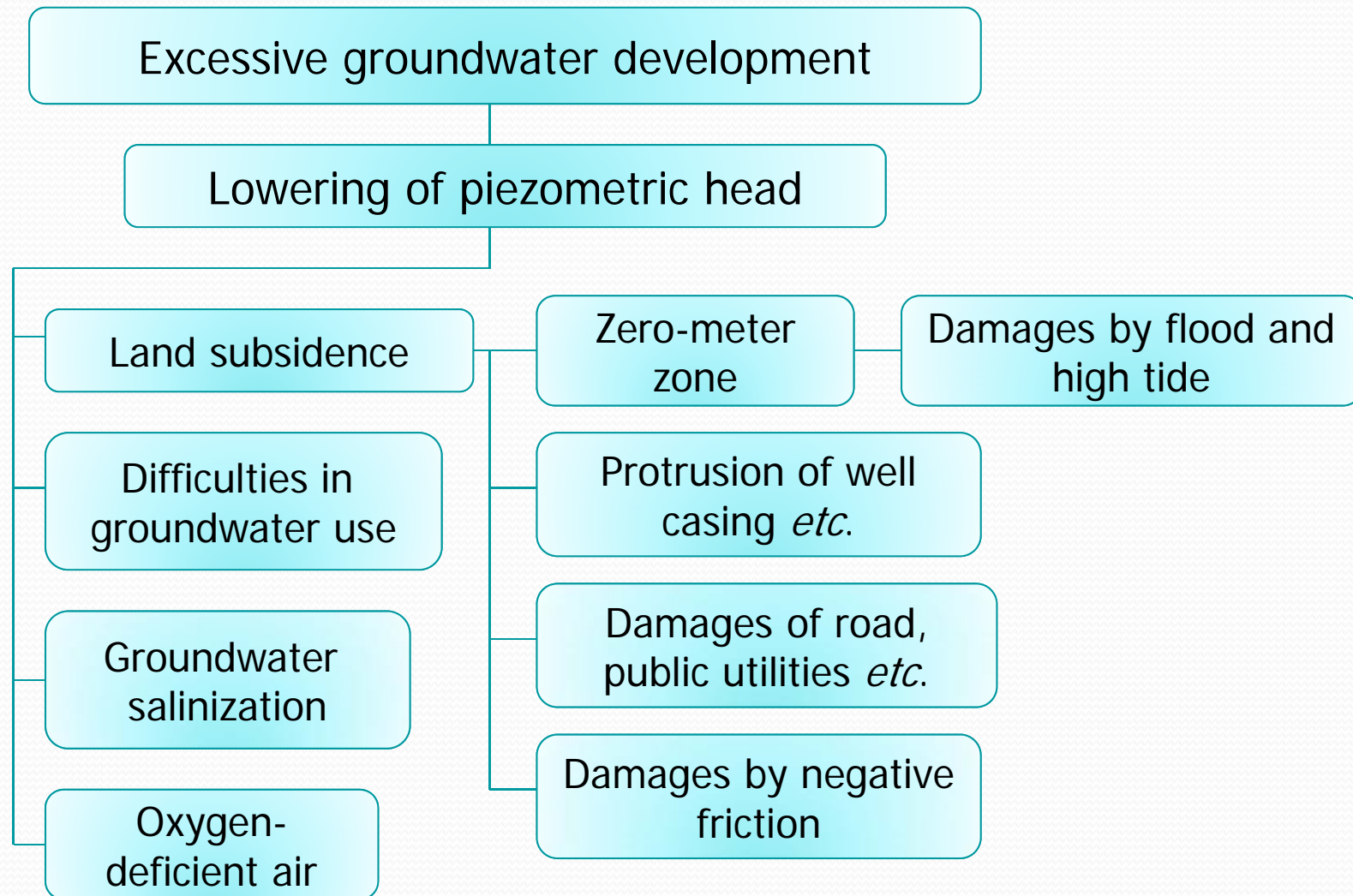
Workshop for Land Subsidence Prevention and Mitigation  
May 14th, 2019, National Cheng Kung University

# The History of Prevention and Mitigation Process for Land Subsidence by Groundwater Management in Japan

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# Consequences of groundwater development



Japanese experiences of environmental consequences of groundwater development (Kayane)

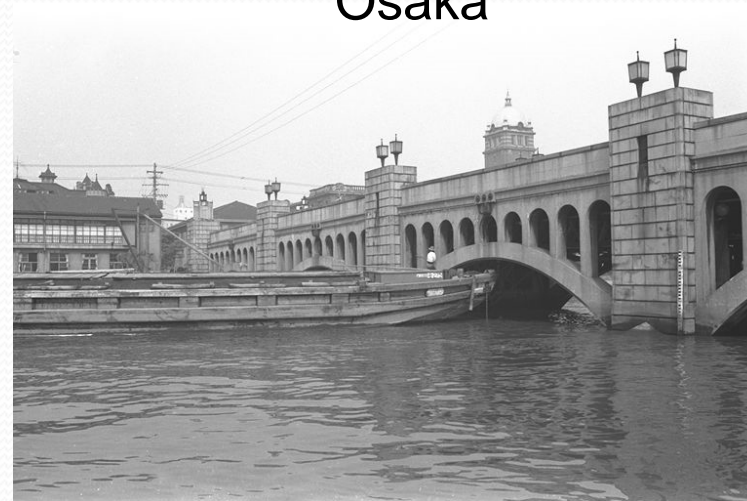
# Japan has suffered from GW overexploitation in 1960's to 70's

## Tokyo



Source: Endo (personal Comm)

## Osaka

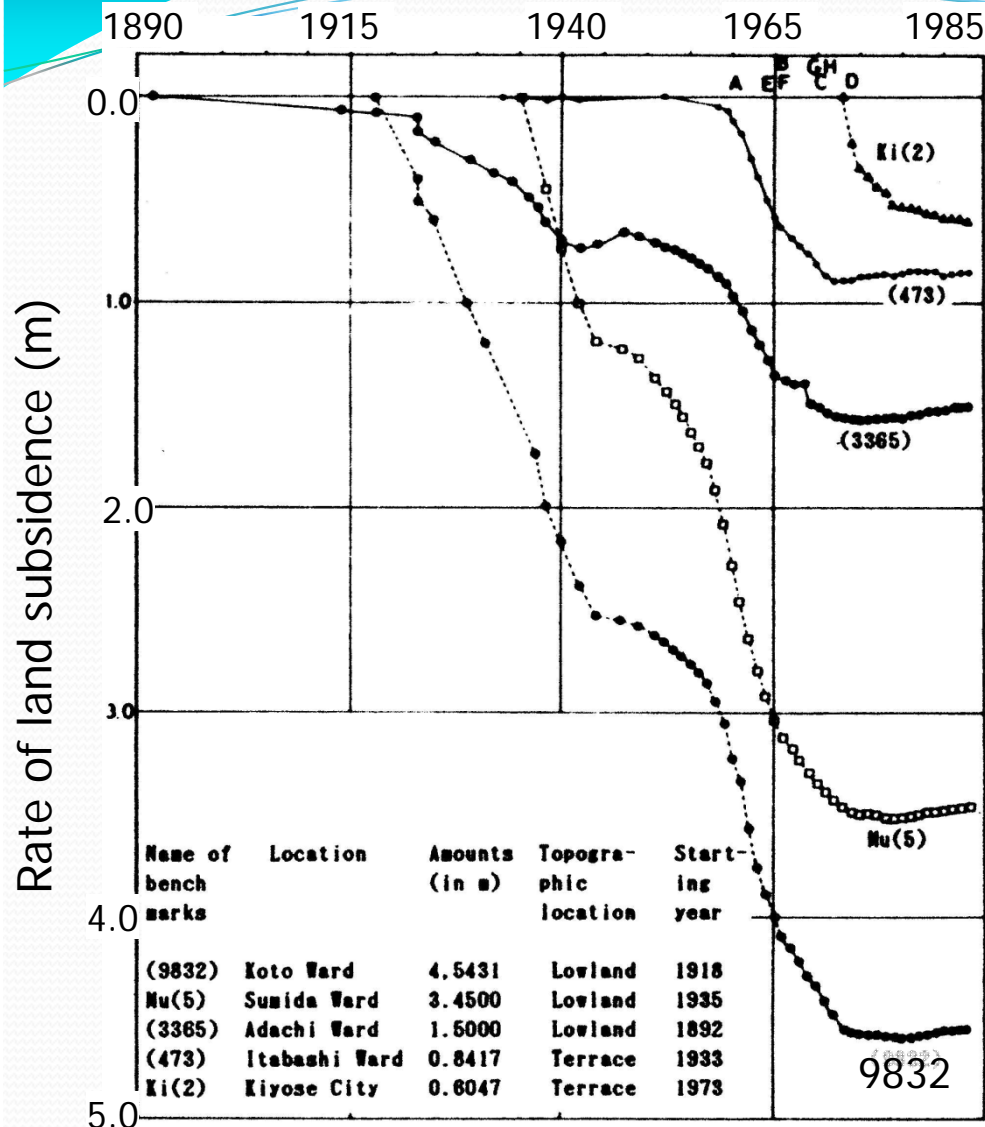


Source: the Osaka City Foundation for Urban Technology and Communication



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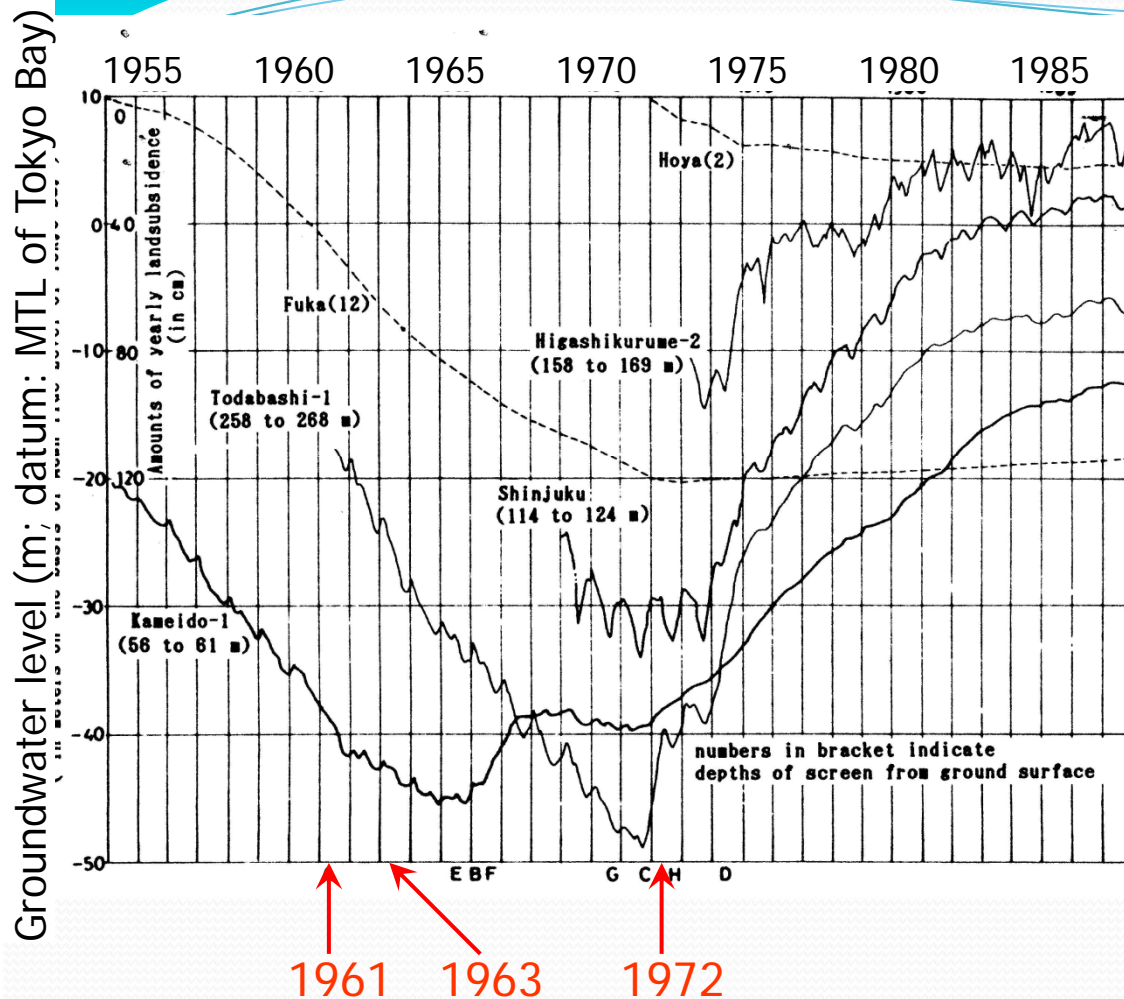
# Land Subsidence



Cumulative land subsidence in the Tokyo area from 1890 to 1986 (Endo, 1992)

- Land subsidence resumed in the middle of the 1950's.
- It spread all over the lowland and even accelerated until about 1965.
- The cumulative land subsidence at benchmark 9832 amounted to over 4.5 m from 1918 to 1987.
- Land subsidence in Tokyo has rapidly declined since about 1973 due to the restrictions of groundwater withdrawals by means of the laws and the ordinance.

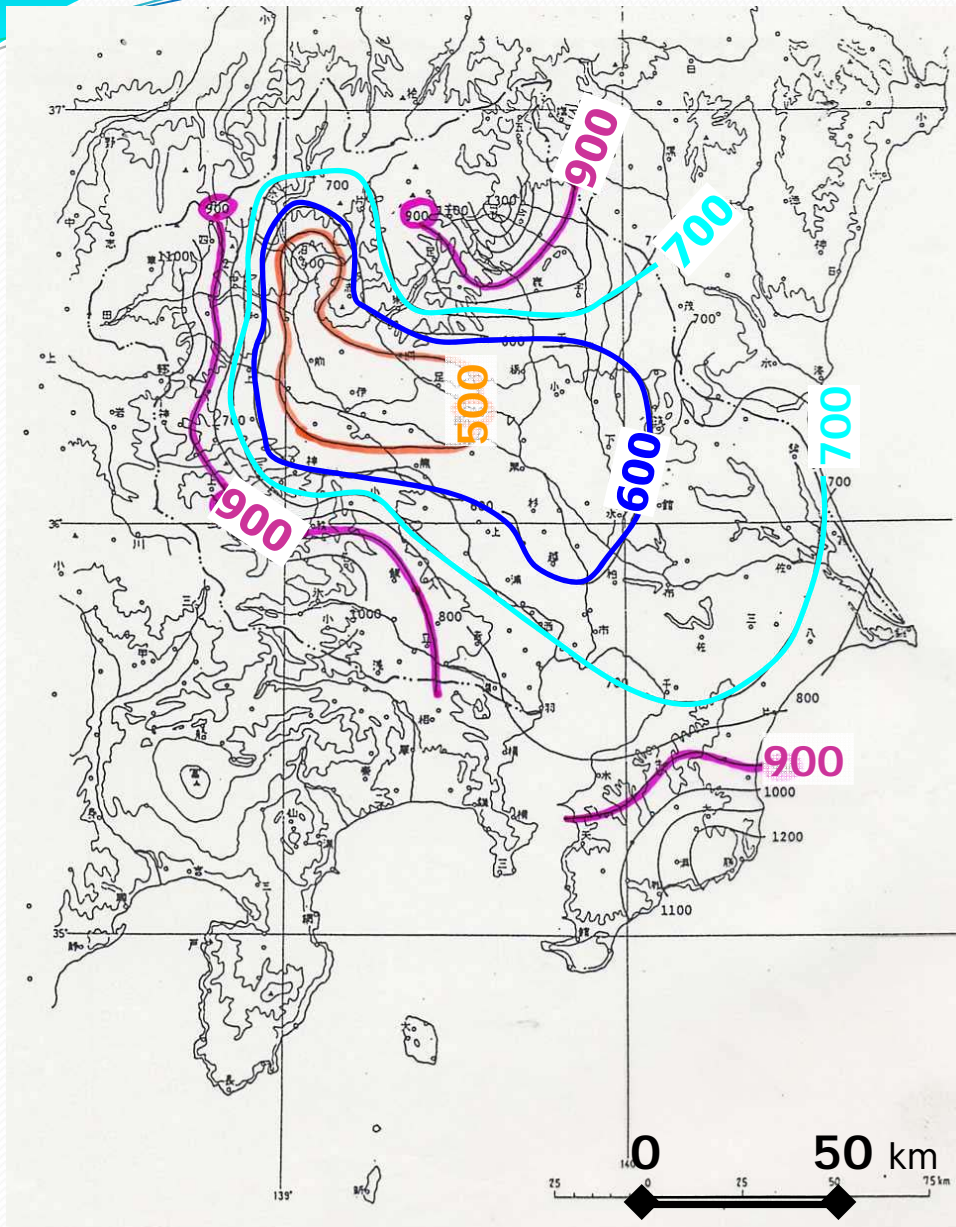
# Countermeasures to prevent land subsidence



Countermeasures to prevent the land subsidence (Endo, 1992)

- Industrial Water Law in 1961:
  - Restricted groundwater withdrawals for industrial use
- Building Water Law in 1963:
  - Restricted groundwater withdrawals for air-conditioning use
- Purchase of the mining rights by Tokyo Metropolitan Government in 1972:
  - Prohibit the extraction of water soluble natural gas
- Local government's and each prefecture's ordinances:
  - Restriction of the new well drilling in the area not covered by the national laws

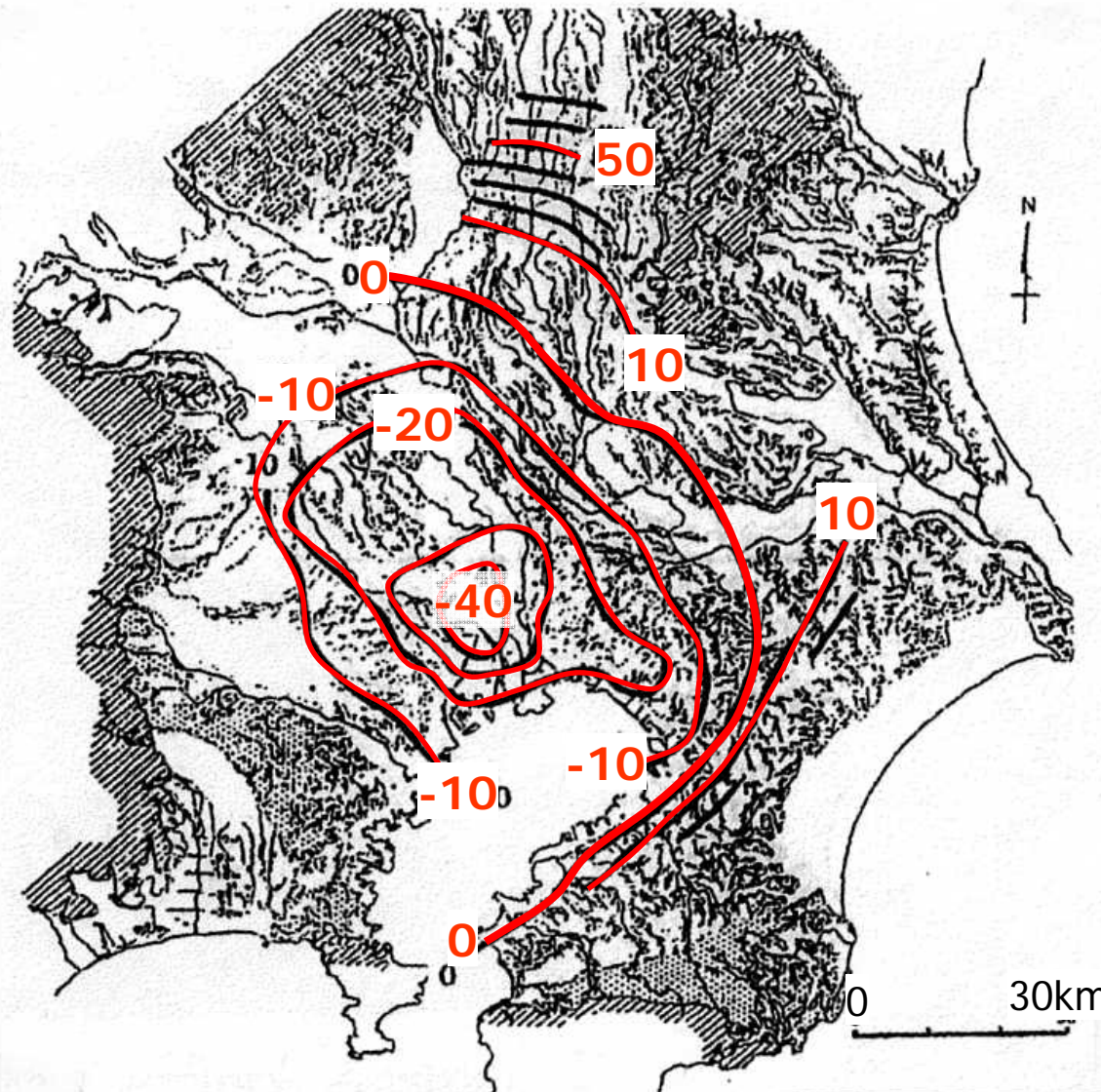
# Potential Recharge



- Expected potential groundwater recharge rate in the Kanto Plain is *500 – 900 mm/year*.
- This high recharge rate, groundwater levels in the confined aquifer have recovered so quickly.

Climatological water balance ( $P - E_t$ ) mm/year in the Kanto Plain (Committee of Land Subsidence Survey in the South Kanto Region, 1974)

## *Depression of Water Level*

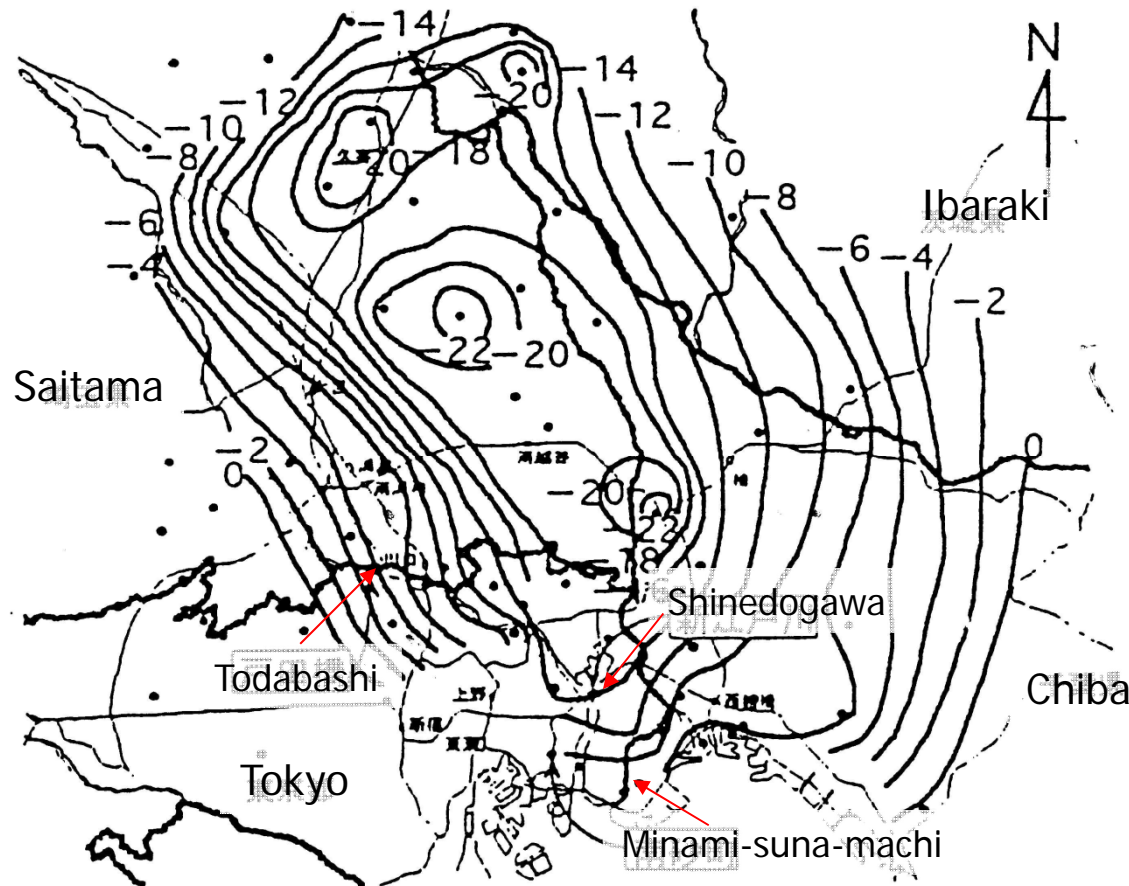


- In 1975, large draw-down of groundwater levels centered around the Tokyo area.

Groundwater potential distribution of the confined aquifer in the Kanto Plain in 1975 (Prefectural Governor's Association of the Kanto Region, 1991)

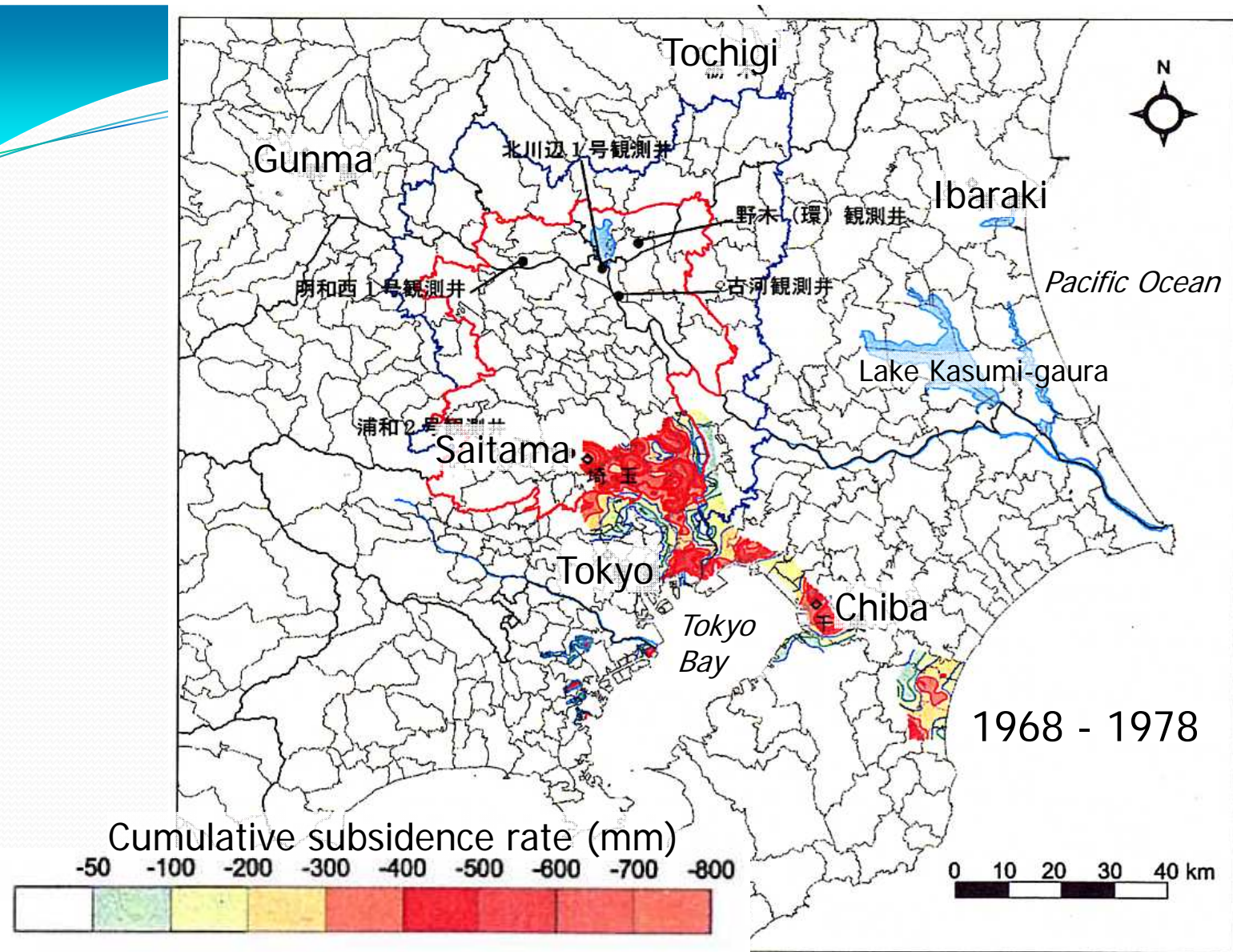
## Depression zone shifted

- In 1992, centered draw-down of groundwater level shifted from south to north region of the Kanto Plain.

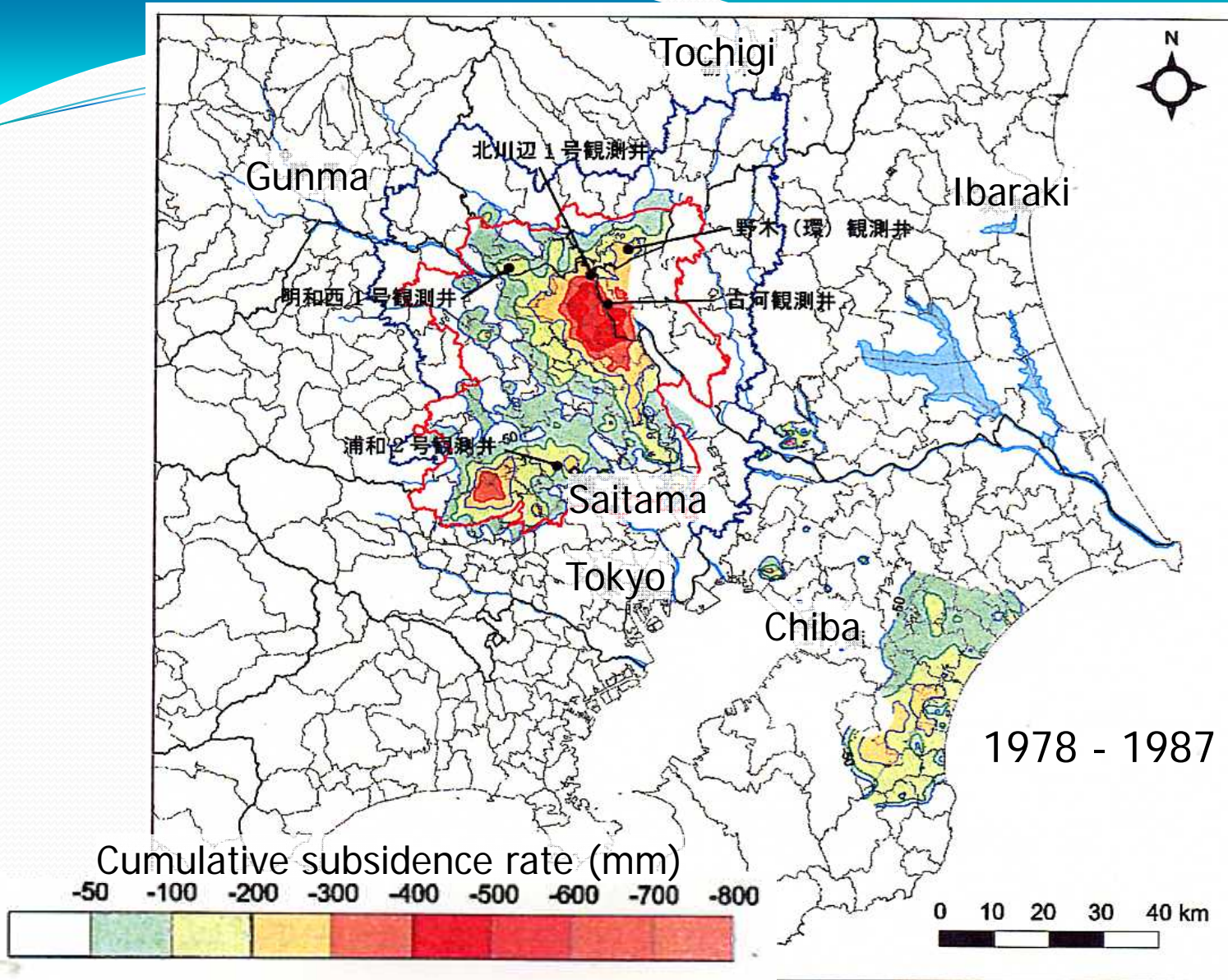


Groundwater potential distribution (unit: m) of the confined aquifer in the Kanto Plain in 1992 (Miyake, 1995)

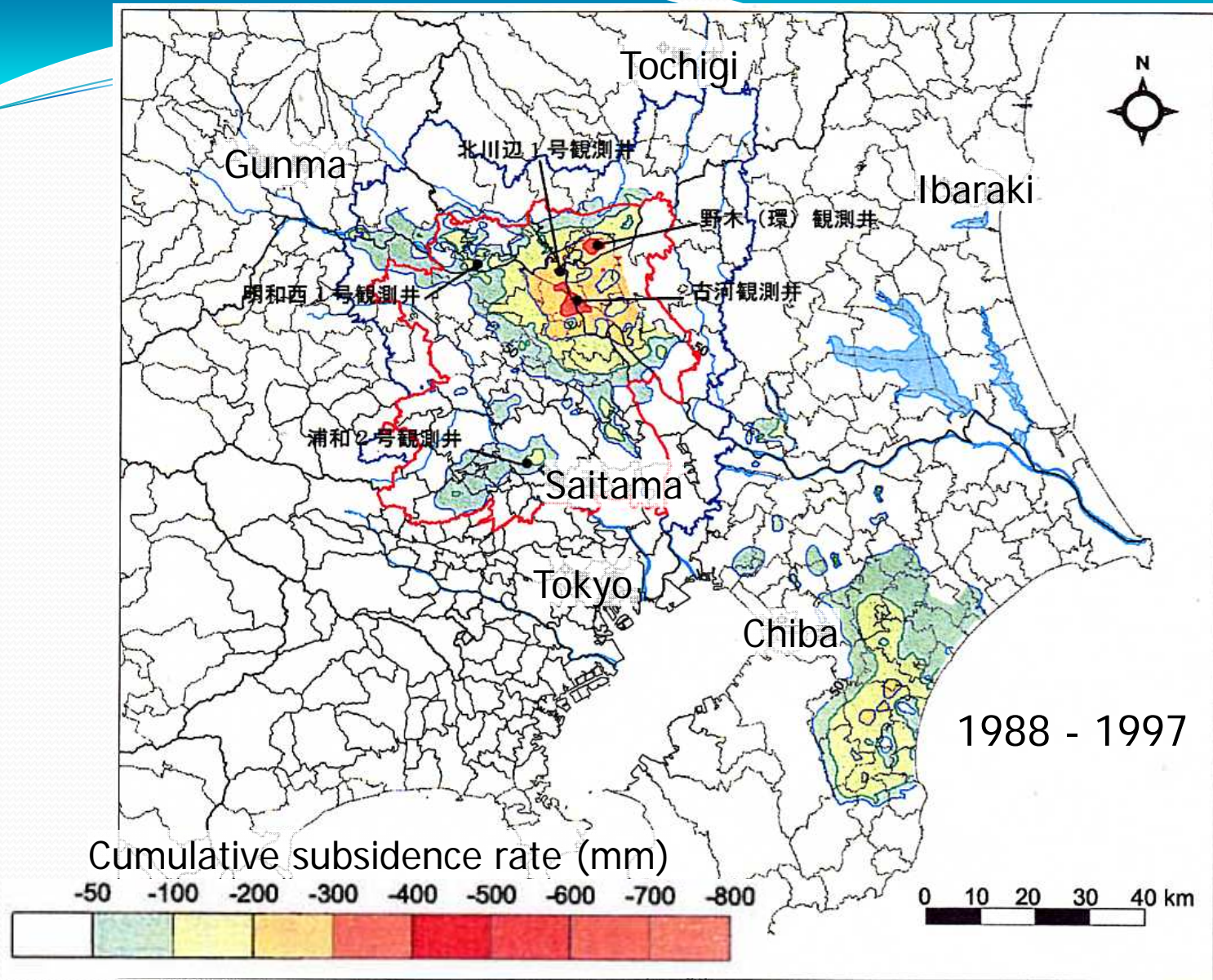




Cumulative land subsidence in the Kanto Plain from 1968 to 1978 (Ministry of Land, Infrastructure and Transport, 2002)



Cumulative land subsidence in the Kanto Plain from 1978 to 1987 (Ministry of Land, Infrastructure and Transport, 2002)



Cumulative land subsidence in the Kanto Plain from 1988 to 1997  
(Ministry of Land, Infrastructure and Transport, 2002)

# Groundwater

## Basic Law of Water Cycle (2014)

### Basic Law of Environment (Quality Standard of Groundwater)

#### Land Subsidence

- Industrial Water Law
- Building Water Law
- Purchase for exploitation (Tokyo)

#### Waste

- Waste Treatment Law

#### Resource Management

- Law of Hot Spring
- Law of Mining
- Law of Public Use in Underground Space
- River Law
- Law of Erosion Control
- Ordinance by Local Government

GROUNDWATER

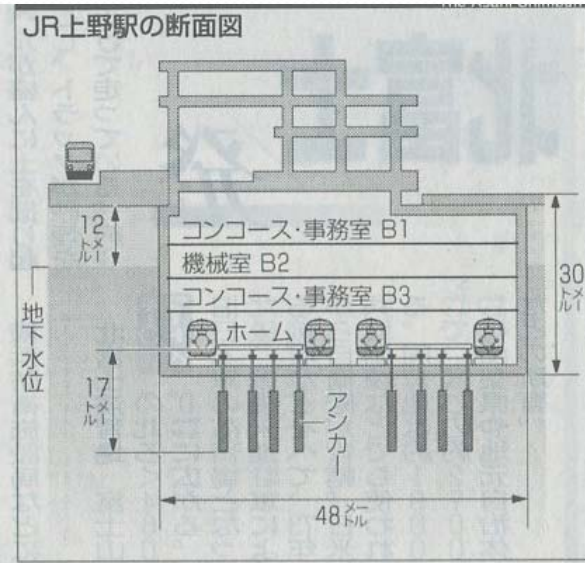
#### Water Quality &

#### Contamination

- Water Quality Conservation Law
- Law of Contamination Prevention for Agricultural Land
- Measure Law of Soil Contamination
- Law of Dioxin Contamination
- Regulation Law of Chemical Materials Inspection
- Management Law of Fertilizer
- Management Law of

Agricultural Chemicals 12

# Ueno station suffering from GW -too much water-



## 上野・地下駅 浮上の危機

水位、ホームより18メートル上に

04. 5. 19 (朝日)

東北、上越新幹線などが発着する上野駅の地下駅は78年に建設工事が始まり、85年3月に開業した。地中にコンクリート製の大きな箱を置くような構造になっている。JR東日本によると、設計の検討をはじめた70年代はじめ、地下水は地下

JR上野駅周辺の地下水の水位が上昇して、新幹線ホーム（地下約30メートル）のある地下駅が浮かび上がった。水圧でひびが入ったりするおそれが出てきた。JR東日本は、6月から約35億円かけて地中に650本もの「いかり」（アンカー）を打ち込み、浮上を防ぐ対策工事を始める。同社は99年、東京駅の総武・横須賀線地下ホーム（地下約27メートル）で同様の工事をしたが、打ち込むアンカーの本数は約5倍になるといふ。

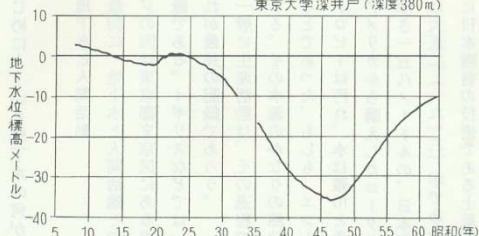
重しでは限界、ワイヤ固定へ

力に耐えるようにする。約650本を打ち込む計画で、工事は来年12月ごろまで続く。新幹線の運転に影響はないという。同社によると、この対策で地下水があと4・5メートル上昇しても、耐えられるようになるという。

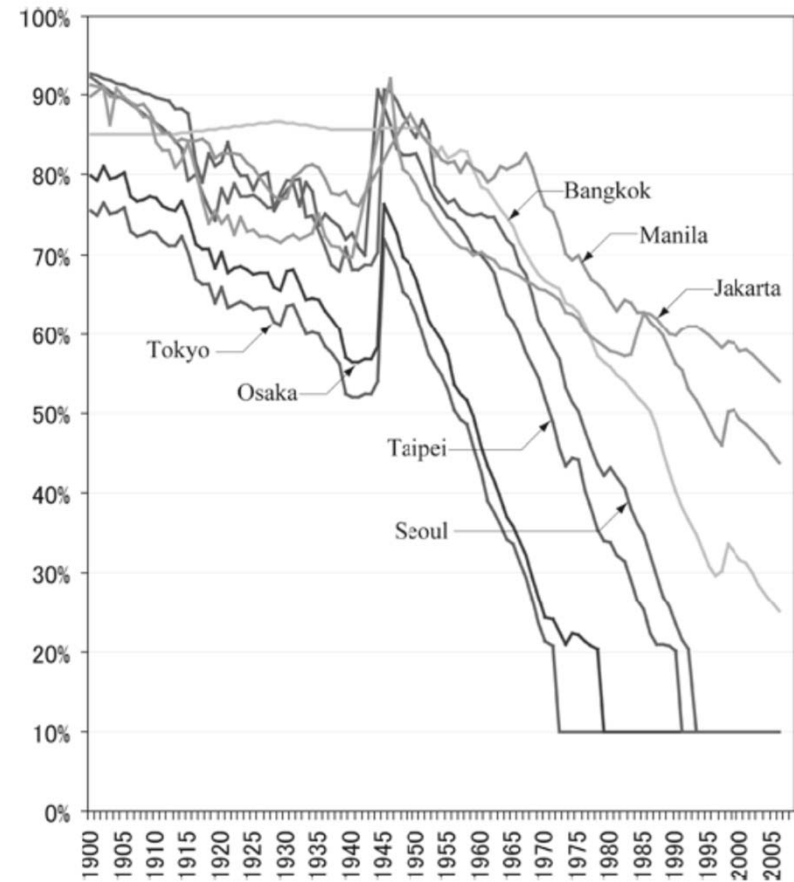
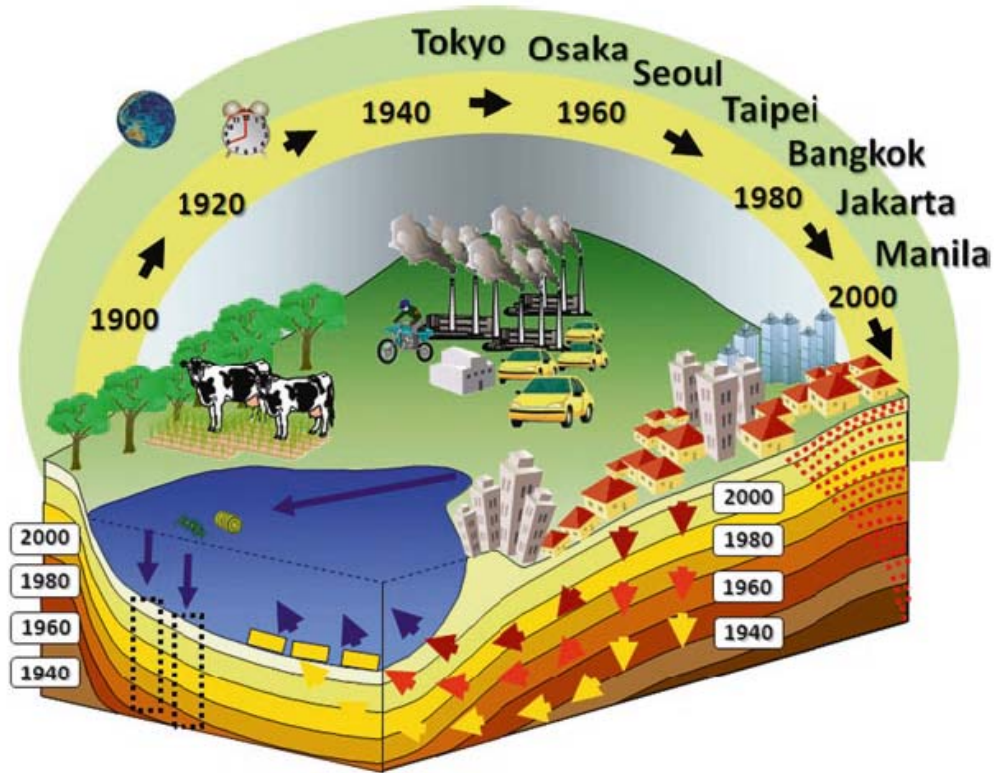
下38メートルの地点にあり、駅より8メートル下だった。その後、東京都の地下水くみ上げ規制などの影響で水位が年々上昇。水位が地下14メートルになった95年、計3万7千トンの鉄の塊を地下駅の底に置いて重しとし、浮かばない対策をした。しかし、その後も水位は上昇。現在は地下12メートルにまで達しており、重しでは限界に近づいてきた。駅の底には、1平方メートルあたり16トンの押し上げる力がかかっていると見られる。

浮上をpushするアンカーは、束ねたワイヤ（直径約10センチ）をホームから地下約17メートルまで入れ、セメントで土中に固定する。ワイヤの先端をひっぱって駅に固定して、浮

地下水位変動グラフ  
東京大学深井戸（深度380m）



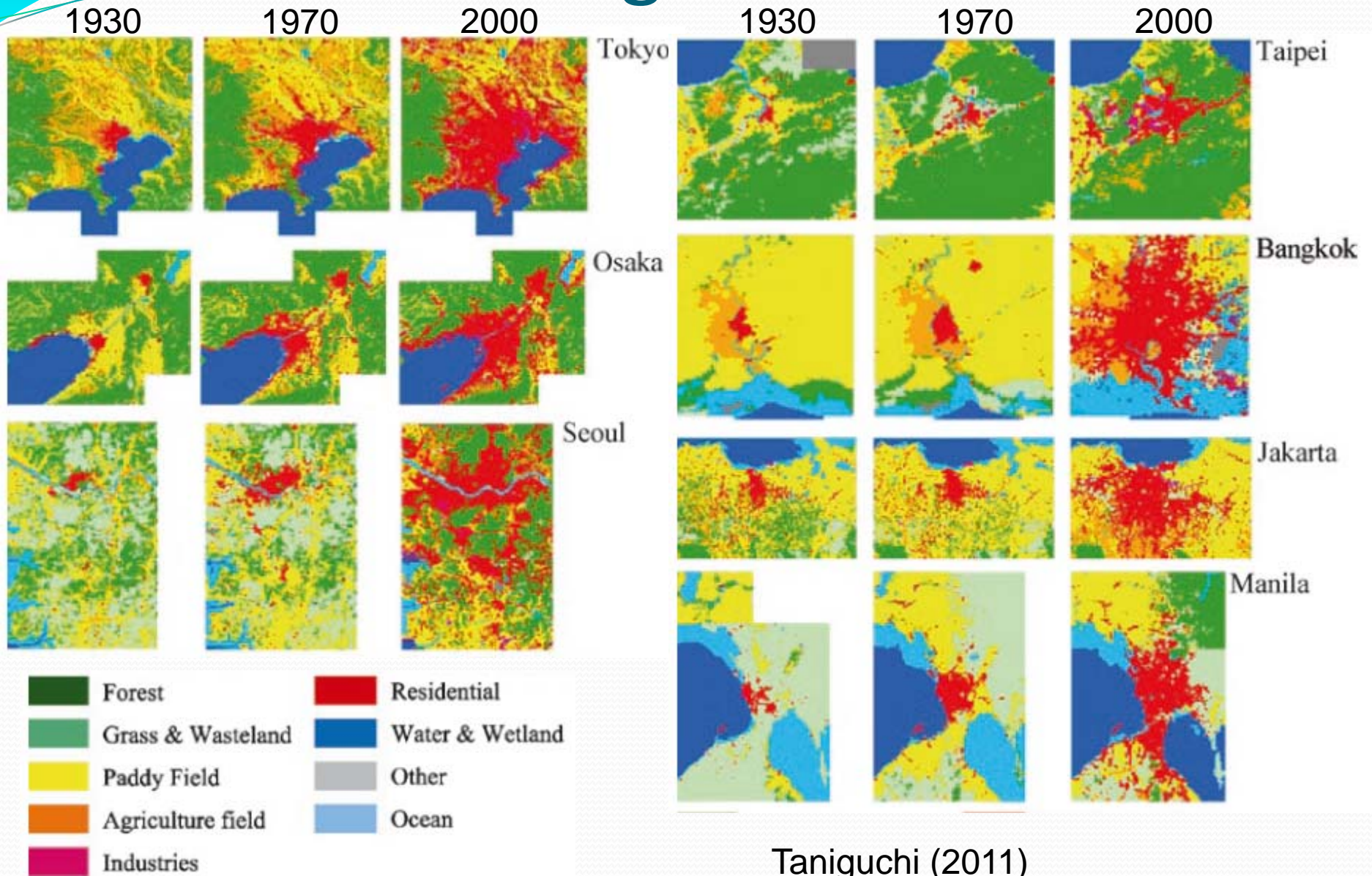
# GW issues at mega cities in Asia



Change of GW dependencies in Asia

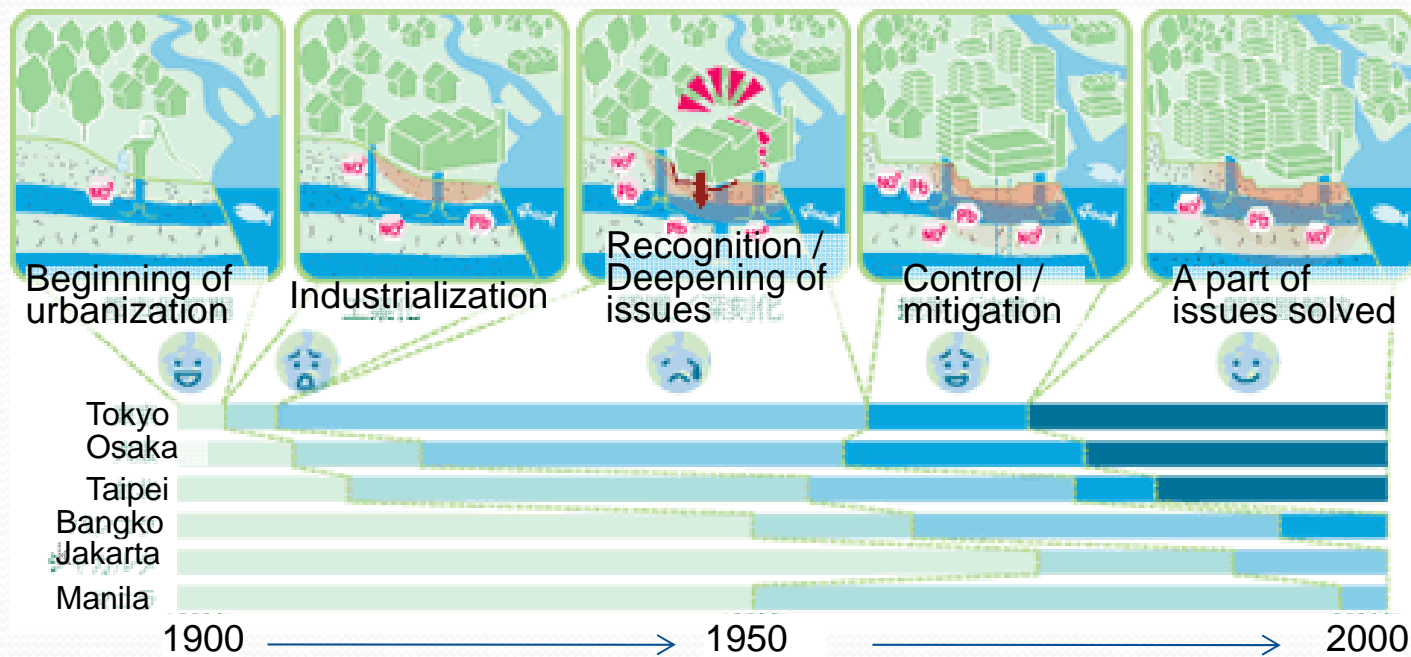
Taniguchi (2011)

# Land cover change in Asia



Taniguchi (2011)

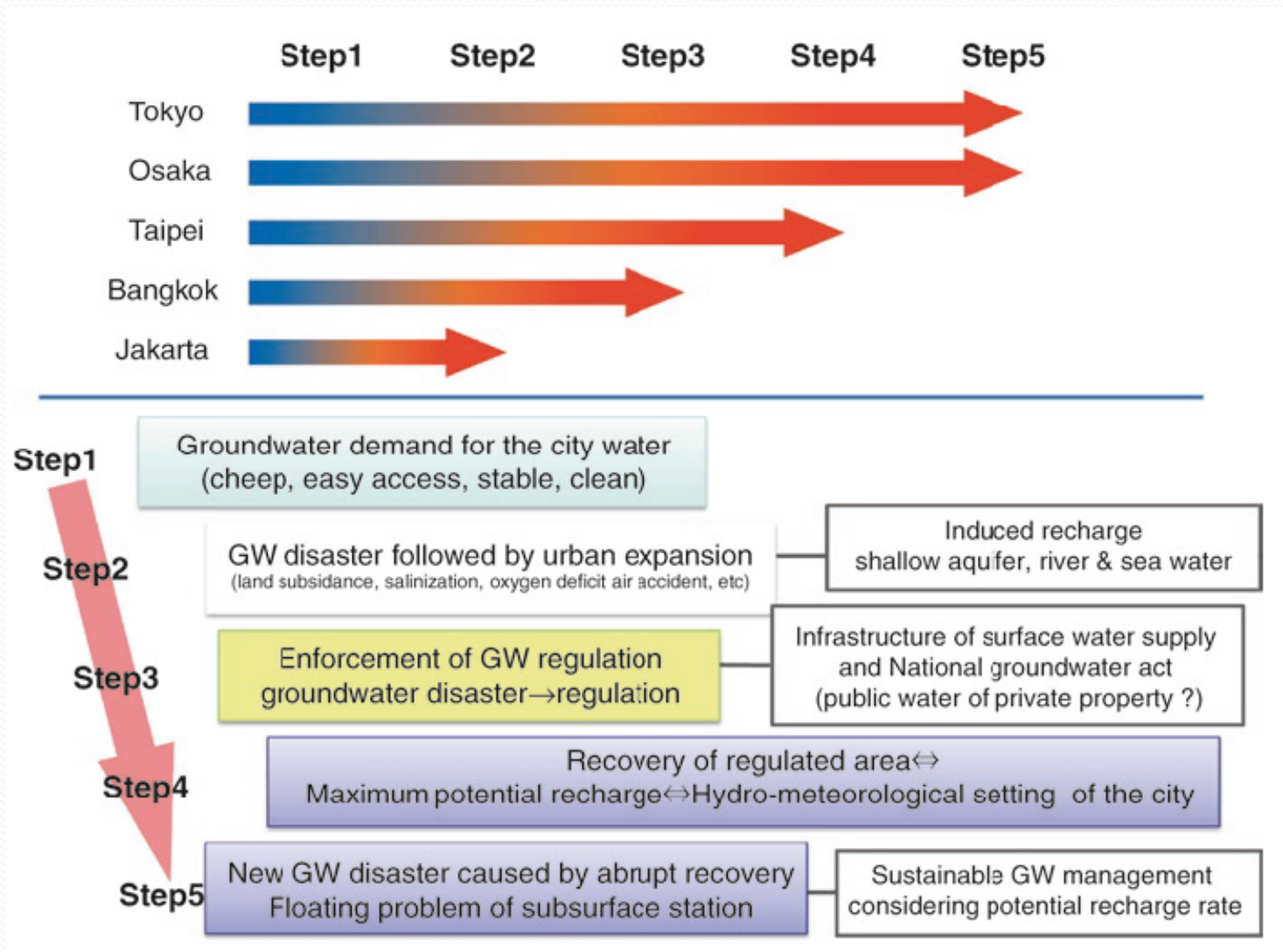
# History of underground environment issues in Asian megacities



Taniguchi et al. (2008)



# Steps of GW development in Asia



Shimada (2011)