

## Case Study 3. Sustainable Groundwater Use and Prevention of Land Subsidence: Osaka City and Saitama Prefecture

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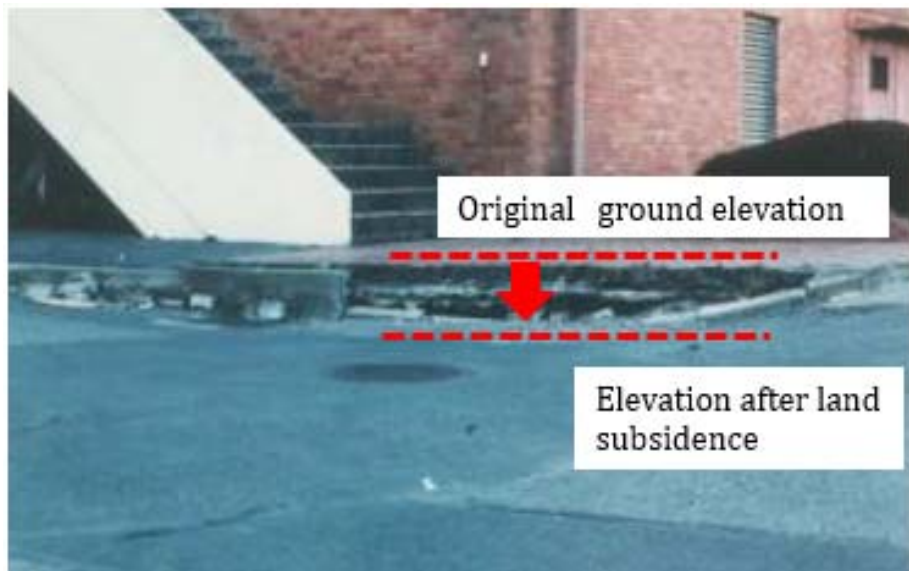
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## 1. Introduction

Clean good quality groundwater is an important source of drinking water. Excessive groundwater pumping that exceeds recharged amount sometimes causes land subsidence because of the drop of groundwater level and compressed clay layer. This phenomenon is often observed in alluvial plains.

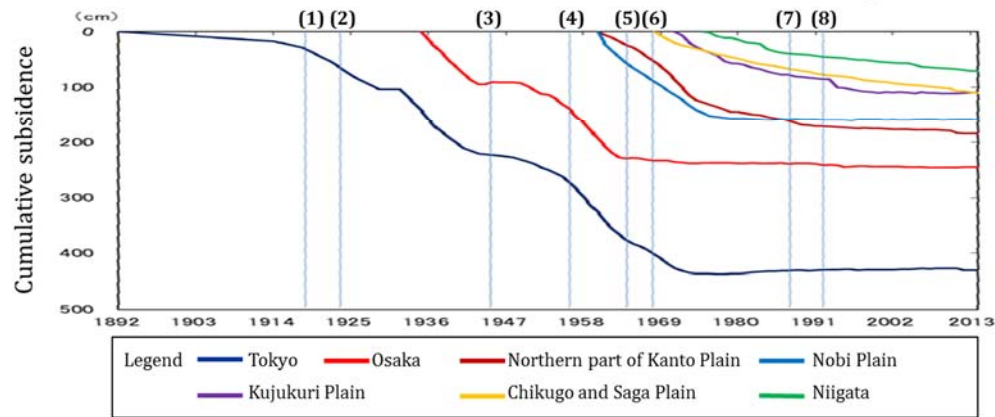
Land subsidence causes many problems, including uneven settlement and infrastructure damages resulting from floods. In coastal areas, subsidence may result in tides moving into low-lying areas that are previously above high tide levels. Solving these problems involves enormous cost and land subsidence is irreversible even when groundwater level recovers.



Source: Saitama prefectural government, <https://www.pref.saitama.lg.jp/a0505/901-20091202-17.html>

**Photo 1. Depression Caused by Land Subsidence**

- |                                                       |                                                                                                        |
|-------------------------------------------------------|--------------------------------------------------------------------------------------------------------|
| (1) Beginning of borehole drilling in various regions | (5) Enactment of "Building Water Act"                                                                  |
| (2) Great Kanto Earthquake                            | (6) Enactment of "Basic Law for Environmental Pollution Control"                                       |
| (3) World War II                                      | (7) Guideline on Countermeasures for Prevention of Land Subsidence (Chikugo Saga plain and Nobi Plain) |
| (4) Enactment of "Industrial Water Act"               | (8) Guideline on Countermeasures for Prevention of Land Subsidence (Northern part of Kanto Plain)      |



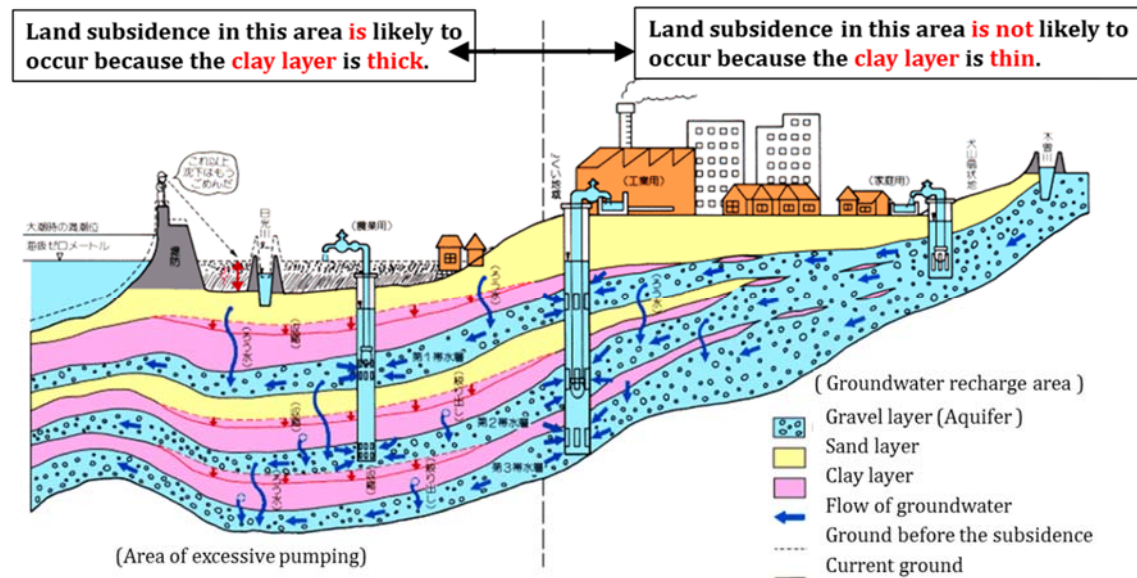
Source: Ministry of the Environment, <http://www.env.go.jp/water/jiban/gaikyo/gaikyo26.pdf>

**Figure 1. Land Subsidence in Japan 1892-2013**

This module explains the occurrence of land subsidence caused by excessive pumping of groundwater during the period of high economic growth and the measures taken by some Japanese cities to avoid or stop subsidence.

## 2. Land Subsidence and Preventive Measures

Japan has taken measures to reduce subsidence mainly by controlling groundwater intake and switching from groundwater to alternative water sources such as industrial water and Bulk Water Supply. Today, land subsidence is a rare occurrence.



Source: Aichi prefectural government, *Outlines of land subsidence*,  
<http://www.pref.aichi.jp/soshiki/mizu/0000035197.html>

**Figure 2. Phenomenon of Land Subsidence**

### (1) Causes of Land Subsidence

Land subsidence is caused by excessive groundwater pumping to meet increased water demand. This can lead to serious social problems.

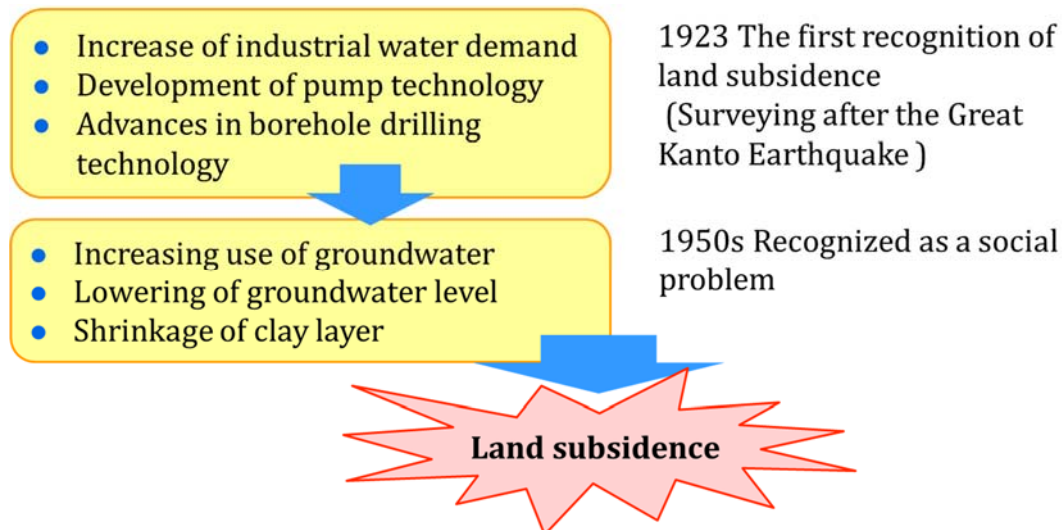
Land subsidence can occur naturally and inevitably but is also a consequence of excessive groundwater pumping.

It was recognized for the first time when surveys were conducted after the 1923 Great Kanto Earthquake. The phenomenon was noticed in Osaka City and the Nagoya area around 1930. Therefore, monitoring of land subsidence and groundwater levels started in these areas. The problem did not appear much until the end of World War II (1945) because groundwater pumping decreased during the war. But in the 1950s, substantial land subsidence reappeared and

resulted in serious social problems.

In Japan, the advance of pumping and deep well drilling technologies made it considerably easy to withdraw large amounts of groundwater to meet increasing demands during periods of high economic growth. As a result, land subsidence occurred frequently because groundwater level was lowered and clay layer was compressed. Unless restricted by special law, land owners have the right to utilize groundwater freely under the Civil Code in Japan. The regulations for groundwater and alternative water sources were developed as a measure to reduce land subsidence in Osaka in the 1960s, and in Tokyo in the 1970s.

In Japan, there were discussions on the causes of the land subsidence including: crustal movement, consolidation due to the load of buildings, and decrease in rainwater penetration. Credible data showed the correlation of dropping groundwater level and incidences of land subsidence. Land subsidence incidences dropped with the decline of industrial activities during the Great Depression from 1929 to 1933 and towards the end of World War II from 1943 to 1945. Therefore, excessive groundwater intake is considered to be the main cause of land subsidence in Japan.



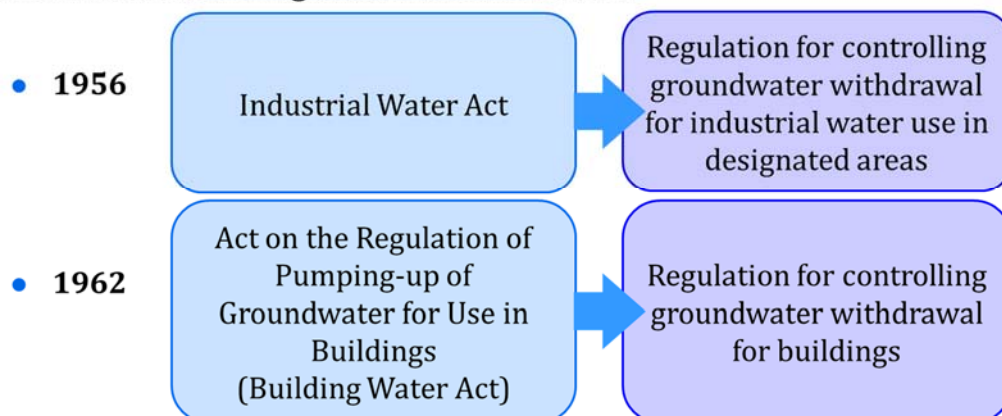
**Figure 3. Causes of Land Subsidence**

## (2) Industrial Water Act and Building Water Act

In Japan, the Industrial Water Act and the Act on the Regulation of Pumping-up of Groundwater for Use in Buildings (Building Water Act) were established to control groundwater intake in areas prone to land subsidence. They provided the legislative framework for measures to prevent land subsidence by significantly decreasing groundwater use.

The key preventive measure against the land subsidence is to regulate groundwater intake. However, general laws do not restrict the rights of land owners to use groundwater from their properties. Two laws were enacted to specifically regulate intake of groundwater for the purpose of preserving this resource and reduce the risk of land subsidence. The Industrial Water Act (1956) regulates intake of groundwater for industrial use in designated areas. The Building Water Act (1962) restricts intake of groundwater for buildings.

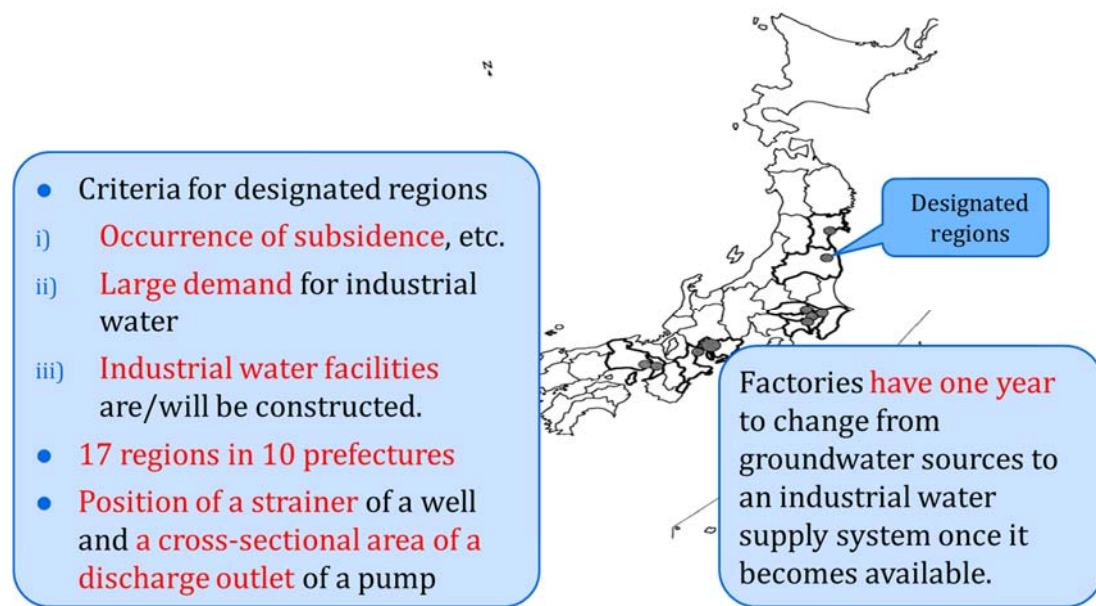
**【 Countermeasures against land subsidence 】**



**Figure 4. Legislations on Groundwater Use**

The Industrial Water Act is designed to ensure rational supply of water for industry, conserve groundwater and prevent land subsidence. In the designated areas (some parts of 10 prefectures, Miyagi, Fukushima, Saitama, Chiba, Tokyo, Kanagawa, Aichi, Mie, Osaka and Hyogo as of 2015), intake of groundwater above certain amount from an industrial well requires the approval of the prefectural governor and if necessary, on-site inspection by the local utility. The Industrial Water Act allows pumping from extremely deep aquifers which are technically difficult and not economically viable. This is an effective deterrent.





Source: Ministry of Economy, Trade and Industry, *Overview on groundwater protection, 2009*, [http://www.meti.go.jp/policy/local\\_economy/kougyouyousui/chikasuitaisakunogaikyo21fy.pdf](http://www.meti.go.jp/policy/local_economy/kougyouyousui/chikasuitaisakunogaikyo21fy.pdf)

**Figure 5. Designated Regions under the Industrial Water Act**

As the Industrial Water Act deals with existing and newly constructed wells in restricting groundwater usage, there were discussions on how to regulate them. The Act exempts existing wells and all wells with discharge outlet cross section of  $\leq 21 \text{ cm}^2$ . This was to exempt household wells. The required distance between wells also does not apply to these wells. The water shortfall resulting from these regulations was expected to be covered by industrial water supply.

Article 14 of the Industrial Water Act stipulates that the prefectural governor shall prevent users from pumping groundwater even from approved wells for a specified period of time in the event of an emergency to conserve the resource. Article 22 provides the authority to the Minister of Economy, Trade and Industry, the Minister for the Environment or prefectural governors to inspect well sites. In practice, on-site inspections are conducted with authorization by prefectural governors in all designated areas.

The Industrial Water Act requires that the regulated areas to be designated jointly by the Minister of International Trade and Industry<sup>1</sup> and the Minister of Construction<sup>2</sup>. In addition, it is necessary to consult with the minister in charge of each industry in establishing and revising

<sup>1</sup> The Ministry of International Trade and Industry changed its name to the Ministry of Economy, Trade and Industry in 2001.

<sup>2</sup> The Ministry of Construction was merged with other Ministries to form the Ministry of Land, Infrastructure and Transport in 2001. The Ministry changed its English name to the Ministry of Land, Infrastructure, Transport and Tourism in 2008.



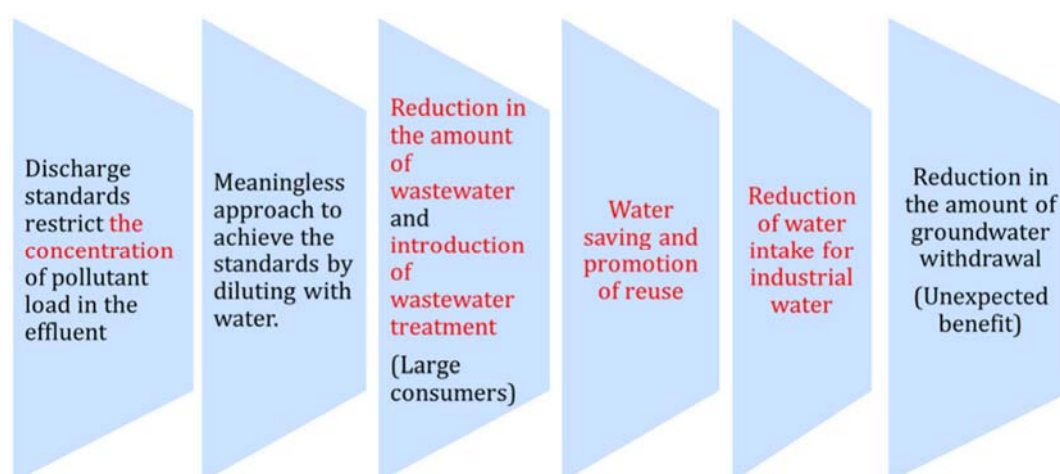
the permission standards. The Act was placed under the joint administration of the Ministry of Economy, Trade and Industry (METI); however when the Ministry of the Environment (MOE) was established in 1971, the aforementioned provisions were deleted and the Act is now jointly administrated by the METI and MOE.

### Column: Prevention of Land Subsidence through the Industrial Wastewater Regulations

In addition to the legislations mentioned above, the Water Pollution Control Act enacted in 1970, played an important role in reducing groundwater consumption. The Water Pollution Control Act regulates the total quantity of pollutant discharged rather than the concentration, making the practice of diluting the effluent no longer acceptable. This significantly, albeit unintentionally, reduced the amount of groundwater used by industry and the occurrence of land subsidence.

Large scale industrial water consumers reduced water discharge, introduced effluent treatment and promoted water reclamation and reuse. As a result, the amount of water intake stabilized even though this is not the original intention of the law.

According to the *Report by Industrial Site and Water of Census of Manufacture* published by the Ministry of Economy, Trade and Industry “recovered water” is used significantly more compared to other water sources, reaching 80% of total industrial consumption in Japan today.



**Figure 6. Effect of the Enactment of Water Pollution Control Act in 1970**

The Building Water Act is established to prevent land subsidence and to safeguard lives and properties. Similar to the Industrial Water Act, the Building Water Act requires the approval of the prefectural governor in the regulated areas (in Osaka, Tokyo, Saitama and Chiba prefectures)

for intake of water above a certain amount from the well of a building (for air conditioning, toilet, car wash, public bath). This practically bans pumping large amounts of groundwater.

These two Acts were established targeting groundwater use which may have impact on public welfare. They address concerns involving relatively large areas, across boundaries of cities, towns and villages, notwithstanding that groundwater use is private right. Many municipalities (311 cities, towns or villages of 27 prefectures out of 47, as of March 2015) outside of the designated areas enacted ordinances to restrict the intake of groundwater according to the local conditions and needs.

### (3) Alternative Water Sources

Alternative sources such as industrial water supply were provided in order to regulate groundwater usage.

The reuse of sewage effluent for industrial water supply is a practical alternative, since the water quality does not have to be as high as that of drinking water. Dam construction to secure alternative water sources also reduces the pressure on groundwater use. The regulation of groundwater use was implemented with provision of these alternatives.

### (4) Comprehensive Preventive Measures: *Guidelines for Prevention of Land Subsidence*

In Japan, the *Guidelines for Prevention of Land Subsidence* was established to promote region wide measures where land subsidence was significant.

Preventive measures for land subsidence must be comprehensive and must be implemented for the entire groundwater basin. Provision of alternative water sources and sustainable water use shall be included in the comprehensive measure. The *Guidelines for Prevention of Land Subsidence* was established as a decision by ministers exclusively for Nobi, Chikugo-Saga (1985) and the northern part of the Kanto Plain (1991).

The *Guidelines* focus on (1) conservation of groundwater by restricting excessive pumping, securing alternative water resources, (2) promotion of comprehensive preventive measures, appropriate for actual conditions in the area, including prevention of accidents and recovery from damage caused by land subsidence.

In 2005, the conference of ministers concerning the *Guidelines for Prevention of Land Subsidence* and subcommittees for Nobi, Chikugo/Saga and the northern part of the Kanto Plain were convened to discuss urgent measures to prevent land subsidence specific for each region.

**Table 1. Prevention of Land Subsidence in Nobi, Chikugo Saga & Kanto**

	Nobi Plain	Chikugo Saga Plain	Northern part of Kanto Plain
<b>Name</b>	Outline on Measures for Prevention of Land Subsidence in Nobi Plain	Outline on Measures for Prevention of Land Subsidence in Chikugo Saga Plain	Outline on Measures for Prevention of Land Subsidence in Northern part of Kanto Plain
<b>Decision year / revision year</b>	1985 / 1995	1985 / 1995	1991
<b>Target value of groundwater</b>	270 million m <sup>3</sup> / year	9 million m <sup>3</sup> / year	480 million m <sup>3</sup> / year
<b>Target areas</b>	Some areas of Gifu Prefecture, Aichi Prefecture and Mie Prefecture	Some areas of Fukuoka Prefecture, Saga Prefecture	Some areas of Ibaraki, Tochigi, Gunma, Saitama, and Chiba Prefecture

Source: Ministry of Land, Infrastructure, Transport and Tourism,  
[http://www.mlit.go.jp/mizukokudo/mizsei/mizukokudo\\_mizsei\\_tk1\\_000065.html](http://www.mlit.go.jp/mizukokudo/mizsei/mizukokudo_mizsei_tk1_000065.html)

#### (5) Monitoring of Groundwater Level and Land Subsidence

Understanding the hydrogeology, periodical monitoring of the total discharge volume, land subsidence and groundwater level, are important to restrict groundwater consumption and to prevent further land subsidence.

Land subsidence can be caused not only by human activities but also by inevitable natural events. As the mechanism of land subsidence is well understood, it is necessary to conduct surveys of subsurface structures to help identify the reason for the occurrence.

Japan has developed a nationwide observation network to monitor the effects of restriction on groundwater abstraction and alternative water supply. Monitoring of groundwater level is conducted once a month using telemeters with precision of  $\pm 1.0$  cm.

The Ministry of the Environment gathers information annually from prefectures and designated cities on preventive measures and outcomes. The status of groundwater use and land subsidence is compiled in a database, which is accessible on the website of the Ministry of the Environment; National Ground Environment Information Directory.

In Japan, land subsidence is almost completely halted. However, the lowering of land surface from this process is permanent. Flood control and drainage of inner basins must be planned and implemented based on the level of sunken ground and this involves huge social costs. Therefore, it is important to take measures before subsidence progresses in a significant way.

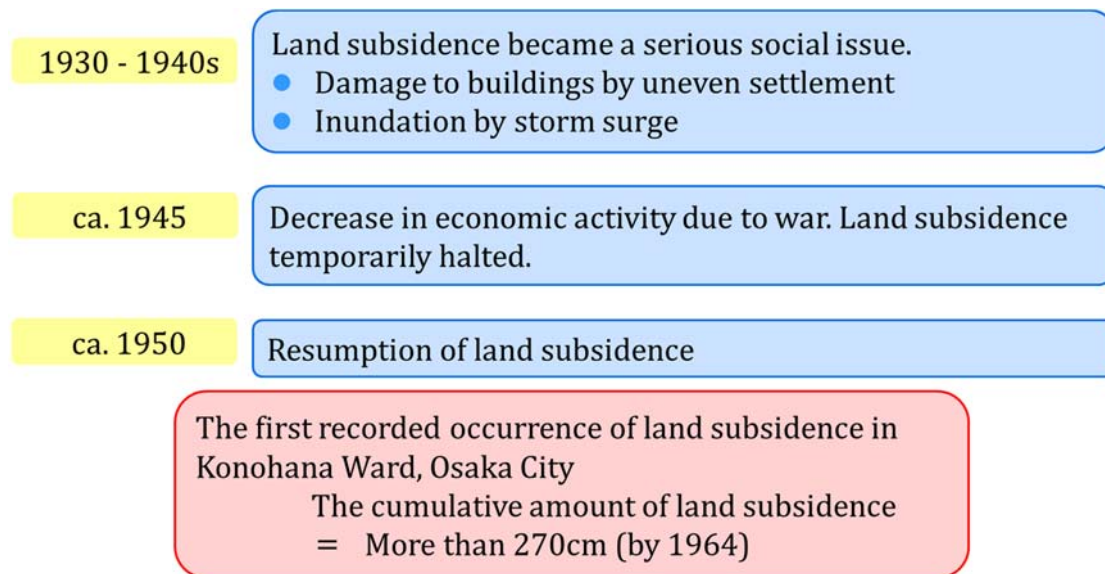
Until recently, Japan did not have any law that clarifies the fundamental principle and policy for the water cycle including groundwater. Groundwater has been generally construed as “private water” associated with the ownership of the land. The 2014 Basic Act on Water Cycle recognizes the concept of water, including groundwater, being owned and shared by the public. A committee was organized to discuss the enactment of individual laws based on this Basic Act.

### 3. Case 1: Osaka City

#### (1) History of Groundwater Use and Land Subsidence

In Osaka City, land subsidence attracted attention in the 1930s and 1940s. A decade later, more significant subsidence occurred as the country entered into economic expansion.

In the 1930s and 1940s, land subsidence in the western area of Osaka city caused major social problems such as building fractured by uneven settlement or ground slipping, and damage by high tides. The phenomenon was less obvious when economy activities slowed down but reappeared after WWII. It became serious again around 1950 as the economy began to recover. There are few data on land subsidence before 1964, but subsidence exceeding 270 cm as of 1964 in the Konohana Ward, drew attention to the problem.



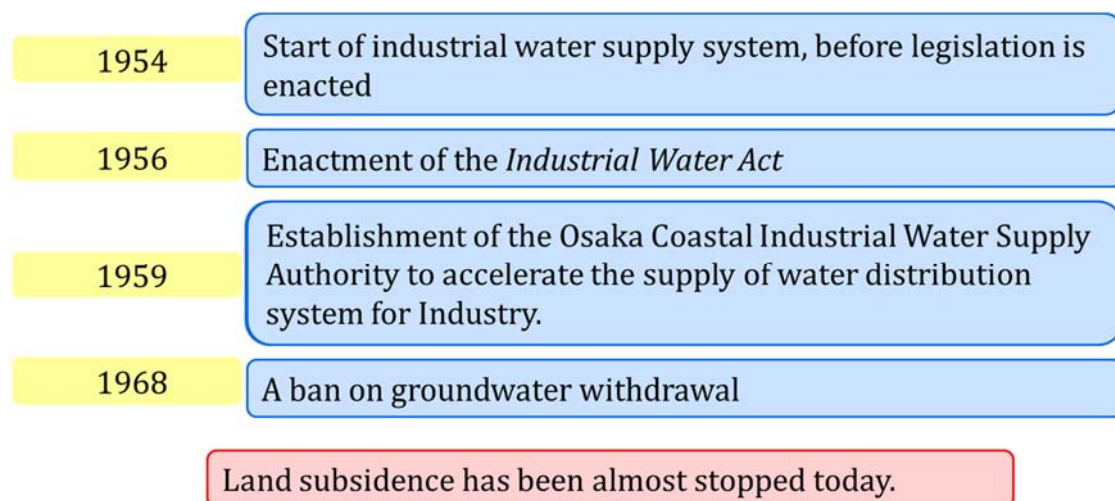
**Figure 7. History of Groundwater Use and Land Subsidence in Osaka City**

## (2) Industrial Water Supply

Osaka City started the supply of industrial water in 1954 to reduce land subsidence. After the enactment of the Industrial Water Act two years later, the restriction of groundwater pumping started, which led to the slowing down of subsidence.

In 1954 Osaka City constructed a treatment plant to supply industrial water as an alternative to groundwater use. The City could use funding from a subsidy allocated to countermeasures against storm surges in western Osaka because a subsidy for countermeasures against land subsidence had not yet been established.

Following the effort by Osaka City, the Industrial Water Act was enacted in 1956 to restrict groundwater pumping and the Act expanded the supply areas. Supply of industrial water by the Osaka Coastal Industrial Water Supply Authority started in 1959. By 1968, intake of groundwater was banned. All these measures helped to control land subsidence.



**Figure 8. History of Industrial Water Supply**

#### 4. Case 2: Saitama Prefecture

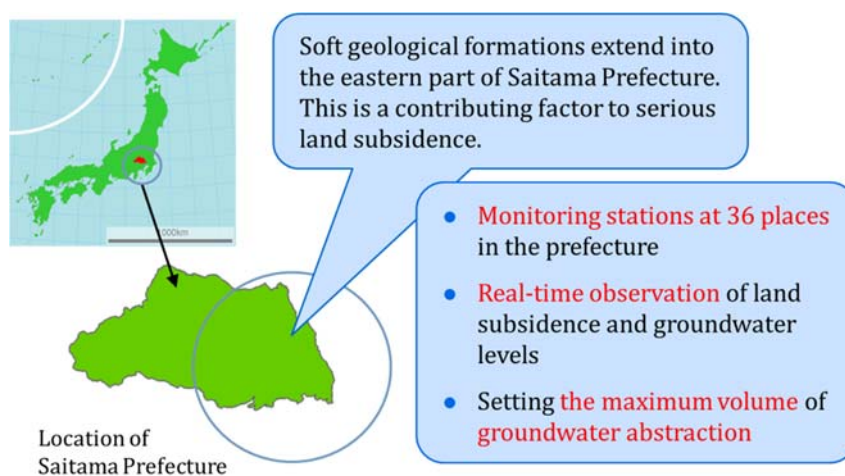
##### (1) History of Groundwater Use and Land Subsidence

In the eastern part of Saitama Prefecture, land subsidence occurred due to its soft soil layer. The pumping volume is restricted and a monitoring system is set up in this area.

Eastern Saitama Prefecture has soft fine grainy soil, so even a small drawdown of groundwater level could cause land subsidence. This area is designated to be regulated by the *Guidelines for Prevention of Land Subsidence*. Saitama Prefecture regulates the pumping of groundwater very strictly under the Ordinance for Living Environment Conservation.

The prefecture is divided into six zones and has 36 monitoring stations which measure groundwater level in real time and provide centralized control with a telemeter. The monitoring system also measures land subsidence and sets the upper limit on the quantity that can be pumped based on expert analysis of available data. Stoppage or reduction of pumping can be implemented when the groundwater level falls below a critical level, especially under severe drought conditions.

Since the Ministry of the Environment started monitoring in 1935, the cumulative land subsidence in Koshigaya City reached 150 cm. Although pumping is significantly reduced, about 1 to 2 cm subsidence per year is still recorded. When the consumption of groundwater temporarily increased during the drought in 1994, noticeable subsidence was observed.



**Figure 9. Local condition and monitoring**



## (2) Industrial Water Supply

Water supply to factories and the provision of alternative water supply to the southern part of Saitama Prefecture prevented further land subsidence.

Many factories were built in the south part of Saitama Prefecture around 1955. The increase in groundwater consumption caused land subsidence. The Enterprise Bureau of Saitama Prefecture started the supply of industrial water to these factories. The Kakinoki water treatment plant began operation in 1964 and Okubo water treatment plant in 1968. Today, they supply about 150 factories in six cities in the area.



**Photo 2. Kakinoki Water Treatment Plant (December 22, 2010)**

## 5. Lessons Learned

The following Japanese experiences could be useful for other countries.

- **(Monitoring)** Land subsidence can occur naturally or can be caused by excessive groundwater pumping. It is essential to monitor ground level and groundwater level continuously in areas where land subsidence occurs. It is also important to understand the relationship between groundwater usage and land subsidence so that the use of groundwater can be regulated.
- **(Alternative Water Sources)** The prevention of land subsidence can be greatly augmented by developing alternative water supplies such as industrial water supply.
- **(Regulations)** The Industrial Water Act, the Act on the Regulation of Pumping-up of Groundwater for Use in Buildings and local ordinances in some prefectures and cities provide the effective legislative framework for controlling groundwater use.
- **(Stakeholder Involvement)** It was effective to arrange the discussions for all the stakeholders including government authorities implicated in the regulation of groundwater usage and work together to find solutions for groundwater depletion and land subsidence.
- **(Prevention in the entire Groundwater Basin)** Preventive measures for land subsidence need to be implemented comprehensively in the entire region which constitutes the groundwater basin. Groundwater monitoring and regulations for groundwater pumping have been implemented in the whole region in order to limit groundwater withdrawal and to prevent further land subsidence.

