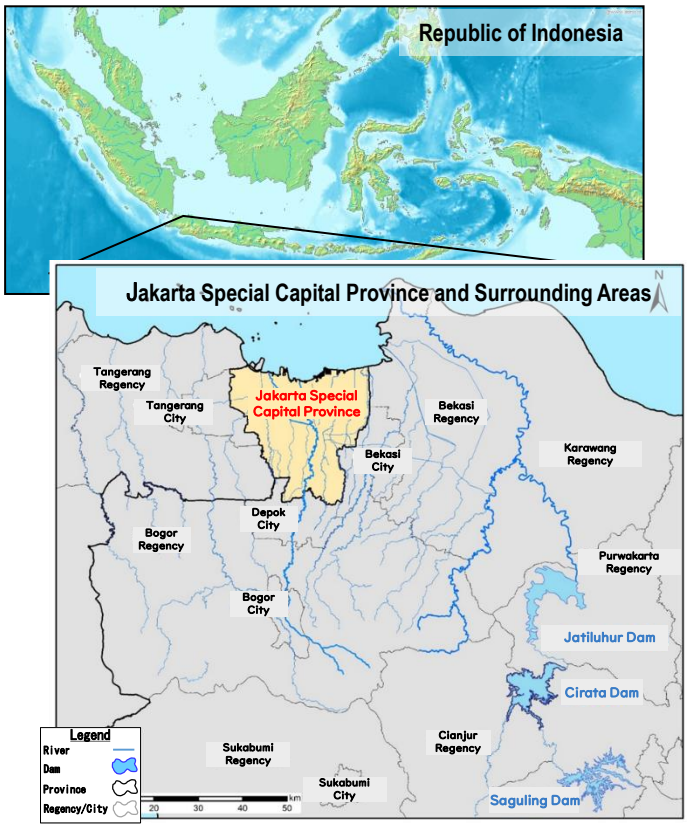
JICA PROJECT BRIEF NOTE

INDONESIA

Project for Promoting Countermeasures against Land Subsidence in Jakarta

—Establishment of Implementation Committee and Action Plan, and Capacity Building—

November 2022



1. Project Background and Challenges

Indonesia is a country located in the southern part of Southeast Asia with a population of about 2.70 billion, GNI per capita of 3,870 US dollars, area of 1.92 million km^2 (Ministry of Foreign Affairs of Japan, July 2022). As the capital city of Indonesia, Jakarta has a population of about 10,560,000 people (Central Statistic Agency, Indonesia in 2020) and is rapidly developing as an economic and political center. Meanwhile, Jakarta have been experiencing significant land subsidence. This is mostly caused by over-abstraction of groundwater by factories or and buildings, accompanied by recent economic growth and increase in population density in the capital. This tendency is especially notable within the lowlands along the northern part where economic activity concentrates, and in some areas wherein damages caused by sea water flooding at high tide is increasingly observed. Comparing with 1970's, the land subsidence rate is more than 4 m at maximum. It is subsiding at a rate rarely seen in the world. Land subsidence is occurring in a wide range including the center of Jakarta, which results to higher flood risks due to more severe floods and storm surges, increasing flood damage, bringing inhibition of civic life such as stagnation of logistics. It also have great impact on the economy.

Countermeasures against land subsidence will require not only monitoring, but also various measures such as restrictions on groundwater abstraction, development of alternative water sources, and promotion of adaptation measures. In order to establish a system in which related government organizations cooperatively promote these countermeasures under one action plan, the following steps are needed to be undertaken: 1. To propose effective mitigation measures against land subsidence: 2. To investigate risks of land subsidence and to estimate the

costs of adaptation measures, 3. To raise awareness among stakeholders about land subsidence and its countermeasures: and 4. To promote activities related to the implementation of the countermeasures.

Under these circumstances, the Government of the Republic of Indonesia (hereinafter referred to as “GOI”) requested Japanese Technical Cooperation, named “The Project for Promoting Countermeasures against Land Subsidence in Jakarta” (hereinafter referred to as "the Project”) to the Government of Japan, aiming to promote countermeasures against land subsidence in Jakarta through integrated groundwater and surface water management. The Project period is four and a half years from May 2018 to November 2022.

2. Project Approach to Tackle the Challenges

By accomplishing the five outputs stated in Figure 1, this Project will achieve the project goal of contributing to the promotion of measures and human resource development by the Indonesian executing agency.

Since many water-related elements such as groundwater management, water supply, and flood control are interrelated and there are many stakeholders and organizations involved in Jakarta's subsidence problem, it is necessary to address the issue based on the concept of "Integrated Water Resources Management (IWRM)". In order to promote IWRM, it is necessary for the organizations responsible for water management to formulate comprehensive policies based on scientific data (engineering approach), establish a system to carry them out while consulting with stakeholders, and create a democratic system among stakeholders to enable policy implementation (social science approach). An overall picture of the Project is shown in Figure 1.

In the Project, countermeasures to mitigate land subsidence phenomenon are referred to as “mitigation measures” while the countermeasures against disasters induced by land subsidence such as floods and high tides are referred to as “adaptation measures”. Since the Project can contribute to the risk reduction of disaster induced by climate change such as sea water rise or torrential rainfall, the Project can also be said to provide adaptation measures against climate change.

In addition, Indonesia established national indicators for achieving the SDGs in 2017, which include "Indicator 6.4.1(a) Control of groundwater use and law enforcement" as an indicator for "Target 6.4: Eliminate water shortages by improving water use efficiency". The Project will study and implement measures to promote appropriate management and use of groundwater as part of land subsidence control measures. In addition, as noted above, the process of achieving the goals of this Project will contribute significantly to the achievement of Target “6.5: Integrated Water Resources Management”.

Table 1　Related SDG's Targets and Indicators

Target	Indicator		Remark
	No.	Contents	
6.4: By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity.	6.4.1	Change in water-use efficiency over time	Global Indicator
	6.4.1(a)	Control and law enforcement for ground water use	National Indicator
	6.4.1(b)	Agricultural water saving incentives/plantation and industry.	National Indicator
	6.4.2	Level of water stress: freshwater withdrawal as a proportion of available freshwater resources	Global Indicator
6.5: By 2030, implement integrated water resources management at all levels, including through transboundary cooperation as appropriate	6.5.1	Degree (0-100) of integrated water resources management (IWRM).	Global Indicator
	6.5.1(a)	Number of Integrated Watershed Management Plans developed as part of Regional Spatial Planning (RTRW)	National Indicator
	6.5.1(b)	Number of hydrologic and meteorological stations updated	National Indicator
	6.5.1(c)	Number of water resources management information systems established	National Indicator
	6.5.1(d)	Number of catchments based on the memorandum of understanding on the increasing number of springs and international rivers.	National Indicator
	6.5.1(e)	Degree of non-productive forest increase for forest development and catchment protection	National Indicator
	6.5.1(f)	Number of catchments where river and lake management is carried out with the participation of local residents	National Indicator
	6.5.1(g)	Organizational formation activities related to water resources	National Indicator
	6.5.1(h)	Number of priority catchments where the number of springs is increasing due to conservation and recharge wells in upstream areas	National Indicator
	6.5.1(i)	Number of priority catchments whose water condition was restored by the construction of reservoirs, dams, and small- and medium-sized dams	National Indicator
	6.5.2	Proportion of transboundary basin area with an operational arrangement for water cooperation	Global Indicator

Source: RINGKASAN METADATA INDOKATOR TUJUAN PEMBANGUNAN BERKELANJUTAN
(https://sdgs.bappenas.go.id/wp-content/uploads/2017/09/Buku_Ringkasan_Metadata_Indikator_TPB.pdf)

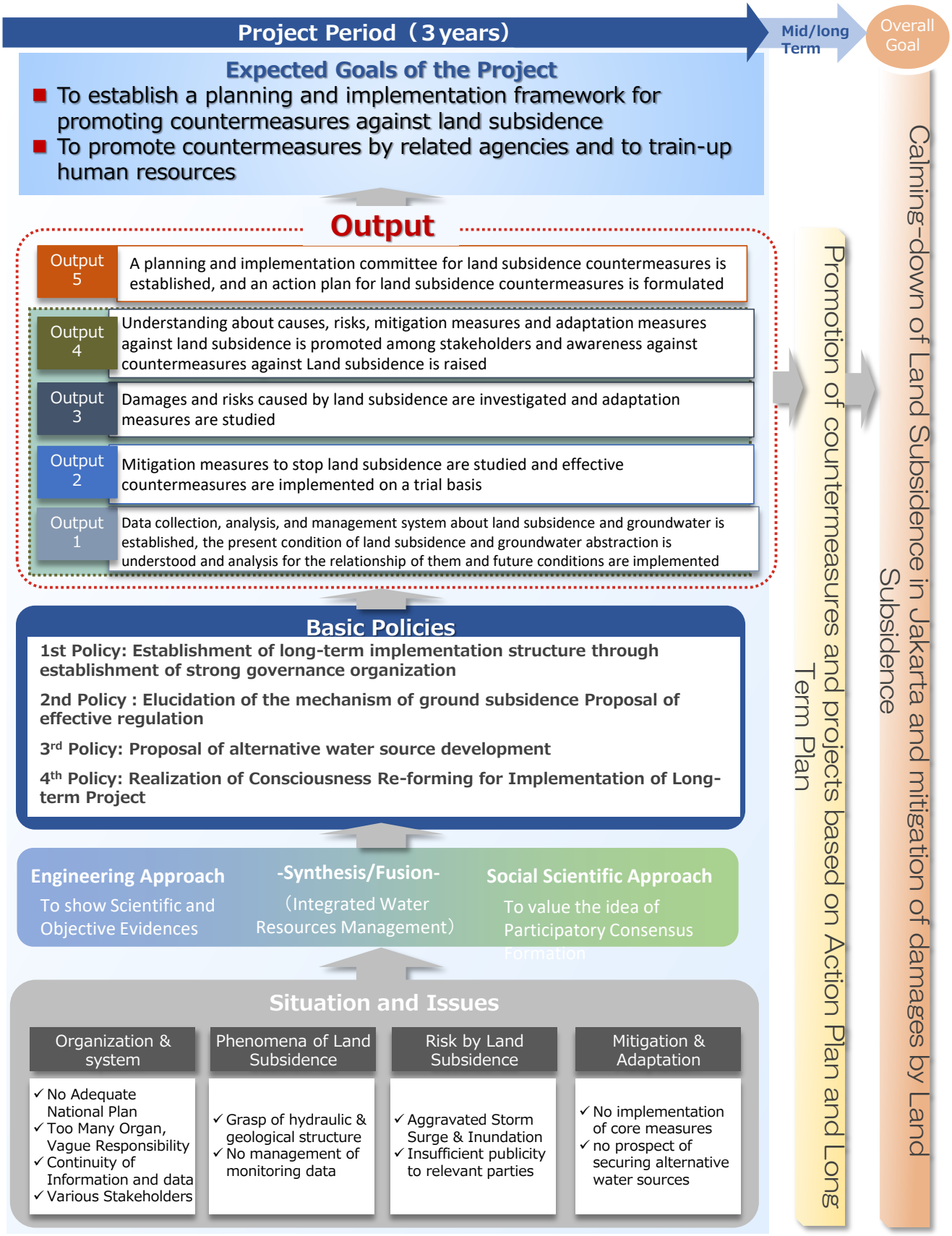


Figure 1 Project Overview

The Project requires various topics to be investigated as shown in the Project's outputs, and various agencies are nominated as the counterpart such as Directorate General of Water Resources, Ministry of Public Works and Housing (herein referred to as the "PUPR"), related agencies of Jakarta Special Capital Provincial Government (hereinafter referred to as the "DKI"), National Development Planning Agency (hereinafter referred to as the "BAPPENAS"), Directorate General of Human Settlement, PUPR, Geology Agency, Ministry of Energy and Mineral Resources, and Ministry of Environment and Forestry. Based on the appointment letter by the Minister of PUPR, the joint coordination committee (JCC) and working groups are organized as shown in Figure 2 and works together with the JICA Project Team.

The Project was implemented in the first phase from April 2018 to May 2019 and in the second phase from July 2019 to November 2022. In the first phase, along with the establishment of the implementation system, the Project mainly conducted surveys and discussions with relevant organizations, selected pilot areas, and formulated short- to long-term action plans, followed by the implementation of short-term measures in the second phase. However, after the start of the second phase, activities were severely restricted due to the Covid-19 pandemic, thus effective short-term measures were implemented using additional budget under the constraints of remote management. Furthermore, this activity led to the establishment of a Project Implementation Committee (PIC) and the formulation of an action plan for the PIC for self-sustaining development after the completion of the Project. Figure 3 shows the main activities and results of the Project.

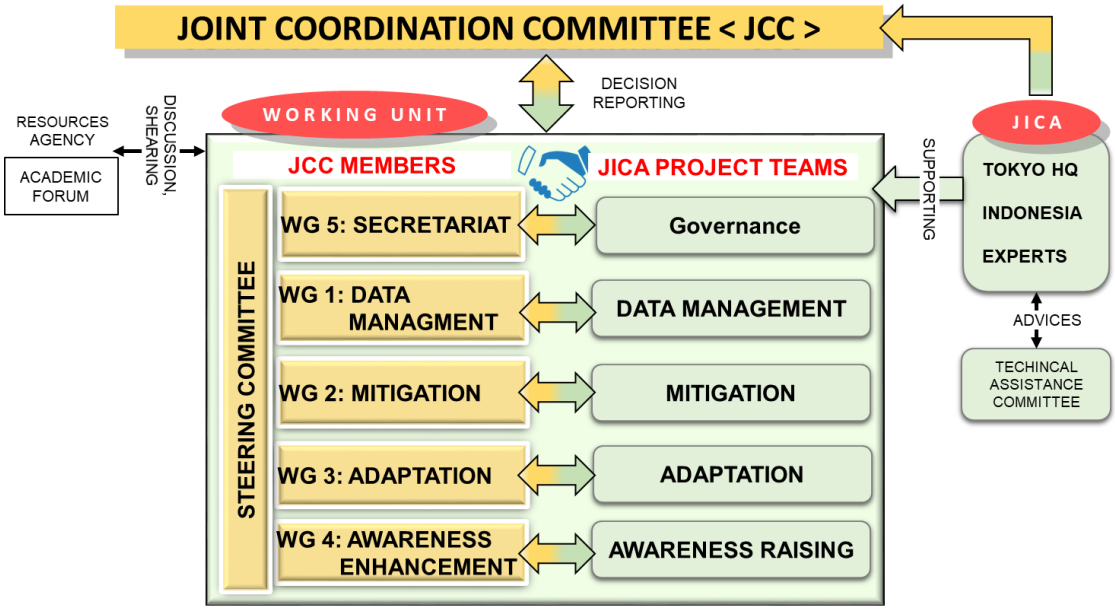


Figure 2 Project Organization

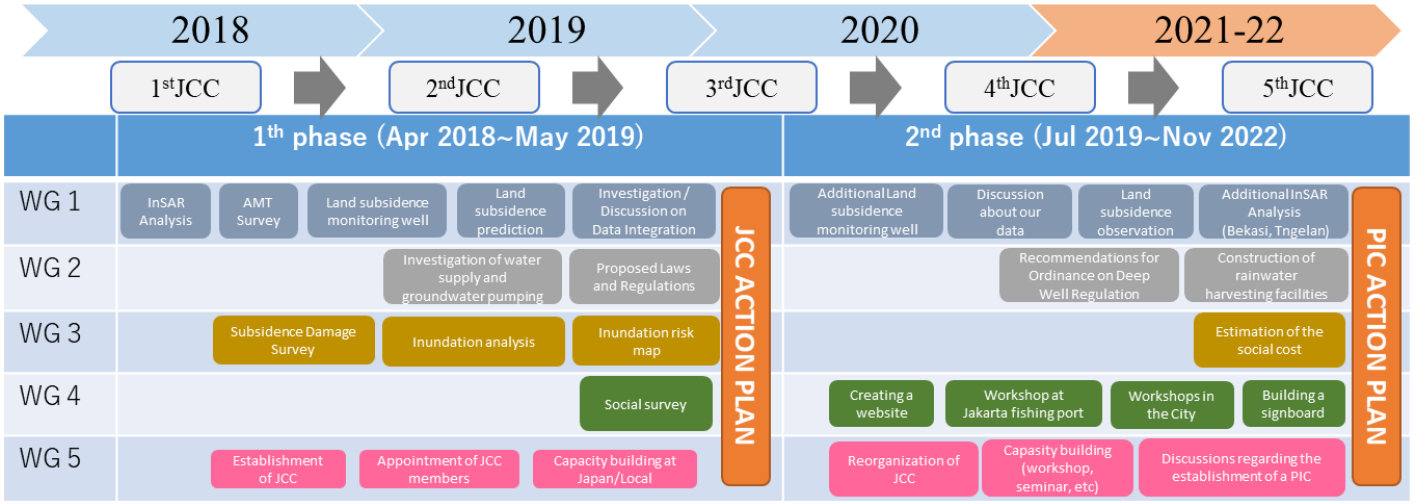


Figure 3 Main Activities and Outcomes of the Project

(1) Data Management (Output 1)

Several causes of land subsidence in Jakarta have been discussed, including excessive groundwater abstraction, consolidation due to urban loading and plate movement, thus no consistent countermeasures have been taken. In the Project, land subsidence and groundwater abstraction data management were conducted to clearly demonstrate that land subsidence is severe in areas with high groundwater abstraction and to cultivate a common understanding among stakeholders to build consensus on mitigation measures.

1) Satellite Imagery Analysis

InSAR analysis, which is used to analyze displacement of land by using differences in the phase of the waves returning to the satellite, is being conducted to measure land subsidence rate in recent years.

For the analysis, ALOS and ALOS2 data (2007 to 2010 and 2014 to date, respectively) by Japan Aerospace Exploitation Agency (JAXA) are used since these data has advantage for land displacement analysis in wide area. Land subsidence in the period 2011-2014 is estimated based on the anteroposterior periods. Analysis results are verified with the past leveling survey data and consensus on it is built among the relevant agencies such as Bandung Institute of Technology. In the second phase, the analysis was updated with the latest data and was also conducted in cities surrounding Jakarta (Bekasi and Tangerang).

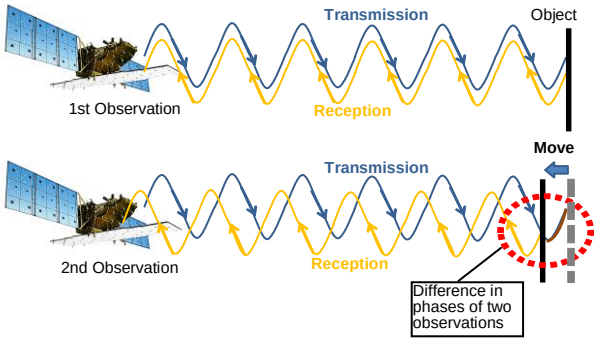


Figure 4 Image of Displacement Measuring by InSAR

2) Construction of Land Subsidence Monitoring Wells

After confirming the existing subsidence observation network in the first phase, subsidence observation wells were constructed at two locations. Based on the results of InSAR analysis, the observation locations were selected as areas with significant land subsidence and no existing observation wells, and public land in DKI was selected after discussions with related organizations.

The double-tube type monitoring well (see Figure 5),

which has a proven track record in Japan and is highly durable, was adopted as the well type. The advantages of this type of well are well understood by the staff of the executing agency in Indonesia (Counterpart, hereinafter referred to as "C/P") through discussions and training in Japan, and the technology was transferred to the C/P by conducting site tours and preparing construction manuals. In the second phase, DKI had planned to construct observation wells with the provincial government budget, but this was cancelled due to the flood damage and the Covid-19 pandemic mentioned above. In response, an additional subcontracting work was carried out to construct observation wells at the Jakarta fishing port, where land subsidence in recent years has been most severe.

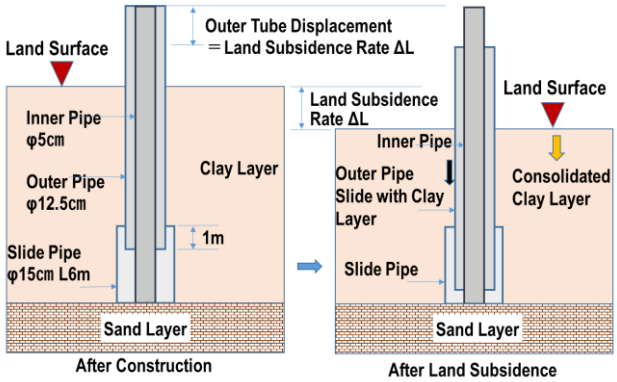


Figure 5 Schematic Drawing of Double-Tube

3) Land Subsidence Mechanism and Prediction

Relationship between land subsidence, land use and historical change of groundwater use are studied. Hydrogeological condition is confirmed based on past analysis and electromagnetic exploitation. Compiling the geological features based on the boring core of monitoring wells and past survey and data on abstraction volume and groundwater level, mechanism of land subsidence is identified by one dimensional land subsidence simulation. The process and results of analysis is shared and discussed with relevant agencies such as the water resources institute of PUPR (hereinafter referred to as the “PUS-AIR”) and the National Capital Integrated Coastal Development (NCICD).

4) Establishment of Well Inventories and Database Management System

With the aim of establishing an integrated database of well locations and parameters, abstraction volumes, groundwater levels, and land subsidence, we held discussions with related organizations to discuss appropriate data integration and sharing. The progress of land subsidence and related existing data was also reviewed, and recommendations for the future expansion of land subsidence observation were made.

5) Groundwater Analysis

Groundwater analysis was conducted in order to provide studying material for appropriate groundwater use to control land subsidence. Considering the applicability of the model and technical transfer to Indonesia, MODFLOW, which is an open-source software and widely used in Indonesia, was adopted as the analysis method.

(2) Mitigation Measures (Output 2)

Activities related to regulations and management of groundwater use, alternative water sources, and groundwater recharge were conducted with the goal of reducing the land subsidence.

1) Study on Related Regulations and Proposal for Improvement

Related laws and regulations to groundwater use, alternative water resources (rainwater and water recycling) and groundwater infiltration are studied and their improvement is proposed.

In particular, the Project Team carefully examined issues such as the inadequacy of the well registration system, which is mandatory only for industrial and commercial use, the large number of unregistered wells, and the fact that some wells are abstracting more than the registered abstraction rate. The Project Team also examined the

early implementation of a system to promote registration for use by public facilities and general households, and proposed the enactment or amendment of regulations.

2) Estimation of Water Use and Groundwater Abstraction Volume

Chronological change and spatial variation of water supply and abstraction volume are summarized, and abstraction volume by unregistered wells is estimated by comparing water demand estimation based on various statistics and water supply volume.

For domestic use, use of water sources except pipe water supply is being estimated by district (*kecamatan*) level.

3) Assess Current Status of Water Supply Services and Make Recommendations for Improvement

Regulating excessive groundwater abstraction, which is causing land subsidence, requires an alternative source of water supply. In DKI, water services used to be provided by the Water Supply Public Corporation (PAM Jaya), which has been privatized through a concession contract since 1998. Although in 2017, Supreme Court decided to re-publificate the system, the prospects are unclear. In addition, the company faces many challenges, including low water supply rates, high leakage rates, and insufficient water supply facility capacity. These situations were thoroughly examined and proposals were made to improve the water supply service.

In particular, the Project Team focused on revising the master plan, which should serve as an action guideline, and on short-term measures to reduce the non-revenue rate (e.g., block water distribution, reducing leakage through pressure management, etc.).

4) Proposal on Alternative Water Resources

In order to fulfill the current and future water demand of the Jakarta Metropolitan Area, new water conveyance systems from Citarum River in West Java Province and Karian Dam in Banten Province are on-going. However, completion is expected to take decades due to several issues on each project. Therefore, possibility of other alternative water resources is explored such as rainwater, water recycling, development of ponds, river course storage, etc. as short to medium term measures. In addition, dam operation improvement of the three cascade dams in Citarum River is also proposed.

5) Proposal on Groundwater Recharge

Installation of rainwater infiltration facility has been promoted by DKI (construction by government in public facilities, recommendation for housing and requirement for new building constructions) with purpose of runoff reduction during heavy rain and groundwater conservation. Approximately 7,500 facilities have been constructed, and new construction is expected to continue. These situations were summarized and suggestions were made regarding the promotion of future construction.

(3) Adaptation Measures (Output 3)

The social risks increased by land subsidence were identified and measures to mitigate these risks were discussed.

1) Examination of Risk caused by Land Subsidence

The risk of disasters caused by land subsidence was assessed by interviewing 24 districts in northern Jakarta to assess the damage to infrastructure and buildings due to land subsidence, and by conducting inundation simulations in the event of progressive land subsidence.

Based on the subsidence projections, several subsidence scenarios were set up, and inundation simulations were conducted to evaluate the increased risk. The effects of climate change were also considered in setting the scenarios.

2) Preparation of Inundation Risk Map

In order to understand the risk of land subsidence and to prepare for flooding, risk maps were created for storm surge, flooding, and the impact on urban infrastructure. The risk maps were considered as materials for

awareness-raising activities for the government and local residents.

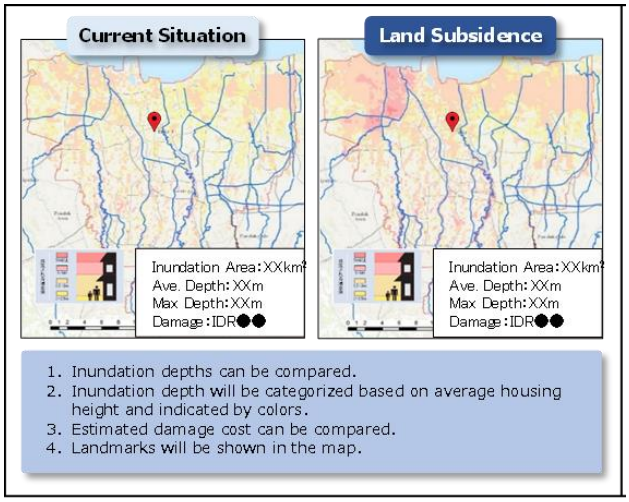


Figure 6 Image of Inundation Risk Map

3) Review of Adaptation Measures

The following existing, on-going and planned facilities and projects are reviewed. Based on this, a plan of land subsidence adaptation measure is formulated and its approximate cost is estimated.

- ✓ High tide levee, river embankment, river improvement that mainly developed and maintained by PUPR
- ✓ Drainage maintenance and pumping station which are mainly developed and maintained by DKI Jakarta
- ✓ Reinforcement of the coast levee and river mouth levee and pumping station listed as maintenance menu of NCICD
- ✓ Others: road, bridge, railway, subway

The National Capital Integrated Coastal Development (NCICD) is a government plan for redevelopment of coastal area in Jakarta with the following four visions and strategies:

1. Reducing Flood Threat
2. Developing Productivity in Coastal Areas
3. Improving Environmental Quality
4. Revitalizing Socio-cultural Aspect in Coastal Area

NCICD includes the projects on (1) Land subsidence control, (2) Flood control from seas and rivers, and (3) Sanitation and industrial waste management, as the "No Regret Measures". Total projects cost by 2050 is estimated at Rp. 447 trillion (JPY 3.5 trillion). The projects consists of national and local governmental projects, PPP projects and donor projects such as the sewerage development project funded by Japan ODA.

The off-shore dike integrated with toll road and land development is also included in the project. The gates of dike and bridges will be closed and pumps and flood gates will be constructed between 2050-2080 as the "Conditional Measures" in case land subsidence remains uncontrolled.

4) Rough Estimate of Social Cost by Land Subsidence

In the Project, the social cost by land subsidence is defined as "the cost borne by the whole society, including citizens and enterprises, as a result of improperly implementation of the countermeasures", and damage cost is estimated based on the inundation area and depth by the flood simulation.

In addition, the cost of additional flood and storm surge countermeasures due to increased inundation was calculated as "adaptation measure cost". In addition, "mitigation costs" were calculated by multiplying the cost of alternative water sources and water supply improvement plans implemented and planned to meet future water demand by the ratio of the area of land subsidence to the total area of DKI Jakarta, and these were compared.

(4) Awareness Raising (Output 4)

One of the reasons for the lack of progress in land subsidence mitigation was the lack of understanding among stakeholders about the phenomenon of land subsidence, its risks and causes. Therefore, a survey on awareness of land subsidence was conducted and an

awareness-raising program based on this survey was developed and implemented.

1) Social Survey

As a baseline survey for awareness raising, social survey is conducted by the University of Indonesia. The survey is noted to avoid social conflict and is implemented after several times of briefing to surveyors.

2) Preparation of Materials

Based on the results of each activity, a project website was created as a resource to explain the current status of subsidence, its causes, risks, and costs of countermeasures in an easy-to-understand manner. At the same time, the Project team discussed where to transfer the website after the completion of the project, and provided guidance to the staff of the targeted DKI-related departments regarding the operation and update of the website.

In the second phase of the project, sign boards were constructed at tourist attractions in the old town area (Kota Tua area), in close discussions with the DKI.

3) Awareness Raising Activities

Workshops for government officials in three northern cities (North Jakarta, West Jakarta, and East Jakarta) and discussions with groundwater users at Jakarta Fishing Port were held with the aim of raising risk awareness, deepening understanding of the need to reduce groundwater usage, and raising public opinion to promote subsidence countermeasures.

(5) Governance (Output 5)

The land subsidence will not be solved in a short period of time, and it is necessary for the Indonesian side to continue its activities in a self-sustaining and developmental manner through its own efforts after the completion of the Project. Therefore, based on Outputs 1 to 4, an activity was conducted to develop an implementation system after the completion of the Project, and also to train human resources.

1) Establishment of Action Plan

Based on the Outputs 1 to 4, an action plan is formulated consisting of short term measures to be implemented within the Project period, medium-term measures to be implemented by 2030 and long-term measures. For the short term measures, some pilot areas are selected and specific pilot activities are conducted together with detailed investigations of local situation.

Short-term measures were implemented in the second phase, and an action plan after the completion of the Project was established based on these experiences.

2) Capacity Building

In order to develop human resources who can cope with the long-term land subsidence countermeasures, C/P agency human resource development was conducted through the training in Japan, workshops, seminar and academic forum as well as OJT during the working group activities.

3. Results of Project Approach

(1) Data Management (Output 1)

The distribution and magnitude of land subsidence areas from 2007 up to 2020 is shown in Figure 7.

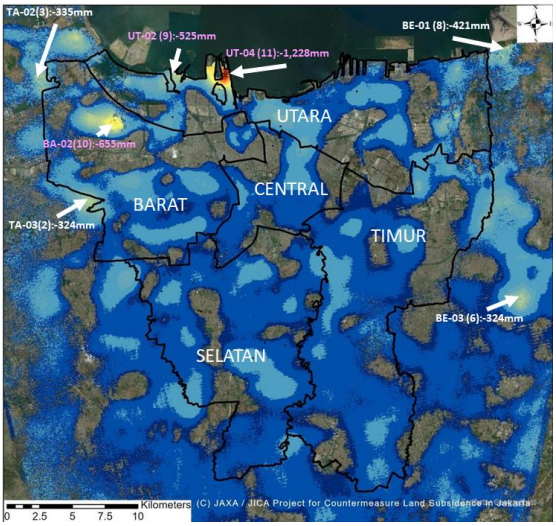


Figure 7 Subsidence distribution based on satellite image analysis

Areas affected by land subsidence are scattered within Jakarta. The area where land subsidence rate ranges from 20 mm to 50 mm are scattered from central to southern Jakarta while severe land subsidence areas having rates more than 50 mm are concentrated along the coastal area in the north. The number of registered wells and abstraction volume is highest in South Jakarta City while the bedrock is shallow in southern areas and deep in the north. The difference of geological formation is suspected to have a significant influence on the magnitude of land subsidence rate. Comparing the land subsidence rates during two periods, 2007-2010 and 2014-2020, land subsidence has stopped in some areas in Jakarta while new land subsidence areas emerged at the surrounding areas where development is progressing.

The InSAR analysis in Bekasi and Tangerang revealed that the land subsidence occurred in these cities, up to 102 cm in Bekasi and 37 cm in Tangerang in 13 years.

The discussion on the plan of construction of land subsidence monitoring well started in May 2018, and construction was commenced in the end of October 2018 and completed in June 2019. By the time of the commencement, three joint surveys and five meetings were conducted which resulted to the encouragement of the C/P's initiative. The double-tube type wells require the vertical insertion of three types of pipes of different diameters to a maximum depth of about 300 m. However, problems occurred during construction due to limitations of locally available materials and construction machinery. In response to this problem, the contractor, C/P, and project team held discussions on site and solved the problem by devising a construction method. In the second phase, based on the experience gained in the first phase, further improvements were made to the construction methods.

Figure 8 Land subsidence monitoring well

For the future expansion of the observation network, priority sites were selected based on the extent of land subsidence, existing GNSS survey (A generic term for satellite-based positioning systems; GPS surveying is a satellite-based system developed by the United States and is one of the GNSS surveying systems.) observation sites, and the observation locations of the electromagnetic survey (AMT method) conducted in the Project. The monitoring well construction is expected to proceed by the relevant organizations in the future.

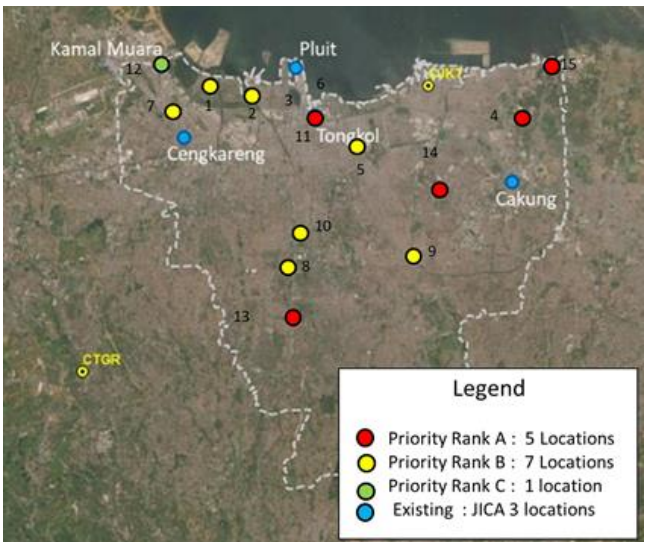


Figure 9 Priority sites for land subsidence observation

After the completion of the observation wells, the observations with C/P personnel started. During the first

year after completion, accurate data could not be obtained because of the lack of adhesion between the pipe and the ground, but from the second year onward, the pipe was stable and clear deformation could be observed. At the observation well site, subsidence of 10 to 15 mm per year was recorded, indicating that subsidence was still in progress.

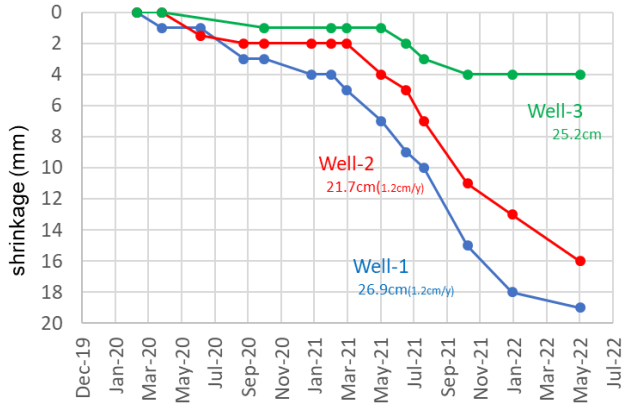


Figure 10 Subsidence observation results from observation wells

The following are the current findings on the mechanism of land subsidence in Jakarta. The following discussion confirms that groundwater abstraction is the main factor.

- ✓ The east and west sides of the coastal area of Jakarta were originally swamp areas that were converted to urban areas through urbanization from the 1960s to 2000. Since at the minimum about 20 years has passed, it is difficult to estimate the load of embankment and/or structure and its influence on land subsidence.
- ✓ Land subsidence has become much lower since 2009 when groundwater abstraction volume drastically decreased. It indicates that over abstraction has a significant influence over land subsidence.
- ✓ Based on one dimensional land subsidence analysis, shrinkage of soil layer occurred mainly in layers more than 40 m deep.

Assuming four levels of abstraction volume, a change on the future subsidence predicted at the nine sites, for which geologic data were obtained, was determined. As a result, the following conclusions were obtained.

1. If the groundwater level drops further without any regulation on groundwater abstraction, land subsidence of 62 to 492 mm (about 0.6 to 4.8 cm/yr) is expected to occur until 2030.
2. When the groundwater abstraction is regulated to not exceed the current groundwater abstraction volume and the groundwater level is maintained, land subsidence of 45 to 363 mm (about 0.4 to 3.5 cm/yr) is expected to occur until 2030.
3. If the groundwater abstraction regulations will be implemented to reduce the current groundwater abstraction volume by 100% until December 2030 and the groundwater level will recover to the original level, land subsidence of 17 to 142 mm (about 0.1 to 1.4 cm/yr) is expected to occur and stop after that.
4. To reduce the land subsidence to less than 1 cm/yr at all locations by 2030, groundwater abstraction volume needs to be reduced by more than 50% by December 2030.

The model was constructed by examining the geological and hydrogeological structures using existing data and the survey data conducted in the Project. Multiple scenarios were set up for total abstraction rate including from unregistered wells, hydraulic conductivity of impermeable layers, groundwater inflow from outside the area and rainfall, etc., and the optimal solution for the water balance was examined. It is hoped that the quality of the data will be improved through accumulation of the data, and the model will be refined and utilized for such as setting the allowance abstraction volume.

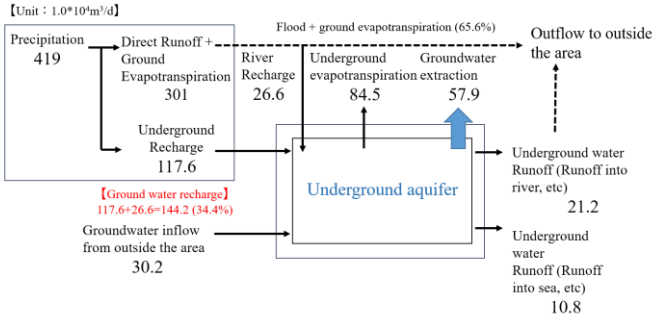


Figure 11 Water balance of Jakarta by analysis

As a result of hearing and discussion with relevant agencies on data management, the WG agreed on a concrete image of the system to be achieved by incorporating or linking data from other organizations into the Groundwater Management System (PASTI) developed and operated by the Groundwater Conservation Center of the Geological Bureau of the Ministry of Mines and Energy (BKAT). Importing of data held by the Project Team has also been undertaken. Discussions are continuing on the integration and sharing of data held by DKI and PUPR.

(2) Mitigation Measures (Output 2)

For the improvement of legal framework, “acceleration of registration by all users” and “setting of critical zones and restriction in these areas” are proposed and as a result of continued discussions with relevant agencies, the Jakarta Governor's Regulation on Groundwater Regulation Zones came into effect in 2021. Under this regulation, the construction and use of deep wells will be prohibited on the condition that a water supply system is in place, and where large groundwater users, such as factories and commercial facilities, are found. The ordinance is scheduled to be enforced by the end of 2022.

Based on the available statistic data and unit water consumption applied in Indonesia or Japan, the water balance in whole Jakarta in 2015 is estimated as shown in Figure 12. Residual deficiency against the demand of 23.4 m^3/s is about 10.5 m^3/s and most of the residual deficiency might be compensated by unregistered wells.

Regarding domestic water, the use of groundwater from shallow layers (0-40 m) was estimated as of 2018, which is the main source other than pipe water. The estimates showed that 37% of household water demand was supplied by tap water, with the remaining 63% coming from other sources, 29% of which were from shallow wells. The use is particularly high in East Jakarta and South Jakarta. The water supply rate in these two cities is lower than in other cities, and according to consumption data from Jakarta Water Supply Reguratory Agency, many households are not using water even though they are connected to pipe water.

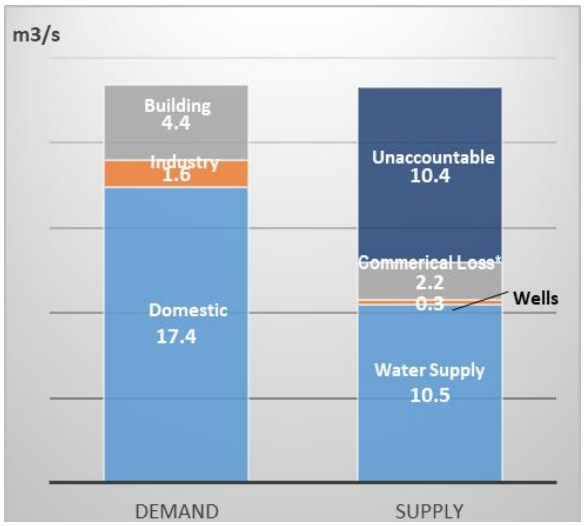


Figure 12 Estimation of Water Balance in 2015

*: Commercial loss is the amount of water that cannot be billed due to faulty water meters, erroneous meter readings, illegal connections, etc., out of the non-revenue water volume.

Current efforts by the Indonesian Government for provision of alternative water supply are reviewed and utilization of reservoirs and the possibility of recycled water was proposed, it was included as one of the PIC's Action Plan.

The Project Team was asked to advise in response to the information that DKI was planning to construct a system to treat and reuse sewage, rainwater, and river water by constructing a reservoir at a public housing complex in the area where water supply does not reach. A joint

survey with DKI was conducted and the improvements to the reservoir and a rainwater harvesting facility were proposed utilizing Japanese products. The initial proposal was to install two rainwater harvesting facilities beside a mosque on the site, collect rainwater from the roof of the mosque, and connect it to the water infiltration system. Schematic drawings and cost estimates were prepared and a proposal was submitted to DKI in October 2019. DKI had considered the budget for the project for 2020, however, due to the January 2020 flooding and the Covid-19 pandemic, it was not possible to budget for the project.

In response, the Project decided to construct a rainwater harvesting facility by subcontracting work as a short-term action in the pilot area. After repeated discussions and investigations with DKI agencies, it was decided to construct a rainwater harvesting system that would purify water and return it to the mosque, instead of supplying stored rainwater to residences, from the viewpoint of the effectiveness of the scale of the facility. The system is capable of meeting the demand for 20 to 30 days/month during the rainy season and 5 to 15 days/month during the dry season.

Figure 13 Overall plan of rainwater harvesting and utilization system

(3) Adaptation Measures (Output 3)

Based on the interview survey on infrastructure damages, road is the most affected infrastructure, and bridge and drainage follow. Type of damage is mostly related to flood and high tide damages such as an increase in inundation depth and period, however, daily affected damages are also pointed out such as dysfunction of facilities by unequal settlement.

For the inundation simulation, the model developed in the "Jakarta Global Warming Simulation Study" (JICA, 2012) was updated to include four land subsidence cases shown in Table 2 and the sea level rise and rainfall increase rates as climate change scenarios adopted from the IPCC Fifth Assessment Report RCP2.6 scenario and RCP8.5 scenario, and the land use change projections based on DKI spatial planning as conditions for the simulations.

Table 2 Land subsidence case setting

Land subsidence cases	Abstraction conditions after October 2019	Water level conditions after October 2019 corresponding to abstraction conditions
Case A	If the current groundwater abstraction rate is **reduced** by 100% by December 2030	Water level will continue to recover from October 2019 onward, returning to initial levels in December 2030.
Case A-1	If the current groundwater abstraction rate is **reduced** by 50% by December 2030	Water level will continue to recover from October 2019 onward, returning to a level equivalent to the abstraction condition in December 2030
Case B	Regulation of groundwater abstraction in excess of **existing groundwater abstraction**	Maintain groundwater levels as of September 2019.
Case C	If groundwater abstraction is not regulated and **groundwater abstraction increase**s	Continuing downward trend through September 2019

Simulation results show that the impact is more significant in the coastal areas of eastern and western Jakarta. If subsidence continues to progress at this rate, inundation volume by a 1-in-100 year flood in 2050 is assumed to increase by 21%, and by 221% in the largest storm surge on record, compared to 2018. Furthermore, assuming that climate change also continues, inundation volumes would increase by 57% and 270%, respectively. Based on these results, inundation risk maps were prepared for the pilot areas.

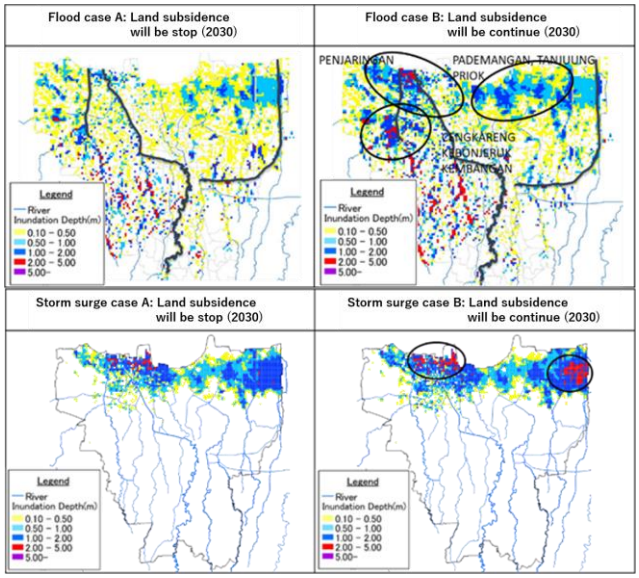


Figure 14 Flood and storm surge simulation results

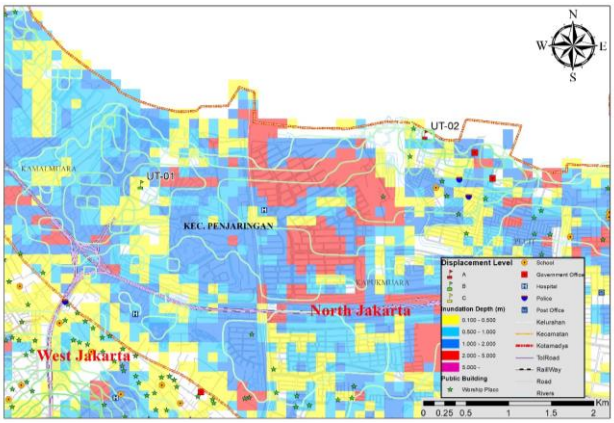


Figure 15 Inundation Risk Map

For adaptation measures, the flood and storm surge countermeasures were reviewed, which was being planned and conducted by the NCICD and the Indonesian government, the additional measures that would be required as a result of ongoing land subsidence (seawalls, pump enhancements, and the sluice gate and pumps for the offshore seawall closure planned for the future by the NCICD) were considered, and the cost of these measures was estimated.

In addition, the amount of damage caused by land subsidence was calculated as a social cost. Assuming continued subsidence and climate change until 2050, the amount of damage caused by a 1-in-100 year flood would increase by 116% from 112 trillion rupiah (about 1.07 trillion yen) to 242 trillion rupiah (about 2.33 trillion yen). In addition, if a storm surge equal to the record high tide recorded in 1925 were to occur, the amount of damage would increase by 341% from 58 trillion rupiah (approximately 0.56 trillion yen) to 256 trillion rupiah (approximately 2.46 trillion yen).

Furthermore, the cost of mitigating land subsidence was calculated by multiplying the ratio of the "area with subsidence of 50 mm or more" to the "total area of the province" based on the results of InSAR analysis, as a cost that contributes to mitigating subsidence against the project cost of water supply system development, including large-scale surface water development projects planned and implemented by the Indonesian government and PPP.

As shown in Figure 16, the social cost, the cost of adaptation measures, and the cost of mitigation measures were calculated to be approximately 498 trillion rupiah (Approx. 4.8 trillion yen, 43% of the GRDP of DKI) and 46 trillion rupiah (Approx. 0.4 trillion yen, 4% of the GRDP of DKI), and 10 trillion rupiah (Approx. 0.1 trillion yen, 1% of the GRDP of DKI) respectively. In addition, the administrative cost of promoting subsidence mitigation measures is about 560 billion rupiah (about 5.4 billion yen), even if it costs 20 billion rupiah/year (about 200 million yen) for 28 years until 2050. The cost of mitigation measures is by far the smallest, at only 21% of the cost of adaptation measures and 2% of the social cost. Therefore, it is clear that subsidence mitigation measures should be promoted immediately in terms of cost.

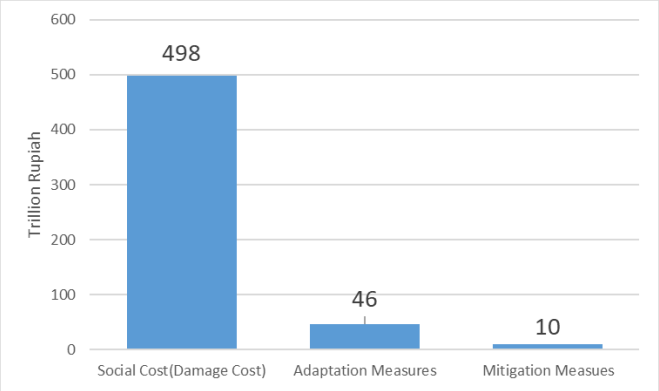


Figure 16 Comparison of social costs, adaptation costs and mitigation costs

(4) Output 4: Awareness Raising

The social survey was conducted in the land subsidence remarkable areas with 400 households, 66 factories and 126 business entities in total. About 75% of those surveyed were aware that subsidence was occurring in Jakarta, but less than 10% were aware that it was happening in their area and was causing increased flooding. Also, understanding of the causes of subsidence and existing regulations was not yet well developed.

At the beginning of the second phase, workshops for administrative officials were held in three northern cities (North Jakarta, West Jakarta, and East Jakarta) where land subsidence was significant.

Figure 17 Workshops for government officials

In West Jakarta, discussions of rainwater harvesting facilities in commercial areas with significant land subsidence were carried out, but due to restrictions on social activities caused by the Covid-19 pandemic, discussions that led to specific activities could not be continued.

On the other hand, as a result of various communications conducted throughout the Project, DKI's Medium-term Development Plan 2023-2026 includes "Monitoring groundwater use for subsidence control" as part of the Objective: Improve urban stability and recovery, and the measures to put this into practice include "Implementing groundwater free zones", "Managing groundwater use through taxation", "Licensing and law enforcement", "implementation of policies related to groundwater use monitoring systems", and "provision of subsidence monitoring tools to promote measurement and assessment".

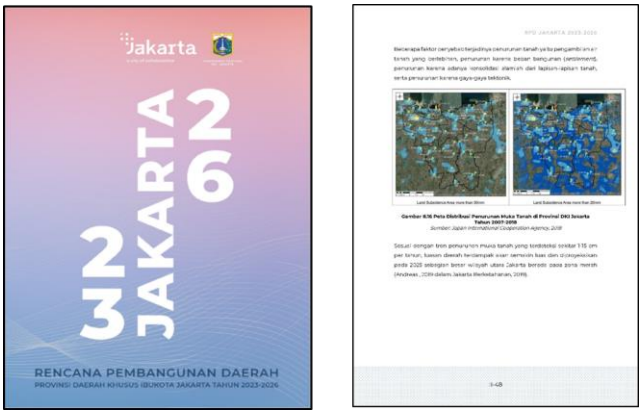


Figure 18 Development plan of DKI Jakata 2023-2026

As an effective educational resource even under the restrictions on social activities, the Project website was created. Discussions were held with related organizations on the content of the website and its operation after the completion of this Project, and it was decided that the website would not only introduce the activities of the Project, but also related government activities, and function as a platform for data sharing. After the completion of the Project, the site will be under the

jurisdiction of the DKI Information and Statistics Bureau, which will be responsible for updating the contents. Since the site was opened to the public, it has received more than 1,300 accesses by March 2022, and the number of hits on search engine sites has been increasing. In addition, after the contents were created, technical transfer of updating work was conducted several times to DKI staff members. It is expected that DKI will update the information and enhance the contents in the future.

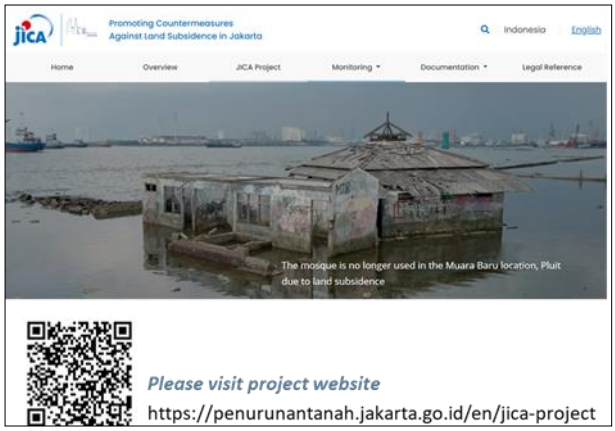


Figure 19 Website and access QR code

Through WG discussions and training in Japan during the first phase, subsidence awareness materials in Tokyo have been introduced, of which DKI showed great interest in a water level sign tower (a tower that indicates where the water surface of rivers and oceans are located in areas where subsidence has progressed). In the second phase, after discussions with DKI, the consensus was obtained to construct a signboard in the old town area (Kota Tua), where a redevelopment project is underway aimed at turning the area into a tourist site. Since the area is protected by a committee of experts led by the DKI Cultural Affairs Bureau and new building construction is restricted, a design company with a license issued by the DKI was recruited. The design was carried out through discussions with the experts. Since the elevation of the installation site is not so low and Jakarta is almost free from storm surge disasters caused by typhoons, the signboard was designed to show the amount of subsidence from the past in North Jakarta, West Jakarta, and East Jakarta, three areas where land subsidence is significant. The signboard is written in Indonesian, English, and Indonesian Braille that explains the design of the signboard and introduces the current status of land subsidence in Jakarta and the Project. The QR code for the website was also on the signboard to promote a synergistic effect between the signboard and the website for better understanding of the Project. DKI plans to construct similar signboards in various locations in the province in the future.

Figure 20 Signboard

Figure 21 Explanation board

(5) Governance (Output 5)

In the first phase, surveys and discussions were mainly conducted, and short-term action plans were developed for three years until the end of the Project, medium-term action plans for three to ten years, and long-term action plans for ten years and beyond. For the short-term action plans, we selected pilot areas with significant land

subsidence or high-risk areas with clear land use characteristics based on the results of satellite image analysis, and developed specific measures for each area, in addition to actions for the entire target area. However, as mentioned above, the short-term actions had to be changed in the second phase due to social restrictions caused by the Covid-19 pandemic.

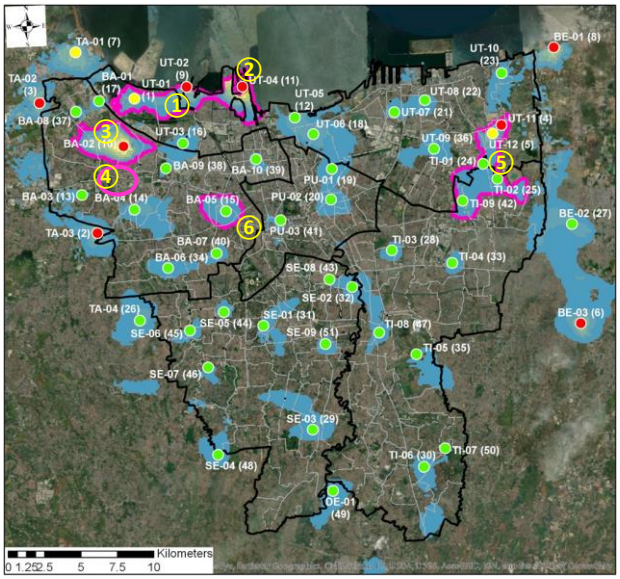


Figure 22 Pilot districts for short-term actions

In addition, there was a major reorganization at PUPR and DKI in 2020, and the jurisdiction related to land subsidence was also changed. Accordingly, personnel changed, and the C/P staff who played a central role in the first phase of the Project left. In response to these, the outline of the Project and its progress to date were carefully explained to the reorganized organization and personnel. By offering future directions, their initiatives were encouraged to participate in the Project again.

In terms of capacity building, the first phase of training was conducted in Japan in October 2018, where seven young to mid-career staff members received a variety of lectures on integrated water resources theory, Tokyo's experience and current efforts by the government and municipalities, and the use of technology by private companies. They also went on site visits where the participants inspected land subsidence traces and observation wells in the Tokyo zero-meter zone, examples of storm surge and flood countermeasures, and rainwater harvesting facilities and sea-level indicator towers that were later implemented as short-term actions. Discussions for action plan were also held based on the knowledge, which became the basis for the current action plan.

In the second phase, five PUPR staff members received training in Japan in February 2020. Since land subsidence is an issue not only in Jakarta but also in regional cities in Indonesia, three staffs from regional river management offices participated in the training at the request of PUPR. As in the first phase of the training, after a wide-range of lectures on subsidence countermeasures in Japan and inspection tours, the participants discussed the current status and challenges of subsidence in each region and how to overcome them. This led to one of the objectives of the PIC, "horizontal development to other cities," as described below.

As a result of exchanges of opinions with the Minister of Public Works and National Housing and the Governor of Jakarta Special Province during the first phase, a Project Implementation Team was formed by both parties, and at the request of the Minister, a technical seminar and site visit were held for 36 persons, mainly team members. In addition, during the second phase of the Project, the Project Implementation Team has conducted academic forums, site visits to the facilities constructed under the Project, and capacity buildings through presentations and discussions at related meetings, bringing the total number of people involved in the Project to more than 2,000.

Figure 23 Training in Japan

In the final stage of this Project, after multiple individual discussions with relevant organizations, JCC5 preliminary meetings, and agreement by relevant agencies at the JCC5 meeting, a Planning and Implementation Committee (PIC) was established to study subsidence countermeasures after completion of the Project and the PIC Action Plan was developed. Initially, the PIC, as the replacement organization of the JCC, was supposed to have the same structure as the JCC, but the C/P pointed out that 67 departments belonged to the 5 WGs and that it was difficult to coordinate with many departments belonging to multiple WGs, so the PIC was divided into WG1: Monitoring and Awareness Raising, WG2: Mitigation and Adaptation Measures, WG3: Administration.

In order to promote stakeholders' understanding, the purpose and role of the PIC's establishment were redefined as follows, referring mainly to the Project's overall goal.

- Implement an action plan for subsidence control in Jakarta
- To apply Jakarta's experience with subsidence countermeasures to other cities where subsidence is also a concern.

The action plans of each WG were subdivided into programs, actions, and activities to clarify responsibilities. Then, budgetary measures, and implementation period were discussed with organizations responsible for each activities. For the implementing organizations for each activity, in addition to the main responsible agency, members who assist the WG, or those who are not WG members but provide support as related agencies, are also selected. In addition, a steering committee was also established to oversee and manage the WG, with representatives from the PUPR, DKI, and Ministry of Mines and Energy as the main agencies involved, as well as the National Development Planning Agency (BAPPENAS) and the Coordinating Ministry of Maritime and Investment (Menko Marves) as coordinating organizations. Table 3 outlines the WG's action plan and Figure 24 shows the overall organizational chart.

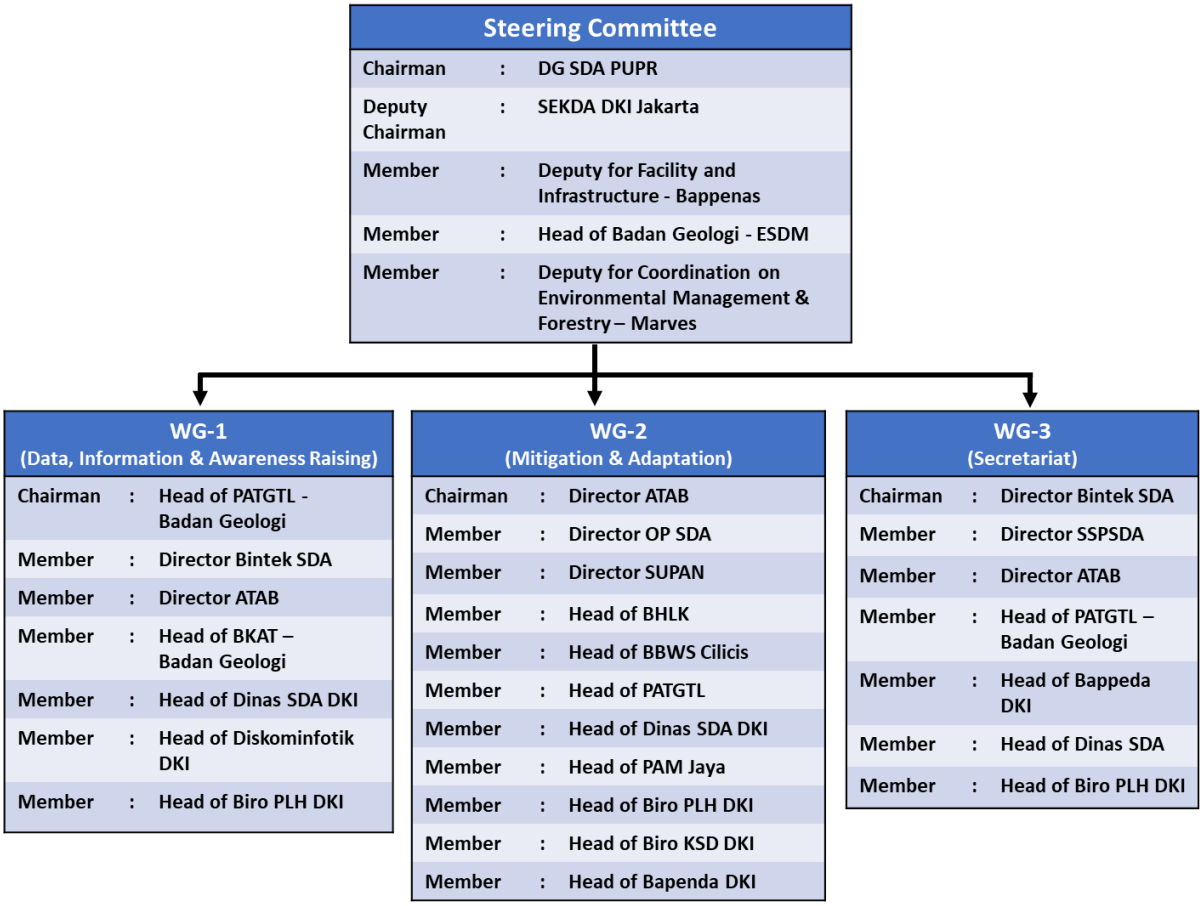


Figure 24 PCI Organization Chart

Table 3 PIC Action Plan

WG	Program	Action	Activity
WG1	Monitoring and Analysis	Continuous Monitoring	①Collecting data from 3 existing monitoring wells ②Regular maintenance of monitoring wells ③Calibration of monitoring system ④Install telemetry system ⑤Improve electrical system ⑥GNSS survey ⑦Conduct InSAR analysis
		Report Monitoring Data	①Prepare simple monthly report ②Prepare annual report
		Integrate Data	①Integrate monitoring data into PASTI ②Prepare database of PUPR ③Prepare & Implement agreement on data sharing
		Data Analysis	①Analyze the relationship between land subsidence and groundwater utilization ②Analysis the land subsidence rate in Jakarta
	Additional Land Subsidence Monitoring Well	Construct More Wells	①Construction of 14 monitoring wells
	Public Awareness	Signboard Instalment	①Install more signboard
		Prepare public friendly campaign materials	①Prepare leaflet & other materials
		Operate Website	①Update monitoring data and other land subsidence related information in website
	program	Action	Activity
WG2	Implementation of Expansion of Groundwater Regulation	Implementation of Pergub Zero Deep Well	①Implementation of Pergub Zero Deep Well
		Expansion of area	①Revise Pergub Zero Deep Well to include all land subsidence risky are in the future
	Alternative Water Resources	Rainwater storage, rational water use	①Continue the maintenance of rain water harvesting (RWH) facility ②Promote the development of RWH ③Promote CSR activities for rain water harvesting systems, such as incentive for factories/building ④Examining measures to promote installation of rainwater harvesting system
		Dam Operation (inc. water resources dev.)	①Dam rationalization operation to increase water supply
		Another alter Water resources	①Study and implementation on another alternative water resources such as utilization of Situ/Lake
	Water Supply Improvement	Kios Air for low income group	①Utilize information of severe area of land subsidence and provide water supply ②Expand the program to other risky area
		Measures against NRW	①Measures against water leakage, Improvement of water tariff collection
		Formulation of RISPAM DKI	①Review of Water Supply MP
		Expansion of WTP and Development of Regional SPAM in DKI	①Jatiluhur Ⅰ, Karian Serpong, Jatiluhur Ⅱ/Djuanda
	Countermeasures against Water related Disasters	Flood Risk Map considering Land Subsidence & Climate Change	①Prepare hazard map of land subsidence ②Prepare flood risk/inundation map
		Flood & High Tide countermeasures	①Design flood countermeasure considering land subsidence's rate
	Program	Action	Activity
WG3	Coordination	Facilitating work plan coordination meeting between working group	①Coordinating the formulation of action plan ②Conduct regular annual meeting
	Budgeting	Programming annual budget for related institution	①Coordinate the preparation of Programs & annual budget
		Monitoring budget allocation of related institution	①Monitoring of budget execution
	Dissemination	Expansion of Disseminating project results to outside Jakarta	①Sharing lesson learned from JICA Project to other future land subsidence monitoring efforts in all Indonesia
		Annual Report	①Prepare annual report of all WG activities for sharing achievement & future targets and distribute to all related stakeholders

4. Lessons and Innovations of Project Implementation

The Project required the participation of many stakeholders in addressing various water-related issues, building consensus on solutions to problems, and drawing a roadmap for the future. In response, under the philosophy of IWRM, the Project organically combined an engineering approach based on Japan's experience and a social science approach tailored to the actual situation in Jakarta, and was able to produce results that led to actual policies and actions by stakeholders.

(1) Engineering Approach

1) Learning from Tokyo's Experiences

The experiences of Tokyo to conquer the land subsidence problem have been discussed in various occasions such as the training in Japan, seminars and working group meetings. The topics and issues discussed were generation of zero-meter zone and induced disasters, verification of relation between over abstraction and land subsidence, mitigation measures taken by the central and local governments and adaptation measures which remains to be taken now. Some Indonesian officers had skeptical views such as whether groundwater abstraction causes land subsidence and whether land subsidence can be stopped etc.

Through sharing knowledges from specific cases of overcoming the same challenges ahead of time, such as by appointing the technical assistance committee members who have actually experienced overcoming challenges as parties concerned or who are in charge of countermeasures, and by observing the actual sites, the C/P recognized the cause of land subsidence and they learned that it can be stopped if optimal countermeasures are taken under proper policies. Discussion on similarities and differences between Tokyo and Jakarta also led to clearer understanding to the C/P resulting to the application of double-tube type land subsidence monitoring well and real time water level sign board. Such approach makes not just learning the lessons and experiences of Tokyo but also knowledge co-creation to meet the situation of Jakarta. This is achieved by the efforts for taking knowledge from Japanese experts and officers through organizing technical advisory committee.

2) Discussion based on Objective Data/Analysis

By generating reliable and accurate data that could be shared by all concerned, such as identification of the extent of subsidence based on satellite image analysis, development of subsidence scenarios based on soil test results, and the relationship between groundwater abstraction and land subsidence based on abstraction data, the Project team were able to proceed with discussions and to reach a concensus while identifying the causes of subsidence and its impact. This enabled to build a consensus among the stakeholders who had different opinions and it also enabled to take coordinated countermeasures against over abstraction of groundwater, which is considered as the primary cause of land subsidence in scientific point of view and the only cause that can be conquered. Besides, by presenting the necessity of comprehensive countermeasures through the future prediction of land subsidence and estimation of social cost, a common future vision among the stakeholders was presented. During the dialogue, conflicts of interests including the regulation of groundwater use were considered and alternative water resources were also discussed.

3) Use of Past Project Experiences

In Jakarta, the "The Institutional Revitalization Project for Flood Management in JABODETABEK" (2007-2010), the "Project for Capacity Development of Jakarta Comprehensive Flood Management" (2010-2013), and the "Jakarta Metropolitan Area Global Warming

Simulation Study" (2012) were conducted in the past with JICA's cooperation. The Project fully utilized the knowledge and data obtained from these activities.

(2) Social Science Approach

1) Communication with C/P Agencies

One of the Project management issues is communication with the various counterpart organizations. To cope with this issue, working group is organized for each output and periodical meetings among various agencies are facilitated to integrate sense of purpose and recognition of issues. Awareness of the counterparts is raised through working group meetings, individual discussions and training in Japan. The training participants and the project implementation team became the main persons in charge of the Project at each C/P agency and led the activities. In April 2019, a social media group was set up to communicate with each other on a daily basis to maintain solidarity in working together on subsidence control among different ministries and organizations and to continuously strengthen capacity. In addition, BAPPENAS, which is in charge of coordinating international cooperation projects and drafting national plans, held regular technical meetings for its staff at the request of its counterpart.

2) Input to High-level Decision Makers

During the implementation of this Project, the Project Team had chances to exchange opinions with the PUPR Minister and the DKI Governor, and were able to directly share with the decision makers the issues, the outline and findings of the Project, and future policies.

This enabled the establishment of the Project Implementation Teams in both PUPR and DKI, as well as increased awareness of the Project throughout the organizations, which in turn helped to further enhance the project activities. In order to deal with a complex issue such as subsidence involving multiple organizations and departments, it is effective to elicit the commitment of the top decision makers in this way.

3) Broad stakeholder involvement

In this Project, disaster risk and social surveys were commissioned to the University of Indonesia and Bandung Institute of Technology. Both universities have extensive experience in conducting the same type of social survey, and were able to conduct the survey with consideration for the sentiments of the survey targets and obtain more information efficiently.

In addition, by exchanging opinions with Indonesian academics who lead public opinion through academic forums and tours of drilling cores, awareness of issues and countermeasures were shared, and support from academics for the administration was also obtained.

In addition, a system was established to obtain the involvement of a wide range of stakeholders through disaster risk surveys and social surveys, workshops at the city and district level, and interviews with fish processing companies at Jakarta fishing ports, thereby communicating with these stakeholders and understanding their awareness of the issues.

4) Implementation of Pilot Projects

The Project implemented pilot projects based on the Action Plan, including construction and monitoring of observation wells, construction of rainwater harvesting facilities, installation of sign boards, and preparation and operation of a website.

This created an opportunity for all parties involved to practices working together toward a shared goal and for all parties involved to experience success through cooperative action.

This created momentum to promote measures based on the formulated plan and strengthened the capacity of the parties to carry out the measures.

5) Dissemination at Relevant Meetings

Land subsidence issue has been noticed in home country and abroad, and it is occasionally reported by foreign

media. Various organizations are holding workshop/seminar for this issue and the Project Team utilizes these opportunities for the dissemination of Project outlines and findings. Besides, the Project Team communicates well with other donors, NGOs and industry groups. Through such activities, confidence from relevant agencies is given to the Project and it has a dramatic effect on Project implementation such as awareness raising of the Project, effective data collection, and active involvement of the C/P and so on.

Table 4 Major Meeting Participation

Date	Participation
2018/7/12	Presentation in the Workshop "Answering the Challenges of Jakarta's Groundwater Problems"
2019/1/27-28	Attending and Guidance of Site Visit for "National Workshop on Integrated Urban Water Management" (WB)
2019/8/22 -27	Participation to "World Water Week" in Stockholm
2019/9/3	Presentation in 3rd World Irrigation Forum
2019/11/18	Presentation in G20 CSWG
2019/11/22-24	Presentation in 3rd International Seminar of Indonesian Association of Hydraulic Engineers

6) Cooperation with On-going Projects

The Project was implemented with information sharing/exchange with other JICA projects such as the "DKI Jakarta Sewerage Development Project", "Jakarta Mass Rapid Transit Project" and "Data Collection Survey on Improvement and Rehabilitation of the Jakarta Fishing Port and Local Fishing Ports in Indonesia". After consulting with a company that planned to develop rainwater harvesting facilities overseas using JICA's SME/SDGs Business Support Program, the Project team assisted in brokering the Project to the relevant C/P organization, and the company's rainwater harvesting facilities are now being constructed on a trial basis in Jakarta. The collaboration was also made with related NCICD organizations (in Netherlands and Korea) to exchange ideas on subsidence prediction and adaptation measures, and to cooperate in presentations at NCICD-sponsored meetings and workshops.

(3) Other: Project management at Covid-19 pandemic

The Covid-19 pandemic in early 2020 was a significant obstacle to the Project's operations. The Project was at the beginning of its second phase when the implementation of the short-term action plan had begun, but there were concerns that Project's activities would stagnate due to restrictions on the travel of Project experts and long-term restrictions on social activities by the C/P organizations, which were the main actors in the Project. However, the following measures and interventions enabled the Project to continue its activities.

- Among the planned short-term action plans, items that could be implemented remotely were focused.
- In response to the cancellation of activities that were planned to be implemented with the government budget, the Project was re-commissioned locally. Since the activities were planned to be implemented under the government budget, the C/P agencies was more actively involved in the implementation, and procedures such as agreement on planning and design, land use, could be carried out promptly.
- A relationship and system of close communication among Project experts, local mercenaries, and C/P personnel, which has been established through the first phase of activities, was utilized.

（Project Period: May 2018 to November 2022）

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