Part 2

STUDY FOR BRANTAS RIVER BASIN

CHAPTER 3 COLLECTION AND COMPILATION OF INFORMATION AND DATA

3.1 Natural Condition of the Project Area

3.1.1 Topography

The Brantas River basin is the second largest river basin in Java Island. It is in East Java Province and lies between 110°30' and 112°55' eastern longitude and between 7°01' and 8°15'southern latitude. The Brantas River stretches to about 320 km in length and has area of about 12,000 km^2. The boundary and major river system within the basin are shown in the location map.

The Brantas River basin is bounded by Mt. Bromo (EL. 2,392m)-Mt. Semeru (EL. 3,676m) in the east, a series of low Kidul ridges (EL. 300-500m) in the south, Mt. Willis (EL. 2,169m) and its families in the west and Kedung ridges and the Madura strait in the north. The Arjuno Mountain Complex consisting of Mt. Arjuno (EL. 3,339m), Mt. Butak (EL. 2,868m) and Mt. Kelud (EL.1,731m) are located in the center of the basin.

3.1.2 Meteorology and Hydrology

(1) Present Meteorology

The present climate in the basin is dominated by tropical monsoon. In a normal year, the rainy season is about six months long from November to April, and the dry season prevails from May to October. The yearly mean temperature in the basin ranges from 24.6 ^{O}C in Malang to 26.8 ^{O}C in Porong.

The average annual rainfall over the basin is around 2,100 mm which is estimated from rainfall data of six PJT-I rainfall gauging stations. Variation of the annual rainfall is large; 2,250 mm in a water rich year and 1,850 mm in a drought year. The average annual rainfall in the high elevation areas is generally high around 3,000 through 4,000 mm especially in southern and western slopes of Mt. Kelud.

The yearly mean relative humidity in the basin ranges from 74 % to 83 % depending on the location.

(2) Future Meteorology under Climate Change Condition

Expected meteorological data under climate change condition from 2046 to 2065 were obtained from the output of Component-1 prepared by the JICA Project Team 1 (Team 1). Based on these data, the JICA Project Team 2 (Team 2) summarizes the expected future meteorological condition.

Under the climate change condition, the future yearly means temperature of the basin will increase to around 2.0 ^{O}C. The yearly mean temperature in the basin is estimated at 26.6 ^{O}C in Malang and 29.4 ^{O}C in Porong. In a normal year, the annual average rainfall over the basin is estimated to around 2,200mm, which is 100mm higher than the current observed average annual rainfall. Around 78% of annual rainfall will occur in the rainy season.

Variation of annual rainfall is estimated from 2,640 mm in a water rich year to 1,940 mm in a drought year.

(3) Present Gauging Stations

1) Meteorological gauging Stations

There are four meteorological gauging stations and they are operated and monitored by the Jasa Tirta I Public Corporation (PJT-I). Temperature, relative humidity, evapotranspiration, atmospheric pressure, sunshine hour and wind velocity at the gauging stations are measured on a daily basis. Table 3.1.1 shows the information of gauging stations.

Table 3.1.1 Meteorological Gauging Stations in the Brantas River Basin

No.	Station Name	Location	Elevation (El.m)	Available Data Period	Remarks
1	Karangkates	S 08° 09' 20" E 112° 27' 09"	285.0	2006 - 2011	Evapotranspiration is not measured.
2	Wlingi	S 08° 08' 36" E 101° 52' 24"	173.8	2005 - 2009, 2012	
3	Wonorejo	-	-	2003-2012	
4	Selorejo	S 07° 53' 00" E 121° 21' 00"	637.0	2003 - 2005, 2007 - 2012	

Source: PJT-I

2) Rainfall Gauging Stations

There are forty eight (48) rainfall gauging stations including interrupted ones surrounding the Brantas River basin and they are managed by PJT-I. Balai Besar Wilayah Sungai (BBWS) Brantas owned and monitored rainfall in thirty-one (31) rainfall gauging stations and five climatology stations. The Irrigation Department of regency level (*Dinas Pengairan Kota/Kabupaten*: DINAS) has 359 rainfall gauging stations in/around the Brantas River basin. Figure 3.1.1 shows the list of rainfall gauging stations and recorded period that are owned by PJT-I. The location map of rainfall gauging stations owned by PJT-I is shown in Figure 3.1.2, and those owned by BBWS Brantas and DINAS are shown in Figure 3.1.3.

3) River Water Level Gauging Stations and Rating Curves between River Water Level and Discharge

There are ten water level gauging stations, and they are managed by PJT-I. Figure 3.1.1 shows the water level gauging stations and recorded period. Figure 3.1.2 shows the location map of water level gauging stations. Rating curves of water level and discharge were established but these rating curves are not updated every year.

Meanwhile, BBWS Brantas owned 21 water level gauging stations in the Brantas River basin. These gauging stations are placed in the tributaries of the Brantas River and no water level gauging station of BBWS Brantas is placed along the main stream of the Brantas River.

(4) Tidal Water Level

The Meteorological and Hydrological Agency (*Badan Meteorologi, Klimatologi dan Geofisika*, "BMKG") maritime meteorological station of Surabaya measures the tidal water level at a port located in Kenjeran in Surabaya City. The tidal water level is measured for maximum, and minimum on a daily basis. The maximum, average and minimum tidal water level measured at Kenjeran from year 2006 to 2013 are shown in Table 3.1.2.

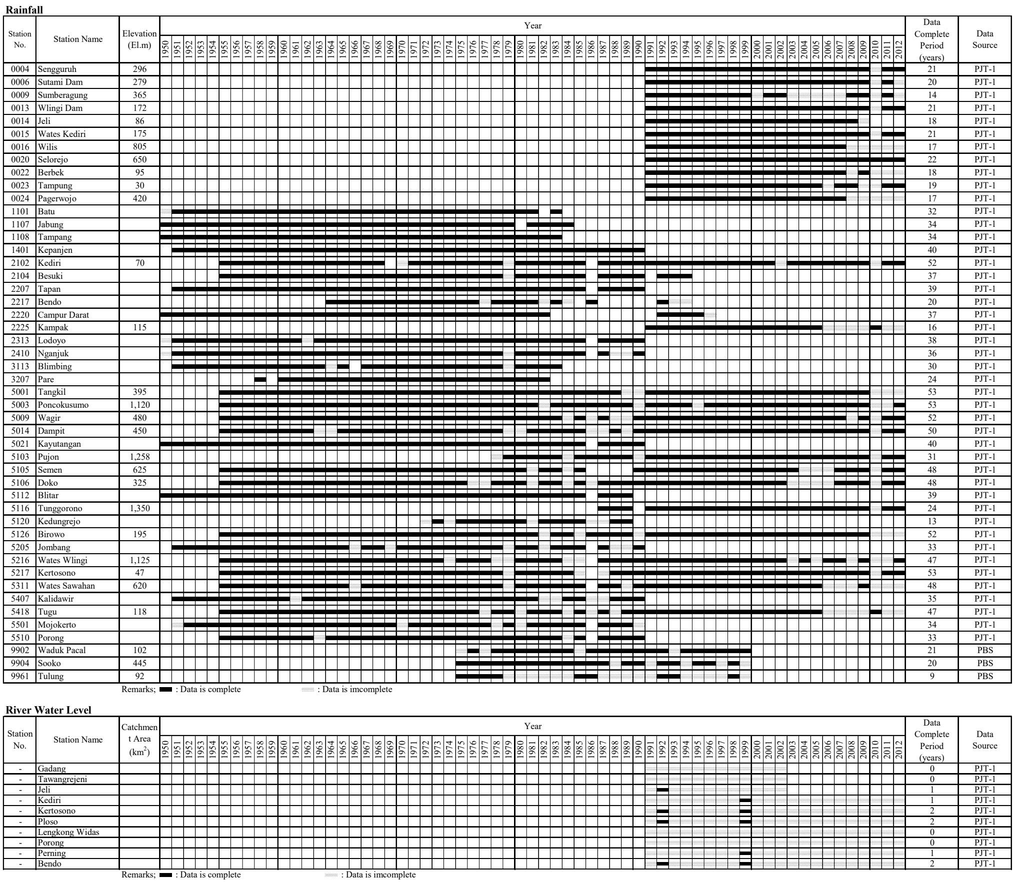
Table 3.1.2 Tidal Level Measured at Kenjeran

(Unit: cm)

	Maximum	Average	Minimum
2006	150.0	-6.4	-170.0
2007	150.0	-6.3	-170.0
2008	160.0	-5.0	-170.0
2009	150.0	-5.7	-170.0
2010	150.0	-5.5	-170.0
2011	160.0	-4.9	-170.0
2012	150.0	-4.5	-170.0
2013	150.0	-4.5	-180.0
Average	152.5	-5.4	-171.3

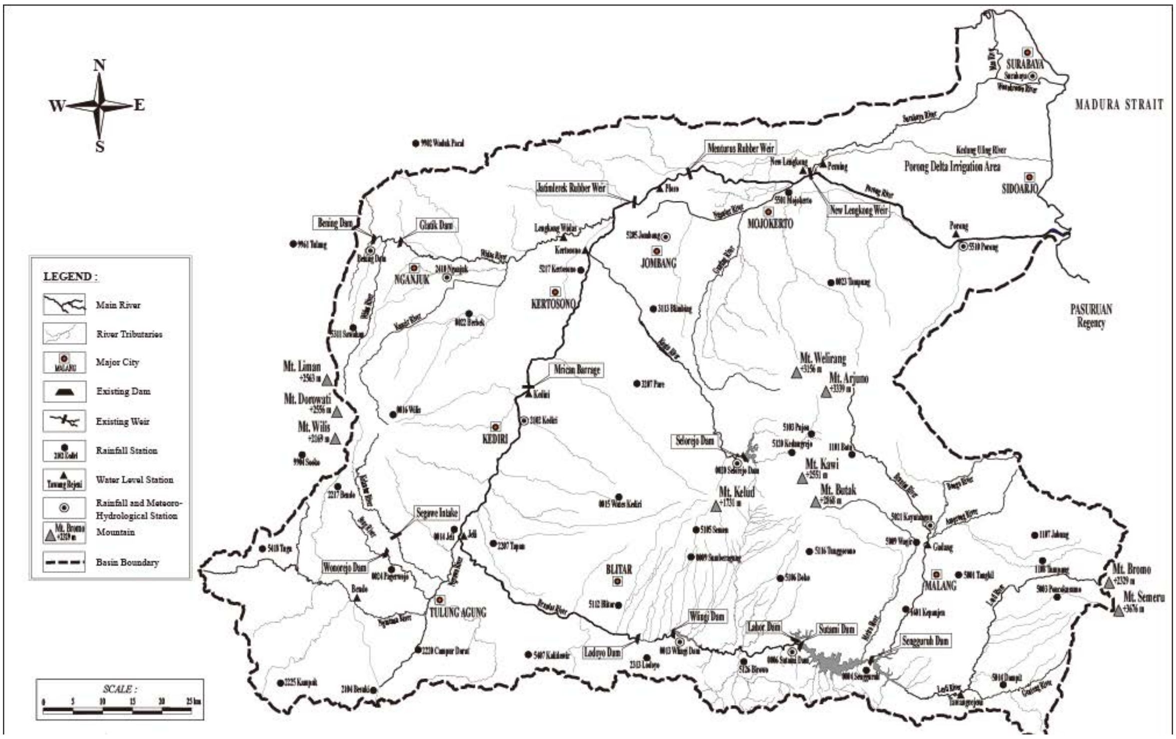
Source: BMKG

According to the data provided by BMKG, the tidal water level varies from -180 cm to 160 cm as shown in Table 3.1.2. The daily fluctuation of sea water level is 320 cm at the maximum and 70 cm at the minimum, while the average of it is 199.8 cm.



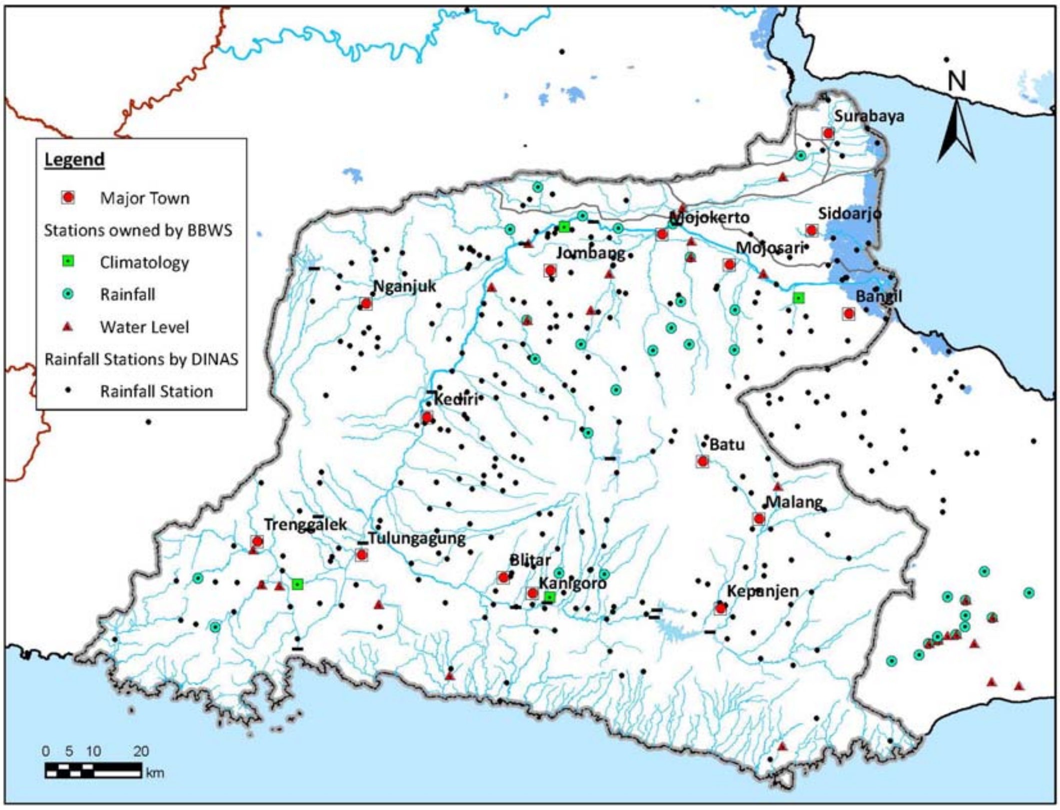
Source: JICA Project Team 2

Figure 3.1.1 Recorded Period of Daily Rainfall and Daily Water Level



Source：JICA Project Team 2

Figure 3.1.2 Location Map of Rainfall Gauging Stations and Water Level Gauging Stations Operated by PJT-I



Source：BBWS Brantas

Figure 3.1.3 Location Map of Rainfall Gauging Stations and Water Level Gauging Stations Operated by DINAS and BBWS Brantas

3.1.3 Geology and Hydrogeology

Documents and data on geology and hydrogeology were collected and analyzed, as basic materials for evaluating the groundwater potential in the Brantas River basin. The outline of the geology and hydrogeology of the Brantas River basin is as follows.

Topography of the Brantas River basin, reflecting a significant geological structural feature which indicates strikes from east to west, are classified into five topographic zone extending strip in the east-west direction as shown in Table 3.1.3. These five zones are appended in the geological map shown in Figure 3.1.4.

Table 3.1.3 Topographical Zone in the Brantas River Basin

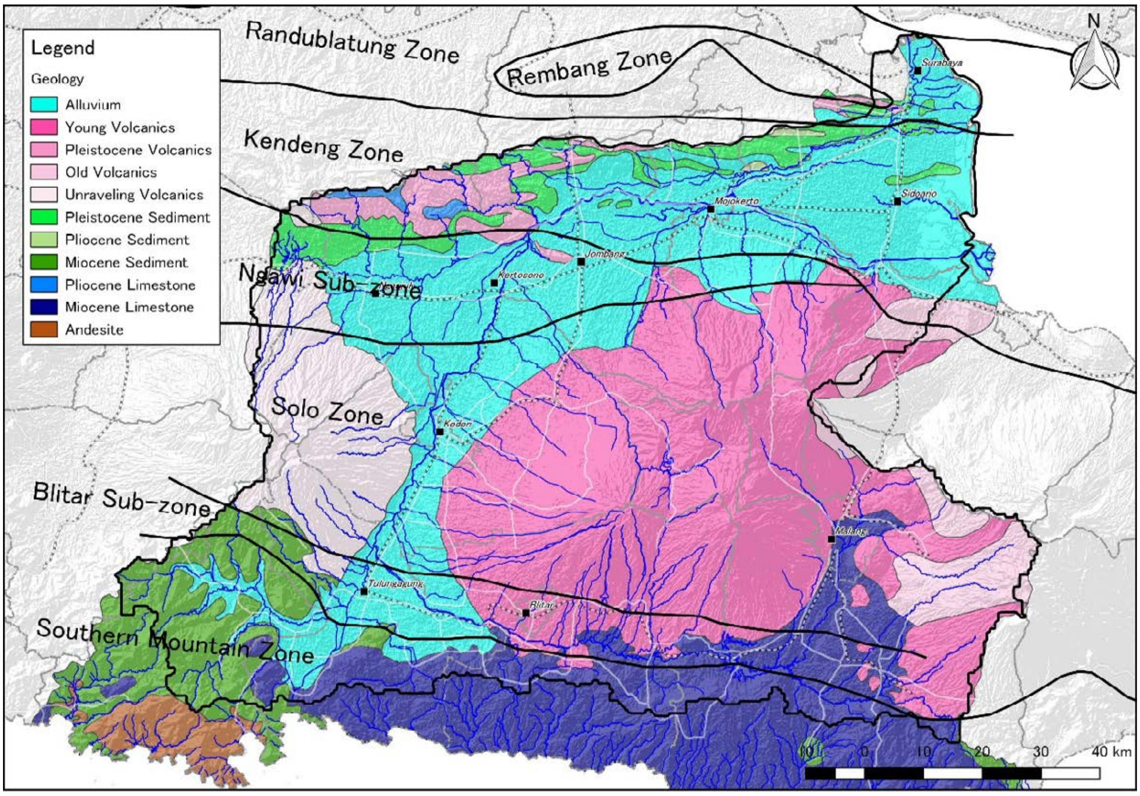
Zone	Distribution Area	Topographical Feature
Remubang Zone	Part of the Randublatung Zone	Hills consisting mainly of limestone and mudstone.
Randublatung Zone	West region of Surabaya	Depression zone composed of alluvial lowland and alluvial soft layer. The depression reaches less than 100m from original surface.
Kedeng Zone	Northern part of the basin	Hills consisting of stratified sedimentary rocks.
Solo Zone	Central portion of the basin	Mountain area consisting of quaternary volcanic chain and piedmont plains between them. There are two sub-zones: Ngawi Sub-zone in the north and Blitar Sub-zone in the south.
Southern Mountain Zone	Most southern part of the basin	Mountainous area where limestone and older volcanic rocks are distributed.

Source: JICA Project Team 2

The oldest formations of the Brantas River basin, composed of Miocene carbonate rocks, limestone, and marl in the upper-Tertiary period, are widely distributed throughout the basin. The upper Pliocene sedimentary rocks cover the oldest strata while the Quaternary layer can be found at the top. Quaternary layer has been developed in the Brantas River basin as one of the productive aquifers. Basically, aquifer system in the area is composed of a two stories structure of shallow and deep aquifers.

Deep aquifers are formed in the intermountain basins, which are extensively underlain by volcanic rocks, pyroclastic rocks and their secondary sediments, and weakly cemented pyroclastic flows associated with their derived deposits and coarse sediments such as conglomerate and sandstone of the Kabuh Formation. These aquifers are widely and unconformably underlain by impervious clayey stones corresponding to the Pucangan Formation. Pleistocene volcanic rocks and sedimentary rocks are mutually interfingered containing several horizons of deep aquifers with high potential.

Moreover, shallow aquifers are developed extensively in the area originated from fluvial washout from the surrounding volcanoes and river deposits.



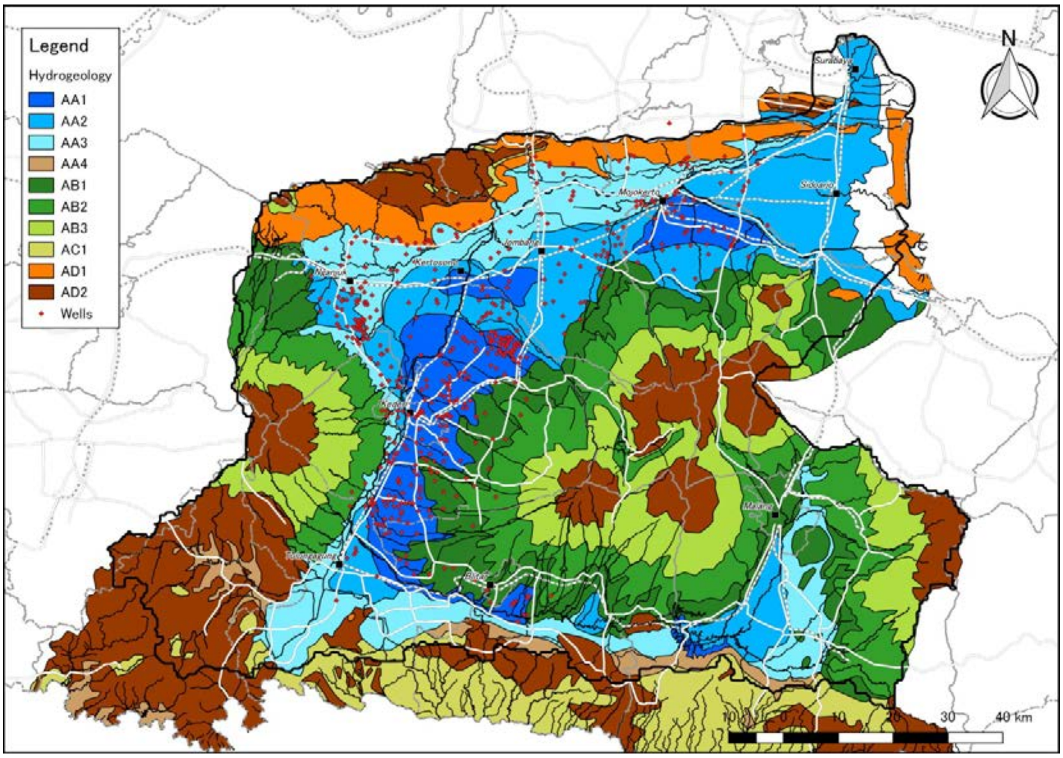
Source: JICA Project Team 2

Figure 3.1.4 Geological Map of the Brantas River Basin

Table 3.1.4 Hydrogeological Classification in the Brantas River Basin

Classification	Aquifer Feature	Description
AA1	Extensive and highly productive aquifers	Moderate to high transmissivity; water table or piezometric head of groundwater near or above land surface; wells yield generally 5 to 10L/s, locally more than 50L/s.
AA2	Extensive and productive aquifers	Aquifer of moderate transmissivity; water table or piezometric head of groundwater near or above land surface; wells yield generally 5 to 10L/s, in some places more than 20L/s.
AA3	Extensive, moderately productive aquifers	Aquifer of low to moderate transmissivity; groundwater table from near land surface to a depth of more than 10m; wells yield generally less than 5L/s.
AA4	Locally, moderately, productive aquifers	Mostly incoherent aquifer of low thickness and transmissivity; wells yield generally less than 5L/s.
AB1	Extensive and highly productive aquifers	Aquifers of largely varying transmissivity; depth to water table varies in wide range; wells yield generally more than 5L/s.
AB2	Extensive, moderately productive aquifers	Aquifers of largely varying transmissivity; depth to groundwater generally great; wells yield generally less than 5L/s.
AB3	Locally productive aquifers	Aquifers of largely varying transmissivity; generally, no groundwater exploitation by drilling to great depth to the groundwater table; locally small springs can be captured.
AC1	Highly to moderate productive aquifers	Groundwater flow is limited to fissures, fracture zones and solution channels; well yields and spring discharges vary in an extremely wide range.
AD1	Poor productive aquifers of local importance	Generally, very low transmissivity; locally, limited shallow groundwater resources can be obtained in valleys and weathered zones of solid rocks
AD2	Region without exploitable groundwater	–

Source: JICA Project Team 2



Source: JICA Project Team 2

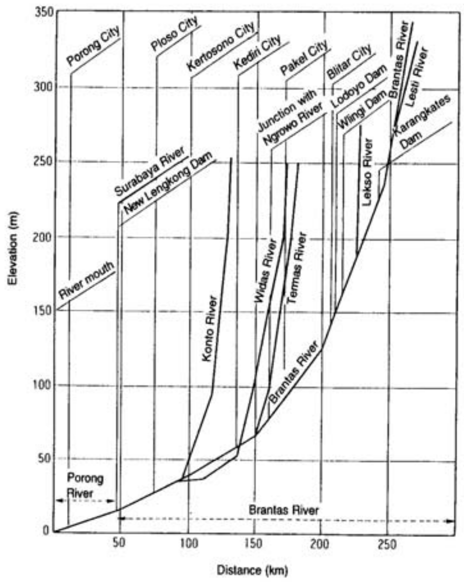
Figure 3.1.5 Hydrogeological Map of the Brantas River Basin

3.1.4 River

The Brantas River originates from the spring of Mt. Arjuno, and it flows down clockwise to Mt. Kelud. The river stretch length at the diverted point of the Surabaya River and Porong River is about 320km. The average riverbed slop was gradually changed from 1 to 200 at the origin to 1 to 2000 at the middle reach. The Porong and Surabaya rivers flow through a very flat plain lower than the elevation of 25 m SHVP.

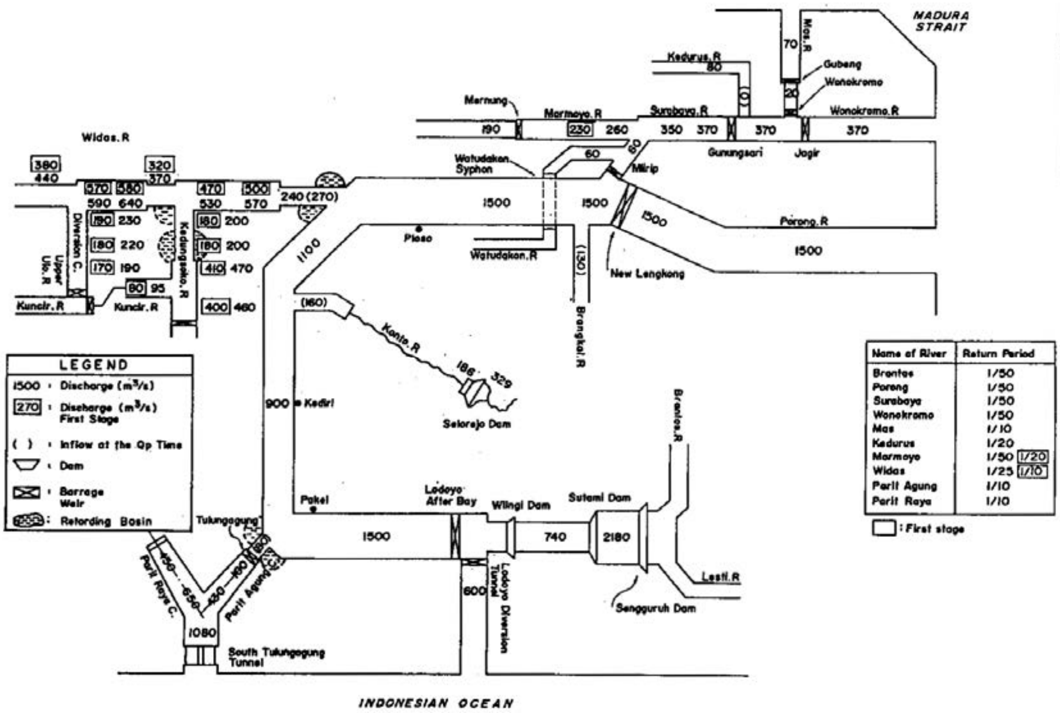
Figure 3.1.6 shows the riverbed profile in the Brantas River basin.

Design discharge of the Brantas River was studied and mainstream was implemented. Figure 3.1.7 shows the design discharge.



Source: "Development of Brantas River Basin"

Figure 3.1.6 River Profile



Source: The Study on Comprehensive Management Plan for the Water Resources of the Brantas River Basin in the Republic of Indonesia Vol.II Main Report, October 1998 JICA

Figure 3.1.7 Design Discharge in the Brantas River

3.1.5 Natural Environment

The following information is summarized through interview survey and collection of secondary information from BBWS Brantas, Center for Watershed Management (*Balai Pengelolaan Daerah Aliran Sungai*: BPDAS), Natural Resources Conservation Agency (*Balai Konservasi Sumer Daya Alam*: BKSDA), National Park Office, Provincial Environmental Office and Non-governmental Organizations (NGOs).

(1) Forest

Recorded forestland is 520,498.7ha (Review POLA 2015 (Draft)), among it, production forest is 354,944ha (68.2%), protection forest is 113,918ha (21.9%), and conservation forest is 51,582ha (9.9%). Nine forest management units (*Kesatuan Pemangkuan Hutan*: KPH) are in charge of the management of the forest land, and Malang and Kediri KPH are the biggest among them which manages approximately 120,000ha each.

(2) Protected area

Bromo Tengger Semeru National Park is overlapping with Brantas watershed. No wildlife reserve (*Suaka Margasatwa*) is located in the watershed, while three nature reserves (*Cagar Alam*) are set in *Besowo Gadungan*, *Manggis Gadungan* and *Gunung Abang*. Five of Important Bird Area (IBA) are located in the watershed.

(3) Ecosystem

The watershed is in East Java Ecoregion, where tropical rainforest vegetation and 103 species of mammal are recorded. As for the endemic species, the followings are important to be protected, such as Javan Warty Pig (*Sus verrucosus*, endangered/EN), Yellow-throated

Marten (*Martes flavigula robinsoni*, least concern/LC), Banteng (*Bos javanicus*, endangered/EN) and Javan Leopard (*Panthera pardus melas*, critically endangered/CR). Cave nectar bat (*Eonycteris spelaea*) is important for the ecosystem for distributing and dispersing pollen and seeds.

In the river systems, following large fish species are recorded, such as *Hemibragus nemurus* (a kind of catfish), *Channa striatus* (a kind of snakehead).

(4) Landscape

Gunung Baung nature tourism park (*Taman Wisata Alam*) and Tretes nature tourism park are designated. Batu area is famous in Indonesia as a tourist destination.

3.1.6 Water Quality

Water quality test is regularly conducted every year. Table 3.1.5 summarizes the monitoring result in 2012 for each monitoring point and Table 3.1.6 summarizes the annual monitoring result from 2010 to 2014. BOD figures exceed the standard value while COD and DO are within the standard (however, they are not so good value). In the upper and medium stream, the water quality is worst in the wet season while in the dry season is the second worst, which is considered to be the effect of impact by water flow in the wet season and impact of enrichment effect in dry season. In the lower stream, the water quality is worse when drier, which is considered to be the effect of enrichment.

In the Surabaya River, mass death of fishes was reported in 2012 due to the pollution from the sugar industry. DO in the downstream of the Brantas River and other branch rivers is low, and it is expected that some spots may have lower figures, which can harm the fishes instantly.

Table 3.1.5 Seasonal Monitoring Result of Water Quality of the Brantas River in 2012

	BOD (mg/l)			COD (mg/l)			DO (mg/l)		
	Upper	Medium	Down	Upper	Medium	Down	Upper	Medium	Down
Wet	3.95	3.50	4.22	10.89	9.01	10.39	7.27	7.31	5.42
Med-Wet	2.98	3.48	4.05	7.28	9.50	9.78	7.65	7.91	5.55
Dry	3.25	3.41	3.91	8.48	8.87	10.11	8.03	8.09	5.49

Note: Wet: November to March, Medium-wet: April to May, and Dry: June to October

Source: Calculation based on the data from BLH East Java Province

Table 3.1.6 Annual Monitoring Result of Water Quality of the Brantas River in 2010-2014

	Unit	2010	2011	2012	2013	2014	Average	Env. Standard
BOD	mg/l	5.12	4.41	4.33	3.60	4.27	4.35	3.00
COD	mg/l	17.94	15.45	13.64	10.92	12.45	14.08	25.00

Source: BLH East Java Province

3.1.7 Land Condition

Expansion of critical land with high potential of soil erosion risk is a serious issue for watershed management throughout Indonesia. Similarly, 435,049 ha or 30.85% of the Brantas River basin area was recognized as critical land according to the Forest and Land Rehabilitation Engineering Plan (RTkRHL DAS) by BP Brantas DAS in 2009. The whole basin is categorized into very critical (4.47%), critical (14.27%), rather critical (12.11%), potential critical (8.21%) and not critical (60.94%).

3.2 Social Condition of the Project Area

3.2.1 Administrative Boundary

The Brantas River basin is in East Java Province where nine regencies and six cities are located. Table 3.2.1 shows the regencies and cities located in the Brantas River basin.

Table 3.2.1 Regencies and Cities Located in the Brantas River Basin

Regency	Sidoarjo, Mojokerto, Malang, Blitar, Kediri, Nganjuk, Jombang, Tulungagung, Trenggalek
City	Surabaya, Mojokerto, Malang, Batu, Kediri, Blitar

Source: Brantas River Basin Water Resources Management Plan (2010)

3.2.2 Population

The population in the Brantas River basin is summarized based on census in 2010. The population in the Brantas River basin was about 16.2 million in 2010 (Census) and about 16.9 million in 2015 (Projection). Annual population growth rate surrounding Surabaya City is higher than the average one in East Java Province.

3.2.3 Land Use

Present land use in the Brantas River basin is shown in Table 3.2.2 with classification and area of each land use category. The land use map indicates that about 65% of land in the Brantas River basin is utilized for agricultural purpose and many farmers are engaging in food crop cultivation works. Land use map is presented in Supporting Report D.

Table 3.2.2 Present Land Use in the Brantas River Basin

Classification	Area (ha)	Percentage (%)
Natural Forest	71,675	6.002
Dry Land Forest	55,650	4.660
Bush/Shrub	675	0.056
Mangrove	50	0.004
Plantation (Estate crop field)	157,995	13.231
Paddy Field	337,925	28.298
Upland Crop Field	273,875	22.935
Fallow Land	6,700	0.561
Mixed Garden	40,030	3.352
Settlement (Residential Area)	225,050	18.846
Fishpond/Pond	22,525	1.886
Lake/Reservoir	1,825	0.153
River	175	0.014
Total	1,194,150	100.000

Source: JICA Project Team 1

3.2.4 Industrial Structure

The historical trend of the gross regional domestic product (GRDP) in East Java Province reached at IDR 1,482 trillion as of 2017 under constant price of 2010. Compared with the value in 2013, GRDP increased at 24% in real term. The average annual growth rate has been 5.6% from 2013 to 2017.

According to the statistical data on the industrial sectors, the “manufacturing” sector produces 29% of the whole GRDP in East Java Province while “Trade, Repair of Motor Vehicle”, “Agriculture, Livestock, Forestry and Fishery” and “Construction” sectors follow.

3.2.5 Socio-economic Condition

Overall living conditions in East Java Province have been improved in the latest 5 years.

The monthly average salary in East Java Province was IDR 1,786,000 in 2016 which was approximately 18% lower than the average of the whole Indonesia. Whereas, the unemployment rate was at 4.14% in 2016, which was 1.36% lower than the national average.

The education level, such as literacy rate and school enrolment rate, has been gradually improved. The coverage ratio of clean water supply also increased to achieve more than 70% in 2015, which imply the improvement of basic infrastructures in rural and urban area.

3.2.6 Social Environment

The Human Development Index (HDI) has been improved, whereas the rate of poor people still remains at 12.3% in 2015 and the trend of Gini ratio shows the inequity of people gradually widened in the same period.

In East Java Province, 22 national cultural heritages are registered which date back to between 8th and 20th century. Most of the cultural heritages are located in Surabaya, Malang and Mojokerto.

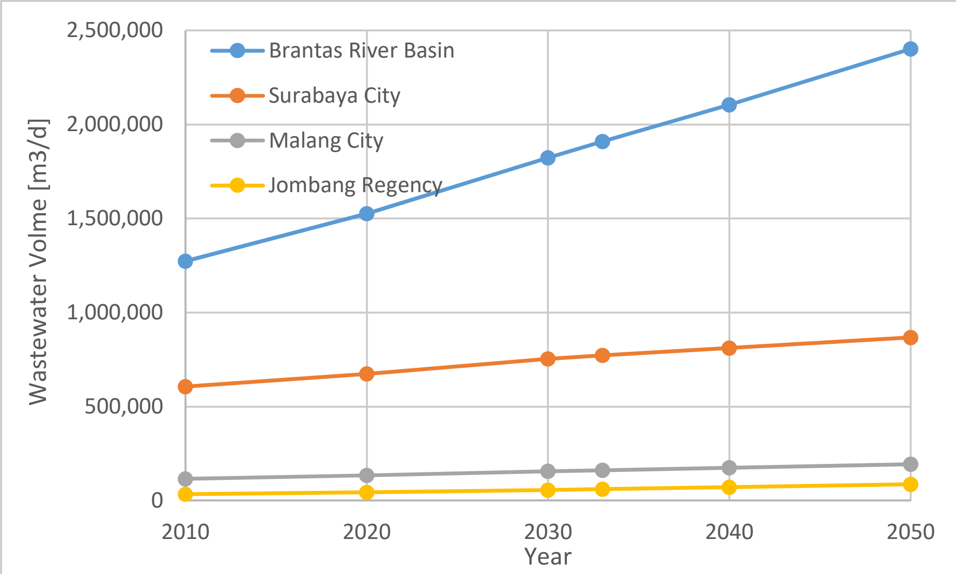
3.2.7 Wastewater

(1) Existing Wastewater Facilities

Sewerage systems in the Brantas River basin are not so fully provided yet. Wastewater from residents is once collected by septic tank and overflowed wastewater is discharged into the drainage channel nearby each house. The collected wastewater by septic tank is usually only for black water, while gray water is discharged directly into the channel. On the other hand, wastewater from the industries is currently the responsibility of each industry operator.

(2) Estimation of Future Sewerage Volume

Team 2 estimated the preliminary wastewater volume based on the water supply demand forecast until 2050 as shown in Figure 3.2.1. It was assumed that wastewater will be treated only for the water in urban area, and also wastewater from industrial area was not counted since the operator of industries has to treat the wastewater before discharging into the drain nearby. Estimated wastewater volume is derived from 80% of water supply demand for domestic and non-domestic water in urban area. Water supply volume will be increased, accordingly wastewater volume will also be increased. Therefore, development for wastewater treatment plant and sewerage system shall be implemented in a phased manner especially for the urban area of dense city which pollution load might be higher than the other area.



Source: JICA Project Team 2

Figure 3.2.1 Estimated Wastewater Volume until 2050

3.3 Current State of Water Sector

3.3.1 Regional Development Plan Related to Water Resources

East Java Province prepared a long-term development plan (2005-2025), middle term plans and a spatial plan (2011-2031). The long-term plan, middle term plan and spatial plan are explained below.

(1) Long-term Development Plan (2005-2025)

Regional Development Planning Agency (*Badan Perencannan Pembangunan Daerah*: BAPPEDA) of East Java has prepared long-term development plan (*Rencana Pembangunan Jangka Panjang*: RPJP). The vision of this plan is "Central Business Opportunities Leading, Global Competitiveness and Sustainable towards Java East Affluence and Morals". There are three major strategies that are 1) sustainability of economic growth, 2) basic people's rights, and 3) equity of infrastructure development.

(2) Medium-term Development Plan (2014-2019)

The general strategy to realize the vision of "East Java More Prosperous, Fair, Independent and Competitive" is through the five missions, as follows:

1) Sustainable development is centered on people (people-centered development) inclusive, and promoting people's participation (participatory-based development),

2) Economic growth is pro-poor (pro-poor growth), in which implicitly includes the pro-poor, pro-jobs, pro-growth and pro-environment, and

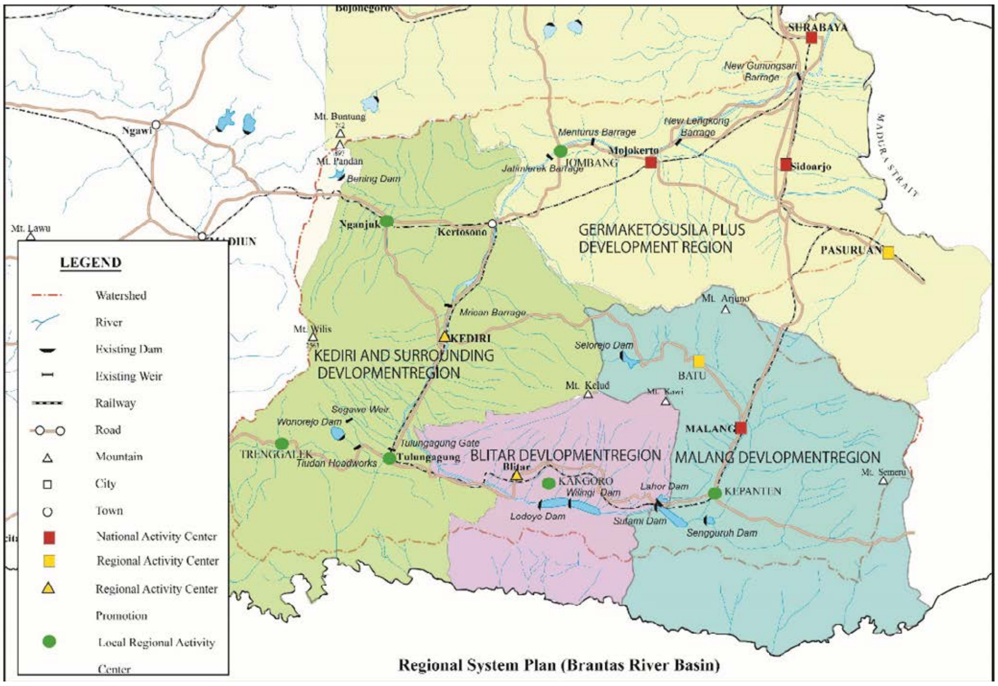
3) Gender is mainstreaming (pro-gender).

(3) Spatial Plan (2011-2031)

BAPPEDA of East Java Province prepared the spatial plan based on the national plan. The purpose of the East Java provincial spatial planning was determined based on the vision and mission of East Java RPJP 2005-2025. Spatial vision of East Java Province expects that agriculture sector becomes one of the main development drivers in East Java Province which is packaged in the form of agribusiness. Agribusiness is the business systems and the activities of agricultural development in the Agro-politan region, especially food production centers and other surrounding areas.

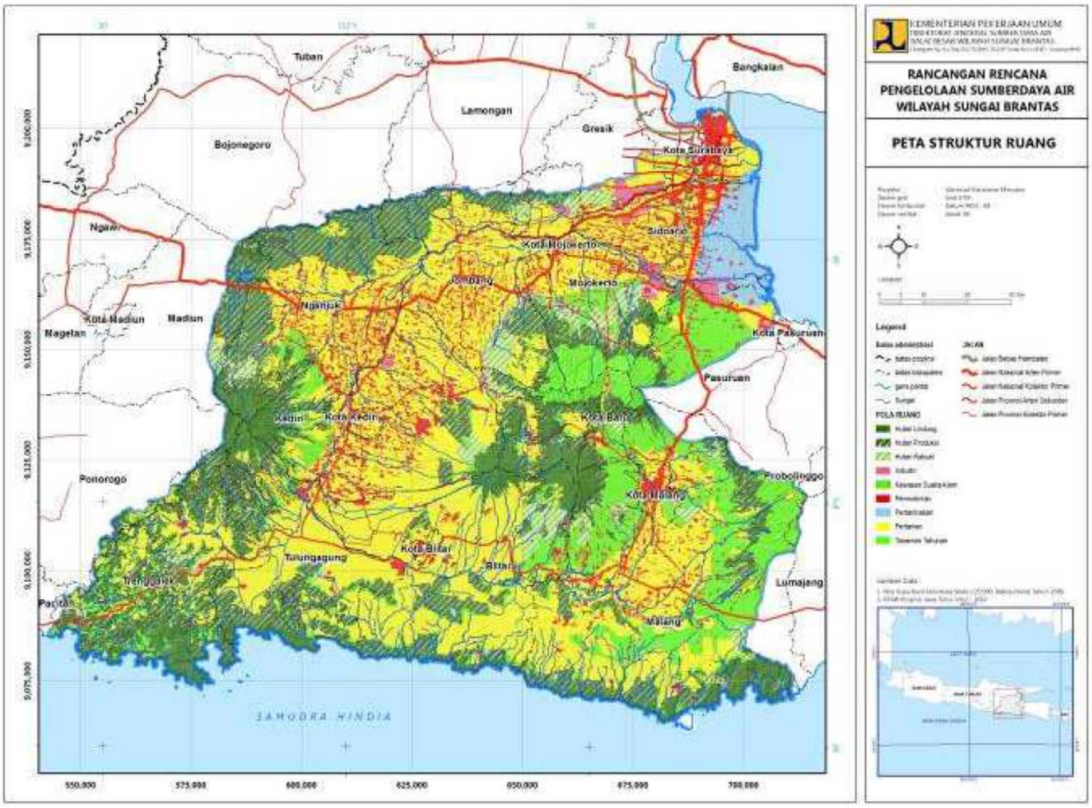
There are four development zones in the Brantas River basin as shown in Figure 3.3.1.

In Review POLA 2015 (Draft), BBWS Brantas prepared a distribution map based on the east Java RTRW depicting protection and utilization zones in the Brantas River basin as illustrated in Figure 3.3.2. According to this zoning map, 23.5% of the total area of 14 Regencies and Cities where the Brantas River basin is distributed is demarcated as the protection zone consisting of protection forest and nature reserved areas, while the remaining area of 76.5% as the utilization zone for residential, industrial and agricultural purposes as well as miscellaneous zone.



Source: Rencana Tata Ruang Wilayah Provinsi Jawa Timur 2011-2031

Figure 3.3.1 Zoning of Development Region in the Brantas River Basin



Source: BBWS Brantas

Figure 3.3.2 Protection and Utilization Zones in the Brantas River Basin

3.3.2 Water Resources Management Strategic Plan (POLA)

The POLA in the Brantas River basin was prepared and approved in 2010. On the other hand, the draft RENCANA is under preparing in 2016 by a local consultant. At present, BBWS Brantas carries out to prepare a review POLA because the requirement of the review and evaluation of POLA is explained in the government regulation (Article 6, No.10/PRT/M/2015).

Thirteen dams were proposed in the strong economic development case of the POLA.

The analysis results, strategies, and operational policies regarding the water resources management in the POLA are shown in Table 3.3.1.

Table 3.3.1 Outline of POLA

Aspects	Analysis Results	Strategy	Operational Policy
Watershed conservation	● Decreasing forest area ● Inappropriate land management ● Changes in land covered area ● Large amount of garbage from Malang Regency and Malang City in the river and the reservoirs	● Rehabilitation of the forestry and critical lands ● Improvement of people's understanding for river environmental management and conservation ● Construction of sediment control structures and infiltration wells to the upstream area ● Prohibition of kinds of farming activities and implementation of new regulation which encourage water conservation attempts ● Intensive and continuous implementation of Prokasih (*Program Kali Bersih*: Clean River	● Revegetation in the beginning of the rainy season ● Legal sanctions to conservation violation ● Involvement of the community in conservation attempts, and coordination among water resources management institutions ● Incorporation of community ● Advise to communities and industrial companies regarding the importance of conservation ● Selective approval for building permission and construction of public service facilities

Aspects	Analysis Results	Strategy	Operational Policy
		Campaign), and creation of the mechanism of incentives for water resources management ● Law enforcement on waste disposers, and water quality control through economic instrument by applying polluter's pay principle	● Presentation to society the importance of environmental preservation through several mass media ● Regular water quality monitoring by community, development of disposal license system, improvement of management capacity for existing industrial waste management, and development of liquid waste management ● Fry dissemination on reservoirs and river ● Strengthening the penalty on illegal waste disposal, restriction on garbage disposal, and recycle/ removal of garbage
Water Resources Utilization	● Conflict of interests in water usage ● Deficit in the fulfilment of needs for water (farming, municipal, industry) ● Illegal water extraction ● Inadequate control for groundwater extraction ● Decreased reservoir storage volume	● Preparation of integrated and effective water allocation calculation method ● Development, utilization, rehabilitation and maintenance of water supply facilities ● Law enforcement in order to control of water allocation of intake, water right and water allocation. ● Review of dredging of sedimentation and reservoir operation rule in the reservoirs, and development of irrigation system and agricultural technology	● Monitoring and evaluation of intake, Effective water use, and penalty on illegal water extraction ● Development of law and regulation regarding operation of groundwater ● Warning and penalty on illegal water extraction ● Improvement, rehabilitation and upgrading of existing irrigation network system ● Review of O&M of reservoirs ● Adoption of SRI
Water's Destructive Power Control	● Large discharge fluctuation during the dry and rainy season ● Lack of river restorative activities ● Illegal sand mining ● Riverbed aggradation at upstream area and riverbed degradation at downstream area	● Comprehensive flood control planning and establishment/ execution of community-based early warning system ● Law enforcement of operation and maintenance for river, and continuous river improvement and maintenance ● Control of riverbed degradation from technical and social points of view ● Law enforcement and control of sand mining	● Implementation of comprehensive flood control in main stream and tributaries ● Rehabilitation, normalization, and management of sustainable structures and rivers ● Improvement of existing early warning system and installation of equipment. ● others
Water Resources Information System	● Lack of information in each water resources management institution ● Inability to access existing information	● Development of inter-agency management system ● Development of water resources management system	● Provision of data to all stakeholders through comprehensive water resources information system ● Establishment of database and utility system ● Provision of reliable data/information
Community Participation	● Participation of restrictive communities	● Establishment of coordination institution from operational point of view	● Establishment of water resources council of provincial, Regency and District level ● Improvement of community support on the river basin management, and supply of funds for planning, construction, supervision and O&M

Source: POLA, Brantas 2010

3.3.3 Review POLA 2015 (Draft)

BBWS Brantas performed the approval procedure in 2016. Several data in POLA 2010 were updated in Review POLA 2015(Draft). The Review POLA 2015(Draft) is reviewed by Team 2 and the following issues are required to re-estimate additional works. Review results are explained in Table 3.3.2.

Table 3.3.2 Review Results of Review POLA 2015 (Draft)

Items	Review POLA 2015 (Draft)	Assessment Results to Reflect Risk Evaluation under Future Climate Condition
Rainfall Data and Discharge Data	Rainfall and water level data in PJT-1 were collected at 11 stations and 6 stations from 2011 to 2015.	These data shall be updated. BBWS Brantas have these data observed by themselves and Dinas PU. Both data shall be collected and referred to re-evaluation of climate change impact.
Water Quality Data	Water quality data were collected from 2011 to 2015.	These data shall be updated. And data by BLH also shall be checked.
Planned Dam Reservoir	There are 23 planned dam reservoirs in the list of Review POLA 2015 (Draft). Out of 23dams, 10 dams are newly added from POLA.	These data shall be referred to the Project. Data and information of 10 newly added dams shall be collected.
Reservoir Sedimentation Data	PJT-I has the latest sedimentation data.	These data shall be collected. Future sedimentation projection is estimated to use latest sedimentation data.
Long Storage Structure	There are three long storage structures newly proposed in the water resource development plan in Review POLA 2015 (Draft).	The storage volume and future plan shall be considered in the water balance study. Data and information shall be collected.
List of Pond	Storage volume of ponds are listed. And the pond construction schedule is mentioned.	The storage volume and future plan shall be considered in the water balance study.
Groundwater Potential	Present groundwater potential is mentioned and estimated from Presidential Decree No. 26, 2011. However, the estimation method, the definition of groundwater potential is not mentioned.	Estimation method and definition of groundwater potential shall be confirmed.
Domestic Water Demand Estimation Method	The domestic water demand in Review POLA 2015 (Draft) is estimated from the Indonesia National Standard (SNI (*Standar Nasional Indonesia*; "SNI"). The per capita in urban area and rural area is applied to 120 l/capita/day and 60 l/capita/day. The domestic water demand is decided from the per capita and population.	Domestic water demand is generally estimated from population, per capita, connection ratio, unaccounted for water and so on. It is better that the related items of water demand are considered as much as possible. And the adaptation and mitigation measures of climate change impacts are considered to each parameter. SNI method is not suitable to study climate change impact because it is very simple method. Domestic water demand estimation method shall be applied above method.
Population Projection	The population projection is carried out based on the recent population growth rate.	BPS has studied long term population projection of each province until 2035. According to long term population

Items	Review POLA 2015 (Draft)	Assessment Results to Reflect Risk Evaluation under Future Climate Condition
		projection, the population of East Java Province is gradually decreased after 2033. However, the present population growth rate at the surrounding Surabaya City is high. If present growth rate is applied to the future population projection, population in Surabaya metropolitan area will become overestimate. The future population is estimated considering long term population and urban ratio of each regency/municipality.
Irrigation Area	The irrigation area is referred from "Profile of Brantas" published in 2014.	Ministerial Ordinance No.14/PRT/M/2015 promulgated in 2015 mentions irrigation area. Irrigation area in the Brantas River basin shall be set from this ordinance.
Irrigation Water Demand	The irrigation water demand is estimated by SNI method. The unit water requirement is applied same value (1 litter/s/ha, Paddy) through a year.	If SNI method applies climate change impact study, it is difficult to evaluate climate change impact because the unit water requirement is affected from the meteorological conditions. SNI method is difficult to consider the meteorological conditions. The unit water requirement is estimated by using KP-1 method (This calculation method is explained in the guideline by irrigation department in DGWR).
Development Concept of Irrigation Area	**POLA:** New irrigation schemes are developed with new dam constructions. **Review POLA 2015 (Draft):** New irrigation schemes are not considered. Cropping area are increased with new dam constructions.	The concept of Review POLA 2015 (Draft) shall be applied because BBWS Brantas requested to follow the concept of Review POLA 2015 (Draft). Cropping areas for the dry season of the existing irrigation schemes are increased with new dam constructions.
Water Balance Model	The water balance model in Review POLA 2015 (Draft) is referred from the PJT-I model. The discharge data of water balance calculation is used from the recorded data.	The discharge data to use the water balance calculation is not natural flow. The water balance model and discharge shall be applied Team 2's model because the water balance model in Review POLA 2015 (Draft) is only considered supply areas covered by PJT-I
Groundwater Development	Groundwater development was not considered in POLA. However, it is planned to develop groundwater, 21m^3/s, until 2030 in Review POLA 2015 (Draft).	Locations, number of wells for groundwater development are not specified in Review POLA 2015 (Draft). It is necessary to study the required development volume.

Note: After study of drought risk under future climate, BBWS Brantas requested to use data in Review POLA 2015 (Draft). Therefore, Team 2 carried out to review POLA 2015 (Draft) due to reevaluation of drought risk. After review of Review POLA 2015 (Draft), Team 2 discussed with JICA head office to carry out re-study of drought risk based on Review POLA 2015 (Draft). Finally, JICA accepted to carry out re-study of drought risk. Therefore, drought risk is evaluated based on Review POLA 2015 (Draft).

Source: JICA Project Team 2

3.3.4 Related Organization and Institution of Water Resources Management

There are several organizations and institutions of water resources management in the Brantas River basin.

(1) Brantas River Basin Organization (*Balai Besar Wilayah Sungai Brantas*: BBWS Brantas)

BBWS Brantas was established in accordance with Ministerial Regulation No.13/PRT/M/2006 and is under and is responsible to the Director General of Water Resources, Ministry of Public Works and Housing. BBWS Brantas is responsible for executing water resources management of Brantas River basin consisting of four watersheds, namely Brantas, Kali Tengah, Ringin Bandulan and Kondang Merak watersheds.

BBWS Brantas is a main actor of planning and construction of the structure for the water resources management in the Brantas River basin. Figure 3.3.2 shows the organization chart of BBWS Brantas in 2015.

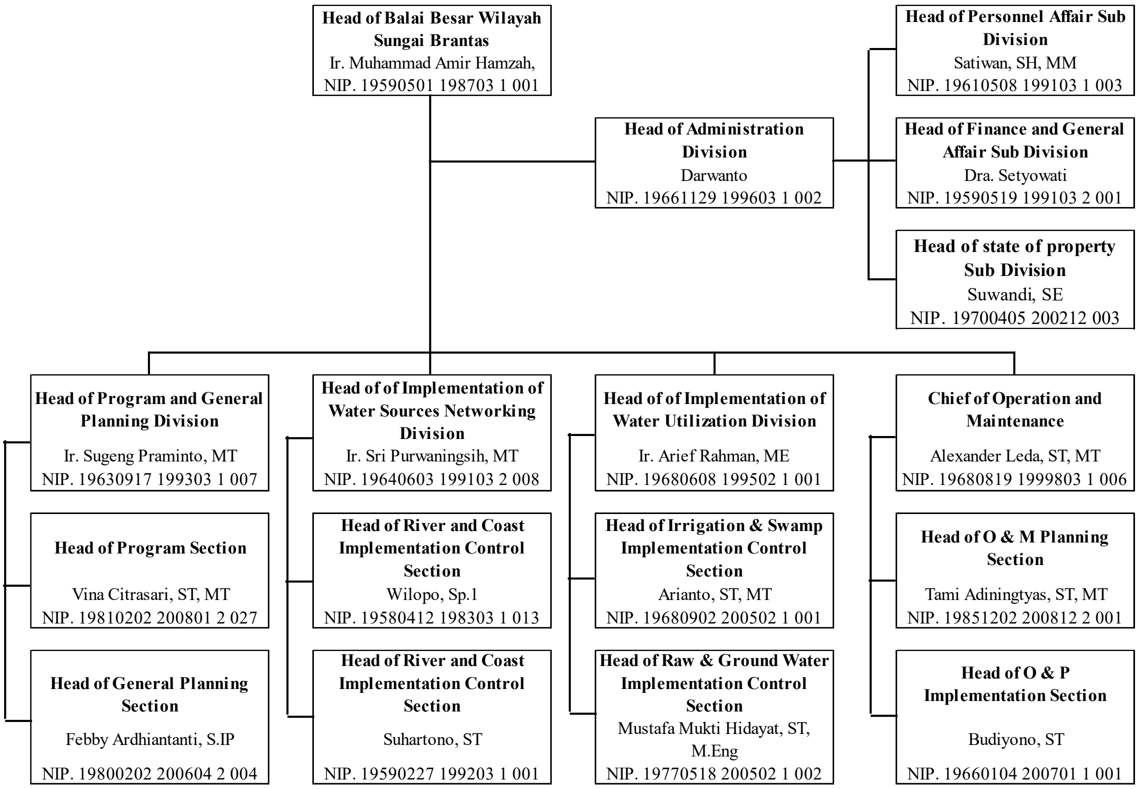
(2) Jasa Tirta I Public Corporation (*Perum Jasa Tirta I*: PJT-I)

PJT-I is a state-owned enterprise, established in 1990. The roles of PJT-I are to perform bulk water services to the various users in its working area; to render operation and maintenance of the related infrastructures to guarantee the water services; and to provide technical advice and assistance to the basin's regulatory body. The working area of PJT-I covers five river basins in Java and Sumatra islands including the Brantas River basin.

PJT-I is a main actor for operation and maintenance of the existing dams and barrages for the water resources management in the Brantas River basin. Figure 3.3.3 shows the organization chart of PJT-I in 2016.

(3) Water Resources Management Coordinating Team (*Tim Koordinasi Pengelolaan Sumber Daya Air*: TKPSDA):

TKPSDA was established in 2009 as a coordinating body for water resources management in the Brantas River basin. A total of 50 members for the period 2019-2024. The tasks of TKPSDA include formulation of POLA and RENCANA for water resources management.



Source：Profile BBWS Brantas

Figure 3.3.3 Organization Chart of BBWS Brantas (2015)

(4) Other Organization and Institution

1) Regional Development Planning Agency of East Java Province (*Badan Perencanaan Pembangunan Daerah Jawa Timur*: BAPPEDA JATIM)

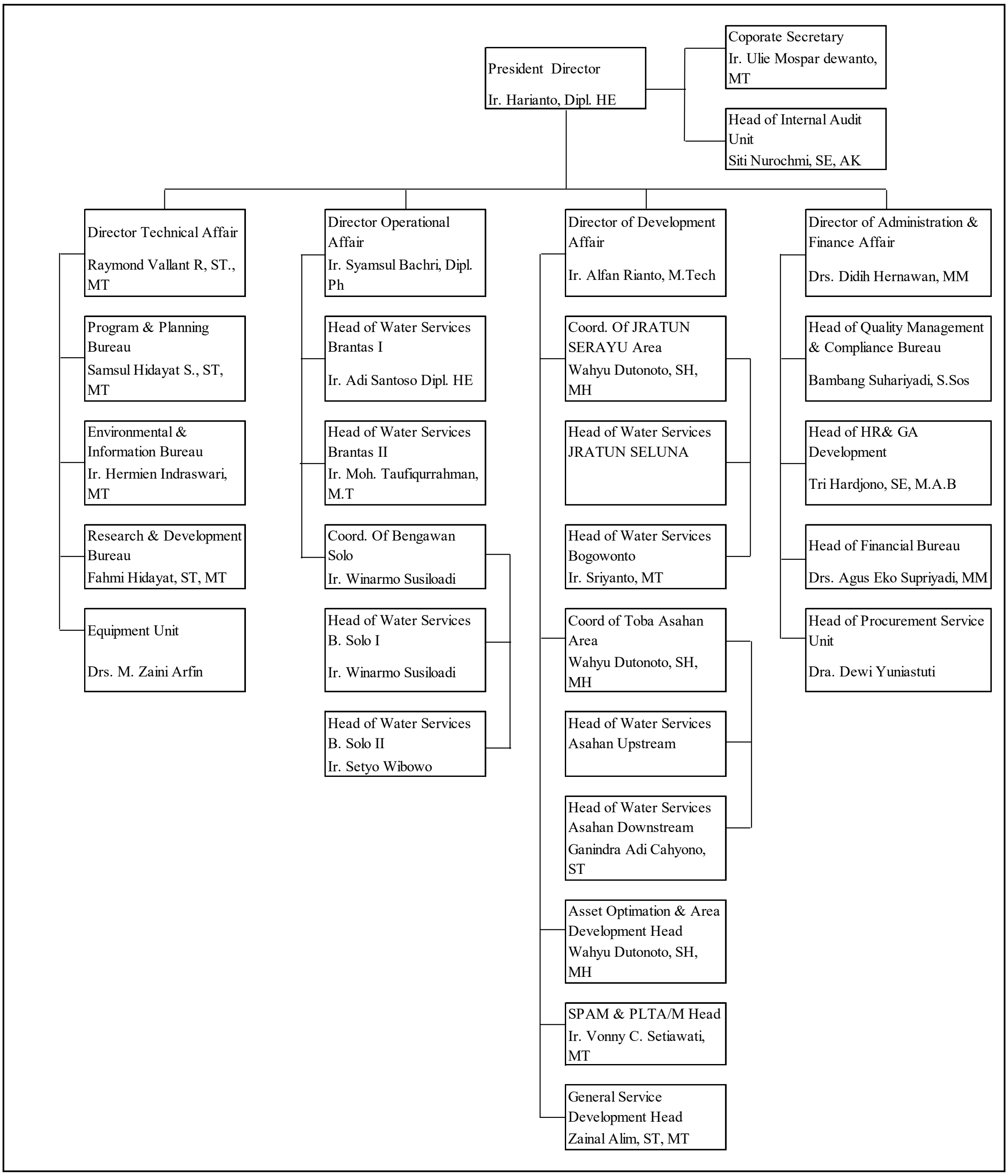
BAPPEDA is a regional technical institution in the field of regional development research and planning, which is under and is responsible to the Governor through the Regional Secretary.

2) Regional Disaster Management Agency of East Java Province (*Badan Penanggulangan Bencana Daerah*: BPBD)

BPBD is a non-departmental government agency that carries out disaster management tasks in the provincial areas based on policies determined by the National Disaster Management Agency (*Badan Nasional Penanggulangan Bencan*a: BNPB).

3) Department of Public Housing, Residential Area and Human Settlement (*Dinas Perumahan Rakyat, Kawasan Permukiman dan Cipta Karya*: DPRKPCK) of East Java Province

DPRKPCK is an implementing unit of the provincial government in the field of public works and spatial planning. The major functions of DPRKPCK are formulation of technical policies, implementation of works of human settlement public services and spatial planning, guidance and implementation of tasks in accordance with the scope of their duties, and other tasks given by the governor.



Source：Annual Report PJT-I and interview from PJT-I

Figure 3.3.4 Organization Chart in PJT-I (2016)

4) Department of Environmental (*Dinas Lingkungan Hidup*: DLH) of East Java Province

DLH is an implementing unit of the provincial government in the field of environment. The major functions of DLH are formulation of technical policies, providing support for the implementation of regional government, guidance and implementation of tasks in accordance with the scope of their duties, and other tasks given by the governor.

5) Department of Forestry (*Dinas Kehutanan:* Dishut) of East Java Province

Dishut is the implementing unit of the provincial government in the field of forestry. The major functions of Dishut are forest management, conservation of living natural resources and their ecosystems, education and training, extension and community empowerment in the field of forestry, and watershed management.

6) Various departments of the respective city/regency in the Brantas River basin

Within the Brantas River basin, there are six cities and nine regencies. Each city/regency has similar departments to that of the Government of East Java Province as stated above.

7) Regional Water Utility Company (*Perusahaan Daerah Air Minum*: PDAM):

PDAM is a regional-owned business unit, which is engaged in the distribution of clean water to the general public. Each city/regency within the Brantas River basin has a respective PDAM.

3.3.5 Present Water Allocation

(1) Domestic and Industry Water

The current situations are summarized into the following three groups:

1) Water supply from each PDAM

PDAMs (like water supply companies) have been supplying to several fields which are classified into (a) domestic water, (b) non-domestic water, and (c) industrial water in an urban area. Its water source consists of (A) surface water and (B) groundwater. Each classification of water usage in urban area is summarized below:

- Domestic water: Water consumption in bath, kitchen, and restroom in residential areas,
- Non-domestic water: Commercial water consumption in shopping malls and public areas such as schools and government offices, among others, and
- Industrial area: Water consumption of industrial clusters, private factories, etc.

2) Domestic and non-domestic water in non-PDAM area

In the area with no PDAM provision (hereinafter, non-PDAM), (a) domestic and (b) non-domestic water relies on underground water mainly.

3) Industrial Water in non-PDAM area

In the non-PDAM area, the water source of industrial water is both (a) surface water and b) groundwater.

The water demands are about 30m^3/s for surface water and about 20m^3/s for groundwater.

(2) Irrigation Water

The irrigation water demand of the existing irrigation schemes commanding 304,620 ha in total in the Brantas River basin for 2007 was roughly estimated at 114.47 m^3/s in the Brantas River Basin Water Resources Management Plan (2010).

(3) Hydropower

According to the PLN's electricity supply business plan from 2015 to 2024 ("RUPTL 2015-2024"), the present installed capacity of East Java Province is 9127.7 MW, of which 8521.1 MW is the generating capacity ready for use.

CHAPTER 4 FIELD SURVEY AND OBSERVATION

4.1 River Cross Section Survey

The river cross section survey and river longitudinal survey were executed by Jasa Tirta I Public Corporation (PJT-1) who was the selected local contractor through the tender process following the Japan International Cooperation Agency's (JICA) guideline. The survey works were carried out from the end of July 2013 to the middle of November 2013.

The number of river cross sections to be surveyed is summarized in Table 4.1.1 and the longitudinal profile is shown in Table 4.1.2.

Table 4.1.1 Number of River Cross Section to Each River

No.	Name of River	Nos. of Cross Section	Remarks
1	Porong River	27	From river mouth (KP235) and just downstream of the New Lengkong Dam (KP1), 1km interval
2	Sadar River	7	Tributary of the Porong River
3	Tributaries	12	Connected to the Sadar River

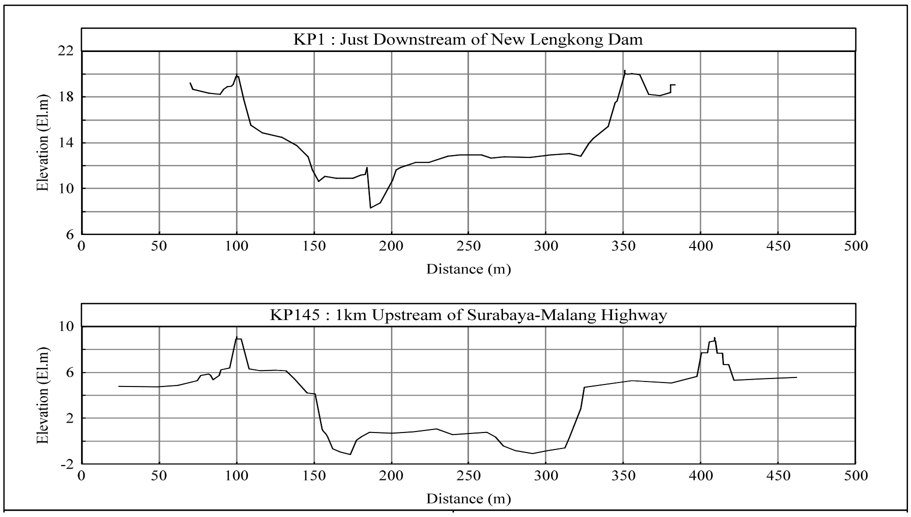
Source: JICA Project Team 2

Table 4.1.2 Longitudinal Profile of Survey Work

No.	Name of River	Length	Remarks
1	Porong River	45.594 km	
2	Sadar River	17.501 km	
3	Tributaries	6.706 km	Kembangan River, Gembolo River, Sumber Glogok River, Sumber Ngrayung River Sumber Kembar River, and Bangsal River

Source： JICA Project Team 2

The sample of the cross section survey results is shown in Figure 4.1.1.



Source: JICA Project Team 2

Figure 4.1.1 Sample of the River Cross Sections

4.2 Groundwater Level Observation

In the Brantas River basin, the groundwater level data was obtained from several projects as shown in Table 4.2.1. The Ministry of Public Works (presently, the Ministry of Public Works and Housing: MPWH) and Groundwater Development Project (*Proyek Pengembangan Air Tanah*: P2AT) has conducted the East Java Groundwater Development Project as a prioritized national project. P2AT had monitored the groundwater level from 1979 to 1985 for the purpose of the groundwater management, so these groundwater level data were collected from P2AT.

Furthermore, other groundwater level data were obtained from the Department of Mines and Mineral Resources of East Java Province and the Ministry of Energy and Mineral Resources (ESDM). The obtained groundwater level data were from three automatic monitoring wells from 2009 to 2013 and 16 observation wells from 2004 to 2009. Those data were sufficient for building and calibrating the groundwater flow model of the basin. Therefore, it was decided that it was not necessary to construct new observation wells and carry out monitoring the groundwater level in the Brantas River basin.

On the other hand, it was confirmed that the latest groundwater data and relevant information were owned by a geological agency (*Badan Geologi*) under ESDM in Bandung.

For groundwater level data, please refer to Data C in the Data Book.

Table 4.2.1 Groundwater Data in the Brantas River Basin Obtained from Several Projects

Report/ Organization	Area	No. of Well	Measurement	Period	Frequency
East Java Groundwater Development Project - Progress of Project and Feasibility Study Report (1986)/P2AT Jawa Timur	Pace, Nganjuk	2	Automatic	1979-1985	Daily – Monthly data not constant
Pengembangum Groundwater Project (P2AT) Jawa Timur	Nganjuk	3	Automatic	1997-1998	Daily – Monthly data not constant
ESDM Jawa Timur Data	Mojokerto, Kediri	3	Automatic	2009-2013	Hourly data one or two year continuous
	Nganjuk, Mojokerto Jombang, Kediri	16	Manual	2004-2009	Monthly data measurement by hand

Source: JICA Project Team 2

CHAPTER 5 ASSESSMENT OF CLIMATE CHANGE IMPACTS IN 2050

5.1 General

In this chapter, the climate change impacts in the Brantas River basin are assessed to the drought and flood situation based on the output from the JICA Project Team 1 (Team 1).

Water demands are estimated considering land use, social conditions and future climate condition. Especially, the unit water requirement of irrigation water is increased under the future climate condition because the unit water requirement is affected from evapotranspiration and daily rainfall at the irrigation area.

The groundwater potential is reduced under the future climate condition while the safety level of drought under the future climate condition is also lower than the present climate condition.

The peak discharge under the future climate condition becomes bigger than the present condition while the safety level of flood is also lower than the present safety level.

5.2 Ground Elevation and Land Use in 2050

5.2.1 Mesh Data of Ground Elevation

The digital elevation model (DEM) for WEB-DHM is used to 500m meshes from Hydrological data and maps based on SHuttle Elevation Derivatives at multiple Scales (HydroSHEDS) (). Five hundred meters mesh size of the DEM is too large to evaluate flood inundation area in the tributaries of the Brantas River basin. Then, 25 meters DEM data developed by the geospetial information agency (Badan Koordinasi Survei dan Pemetaan Nasional: BAKOSURTANAL) is occupied in the flood inundation analysis.

5.2.2 Land Use in 2050

In predicting the future land use in the Brantas River basin for 2050, the followings are referred to as basic data and used for making assumptions:

- Wet paddy field will decrease annually by 0.4% until 2031 considering the planned area of land resources management zone set up in the Spatial Plan of East Java (*RTRW Jawa Timur 2011-2031*) as well as target area of the irrigated and the rain-fed paddy field by regency/ city in East Java Province for preserving sustainable food production base (LP2B) according to the instruction of the Ministry of Agriculture relevant to RTRW,
- Other categories of agricultural land use such as dry upland, and permanent estate crop planting area will not change in their coverage;
- Residential and industrial areas will increase by 1.5% up to 2031 and 0.8% afterwards, respectively,
- Natural and man-made forest coverage rate are to be maintained at the same level for watershed conservation purpose, and
- Water surface areas (fish pond, farm pond, river, reservoir, inland swamp and tidal swamp) are to be kept at the present level.

The projected land use condition in the Brantas River basin for 2031 and 2050 is discussed with BBWS Brantas and summarized in Table 5.2.1.

Table 5.2.1 Projected Land Use in the Brantas River Basin for 2031 and 2050

Land Use Category	2010 (ha)	Annual change	2031 (ha)	Annual change	2050 (ha)
Natural Forest	71,675	0.0%	71,675	0.0%	71,675
Dry Land Forest	55,650	0.0%	55,650	0.0%	55,650
Bush/Shrub	675	0.0%	675	0.0%	675
Mangrove	50	0.0%	50	0.0%	50
Plantation (Perennial crop field)	157,995	0.0%	157,995	0.0%	157,995
Paddy Field	337,925	-0.40%	309,600	0.0%	309,600
Upland Crop Field	273,875	0.0%	273,875	0.0%	273,875
Fallow Land	6,700	0.0%	6,700	-3.1%	2,530
Mixed Garden	40,030	0.17%	41,465	0.0%	41,465
Residential/ Industrial Area	225,050	0.57%	251,940	0.08%	256,110
Fishpond/Pond	22,525	0.0%	22,525	0.0%	22,525
Lake/Reservoir	1,825	0.0%	1,825	0.0%	1,825
River	175	0.0%	175	0.0%	175
Total	1,194,150		1,194,150		1,194,150

Source: BBWS Brantas (2010), JICA Project Team 2 (2031, 2050)

5.3 Water Use

5.3.1 Water Demand Projection

(1) Municipal and Industrial Water Demand Projection

1) Methodology

The basis for the demand forecast is set at the condition in 2010 as a current water supply demand in the Brantas River basin as shown in Table 5.3.1

Projection of water supply demand until 2050 is prepared based on the demand in 2010 taking into consideration the increasing target factors as summarized in Table 5.3.2.

2) Projected Population

There is no projected population data until 2050. The central agency on statistics (Badan Pusat Statistik: BPS) has projected to each province from 2010 to 2035. The projection of population growth until 2050 is prepared with the following basis:

- Growth ratio of projected population and urbanization factor in East Java Province until 2035 published by BPS, and
- Allocation ratio between urban and rural for each city and regency in 2010 referred to census data of Indonesia.
- Population of East Java projected by BPS will be at maximum in 2033 and will gradually reduce until 2035. The population projected by BPS is estimated until 2035, therefore the JICA Project Team 2 (Team 2) assumed that the maximum population in 2033 will be stable until 2050 and the projected population is used for the demand forecast until 2050 since it will be safer.

Table 5.3.1 Basic Condition for Demand Forecast – Demand in 2010

Organization		PDAM		Non-PDAM	
Water Source*1		Surface	Ground	Surface	Ground
Purpose to Use	Domestic	- Population (Census Data), - Unit Water Consumption*2, - Coverage*3, - NRW*3		N/A	- Lpcd =(Lpcd(PDAM)+30*5)/2 - Area which is not supplied by PDAM. (100%-PDAM area) - NRW=0%
	Non-domestic*4	20% of Domestic		N/A	20% of Domestic
	Industrial	Total Water Resource*3 – (Domestic + Non-domestic).		$12m^3/s$ in the Brantas basin*6.	$1.68m^3/s$ in the Brantas basin. Actual Data from ESDM

Note: *1: Ratio of surface/ground is referred to the actual consumption in 2010 (ref: Direktori Perpamsi 2010).
*2: Calculated from actual supplied water volume (sell volume) and number of user (ref: Direktori Perpamsi 2010).
*3: All numbers are referred from Direktori Perpamsi 2010. Coverage is calculated at population ratio which is supplied by PDAM.
*4: Water for public facility is calculated by 10-15% of domestic water demand according to the criteria of Directorate General of Human Settlement, Ministry of Public Work 1996. Twenty percent of the domestic water is estimated taking into consideration the commercial use of about 5-10%.
*5: 30 liter is a unit consumption for residents in agricultural area which is estimated in the Study on Formulation of Spatial Planning for GERBANGKERTOSUSILA (GKS) Zone in East Java Province in Indonesia.
*6: 12 m^3/s is calculated from the list of industrial water consumption in the Brantas River basin which was provided by PJT1.

Source: JICA Project Team 2

Table 5.3.2 Increasing Ratio for Demand Forecast until 2050

Organization		PDAM		Non-PDAM	
Water Source		Surface	Ground	Surface	Ground
Purpose to Use	Domestic	1)Pop. growth, 2)Future lpcd*1, 3)Coverage*2, 4)NRW*3	Increase until available ground water potential by 2030 and fixed the maximum demand from 2030 to 2050.	N/A	Increase until available ground water potential by 2030 and fixed the maximum demand from 2030 to 2050.
	Non-domestic	20% of domestic	Fixed as 2010	N/A	Fixed as 2010
	Industrial	Based on development (population) growth ratio	Fixed as 2010	Based on development (population) growth ratio	Fixed as 2010

Note: *1: Per capita in 2050; 200 lpcd for Surabaya, 150 lpcd, 120 lpcd for others (Ref. Criteria of Cipta Karya)
*2: 1% increase in average to meet total coverage ratio of 70% in the Brantas River basin in 2050
*3: By 2050 gradually reduce NRW to 20%-25% depending on the current NRW in 2010

Source: JICA Project Team 2

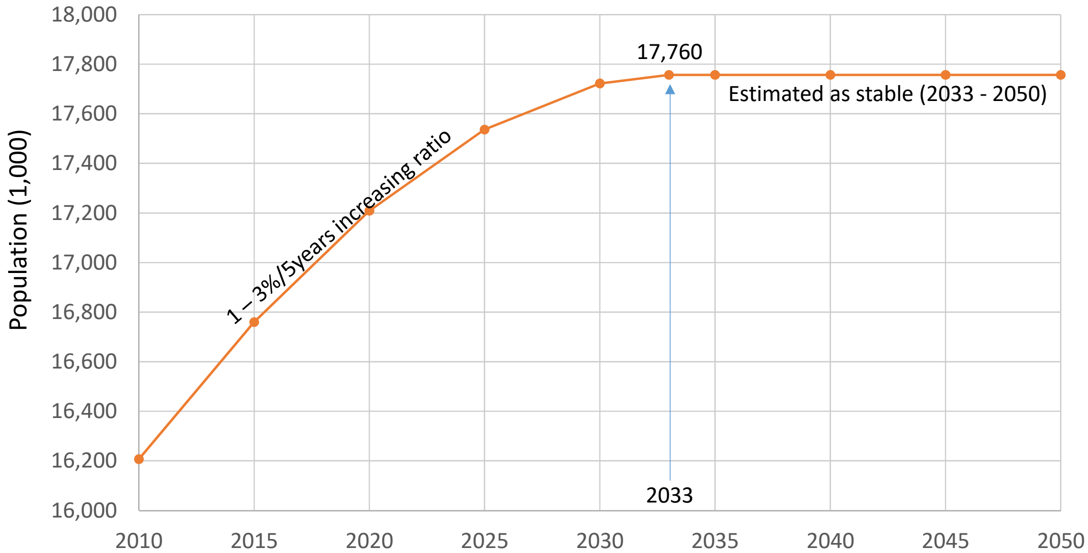
Table 5.3.3 Projection of Population until 2050

(Unit: 1,000 People)

No	City/Regency	2010	2015	2020	2030	2033	2050
1.	Batu City	190	200	203	211	211	211
2.	Malang Regency	2,446	2,554	2,586	2,651	2,652	2,652
3.	Malang City	820	851	879	913	917	917
4.	Kediri Regency	1,500	1,546	1,584	1,623	1,624	1,624
5.	Blitar Regency	1,117	1,145	1,177	1,204	1,203	1,203
6.	Sidoarjo Regency	1,941	2,117	2,075	2,152	2,160	2,160
7.	Mojokerto Regency	1,025	1,080	1,084	1,111	1,112	1,112
8.	Jombang Regency	1,202	1,250	1,276	1,313	1,315	1,315
9.	Kediri City	269	280	288	299	300	300

No	City/Regency	2010	2015	2020	2030	2033	2050
10.	Mojokerto City	120	125	129	134	134	134
11.	Surabaya City	2,765	2,848	2,963	3,078	3,093	3,093
12.	Trenggalek Regency	674	689	709	723	723	723
13.	Blitar City	132	137	141	147	148	148
14.	Tulungagung Regency	990	1,021	1,046	1,072	1,072	1,072
15.	Nganjuk Regency	1,017	1,041	1,072	1,095	1,095	1,095
	Total	**16,210**	**16,890**	**17,211**	**17,725**	**17,760**	**17,760**

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure 5.3.1 Projected Population for Demand Forecast

3) Water Demand Projection

The demand forecast until 2050 by means of the applying factors as described above is summarized in Table 5.3.4. Figure 5.3.2 also shows the water demand in comparison with population growth and reduction of NRW graphically.

Table 5.3.4 Summary for Water Demand Projection until 2050

(Unit: m^3/s)

Year	2010		2015		2030		2050	
Purpose	Surface	Ground	Surface	Ground	Surface	Ground	Surface	Ground
Domestic	8.37	11.10	10.41	11.09	13.80	13.95	20.00	13.95
Non-Domestic	1.68	2.20	2.08	2.21	2.91	2.78	4.73	2.78
Industry	19.49	6.50	20.84	6.50	20.53	7.87	21.15	7.87
Total	29.54	19.80	33.33	19.80	37.24	24.60	45.88	24.60
	49.34		53.13		61.83		70.48	

Source: JICA Project Team 2

Note: Average NRW of cities and regencies in Brantas River basin is shown.
Source: JICA Project Team 2

Figure 5.3.2 Water Supply Demand Forecast until 2050

(2) Irrigation Water Demand Projection

1) Methodology of Irrigation Water Demand Calculation in Review POLA 2015 (Draft)

In Review POLA 2015 (Draft), the Indonesian National Standard (SNI 19-6728.1-2002) is applied to calculate irrigation water demand. Unit irrigation water consumption is uniformly set up at 1.0 l/s/ha for all irrigation schemes. In calculating annual irrigation water diversion requirement, two factors such as irrigation command area and cropping intensity are used so that no climatic factor is included in this SNI formula.

Aiming to quantify effects of the climate change on irrigation water demand in line with the Project scope, therefore, the formula of "Irrigation Planning Standard, Design Criteria for Irrigation Networks (KP-1)" of DGWR is taken up. In this formula, irrigation water demand is calculated based on several factors including two climate factors such as rainfall and evapotranspiration.

Both formulas are compared in Table 5.3.5.

Table 5.3.5 Comparison of Irrigation Water Requirement Calculation Methodologies

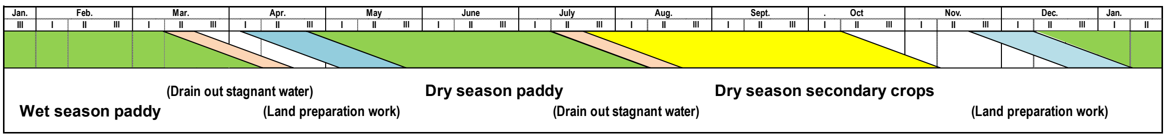
SNI Formula	KP-1 Formula
IWR = A x CI x a Where, IWR: Irrigation water requirement A: irrigation command area (ha) CI: cropping intensity (%) α: unit water requirement (l/s/ha)	*KAI = (Etc + IR + WLR + P- Re)/IE ×A* Where KAI: supplemental irrigation water requirement Etc: consumptive water needs (mm/day) IR: irrigation water needs at paddy field level (mm/day) WLR: water needs to replace the water layer (mm/day) P: percolation (mm/day) Re: effective rainfall (mm/day) IE: irrigation efficiency (%) A: irrigation area (ha)

Source: SNI and KP-1

2) Cropping Calendar

For calculating irrigation water needs for crop cultivation on irrigated paddy field, it is required to set up a cropping calendar for each cropping season of paddy and secondary crops. Also, it is prerequisite to use the sole cropping calendar in clarifying the impact of climate change on irrigation water needs in the Brantas River basin aiming to simplify comparative examination procedure for alternative climate change cases.

To cope with such pre-condition, the sole cropping calendar is set up by referring to BPS report (*Survei Pertanian Produksi Padi dan Palawija di Jawa Timur 2015*) which reveals crop growing period on wetland paddy field for both wet and dry seasons in the respective regencies and cities. In setting up, duration of farming practices on irrigated paddy field is assumed as 20 days for land preparation before transplanting seedlings of both wet and dry season paddy as well as ten days for water supply cutting period before harvesting time of both seasons. The sole cropping calendar is illustrated in Figure 5.3.3.



Source: JICA Project Team 2

Figure 5.3.3 Sole Cropping Calendar for the Brantas River Basin

3) Existing Surface Water Irrigation Schemes in the Brantas River Basin

In the Ministerial Ordinance No.14/2015 concerning criteria and status of irrigation, 3,698 surface water irrigation schemes are listed up with designed irrigation command areas in 15 regencies/ cities covering the Brantas River basin. These schemes are also categorized in three groups based on management authority criteria of the ordinance as shown in Table 5.3.6. The main stream of the Brantas River is functioning as irrigation water source river for seven existing surface water irrigation schemes, while tributaries are water source rivers of all other schemes including five BBWS Brantas managed schemes as listed up in Table 5.3.7.

Table 5.3.6 Existing Surface Water Irrigation Areas in the Brantas River Basin

Regency (R) / City (C)	BBWS Brantas		Province*		Regency / City**				Total	
	Over 10,000 ha		10,000 – 1,000 ha		1,000 - 100 ha		Below 100 ha			
	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)	(nos.)	(ha)
Batu C.	0	0	(2)	328	6	1,139	36	968	42 (2)	2,435
Malang R.	2 (1)	8,771	11 (9)	3,165	99	19,033	618	16,313	730 (10)	47,282
Malang C.	(1)	587	9 (9)	1,287	0	0	10	276	19 (10)	2,150
Blitar R.	(1)	1,637	4 (9)	2,123	53	11,553	621	16,460	678 (10)	31,773
Blitar C.	0	0	8 (2)	333	0	0	36	1,051	44 (2)	1,384
Tulungagung R.	1	10,580	3 (2)	4,915	27	5,825	141	4,397	172 (2)	25,717
Trenggalek R.	0	0	1 (2)	1,894	11	3,342	512	6,366	524 (2)	11,602
Kediri R.	(3)	9,179	11 (2)	4,611	97	17,763	538	17,021	646 (5)	48,574
Kediri C.	0	0	2 (7)	620	3	363	39	1,345	44 (7)	2,328
Nganjuk R.	2	21,106	3	3,866	41	11,106	169	3,845	215 (0)	39,923
Jombang R.	2 (1)	31,962	5 (2)	3,419	38	9,145	158	3,503	203 (3)	48,029
Mojokerto R.	2 (1)	7,655	6 (4)	5,477	35	9,173	330	8,584	373 (5)	30,889
Mojokerto C.	(1)	53	1 (4)	580	0	0	0	0	1 (5)	633
Sidoarjo R.	1	17,766	0	0	12	3,827	6	291	19 (0)	21,884
Surabaya C.	0	0	0	0	0	0	0	0	0 (0)	0
Total	8	109,296	54	32,618	422	92,269	3,214	80,420	3,698	314,603

Note: *; Dinas PU Sumber Daya Air Jawa Timur, **; PU Local Government
Source: DGWR

Table 5.3.7 List of BBWS Brantas Managed Irrigation Schemes by Water Source River

Brantas Main Stream as Water Source River				Brantas Tributaries as Water Source River			
Scheme	Design Area (ha)		Location	BBWS Brantas Scheme	Design Area (ha)		Location
D.I. Lodoyo	12,217	1,637	Blitar R.	D.I. Kedung Kandang	5,160	4,573	Malang R.
		10,580	Tulungagung R.			587	Malang C.
D.I. Mrican Kanan	17,612	3,952	Kediri R.	D.I. Molek	3,883		Malang R.
		13,660	Jombang R.	D.I. Waduk Bening	8,752		Nganjuk R.
D.I. Mrican Kiri	12,729	375	Kediri R.	D.I. Siman	23,060	315	Malang R.
		12,354	Nganjuk R.			4,852	Kediri R.
D.I. Jatimlerek		1,812	Jombang R.			17,893	Jombang R.
D.I. Mentrus	3,632	409	Jombang R.	D.I. Padi Pomahan	4,309	4,256	Mojokerto R.
		3,223	Mojokerto R.			53	Mojokerto C.
D.I. Jati Kulon	638	586	Mojokerto R.				
		52	Mojokerto C.				
D.I. Delta Brantas	17,942	176	Mojokerto R.				
		17,766	Sidoarjo R.				
Total	64,770				45,164		

Source: DGWR

(3) Cropping Intensity

Throughout the country, some of the surface water irrigation schemes are not functioning to partly or full extent of each design area due to physical damages of irrigation facilities, not yet completion of construction works, not yet full conversion to paddy field by beneficiary farmers or conversion of paddy field for other non-agricultural purposes. In case of 15 regencies/ cities covering the Brantas River basin, current utilization rate of all existing surface water irrigation schemes is estimated at 81.9% through dividing actual irrigated paddy field area by design irrigation area, while paddy cropping intensity is estimated at 173.7% through dividing annual paddy harvested area by the total wetland paddy field areas. Table 5.3.8 indicate the current utilization rate of irrigation design areas and paddy cropping intensity in wetland paddy field areas by regency/ city.

Table 5.3.8 Current Utilization Rate and Paddy Cropping Intensity of Irrigation Schemes

Regency (R) / City (C)	Registered Irrigation Scheme Design Area (ha)	Actual Wetland Paddy Field			Annual Paddy Harvested Area (ha)	Wetland Paddy Cropping Intensity (%)	Utilization Rate of Irrigation Design Area (%)
		Irrigated (ha)	Non-irrigated (ha)	Total (ha)			
Batu C.	2,435	474	0	474	691	145.8	19.5
Malang R.	47,282	34,641	2,183	36,824	63,047	171.2	73.3
Malang C.	2,150	865	0	865	1,977	228.6	40.2
Blitar R.	31,773	27,843	3,151	30,994	51,020	164.6	87.6
Blitar C.	1,384	1,097	0	1,097	1,850	168.6	79.3
Tulungagung R.	25,717	23,454	2,410	25,864	45,003	174.0	91.2
Trenggalek R.	11,602	11,049	890	11,939	24,648	206.4	95.2
Kediri R.	48,574	37,866	335	38,201	55,625	145.6	78.0
Kediri C.	2,328	1,005	0	1,005	1,901	189.2	43.2
Nganjuk R.	39,923	37,212	4,269	41,481	83,188	200.5	93.2
Jombang R.	48,029	37,235	4,742	41,977	73,796	175.8	77.5
Mojokerto R.	30,889	26,777	4,676	31,453	53,205	169.2	86.7
Mojokerto C.	633	511	0	511	965	188.8	80.7
Sidoarjo R.	21,884	17,517	0	17,517	30,266	172.8	80.0
Surabaya C.	0	0	1,353	1,353	1,758	129.9	0.0
Total	314,603	257,546	24,009	281,555	488,940	173.7	81.9

Source: Dalam Angka 2016, BPS Jawa Timur

(4) Projection of Future Surface Water Irrigation Area

The future surface water irrigation area in the Brantas River basin is to be predicted in conjunction with the projection of land use in 2050 as described in Section 5.2.2. Further assumptions are made as follows:

- All the existing schemes are separated into two groups based on irrigation water sources. The first group consists of schemes depending on irrigation water sources on regulated flow supplied from the existing and planned dam reservoirs, while the second group consists of schemes diverting natural river flow from intake facilities;
- Along with the LP2B policy, the Group A irrigation schemes shoud be maintained to full extent of the respective design areas including four new schemes with the total design area of 5,134 ha along the tributaries of the Brantas River. On the other hand, 5,736 ha out of Delta Brantas irrigation scheme area will be converted to non-residential areas due to its location adjacent to Surabaya City and thereby the future design irrigation area will be reduced to 12,206 ha; and
- On the other hand, Group B schemes located in the urban areas will be converted for meeting residential and industrial land resource requirements to considerable while maintained schemes will be utilized to full extent of the design irrigation areas.

Based on the above assumptions, the future surface water irrigation areas are predicrted by regenct/ city as shown in Table 5.3.9.

Table 5.3.9 Prediction of Future Irrigation Areas in the Brantas River Basin

Regency (R.) / City (C.)	Present Condition for 2010 (ha)			Future Condition for 2050 (ha)		
	Irrigation Total Area	Irrigation Water Source		Irrigation Total Area	Irrigation Water Source	
		Regulated	Natural flow		Regulated	Natural flow
Batu C.	2,435	0	2,435	1,252	0	1,252
Malang R.	47,282	8,771	38,511	35,559	11,220	24,339
Malang C.	2,150	587	1,563	587	587	0
Blitar R.	31,773	1,637	30,136	27,599	1,637	25,962
Blitar C.	1,384	0	1,384	677	0	677
Tulungagung R.	25,717	10,580	15,137	20,000	10,580	9,420
Trenggalek R.	11,602	0	11,602	9,824	1,185	8,639
Kediri R.	48,574	9,179	39,395	40.865	9,179	31,686
Kediri C.	2,328	0	2,328	500	0	500
Nganjuk R.	39,923	21,106	18,817	35,477	21,806	13,671
Jombang R.	48,029	33,774	14,255	42,488	34,574	7,914
Mojokerto R.	30,889	8,241	22,648	27,996	8,065	19,931
Mojokerto C.	633	105	528	105	105	0
Sidoarjo R.	21,884	17,766	4,118	12,206	12,206	0
Surabaya C.	0	0	0	0	0	0
Total	314,603	111,746	202,857	255,135	111,144	143,991

Source: JICA Project Team 2

1) Unit Irrigation Water Requirement

In order to quantify the effects of different climate change models on irrigation water demand, unit irrigation water requirement is calculated by substituting evapotranspiration and effective rainfall data of future upper, medium, lower scenario patterns as well as present rainfall pattern in the KP-1 formula. The focal points are as follow:

- Effective rainfall indicates daily rainfall between 5.0 mm and 80.0 mm;
- The calculation works are carried out on the 10-day period basis by using 10-day average evapotranspiration and effective rainfall data;
- The calculation period is 20 years from 1991 to 2010 for the present pattern and 2046 to 2065 for the future scenario patterns; and
- The calculation results are shown as the average unit irrigation water requirement of the ten-day period for each crop growing period of wet season paddy (MH), dry season paddy (MK-1) and dry season secondary crop (MK-2).

Table 5.3.10 shows the calculation results of the scenario-based unit irrigation water requirement for the respective surface water irrigation schemes managed by BBWS Brantas including three medium-scale schemes using the main stream flow of the Brantas River. The calculation results on regency/city basis are shown in Table 5.3.11.

Table 5.3.10 Seasonal Average of Unit Irrigation Water Requirement by Major Scheme

Regency (R) / City (C)	10-day Average Unit Irrigation Water Requirement by Crop Season (l/s/ha)											
	Present Rainfall (1995 – 2010)			Low Scenario (2046 – 2065)			Medium Scenario (2046 – 2065)			High Scenario (2046 – 2065)		
	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2
BBWS Brantas Managed Irrigation Schemes withdrawing water from tributaries of Brantas River												
Kedung Kandang	0.39	0.88	0.29	0.44	0.84	0.32	0.42	0.96	0.31	0.53	0.97	0.24
Molek	0.41	0.84	0.25	0.58	0.79	0.22	0.44	0.91	0.24	0.52	0.87	0.14
Siman	0.56	0.96	0.32	0.35	0.87	0.27	0.54	1.00	0.22	0.58	0.99	0.19
Waduk Bening	0.34	0.86	0.24	0.36	0.75	0.24	0.43	0.91	0.23	0.44	0.91	0.18
Padi Pomahan	0.49	0.98	0.33	0.42	0.89	0.29	0.52	1.02	0.24	0.53	1.02	0.21
Jaruma I & II	0.43	0.88	0.29	0.44	0.84	0.32	0.42	0.96	0.31	0.53	0.97	0.24
Ngasinan	0.41	0.96	0.35	0.36	1.03	0.45	0.42	1.01	0.39	0.44	1.02	0.35
Kedung Soko	0.35	0.86	0.24	0.39	0.74	0.20	0.42	0.88	0.18	0.43	0.87	0.15
Bareng	0.46	0.93	0.32	0.42	0.84	0.32	0.52	0.95	0.27	0.52	0.95	0.22
BBWS Brantas Managed Irrigation Schemes withdrawing water from main stream of Brantas River												
Lodoyo (Lodagung)	0.47	0.94	0.37	0.51	0.96	0.44	0.50	1.07	0.42	0.60	1.10	0.30
Mrican Kanan	0.53	0.98	0.37	0.46	0.91	0.34	0.55	1.04	0.30	0.57	1.02	0.23
Mrican Kiri	0.44	0.98	0.39	0.40	0.91	0.42	0.49	1.05	0.36	0.51	1.07	0.31
Jatimlerek	0.49	0.92	0.33	0.43	0.87	0.32	0.52	1.00	0.27	0.54	0.99	0.22
Mentrus	0.53	0.97	0.34	0.46	0.90	0.30	0.55	1.03	0.25	0.57	0.98	0.25
Jatikulon	0.51	0.91	0.36	0.43	0.92	0.38	0.54	1.06	0.34	0.57	1.08	0.31
Brantas Delta	0.43	0.95	0.16	0.39	0.89	0.21	0.49	1.02	0.24	0.51	1.00	0.19

Source: JICA Project Team 2 (Data Book E1)

Table 5.3.11 Seasonal Average of Unit Irrigation Water Requirement by Regency/ City

Regency (R) / City (C)	10-day Average Unit Irrigation Water Requirement for Crop Season (l/s/ha)											
	Present Rainfall (1995 – 2010)			Low Scenario (2046 – 2065)			Medium Scenario (2046 – 2065)			High Scenario (2046 – 2065)		
	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2
Batu C.	0.19	0.80	0.28	0.27	0.78	0.35	0.29	0.82	0.33	0.44	0.84	0.32
Malang R.	0.32	0.81	0.30	0.39	0.84	0.32	0.38	0.96	0.30	0.45	0.79	0.22
Malang C.	0.32	0.81	0.30	0.39	0.84	0.32	0.38	0.96	0.30	0.58	0.92	0.23
Blitar R.	0.36	0.83	0.27	0.39	0.81	0.27	0.39	0.91	0.25	0.48	0.80	0.17
Blitar C.	0.36	0.83	0.27	0.45	0.96	0.44	0.44	1.07	0.42	0.49	0.84	0.25
Tulungagung R.	0.42	0.76	0.37	0.43	0.84	0.25	0.44	0.95	0.23	0.44	0.85	0.31
Trenggalek R.	0.54	0.92	0.29	0.52	0.92	0.23	0.52	1.02	0.24	0.46	0.87	0.27
Kediri R.	0.38	0.87	0.28	0.36	0.85	0.29	0.43	0.97	0.26	0.36	0.75	0.24
Kediri C.	0.26	0.78	0.28	0.24	0.74	0.31	0.34	0.79	0.24	0.36	0.87	0.47
Nganjuk R.	0.30	0.77	0.25	0.32	0.75	0.24	0.39	0.91	0.23	0.35	0.74	0.20
Jombang R.	0.43	0.91	0.36	0.38	0.92	0.38	0.49	1.06	0.34	0.39	0.82	0.35
Mojokerto R.	0.39	0.91	0.31	0.38	0.87	0.32	0.44	1.10	0.36	0.40	1.06	0.39
Mojokerto C.	0.43	0.91	0.34	0.38	0.89	0.21	0.47	1.02	0.24	0.42	0.84	0.32
Sidoarjo R.	0.26	0.90	0.23	0.34	0.95	0.38	0.37	0.95	0.24	0.42	0.87	0.29

Source: JICA Project Team 2

2) Irrigation Water Demand Projection

The irrigation water demand is defined as the supplemental requirement for meeting insufficient irrigation water needs which cannot be fulfilled by effective rainfall. In surface water irrigation scheme areas, such supplemental irrigation water should be diverted from water source rivers. In predicting irrigation water diversion requirements, the following points are considered:

- Cropping intensity of the existing and future irrigation schemes with water sources of regulated flow is 250% (100% each for paddy in the both wet and dry seasons and 50% for dry season secondary crop) under present and future climate conditions; and

- Cropping intensity in irrigation schemes depending water sources on natural river flow is assumed to be 73.5% for the wet season paddy, 45.6% for the dry season paddy and 4.9% for the dry season secondary crop at present level, while the future cropping intensity increases to 55.4% only for the dry season paddy.

Taking the above assumptions into account, the irrigation water demand is predicted for the schemes with regulated water sources as shown in Table 5.3.12 and for the schemes depending on the irrigation water sources on natural river flow as shown in Table 5.3.13. The calculation results indicate the average irrigation water diversion requirements for every 10-day period during each crop season for the 20-year period of each scenario.

Table 5.3.12 Average Irrigation Water Demand for Regulated Flow-based Irrigation Schemes

Surface Water Irrigation Scheme	Scheme Area (ha)	Present Rainfall Pattern (m^3/s) 1991 - 2010			Scheme Area (ha)	Low Scenario Pattern (m^3/s) 2046 - 2065		
		MH	MK-1	MK-2		MH	MK-1	MK-2
BBWS Brantas Managed Irrigation Schemes withdrawing water from tributaries of Brantas River								
Kedung Kandang	5,160	2.0	4.5	0.7	5,160	2.7	5.2	1.3
Molek	3,883	1.1	3.1	0.5	3,883	1.2	3.2	0.8
Siman	23,060	12.7	22.0	3.7	23,060	12.9	24.2	6.5
Waduk Bening	8,752	3.0	7.6	1.0	8,752	3.7	8.4	2.4
Padi Pomahan	4,309	2.1	4.2	0.7	4,309	2.3	4.5	1.2
Jaruma I & II	2,449	1.2	2.1	0.3	2,449	1.3	2.4	0.6
Ngasinan	1,185	0.7	1.1	0.2	1,185	0.8	1.3	0.3
Kedung Soko	700	0.2	0.6	0.1	700	0.3	0.7	0.2
Bareng	800	0.4	0.7	0.1	800	0.4	0.8	0.2
BBWS Brantas Managed Irrigation Schemes withdrawing water from main stream of Brantas River								
Lodoyo (Lodagung)	12,217	5.8	11.5	2.2	12,217	6.8	12.5	3.2
Mrican Kanan	17,612	9.3	17.3	3.2	17,612	9.6	18.2	4.7
Mrican Kiri	12,729	5.6	12.5	2.5	12,729	6.0	12.8	3.5
Jatimlerek	1,812	0.9	1.7	0.3	1,812	1.0	1.9	0.5
Mentrus	3,632	1.9	3.5	0.6	3,632	2.0	3.8	1.0
Jatikulon	638	0.3	0.6	0.1	638	0.3	0.7	0.2
Brantas Delta	17,765	5.9	16.8	2.2	12,206	5.1	12.4	3.2
Surface Water Irrigation Scheme	**Scheme Area (ha)**	**Medium Scenario Pattern (m^3/s) 2046 - 2065**			**Scheme Area (ha)**	**High Scenario Pattern (m^3/s) 2046 - 2065**		
		MH	**MK-1**	**MK-2**		**MH**	**MK-1**	**MK-2**
BBWS Brantas Managed Irrigation Schemes withdrawing water from tributaries of Brantas River								
Kedung Kandang	5,160	2.3	5.5	1.2	5,160	3.0	6.0	1.3
Molek	3,883	1.8	4.1	0.9	3,883	1.6	3.9	0.8
Siman	23,060	13.4	27.0	6.6	23,060	14.0	28.5	6.3
Waduk Bening	8,752	4.5	9.9	2.3	8,752	4.2	10.3	2.3
Padi Pomahan	4,309	2.4	5.1	1.2	4,309	2.5	5.3	1.2
Jaruma I & II	2,449	1.1	2.6	0.6	2,449	1.4	2.9	0.6
Ngasinan	1,185	0.8	1.3	0.3	1,185	0.8	1.5	0.3
Kedung Soko	700	0.3	0.8	0.2	700	0.3	0.8	0.2
Bareng	800	0.4	0.9	0.2	800	0.5	1.0	0.2
BBWS Brantas Managed Irrigation Schemes withdrawing water from main stream of Brantas River								
Lodoyo (Lodagung)	12,217	6.0	13.6	3.2	12,217	6.8	14.8	3.1
Mrican Kanan	17,612	10.2	20.8	5.1	17,612	10.6	21.8	4.8
Mrican Kiri	12,729	6.2	14.4	3.6	12,729	6.6	15.3	3.4
Jatimlerek	1,812	1.0	2.1	0.5	1,812	1.1	2.2	0.5
Mentrus	3,632	2.1	4.3	1.0	3,632	2.2	4.5	1.0
Jatikulon	638	0.4	0.8	0.2	638	0.4	0.8	0.2
Brantas Delta	12,206	5.7	13.9	3.2	12,206	5.9	14.4	3.0

Source: JICA Project Team 2 (Data Book E1)

Table 5.3.13 Average Irrigation Water Demand for Natural Flow-based Irrigation Schemes

Regency (R) / City (C)	Scheme Area (ha)	Present Rainfall Pattern (m^3/s) 1991 - 2010			Scheme Area (ha)	Low Scenario Pattern (m^3/s) 2046 - 2065		
		MH	MK-1	MK-2		MH	MK-1	MK-2
Batu C.	2,435	0.3	0.9	0.03	1,252	0.2	0.5	0.02
Malang R.	38,511	9.2	14.2	0.55	24,339	6.1	9.3	0.23
Malang C.	1,563	0.4	0.6	0.02	0	0.0	0.0	0.00
Blitar R.	30,136	7.9	11.3	0.40	25,962	7.4	11.5	0.22
Blitar C.	1,384	0.4	0.5	0.02	677	0.1	0.3	0.01
Tulungagung R.	15,137	4.6	5.3	0.27	9,420	3.0	4.4	0.14
Trenggalek R.	11,602	4.6	4.9	0.16	8,639	3.3	3.5	0.10
Kediri R.	39,395	10.9	15.5	0.50	31,686	8.2	13.2	0.37
Kediri C.	2,328	0.4	0.8	0.03	500	0.1	0.2	0.01
Nganjuk R.	18,817	4.2	6.6	0.22	13,671	3.0	5.4	0.15
Jombang R.	14,255	4.5	5.9	0.25	7,914	1.5	2.7	0.10
Mojokerto R.	22,648	6.5	9.4	0.34	19,931	5.4	9.4	0.31
Mojokerto C.	528	0.2	0.2	0.01	0	0.0	0.0	0.00
Sidoarjo R.	4,118	0.8	1.7	0.04	0	0.0	0.0	0.00
Regency (R) / City (C)	**Scheme Area (ha)**	**Medium Rainfall Pattern (m^3/s) 2046 - 2065**			**Scheme Area (ha)**	**High Scenario Pattern (m^3/s) 2046 - 2065**		
		MH	**MK-1**	**MK-2**		**MH**	**MK-1**	**MK-2**
Batu C.	1,252	0.3	0.6	0.02	1,252	0.4	0.6	0.02
Malang R.	24,339	6.0	9.9	0.33	24,339	7.0	11.3	0.31
Malang C.	0	0.0	0.0	0.00	0	0.0	0.0	0.00
Blitar R.	25,962	7.4	11.7	0.34	25,962	9.2	13.1	0.32
Blitar C.	677	0.2	0.4	0.01	677	0.2	0.4	0.01
Tulungagung R.	9,420	3.0	4.4	0.12	9,420	3.0	5.0	0.11
Trenggalek R.	8,639	2.8	3.8	0.08	8,639	2.5	4.2	0.09
Kediri R.	31,686	10.0	14.9	0.45	31,686	8.4	17.0	0.40
Kediri C.	500	0.1	0.2	0.01	500	0.1	0.2	0.01
Nganjuk R.	13,671	3.3	5.3	0.15	13,671	3.8	6.5	0.13
Jombang R.	7,914	1.5	2.4	0.09	7,914	1.9	3.1	0.09
Mojokerto R.	19,931	5.7	11.4	0.34	19,931	6.3	11.9	0.37
Mojokerto C.	0	0.0	0.0	0.00	0	0.0	0.0	0.00
Sidoarjo R.	0	0.0	0.0	0.00	0	0.0	0.0	0.00

Source: JICA Project Team 2

(5) Maintenance Flow

Article 25 in PP No.38/2011 (Sungai) is mentioned in the maintenance flow. Article 25 shows below:

Article 25 (Translation to English)

(1) Protection of the flow of the river maintenance as referred to in Article 20 paragraph (3) letter is intended to maintain the river's ecosystem.

(2) Keeping the river ecosystem as referred to in paragraph (1) shall be carried from the upstream to the mouth of the river.

(3) Protection of the flow of the river maintenance is done by controlling the availability of discharge mainstay of 95%.

(4) In case of discharge of 95% is not reached, the management of water resources need to control the use of water upstream.

The maintenance flow is set from 95% of the flow regime at the present condition. Even the future condition under the climate change, the maintenance flow is applied to the same value at the present condition.

The reference points in the Brantas River are set at downstream of the Sutami Dam, the Mrican Barrage and the New Lengkong Dam along the mainstream and the major tributaries at just before confluence of the mainstream. Table 5.3.14 shows the maintenance flow at each reference point.

Table 5.3.14 Maintenance Flow

Reference Point	Discharge (m^3/s)	Reference Point	Discharge (m^3/s)
1. mainstream		**2. Tributary**	
Downstream of Sutami Dam	29.9	Tulungagung	12.33
Downstream of Mrican Barrage	54.1	Konto	1.64
Downstream of New Lengkong Dam	32.1	Widas	4.38
		Sadar	1.11

Note: Maintenance flow of the tributaries set at just before confluence of the mainstream
Source: JICA Project Team 2

(6) Power Output Projection

According to RUPTL 2015-2024, the projected power supply and demand in East Java Province is as shown in Table 5.3.15.

Table 5.3.15 Power Supply Projection

Year	Economic Growth	Energy Demand	Energy Production	Peak Load
	(%)	(GWh)	(GWh)	(MW)
2015	7.2	33.422	35.487	5.471
2016	7.2	36.104	38.310	5.854
2017	7.2	39.327	41.695	6.318
2018	7.2	42.704	45.242	6.797
2019	7.2	46.544	49.273	7.341
2020	7.2	50.633	53.580	7.913
2021	7.2	54.714	57.880	8.483
2022	7.2	59.014	62.403	9.078
2023	7.2	63.553	67.181	9.699
2024	7.2	68.355	72.234	10.351
Annual Growth Rate (%)	7.2	8.27	8.22	7.34

Source: RUPTL 2015-2024

As shown in Table 5.3.15 the power demand in the region will be increased with annual economic growth rate of 7.2%. In order to catch up the power demand growth, the power plant capacity of 2.752MW will be added by the year 2024. Although the power supply plan of the existing hydropower plants in the Brantas River basin is not mentioned in the RUPTL 2015-2024, it can be considered that the existing power plants need to generate electricity according to the planned generating capacity. The installed capacity and the generating capacity of the hydropower plants in the Brantas River basin is shown in Table 5.3.16.

Table 5.3.16 Hydropower Plant in the Brantas River Basin

No.	Name of Power Plant	Type	Owner	Installed Capacity MW	Generating Capacity MW
1	Karangkates	PLTA	PJB	105	103
2	Wlingi	PLTA	PJB	54	53.6
3	Lodoyo	PLTA	PJB	4.5	4.5
4	Selorejo	PLTA	PJB	4.5	4.7
5	Sengguruh	PLTA	PJB	29	28.5
6	Tulungagung	PLTA	PJB	36	35.7
7	Mendalan	PLTA	PJB	23	20.7
8	Siman	PLTA	PJB	10.8	10.2
	Total			266.8	260.9

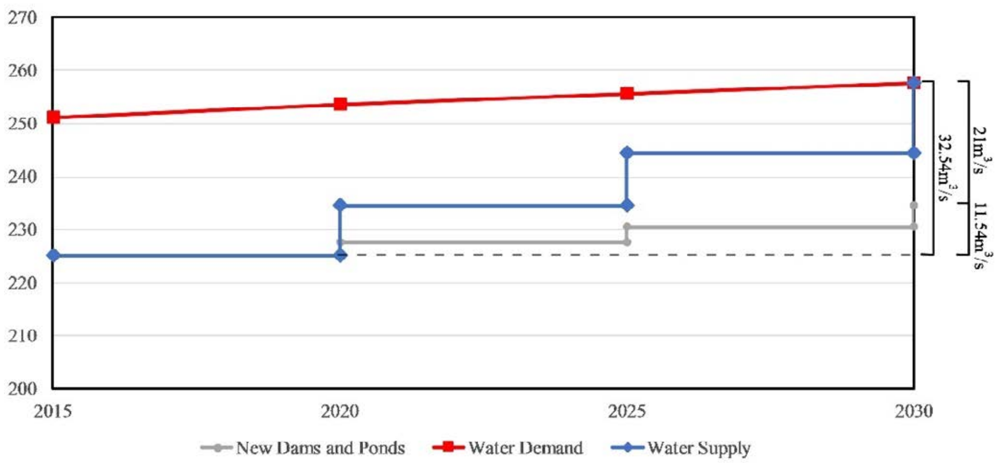
Source: RUPTL 2015-2024

Even the PLN Java Bali Power Company (*PT PLN Penyaluran dan Pusat Pengaturan Beban Jawa Bali*: PJB) plans the hydropower plants, the water supply from the reservoir is considered to the irrigation water and municipal and industrial water. The power output will be decided from other demands.

5.3.2 Groundwater Use

(1) Groundwater Development Plan up to 2030

Groundwater Development Plan from 2015 to 2030 indicated in Review POLA 2015 (Draft) is at a total of 21m^3/s (7m^3/s every five years) as shown in Figure 5.3.4.



Source: Review POLA 2015 (Draft)

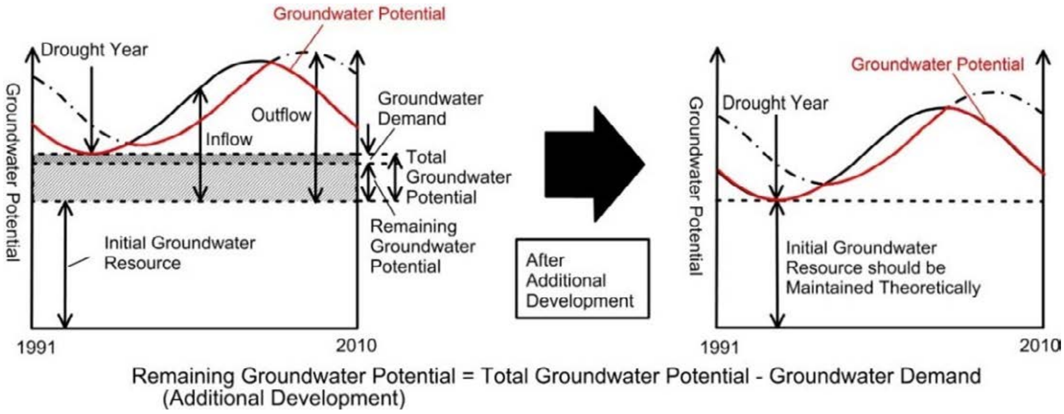
Figure 5.3.4 Relationship between Water Supply and Demand in the Brantas River Basin

Although the location of the development should be selected carefully, it is considered that the groundwater development of 21m^3/s (662.26 million m^3/y) up to 2030 is possible based on the existing groundwater potential values found in Review POLA (Draft) and reports of the Ministry of Energy and Mineral Resources (ESDM) (2005 and 2010).

(2) Definition of Groundwater Potential

The aquifer in the groundwater basin is divided into two kinds of aquifers, i.e.; unconfined (shallow) aquifer and confined (deep) aquifer, and their groundwater potentials for each aquifer are shown in the reports prepared by the Geological Agency. However, the definition and evaluation process for the potential has not been shown in the reports.

The definition of groundwater potential in this project is more specific and rigorous than the Geological Agency. The concept of groundwater potential is shown in Figure 5.3.5. The groundwater potential is defined from the result of groundwater flow simulation using the United States Geological Survey (USGS) MODFLOW as "minimum annual inflow/outflow value into/to specified area (regency/city) in 20 years calculation under the stable condition".



Source: JICA Project Team 2

Figure 5.3.5 Definition of Groundwater Potential in the Project

(3) Groundwater Flow Simulation

1) Model Structure and Hydrogeology

The model structure is summarized in Table 5.3.17. The interpolated data from Shuttle Radar Topography Mission (SRTM), whose elevations were calculated relative to the EGM96 geoid, was imported to the top surface of the model. Hydrogeological classification of hydrogeological map published by ESDM in 1984 was adopted for the model.

Table 5.3.17 Model Structure

Item	Condition
Modeling Region	19,557km^2(E-W 159km x S-N 123km)
Horizontal Analytical Area	Approximately 11,596km^2 including the Brantas River Basin
Vertical Limit	Top: Ground surface Bottom: About 200m from the ground surface
Layer	6 layers (Shallow Aquifer: 1, Aquiclude: 1, Deep Aquifer: 4)
Unit Grid Cell Size	1.0km x 1.0km

Source: JICA Project Team 2

2) Analytical Method

The code selected to simulate was MODFLOW 2005, a modular three-dimensional finite difference groundwater flow model developed by the USGS. The application for pre-/post-processing is Visual MODFLOW 2009.1. To recreate the present groundwater environment, monthly basis transient simulation was carried out from 1991 to 2010 (20 years) using recharge data provided from Team 1, as shown in Table 5.3.18.

Table 5.3.18 Analytical Method of Simulation

Item	Condition
Code	MODFLOW2005 (Visual MODFLOW 2009.1)
Calculation	Transient Simulation
Duration	1991 - 2010 (20years)
Time Steps	1 month
Calibration Target	Collected groundwater level data

Source: JICA Project Team 2

3) Boundary Conditions

The boundary conditions are summarized in Table 5.3.19. Constant head boundaries were used for the cells of the ocean with elevation of equal to mean sea water level based on the existing average Surabaya tidal water level data which is about EL. -0.05m SHVP. Since it is assumed that the sea water level is rising at a speed of 5 mm/year in Indonesia, this sea level rise effect is taken into account in future prediction model. River boundaries were assigned as the main stream including the Brantas River. Recharge from the ground surface was provided as daily recharge data on a drainage basis from Team 1. Recharge rate has high value in mountainous drainages and low in drainages facing the coastal area proportional to rainfall increased with the elevation.

Table 5.3.19 Boundary Conditions

<table>
<tr><th>Setting Position</th><th colspan="2">Contents</th></tr>
<tr><td>Ground Surface</td><td colspan="2">Groundwater Recharge: Provided data from Team 1</td></tr>
<tr><td>Ocean</td><td>Constant Head Boundary
(Sea Water Level)</td><td>-0.05m: for present model
0.05m: for near future (2030) prediction model
0.15m: future (2050) prediction model</td></tr>
<tr><td>River</td><td colspan="2">River Boundary</td></tr>
<tr><td>Ground Surface except for Main River</td><td colspan="2">Drainage Boundary</td></tr>
<tr><td>Pumping Wells</td><td colspan="2">Pumping Rate: Aggregated total groundwater demand by regency/city</td></tr>
</table>

Source: JICA Project Team 2

(4) Groundwater Demand

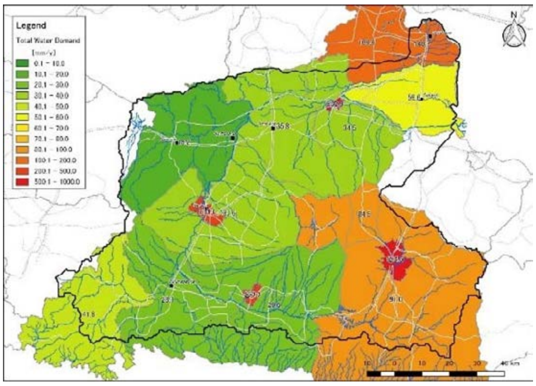
The groundwater use is mainly divided into three categories by its allocation, i.e.: domestic / non-domestic water use, industrial water use, and irrigation water use. Total present and future groundwater demands are shown in Table 5.3.20 and Figure 5.3.6.

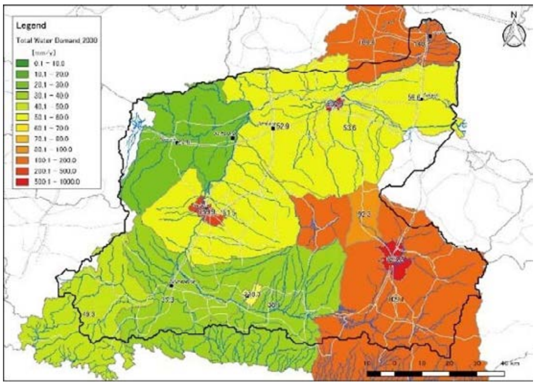
Future (2030 / 2050) groundwater demand was studied in Review POLA 2015 (Draft) and planned groundwater development volume in the future was also estimated. Taking into consideration the current groundwater use, areas for groundwater use are divided into two zones due to unevenly groundwater potential, i.e.: the zone where additional groundwater can be developed and the zone where it is better to avoid additional groundwater development. In this project, additional groundwater development potential is evaluated based on the result of present groundwater flow simulation, and groundwater demand for domestic/non-domestic and industrial water in the future is evaluated.

Table 5.3.20 Total Present and Future Groundwater Demand in the Brantas River Basin

No.	Regency / City	Model Area (km²)	Total Groundwater Demand			
			Present		Future (2030 / 2050)	
			(10^6 m³/y)	(mm/y)	(10^6 m³/y)	(mm/y)
1	Batu City	211.9	17.89	84.5	19.60	92.3
2	Malang Regency	2216.5	201.63	91.0	241.80	109.1
3	Malang City	109.4	58.5	534.6	69.29	633.2
4	Kediri Regency	1521.0	57.2	37.6	78.33	51.5
5	Blitar Regency	1281.3	38.17	29.8	48.83	38.1
6	Sidoarjo Regency	690.4	40.46	58.6	40.46	58.6
7	Mojokerto Regency	899.4	31.01	34.5	48.22	53.6
8	Jombang Regency	1102.8	39.45	35.8	58.37	52.9
9	Kediri City	66.6	20.66	310.1	23.98	359.9
10	Mojokerto City	20.3	11.81	582.9	11.81	582.9
11	Surabaya City	237.5	34.85	146.7	34.85	146.7
12	Trenggalek Regency	632.3	26.45	41.8	31.15	49.3
13	Blitar City	33.4	8.71	260.3	10.65	318.3
14	Tulungagung Regency	951.9	26.73	28.1	35.51	37.3
15	Nganjuk Regency	1292.8	23.31	18.2	35.44	27.6
16	Gresik Regency	105.6	11.26	106.6	11.26	106.6
Total		11363.1	648.09	57.0	799.50	70.4

Source: JICA Project Team 2


Present groundwater demand


Future groundwater demand

Source: JICA Project Team 2

Figure 5.3.6 Distribution of Total Present and Future Groundwater Demand in Height

(5) Groundwater Potential

1) Present Groundwater Potential

Groundwater potential under the present condition evaluated for regency/city is shown in Table 5.3.21 and remaining groundwater potential in height is shown in Figure 5.3.7. Groundwater demand of bold character regencies/cities is higher than their average recharge between 1991 and 2010. It means that these regencies/cities are not capable to provide groundwater demand from their own groundwater recharge.

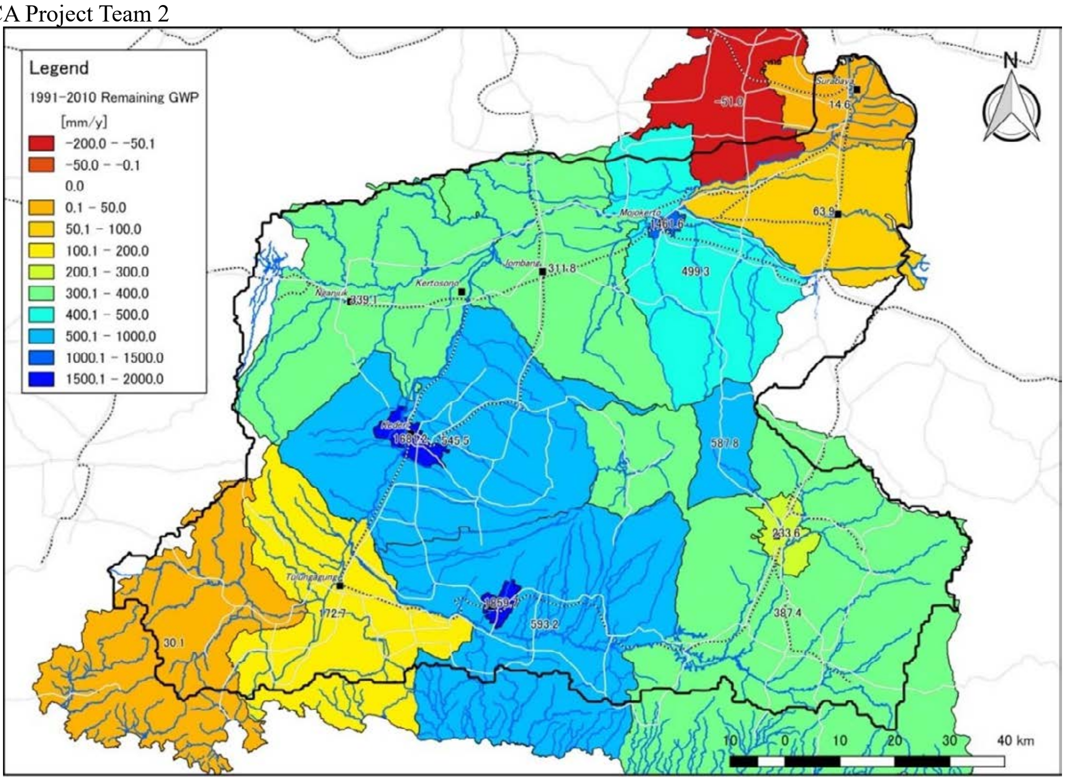
Furthermore, Gresik Regency indicates minus value for remaining groundwater potential. It means that the groundwater is already over use condition. Gresik Regency has area facing the coast, and when groundwater is excessively pumped in this area, the possibility of salt water intrusion and land subsidence is increased. Sidoarjo Regency, Surabaya City and Mojokerto City are under the critical condition about groundwater potential because the supply of groundwater should rely on inflow from aquifer in surrounding areas or infiltration through the riverbed.

Table 5.3.21 Evaluation of Present Groundwater Potential by Regency/City in the Brantas River Basin

No.	Regency / City	Model Area*1 (km^2)	(A) Groundwater Demand		(B) Recharge (1991-2010)		(B) - (A)		(C) Total Potential (1991-2010)		(C) - (A) Remaining Potential (1991-2010)	
			($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1
1	Batu City	211.8	17.89	84.5	274.49	1296.3	256.60	1211.8	142.36	672.3	124.47	587.8
2	Malang Regency	2216.5	201.63	91.0	1727.40	779.3	1525.77	688.4	1060.40	478.4	858.77	387.4
3	Malang City	109.4	58.50	534.6	74.91	684.6	16.41	150.0	84.06	768.2	25.56	233.6
4	Kediri Regency	1521.0	57.20	37.6	821.27	540.0	764.06	502.3	886.89	583.1	829.69	545.5
5	Blitar Regency	1281.3	38.17	29.8	951.21	742.4	913.04	712.6	798.18	623.0	760.01	593.2
6	**Sidoarjo Regency**	690.4	40.46	58.6	33.85	49.0	**-6.61**	**-9.6**	84.59	122.5	44.13	63.9
7	Mojokerto Regency	899.4	31.01	34.5	420.70	467.8	389.69	433.3	480.02	533.7	449.01	499.3
8	Jombang Regency	1102.8	39.45	35.8	350.57	317.9	311.12	282.1	383.26	347.5	343.82	311.8
9	Kediri City	66.6	20.66	310.1	22.89	343.5	2.22	33.3	132.69	1991.3	112.02	1681.2
10	**Mojokerto City**	20.3	11.81	582.9	5.20	256.5	**-6.61**	**-326.4**	41.43	2044.5	29.62	1461.6
11	**Surabaya City**	237.5	34.85	146.7	0.27	1.1	**-34.58**	**-145.6**	38.32	161.3	3.47	14.6
12	Trenggalek Regency	632.3	26.45	41.8	256.88	406.2	230.42	364.4	45.48	71.9	19.03	30.1
13	Blitar City	33.4	8.71	260.3	23.90	714.5	15.19	454.2	70.90	2120.0	62.20	1859.7
14	Tulungagung Regency	951.9	26.73	28.1	405.65	426.1	378.92	398.0	191.13	200.8	164.40	172.7
15	Nganjuk Regency	1282.8	23.31	18.2	473.09	368.8	449.78	350.6	458.34	357.3	435.03	339.1
16	**Gresik Regency**	105.6	11.26	106.6	0.38	3.6	**-10.88**	**-103.0**	5.88	55.6	**-5.39**	**-51.0**
	Total	11363.1	648.08	57.0	5842.63	514.2	5194.54	457.1	4903.94	431.6	4255.85	374.5

*1: Calculated using Model Area (km^2)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure 5.3.7 Distribution of Evaluated Present Remaining Groundwater Potential

2) 2030 Groundwater Potential

Groundwater potential in 2030 is evaluated using calibrated present groundwater model with the same analytical condition as present model except for constant head boundary (sea water level) and groundwater demand. Groundwater potential in 2030 evaluated for regency/city is shown in Table 5.3.22 and the remaining groundwater potential in height is shown in Figure 5.3.8.

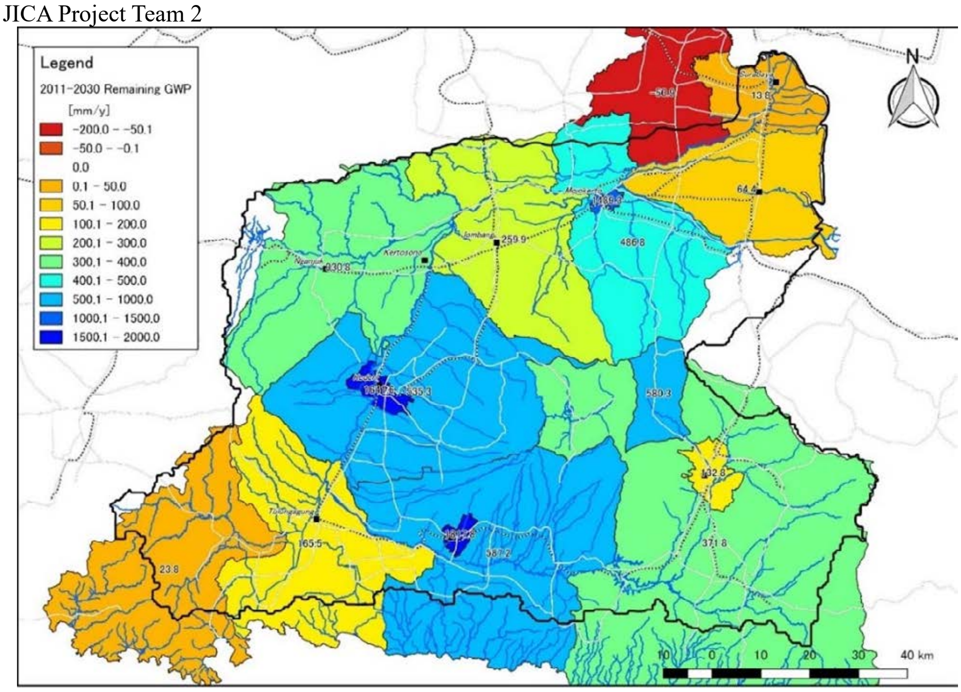
Kediri City has changed to an area under the critical condition about groundwater potential where it is better to avoid further development from possible groundwater development area.

Table 5.3.22 Evaluation of 2030 Groundwater Potential in the Brantas River Basin

No.	Regency / City	Model Area*1 (km^2)	(A) Groundwater Demand		(B) Recharge (2011-2030)		(B) - (A)		(C) Total Potential (2011-2030)		(C) - (A) Remaining Potential (2011-2030)	
			($10^6 m^3/y$)	(mm/y)*1	($10^6 m^3/y$)	(mm/y)*1	($10^6 m^3/y$)	(mm/y)*1	($10^6 m^3/y$)	(mm/y)*1	($10^6 m^3/y$)	(mm/y)*1
1	Batu City	211.8	19.56	92.4	274.49	1296.3	254.93	1203.9	142.44	672.7	122.89	580.3
2	Malang Regency	2216.5	241.76	109.1	1727.40	779.3	1485.64	670.3	1065.78	480.8	824.03	371.8
3	Malang City	109.4	69.29	633.2	74.91	684.6	5.62	51.4	83.82	766.1	14.53	132.8
4	Kediri Regency	1521.0	78.33	51.5	821.27	540.0	742.93	488.5	892.54	586.8	814.20	535.3
5	Blitar Regency	1281.3	48.83	38.1	951.21	742.4	902.38	704.3	801.24	625.3	752.40	587.2
6	**Sidoarjo Regency**	690.4	40.46	58.6	33.85	49.0	**-6.61**	**-9.6**	84.94	123.0	44.49	64.4
7	Mojokerto Regency	899.4	48.22	53.6	420.70	467.8	372.48	414.2	486.00	540.4	437.78	486.8
8	Jombang Regency	1102.8	58.37	52.9	350.57	317.9	292.19	265.0	384.71	348.9	326.34	295.9
9	**Kediri City**	66.6	23.98	359.9	22.89	343.5	**-1.10**	**-16.5**	133.37	2001.5	109.38	1641.6
10	**Mojokerto City**	20.3	11.81	582.9	5.20	256.5	**-6.61**	**-326.4**	41.99	2072.2	30.18	1489.3
11	**Surabaya City**	237.5	34.85	146.7	0.27	1.1	**-34.58**	**-145.6**	38.12	160.5	3.27	13.8
12	Trenggalek Regency	632.3	31.15	49.3	256.88	406.2	225.73	357.0	46.20	73.1	15.05	23.8
13	Blitar City	33.4	10.65	318.3	23.90	714.5	13.25	396.2	71.44	2136.1	60.80	1817.8
14	Tulungagung Regency	951.9	35.51	37.3	405.65	426.1	370.14	388.8	193.05	202.8	157.54	165.5
15	Nganjuk Regency	1282.8	35.44	27.6	473.09	368.8	437.64	341.2	459.73	358.4	424.29	330.8
16	**Gresik Regency**	105.6	11.26	106.6	0.38	3.6	**-10.88**	**-103.0**	5.89	55.7	**-5.38**	**-50.9**
	Total	11363.1	799.48	70.4	5842.63	514.2	5043.15	443.8	4931.28	434.0	4131.80	363.6

*1: Calculated using Model Area (km^2)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure 5.3.8 Distribution of Evaluated Remaining Groundwater Potential (2030)

3) 2050 Groundwater Potential

Three scenarios of groundwater potential in 2050 are estimated under climate change condition, which were selected by Team 1 based on nine Global Climate Models (GCMs). Groundwater potential in 2050 is evaluated using calibrated groundwater model with the same analytical condition as 2030 model except for constant head boundary (sea water level) and recharge data. Recharge data of three scenarios was provided from Team 1. The comparison of future groundwater potential and groundwater demand among three scenarios, and the estimations of future groundwater potential and remaining development potential are summarized in Table 5.3.23 and Table 5.3.24, respectively. The evaluation of medium scenario shows that remaining groundwater development potential of bold (red) five regencies/cities except for Gresik City in Table 5.3.23 are apparently sufficient for groundwater development from Table 5.3.24. However, in fact groundwater recharges are not enough and those five regencies/cities have to expect other groundwater resource such as inflow from surrounding areas via aquifer as groundwater or infiltration through riverbed.

Although groundwater recharge of medium scenario is smaller than that of low scenario, the total potential and remaining potential of medium scenario is larger than low scenario. Smaller variation of groundwater recharge of medium scenario in 20 years resulted in this inversion phenomenon of groundwater potential.

Detailed evaluation of medium scenario, which is base scenario under the climate change, with component of groundwater flow from simulation is shown in Table 5.3.25. The remaining groundwater potential of all regencies/cities except for Gresik Regency shows positive value. However, if groundwater inflow from surrounded regencies/cities and water infiltration through riverbed decrease, the potential may reduce and it cannot be denied the occurrence of problem in the use of groundwater.

Table 5.3.23 Groundwater Recharge and Groundwater Demand in the Brantas River Basin (2050)

No.	Regency / City	Model Area[*1] (km^2)	(A) Groundwater Demand (2050 = 2030)		High Scenario (2046-2065)				Medium Scenario (2046-2065)				Low Scenario (2046-2065)			
					(B1) Recharge		(B1) - (A)		(B2) Recharge		(B2) - (A)		(B3) Recharge		(B3) - (A)	
			($10^6 m^3/y$)	(mm/y)[*1]	($10^6 m^3/y$)	(mm/y)[*1]	($10^6 m^3/y$)	(mm/y)[*1]	($10^6 m^3/y$)	(mm/y)[*1]	($10^6 m^3/y$)	(mm/y)[*1]	($10^6 m^3/y$)	(mm/y)[*1]	($10^6 m^3/y$)	(mm/y)[*1]
1	Batu City	211.8	19.56	92.36	244.37	1154.1	224.82	1061.7	251.98	1190.0	232.42	1097.6	277.93	1312.52	258.37	1220.2
2	Malang Regency	2216.5	241.76	109.07	1217.43	549.2	975.67	440.2	1346.16	607.3	1104.40	498.3	1480.21	667.81	1238.46	558.7
3	**Malang City**	109.4	69.29	633.23	53.98	493.3	**-15.31**	**-139.9**	61.36	560.8	**-7.93**	**-72.4**	66.10	604.10	**-3.19**	**-29.1**
4	Kediri Regency	1521.0	78.33	51.50	569.43	374.4	491.09	322.9	538.95	354.3	460.62	302.8	698.21	459.05	619.88	407.5
5	Blitar Regency	1281.3	48.83	38.11	543.36	424.1	494.52	386.0	708.02	552.6	659.19	514.5	731.18	570.67	682.35	532.6
6	**Sidoarjo Regency**	690.4	40.46	58.60	29.68	43.0	**-10.78**	**-15.6**	25.57	37.0	**-14.88**	**-21.6**	38.61	55.92	**-1.85**	**-2.7**
7	Mojokerto Regency	899.4	48.22	53.62	310.47	345.2	262.25	291.6	274.09	304.8	225.87	251.1	393.47	437.50	345.25	383.9
8	Jombang Regency	1102.8	58.37	52.93	255.31	231.5	196.94	178.6	225.36	204.4	166.98	151.4	330.43	299.64	272.06	246.7
9	**Kediri City**	66.6	23.98	359.94	16.14	242.2	**-7.85**	**-117.8**	14.64	219.7	**-9.35**	**-140.3**	20.73	311.04	**-3.26**	**-48.9**
10	**Mojokerto City**	20.3	11.81	582.90	3.30	162.7	**-8.52**	**-420.2**	2.71	133.6	**-9.11**	**-449.3**	5.08	250.72	**-6.73**	**-332.2**
11	**Surabaya City**	237.5	34.85	146.71	4.27	18.0	**-30.58**	**-128.7**	3.89	16.4	**-30.96**	**-130.3**	4.22	17.78	**-30.63**	**-128.9**
12	Trenggalek Regency	632.3	31.15	49.26	126.36	199.8	95.21	150.6	133.57	211.2	102.42	162.0	180.30	285.14	149.15	235.9
13	**Blitar City**	33.4	10.65	318.29	9.00	269.2	**-1.64**	**-49.1**	15.28	456.8	4.63	138.5	16.86	503.98	6.21	185.7
14	Tulungagung Regency	951.9	35.51	37.30	253.57	266.4	218.06	229.1	257.54	270.5	222.03	233.2	334.67	351.57	299.16	314.3
15	Nganjuk Regency	1282.8	35.44	27.63	342.40	266.9	306.96	239.3	312.90	243.9	277.45	216.3	440.64	343.50	405.20	315.9
16	**Gresik Regency**	105.6	11.26	106.65	1.84	17.4	**-9.42**	**-89.2**	1.91	18.1	**-9.36**	**-88.6**	3.12	29.50	**-8.15**	**-77.2**
Total		11363.1	799.48	70.36	3980.90	350.3	3181.43	280.0	4173.92	367.3	3374.44	297.0	5021.76	441.94	4222.29	371.6

*1: Caliculated using Model Area (km^2)

Source: JICA Project Team 2

Table 5.3.24 Evaluation of Groundwater Potential in the Brantas River Basin (2050)

No.	Regency / City	Model Area*1 (km²)	(A) Groundwater Demand (2050 = 2030)		High Scenario (2046-2065) (C1) Total Potential		Remaining Potential (C1) - (A)		Medium Scenario (2046-2065) (C2) Total Potential		Remaining Potential (C2) - (A)		Low Scenario (2046-2065) (C3) Total Potential		Remaining Potential (C3) - (A)	
			($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1	($10^6m^3/y$)	(mm/y)*1
1	Batu City	211.8	19.56	92.36	145.89	689.0	126.33	596.6	162.75	768.6	143.19	676.2	154.89	731.47	135.33	639.1
2	Malang Regency	2216.5	241.76	109.07	1057.29	477.0	815.53	367.9	1309.67	590.9	1067.91	481.8	1191.74	537.66	949.98	428.6
3	Malang City	109.4	69.29	633.23	86.56	791.1	17.27	157.9	96.29	880.0	27.00	246.8	89.99	822.41	20.70	189.2
4	Kediri Regency	1521.0	78.33	51.50	799.58	525.7	721.25	474.2	848.29	557.7	769.95	506.2	888.35	584.06	810.02	532.6
5	Blitar Regency	1281.3	48.83	38.11	660.38	515.4	611.54	477.3	844.03	658.7	795.20	620.6	745.88	582.14	697.05	544.0
6	Sidoarjo Regency	690.4	40.46	58.60	88.44	128.1	47.98	69.5	93.72	135.7	53.26	77.1	105.76	153.19	65.31	94.6
7	Mojokerto Regency	899.4	48.22	53.62	433.30	481.8	385.08	428.2	460.74	512.3	412.52	458.7	487.39	541.93	439.17	488.3
8	Jombang Regency	1102.8	58.37	52.93	303.63	275.3	245.26	222.4	324.47	294.2	266.10	241.3	381.98	346.39	323.61	293.5
9	Kediri City	66.6	23.98	359.94	130.83	1963.5	106.85	1603.5	131.95	1980.2	107.96	1620.2	134.40	2016.98	110.42	1657.0
10	Mojokerto City	20.3	11.81	582.90	40.29	1988.2	28.48	1405.3	40.54	2000.5	28.73	1417.6	41.77	2061.31	29.96	1478.4
11	Surabaya City	237.5	34.85	146.71	40.32	169.8	5.48	23.1	41.18	173.4	6.33	26.7	42.40	178.51	7.55	31.8
12	Trenggalek Regency	632.3	31.15	49.26	43.17	68.3	12.02	19.0	81.36	128.7	50.21	79.4	57.39	90.76	26.24	41.5
13	Blitar City	33.4	10.65	318.29	65.19	1949.1	54.54	1630.8	68.70	2054.1	58.05	1735.8	66.94	2001.58	56.30	1683.3
14	Tulungagung Regency	951.9	35.51	37.30	224.88	236.2	189.37	198.9	301.06	316.3	265.55	279.0	233.84	245.65	198.33	208.3
15	Nganjuk Regency	1282.8	35.44	27.63	409.44	319.2	374.00	291.5	430.30	335.4	394.86	307.8	472.43	368.28	436.99	340.6
16	**Gresik Regency**	105.6	11.26	106.65	7.58	71.8	**-3.68**	**-34.9**	7.98	75.6	**-3.28**	**-31.1**	9.64	91.30	**-1.62**	**-15.3**
	Total	11363.1	799.48	70.36	4536.77	399.3	3737.30	328.9	5243.03	461.4	4443.55	391.1	5104.81	449.24	4305.33	378.9

*1: Caliculated using Model Area (km²)

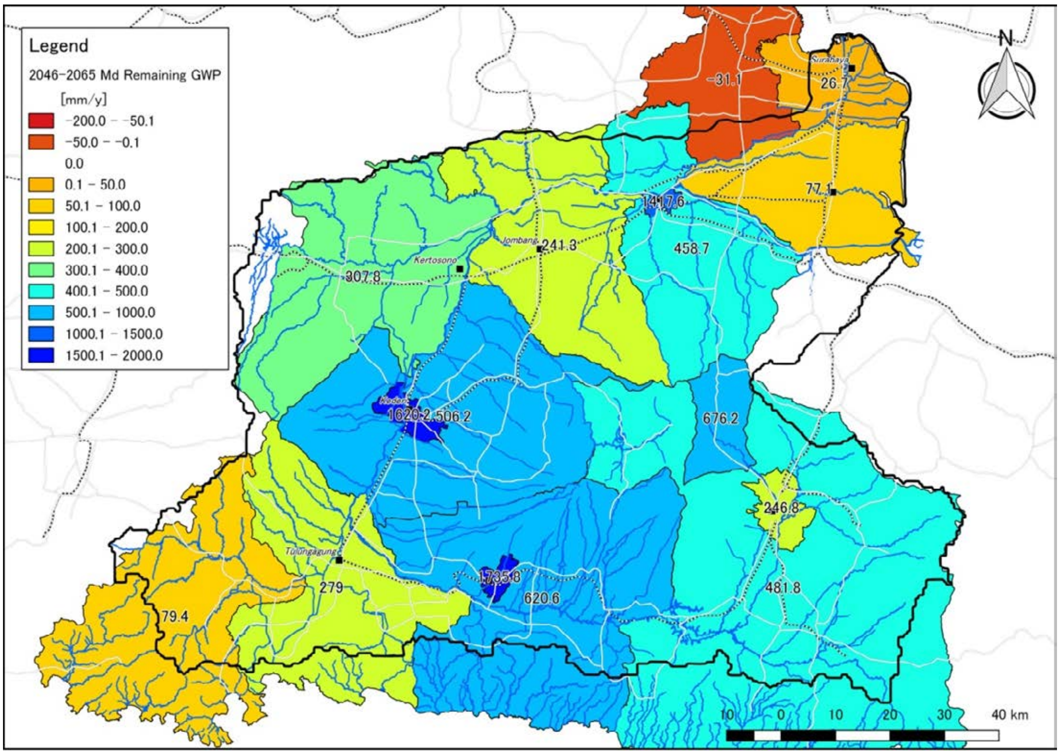
Source: JICA Project Team 2

Table 5.3.25 Detailed Evaluation with Component of Groundwater Flow (Medium Scenario)

No.	Regency / City	Model Area*1 (km²)	(A) Groundwater Demand (2050 = 2030)		(C) Total Potential (2046-2065Md)		(C) - (A) Remaining Potential 1		(D) Groundwater Inflow from Other District/City		(C) - (A) - (D) Remaining Potential 2		(E) Groundwater Inflow from River (2046-2065Md)		(C) - (A) - (D) - (E) Remaining Potential 3	
			(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1	(Mm^3/y)	(mm/y)*1
1	Batu City	211.8	19.56	92.36	162.75	768.6	143.19	676.2	1.33	6.3	141.86	669.9	0.63	3.0	141.23	667.0
2	Malang Regency	2216.5	241.76	109.07	1309.67	590.9	1067.91	481.8	56.08	25.3	1011.83	456.5	99.26	44.8	912.57	411.7
3	Malang City	109.4	69.29	633.23	96.29	880.0	27.00	246.8	35.21	321.8	**-8.21**	**-75.0**	5.16	47.2	**-13.37**	**-122.2**
4	Kediri Regency	1521.0	78.33	51.50	848.29	557.7	769.95	506.2	126.68	83.3	643.27	422.9	234.40	154.1	408.88	268.8
5	Blitar Regency	1281.3	48.83	38.11	844.03	658.7	795.20	620.6	84.56	66.0	710.64	554.6	145.37	113.5	565.26	441.2
6	**Sidoarjo Regency**	690.4	40.46	58.60	93.72	135.7	53.26	77.1	29.66	43.0	23.60	34.2	29.49	42.7	**-5.89**	**-8.5**
7	Mojokerto Regency	899.4	48.22	53.62	460.74	512.3	412.52	458.7	27.07	30.1	385.45	428.6	183.76	204.3	201.69	224.3
8	Jombang Regency	1102.8	58.37	52.93	324.47	294.2	266.10	241.3	58.42	53.0	207.68	188.3	26.18	23.7	181.50	164.6
9	Kediri City	66.6	23.98	359.94	131.95	1980.2	107.96	1620.2	104.06	1561.6	3.91	58.6	10.53	158.1	**-6.63**	**-99.5**
10	Mojokerto City	20.3	11.81	582.90	40.54	2000.5	28.73	1417.6	35.64	1758.8	**-6.91**	**-341.2**	1.04	51.4	**-7.96**	**-392.6**
11	**Surabaya City**	237.5	34.85	146.71	41.18	173.4	6.33	26.7	1.63	6.9	4.70	19.8	36.08	151.9	**-31.37**	**-132.1**
12	Trenggalek Regency	632.3	31.15	49.26	81.36	128.7	50.21	79.4	3.03	4.8	47.18	74.6	20.62	32.6	26.56	42.0
13	Blitar City	33.4	10.65	318.29	68.70	2054.1	58.05	1735.8	53.18	1590.1	4.87	145.7	3.44	102.8	1.44	43.0
14	Tulungagung Regency	951.9	35.51	37.30	301.06	316.3	265.55	279.0	26.78	28.1	238.77	250.8	28.40	29.8	210.36	221.0
15	Nganjuk Regency	1282.8	35.44	27.63	430.30	335.4	394.86	307.8	101.70	79.3	293.16	228.5	41.22	32.1	251.94	196.4
16	**Gresik Regency**	105.6	11.26	106.65	7.98	75.6	**-3.28**	**-31.1**	1.73	16.3	**-5.01**	**-47.4**	3.92	37.1	**-8.93**	**-84.5**
	Total	11363.1	799.48	70.36	5243.03	461.4	4443.55	391.1	746.78	65.7	3696.78	325.3	869.50	76.5	2827.28	248.8

*1: Caliculated using Model Area (km²)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure 5.3.9 Distribution of Evaluated Groundwater Potential (2050) (Medium Scenario)

4) Evaluation and Additional Groundwater Development Potential for Each Scenarios

(a) Evaluation Method

The remaining groundwater potential can be read as groundwater potential which can be developed. However, additional groundwater development can be considered based on region-specific constraints and careful investigation is needed before development. Examples of region-specific constraints are as follows: hydrogeological distribution, to ensure river discharge for maintenance, protection of springs as water source, to keep water level in specific well, setting of appropriate pumping rate not to generate land subsidence; groundwater demand as supplier for other regencies/cities; Additional groundwater development potential can be evaluated following formula under the constraints;

(Additional Groundwater Development Potential) =
(Hydrogeological Coefficient) x (Total Groundwater Potential)
- Groundwater Demand
- ∑ (Additional Groundwater Demand under the Constraints)

For more realistic evaluation, hydrogeological distribution, which is one of the main constraints expressed by a coefficient, was taken into consideration in this project. Detail information is explained in Supporting Report C. Possibility of additional groundwater development is evaluated using the standards as shown in Table 5.3.26. Threshold of 100mm/year for "Modified Remaining Groundwater Potential – Additional Groundwater Demand as Water Supplier for Other Regencies/Cities" is a temporary value including other constraints.

Table 5.3.26 Evaluation Standard for Additional Groundwater Development Potential

Symbol	Additional Groundwater Development	Average Recharge – Groundwater Demand	Modified Remaining Groundwater Potential[*1] – Additional Groundwater Demand as Water Supplier for Other Cities / Regencies
A	Possible	Plus	More than 100mm/y
B	Partially possible	Plus	Groundwater supplier to other area or less than 100mm/y
C	Impossible	Minus	Minus

Note: *1: (Hydrogeological Coefficient) x (Total Groundwater Potential)-Groundwater Demand

Source: JICA Project Team 2

(b) Results of the Evaluation

The final evaluation and additional groundwater development potential for each scenario are shown in Table 5.3.27. Although the average groundwater recharge of medium scenario is smaller than that of low scenario, the additional groundwater development potential of medium scenario in some regencies/cities is larger than that of low scenario. The same tendency can be confirmed between high scenario and medium scenario. Thus, the scenario analysis includes the uncertainty that the High scenario is not necessarily the minimum groundwater potential evaluation.

Based on the above, points to be noted in groundwater development for regencies/cities are shown in Table 5.3.28.

Table 5.3.27 Evaluation and Additional Groundwater Development Potential for Each Scenario

No.	Regency / City	Model Area (km^2)	Hydro-geological Coefficient	Evaluation			Additional Groundwater Development Potential (10^6 m^3/y)		
				Medium	High	Low	Medium	High	Low
1	Batu City	211.8	0.20	B	B	B	13.26	9.86	11.67
2	Malang Regency	2,216.5	0.47	B	B	B	365.35	239.44	314.70
3	Malang City	109.4	0.74	C	C	C	—	—	—
4	Kediri Regency	1,521.0	0.69	B	B	B	497.54	463.94	531.27
5	Blitar Regency	1,281.3	0.50	A	B	A	374.70	280.90	325.45
6	Sidoarjo Regency	690.4	0.59	C	C	C	—	—	—
7	Mojokerto Regency	899.4	0.63	B	B	B	233.74	216.40	252.95
8	Jombang Regency	1,102.8	0.58	A	A	A	128.92	116.89	162.12
9	Kediri City	66.6	0.85	C	C	C	—	—	—
10	Mojokerto City	20.3	0.84	C	C	C	—	—	—
11	Surabaya City	237.5	0.47	C	C	C	—	—	—
12	Trenggalek Regency	632.3	0.08	C	C	C	—	—	—
13	Blitar City	33.4	0.78	A	C	A	42.65	—	41.29
14	Tulungagung Regency	951.9	0.48	B	B	B	108.59	72.13	76.42
15	Nganjuk Regency	1,282.8	0.51	A	A	A	184.64	173.97	206.18
16	Gresik Regency	105.6	0.31	C	C	C	—	—	—
Total		11,363.1					1949.39	1537.54	1,922.06

Source: JICA Project Team 2

Table 5.3.28 Points to be Noted in Groundwater Development

No.	Regency / City	Note
1	Batu City	Brantas River headwaters area. Groundwater development area is limited to the plains in valleys.
2	Malang Regency	Supply the groundwater to Malang City through aquifer and river runoff. Groundwater development area is limited to the plains in valley.
3	Malang City	Depend on the groundwater flow from the Malang Regency.
4	Kediri Regency	Supply the groundwater for Kediri City through aquifer and river runoff. Productive aquifer is distributed. A number of wells already exist. There are many springs in the mountainous region.
5	Blitar Regency	Groundwater demand is small.
6	Sidoarjo Regency	Groundwater development along the coastal areas bring a possibility that the salt water intrusion occurs.
7	Mojokerto Regency	Supply the groundwater for Mojokerto City through groundwater flow and river runoff.
8	Jombang Regency	Productive aquifer is distributed. A number of well already exist.
9	Kediri City	Depends on the groundwater flow from the Kediri Regency.
10	Mojokerto City	Depends on the groundwater inflow from the Mojokerto Regency.
11	Surabaya City	Small amount of groundwater recharge and low probability of groundwater inflow from surrounding municipalities. Risk for saltwater intrusion is relatively high.
12	Trenggalek Regency	Low groundwater potential due to volcanic rock distribution area. Possible development area is limited to the plain in valley.
13	Blitar City	Large amounts of groundwater inflow from Blitar Regency.
14	Tulungagung Regency	Aquifer is developed and a lot of wells exist.
15	Nganjuk Regency	Productive aquifer is distributed. A number of wells already exist.
16	Gresik Regency	Small amount of groundwater recharge and small expectation of groundwater inflow from surrounding municipalities.

Source: JICA Project Team 2

Conclusion and remarks of this groundwater simulation study are as follows:

- Malang City, Sidoarjo Regency, Kediri City, Mojokerto City, Surabaya City, Trenggalek Regency and Gresik Regency are having difficulty in developing additional groundwater resource under the climate change environment because of the large amount of groundwater demand and the region-specific constraints.
- Batu City, Malang Regency, Kediri Regency, and Mojokerto Regency are able to develop some additional groundwater resources under the region-specific constraints.
- Blitar Regency, Jombang Regency, Blitar City, Tulungagung Regency, and Nganjuk Regency have enough potential to be able to develop additional groundwater resources under the region-specific constraints.
- It is strongly recommended to conduct sufficient investigation and analysis before additional groundwater development in order to manage groundwater resource in the Brantas River basin properly and integrally, and make effective use of valuable groundwater resource.

The groundwater model has been calibrated only under the 26 calibration targets and hydrogeological information has been very much limited. Therefore, the evaluation of groundwater potential using this model entails a lot of uncertainty. To improve the accuracy of calculation, it is important to collect further information of hydrogeology and groundwater data including continuous groundwater level observation.

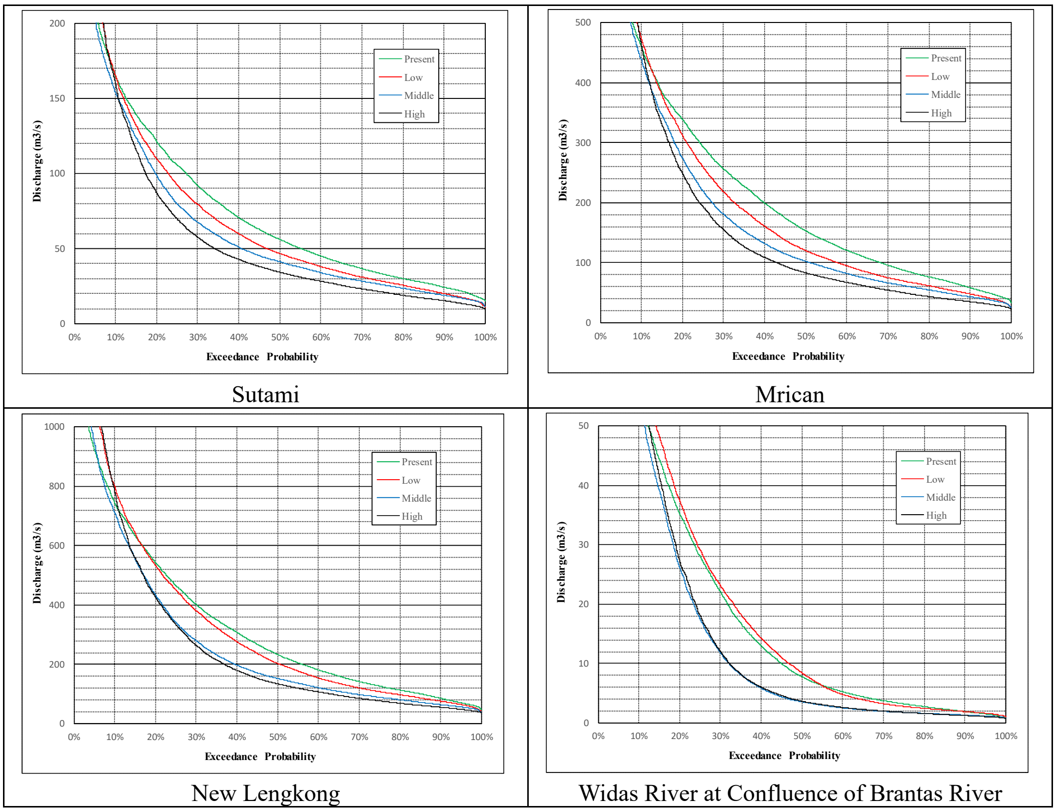
5.3.3 Surface Water Use

(1) Flow Regime

Team 1 estimated the future surface flow of the Brantas River and its tributaries from 2046 to 2065 by Water and Energy Budget based Distribution Hydrological Model (WEB-DHM) prepared by the Tokyo University based on the selected three GCMs. Three scenarios based on the selected GCMs are as follows; low, medium and high scenarios. The flow duration curves (FDCs) under the present climate and three scenarios are made for the Sutami Dam, the Mrican Barrage, the New Lengkong Dam sites and Widas River at confluence point as shown in Figure 5.3.10. Figure 5.3.11 to Figure 5.3.14 show the sequence of discharge at four locations.

As shown in Figure 5.3.10, all FDCs of future climates are lower than that of the present in the range in low flow, which is below 10% of exceedance probability in percentage. As it is indicated by the name, high scenario is the lowest in the lower flow. While the low scenario is positioned at the highest among the three scenarios but it is still lower than the present climate.

However, the discharge of low scenario sometimes become the lowest value among three cases during the dry season as shown in Figure 5.3.13.



Source: JICA Project Team 1

Figure 5.3.10 Flow Duration Curves at Sutami Dam, Mrican Barrage, New Lengkong Dam and Widas River for Present and Three Scenarios

(2) Methodology

1) Flow of Water Balance Analysis

The network flow model is established based on the water allocation plan of the Brantas River basin. Then, the network flow model is calibrated with actual stream flow record, so that the model correctly reproduces the flow regime of the Brantas River basin. After the calibration of the model, the model data such as planned water demand, natural stream flow from watersheds estimated by Team 1 are inputted into the model, and those values vary dependent on the assumed year, development scenarios, and climate conditions. The type of water demands includes irrigation, domestic and industrial water supply and hydropower operation. The flow of the water balance analysis for the Brantas River basin is shown in Figure 5.3.15. The locations of existing dams, intake facilities, and irrigation intake locations are also shown in Figure 5.3.16.

The flow diagram of the Brantas River basin is shown in Figure 5.3.17 and Figure 5.3.18.

2) Priority of Water Demand

Priority of the demand is set as follows based on PP No.121, 2015:

1. Municipal water
2. Irrigation water
3. Industrial water
4. Hydropower

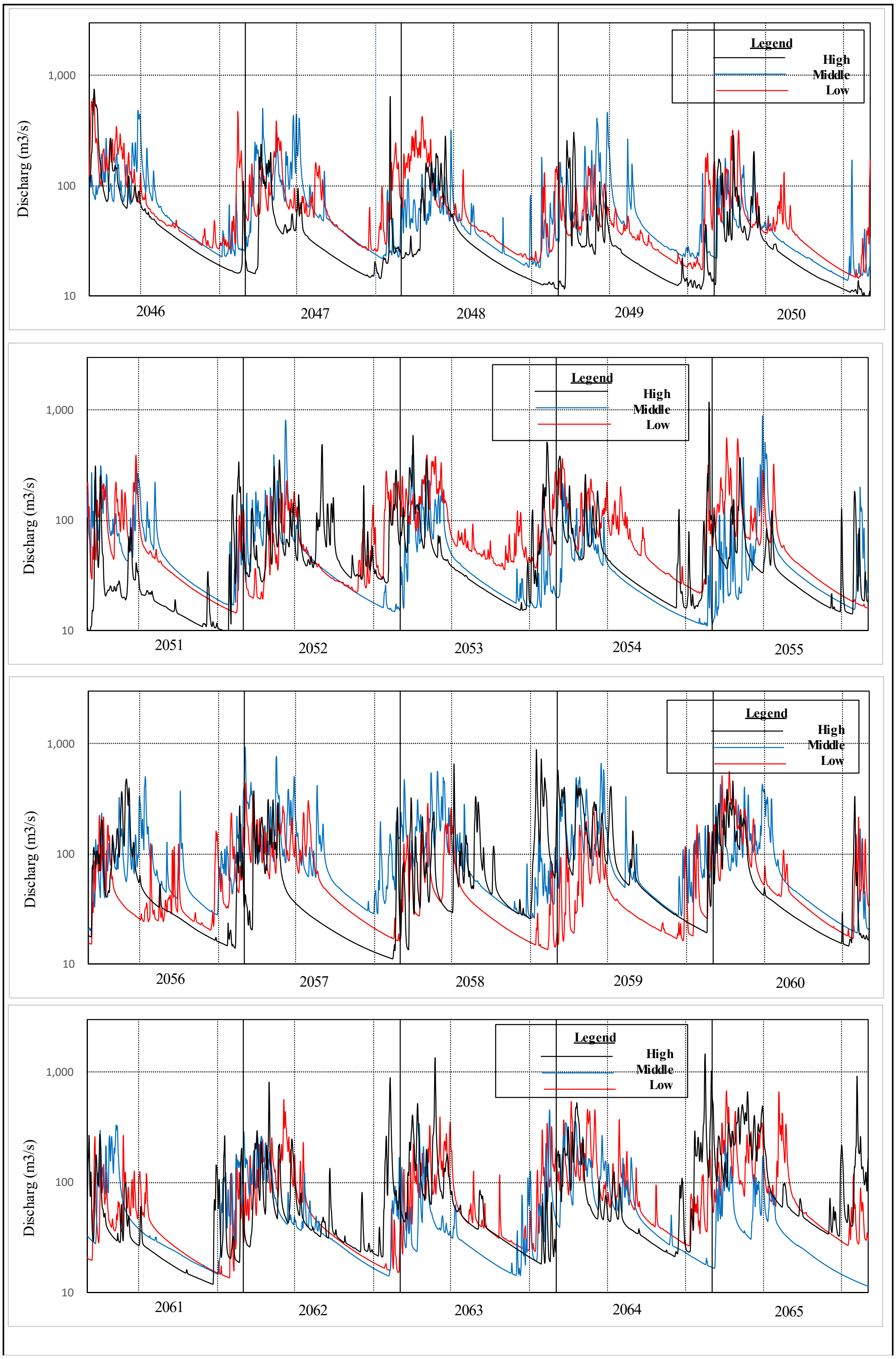
3) Environmental Flow

The environmental flow is a minimum flow rate of the river that enables to sustain the ecosystem soundness and human livelihood along the river. In Indonesia, the environmental flow is required to keep higher discharge than 95% discharge of the flow duration. Table 5.3.29 shows the environmental flow at three locations.

Table 5.3.29 Assigned Environmental Flow at Sutami, Mrican and New Lengkong

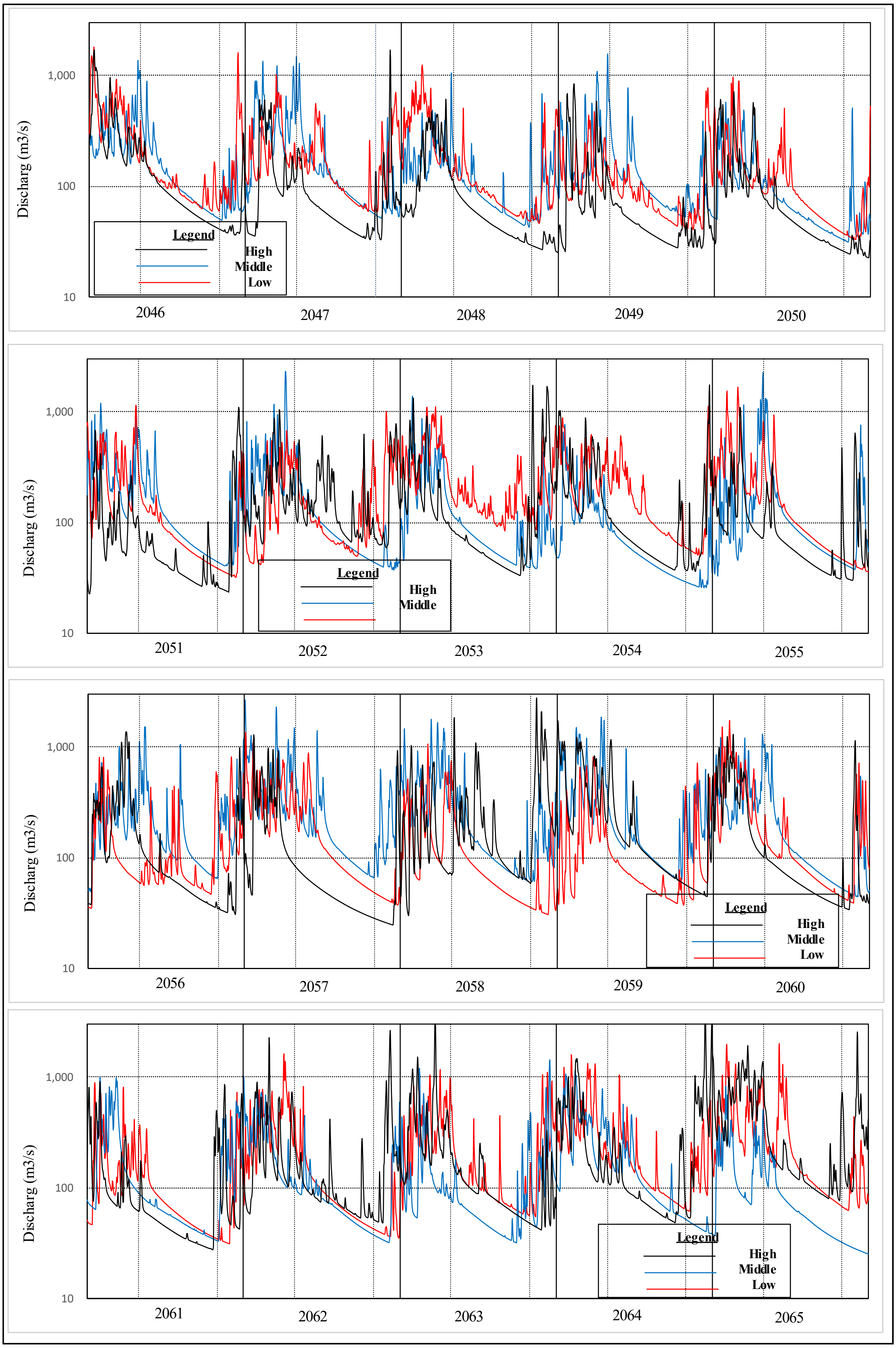
Assigned Location	Sutami Dam	Mrican Barrage	New Lengkong Dam
Env. Flow (m^3/s)	29.9	54.1	32.1

Source: JICA Project Team 2



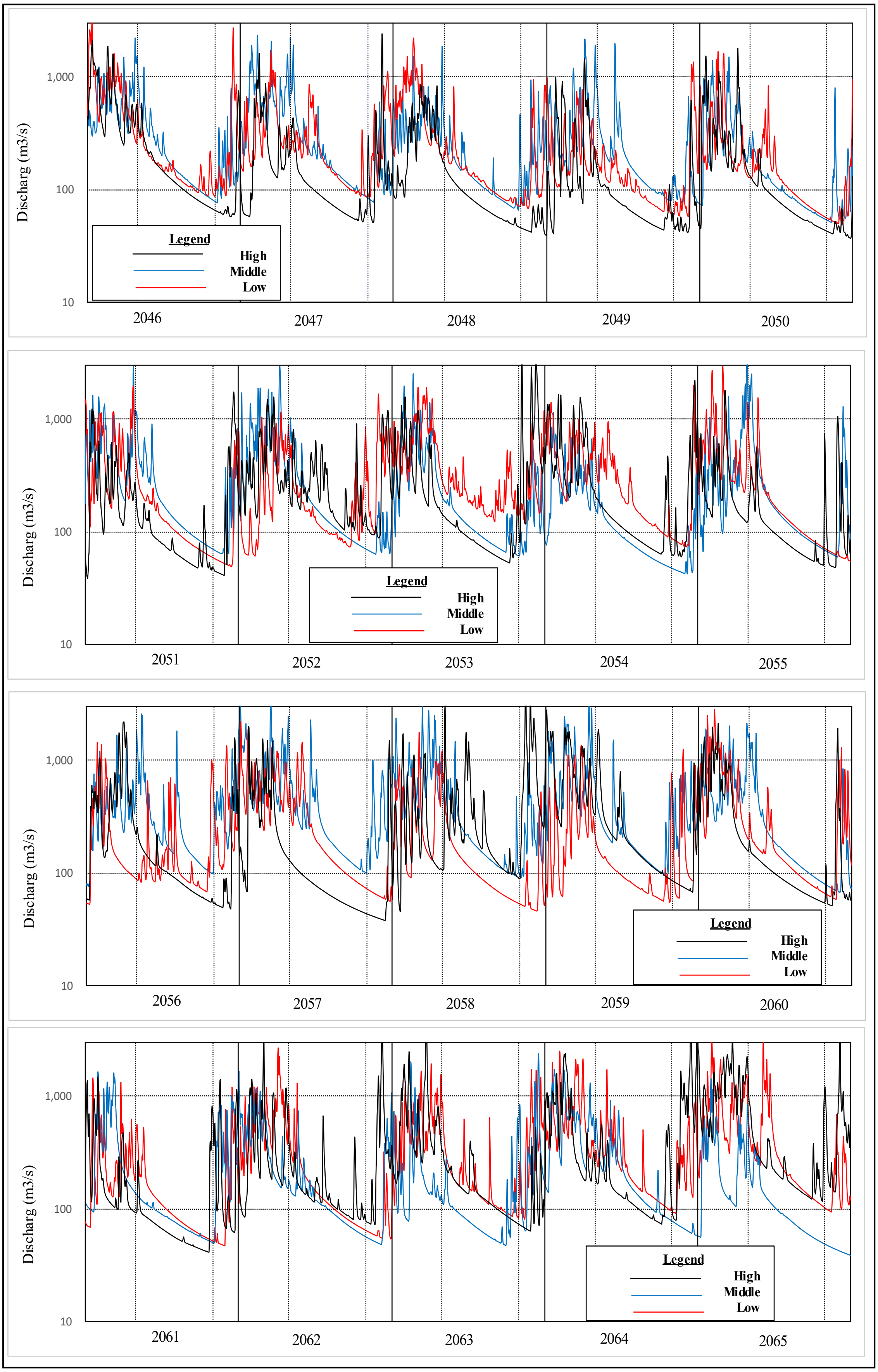
Source: JICA Project Team 2 prepared based on Data from JICA Project Team 1

Figure 5.3.11 Sequence of Discharge Data at Sutami Dam under Future Condition



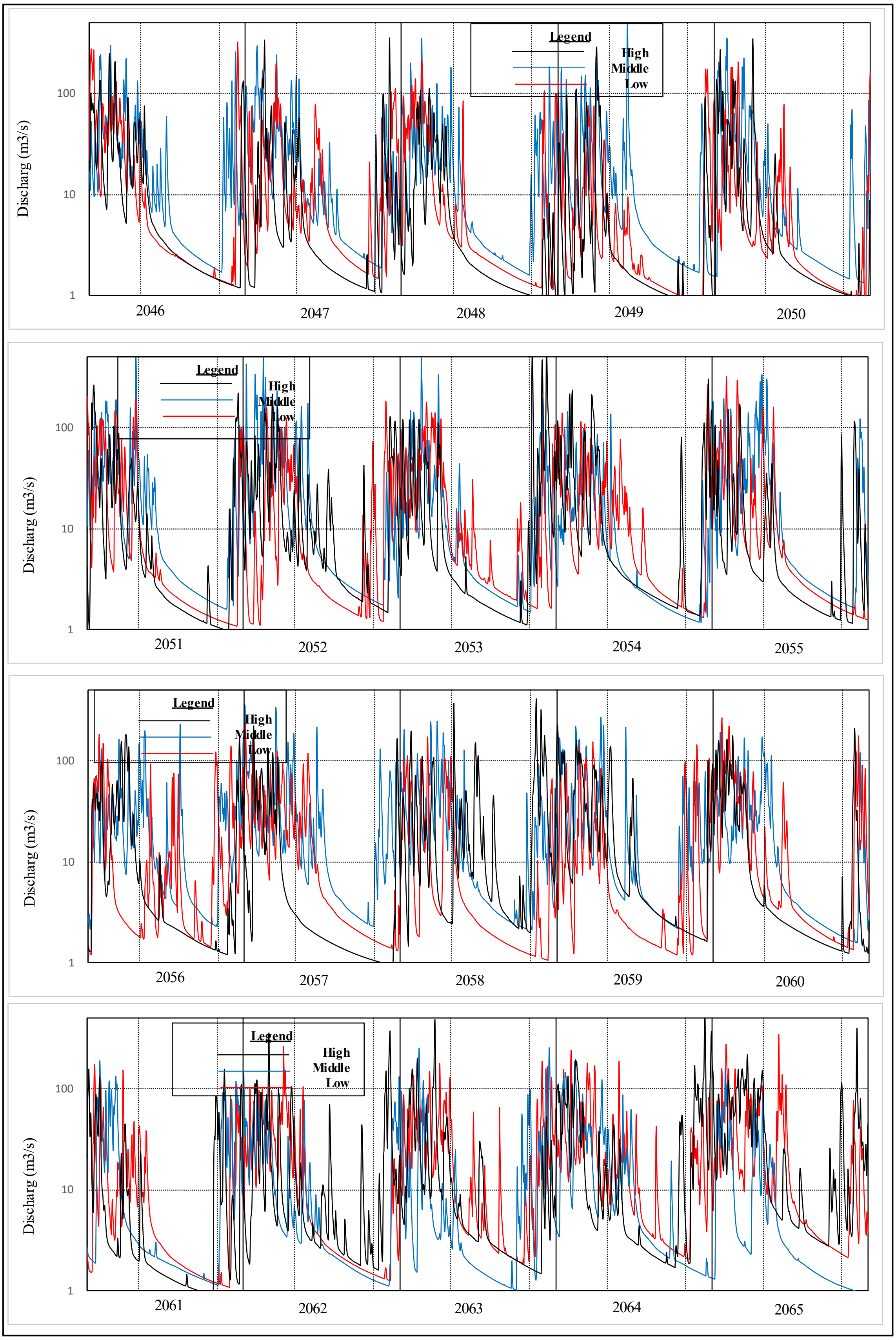
Source: JICA Project Team 2 prepared based on Data from JICA Project Team 1

Figure 5.3.12 Sequence of Discharge Data at Mrican Barrage under Future Condition



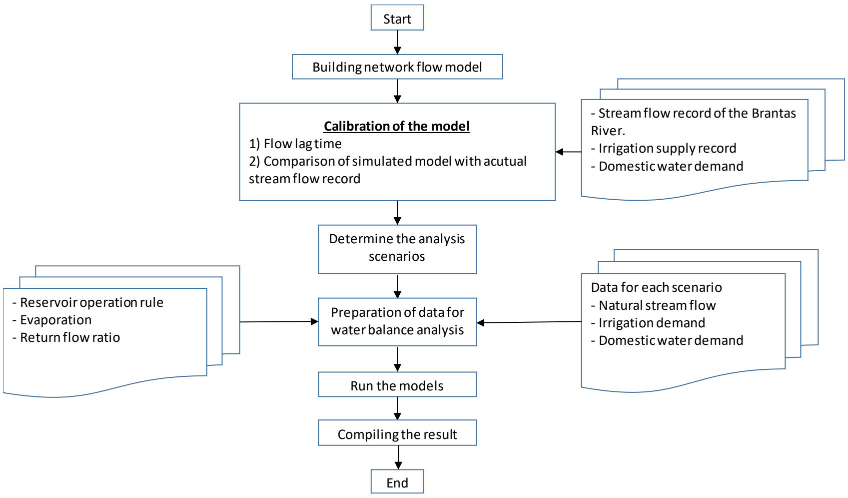
Source: JICA Project Team 2 prepared based on Data from JICA Project Team 1

Figure 5.3.13 Sequence of Discharge Data at New Lengkong Dam under Future Condition



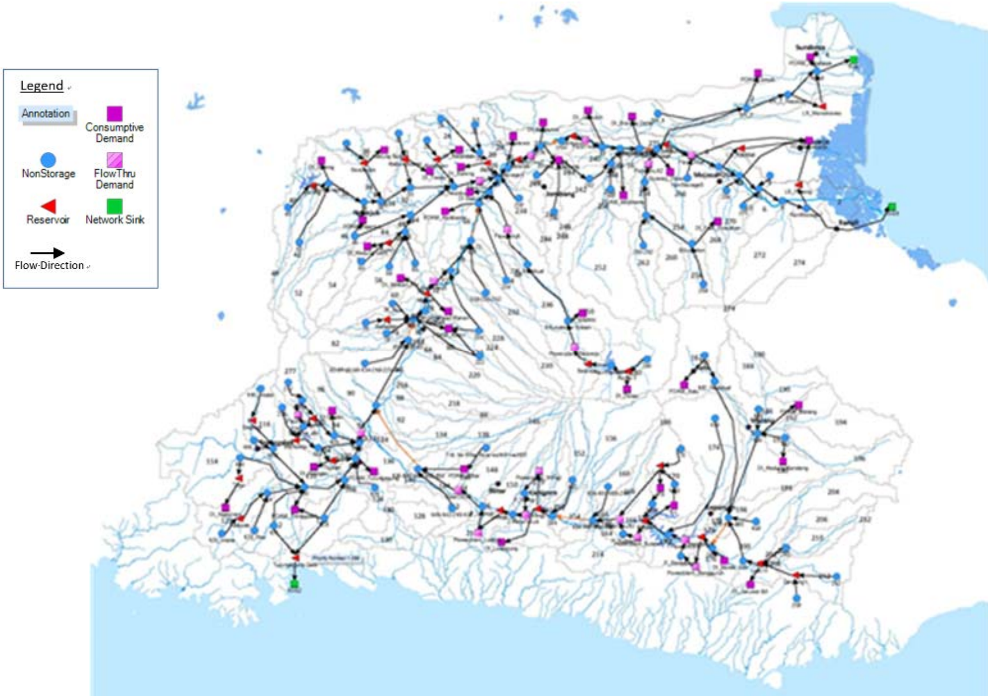
Source: JICA Project Team 2 prepared based on Data from JICA Project Team 1

Figure 5.3.14 Sequence of Discharge Data of the Widas River at Confluence of the Brantas River under Future Condition



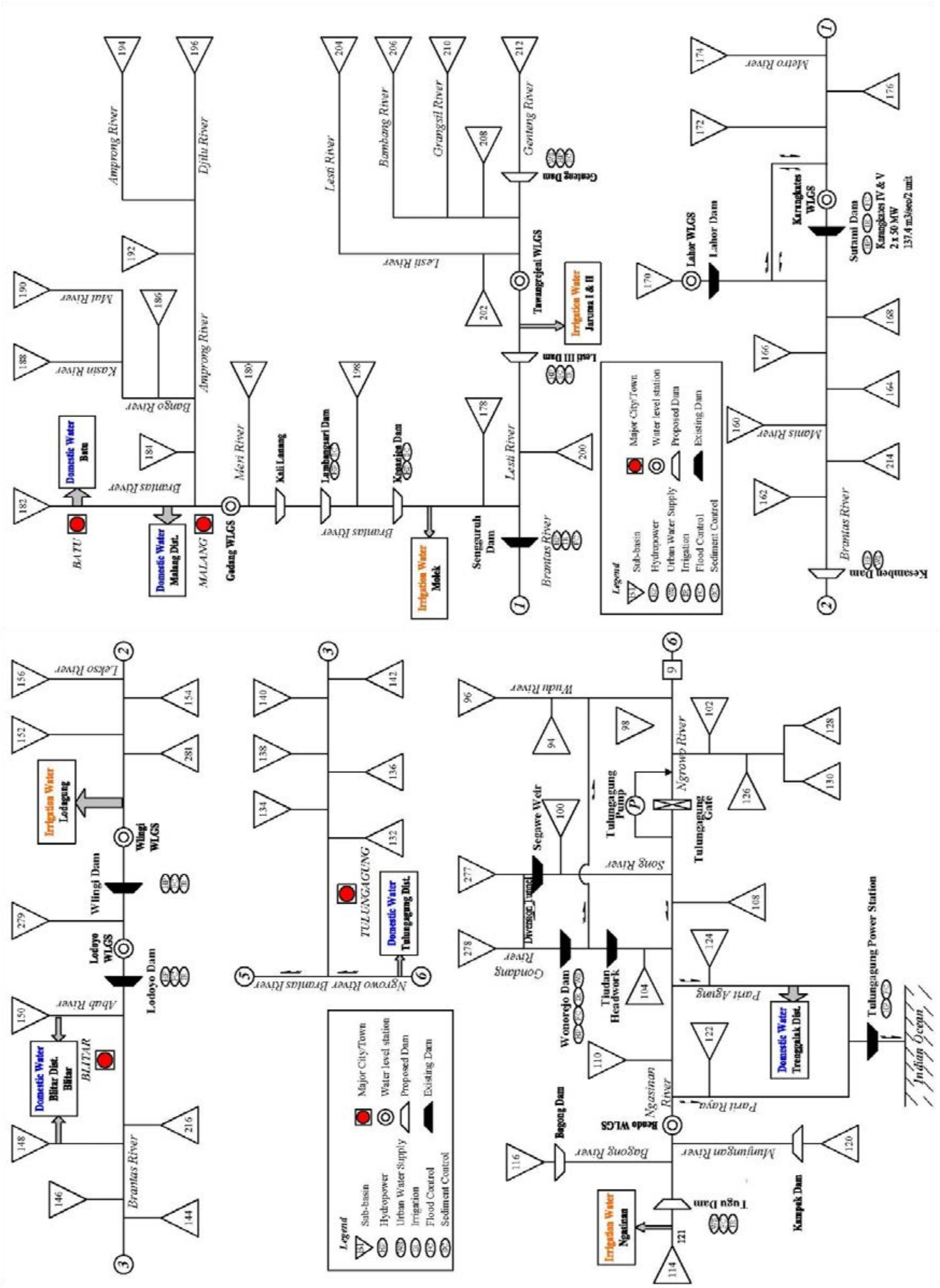
Source: JICA Project Team 2

Figure 5.3.15 Analysis Flow of the Water Balance Analysis of the Brantas River Basin



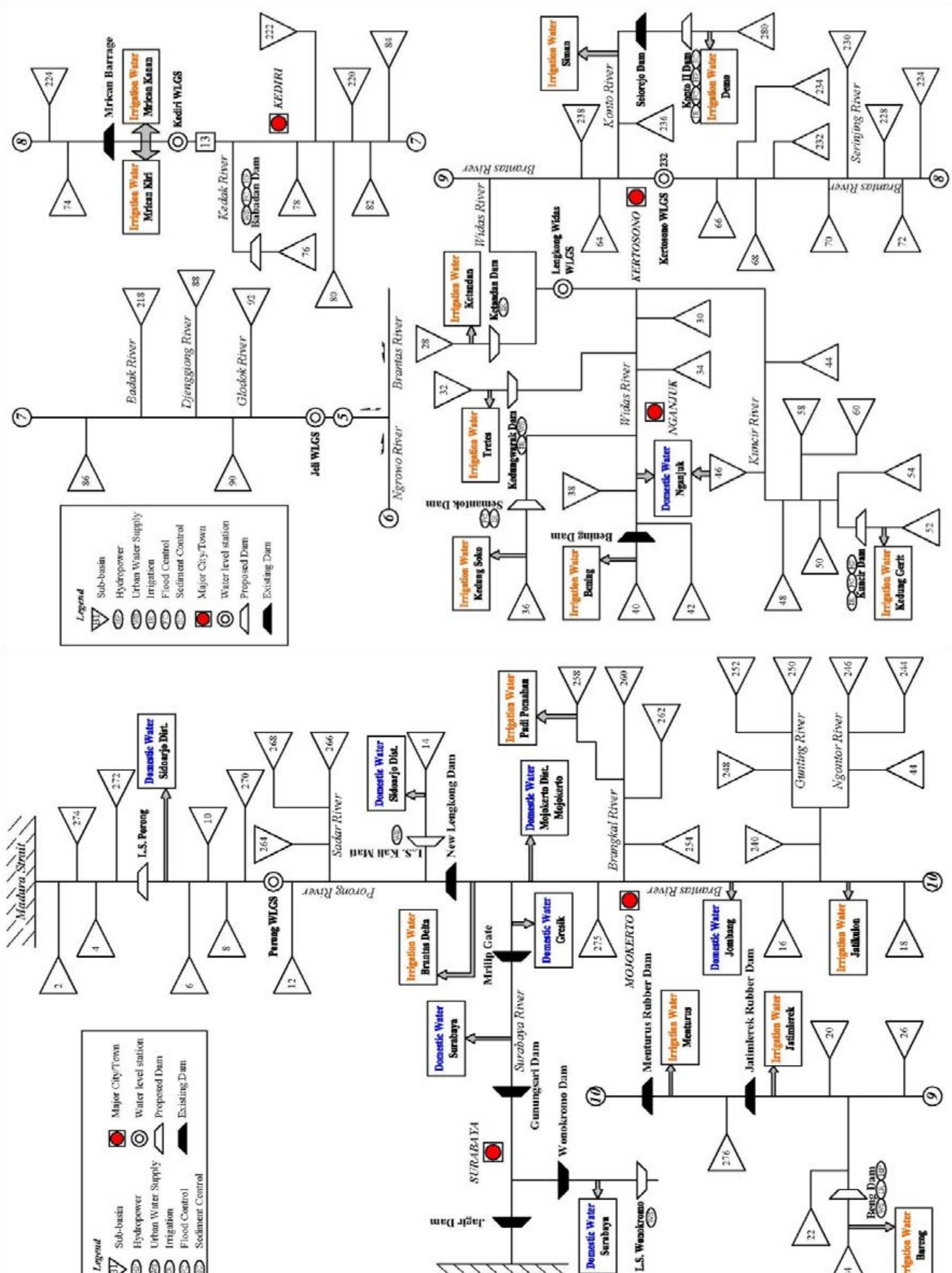
Source: JICA Project Team 2

Figure 5.3.16 Water Balance Simulation Model of the Brantas River Basin



Source: JICA Project Team 2

Figure 5.3.17 Basin Diagram in the Brantas River Basin for Water Balance (1/2)



Source: JICA Project Team 2

Figure 5.3.18 Basin Diagram in the Brantas River Basin for Water Balance (2/2)

(3) Planned Storage Structures until 2030

The concept of water resources development until 2030 in Review POLA 2015 (Draft) has been revised from POLA 2010. The list of dam structures is changed, and the list of ponds, development plan of ponds and long storage structures are added to the Review POLA 2015 (Draft).

Table 5.3.30 shows the list of dams, ponds, and long storage structures.

Table 5.3.30 List of Existing and Planned Storage Structures until 2030

No.	Name	Status	Storage Volume (mil. m^3)
Dam			
1	Sengguruh Dam	Existing	135.43
2	Sutami Dam	Existing	24.52
3	Lahor Dam	Existing	2.05
4	Wlingi Dam	Existing	2.37
5	Lodoyo Dam	Existing	33.32
6	Selorejo Dam	Existing	25.44
7	Bening Dam	Existing	97.09
8	Wonorejo Dam	Existing	135.43
9	Tugu Dam	Under Construction	21.2
10	Lesti III Dam	Planned	4.0
11	Bagong Dam	Planned	5.0
12	Semantok Dam	Planned	40
13	Beng Dam	Planned	147
Long Storage			
1	L/S Porong	Planned	8
2	L/S Kali Mati	Planned	1.5
3	L/S Wonokromo	Planned	2
Pond			
1	77 existing ponds	Existing	0.5 x 77
2	2 nos./Regency/Year	Planned	9/year

Source: Review POLA 2015 (Draft)

1) Proposed Dams

In Review POLA 2015 (Draft), there are five dams to be constructed in the Brantas River basin until 2030, which are:

By Year 2020: Tugu Dam, Lesti III Dam,

By Year 2025: Bagong Dam, Semantok Dam, and

By Year 2030: Beng Dam.

The locations of the above five proposed dams are shown in Figure 5.3.18. The present status of the five dams was updated through an interview survey with BBWS Brantas as shown in Table 5.3.31.

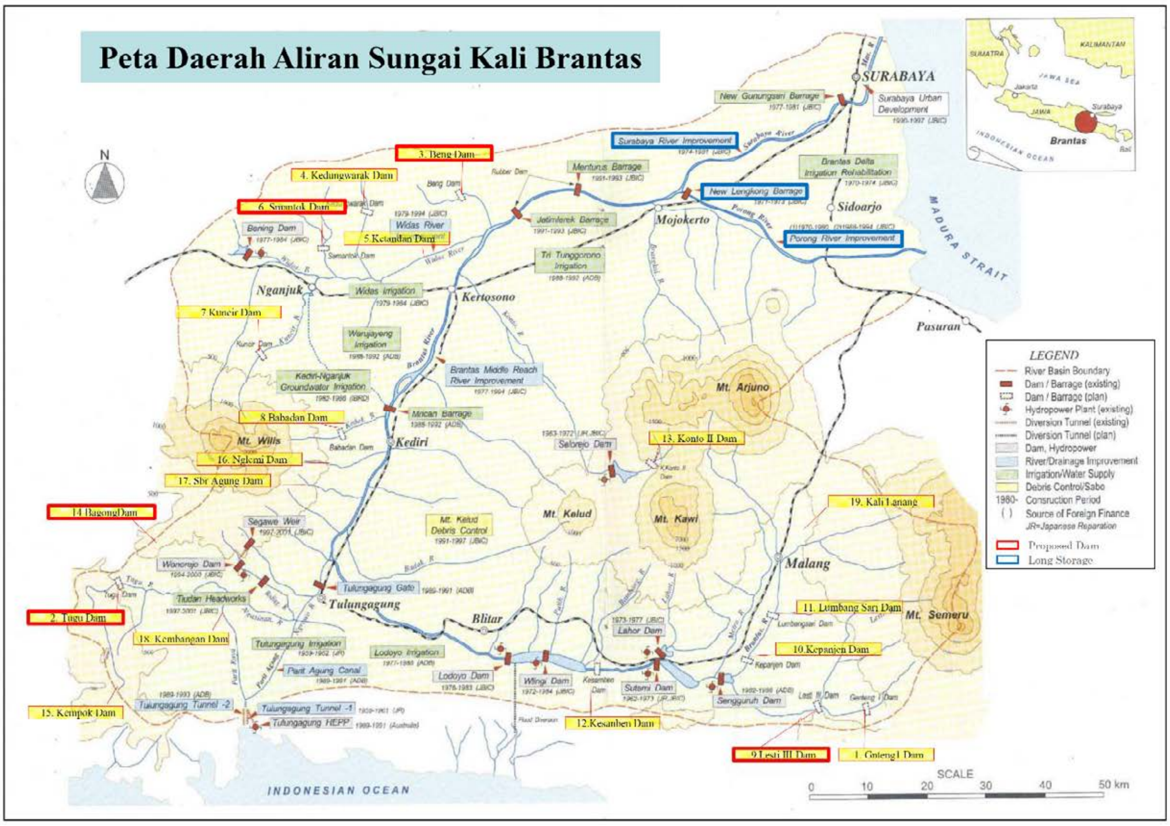
Table 5.3.31 Status of Proposed Dams in the Brantas River Basin as of September 2016

No.	Name of Dam	River /Location	Effective Storage Volume (Mil. m^3)	Purpose	Updated information based on interview with BBWS Brantas as of September 2016
1	Tugu	Keser River Kab. Trenggalek	7.8	FC, IR, WS	One of the three priority dams in BBWS Brantas. The construction works is on-going and will be completed after 2017. Since there are geotechnical problems in the construction site, review on design of spillway is being undertaken. There are some land acquisition problems.
2	Lesti III	Lesti River Kab. Malang	7.4	IR, HP, SC	Detailed Design (D/D) review and additional geological investigation were made in 2014. Environmental Impact Assessment (*Analisis Mengenai Dampak Lingkungan*: AMDAL) was finished. Budget allocation is being await. Land acquisition of the project is to be started soon.
3	Bagong	Bagong River Kab. Trenggalek	13.5	FC, IR	One of the three priority dams in BBWS Brantas. The Survey, Investigation and Design (SID) was conducted in April 2014. Design certification was issued. Land acquisition as started in 2015. The construction works will be started in 2017/2018. There is budget problem.
4	Semantok	Semantok River Kab.Nganjuk	8.3	FC, IR, HP	One of the three priority dams in BBWS Brantas. SID was conducted in May 2013. The design has been almost finished. The project continues up to the construction phase. Regarding the dam location, two alternatives of upstream and downstream sites are being discussed with the local government.
5	Beng	Beng River	147.0	IR, HP,WS	F/S of Beng Multipurpose Dam Work was conducted in 2003. Social issues are arisen at present.

Note: WS: Urban water supply, IR: Irrigation, FC: Flood control, HP: Hydropower, SC: Sediment control
Source: JICA Project Team 2

2) Proposed Ponds

Information about the planned locations of new ponds are unavailable in Review POLA 2015 (Draft). However, the local governments of regencies have carried out new pond constructions. Even though the number of new pond constructions is planned to be two /year/ regency, the actual number of new ponds has been decided based on the annual budget by the local governments.



Source: JICA Project Team 2

Figure 5.3.19 Location Map of Proposed Dams and Long Storage Structures in the Brantas River Basin

3) Proposed Long Storage Structures

In Review POLA 2015 (Draft), there are three long storage structures to be constructed in the Brantas River basin until 2020. The locations of these long storages are shown in Figure 5.3.19.

However, a study report is available only for a Kali Mati long storage structure. The remaining two structures have not been studied yet. The storage volumes of the two long storages are roughly estimated in this Project.

The storage volumes of proposed long storage structures are assessed in Table 5.3.32. In addition, the detailed information and evaluation results of the three long storage structures are also compiled in Table 5.3.32.

Table 5.3.32 Assessment Results of Storage Volumes of Long Storage Structures Proposed in Review POLA 2015 (Draft)

No.	Name of Long Storage	Possible Storage Volume	NWL	LWL	Design Bed Level	Design Dike Level
		(m^3)	(El.m)	(El.m)	(El.m)	(El.m)
1	Wonokromo	309,000	3.10	2.60	-	4.10
2	Porong	2,410,000	7.40	3.10	2.10	8.90
3	Kali Mati					
3-1	Longstorage1	553,300			10.20	15.94
3-2	Longstorage2	597,200			9.70	15.15
3-3	Longstorage3	504,300				13.14
	Total of Kali Mati	1,654,800				

Source: For data of Kali Mati long storage, BBWS Brantas. For Porong and Wonokromo long storages, JICA Project Team 2

(4) Storage Reservoir Volume

As to the dam reservoirs, the decrease in effective storage capacity due to sedimentation is one of the big issues in the Brantas River basin. It is anticipated that a sediment yield will further increase due to more intensive rainfalls by climate change. The sediment yield mechanism is studied based on available data such as sedimentation records, land use, rainfall records, etc., and future sediment yields in the target year 2050 under climate change is estimated as stated hereunder.

1) Estimation of Future Sediment Inflow into Reservoirs

Increase in future sediment yield due to more intensive rainfalls by climate change is estimated by the following three methodologies.

- United Soil Loss Equation (USLE)
- Equation of Suspended Load
- Assessment of Erodible Rainfall Amount

The comparison of three methods is presented in Table 5.3.33.

Table 5.3.33 Estimation of Increase Rates in Future Sediment Yield

Method	Increase Rates of Future Sediment Yields to the Present Condition (α)		
	Future Climate Change Scenarios (2050)		
	Low	Medium	High
USLE	1.10	1.15	1.25
Suspended Load*	1.74	0.92	1.37
Erodible Rainfall (R>10mm/day)	1.02	0.96	1.05
Adopted	1.10	1.15	1.25

Note: *Recommendation Report on Countermeasures against Sediment Inflow to Wlingi Reservoir, 1990
Source: JICA Project Team 2

In this project, the increase rate of future annual sediment inflow derived from the USLE is adopted for each future scenario as a conservative value.

2) Estimation of Future Storage Reservoir Volumes

The future sediment inflow is estimated from the following formula (ref. Figure 5.3.20)

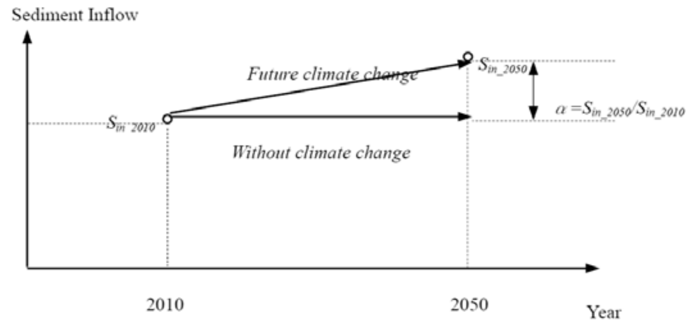
$S_{in\_2050} = \alpha \times S_{in\_2010}$

The simulation case for estimation of future dam reservoir sedimentation in each future climate scenario is summarized in Table 5.3.34.

Table 5.3.34 Case for Estimation of Future Dam Reservoir Sedimentation

Item	Present Climate	Future Climate Scenarios (2050)		
		Low	Medium	High
Annual Dam Inflow	Past average	Results of WEB-DHM run-off analysis		
Annual Dam Sediment Inflow	Past average	Increase by 1.10 time of present sediment inflow(α=1.10)	Increase by 1.15 time of present sediment inflow(α=1.15)	Increase by 1.25 time of present sediment inflow(α=125)

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure 5.3.20 Estimation of Future Dam Reservoir Sediment Inflow

Adopting the above-mentioned predicted annual sediment inflows; the future storage reservoir volume in the target year 2050 is estimated.

The predicted gross storage volumes of dam reservoirs in the Brantas River basin in 2030 and the target year of 2050 are presented in Table 5.3.35 and Table 5.3.36.

Table 5.3.35 Prediction of Gross Storage Volumes of Dam Reservoirs in 2030

Dam	Gross Storage under Present Climate	Future Climate Change Scenario (2050) unit: Million m^3		
		Low	Medium	High
Sengguruh Dam	1.38	1.35	1.34	1.32
Sutami Dam	140.80	140.73	140.70	140.63
Lahor Dam	25.64	25.59	25.57	25.53
Wlingi Dam	4.36	4.35	4.34	4.32
Lodoyo Dam	0.67	0.67	0.67	0.67
Selorejo Dam	29.52	29.40	29.34	29.21
Wonorejo Dam	97.71	97.57	97.50	97.35
Bening Dam	24.81	24.77	24.75	24.70

Source: JICA Project Team 2

Table 5.3.36 Prediction of Gross Storage Volumes of Dam Reservoirs in 2050

Dam	Gross Storage under Present Climate	Future Climate Scenario (2050) unit: Million m^3		
		Low	Medium	High
Sengguruh Dam	1.39	1.31	1.28	1.21
Sutami Dam	119.37	119.03	118.86	118.50
Lahor Dam	21.46	21.24	21.13	20.89
Wlingi Dam	4.20	4.15	4.13	4.07
Lodoyo Dam	0.12	0.12	0.12	0.12
Selorejo Dam	23.18	22.57	22.25	21.60
Wonorejo Dam	87.71	87.08	86.75	86.08
Bening Dam	1.39	1.31	1.28	1.21

Source: JICA Project Team 2

(5) Water Balance Simulation

Water balance simulation is carried out for two cases, i.e., Case1: Full demand case and Case2: Considering safety level of water supply

The following scenarios are considered and simulated for Case 1 and 2 of the water balance simulation.

Table 5.3.37 Water Balance Study Scenario

Scenario	Assumed Year	Climate	Irrigation Area	Domestic Water Demand	Reservoir Sedimentation
Scenario 1	2015	Present	2015 Area	2015	2015
Scenario 2	2030	Present	2030 Area	2030	2030
Scenario 3	2050	Present*	2050 Area	2050	2050
Scenario 4	2050	2050 Medium	2050 Area	2050	2050
Scenario 5	2050	2050 Low	2050 Area	2050	2050
Scenario 6	2050	2050 High	2050 Area	2050	2050

Note: *Assuming there is no climate change occurring.
Source: JICA Project Team 2

1) Water Balance against Case 1

Each scenario is calculated to evaluate drought risk of Municipal and Industrial (M&I) water and irrigable cropped area through water balance simulation model.

Drought risk is evaluated to consider the following conditions:

- Cropping Intensity: 250% to all irrigation area
- D&I: Result of demand forecast
- Safety Level: Not considered

The results of the water balance are not considered to the safety level of water supply. Table 5.3.38 shows the second largest deficit for D&I water and Table 5.3.39 shows the fourth largest deficit crop area for irrigation water as a matter of convenience. Table 5.3.40 shows the annual power output from each power station.

Table 5.3.38 Second Largest Deficit of Municipal and Industrial Water Supply

No.	District/ Municipality	Deficit (Second Largest in 20 Years) (m^3/s)					
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Batu	0.00	0.00	0.00	0.00	0.00	0.00
2	Malang	0.00	0.00	0.00	0.00	0.00	0.68
3	Kediri	0.00	0.00	0.00	0.00	0.00	0.24
4	Blitar	0.00	0.00	0.46	0.57	0.58	0.64
5	Sidoarjo	0.00	0.00	0.00	0.00	0.00	0.00
6	Mojokerto	0.00	0.00	0.00	0.00	0.00	0.00
7	Jombang	0.00	0.00	0.00	0.00	0.00	0.09
8	Surabaya	0.00	0.00	0.00	0.00	0.00	0.00
9	Trenggalek	0.00	0.00	0.00	0.00	0.00	0.00
10	Tulungagung	0.00	0.00	0.00	0.00	0.00	0.00
11	Nganjuk	0.00	0.00	0.00	0.00	0.00	0.14
12	Gresik	0.00	0.00	0.00	0.00	0.00	0.63
Total		0.00	0.00	0.46	0.57	0.58	2.42
Demand		33.33	37.24	45.87	45.87	45.87	45.87

Source: JICA Project Team 2

Table 5.3.39 Fourth Largest Deficit of Cropped Area for Each Scenario

Irrigation District	Irrigation Area (ha)	Deficit of Cropped Area (Fourth Deficit in 20 Years) (ha)					
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Tributaries							
DI_Kedung kandang	5,160	0	0	0	357	86	683
DI_Molek	3,883	0	0	0	0	0	1,643
DI_Siman	23,060	15,502	15,505	15,511	16,890	14,361	27,072
DI_Bening	8,752	5,828	5,828	5,810	7,546	6,185	11,767
Di_Padi Pomahan	4,309	2,627	2,627	2,627	2,835	1,704	4,573
DI_Jaruma I&II	2,449	0	0	0	0	0	858
DI_Ngasinan	1,185	440	0	46	0	0	953
DI_Kedung Soko	700	440	0	0	591	0	850
DI_Bareng	800	132	0	0	0	0	815
Sub-total	50,298	24,969	23,960	23,948	28,219	22,336	49,214
Mainstream							
DI_Lodagung	12,217	0	0	0	0	0	6,108
DI_Mrican Kanan	17,612	0	0	63	22	0	8,806
DI_Mrican Kiri	12,729	0	0	17	10	0	12,973
Di_Jatimlerek	1,812	0	0	0	0	0	906
DI_Mentrus	3,632	0	0	174	0	0	2,151
DI_Jatikulon	638	0	0	0	2	0	319
DI_Brantas Delta	17,942	0	0	0	0	0	6,311
Sub-total	66,132	0	0	254	34	0	37,858
Total	116,430	24,969	23,960	24,202	28,253	22,336	87,072

Note: Maximum cropping intensity is 250%.
Source: JICA Project Team 2

Table 5.3.40 Power Generation of Principal Hydropower Station in the Brantas River Basin

No.	Principal Hydropower Station	Annual Power Generation (Average) (MWh)					
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Sengguruh	104,106	103,977	102,574	81,657	91,883	75,109
2	Sutami	424,135	422,732	418,758	351,825	368,467	316,682
3	Wlingi	181,793	181,602	180,091	155,629	158,324	137,335
4	Lodoyo	34,715	34,639	33,981	29,559	31,386	26,653
5	Wonorejo	27,531	28,057	27,673	19,070	27,071	16,566
6	Tulungagung Gate	53,408	54,838	47,200	43,121	60,592	46,309
7	Selorejo	27,411	28,704	29,696	27,739	30,401	27,891
	Total	853,099	854,548	839,968	708,601	768,124	646,545

Note: Depended power generation by irrigation and M&I water demands
Source: JICA Project Team 2

2) Water Balance considering Safety Level

Each scenario is calculated to evaluate the available water to M&I water and irrigable cropped area. Safety level of water utilization is set as follows;

- Irrigation Water Supply:5-year dependability
- M&I Water Supply: 10-year dependability

The results of the water balance considering safety level of water utilization are shown from Table 5.3.41 to Table 5.3.43.

Table 5.3.41 Available Municipal and Industrial Water Supply

No.	District/ Municipality	Available Water Supply (m^3/s)					
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Batu	0.06	0.06	0.11	0.11	0.11	0.11
2	Malang	1.70	1.70	3.56	3.56	3.56	2.49
3	Kediri	1.64	1.64	2.49	2.49	2.49	2.49
4	Blitar	0.17	0.17	0.13	0.07	0.07	0.03
5	Sidoarjo	9.57	10.69	12.02	12.02	12.02	12.02
6	Mojokerto	0.70	0.78	0.90	0.90	0.90	0.90
7	Jombang	0.28	0.28	0.91	0.91	0.91	0.91
8	Surabaya	15.45	17.45	18.35	18.35	18.35	18.35
9	Trenggalek	0.13	0.15	0.38	0.38	0.38	0.38
10	Tulungagung	0.40	0.40	0.71	0.71	0.71	0.71
11	Nganjuk	0.38	0.38	0.84	0.84	0.84	0.84
12	Gresik	2.85	3.54	4.34	4.34	4.34	2.17
Total		33.33	37.24	44.74	44.68	44.68	41.40
Demand		33.33	37.24	45.28	45.28	45.28	45.28

Source: JICA Project Team 2

Table 5.3.42 Cropped Area for Each Scenario

	Irrigation District	Irrigation Area (ha)	Cropped Area (ha)					
			Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
Tributaries								
	DI_Kedung kandang	5,160	12,900	12,900	12,900	12,900	12,900	11,868
	DI_Molek	3,883	9,708	9,708	9,708	9,708	9,708	9,708
	DI_Siman	23,060	48,426	48,426	46,120	46,120	48,426	39,202
	DI_Bening	8,752	19,254	19,254	18,379	15,754	20,130	14,878
	Di_Padi Pomahan	4,309	8,618	8,618	8,618	8,618	9,480	7,325
	DI_Jaruma I&II	2,449	6,123	6,123	6,123	6,123	6,123	6,123
	DI_Ngasinan	1,185	2,015	2,963	2,963	2,963	2,963	2,963
	DI_Kedung Soko	700	1,260	1,750	1,750	1,470	1,750	1,330
	DI_Bareng	800	2,000	2,000	2,000	2,000	2,000	1,680
	Sub-total	50,298	110,304 219%	111,742 222%	108,561 216%	105,656 210%	113,480 226%	73,501 146%
Mainstream								
	DI_Lodagung	12,217	30,543	30,543	30,543	30,543	30,543	28,099
	DI_Mrican Kanan	17,612	44,030	44,030	44,030	44,030	44,030	44,030
	DI_Mrican Kiri	12,729	31,823	31,823	31,823	31,823	31,823	31,823
	Di_Jatimlerek	1,812	4,530	4,530	4,530	4,530	4,530	4,168
	DI_Mentrus	3,632	9,080	9,080	9,080	9,080	9,080	8,354
	DI_Jatikulon	638	1,595	1,595	1,595	1,595	1,595	1,467
	DI_Brantas Delta	17,942 (12,206)	44,855	44,855	30,515	30,515	30,515	28,074
	Sub-total	66,582 (60,846)	166,456 250%	166,456 250%	152,116 250%	152,116 250%	152,116 250%	146,015 240%
	Total	116,880 (111,144)	276,760 237%	278,198 238%	260,677 235%	257,772 232%	265,596 239%	219,516 198%

Note: Maximum cropping intensity is 250%.
Source: JICA Project Team 2

Table 5.3.43 Power Generation of Principal Hydropower Station in the Brantas River Basin

No.	Principal Hydropower Station	Annual Power Generation (Average) (MWh)					
		Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
1	Sengguruh	104,106	103,979	102,573	81,666	91,895	76,107
2	Sutami	424,120	422,919	418,823	352,086	369,008	319,961
3	Wlingi	181,649	181,631	180,117	155,698	158,510	138,079
4	Lodoyo	34,764	34,647	34,075	29,636	31,408	27,126
5	Wonorejo	27,835	28,168	28,052	19,112	27,125	17,961
6	Tulungagung Gate	52,946	55,517	46,359	43,334	60,899	46,620
7	Selorejo	30,927	31,317	32,815	29,896	32,382	30,707
Total		856,347	858,178	842,815	711,428	771,227	656,561

Note: Depended Power generation by irrigation and M&I water demands
Source: JICA Project Team 2

(6) Results of Water Balance Study

1) Present Climate Condition

Results of Scenario 1 to 3 indicated the water utilization under present climate condition. Scenario 1 is a present demand and Scenario 2 is a future demand in 2030. These scenarios are same condition of Review POLA (2015) (Draft). According to Review POLA (2015) (Draft), planned 5 dams are considered in the water balance model. Therefore, deficit in Scenario 2 is improved.

Scenario 3 is a future demand in 2050. It is not considered in the new dam construction after 2030. M&I water demand is increased during 20 years, and the reservoir volume is decreased due to sedimentation. Irrigation area of Delta Brantas becomes smaller. As a result of the situation in 2050, the cropped area in the Brantas River becomes smaller.

2) Comparison of Scenarios 3 and 4

Difference between Scenario 3 and Scenario 4 is a climate condition. It is noted that the irrigation water demand is also changed by different climate condition. The result of both scenarios indicates a climate change impact. Table 5.3.44 shows a summary of both scenarios.

Table 5.3.44 Summary of Scenarios 3 and 4 Considering Safety Level

Scenario	M&I Water (m^3/s)	Cropped Area (ha)	Power Generation (MWh)
3	44.74	260,677	842,815
4	44.68	257,772	711,428
Difference	0.06	2,905	131,387

Source: JICA Project Team 2

3) Total Water Demand and Natural Stream Flow

The total water demand (Domestic and Industrial Water + Irrigation) in the Brantas River basin is compared with the natural stream flow at the New Lengkong Dam. Figure 5.3.21 shows the comparison of total demand, stream flow and shortage of supply for the present climate condition (Scenario 1), and Figure 5.3.22 shows its comparison for the future medium climate change scenario (Scenario 4).

The figures show that the natural flow in the rainy season is abundant if it is compared with the total water demand. The water demand exceeding the natural stream flow may be supplied by the storage water in reservoirs. But there is some shortage occurring in the dry season for both Scenario 1 and Scenario 4.

4) Reservoir Operation

The results of reservoir operation of Sutami & Lahor Dam located at the mainstream and Selorejo Dam located at tributary for Scenarios 1 and 4 are shown in Figure 5.3.23 and Figure 5.3.25, respectively. The comparison of the average reservoir water level of Sutami & Lahor and Selorejo reservoirs for Scenarios 1 and 4 are shown in Figure 5.3.26.

The simulated water level for 20 years of Sutami Reservoir for Scenario 1 and Scenario 4 is shown in Figure 5.3.27 and Figure 5.3.27, respectively.

As shown in the figure, the reservoir water level of future climate condition (Scenario 4) of Sutami & Lahor and Selorejo reservoirs are lower than that of Scenario 1. This result indicates that the more water will be released from the reservoir in the future than the present climate condition and/or inflow discharge will be decreased compared with the present climate condition.

(7) Climate Change Impacts on Tributary Irrigation Schemes

Irrigation schemes of each regency/city, province and central government are stipulated in the Ministerial Ordinance No.14/PRT/M/2015 in 2015. The cropped area of the irrigation schemes on tributaries operated by the local governments is evaluated considering the climate change impact.

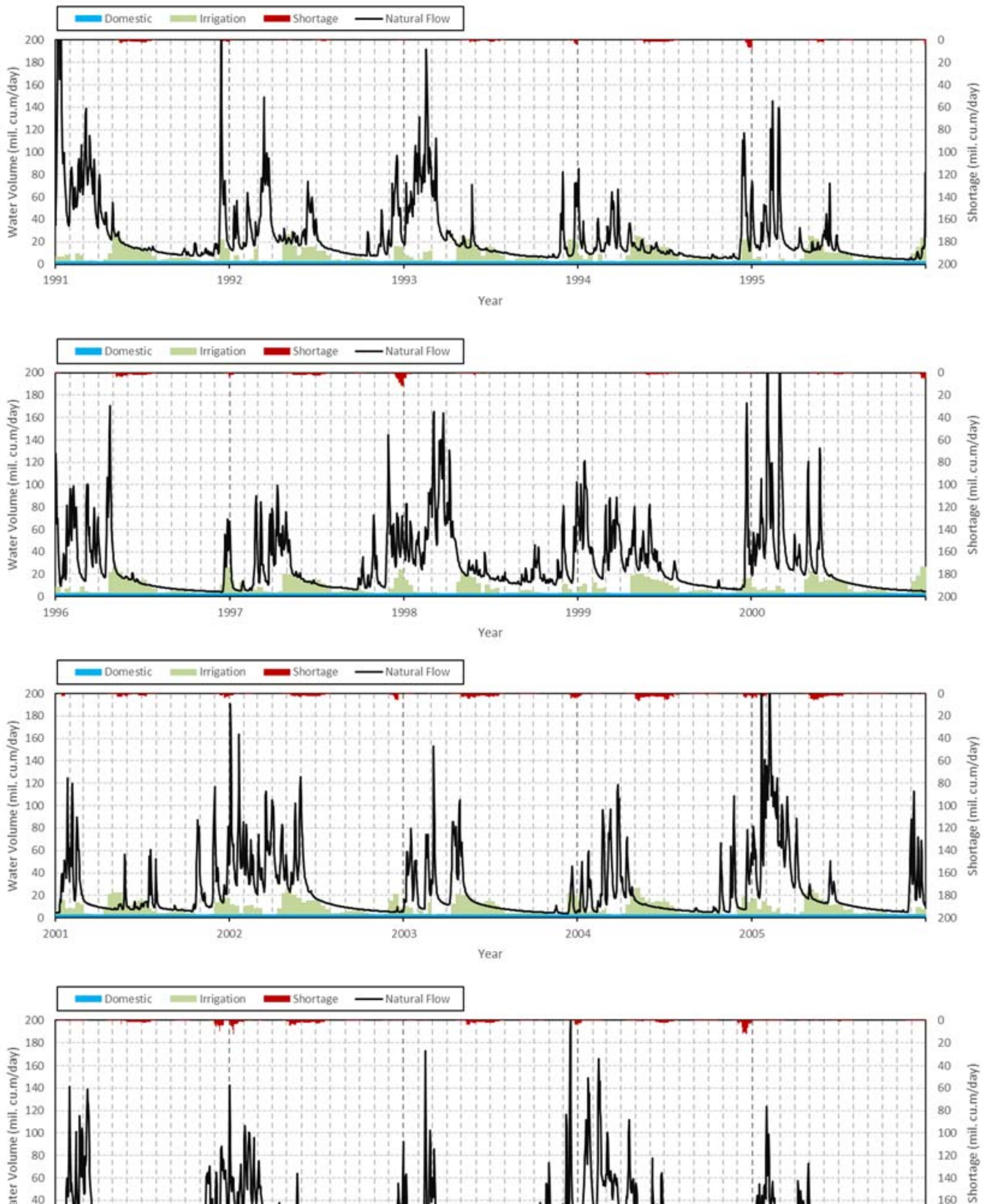
1) Irrigation Area under the Local Governments

Irrigation schemes of the local governments are grouped on a regency basis as shown in . The total irrigation area in 2050 under the local governments plans is about 65% of the present one.

Table 5.3.45 Total Irrigation Area under the Local Governments

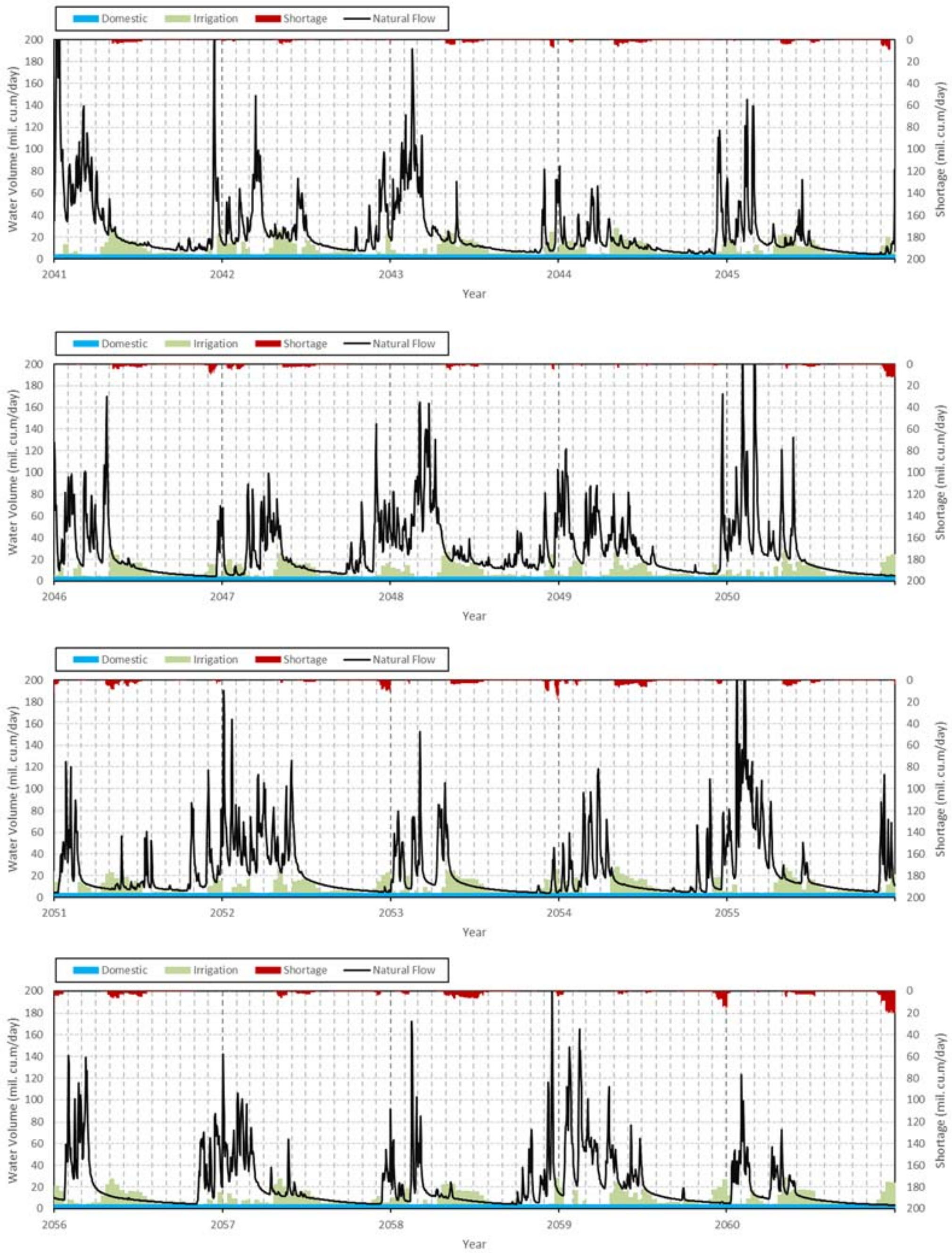
Regency		Irrigation Area (ha)		
		(2015-2030)	2050	Difference
1	Malang	42,509	25591	-16,918
2	Blitar	35,653	26639	-9,014
3	Trenggalek	13,976	8639	-5,337
4	Tulungagung	25,884	9420	-16,464
5	Kediri	41,723	32186	-9,537
6	Nganjuk	18,817	13671	-5,146
7	Jombang	13,073	7914	-5,159
8	Mojokerto	23,812	19931	-3,881
9	Sidoarjo	7,112	0	-7,112
Total		222,559	143,991	-78,568

Source: JICA Project Team 2



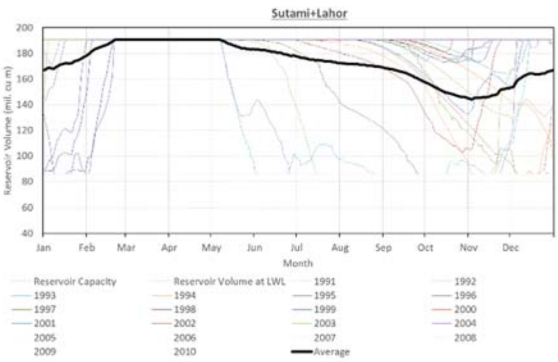
Source: JICA Project Team 2

Figure 5.3.21 Balance Between Total Water Demand and River Stream Flow (Scenario 1)

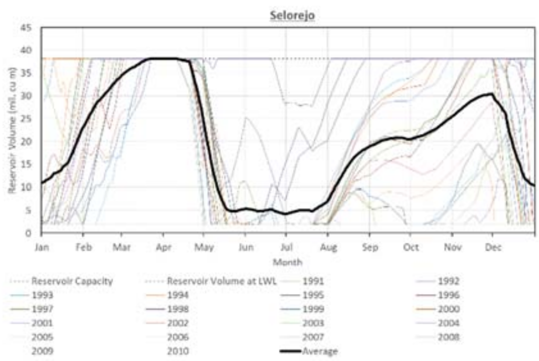


Source: JICA Project Team 2

Figure 5.3.22 Balance Between Total Water Demand and River Stream Flow (Scenario 4)



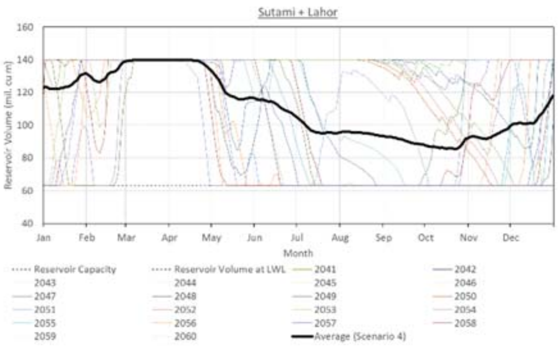
Sutami & Lahor Dam



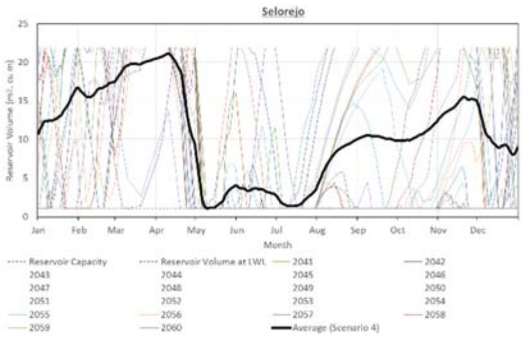
Selorejo Dam

Source: JICA Project Team 2

Figure 5.3.23 Reservoir Operation of Sutami Dam and Selorejo Dam for Scenario 1



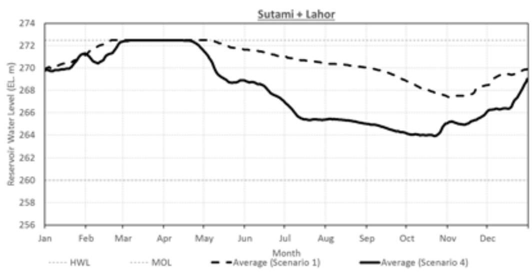
Sutami & Lahor Dam



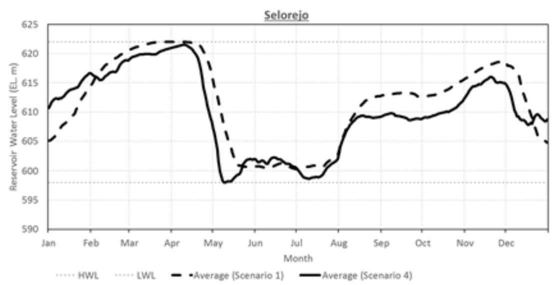
Selorejo Dam

Source: JICA Project Team 2

Figure 5.3.24 Reservoir Operation of Sutami & Lahor Dam and Selorejo Dam for Scenario 4



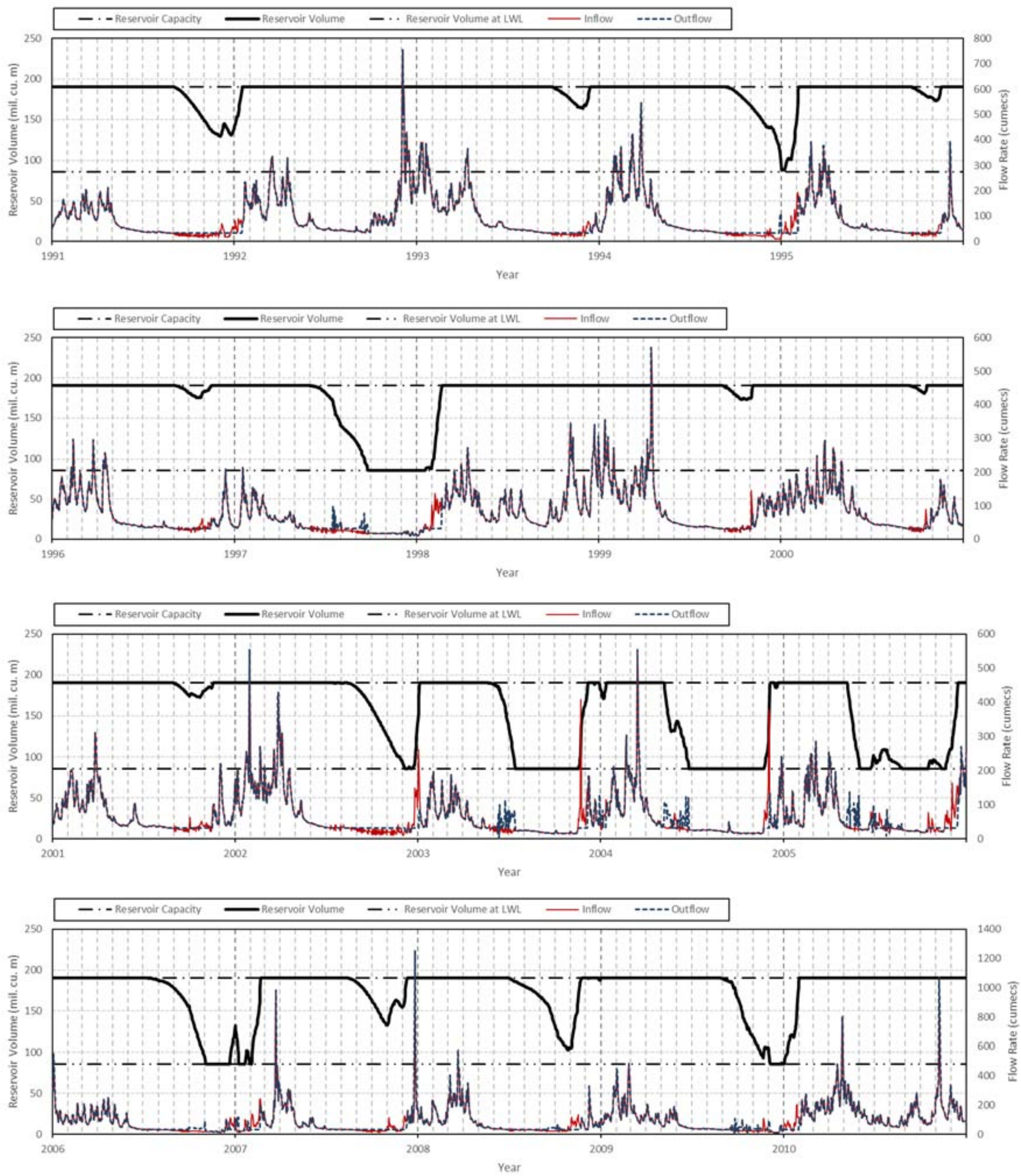
Sutami & Lahor Dam



Selorejo Dam

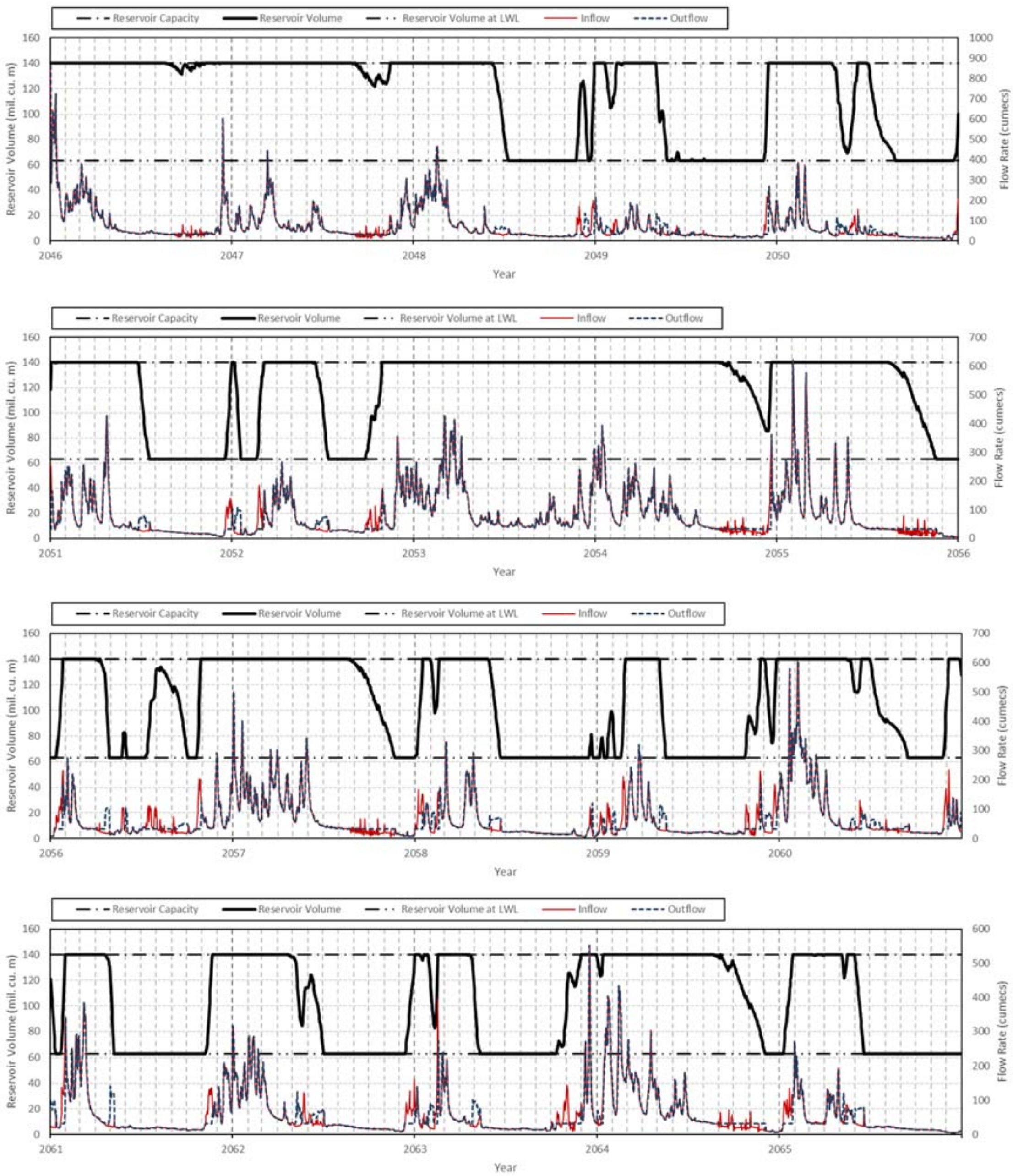
Source: JICA Project Team 2

Figure 5.3.25 Comparison of Reservoir Water Level for Scenario 1 and Scenario 4



Source: JICA Project Team 2

Figure 5.3.26 Reservoir Operation of Sutami & Lahor Reservoir for Scenario 1



Source: JICA Project Team 2

Figure 5.3.27 Reservoir Operation of Sutami & Lahor Reservoir for Scenario 4

2) Cropping Intensity of the Present Irrigation Area

The present cropping intensity of the irrigation schemes under the local governments is estimated as shown in Table 5.3.46. Cropping intensity is estimated based on the cropping pattern and calendar. Each irrigation scheme under the local governments is applied from the three types of cropping pattern, such as paddy-paddy-*palawijia*, paddy-paddy, and wet paddy only based on topographical and hydrological conditions, irrigation water supply systems and so on.

Table 5.3.46 Cropping Intensity of Present Irrigation Area

Regency	Irrigation Area (ha)	Cropped Area (ha)				Cropping Intensity (%)			
		MH	MK-1	MK-2	Total	MH	MK-1	MK-2	Total
1 Malang	42,509	27,421	18,864	2,188	48,473	64.5	44.4	5.1	114.0
2 Blitar	35,653	27,303	18,129	5,066	50,498	76.6	50.8	14.2	141.6
3 Trenggalek	13,976	11,049	9,356	3,547	23,952	79.1	66.9	25.4	171.4
4 Tulungagung	25,884	12,655	8,212	0	20,867	48.9	31.7	0.0	80.6
5 Kediri	41,723	37,213	15,874	212	53,299	89.2	38.0	0.5	127.7
6 Nganjuk	18,817	16,106	11,130	0	27,236	85.6	59.1	0.0	144.7
7 Jombang	13,073	8,973	0	0	8,973	68.6	0.0	0.0	68.6
8 Mojokerto	23,812	20,794	11,896	0	32,690	87.3	50.0	0.0	137.3
9 Sidoarjo	7,112	2,000	2,000	0	4,000	28.1	28.1	0.0	56.2
Total	222,559	163,514	95,461	11,013	269,988	73.5	42.9	4.9	121.3

Note: MH; Wet season, MK; Dry season
Source: JICA Project Team 2

There are 75 ponds in the Brantas River basin. It is assumed that these storages are only supplied to irrigation schemes under the local governments during MK-1. However, locations of these existing ponds are not clear. Efficiency of water supply from ponds is evaluated to the whole irrigation schemes under the local governments.

<u>Efficiency of Ponds</u>

- Capacity: 0.5×10^6 m^3 per pond
- Number of ponds: 75 nos.
- Total capacity: 500,000 m^3 x 75 nos. = 37.5×10^6 m^3
- Average unit water requirement in MK-1: 0.552 litter/s/ha
- Period of MK-1: 130 days
- Available water supply irrigation area: $37.5\text{x}10^6$ /(0.552 x 0.001 x 86,400 x 130) =6,048 ha

Cropped area in MK-1 additionally increased 6,048 ha in the existing ponds. Table 5.3.47 shows the efficiency of ponds at present and year 2030.

Table 5.3.47 Efficiency of Ponds

Case	Number of Ponds	Capacity of Ponds (mil. m^3)	UWR (l/s/ha)	Available Water Supply Irrigation Area (ha)
Present	75	37.5	0.552	6,048
2030	345	172.5	0.552	27,822

Source: JICA Project Team 2

Cropped area and cropping intensity at present and year 2030 are shown in Table 5.3.48.

Table 5.3.48 Cropped Area and Cropping Intensity

Scenario	Cropped Area (ha)				Cropping Intensity (%)			
	MH	MK-1	MK-2	Total	MH	MK-1	MK-2	Total
1.Present	163,514	101,509	11,013	276,036	73.5	45.6	4.9	124.0
2.2030	163,514	123,283	11,013	297,810	73.5	55.4	4.9	133.8

Source: JICA Project Team 2

3) Cropping Intensity of Future Irrigation Area

Cropped area and cropping intensity under future condition are estimated from the following procedure;

(a) Difference of discharge between present and future conditions

Irrigation water is supplied from the tributaries. River discharge is one of the important factors to decide cropped area from the supply side.

(b) Difference of unit water requirements between present and future conditions

Unit water requirement is decided from evapotranspiration, rainfall, variety of crops and so on. Evapotranspiration and rainfall are affected from the climate change condition. And irrigation water requirement is estimated from irrigation area and unit water requirement. Therefore, unit water requirement is also one of the important factors from the demand side.

(c) Synthesis magnification of discharge and unit water requirement

To evaluate cropped area and cropping intensity under future condition, synthesis magnification of discharge and unit water requirement are applied. It is assumed that cropped area is affected from the decreasing of discharge and increasing of unit water requirements under climate change. Cropped area under future condition is estimated using the following formula;

(Cropped area under future condition) = (Cropped area under present condition)
x (Synthesis magnification)

Table 5.3.49 shows the rate of change of discharge and unit water requirement that were calculated from the output of Team 1.

Table 5.3.49 Rate of Change between Present and Future Conditions

Scenario	Discharge			Unit Water Requirement			Synthesis Magnification		
	MH	MK-1	MK-2	MH	MK-1	MK-2	MH	MK-1	MK-2
W/O Climate Change	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
Medium	0.857	0.846	0.846	1.144	1.137	0.939	0.749	0.744	0.901
Low	0.916	1.223	1.223	1.207	1.152	0.795	0.759	1.062	1.538
High	0.647	0.841	0.841	1.012	1.000	1.015	0.639	0.841	0.829

Source: JICA Project Team 2

Future cropping intensity of the irrigation scheme under the local governments is estimated as shown in Table 5.3.50.

Table 5.3.50 Cropping Intensity with Efficiency of Ponds under Future Scenario

Scenario	Irrigation Area (ha)	Cropped Area (ha)				Cropping Intensity (%)			
		MH	MK-1	MK-2	Total	MH	MK-1	MK-2	Total
W/O 3 Climate Change	143,991	143,991	120,589	11,013	275,593	100.0	83.7	7.6	191.4
4 Medium	143,991	117,449	93,910	9,481	220,840	81.6	65.2	6.6	153.4
5 Low	143,991	117,673	122,640	15,019	231,184	81.7	85.2	10.4	177.3
6 High	143,991	70,900	81,066	6,002	157,968	49.2	56.3	4.2	109.7

Source: JICA Project Team 2

5.3.4 Assessment of Land Use Change

Future land use is explained in Section 5.2. And the daily natural discharge under the present condition and future condition is estimated by WEB-DHM which is calculated by Team 1. The result of comparison between present and future condition is almost the same natural discharge because the land use is not drastically changed.

5.4 Flood

5.4.1 Flood Inundation Simulation

(1) Target Area of Flood Inundation Simulation

As shown in Figure 5.4.1 which show the inundation map in the Brantas River basin prepared by Ministry of Public Works and Housing (MPWH), it can be seen that flood damage has occurred in the following places

- Brantas Mainstream: Confluence of the tributary
- Tributaries: Tawing River in Tulungagung area, Widas River, Brangkal River, and Sadar River, and so on.

Considering the existing reports availability, importance of the location and information from BBWS Brantas, flood inundation simulation is carried out to the frequently inundated locations such as

- Widas River basin
- Sadar River basin (Tributary of the Porong River basin)
- Ngotok Ring River basin (Tributary of the Brangkal River basin)
- Tawing River basin (Tulungagung Area)

In addition, the mainstream from downstream of the Mrican Barrage to the river mouth is checked to the possibility of overtopping from the crest of dike under the present and future conditions. As mentioned below, there is a possibility of overtopping in the Porong River, inundation analysis for the Porong River is conducted.

(2) Methodology of Flood Inundation Simulation

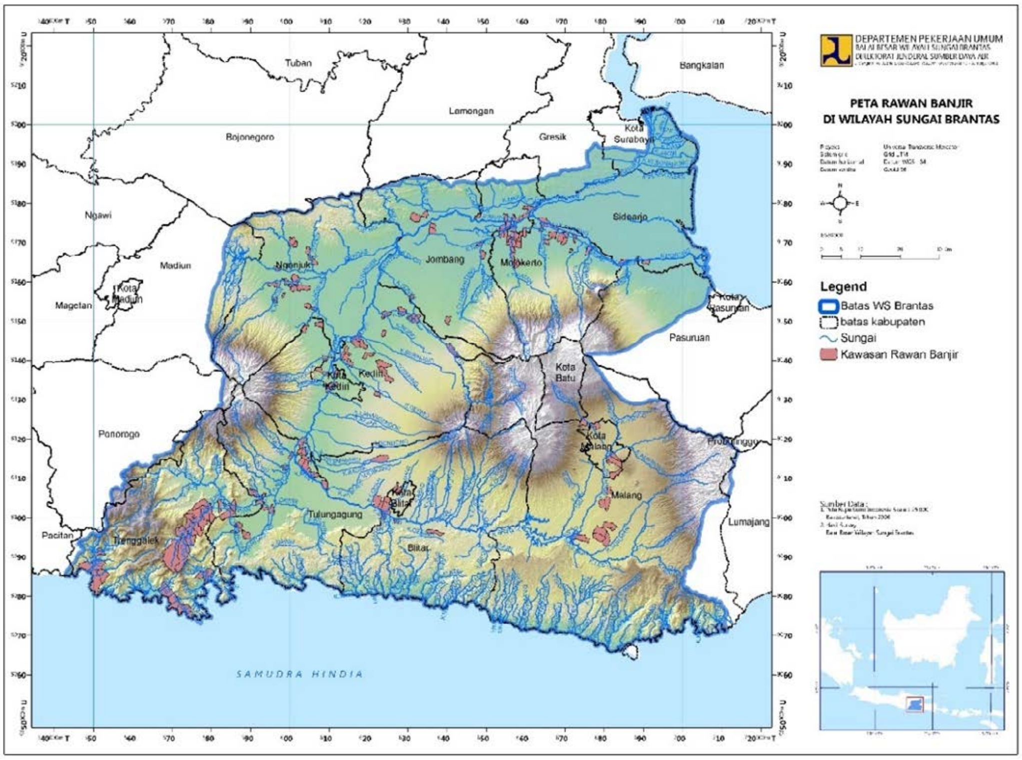
Method of flood inundation simulation model is selected by the characteristic of the inundation and its target of the analysis.

Commonly, relationship between inundation pattern and analysis model is as shown in Table 5.4.1.

Table 5.4.1 Relationship between Inundation Pattern and Analysis Model

Type	Inundation Pattern	Analysis Models
Flowing down type	Flooded water in inundation area is flowed together with flood in the river channel. Inundation area is limited along a river.	· One dimensional flow model · Two-dimensional flow model (if necessary)
Storage type	It is a flood that floods within a limited area such as a closed watershed. There is no change of inundation range by the scale of flood.	· Pond model
Diffusion type	It is a typical flood form, and flooding is influenced by topography and structures. Inundation area is diffused.	· One dimensional flow + Two-dimensional flow · Two-dimensional flow

Source: JICA Project Team 2



Source: Ministry of Public Works and Housing of the Republic of Indonesia

Figure 5.4.1 Inundation Area in the Brantas River Basin

(3) Flood Control Storage and Effects of Each Dam

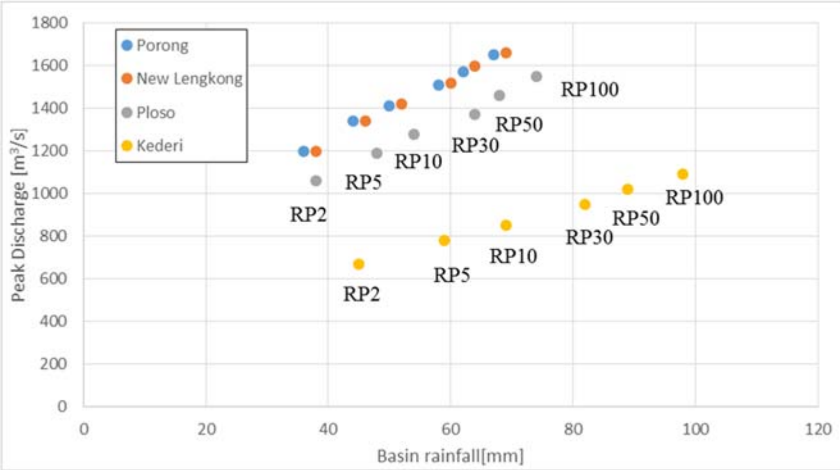
The location where the reservoir sedimentation is accumulated is in the effective storage space of the reservoir under Full Supply Level (FSL). The impact of reservoir sedimentation to the flood control space above FSL is smaller than that in the effective storage.

In this study, the flood control capacity of each dam in the future is assumed to be the same as that in 2012.

(4) Peak Discharge of Mainstream under Future Condition

The probable peak discharge at the mainstream under the future condition is required to clarify the overtop locations. The basin mean rainfall of the three scenarios (low, medium, and high under the future condition) is estimated by Team 1. On the other hand, the relation between the basin mean rainfall and the peak discharge was explained in "Widas Flood Control and Drainage Project, 1985". Figure 5.4.2 shows the relation between the basin mean rainfall and the peak discharge in Brantas Mainstream.

The peak discharges under the future conditions are estimated and summarized in Table 5.4.2.



Source: Widas Flood Control and Drainage Project, 1985

Figure 5.4.2 Relationship between Basin Mean Rainfall and Peak Discharge

Table 5.4.2 Probable Peak Discharge under Future Conditions

Scenario	Hydrology	Average Return Period (Year)					
		RP2	RP5	RP10	RP30	RP50	RP100
1. Kediri							
Low	Basin Mean Rainfall (mm)	52	68	76	90	93	103
	Peak Discharge (m^3/s)	720	850	920	1,030	1,050	1,130
Medium	Basin Mean Rainfall (mm)	52	68	79	94	102	113
	Peak Discharge (m^3/s)	720	850	940	1,060	1,130	1,210
High	Basin Mean Rainfall (mm)	56	74	86	107	120	137
	Peak Discharge (m^3/s)	760	900	1,000	1,160	1,270	1,400
2. Ploso							
Low	Basin Mean Rainfall (mm)	44	55	59	70	71	78
	Peak Discharge (m^3/s)	1,140	1,290	1,350	1,490	1,510	1,590
Medium	Basin Mean Rainfall (mm)	44	55	62	74	78	85
	Peak Discharge (m^3/s)	1,140	1,290	1,380	1,530	1,600	1,690
High	Basin Mean Rainfall (mm)	48	60	68	83	92	104
	Peak Discharge (m^3/s)	1,190	1,350	1,450	1,660	1,780	1,930
3. New Lengkong Dam							
Low	Basin Mean Rainfall (mm)	44	53	57	66	67	72
	Peak Discharge (m^3/s)	1,300	1,430	1,500	1,630	1,640	1,720
Medium	Basin Mean Rainfall (mm)	44	53	60	69	74	79
	Peak Discharge (m^3/s)	1,300	1,430	1,530	1,670	1,740	1,820
High	Basin Mean Rainfall (mm)	48	58	65	78	86	97
	Peak Discharge (m^3/s)	1,350	1,500	1,610	1,800	1,920	2,070
4. Porong							
Low	Basin Mean Rainfall (mm)	41	51	55	64	65	70
	Peak Discharge (m^3/s)	1,290	1,420	1,480	1,610	1,620	1,700
Medium	Basin Mean Rainfall (mm)	41	51	58	67	71	77
	Peak Discharge (m^3/s)	1,290	1,420	1,520	1,650	1,710	1,790
High	Basin Mean Rainfall (mm)	45	55	63	75	84	94
	Peak Discharge (m^3/s)	1,340	1,480	1,590	1,770	1,880	2,030

Source: JICA Project Team 2

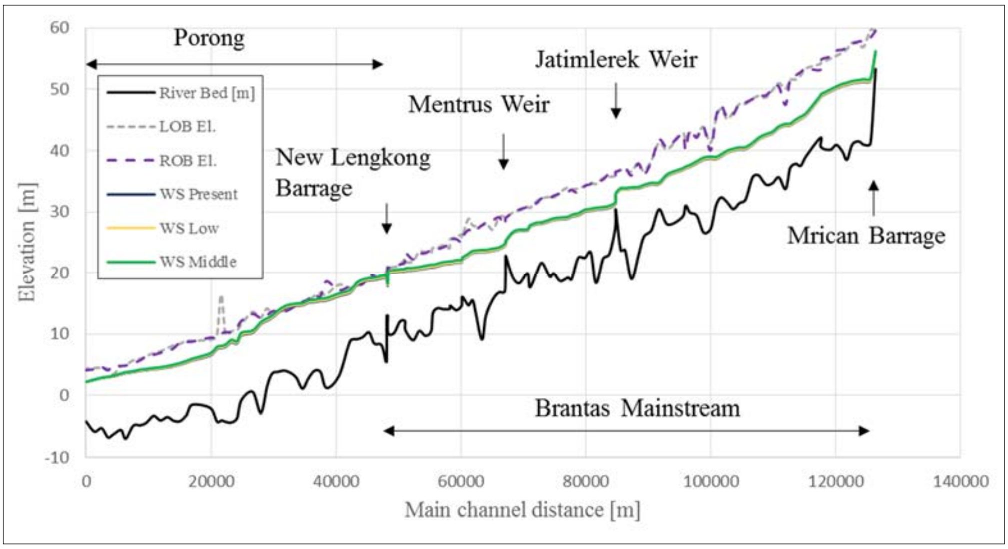
5.4.2 Assessment of the Existing River Facilities

(1) Relation of Discharge and Freeboard of Dike along the Mainstream

The river profile and flood water level along the mainstream from the Mrican Barrage to the New Lengkong Dam are shown in Figure 5.4.3. Freeboard of dike along the mainstream was set at 1.0 m. Table 5.4.3 shows the freeboard of the present and future conditions.

As the result of relation between the peak discharge and the freeboard of dike along the mainstream, locations of overtop are shown in Figure 5.4.4.

According to Table 5.4.3, overtopping from the crest of the dike will occur in some locations along the Porong River. The overtop sections shall be needed to the heightening of the dike. The flood fighting team shall monitor the water level during the flood event at the locations of the overtop sections and lack of freeboard sections. And sand bags shall be stored near the identified locations in this analysis.



Source: JICA Project Team 2

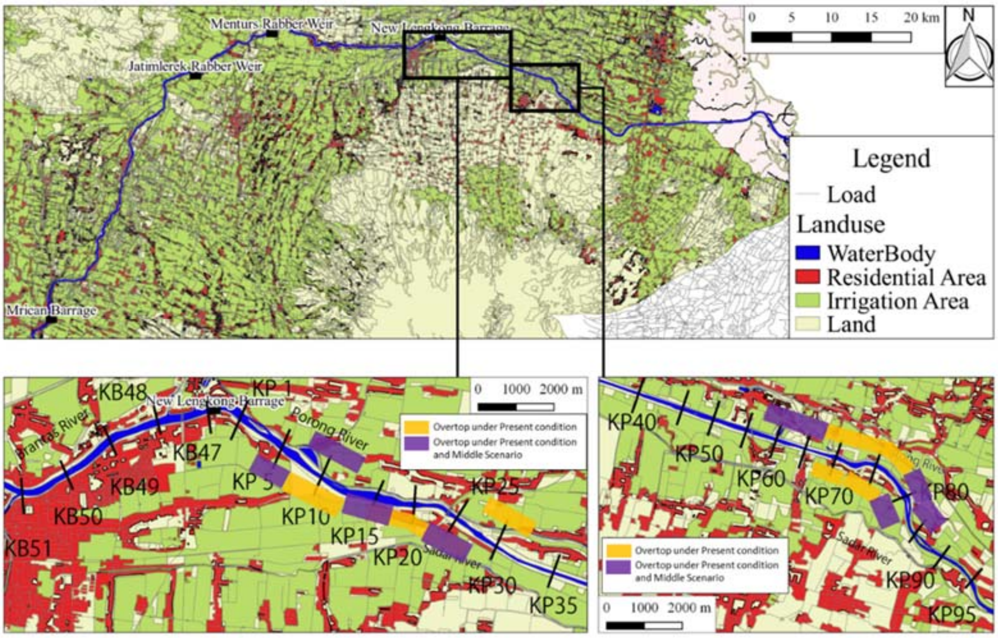
Figure 5.4.3 River Profile and Water Surface under 50-year Probable Flood

Table 5.4.3 Freeboard Comparison with Present and Future Conditions

Location	Main Channel Distance from River Mouth (km)	Present	Future		
			High	Medium	Low
KB125~KB99	126 ~ 101	>100 cm	>100 cm	>100 cm	>100 cm
KB98	100	>100 cm	< 100 cm	>100 cm	> 100 cm
KB97~KB52	99 ~ 53	>100 cm	>100 cm	>100 cm	> 100 cm
KB51~New Lengkong dam	52~48	< 100 cm in several section	Overtop at New Lengkong Dam < 100 cm in several sections	<100 cm in several sections	<100 cm in several sections

Location	Main Channel Distance from River Mouth (km)	Present	Future		
			High	Medium	Low
KP1~KP15	48 ~ 45	<100 cm	Overtop	< 100 cm	< 100 cm
KP20~KP30	43 ~ 42	Overtop	Overtop	Overtop	Overtop
KP40~KP55	40 ~ 37	< 100 cm	< 100 cm	< 100 cm	< 100 cm
KP60~KP85	36 ~ 30	Overtop in Several sections	Overtop in almost sections	Overtop in almost sections	Overtop in almost sections
KP90~KP125	29 ~ 23	> 100 cm	< 100 cm	>100 cm	> 100 cm
KP130~KP195	22 ~ 9	> 100 cm	>100 cm	> 100 cm	>100 cm
KP200~KP220	7.5 ~ 3.5	< 100 cm at KP215	< 100 cm	< 100 cm at KP215	< 100 cm at KP215
KP225~River mouth	2.5 ~ 0	> 100 cm	> 100 cm	> 100 cm	> 100 cm

Source: JICA Project Team 2



Source: JICA Project Team 2

Figure 5.4.4 Location of Overtop Sections under 50-year Probable Flood

(2) Flood Inundation at Present and Future Climate Change Conditions

1) Flood Damage

The flood damage is mainly assessed from the irrigation area, affected houses and affected people in this section. The irrigation area is estimated from the inundation area and land use. The affected houses which mean the converted completely destroyed houses in the Project are estimated from the number of houses in the inundation area and the damage ratio. The affected houses are estimated from the following formula:

(Affected Houses) = (Number of houses in the inundation area) x (Damage ratio)

In Japan, house damage is estimated from the house asset and damage ratio as shown in Table 5.4.4. As to the flood damage of houses, the number of houses is applied instead of the house asset. And damage ratio is applied as same value of flood damage estimation manual in Japan.

Table 5.4.4 Damage Ratio of Houses

Slope of Land	Inundation Depth above Floor Level (cm)				
	<50	50-99	100-199	200-299	>300
Less than 1/1,000	0.092	0.119	0.266	0.580	0.834
1/1,000-1/500	0.126	0.176	0.343	0.647	0.870
Greater than 1/500	0.144	0.205	0.382	0.681	0.888

Source: Flood Damage Estimation Manual in Japan

Affected people are estimated from the number of houses and number of people per household in each regency and city.

2) Brantas Main Stream

(a) Calculation Condition

From the result of 5.4.2 (1) in Brantas mainstream, it is evaluated that the 50-years flood under present and future conditions, are overtopped in the section of the Porong River. Estimate the increase of flood damage in the future climate by conducting inundation analysis on the 50-year probability scale of each of the present and future climate scenarios. Conditions for inundation simulations are shown in Table 5.4.5.

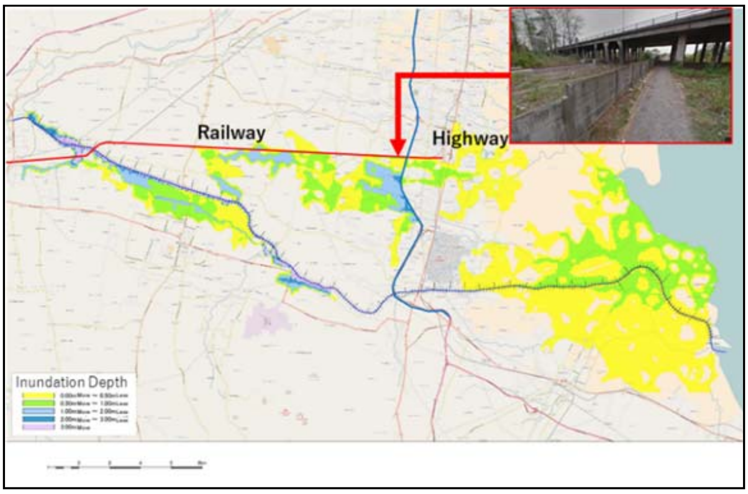
Table 5.4.5 Calculation Condition for Flood Inundation Analysis on the Porong River

Item	Contents
Method	2-Dimensional unsteady flow
Target River	from the Porong River mouth to New Lengkong (KP.001-KP270)
Calculation Mesh	River channel 200m
	Flood plain 100m
Topography	DEM (25mx25m) by BAKOSURTANAL
	River cross section data by PU BBWS Brantas 2013 survey
Manning's n	River: 0.025 (Same as Master Plan 1985)
	Flood plain residential area: 0.1, Irrigation area : 0.06
Boundary Condition	Downstream condition: Tidal water level (present 1.53m, feature 1.72m)
	Upstream condition: each return period discharge
Case	Present condition: 1,570m^3/s
	Low: 1,620m^3/s
	Medium: 1,710m^3/s
	High: 1,880m^3/s

Source: JICA Project Team 2

(b) Model Calibration

There is no available evidence of inundation from the Porong river, the calibration for hydraulic analysis was conducted considering the highway road and railway. Figure 5.4.5 shows the crossing point of railway and highway. There are constructed wall along the railway, and railroad is embanked. Type of highway at crossing with railway is flyover. For that reason, the flood flow will be passed at crossing point between railway and highway.



Source: JICA Project Team 2, photo image: Google Street View, background image: Google Map

Figure 5.4.5 Calibration for the Porong River

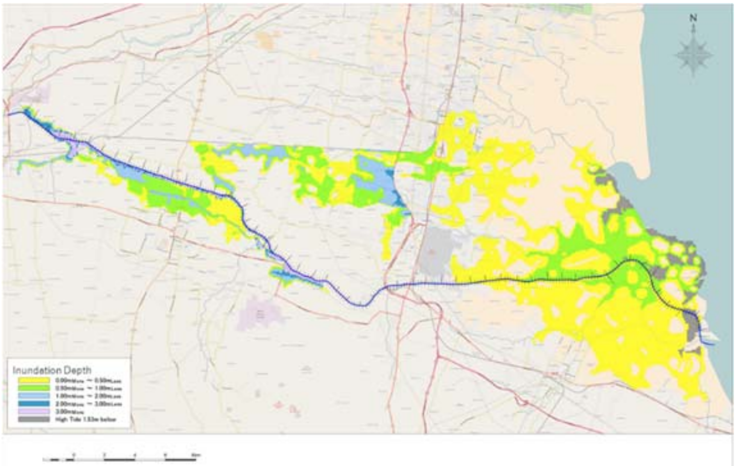
(c) Result of the Calculation

Inundation analysis result is as shown in Table 5.4.6, and inundation area of the present condition is shown in Figure 5.4.6.

Table 5.4.6 Summary of Inundation Depth and Inundated Area (Porong River)

Condition	Residential		Irrigation		Total
	Area (ha)	Average Depth (m)	Area (ha)	Average Depth (m)	Area (ha)
Present	888	1.2	2,390	1.2	3,278
Low	933	1.2	2,554	1.2	3,487
Medium	1,143	1.2	2,902	1.3	4,045
High	2,509	1.1	5,509	1.3	8,018

Source: JICA Project Team 2



Source: JICA Project Team 2, background image: Google map

Figure 5.4.6 Maximum Inundation Depth and Area in the Present Climate (Porong River)

3) Widas River Basin

(a) Present Condition of Widas River Basin

Flood analysis for the Widas River basin was conducted in "The Study of Widas Flood Control and Drainage Project (1986)", it was recommended that protected target level is set at 25year return period. It is difficult to judge direction of the inundation flow. In this case, inundation type is categorized diffusion type. Therefore, the two-dimensional unsteady flow analysis model is applied in this inundation area.

(b) Simulation Model

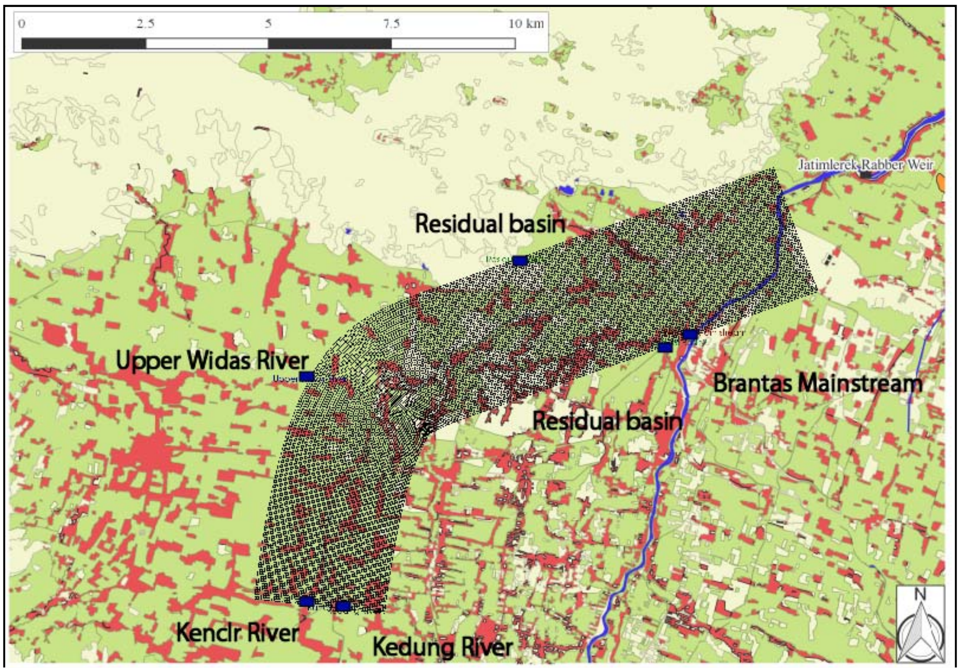
The inundation analysis in the Widas River basin applied a 2-D unsteady flow analysis method. The target area for the simulation model area is shown in Figure 5.4.7.

(c) Conditions of Analysis

The conditions of simulation are set as follows:

Boundary Condition

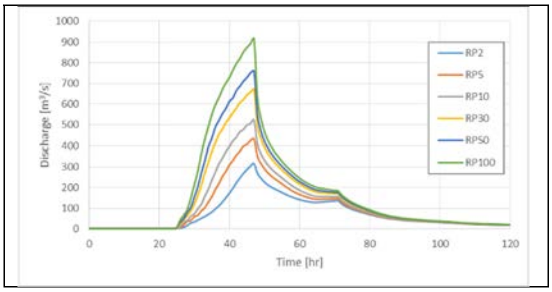
- Downstream End: The boundary condition of the downstream end is set at the water level of the mainstream. The probable water levels of the mainstream are estimated from the non-uniform flow calculation by Hydrologic Engineering Center's River Analysis System (HEC-RAS).



Source: JICA Project Team 2

Figure 5.4.7 Model Area of Inundation Analysis in the Widas River Basin

- Upstream End: The hydrographs and adjustment magnitude under the present and future conditions are estimated and provided by Team 1. Figure 5.4.8 shows the hydrographs from the Upper Widas River as an example. And the peak discharge of each upstream boundary conditions is shown in Table 5.4.7.



Source: JICA Project Team 2

Figure 5.4.8 Hydrograph of Upper End Boundary Condition (Upper Widas River)

Table 5.4.7 Peak Discharge of Upper End Boundary (Widas River Basin)

Average Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Upper Widas River				
2	316	384	384	432
5	432	527	527	593
10	523	597	632	717
30	671	786	855	1,069
50	759	833	985	1,305
100	916	916	1,175	1,629
2. Kedung River				
2	201	248	248	279
5	289	344	344	404
10	341	403	426	511
30	471	580	637	796
50	561	621	718	1045
100	673	673	906	1387
3. Kuncir River				
2	47	57	57	66
5	65	79	79	90
10	79	91	98	113
30	105	127	142	193
50	123	136	171	253
100	154	154	219	338
4. Residual Basin				
2	12	13	13	15
5	15	17	17	18
10	17	18	20	25
30	23	28	32	42
50	27	31	38	54
100	34	34	47	73

Source: JICA Project Team 2

Other Conditions

- Roughness coefficient: River area (n = 0.03), Land area (n = 0.045)
- Calculation pitch: dt = 1 [sec]
- River cross section: River cross section survey was not carried out in this project.

(d) Model Calibration

Calibration of the parameters for the two-dimensional unsteady flow analysis is carried out to adjust the inundation volumes of the three retarding basins which is mentioned in the existing report.

(e) Results of Flood Inundation Analysis

The flood inundation analysis is carried out to the present and future conditions (low, medium, high scenarios) under the climate change. The results of the analysis are shown in Table 5.4.8 and Figure 5.4.9. Figure 5.4.9 shows each scenario of a 30-year return period.

Table 5.4.8 Results of Flood Inundation Analysis (Widas River Basin)

1. Present Condition

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	12.2	0.9	18
5	29.0	11.4	232
10	97.5	26.8	547
30	390.2	110.6	2,256
50	536.4	175.4	3,580
100	524.6	294.2	6,003

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

2. Future Condition (Medium)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	22.5	7.2	148
5	106.0	27.6	562
10	309.1	73.1	1,492
30	699.0	259.0	5,286
50	880.2	335.3	6,843
100	1,347.8	474.9	9,693

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

3. Future Condition (Low)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	22.5	2.4	48
5	89.2	13.9	283
10	249.0	36.8	752
30	570.7	197.4	4,030
50	627.1	242.6	4,952
100	750.8	294.2	6,003

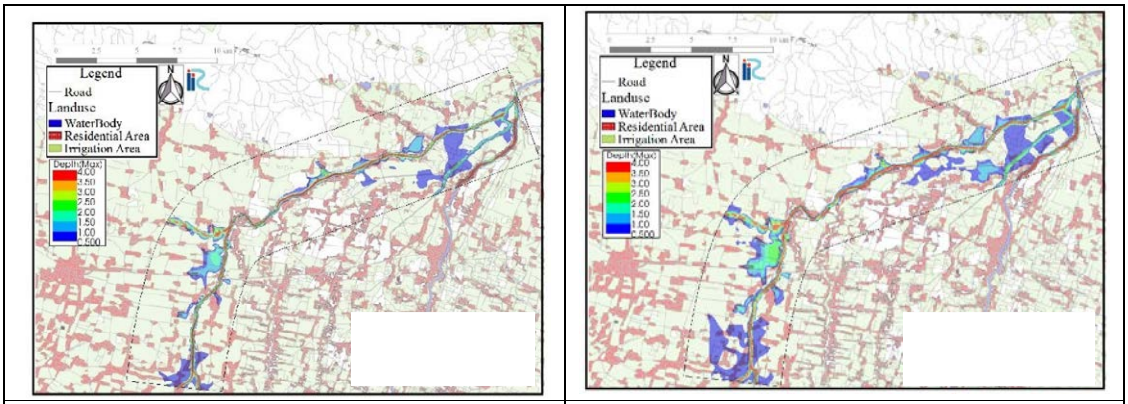
Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

4. Future Condition (High)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	36.1	11.4	232
5	247.5	36.4	742
10	450.5	148.1	3,022
30	1,172.7	393.1	8,024
50	1,646.3	1,050.0	10,996
100	1,996.8	1,160.5	12,153

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

Source: JICA Project Team 2



Present Condition	Medium Scenario

Source: JICA Project Team 2

Figure 5.4.9 Maximum Inundation Depth and Area in the Widas River Basin (30-year probable flood)

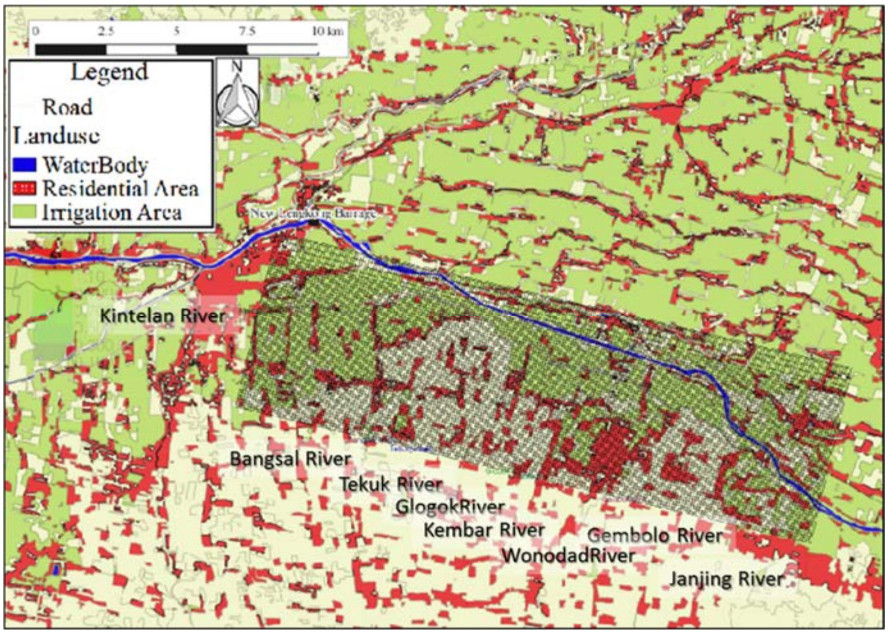
4) Sadar River Basin

(a) Present Condition of the Sadar River Basin

The study for flood protection in the Sadar River Basin, has been conducted in "*Studi Evaluasi System Pengendalian Banjir Kali Sadar Kabupaten dan Kota Mojokerto, 2013*". It is concluded that pump drainage system would be applied. Small tributaries meet the mainstream of the Sadar River and cause flood. Located in a flat area, then the type of inundation flow is judged as diffusion type. Therefore, a two-dimensional model is applied in this inundation area.

(b) Simulation Model

The model area is decided from the inundation area from the past flood events. The simulation model is shown in Figure 5.4.10.



Source: JICA Project Team 2

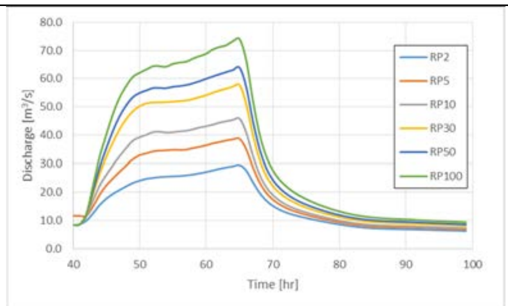
Figure 5.4.10 Model of Inundation Analysis in the Sadar River Basin

(c) Conditions of Analysis

The conditions of simulation are set as follows:

Boundary Condition

- Downstream End: The boundary condition of the downstream end is set at the water level of the mainstream. The probable water levels of the mainstream are estimated from the non-uniform flow calculation by HEC-RAS.
- Upstream End: The hydrographs and adjustment magnitude under the present and future conditions are estimated and provided by Team 1. Figure 5.4.11 shows the hydrographs at the tributary, which has the biggest discharge as an example. The peak discharge of each upstream boundary condition is shown in Table 5.4.9.
- The hydrographs under the present and future condition are estimated by Team 1. These hydrographs are applied to the upstream boundary.



Gembolo River

Source: JICA Project Team 2

Figure 5.4.11 Hydrograph of Each Upper End Boundary Condition (Gembolo River)

Table 5.4.9 Peak Discharge of Upper End Boundary (Sadar River Basin)

Average Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Kintelan River				
2	2.6	3.0	3.0	3.3
5	3.4	4.0	4.0	4.3
10	4.1	4.5	4.8	5.3
30	5.3	6.0	6.4	8.0
50	6.0	6.4	7.6	11.3
100	7.3	7.3	10.0	20.2
2. Bangsal River				
2	5.5	6.3	6.3	6.8
5	7.2	8.3	8.3	9.1
10	8.5	9.5	10.0	11.1
30	11.0	12.6	13.4	16.8
50	12.5	13.5	15.8	23.7
100	15.2	15.2	21.0	42.4
3. Tekuk River				
2	3.5	4.0	4.0	4.3
5	4.6	5.2	5.2	5.7
10	5.4	6.0	6.3	7.0
30	7.0	7.9	8.5	10.6
50	7.9	8.5	10.0	14.9
100	9.6	9.6	13.3	26.7
4. Glogok River				
2	1.5	1.6	1.6	1.7
5	1.8	2.1	2.1	2.3
10	2.1	2.4	2.5	2.8
30	2.8	3.2	3.4	4.2
50	3.2	3.4	4.0	6.0
100	3.8	3.8	5.3	10.7

Average Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
5. **Kembar River**				
2	1.3	1.4	1.4	1.5
5	1.6	1.9	1.9	2.1
10	1.9	2.1	2.3	2.5
30	2.5	2.8	3.0	3.8
50	2.8	3.0	3.6	5.4
100	3.4	3.4	4.8	9.6
6. **Wonodad River**				
2	1.6	1.8	1.8	2.0
5	2.1	2.4	2.4	2.7
10	2.5	2.8	2.9	3.2
30	3.2	3.7	3.9	4.9
50	3.7	3.9	4.6	6.9
100	4.4	4.4	6.1	12.4
7. **Gembolo River**				
2	29.5	33.9	33.9	36.7
5	38.7	44.7	44.7	48.6
10	45.8	50.7	53.1	57.8
30	57.7	63.9	67.3	78.6
50	63.9	67.6	76.0	96.6
100	74.0	74.0	90.3	122.6
8. **Janjing River**				
2	26.6	30.9	30.9	33.7
5	36.0	42.2	42.2	46.2
10	43.3	43.3	50.0	54.7
30	54.4	60.5	63.5	73.7
50	60.3	63.9	71.4	87.8
100	69.3	69.3	83.6	111.6

Source: JICA Project Team 2

Other Conditions

- Roughness coefficient: River area (n = 0.03), Land area (n = 0.045)
- Calculation pitch: Calculation pitch: dt = 1 [sec]
- River cross section: River cross section survey for all tributaries was not conducted.

(d) Model Calibration

The frequently inundated area in the administrative area was mentioned in the "*Studi Evaluasi System Pengendalian Banjir Kali Sadar Kabupaten dan Kota Mojokerto, 2013*". The calibration of the model is adjusted so that floods occur at similar location in the existing report.

(e) Results of the Flood Inundation Analysis

The flood inundation analysis is carried out to the present and future conditions (low, medium, high scenarios) under the climate change. The results of the analysis are shown in Table 5.4.10 and Figure 5.4.12. Figure 5.4.12 shows inundation depth and area for 30-year return period under the present condition and medium scenario.

Table 5.4.10 Results of Flood Inundation Analysis (Sadar River Basin)

1. Present Condition

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	91.1	88.2	962
5	127.1	99.5	1,084
10	149.2	105.2	1,147
30	174.3	115.8	1,262
50	186.2	120.2	1,311
100	215.1	141.5	1,543

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

2. Future Condition (Medium)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	106.8	92.6	1,009
5	143.6	108.5	1,183
10	173.7	117.5	1,281
30	193.2	125.2	1,364
50	208.4	137.6	1,500
100	262.0	161.9	1,765

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

3. Future Condition (Low)

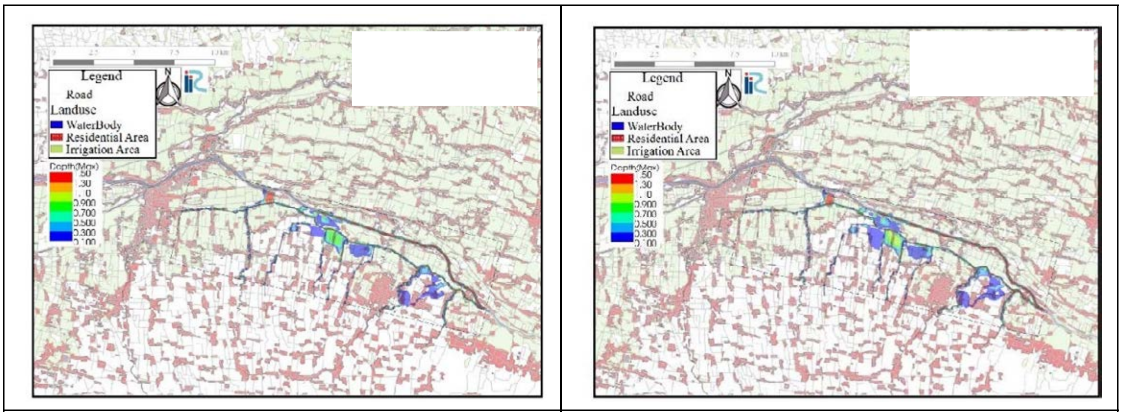
Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	106.8	92.6	1,009
5	137.8	106.1	1,157
10	161.8	112.2	1,224
30	186.2	120.8	1,317
50	193.6	127.1	1,386
100	215.2	141.5	1,543

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

4. Future Condition (High)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	113.3	95.7	1,043
5	149.4	110.9	1,208
10	180.8	120.1	1,309
30	215.2	139.4	1,519
50	268.2	162.1	1,767
100	502.8	319.8	3,486

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage
Source: JICA Project Team 2



Present Condition	Medium Scenario

Source: JICA Project Team 2

Figure 5.4.12 Maximum Inundation Depth and Area in the Sadar River Basin (30-year Probable Flood)

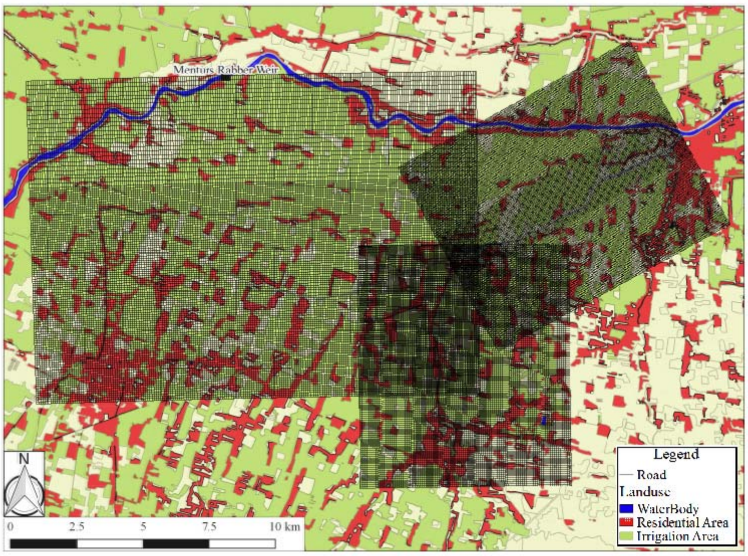
5) Ngotok River Basin (Tributary of the Brangkal River)

(a) Present Condition of the Brangkal River Basin

Flood protection study in the Brangkal River basin was conducted and river dike construction is under construction. However, damage caused by flood inundation still occur in the Ngotok River, which is a tributary river of the Brangkal River. The study of the Ngotok River basin was conducted in the "*SID Sistem Penanggulangan Banjir Ngotok Ring Kanal Kabupaten Mojokerto , 2008*", where it mentioned that inundation occur at several points, which is shown in Figure 5.4.13. The terrain type of the area is flat and to present inundation of this area, a two-dimensional unsteady analysis model is applied.

(b) Simulation Model

The model area is decided from the inundation area from the past flood events. Flooding area in the Ngotok Ring River was located separately along the river, so inundation model was separated into three parts. The simulation model is shown in Figure 5.4.13.



Source: JICA Project Team 2

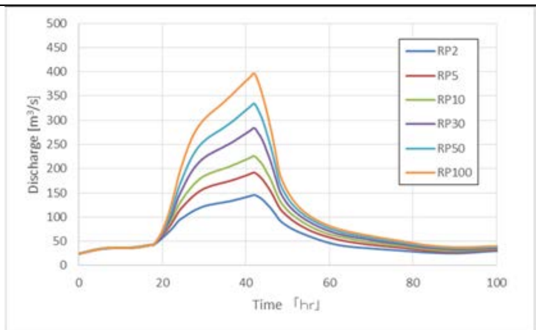
Figure 5.4.13 Model of Inundation Analysis in the Ngotok River Basin

6) Conditions of Analysis

The conditions of simulation are set as follows:

Boundary Condition

- Downstream End: The boundary condition of the downstream end at the confluence point of the Brantas mainstream sets the probable water levels of the mainstream which are estimated from the non-uniform flow calculation by HEC-RAS.
- Upstream End: The hydrographs and adjustment magnitude under the present and future conditions are estimated and provided by Team 1. Figure 5.4.14 shows the hydrographs at present condition. And the peak discharge of each upstream boundary condition is shown in Table 5.4.11.



Brangkal River

Source: JICA Project Team 2

Figure 5.4.14 Hydrograph of Each Upper End Boundary Condition (Brangkal River)

Table 5.4.11 Peak Discharge of Upper End Boundary (Ngotok River Basin)

Average Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Temblang River				
2	58	67	67	72
5	77	89	89	99
10	94	89	113	130
30	114	134	145	183
50	134	145	172	232
100	164	164	214	310
2. Jombang River				
2	68	78	78	84
5	86	100	100	111
10	94	100	113	130
30	123	146	157	198
50	143	156	184	249
100	174	174	226	328
3. Bening River				
2	117	133	133	144
5	144	166	166	185
10	170	166	204	234
30	218	258	278	350
50	258	280	332	448
100	310	309	402	583

Average Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
4. Gunting River				
2	146	167	167	180
5	182	211	211	235
10	217	211	261	299
30	274	325	351	442
50	325	353	418	564
100	387	387	503	728
5. Brangkal River				
2	146	167	167	180
5	192	222	222	247
10	226	222	272	312
30	284	336	363	457
50	334	363	430	581
100	397	397	515	746

Source: JICA Project Team 2

Other Conditions

- Roughness coefficient: River area (n = 0.025), Land area (n = 0.03)
- Calculation pitch: Calculation pitch: dt = 1 [sec]
- River cross section: River cross section survey was carried out on "*SID Sistem Penanggulangan Banjir Ngotok Ring Kanal Kabupaten Mojokerto (2008)*" in 2008. The shape of the river cross section is represented with rectangle in reference to the survey data.

(a) Model Calibration

Flood inundation frequently occurs in the Ngotok River basin, where it's a tributary of the Brangkal River basin. The calibration of the model is adjusted therefore floods occur at similar location in the existing report.

(b) Results of Flood Inundation Analysis

The flood inundation analysis is carried out to the present and future conditions (low, medium, high scenarios) under the climate change. The results of the analysis are shown in Table 5.4.12 and Figure 5.4.15. Figure 5.4.15 shows inundation depth and area for 30-year return period under the present condition and medium scenario .

Table 5.4.12 Results of Flood Inundation Analysis (Ngotok River Basin)

1. Present Condition

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	1	15	300
5	6	109	1,110
10	13	606	6,161
30	33	1,117	11,357
50	50	1,394	14,168
100	74	1,826	18,561

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

2. Future Condition (Medium)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	8	87	1,728
5	25	259	5,133
10	41	428	8,471
30	76	1,544	15,688
50	103	2,065	20,991
100	150	2,926	29,733

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

3. Future Condition (Low)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	8	87	1,728
5	25	259	5,133
10	34	355	7,031
30	70	1,415	14,384
50	80	1,619	16,451
100	91	1,840	18,704

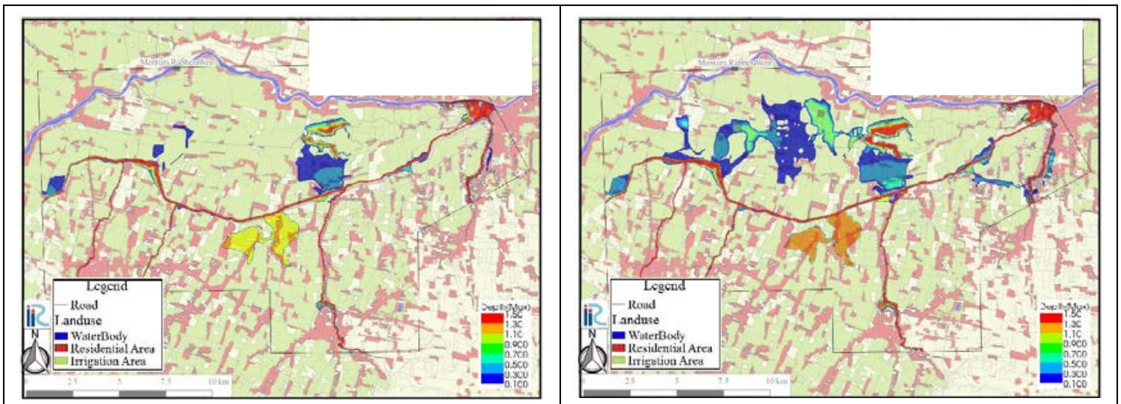
Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

4. Future Condition (High)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	15	159	1,152
5	35	364	10,080
10	63	1,279	12,499
30	127	2,512	23,421
50	182	3,496	37,522
100	250	4,648	49,418

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

Source: JCIA Project Team 2



Present Condition | Medium Scenario

Source: JICA Project Team 2

Figure 5.4.15 Maximum Inundation Depth and Area in the Ngotok River Basin

7) Tawing River Basin

(a) Present Condition of the Tawing River Basin

In Tulungagung area, flood protection constructions were conducted such as the Neyama drainage canal. However, flashfloods occurred in the Tawing River in Trenggalek regency, then inundation analysis is conducted in the Tawing River. The Tawing River is located in the mountainous area, therefore, floods in the rivers and in the inundated area simultaneously flow down together. On the other hand, the downstream area is relatively flat, flood water will tend to be diffused. Inundation model is applied to 1D and 2D combined model to the present inundation catachrestic in the Tawing River.

(b) Simulation Model

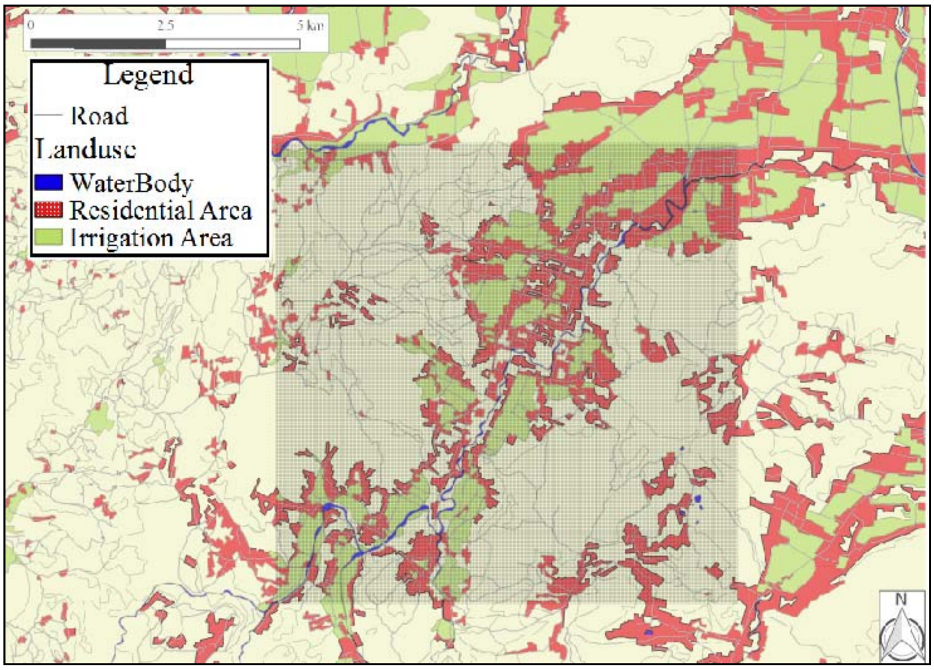
The inundation analysis in the Tawing River basin, where a small river is located in Tulungagung area, applied 1-D and 2-D unsteady flow analysis method. The model area is decided from the inundation area from the past flood events. The simulation model is shown in Figure 5.4.16.

(c) Conditions of Analysis

The conditions of simulation are set as follows:

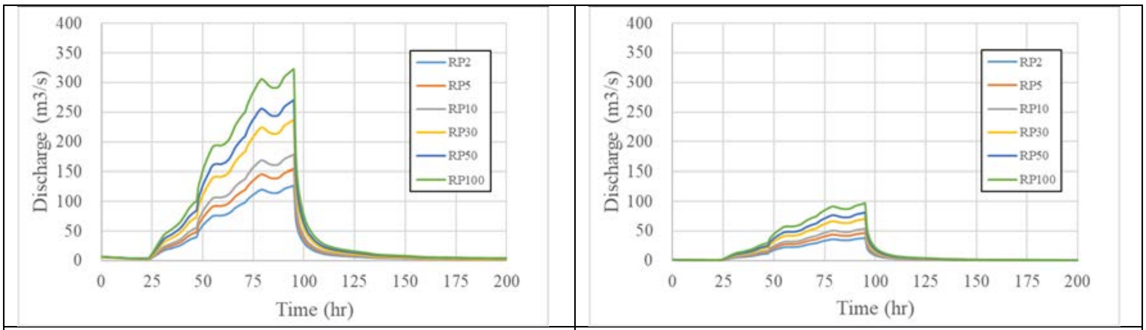
<u>Boundary Conditions</u>

- Downstream End: The boundary condition of the downstream end is set at the normal depth.
- Upstream End: The hydrographs under the present and future conditions evaluated by Team 1 were adjusted by Team 2. Table 5.4.13 shows each peak discharge of tributaries. Figure 5.4.17 shows the hydrographs at the present condition in the Tawing River.



Source: JICA Project Team 2

Figure 5.4.16 Model of Inundation Analysis in the Tawing River Basin



Upper Tawing River	Tributary of the Tawing River

Source: JICA Project Team 2

Figure 5.4.17 Modified Hydrograph of Each Upper End Boundary Condition (Tawing River)

Table 5.4.13 Peak Discharge of Upper End Boundary (Tawing River Basin)

Average Return Period (Year)	Peak Discharge (m^3/s)			
	Present	Low	Medium	High
1. Upper Tawing River				
2	127.1	134.9	142.7	154.3
5	154.0	167.4	180.8	205.3
10	178.2	205.9	222.0	257.9
30	236.6	271.1	305.7	384.3
50	270.1	295.7	350.9	469.8
100	322.1	322.1	417.4	587.4
2. Tributary of Tawing River				
2	38.0	40.3	42.6	46.1
5	46.0	50.0	54.0	61.3
10	53.2	61.5	66.3	77.0
30	70.7	81.0	91.3	114.8
50	80.7	88.3	104.8	140.3
100	96.2	96.2	124.7	175.5

Source: JICA Project Team 2

<u>Other Conditions</u>

- Roughness coefficient: River area (n = 0.025), Land area (n = 0.03)
- Calculation pitch: Calculation pitch: dt = 0.2 [sec]
- River cross section: River cross section survey was not carried out in this project.

(d) Model Calibration

Model calibration was carried out with unsteady flow to compare with the estimated water level mentioned in "*SID Pengendalia Banjir Kali Tawing Kabupaten Trenggalek, 2013*" and calculated water level in this model. The calibration of the model is carried out to a 10-year probable flood because the estimated water level in the past report mentioned the 10-year probable flood.

(e) Results of Flood Inundation Analysis

The flood inundation analysis is carried out to the present and future conditions (low, medium, high scenarios) under the climate change. The results of the analysis are shown in Table 5.4.14 and Figure 5.4.18. Figure 5.4.18 shows inundation depth and area for 30-year return period under the present condition and medium scenario.

Table 5.4.14 Results of Flood Inundation Analysis (Tawing River Basin)

1. Present Condition

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	144.3	69.6	1,378
5	237.3	165.9	1,686
10	267.3	186.0	1,891
30	317.3	204.3	2,076
50	334.2	211.0	2,145
100	352.5	224.3	2,280

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

2. Future Condition (Medium)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	220.2	77.2	1,528
5	269.6	186.6	1,896
10	305.4	199.6	2,029
30	352.1	218.8	2,224
50	362.6	231.6	2,354
100	220.2	245.0	2,490

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

3. Future Condition (Low)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	171.5	72.7	1,440
5	253.4	181.9	1,849
10	293.1	192.8	1,959
30	334.6	211.4	2,149
50	343.6	214.9	2,184
100	352.5	224.3	2,280

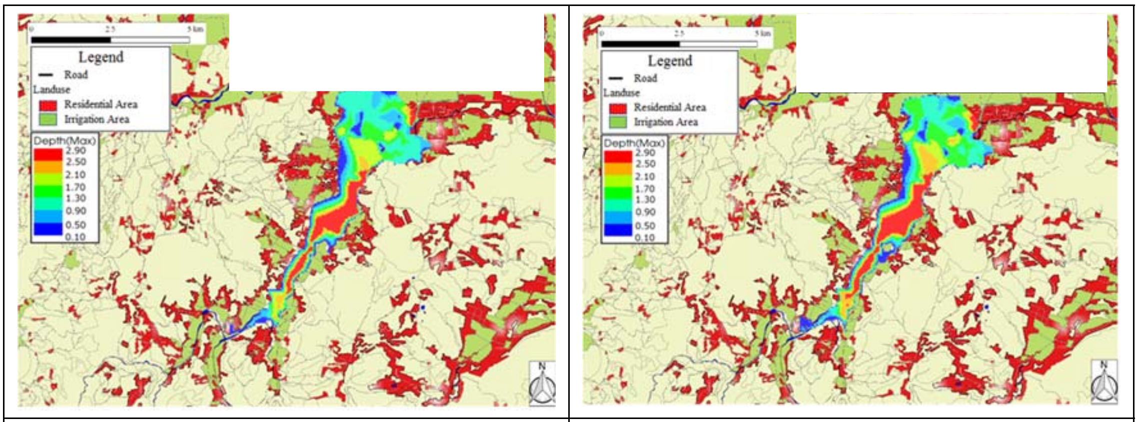
Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

4. Future Condition (High)

Average Return Period (Year)	Irrigation Area (ha)	Affected Houses (nos.)	Affected People (Person)
2	237.7	166.1	1,689
5	292.9	192.8	1,959
10	329.2	209.0	2,124
30	379.7	239.3	2,432
50	397.7	258.3	2,626
100	426.1	269.7	2,741

Note: Parameter of affected houses are applied from the Japanese Guideline of Estimation for Flood Damage

Source: JICA Project Team 2



Present Condition	Medium Scenario

Source: JICA Project Team 2

Figure 5.4.18 Maximum Inundation Depth and Area in the Tawing River Basin

5.4.3 Flood Control Storage and Effects by Sutami Dam

While flood control capacity is assumed to be the same in the future, flood inflow into the dam reservoir is predicted to increase due to climate change. The impact of climate change to the flood control effects on the existing dam is studied targeting the Sutami Dam, which has the biggest flood control capacity in the Brantas River basin.

(1) Designed Flood Control Operation for Sutami Dam

Flood control operation of the Sutami Dam was studied and determined in the "Report on the Revision of Design of the Karangkates Dam[1], August 1965" (hereinafter called as 1965 Study). Two kinds of design hydrographs were prepared, one for the design flood and another for the abnormal flood, to simulate flood routing in the dam reservoir. The design values of spillway discharge, flood water level and dam crest elevation are determined as presented in Table 5.4.15. The simulation result of flood routing in case of the design flood is shown in Figure 5.4.19.

Table 5.4.15 Designed Flood Control Operation of Sutami Dam

Items		Design Flood	Abnormal Flood
Inflow	Peak discharge	3,000 m^3/s	4,200 m^3/s
	Average return period	1/200	1/1000
Initial Water Level	-	WL 272.500	WL 272.500
Outflow under Case A*	Discharge	1,060 m^3/s	1,580 m^3/s
	RWL	WL 275.500	WL 276.630
Outflow under Case B*	Discharge	920 m^3/s	1,400 m^3/s
	RWL	WL 276.150	WL 277.230
Designed Value	Design spillway	1,600 m^3/s	
	Flood WL	FWL 277.000 m	
	Dam crest	EL. 279.000 m	

Note: * Case A : with spillway gate operation, Case B: without spillway gate operation
Source: 1965 Study Report

(2) Simulation of Flood Control Operation for Sutami Dam in 2050

Flood control operation for Sutami Dam under future climate change in the target year of 2050 is simulated adopting the same manner in case A (with spillway gate operation) of the original

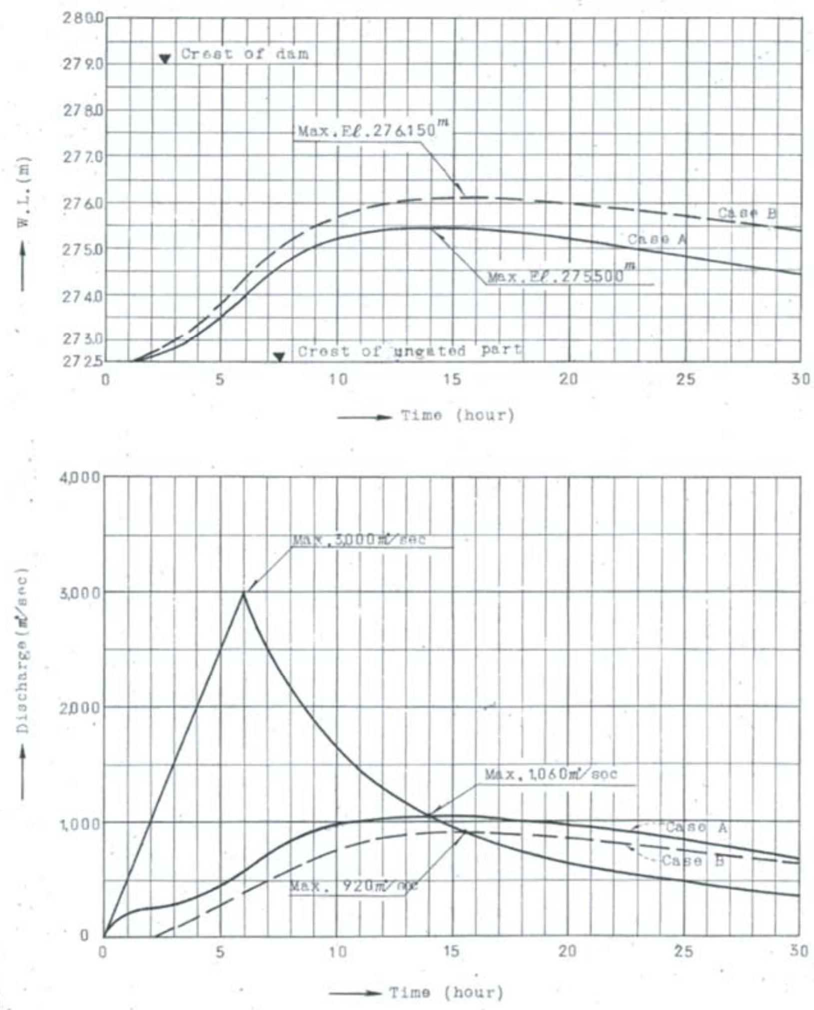
[1] The Sutami dam was previously called "Karangkates Dam".

design as mentioned above. For the flood hydrographs in the future climate change scenario, the original design hydrograph is enlarged as shown in Figure 5.4.20 taking into account the increase rate of the probable rainfall obtained from the analysis result of the climate change study undertaken by Team 1. Simulation cases and conditions are summarized below:

Table 5.4.16 Cases for Simulation of Flood Control Operation of Sutami Dam in 2050

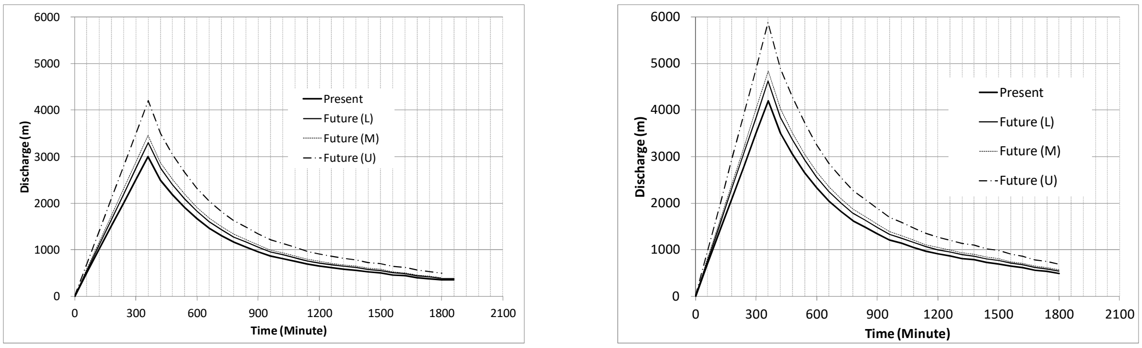
Cases		Design Flood	Abnormal Flood	Dam HV-Curve
(1) Original Design (1972)		3,000 m³/s	4,200 m³/s	1972 data
(2) Present Condition(2012)		3,000 m³/s	4,200 m³/s	2012data
(3) Future Condition (2050)				
i) Under Present Climate		3,000 m³/s	4,200 m³/s	2050 estimation (P)*
Under Future Climate Change Scenario	ii) Low	3,300 m³/s	4,620 m³/s	2050 estimation (L)*
	iii) Medium	3,450m³/s	4,830 m³/s	2050 estimation (M)*
	iv) High	4,200 m³/s	5,880 m³/s	2050 estimation (U)*

Note: * Dam HV-curve above NWL in the flood control storage is assumed with no change since 2012. P: Present, L, Low scenario, M, Medium scenario, U, High scenario
Source: JICA Project Team 2



Source: 1965 Study Report

Figure 5.4.19 Flood Routing of Sutami Dam for Design Flood with Peak Discharge of 3,000 m³/s



Design Flood　　　Abnormal Flood

Source: JICA Project Team 2

Figure 5.4.20 Flood Hydrographs in Future Climate Change Scenario in 2050

(3) Result of Simulation of Flood Control Operation for Sutami Dam in 2050

The result of simulation are presented in Figure 5.4.21 and summarized in Table 5.4.17.

Table 5.4.17 Simulation Results of Flood Control Operation of Sutami Dam in 2050

< Design Flood>

Cases		Maximum Reservoir Water Level		Dam Outflow Discharge	
		Value (El.m)	Difference (m)	Value (m^3/s)	Difference(m^3/s)
(1) Original Design (1972)		275.50		1,060	
(2) Present Condition(2012)		275.74	+ 0.24	1,291	+ 231
(3) Future Condition (2050)					
i) Under Present Climate		275.74	+ 0.24	1,291	+ 231
Under Future Climate Change Scenario	ii) Low	276.09	+ 0.59	1,428	+ 368
	iii) Medium	276.25	+ 0.75	1,517	+ 457
	iv) High	277.00	+ 1.50	1,955	+ 895

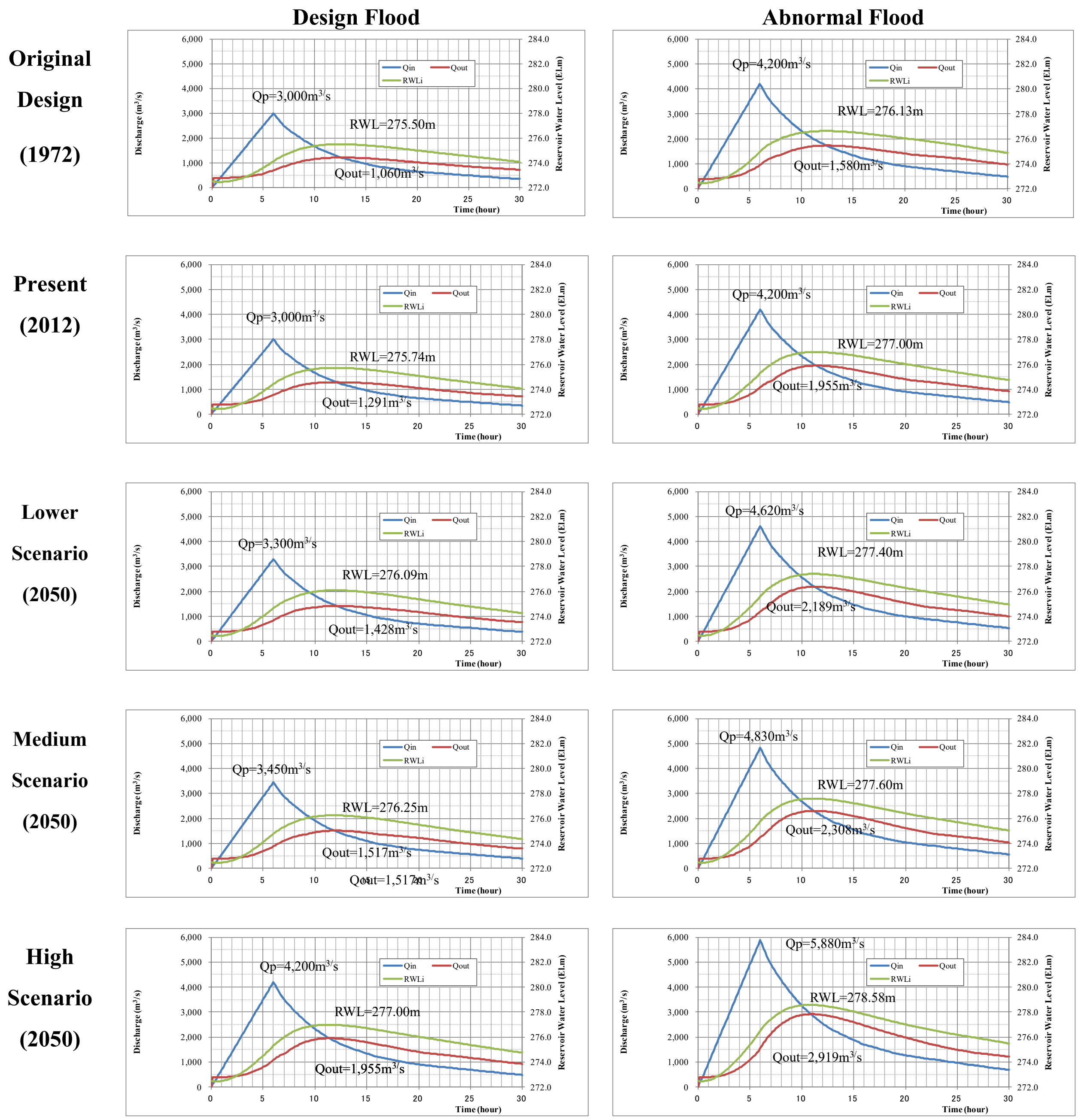
< Abnormal Flood>

Cases		Maximum Reservoir Water Level		Dam Outflow Discharge	
		Value (El.m)	Difference (m)	Value (m^3/s)	Difference(m^3/s)
(1) Original Design (1972)		276.63	-	1,580	-
(2) Present Condition(2012)		277.00	+ 0.37	1,955	+ 375
(3) Future Condition (2050)					
i) Under Present Climate		277.00	+ 0.37	1,955	+ 375
Under Future Climate Change Scenario	ii) Low	277.40	+ 0.77	2,189	+ 609
	iii) Medium	277.60	+ 0.97	2,308	+ 728
	iv) High	278.58	+ 1.95	2,919	+ 1,339

Source: JICA Project Team 2

- Comparing with the designed values, increase of maximum reservoir water level in the future condition is ranging from +0.59 m to +1.50 m for the design flood, and from +0.77 m to +1.95 m for the abnormal flood.
- Increase of maximum spillway discharge in the future condition is ranging from +368 m^3/s to +895 m^3/s for the design flood, and from +609 m^3/s to +1,335 m^3/s.
- In the most extreme case of the abnormal flood with future climate scenario (high), the maximum reservoir water level would reach up to 278.58 m which is only 0.42 m lower than the dam crest elevation.

- As shown in the above, the flood risk of overtopping of dam is increasing in the Sutami Dam due to climate change. Any countermeasures shall be applied before the situation will be critical.



Source: JICA Project Team 2

Figure 5.4.21 Result of Flood Control Operation of Sutami Dam

5.5 Assessment of Climate Change Impacts in 2050

5.5.1 Safety Level

(1) Safety Level against Drought

1) Present Water Demand and Supply Water under Present Hydrological Condition

The safety level of the municipal and industrial water supply is kept to 10-year dependable level. And total cropping intensity to keep 5-year dependable level is 224%.

2) Present Water Supply Demand and Supply Water under Climate Change Condition

As the comparison scenario, the following conditions are considered. Table 5.5.1 shows the comparison of number of deficit and the annual power generation.

<Condition of comparison>

Condition	Present	Future
Climate	Present	Climate Change
Scenario	-	Medium
Irrigation Demand	Present	Present
M&I Demand	Present	Present
Reservoir Volume	Present	Future

Source: JICA Project Team 2

Table 5.5.1 Comparison Results of Deficit to Irrigation Water Supply and Municipal and Industrial Water Supply, and Annual Power Generation

1. Irrigation

	Irrigation Scheme	Irrigation Area (ha)	No. of Year to Occur Deficit	
			Present Climate	Future Climate
Tributaries	DI_Kedung kandang	5,160	0	4
	DI_Paingan	551	0	1
	DI_Blader	286	1	1
	DI_Siman	23,060	4	6
	DI_Bening	8,752	4	10
	DI_Padi Pomahan	4,309	3	4
Main Stream	DI_Lodagung	12,217	0	1
	DI_Mrican Kanan	17,612	0	2
	DI_Mrican Kiri	12,729	0	2
	Di_Jatimlerek	1,812	0	2
	DI_Mentrus	3,632	0	3
	DI_Jatikulon	638	0	3
	DI_Brantas Delta	17,942	0	3
	Total	108,700		

2. Municipal and Industrial Water

No.	District/ Municipality	No of Year of Failure of M&I Water	
		Present Climate	Future Climate
1	Batu	0	0
2	Malang	0	1
3	Kediri	0	0
4	Blitar	0	0
5	Sidoarjo	0	0
6	Mojokerto	0	0
7	Jombang	0	0
8	Surabaya	0	0
9	Trenggalek	0	0
10	Tulungagung	0	0
11	Nganjuk	0	0
12	Gresik	0	0

3. Annual Power Generation

No.	Principal Hydropower Station	Annual Power Generation (GWh)	
		Present Climate	Future Climate
1	Sengguruh	114	92
2	Sutami	475	397
3	Wlingi	189	162
4	Lodoyo	36	33
5	Wonorejo	31	20
6	Selorejo	32	30
	Total	877	735 (86%)

Source: JICA Project Team 2

3) Irrigation Water Supply

A number of deficits are increased. Especially, safety level of Siman and Bening irrigation schemes is lower than the 5-year dependability.

4) M&I Water Supply

Safety level of M&I is not lower than the 10-year dependability due to priority of water supply.

5) Power Generation

Annual power generation is reduced to 86% of the present climate.

(2) Safety Level against Flood

1) Widas River Basin

Safety level under the future condition is compared with the present condition. Table 5.5.2 shows the average return period of the peak discharge based on each case.

Table 5.5.2 Average Return Period Estimated from Future Condition (Widas River)

Probable Flood under Present Condition (m^3/s)	Average Return Period (year)			
	Present	Low	Medium	High
172	2	1.6	1.5	1.4
229	5	2.5	2.5	2.0
278	10	4.7	4.7	3.1
389	30	17.0	12.8	7.7
441	50	26.3	19.0	10.8
532	100	100.0	37.9	17.8

Source: JICA Project Team 2

2) Sadar River Basin

Table 5.5.3 shows the average return period of the peak discharge based on each case.

Table 5.5.3 Average Return Period Estimated from Future Condition (Sadar River)

Probable Flood under Present Condition (m^3/s)	Average Return Period (year)			
	Present	Low	Medium	High
51	2	1.5	1.5	1.3
67	5	2.9	2.9	2.3
78	10	6.7	6.7	4.0
95	30	19.3	17.5	11.3
105	50	30.0	25.4	15.3
114	100	100.0	37.1	20.8

Source: JICA Project Team 2

3) Ngotok River Basin

Table 5.5.4 shows the average return period of the peak discharge based on each case.

Table 5.5.4 Average Return Period Estimated from Future Condition (Ngotok River)

Probable Flood under Present Condition (m^3/s)	Average Return Period (year)			
	Present	Low	Medium	High
464	2	1.7	1.7	1.4
529	5	2.9	2.9	2.0
597	10	6.5	5.8	3.7
684	30	16.8	13.5	7.0
754	50	34.2	26.7	11.9
823	100	149.3	45.4	18.8

Source: JICA Project Team 2

4) Tawing River Basin

Table 5.5.5 shows the average return period of the peak discharge based on each case.

Table 5.5.5 Average Return Period Estimated from Future Condition (Tawing River)

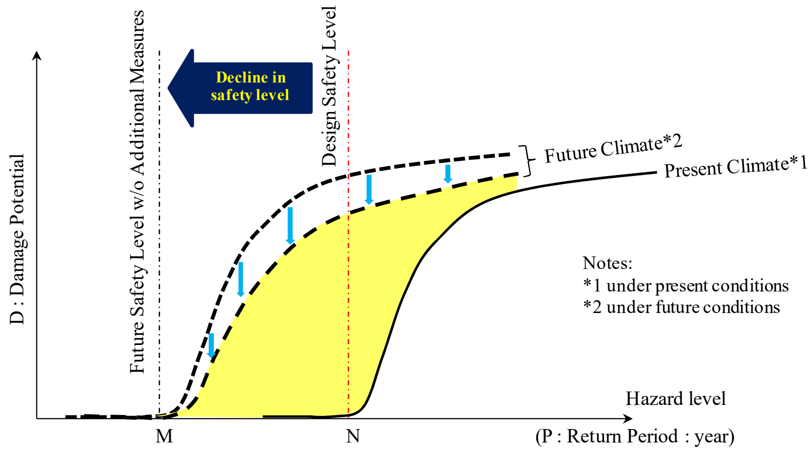
Probable Flood under Present Condition (m^3/s)	Average Return Period (year)			
	Present	Low	Medium	High
165.1	2	1.7	1.3	1.1
199.9	5	3.8	2.8	2.2
231.4	10	5.8	4.5	3.4
307.3	30	15.1	12.0	7.4
350.7	50	30.0	19.5	10.1
418.3	100	100.0	39.5	17.7

Source: JICA Project Team 2

5.5.2 Risk and Resilience

(1) Concept of Risk and Resilience Assessment for Water Resources Management

This Project deals with the assessment of risk and resilience for water resources management under future climate change conditions on the basis of the concept presented in Figure 5.5.1.



➢ **Risk = $\sum D \times \Delta(1/P)$: Expected Value (Eq. 1)**

Legend:	
--------	Before exercise of resilience
- - - - -	After exercise of resilience
(blue arrow)	Decrease of Risk by Exercising Resilience
(yellow)	For Structural and Non-structural Measures
N, M	Years (M < N)

Source: JICA Project Team 2

Figure 5.5.1 Concept of Risk and Resilience for Water Resources Management (Hazard: Flood and Drought)

The risk is estimated with Eq. 1, and the term of "Resilience" is defined below according to the United Nations International Strategy for Disaster Reduction (UNISDR) Terminology on Disaster Risk Reduction (2009).

> **Resilience** = The ability of a system, community or society exposed to hazards to resist, absorb, accommodate to and recover from the effects of a hazard in a timely and efficient manner, including through the preservation and restoration of its essential basic structures and functions.
> Comment: Resilience means the ability to "resile from" or "spring back from" a shock. The resilience of a community in respect to potential hazard events is determined by the degree to which the community has the necessary resources and is capable of organizing itself both prior to and during times of need.
>
> Source**:** UNISDR (United Nations International Strategy for Disaster Reduction) Terminology on Disaster Risk Reduction (2009)

The orange part in Figure 5.5.1 means the remaining risk under future climate change conditions after exercise of resilience and is to be the objective risk for consideration of additional structural and non-structural measures in the future.

The assessment has been made, paying due attention to the indices and the methods of resilience exercise mentioned in Table 5.5.6 and Table 5.5.7.

Table 5.5.6 Conceivable Assessment of Flood Damage and Resilience in the Brantas River Basin

Assessment Items	Indices of Damage Assessment	Methods for Resilience Exercise*
< Quantitative Assessment >		
Properties		
- Direct damage	Damage of general properties (Number of damaged houses)	• Review of the present operation rules of existing facilities for flood control （incl. : over-year storage dams, coordinated dam operation) • Repair and restoration of existing facilities for flood control
	Damage of agricultural products (Area of damaged cultivation land)	
	Damage of cultural assets (Number of damaged facilities)	
- Indirect damage	Declination of social function • Blocking of transportation (such as blocked section lengths of major roads and railways, number of impassable bridges, etc.) • Suspension of lifeline (Number of people affected by suspension of water supply and sewage systems) • Declination of hub facility function for disaster-prevention (Numbers of police and fire stations, government offices, etc. in the inundation areas)	• Same as above • Water-resistance improvement of existing infrastructure and flood control facilities • Introduction of redundant facility measures (use of substitute facilities)
	Economic damage (Numbers of companies and factories subject to business suspension, etc.)	• Review of the present operation rules of existing facilities for flood control （Incl. : over-year storage dams, coordinated dam operation) • Repair and restoration of existing facilities for flood control
Population	Number of people in inundation areas	• Enhancement of evacuation facilities (Evacuation roads, evacuation centers, hilly areas, etc.） • Land use control
< Qualitative Assessment >		
Organization and Institution	Organizational and institutional capacity on unforeseen flood disaster (Hub-functions of government offices, evacuation and flood-fighting system, restoration activities, etc.) (Insufficiency, Malfunction)	Capacity enhancement of existing organizations and institutions for flood prevention

Note: * Best possible use of existing facilities

Source: JICA Project Team 2

Table 5.5.7 Conceivable Assessment of Drought Damage and Resilience in the Brantas River Basin

Assessment Items	Indices of Damage Assessment	Methods for Resilience Exercise*
< Quantitative Assessment >		
Properties		
- Direct damage	Damage of agricultural products (Area of damaged cultivation land)	• Review of the present operation rules of existing facilities for drought management (incl. : over-year storage dams, coordinated dam operation) • Repair and restoration of existing facilities for drought management • Introduction of redundant facility measures (use of substitute facilities)
	Lifeline damage, such as • Suspension of hydro power generation (Number of affected people) • Suspension of water supply (Number of affected people)	
	Damage of cultural assets (Number of damaged facilities)	
	Environmental damage • Aggravation of river water quality (Decrease of environmental flow) • Deterioration of natural ecosystem (Damaged area)	• Same as above • Enhancement of wastewater management
- Indirect damage	Economic damage (Number of companies and factories subject to business suspension, etc.)	• Introduction of redundant facility measures (Use of substitute facilities)
Population	Number of people in affected water supply areas	• Improvement of water supply facilities (Enhancement of conveyance efficiency, etc.) • Introduction of redundant facility measures (Use of substitute facilities)
< Qualitative Assessment >		
Organization and Institution	Capacity of relevant organizations (Drought management committee, etc.) and institutions (insufficiency, malfunction)	Capacity enhancement of relevant organizations and institutions for drought management

Note: * Best possible use of existing facilities
Source: JICA Project Team 2

(2) Risk for Water Resources Management under Five Pillars in Indonesia

According to the Minister Decree of Public Works and Housing No.10/PRT/M/2015, five pillars of water resources management are studied in POLA, as follows;

1) Water Resources Conservation,

2) Water Resources Utilization,

3) Water's Destructive Power Control,

4) Water Resources Information System, and

5) Empowerment and Improvement of Community's and Business World's Role.

Table 5.5.8 shows the 1) Expected Future Situation and 2) Expected Risk at Future Situation of the five pillars.

Table 5.5.8 Expected Future Situation and Risk

1. Water Resources Conservation

Sub-aspect	Expected Future Situation	Expected Future Risk
Protection and Conservation of Water Resources	・ Even the provincial government plans to keep the forest area, illegal felling will not be eliminated. ・ Vegetation of slope land area will be changed to bare land due to climate change impact. The grasses at slope area will wither due to prolonged drought. ・ Peak discharge will be higher than the present due to climate change.	・ Following risks will be worse. [Expected risk at present] ・ Reducing function of water-retaining ・ Increasing sediment production Slope land of forestry is gradually changed to bare land. At that time, peak discharge will become higher and refill volume to ground water will be reduced. Gully erosion will occur at the bare lands.
Water Preservation	・ Further construction of river facilities may cause fragmentation of the ecosystem and change of water flow, riverbank and dry riverbed which affect the habitat. ・ Flood, drought and water temperature rise may affect ecosystem (habitat, seasonal migration, life cycle, etc.) ・ Change in river condition may accelerate the introduction of alien species ・ Available groundwater volume will be reduced due to illegal extraction and climate change impact.	・ Following risks will be worse. [Expected risk at present] ・ Increasing frequency of drought situation ・ When available groundwater is reduced during the dry season, the possibility of drought is increased.
Management of Water Quality and Water Pollution Control	・ [By higher peak discharge and rainfall] pollutants from non-point sources such as fertilizer from agricultural land, sedimentation will be increased. ・ [By drought] water quality will be deteriorated by enrichment effect during lower discharge. ・ Water quality will be worse because of increasing factory effluent, agricultural application of fertilizers, and human sewage. ・ Possibility of damage to fishes may increase due to water quality deterioration.	・ Following risks will be worse. [Expected risk at present] ・ Health risk for drinking water ・ Deterioration of water quality for domestic and industrial use ・ Possibility of damage to river ecosystem

2. Water Resources Utilization

Sub-aspect	Expected Future Situation	Expected Future Risk
Water Resources Management	・ Available groundwater volume will be reduced due to illegal extraction and climate change impact. ・ Reservoir volumes will be reduced compare with the present ones. ・ Water quality in the reservoirs will become worse because thermocline layers may be formed more easily. (Eutrophication)	・ Following risk will be worse. [Expected risk at present] ・ Increasing frequency of drought ・ Outflow from the reservoir will be increased during the flood event due to decreasing flood control space and increasing peak discharge. ・ Water quality deterioration in reservoirs

Sub-aspect	Expected Future Situation	Expected Future Risk
Water Resources Provision	･ The supply side will not be able to satisfy the safety level of water utilization. This situation will be severe. ･ Sediment inflow will be increased compare with the present situation. ･ The river flow in the dry season will be reduced.	･ Expected risk at the present will be worse. [Expected risk at present] ･ Supply water volume from the reservoirs is reduced because the sediment from upstream of the reservoirs is settled at the effective storage area.
Water Resources Use	･ The river flow during the dry season will be reduced. ･ The reservoir volume will be smaller than the present one. ･ The available groundwater volume will be reduced. ･ Water quality of surface water and groundwater will become worse.	･ Expected risk at the present will be worse. [Expected risk at present] ･ Decreasing cropping intensity compare with planned one. ･ Water quality deterioration will occur.
Existing Water Resources Development Plan	･ The construction of some planned dams will not be constructed due to budget problem.	･ This sub-aspect is excluded from the evaluation due to conceptual evaluation.
New Plan of Water Resources Development	･ The existing water resources development plans will not be completed.	･ This sub-aspect is excluded from the evaluation due to conceptual evaluation.

3. Water's Destructive Power Control

Sub-aspect	Expected Future Situation	Expected Future Risk
Disaster Prevention	･ Dike will be broken frequently due to extreme flood event. ･ Flood control space will be smaller than the present situation due to increasing sediment inflow in future situation. And inflow discharge to dams will be increased.	･ Following risks will be worse. [Expected risk at present] ･ Flood inundation will occur. ･ Outflow from each dam is increased during the flood event.
Disaster Relief	･ According to the population projection, the percentage of old persons will be increased compare with the present situation. It means that they will need assistance in the evacuation to the shelters. ･ Peak discharge will be higher than the present situation, and the frequency of the flood events will be also increased due to climate change condition.	･ Following risks will be worse. [Expected risk at present] ･ Flood inundation is occurred because of poor skills of the flood fighting team (For example: strengthening of dike body). ･ Some persons will die and/or get injured due to delay or no evacuation. ･ Evacuation frequency will be increased. ･ Number of overtopping from the dike will be increased. ･ Inundation area will be wider.
Disaster Recovery	･ The damage area of the dike, public infrastructures, houses, industrial companies and crop will be increased. The magnitude of the rehabilitation works will be increased.	･ Following risk will be worse. [Expected risk at present] ･ Possibility of flood inundation from broken area of dike is increased. ･ Damaged area of dike, public infrastructures will be wider. ･ Budget of the recovery and reconstruction works will be increased.

4. Water Resources Information System

Sub-aspect	Expected Future Situation	Expected Future Risk
Water Resources Information System	・ The system is not timely updated. ・ Software is not updated.	・ All water resources management data are not timely put into the system.
Managing Institution	・ Data managing system will be the same as the present situation.	Same expected risks as the present one. [Expected risk at present] ・ Data management is carried out by the Balai. However, data are collected from other agencies. Interface between the Balai and the other agencies is not clear.
Improvement of institutions and human resources in water resources information system management	・ The management data will be larger compare with the present situation.	Same expected risk as the present one. [Expected risk at present] ・ There are few specialists of database system.

5. Empowerment and Improvement of Community's and Business World's Role

Sub-aspect	Expected Future Situation	Expected Future Risk
Improvement of community's and business world's role in the planning	・ Future situation of empowerment and improvement of community's and business world's role will be the same as present situation.	Same expected risk as the present one. [Expected risk at present] ・ Limited information related to the Water Resources Development Plan. ・ These stakeholder groups did not seriously study by themselves the positive and negative impacts.
Improvement of community's and business world's role in the implementation	・ Future situation of empowerment and improvement of community's and business world's role will be the same as present situation.	Same expected risk as the present one. [Expected risk at present] ・ The project implementation is sometimes delayed because affected water user groups don't agree with the land acquisition price.
Improvement of community's and business world's role in the monitoring	・ Future situation of empowerment and improvement of community's and business world's role will be the same as present situation	Same expected risk as the present one. [Expected risk at present] ・ The farmer's group cannot get the required water because of water leakage along the primary canal. ・ The actual extraction volume of groundwater is not measured.

Source: JICA Project Team 2

(3) Resilience to Selected Risk

Even the Indonesian side considers the five pillars of water resources management, Team 2 studied the resilience against the flood risk and the drought damage in 2050 under the climate change condition. Therefore, screening of five pillars is carried out. Table 5.5.9 shows a selection result.

Table 5.5.9 Risk under Climate Change Condition

1. Water Resources Conservation

Sub-aspect	Hazard	Risk	Risk Evaluation Index	Risk Evaluation
Protection and Conservation of Water Resources	Illegal felling	・ Reduced in function of water retaining ・ Increased in sediment inflow	Qualitative	This hazard is not affected from the climate change impact.
	Flood		Qualitative	Risk will be more severe in situation under the climate change condition.
	Drought		Qualitative	Risk will be more severe in situation under the climate change condition.
Water Preservation	Illegal felling	・ Increased in frequency of drought situation	Qualitative	This hazard is not affected from the climate change impact.
	Drought		Qualitative	The aquifer of the groundwater will be decreased not only the illegal felling but also the severe climate condition under climate change.
Management of Water Quality and Water Pollution Control	Factory effluent	・ Possibility of health damage in using surface water directly ・ Possibility of damage to fish	Qualitative	This hazard is not affected from the climate change impact.
	Human sewage		Qualitative	This hazard is not affected from the climate change impact.
	Flood		Qualitative	Fertilizer and pesticide flow to the river during the flood event. When the rainfall intensity is increased under the climate change condition, the outflow of these materials is also increased. In this case, the water quality in the river will be worse. It is difficult to measure the dissolved pesticide in the river.
	Drought		Qualitative	Under the climate change condition, the dilution water in the river is reduced. This phenomenon will occur during the dry season. In this case, this impact will affect the health of the human and the aquatic resources.

2. Water Resources Utilization

Sub-aspect	Hazard	Risk	Risk Evaluation Index	Risk Evaluation
Water Resources Management	Illegal water intake	・ Increased in frequency of drought	Qualitative	Risk will be more severe because the total amount of groundwater will be decreased under climate change. This risk will not be reduced until the government creates the new water storage structures.
	Drought		Cropping area (ha) Municipal and industrial water (l/s) Power Generation (GWh)	Total amount of available water will be reduced under the climate change condition. Risk will be evaluated from the water balance analysis result. However, the evaluation result of the water balance analysis is indicated in all sub-aspects related to the drought
Water Resources Provision	Drought	・ Reduced supply water volume from the reservoir	Cropping area (ha) Municipal	The reservoir volume will be reduced year by year due to sediment inflow. The annual

Sub-aspect	Hazard	Risk	Risk Evaluation Index	Risk Evaluation
			and industrial water (l/s) Power Generation (GWh)	sediment inflow volume is expected to increase due to climate change. Risk will be evaluated from the water balance analysis result.
Water Resources Use	Drought	・ Increased in frequency of drought		Risk will be evaluated based on the result of the water balance analysis. The evaluation result is indicated in all related sub-aspects. Its result is not divided to sub-aspects.
Existing Water Resources Development Plan	Flood and drought	・ Increased in frequency of drought. ・ Delay of the development schedule (Budget allocation problem)	Qualitative	If these proposed structures are not constructed until 2050, water shortage will occur and flood peak discharge will be increased. The risk will not be reduced until the construction of all planned structures is completed.
New Plan of Water Resources Development	Flood and drought	・ Uncertainty until completion of all existing water resources development plan.	Qualitative	The risk will not be reduced until the new water resources developments are planned and implemented under climate change condition.

3. Water's Destructive Power Control

Sub-aspect	Hazard	Risk	Risk Evaluation Index	Risk Evaluation
Disaster Prevention	Defective condition of structures	・ Number of flood inundation is increased. ・ Outflow from each dam is increased during the flood event.	Qualitative	This risk will not be improved until the governments carry out the monitoring and rehabilitation of the structures.
	Poor maintenance of flood management structures		Qualitative	The risk of dike damage will not be reduced until the governments carry out regular inspection and repair works to the dike. The risk of storage will not be improved until PJT-I decides on the new reservoir operation rule and countermeasures to sediment inflow.
	Insufficient condition of evacuation centers		Qualitative	The risk faced by the evacuation center will not be diminished until the governments study the flood inundation condition of all evacuation centers and check the building condition and stocks.
	Flood		Number of affected houses (nos.) Inundation area of agricultural land (ha) Number of affected people (person)	Risk will be evaluated from the inundation analysis result. However, the evaluation result of the inundation analysis is indicated in all sub-aspects related to flood. Its result is divided into each sub-aspect for convenience.
Disaster Relief	Flood	・ Increased in number of casualties	Qualitative	The risk of immature skills of persons performing evacuation guidance increases the casualties.

Sub-aspect	Hazard	Risk	Risk Evaluation Index	Risk Evaluation
			Number of old person and child	It is difficulty to evacuate old persons and children to the evacuation center. According to the projected age structure of the population, old person will be increased. The risk of the evacuation is estimated from their numbers.
Disaster Recovery	Flood	・ Flood damage is increased.	Number of houses (nos.) Inundation area of agricultural land (ha) Number of affected people (person)	Risk will be evaluated from the inundation analysis result. However, the evaluation result of the inundation analysis is indicated in all sub-aspects related to flood. Its result is divided into each sub-aspect for convenience.

4. Water Resources Information System

Sub-aspect	Hazard	Risk	Risk Evaluation Index	Risk Evaluation
Water Resources Information System	Institution	・ Other related agencies don't carry out the input and collection of data related to the water resources management.	Qualitative	They decided to use the water resources information system in the BBWS Brantas. BBWS Brantas shall timely update the data and system. BBWS Brantas considers data shearing through homepage but it is under preparation.
Managing Institution	Institution	・ It is not clear who is in-charge of this system at each related agency. ・ Updating the data base system	Qualitative	It is not clear who is the one carrying out the data collection and data input in the system.
Improvement of Institutions and Human Resources in Water Resources Information System Management	Institution	・ Lack in number of staffs in BBWS Brantas	Qualitative	It is difficult to hire a database specialist.

5. Empowerment and Improvement of Community's and Business World's Role

Sub-aspect	Hazard	Risk	Risk Evaluation Index	Risk Evaluation
Improvement of Community's and Business World's Role in the Planning	Limited information	・Poor sense of ownership	Qualitative	It is difficult to control conflict among them. It is necessary to coordinate their requirement in meeting of TKPSDA.
Improvement of Community's and Business World's Role in the Implementation	Limited information	・Poor sense of ownership	Qualitative	They don't assist the implementation organization. The beneficiary shall assist the implementation organization.
Improvement of Community's and Business World's Role in the Monitoring	Limited information	・Poor sense of ownership	Qualitative	They get benefits from the water resources management structures but they don't have the sense of ownership. It is necessary that they shall assist a part of the monitoring.

Source: JICA Project Team 2

1) Screening of Risk related to Drought

The major risk of drought under future condition is reducing of cropping intensity and annual power generation. Table 5.5.10 shows the summary of damage to drought condition.

Table 5.5.10 Damage of Drought

Case	Cropped Area (ha)			Cropping Intensity (%)	M&I (m^3/s)	Power Generation (GWh)
	Mainstream	Tributaries	Total			
Present	166,455	77,350	243,805	224	29.5	877
Future						
Medium	131,315	69,796	201,111	150	50.2	730
Low	166,465	96,348	262,813	196	50.4	767
High	93,182	63,265	156,447	116	46.7	657

Note: Safety level: Irrigation 5-yr probability, Municipal and Industrial water 10-yr probability
Source: JICA Project Team 2

2) Screening of Risk related to Flood

The major risk of flood is overtopping of structure. Therefore, the risks of the following rivers are organized.

(a) Porong River

Table 5.5.11 shows the overtop locations at the present and future conditions.

It is expected that overtop from the dike near the New Lengkong Dam and at KP1-KP15, KP20-KP30 and KP60-KP85 occurred. The downstream of these sections will be considered in the adaptation measures.

Table 5.5.11 Location of Overtop Sections

Location	Main Channel Distance from River Mouth (km)	Present	Future		
			High	Medium	Low
KB51~New Lengkong Dam	52~48	< 100 cm in several section	Overtop at New Lengkong Dam < 100 cm in several sections	<100 cm in several sections	<100 cm in several sections
KP1~KP15	48 ~ 45	<100 cm	Overtop	< 100 cm	< 100 cm
KP20~KP30	43 ~ 42	Overtop	Overtop	Overtop	Overtop
KP60~KP85	36 ~ 30	Overtop in several sections	Overtop in almost sections	Overtop in almost sections	Overtop in almost sections

Source: JICA Project Team 2

(b) Other Tributaries

The annualized incremental damage under future condition is summarized in Table 5.5.12.

Table 5.5.12 Summary of Flood Risk

Scenario	River Basin	Irrigation Area (ha)	Affected House (nos.)	Affected People (nos.)
Medium	Widas	100.3	31.1	634.9
	Sadar	96.9	75.5	822.8
	Ngotok	16.6	222.3	3,346.2
	Tawing	186.6	97.1	1,280.8
Low	Widas	81.4	19.0	387.2
	Sadar	94.0	74.2	808.6
	Ngotok	15.2	200.4	3,156.0
	Tawing	162.0	93.3	1,224.8
High	Widas	177.4	57.9	1,001.9
	Sadar	104.0	79.1	861.5
	Ngotok	26.6	406.7	5,439.6
	Tawing	201.9	135.5	1,337.7

Source: JICA Project Team 2

3) Resilience to Selected Risks

(a) Resilience

The water resources management of the water use is considered in the operation of the existing structures. If the water supply is in a severe situation, the water supply management and demand management (control) shall be considered. The demand management is carried out to the irrigation and municipal and industrial water demand. The resilience items are explained below.

a) Demand management for irrigation

- Breed improvement (to resist high temperature and high product)
- To introduce the System of Rice Intensification (SRI)
- To introduce real time operation
- To change the cropping calendar

b) Demand management for M&I

- To reduce per capita for the municipal water and industrial water
- To develop the reuse water system in the industrial companies

Table 5.5.13 shows the summary of qualitative risk items and resilience in the Brantas River basin.

Table 5.5.13 Summary of Risk and Resilience of Water Resources Management

Hazard	Sub-Aspect	Risk	Resilience	
			Structure	Non-structure
Drought	1.2 Water Preservation	・Increased in frequency of drought situation		・To control water extraction by monitoring of related agency*1
	2.2 Water resources Provision	・Reduced supply water volume from the reservoir	・To install rainfall utilization system (rainfall storage tank, underground rainfall storage facility, etc.)	・To change full supply level in dry season*2 ・To carry out maintenance dredging*1 ・To carry out flushing and sluicing*1
	2.3 Water Resources Use	・Increased in frequency of drought		・To use storage between MOL and LWL at Sutami Dam*2 ・To allow over-year storage to each dam*2 ・To optimize reservoir operation of dams in the Brantas River basin*2 ・To change water source from surface water to groundwater*2
Flood	3.1 Disaster Prevention	・Number of flood inundation is increased and flood inundation area is also expanded. ・Outflow from each dam is increased during the flood event	・To carry out monitoring and repairing the dike every year based on the regular inspection*1	・To keep same flood control space at each dam (lowering FSL)*2
	3.2 Disaster Relief	・Increased in number of casualties	・To carry out the repair works of dike and evacuation center based on the result of regular inspection*1	・To carry out capacity development for the staffs of evacuation guidance *1 ・To prepare hazard map and evacuation route map*1 ・To grasp persons who need to be supported

Hazard	Sub-Aspect	Risk	Resilience	
			Structure	Non-structure
				in evacuation[*1] ・To carry out capacity development to the flood fighting teams[*1] ・To improve accuracy of FFWS[*1]
	3.3 Disaster Recovery	・Flood damage is increased.	・To carry out the repair works (temporary) of dike at breaching location[*1]	

Note: *1: Qualitative, *2: Quantitative,
Source: JICA Project Team 2

(b) Evaluation of Resilience

Resilience in Table 5.5.9 shows the qualitative and quantitative measures. Resilience of quantitative measures shall be evaluated. Table 5.5.14 shows the list of the quantitative measures.

Table 5.5.14 List of Quantitative Measures of Resilience

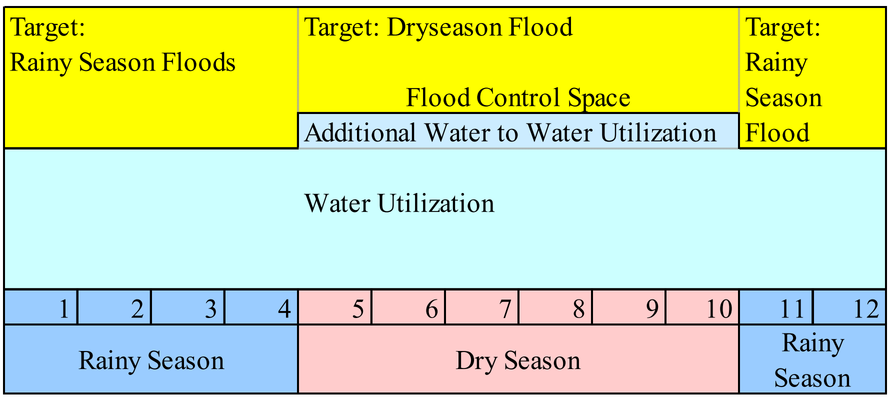
Hazard	Sub-aspect	Resilience (Measures)
Drought	2.2 Water Resources Provision	・To change the full supply level at each dam in the dry season (Control Water Level method)
	2.3 Water Resources Use	・To use the storage between MOL and LWL at Sutami Dam ・To allow over-year storage to each dam ・To optimize the reservoir operation of dams in the Brantas River basin
Flood	3.1 Disaster Prevention	・To keep same flood control space at each dam (lowering FSL)

Source: JICA Project Team 2

(4) Control Water Method for Sutami Dam

1) Control Water Level for Drought

The Wonogiri Dam located at the upper Solo River basin applied the control water level method due to the characteristics of the climate condition in Java Island. This method applies two kinds of the full supply level in the rainy and dry seasons as shown in Figure 5.5.2.



Source: JICA Project Team 2

Figure 5.5.2 Conceptual Illustration of Control Water Level Method

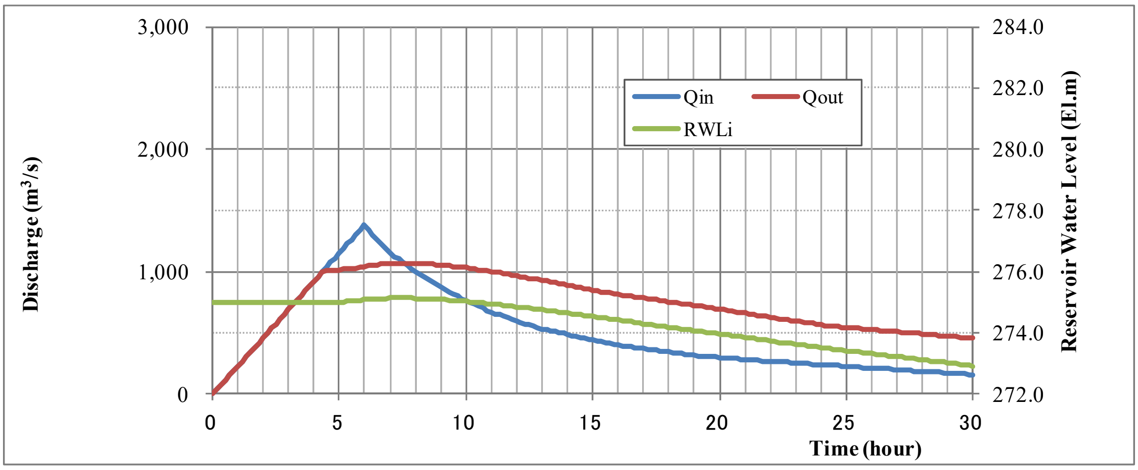
(a) Control Water Level

Hydrograph of design flood in the dry season of Sutami Dam is adjusted from the design flood in the rainy season. The design flood in the dry season is estimated. Table 5.5.15 and Figure 5.5.3 show the result of flood routine in the dry season.

Table 5.5.15 Result of Control Water Level in Dry Season

Case	CWL (EL.m)	Peak Inflow (m^3/s)	Max. RWL (EL.m)	Max. Outflow (m^3/s)
0	272.50	1,380	273.76	630
1	273.00		274.01	700
2	274.00		274.49	831
3	274.90		275.07	1,041
4	275.00		275.14	1,070
Original	FSL 272.50	3,450	FWL 275.500	1,060

Note: CWL; Control Water Level, RWL; Reservoir Water Level, FSL; Full Supply Level, FWL; Flood Water Level
Source: JICA Project Team 2



Source: JICA Project Team 2

Figure 5.5.3 Result of Flood Routine in the Dry Season (Case 3)

Full supply level can be risen from WL. 272.50m to WL. 274.90m.

(b) Water Balance Study

The following resilience measures are considered.

- Full supply level of Sutami Dam is changed to EL. 274.9m,
- The reservoir volume in Sutami Dam is utilized to low water level, and
- The over year storage is allowed to all dams.

The water balance study under future condition (medium scenario) is carried out. Table 5.5.16 shows the impact of the control water level method.

To consider the measures of resilience, the irrigation water is improved as shown in Table 5.5.17.

Table 5.5.16 Result of Control Water Level Method

Scenario	Without Resilience			With Resilience		
	Cropping area (ha)	Municipal and Industrial Water (m^3/s)	Power Generation (GWh)	Cropping area (ha)	Municipal and Industrial Water (m^3/s)	Power Generation (GWh)
Medium	201,111	50.27	730	216,827	50.27	702
Low	262,803	50.40	767	272,031	50.40	752
High	156,448	46.73	657	164,651	46.73	634

Source: JICA Project Team 2

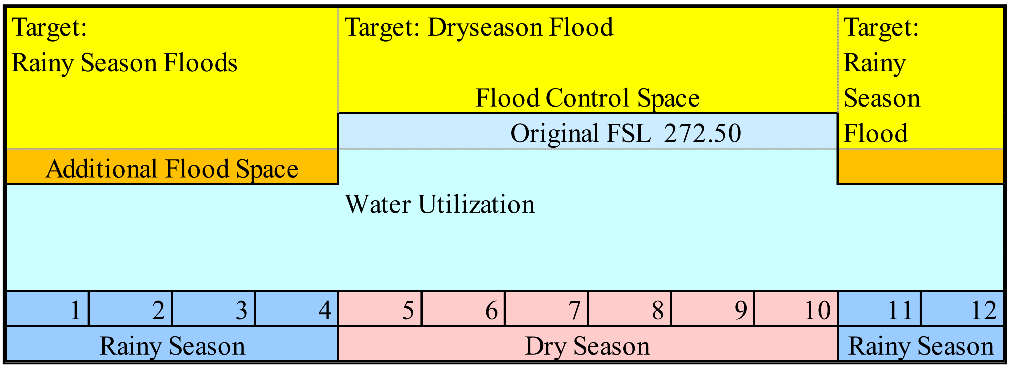
Table 5.5.17 Efficiency of Resilience (Medium Scenario)

Scenario	Cropping area (ha)	Municipal and Industrial Water (m^3/s)	Power Generation (GWh)
Medium	15,716	0.00	-28
Low	9,228	0.00	-15
High	8,203	0.00	-23

Source: JICA Project Team 2

2) Setting Control Water Level to Flood Management at Sutami Reservoir

The flood storage space becomes smaller year by year because the sediment inflow is bigger than the dredging capacity. Figure 5.5.4 shows the conceptual illustration. Table 5.5.18 shows the result of the analysis.



Source: JICA Project Team 2

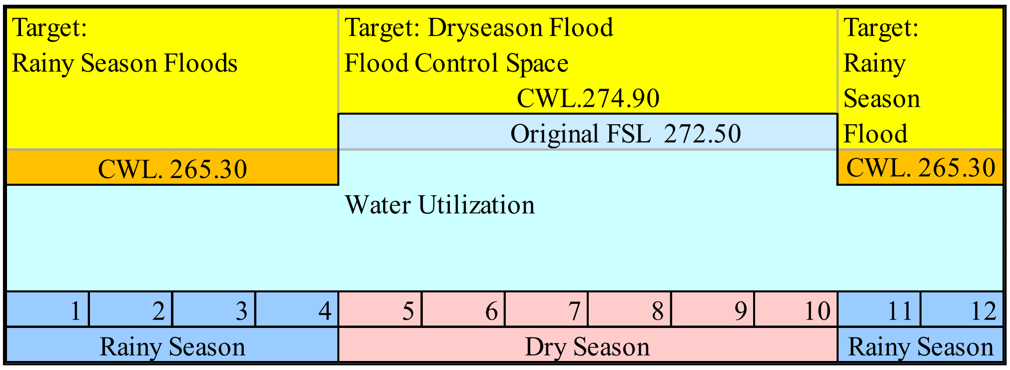
Figure 5.5.4 Conceptual Illustration of Control Water Level to Flood Management

Table 5.5.18 Result of Reservoir Operation

Case	Design Flood		Abnormal Flood	
	Full Supply Level (EL.m)	Flood Water Level (EL.m)	Full Supply Level (EL.m)	Abnormal Flood Water Level (EL.m)
Original	272.50	275.50	272.50	276.63
Low	269.40		267.10	
Medium	268.30		265.30	
High	261.40		252.30	

Source: JICA project Team 2

Full supply level in medium scenario shall be set at EL. 265.30 m. Figure 5.5.5 shows the control water level considering the resilience.



Source: JICA Project Team 2

Figure 5.5.5 Proposed Reservoir Operation of Sutami Dam in 2050