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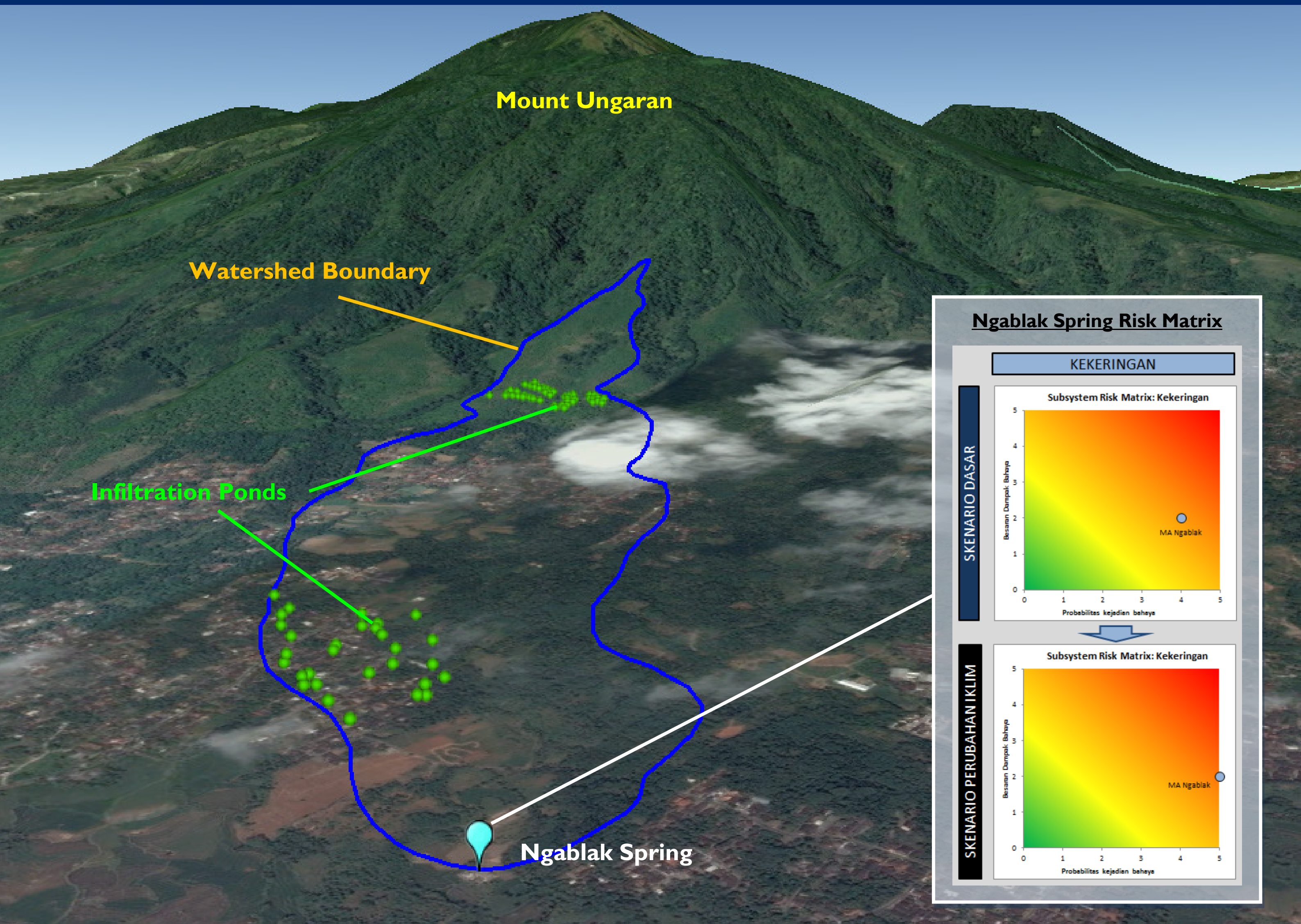
WATER SUPPLY VULNERABILITY ASSESSMENT AND ADAPTATION PLAN

PDAM SEMARANG DISTRICT SUMMARY REPORT



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This document was produced for review for USAID/Indonesia by the Indonesia Urban Water, Sanitation and Hygiene (IUWASH) project, implemented by DAI, in accordance with ADS Chapter 320.3.2.4 (e) 05/05/2009 Revision.

The Asset Risk Matrix for Ngablak spring developed through stakeholder discussion process shows that the risk of flood is increased under the climate change scenario. As an adaptation action, infiltration ponds are constructed upstream of the spring to help improve the recharge into the spring's aquifer.

USAID INDONESIA URBAN WATER SANITATION AND HYGIENE

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PDAM SEMARANG DISTRICT SUMMARY REPORT

Project:	**Indonesia Urban Water, Sanitation and Hygiene (IUWASH)**
DAI Project Number:	**1001457.**
Assistance Objective (AO):	**AO Improved Management of Natural Resources, under (IR) 3 – Increased Access to Water and Sanitation.**
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EXECUTIVE SUMMARY

Given the potential implications presented by climate change, it is critical that PDAMs and their local government owners begin to assess how temperature fluctuations and shifts in precipitation patterns will impact their municipal water supply systems, and, further, include appropriate adaptation measures in local planning documents to help reduce future risks. Toward this end, USAID's Indonesia Urban Water, Sanitation, and Hygiene (IUWASH) Project supported PDAM and the Local Government of Semarang district to undertake a **Water Supply Vulnerability Assessment and Adaptation Planning Process**. The results of this process are summarized in the following capstone report which seeks to: highlight the current risks facing the PDAM's natural and physical assets, consider how those risks may fluctuate due to climate change, propose a list of practical adaptation actions to reduce both the risks of today and in the future, and identify specific next steps to begin the implementation of the identified actions.

The content of the Water Supply Vulnerability Assessment and Adaptation Plan (VA&AP) was developed over a period of approximately20monthswith IUWASH technical assistance. Key steps in the process included the completion of a baseline water resources vulnerability study by PT Miranthi, a series of workshops and focus group discussion with the PDAM and its stakeholders. Supporting technical tools that informed the VA&AP process included the completion of the Asset Risk Matrix (ARM), geospatial analysis, global and regional climate change models, and multi-criteria analysis.

Concerning the results of the vulnerability assessment process, the major "vulnerability hotspots" for PDAM Semarang district are the freshwater springs that have been affected by drought. **Mata Air Ngablak, Mata Air Lempuyang, Mata Air Ngrawan,** and **Mata Air Senjoyo** have exhibited decreased dry season flows in recent years, a trend that is only predicted to be worsened by climate change as fluctuations in precipitation patterns are likely to lead to less groundwater infiltration. The intake at **Mata Air Lempuyang** is situated at the bottom of a steep embankment for an irrigation channel, so the intake is vulnerable to landslides. **Mata Air Ngrawan's** intake is situated just below a river, so it had to be raised in order to protect it from flooding, but transmission pipes still are vulnerable to landslides. Pipes are vulnerable to landslides in several sub-systems throughout the district.

Based on these results, local stakeholders identified a series of possible adaptation actions to reduce current risks and mitigate the longer term risks posed by climate change. Among the short list of options discussed by representatives from the PDAM and Local Government to protect natural assets were: building stronger relationships with stakeholders in the watershed area, the installation and maintenance of artificial recharge systems such as infiltration ponds, and water resources decision support systems. For vulnerabilities to built assets, they discussed protecting infrastructure that was in danger from flooding or landslides. They are building a GIS map of assets in order to be able to manage them more efficiently. Building on the adaptation options identified by the PDAM and local government officials, IUWASH also recommended consideration of improved asset management.

As a part of immediate follow-up steps, the PDAM is using its own funds to expand a GIS information system that eventually will include its customer locations. Either the PDAM, local government, or communities will set aside funds for the maintenance of infiltration wells in critical recharge areas while the PDAM is providing payment for environmental services to communities in the upper watershed for water conservation activities. Some communities are considering using local government village development funds to build more infiltration ponds in their areas. The PDAM has taken the lead to establish a community forum at Mata Air Senjoyo to support sustainable water resources management and the mitigation of potential hazards such as landslides.

Medium term steps that are under discussion with the PDAM include additional strengthening of hydrological and meteorological monitoring, the replacement of key aging infrastructure, and the fortification of above-ground pipelines in flood and landslide prone areas. In conjunction with the implementation of immediate and short-term adaptation options, it is also important that the results of this assessment and planning exercise be integrated into the PDAM and local government's broader development planning.

1 INTRODUCTION

1.1 PURPOSE AND STRUCTURE OF THE REPORT

Perusahaan Daerah Air Minum (PDAMs) across Indonesia face many different types of risks as they seek to deliver clean water to their customers. These risks include land use change, rapid and unplanned urbanization, competition for scarce water resources, natural disasters, and many others. Importantly, many of these risks will be—and in some ways already are—exacerbated by the negative impacts of climate change, which is expected to modify the duration and intensity of rainfall patterns across the archipelago.

Given the potential complications presented by such changes in precipitation patterns, it is critical the PDAMs and their local government owners begin to assess how climate change will specifically impact their water supply systems, and include appropriate adaptation measures in local planning documents to help reduce future risks. **The Water Supply Vulnerability Assessment and Adaptation Plan for PDAM Kabupaten Semarang** represents an important milestone towards achieving these goals. The specific objectives of this capstone report are to:

1. Summarize the current risks facing the PDAM's natural assets (i.e. sources of water and the surrounding watersheds) and physical assets (i.e. water supply infrastructure such as treatment plants and reservoirs) under existing climate conditions (Chapter 2);
2. Consider how these risks may be increased by climate change by midcentury(Chapter 2);
3. Propose a portfolio of practical adaption actions that the PDAM can take to reduce risk under both today's climate and the climate change scenario (Chapter 3); and
4. Identify specific next steps to begin the implementation of the proposed adaptation actions and integrate these actions into local planning documents (Chapter 4).

The content of the Water Supply Vulnerability Assessment and Adaptation Plan (VA&AP) was developed over a period of approximately 20 months with the support of USAID's Indonesia Urban Water, Sanitation, and Hygiene (IUWASH) Project. Key steps included the completion of a baseline water resources vulnerability study by PT Miranthi, a series of workshops and focus group discussion with the PDAM and its stakeholders. The results of these steps are discussed throughout the report as well as in the annexes.

It is important to note from the outset that the completion of this report in no way means that the process of identifying water supply vulnerabilities to climate change and associated adaptation actions is also "complete." Indeed, given limited time and resources, this report (and the related inputs) provides only a broad overview of climate change vulnerabilities and potential adaptation actions. It is, in other words, a first step down toward improving the resilience of water supply systems in Semarang. Ultimately, resilience can only be achieved through an iterative process of assessment, planning, action, and the deliberate monitoring of impact to better understand what works and what does not.

1.2 THE WATER SUPPLY VULNERABILITY ASSESSMENT AND ADAPTATION PLANNING FRAMEWORK

The methodology guiding the compilation of **The Water Supply Vulnerability Assessment and Adaptation Plan for PDAM Semarang district** is based upon an IUWASH document entitled, "Climate Change Vulnerability Assessment Inception Report" at http://iuwash.or.id/category/downloadpublication/technical-report/ Based upon emerging best practices in climate change adaption in the water sector, this document presents vulnerability assessment and adaptation planning framework built on the following principles:

a. Climate change is not an isolated issue or separate field of expertise, but a source of risk that is inextricably linked to the way utilities and the communities they serve use and manage water and land resources. It is thus is best approached in an **integrated manner**, building off of and contributing to the utility's and local government's broader planning efforts;

b. Given that "top-down" climate change models are both expensive to develop and require extensive data, a **"bottom-up" approach** that focuses on what is known about the current environment and how the water system may be sensitive to climate change is the more appropriate for the water sector in Indonesia;

c. To focus the vulnerability assessment and adaptation planning process, the IUWASH Water Supply VAAP Framework distinguishes between a utility's **natural assets** (in the form of water resources such as rivers, spring, and wells) and **constructed assets** (in the form of intakes, transmission lines, treatment facilities, and storage facilities). Further, the Framework considers the extent to which these assets are able to meet demand under both existing conditions as well as under climate change. Indeed, understanding the supply and demand balance is critical to future water security;

d. The vulnerability assessment and planning process itself is a means of **learning, collaboration, and capacity-building**. In other words, it is not just about "making another plan," but thinking and learning in a collaborative manner with PDAMs, local governments, and supporting stakeholders on how to better plan for a highly variable future; and

e. Vulnerability assessment and adaption planning must be conducted on an **iterative basis**. Given the degree to which climate change knowledge and research continues to evolve, PDAMs should revisit the vulnerability assessment and adaptation process with each new five year business plan, ensuring that plans fully reflect the latest scientific findings and local conditions.

Building off of the principles discussed above, Table 1 below summarizes the four phases and associated steps that make up the framework used in Semarang district.

Table 1: IUWASH Vulnerability Assessment and Adaptation Planning Framework

Phases		Steps	Tools/Methodologies
1.	**Evaluation of the Current Situation: The Baseline Scenario**	a. Stakeholder Engagement: Understanding the objectives and perspectives of the PDAM and Local Government; b. Data Collection and Analysis: Description of current system, types of water resources, historical hydro-met data, customer data, and supply/demand projections; c. Baseline Scenario Vulnerability Assessment: Identification of existing hazards and evaluation of associated risks.	• Stakeholder Kickoff Meeting • Key Informant Interviews • Geospatial Analysis • PDAM Asset Risk Matrix

Phases		Steps	Tools/Methodologies
2.	**Climate Change Vulnerability Assessment: The Climate Change-Driven Scenario**	a. Analysis and synthesis of localized climate change data using existing research, interviews, and models; b. Development of Climate Change-Driven Scenario: Using quantitative and qualitative information to envision future impacts; c. Climate Change-Driven Scenario Vulnerability Assessment: Considering how the hazards may change, altering the PDAM's risk profile.	• Geospatial Analysis • General Circulation Models • PDAM Asset Risk Matrix • Stakeholder Workshop
3.	**Adaptation Planning: A Portfolio of Prioritized Responses**	a. Develop Long-List of Adaptation Options for Natural and Constructed Assets; b. Develop a Short-List of Adaptation Options; c. Prioritize Actions within Portfolio	• Multi-Criteria Analysis • Cost-benefit analysis • Decision-Maker Workshop
4.	**Implementation, Integration, and Learning**	a. Implementation of balance portfolio of adaptation options b. Integrate prioritized adaptation responses into PDAM planning documents; c. Begin implementation and monitoring, emphasizing an iterative approach to regularly incorporate new knowledge and experiences (learning).	• PDAM Corporate Plan • Project Feasibility Studies • M&E systems

As noted in Phases 1 and 2, an important aspect of the vulnerability assessment and adaptation planning (VAAP) process is the identification of the types of hazards to which the PDAM's natural and constructed assets are currently exposed. To facilitate this analysis, these hazards are organized under the following four categories:

- **Drought (Water Scarcity):** Most water utilities face some degree of risk pertaining to shortages of raw water resources, whether it is due to prolonged periods of little to no precipitation or decreased recharge stemming from land use change. Climate change is only expected to worsen the risk of such hazards, particularly as dry seasons are predicted to lengthen over time and more intense, compacted rainy seasons will yield less recharge.

  Concerning constructed assets, one might normally anticipate that drought would not result in actual physical damages. While the infrastructure would not operate effectively with low levels of raw water, the plant itself would not be damaged meaning that it could return to operating when access to raw water is restored. The reality, however, is that the transmission systems are frequently exposed to damages during drought, as local communities break pipes in search of available water. This is especially true for above-ground pipes.

- **Flooding**. The elevated intensity of storms under climate change is expected to lead to more frequent flood events. Flooding poses an obvious risk to a PDAM's physical assets, particularly to intakes, treatment facilities, and storage facilities given that they tend to be located near rivers and other sources of surface water. Floods can also be detrimental to the water quality of natural assets, leading to spikes in turbidity that can make the raw water more difficult and costly to treat.

- **Landslides**. Also associated with increases in the intensity and duration of precipitation events, landslide hazards pose the greatest risk to physical infrastructure, particularly well and spring heads and surface water intakes given their tendency to be located in steeper, upstream topography. Landslides pose minimal threat, however, to the quality and quantity of natural assets, with the exception of an extreme event that alters the course of the river channel.

- **Sea Level Rise**. A final hazard that is commonly associated with climate change is sea level rise induced by warming oceanic temperatures. Sea level rise (SLR) generally presents the greatest risk to a PDAM's natural assets in the form of saltwater intrusion, which is already common in many of Indonesia's coastal cities due to the over-pumping of groundwater resources. SLR will only exacerbate this problem, and may also pose a threat to constructed assets located near the coast due to more frequent inundation of the shoreline.

On a final note, the implementation of the Framework is supported by several tools and methodologies (see the right-hand column of Table 1), including the PDAM Asset Risk Matrix, geospatial analysis, general circulation models, and multi-criteria analysis. Each of these tools played an important role in the vulnerability assessment and adaptation planning process with PDAM Semarang district, and the results are presented in the following chapters.

2 WATER SUPPLY VULNERABILITY ASSESSMENT

Chapter 2 of the Semarang Water Supply VA & AP Report summarizes the current state of the piped water supply system in Semarang district (Section 2.1) and then identifies the specific vulnerabilities of this system under current climate conditions (Section 2.2) as well as under a fifty-year (2011 – 2061) climate change scenario (Section 2.3).

2.1 WATER SUPPLY CONTEXT

The following subsections provide an introduction to the water supply context for Semarang district, including the general characteristics of the PDAM, the natural assets on which the PDAM relies for its raw water, and the built assets that the PDAM uses to clean, store, and deliver that water to its customers. These subsections are based upon the IUWASH-supported report by PT Miranthi entitled "Water Supply Vulnerability Assessment Scoping Study PDAM Kabupaten Semarang, Central Java Province", while also drawing from stakeholder consultations and other secondary data sources where noted.

2.1.1 Overview of PDAM Semarang district

PDAM Semarang district provides piped water service to the citizens of Semarang district, a large district composed of 19 sub-districts (*kecamatan*) and home to approximately 939,000 people. With nearly 950 square kilometers and an average population density of 988 people per square kilometer, the district lies between the growth centers of Yogyakarta, Solo, and Semarang. It extends from the low-lying Semarang City area and Kabupatens Grobogan and Demak in the north and east to the highlands of Kabupatens Kendal and Temanggung and Kabupaten Boyolali in the west and south. The district surrounds Salatiga city, which is a separate administrative jurisdiction. Over the past five years the population has increased by an average of almost 1% per year with almost 1.75% growth between 2009 and 2010. The most rapid growth occurred in Bergas, Ungaran Barat, and Ungaran Timur sub-districts in the northernmost part of the district where the provincial capital is located. According to the district's growth plan, this is the main growth area, consisting mainly of housing as an extension of Semarang City. The land use has changed over the last ten years from mainly dry fields to forest vegetation industry.

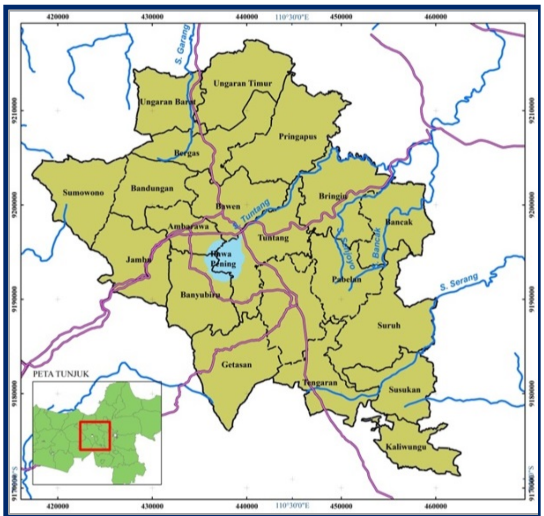


Figure 1: Semarang District.

First established in 1980, PDAM Semarang district is the official source of piped water for the District's residents. The PDAM, with its head office in Ungaran, consists of three independent and stand-alone branches, each with its own water sources and customers. These branches are Ungaran, Ambarawa, and Salatiga. A private company, PT Sarana Tirta Ungaran (STU) was formed in 2001 to cooperate with PDAM Semarang District in order to supply water to industries in the area of the Ungaran-Bawen highway. The main water treatment plant uses raw water from the Tuntang River, and treated water is transmitted through underground pipes to consumers. STU is capable of operating at a capacity of 200 liters per second, but it is selling only 100 liters per second. One plant of 50 liters per second capacity was built and given to the PDAM. PT STU pays a royalty of 4% plus an additional 14% of profits to the local government, but it has not yet been able to sell all of its water. According to the agreement, the facilities will become the property of the local government in 2031, but it is quite possible that if the company cannot increase sales, the assets will be sold to the PDAM before that date. Thus, PT STU's assets are not included in this vulnerability assessment and adaptation plan.

Table 2: PDAM Semarang district Characteristics

	Characteristic	2011	2010	2009
Customer	Number of Customers	29,025	n/a	n/a
	Population of district	938,802	931,041	917,745
	Coverage of Service Area	16.1%	14.6%	13.8%
Technical	Production efficiency	70.1%	78.3%	79.7%
	Hours per day of operation	23	22	19
	Non-Revenue Water	37.2%	39.4%	42.7%
	Staff/1,000 connections	5.4	6.1	6.6
Financial	Average Tariff	Rp. 2,917	Rp. 2,917	Rp. 2,917
	Operating ratio	0.8	0.9	1.1
	Billing effectiveness	96.9%	81.9%	87.5%
	Total Asset Value	39,992,790	n/a	n/a

Source: BPP SPAM 2012

Table 2 summarizes the key characteristics of the PDAM and its service area for the past three years of audited data.

2.1.2 Natural Assets of the PDAM

The "natural assets" of a PDAM include all sources of raw water, including the aquifers and groundwater systems that feed into springs and wells as well as surface water sources such as streams, rivers, and lakes. Broadly speaking, the watershed in which these water resources exist can also be seen as part of the PDAM's natural assets given that the condition of watershed directly impacts the condition of these resources.

Raw Water Sources. PDAM Semarang district derives its raw water from natural springs and deep wells. It also has a BOT contract with a private company that extracts water from the Tuntang River and treats, distributes and sells it to commercial and residential consumers. Figure 2 at right accompanied by the map (Figure 3) on the following page highlight the principle sources of raw water for the PDAM and their spatial location in the watershed. It is important to note that, while many of the natural assets of PDAM Salatiga City are outside of the city limits, all of the natural assets of PDAM Semarang district are within the administrative region of the District, thereby making the management of these water resources easier to control.

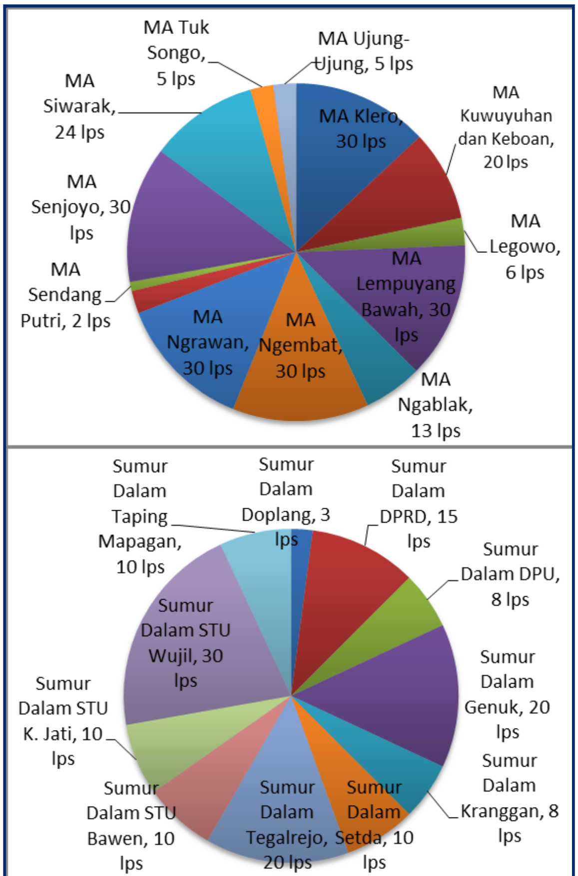
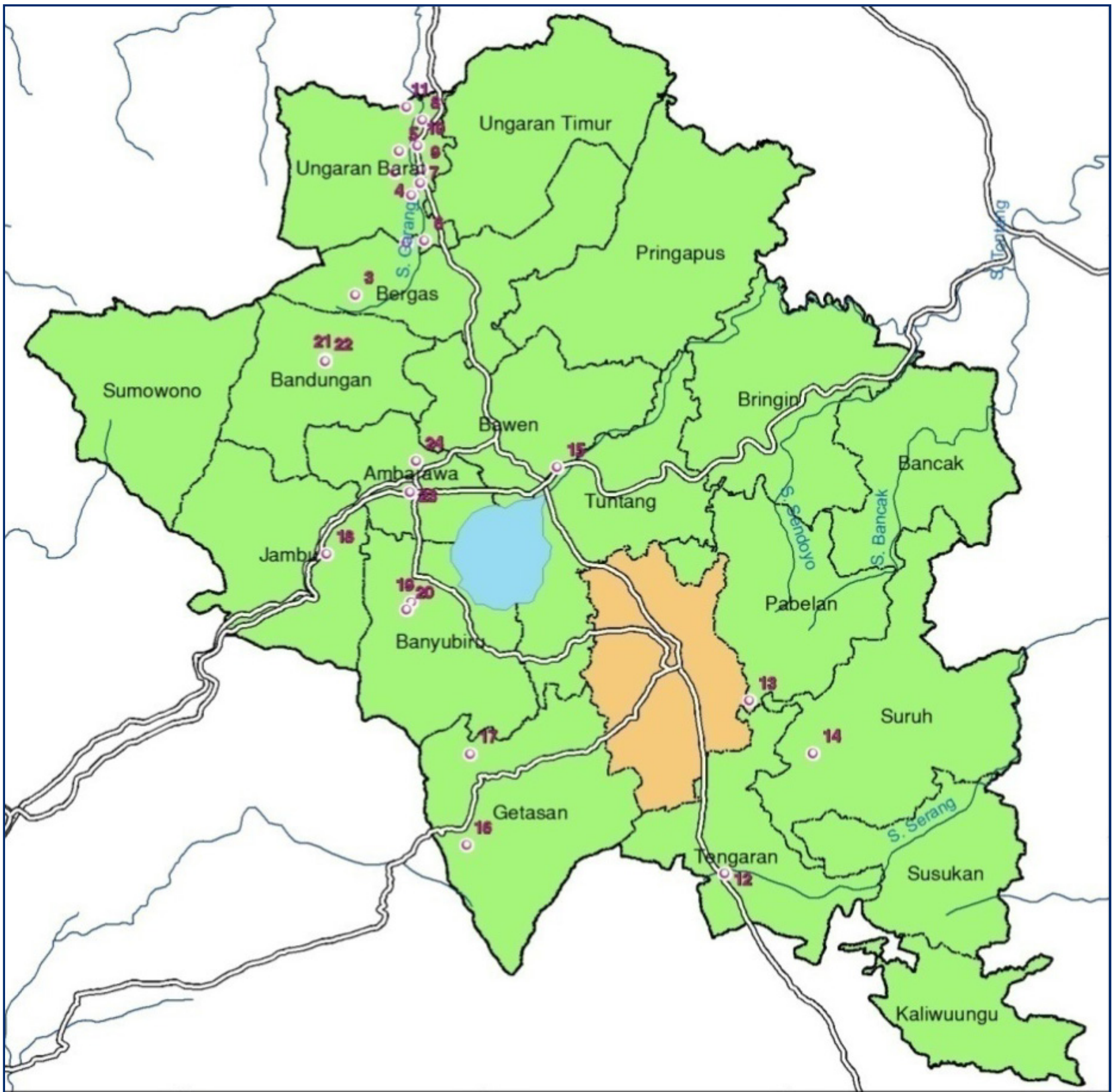


Figure 2: Major springs (above) and deep wells (below).

As shown in the pie chart in Figure 2, the PDAM uses a diverse set of springs and deep wells to supply water to the residents of Semarang district, including about 21 fresh water springs and about eleven deep wells. It is important to note that the pie chart shows the connected capacity of each source, which does not necessarily reflect the total flow capacity of the spring or well. The total connected capacity of these sources is about 446 liters per second (lps) while the total production capacity is approximately 366 lps.



Source: PT Miranthi.

Figure 3: Map of main sources of raw water for PDAM Semarang district.

The main sources of raw water for PDAM Semarang district are shown in Tables 3 and 4 and in Figures 4, 5, and 6, which show Google Earth maps of infrastructure and water sources in the Ungaran, Ambarawa, and Salatiga systems, respectively.

Table 3: Main sources of spring water for PDAM Semarang District.

No	Water source	Capacity (L/S)	
		Installed	Production
1	MA Gogik	20	13.74
2	MA Grenjengan	4	0.97
3	MA Jeporo	10	5.23
4	MA Kali Taman	25	25
5	MA Kalidoh	2	1.45
6	MA Kalidoh Kecil	11	6.2
7	MA Kalitrowong	10	12.43
8	MA Kawalan	0.1	0.1
9	MA Klero	30	17.5
10	MA KuwuyuhandanKeboan	20	16.6
11	MA Legowo	6	4
12	MA LempuyangBawah	30	26
13	MA Ngablak	13	10.9
14	MA Ngembat	30	29.29
15	MA Ngrawan	30	26
16	MA Rekesan	5	4
17	MA SendangPutri	2	0.5
18	MA Senjoyo	30	31.84
19	MA Siwarak	24	19.27
20	MA TukSongo	5	4
21	MA Ujung-Ujung	5	5.73
Total		**312.10**	**260.75**

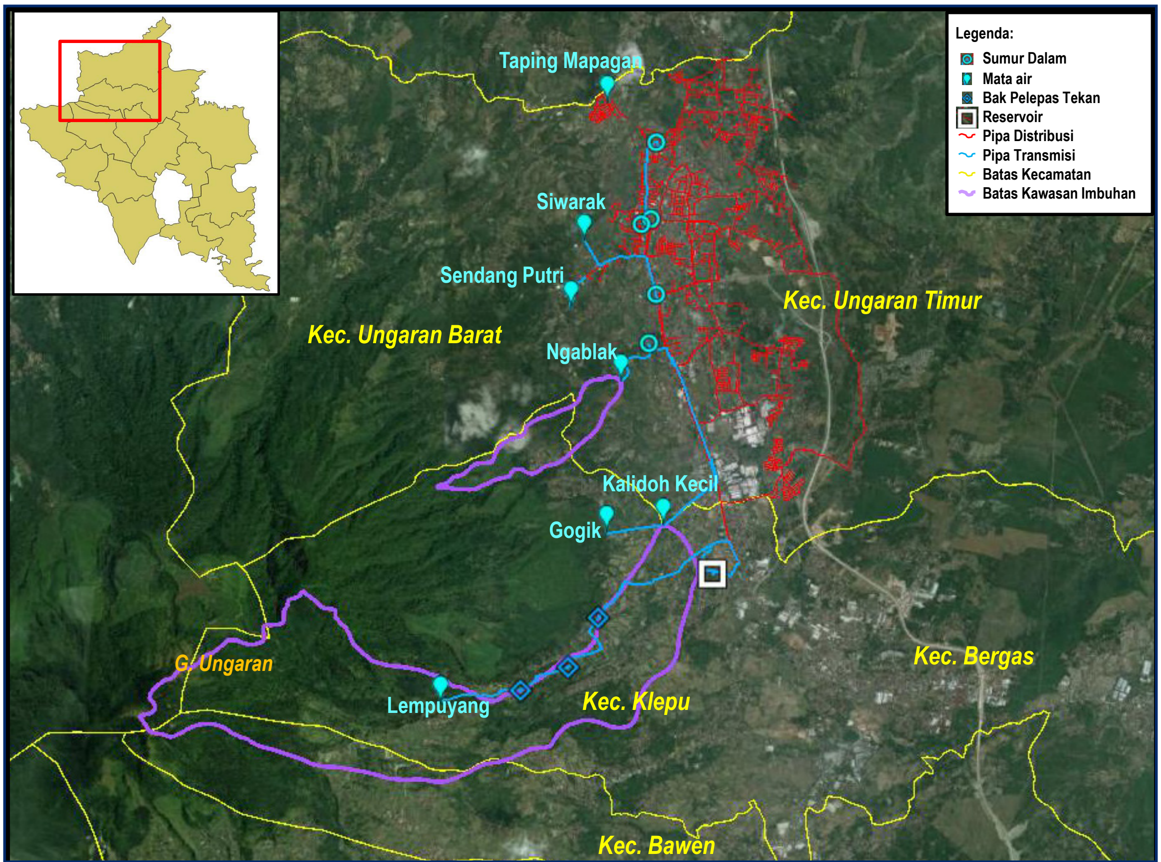
Source: PDAM Semarang district 2012

Beginning with the fresh water springs, the key characteristics of these natural assets are as follows:

- **Mata Air Senjoyo** provides about 8.5 per cent of PDAM Semarang District'sraw water. It is one of the PDAM's largest single sources of raw water, with a production capacity of more than30 liters per second. The first bronkaptering on Mata Air Senjoyo was built in 1921, and the second in 1973. It is shared with PDAM Salatiga City (about 140 liters per second), users of irrigation, the community, and other institutions. In 2006, about 67 liters per second were withdrawn by the private sector and local communities, and 868 liters per second were withdrawn for irrigation. The discharge from MA Senjoyo appears to have declined about 13% between 2000 and 2004. In 2008, a study by the Faculty of Economics, University of Diponegoro, found that Air Mata Senjoyo already was supplying less than what was needed for agriculture, households, and the PDAM. This steady downward trend has been of concern to the PDAM even though there are additional groundwater and surface water sources of raw water available to the PDAM. The reduction in discharge may be caused by many factors such as change in land use, greater rate of withdrawal, climate change, or both.
- **Mata Air Ngembat** was established shortly after 2003 when the PDAM signed an agreement with a private company, PT STU, for cooperation for provision of water. As part of the agreement, PT STU would build a production unit at Mata Air Ngembat in Ambarawa region,

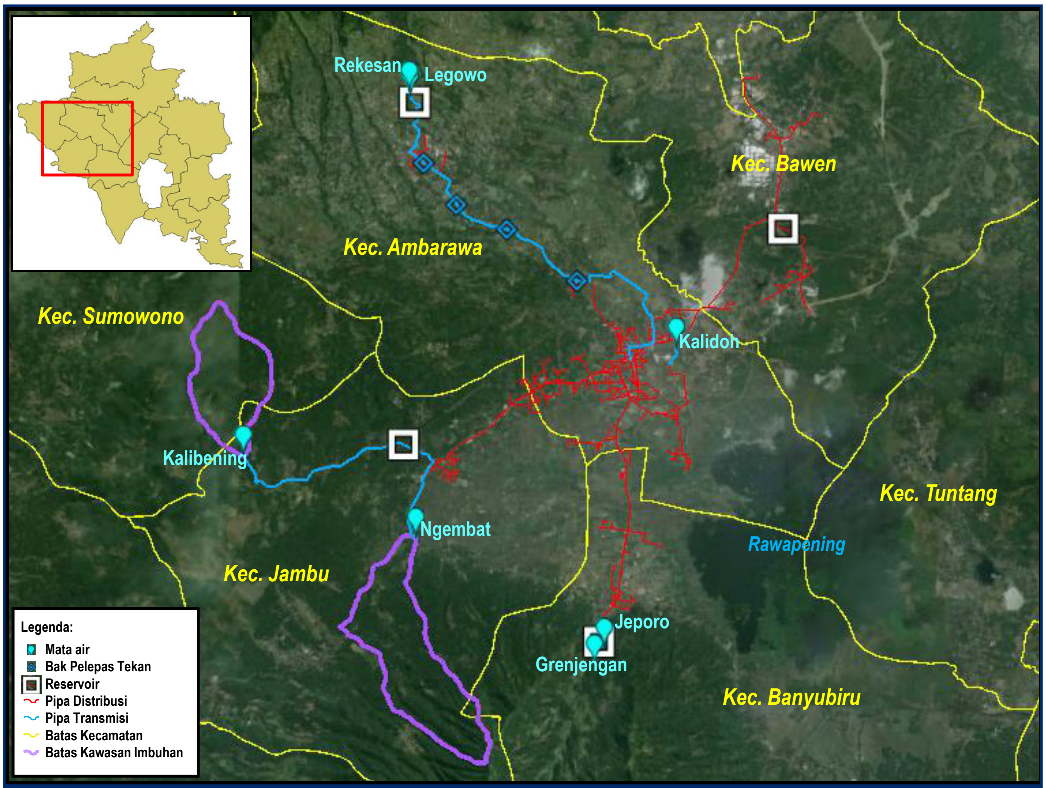
Jambu sub-district, near an area of rice paddies. In addition, PT STU installed pumps, and laid a pipeline for the use of PDAM Semarang City to supply houses in communities in Ambarawa. The current production of the Ngembat facility is a bit less than 30 liters per second, but during the dry season, the flow is reduced by 20-30 per cent. Part of the transmission pipe is located on a main road, so there is frequent damage to the pipe whenever the road is being repaired.

- **Mata Air Lempuyang Bawah** in the Ungaran system has been used by the PDAM since 1994. It has a production capacity of 26-30 liters per second. The intake is located at the bottom of a steep embankment that is topped by an irrigation channel. Thus, the intake is vulnerable to damage from flood and landslide. The flow during the dry season is reduced by 25-30 per cent.
- **Mata Air Ngablak**, also in the Ungaran system (Figure 4), has been used by the PDAM since 1987 when the flow was initially 40 liters per second. Now the flow has declined to only about 10 liters per second, and the flow is reduced by about 30 per cent during the dry season.
- **Mata Air Ngrawan** in the Salatiga system (IKK Getasan & Salatiga) has been used by the PDAM since 1998, and the flow is now about 26 liters per second. The spring is located just below a river which often overflows onto the bronkaptering when there is flooding of the river. The bronkaptering has been elevated in order to keep it safe from flooding in the future.



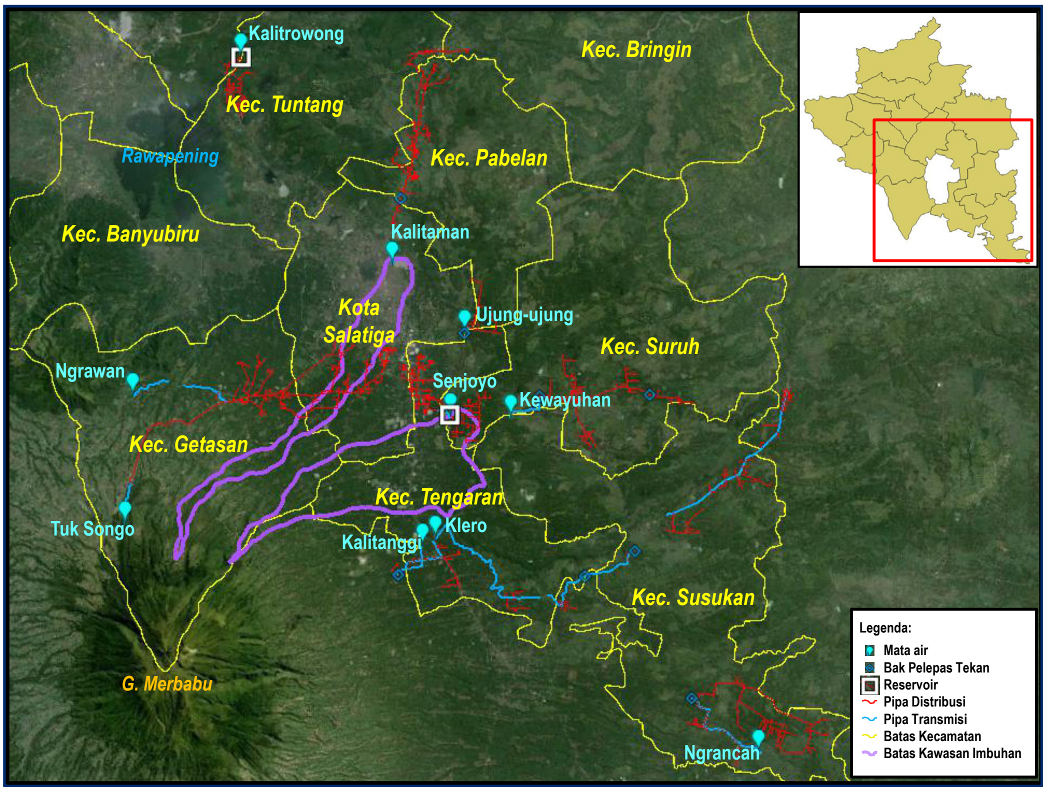
(Map View: Google Earth©)

Figure 4: Map of infrastructure and water sources of Ungaran sub-system, PDAM Semarang District.



(Map View: Google Earth©)

Figure 5: Google Earth map of infrastructure and raw water sources of the Ambarawa Sub-system, PDAM Semarang District.



(Map View: Google Earth©)

Figure 6: Google Earth map of Salatiga sub-system infrastructure and raw water sources, PDAM Semarang District.

Deep wells also represent an important source of raw water for the PDAM. Table 5 below describes the eight deep wells that the PDAM utilizes to service the residents of Semarang district and the three deep wells operated by PT STU. Generally speaking, the water pressure and water quality from deep wells in Semarang district are quite good. Under the PT Miranthi baseline study, for example, the research team tested samples from a number of locations and found that all samples could be classified as "clean water" given that the parameters were found to be better than those set forth in Ministry of Health Regulation No. 416/1990.

Table 4: Deep Wells in Semarang District.

No	Location	Liters per second	
		Installed	Production
1	Sumur Dalam Doplang	3	1,5
2	Sumur Dalam DPRD	15	14,48
3	Sumur Dalam DPU	8	5,95
4	Sumur Dalam Genuk	20	0
5	Sumur Dalam Kranggan	8	7,77
6	Sumur Dalam Setda	10	0
7	Sumur Dalam Tegalrejo	20	18,19
8	Sumur Dalam STU Bawen	10	13,33
9	Sumur Dalam STU K. Jati	10	8,09
10	Sumur Dalam STU Wujil	30	33,02
11	Sumur Dalam Taping Mapagan	10	9,81
Total		**144,0**	**112,14**

Source: PDAM Semarang district 2012

Surrounding Watershed. The productivity and sustainability of the PDAM's raw water resources is closely linked to the characteristics of the surrounding watershed. In this regard, the jurisdiction of Semarang district falls within the Jrantunseluna River Basin that runs more or less from east to west through the northern parts of East Java and Central Java. Semarang district includes parts of seven watershed areas, but it is dominated by three rivers: the Garang River in the northern area, Tuntang River in the middle, and Senjoyo River in the East. (see **Annex 2** for a map of the relevant watersheds). The Tuntang is by far the largest and most important watershed, covering 516 square kilometers of the District. The district's only large lake, Lake Rawapening, is located close to the geographic center of the district. It covers 27.7 square kilometers, containing 65 million m3 of water in the wet season and 17.6 sq. km. with 25 million m3 of water in the dry season.

Broadly speaking, land use in Semarang district can be divided into three types: planted forests, dry land agriculture, and settlements. The greatest growth has been the conversion of dryland agriculture areas to planted forests. Population centers have grown, as well, with the areas in the north nearest Semarang city growing an average of 3-4% per year between 2007 and 2011, while the average population growth of the entire district has been less than 1% per year. **Annex 3** displays a map of the different types of land use across the district in 2003.

Physical Assets of the PDAM

The physical or "constructed" assets of the PDAM include the intake, the transmission pipeline, water treatment facilities, and storage and distribution facilities. These built assets allow the PDAM to obtain raw water from its natural assets and then clean, store, and transport clean water to its customers. The depreciated value of PDAM Semarang District's fixed assets at the end of 2011 was Rp. 19,160,976, indicating that significant savings are likely to result from protection of the PDAM's built assets. Several noteworthy characteristics of PDAM Semarang District's constructed assets are as follows:

- Given the size of the District, the PDAM maintains an expansive distribution network across varied terrain. Importantly, a significant portion of the PDAM's built asset value is contained within the transmission and distribution system.
- Since the PDAM uses only high quality raw water from springs and aquifers, minimal treatment infrastructure is necessary, which represents a significant cost savings to the PDAM. However, a private company, PT STU, treats water from the Tuntang River, mainly for the use of industry.
- The PDAM faces a common problem in Indonesia in the form of aging infrastructure. Some of its spring systems and distribution pipes will require significant investment costs to replace.

- According to the study by PT Miranthi, the transmission pipes generally are well maintained, and the main dangers to the life of pipes are corrosion and breaking at the joints.

2.1.3 Asset Monitoring Systems

A critical aspect of providing water supply services is the regular monitoring of the utility's natural and constructed assets. On the natural assets side, it is extremely important to understand the condition of raw water resources and the hydrological characteristics of the surrounding watershed more broadly. As such, a water utility needs to have access to hydrological data such as precipitation data, ground water levels, spring flow volume, stream flow volume, as well as an awareness of the competing uses of raw water that may impact the available supply. Ideally, hydro-meteorological (hydro-met) data at key locations is recorded on a daily (if not hourly) basis, thereby allowing water utility managers to understand how the watershed responds to weather events.

Similarly, on the constructed assets side, it is necessary to understand the condition of each capital asset, its remaining useful life, and estimated replacement cost. In the absence of this data, these assets are more difficult to maintain and utility managers cannot easily plan for capital asset replacement or rehabilitation costs.

Table 5 below summarizes the availability of important natural asset monitoring data, including the relevant stations and systems that are in place to capture this data.

Table 5: Natural Asset Monitoring Systems

Topic	System/Equipment	Type of Data	Historical Data
Precipitation	Stations across Central Java operated by BMKG (Dept. Meteorology, Climate, and Geophysics)	Daily rainfall data manually recorded.	- Since 1990s for most stations
Temperature	Stations in Semarang district operated by BKMG	Daily high, low, and average data recorded	- Since 1990s for most stations - Longest running station: Getas
Stream Flow	No gauging stations documented by PT Miranthi	No usable river flow data is currently available for the study area.	- No reliable historical river flow data is currently available for the study area.
Spring Flow	Flow meters at some springs used by PDAM	Flow rate (liters per second) manually recorded once per day.	- Limited historical data available.
Deep Well Flow (Aquifer)	No flow meters documented by PT Miranthi	No hourly or daily data is recorded for the deep wells.	- Not available. Well flow is only tested on an intermittent basis.

Source: PT Miranthi

Per the above table, there is only limited hydrological and meteorological data available in Semarang district, making it very difficult to develop accurate predictive models of how stream flows and recharge rates may change in the future based upon land use change, climate change, or, more likely, both factors occurring simultaneously. The PT Miranthi Team did analyze the effect of climate change incorporating rainfall data and various emissions scenarios. The results are presented in Chapter 4 of the Baseline Study.

In terms of raw water quality, the PT Miranthi Team did not present evidence that resources are tested on a regular basis by the PDAM or local government. That said, the Team did conduct its own sampling and analysis, which is presented in Chapter 4.4 of the Baseline Report.

Regarding tracking systems for constructed assets, PDAM Semarang District does not currently utilize a geographic information system (GIS) to plot the location of its assets and record key characteristics concerning these assets (such as recent maintenance, breakages, year constructed, etc.). Instead, this information is generally maintained in spreadsheet format only.

2.2 WATER SUPPLY VULNERABILITY ASSESSMENT: BASELINE SCENARIO

Utilizing the historical and current hazards identified during the data collection, the final step under Phase I of the VA & AP Framework is the development of the vulnerability assessment for the baseline scenario which estimates the level of risk to the PDAM's natural and constructed assets *in the current climate*. PDAM assets are already threatened by a broad spectrum of existing hazards, including flooding, drought/water-stress, landslides, and sea level rise. These hazards represent a critical point of reference for understanding how changes to the climate may alter the severity of these hazards in the years to come.

Key resources utilized in the development of the baseline scenario include: (1) the "Water Supply Vulnerability Assessment for PDAM Kabupaten Semarang, Central Java" (also referred to as the "Baseline Study") as compiled by local partner PT Miranthi, (2) the Asset Risk Matrix compiled during a stakeholder workshop in November 2014, and (3) key information interviews and focus group discussions with PDAM and PEMDA representatives. Regarding the ARM compilation, the workshop participants assessed the vulnerabilities of three of the PDAM's subsystems during the two-day event, including the fresh water springs at Senjoyo, Ngrawan, Ngembat, Lempuyang, DPU, and Ngablak.

2.2.1 Baseline Scenario: Natural Assets

The basic risk to PDAM Semarang district's natural assets is quantity of water. For a fresh water spring such as Mata Air Senjoyo, for example, there is a risk that there will be insufficient water to meet the demands for irrigation, industry, and communities. Based upon the baseline vulnerability study as well as the compilation of the Asset Risk Matrix with local stakeholders, the following levels of vulnerability were identified under the current context for the water resources supplying the citizens of Semarang district:

- **Drought/Water Scarcity**. In 2014-2015, Semarang District was one of 12 districts in Central Java that were reported as emergency drought areas to the National Disaster Management Agency (BNPB). The drought was most severe in Pringapus and Ambarawa sub-districts.

  The risk scores under the Asset Risk Matrix (ARM) analyzed during the workshop underscore the water scarcity risk. The highest of all baseline risks was a **medium** risk for water scarcity at Ngembat, Ngrawan, Lempuyang, and Ngablak Springs. A decline in the flow of Senjoyo Spring has been noticed for many years.
- **Flooding**. The risk to the PDAM's natural assets from flooding ranges from low at Ngembat Spring to medium at Lempuyang and Ngablak Springs to high at Ngrawan Spring. **Ngrawan**

Spring's source is located just below a river that often overflows into the spring when there is flooding. Flooding occurs especially in low areas around Lake Rawapening, but it does not present a risk to the natural assets. Also, given that the PDAM relies only on groundwater, increases in turbidity in surface water sources during floods will not impact the PDAM's ability to provide clean water to its customers.

- **Landslides**. The risk of landslides to the quantity of natural assets under the baseline scenario ranges from **low** at Kalibening to **medium** at Lempuyang to **high** at Ngrawan Springs. Still, landslides are unlikely to impact the water quality of the groundwater sources used by the PDAM.
- **Sea Level Rise**. There is no risk to the water quantity or water quality of the PDAM's natural assets from sea level rise.

As noted under the risk of drought/water scarcity, land use change in the upper watershed could lead to higher incidences of water scarcity as well as flooding and landslides, **no matter how the climate may change**. As such, ensuring that infiltration levels remain sufficient to recharge the underlying aquifer will be of paramount importance no matter how levels of precipitation may fluctuate in the decades to come.

Finally, per section 2.1.4, the PDAM does not have systematic monitoring systems for regular measuring of groundwater depth levels and spring flow levels. Accessing this data on a regular basis and analyzing the status of the PDAM's natural assets will help water managers to plan for the future needs of the community and alert local government authorities when raw water resources are degrading.

2.2.2 Baseline Scenario: Physical Assets

The fundamental risk to the PDAM's constructed assets is that of physical damages to the infrastructure. A landslide, for example, could damage transmission pipes requiring costly rehabilitation and repairs. Also, drought conditions could lead local communities to damage transmission pipes in the hopes of accessing clean water. Based upon the vulnerability study as well as the Asset Risk Matrix, the following levels of vulnerability were identified under the current context for the constructed assets servicing the four areas:

- **Drought/Water Scarcity**: There is no risk of physical damages to the PDAM's water supply infrastructure due to drought. In the event of drought conditions, communities are more likely to seek alternative springs or groundwater sources given the abundance of these sources available. Also, PDAM Semarang district has not yet experienced purposeful damage to its water supply infrastructure during times of drought.
- **Flooding**: The risk of flooding of infrastructure under the baseline scenario is **medium** for the Lempuyang Spring intake and Ngrawan intake, transmission and pumping system. The risk to flooding of transmission pipes at Kalibening Spring is low. Given the higher elevations of the southwestern areas of the District, flooding is generally confined to the middle section of the District around Lake Rawapening.
- **Landslides**: Given the combination of the steep topography in the southern areas of the District and the concentration of valuable physical assets located there, there is a possibility of landslides near some constructed assets in sub-districts such as Getas, Banyubiru, Ambarawa, Jambu, Sumowono, Bergas, and Ungaran. Based on the field observations of the PT Miranthi Research Team, there are several locations where intakes may be buried or pipes may be buried or broken by landslides shown in Table 6. The risk of landslides to infrastructure under the baseline scenario is highest at Ngrawan Spring where the risk to the intake, transmission pipes, and pumps is **medium**. The risk to the Lempuyang Spring intake is also **medium.**

- **Sea Level Rise:** There is no risk to the PDAM's physical assets from sea level rise under the current climate.

Table 6: Possible threats of landslide to intakes and pipes.

No.	Water Source	Risk	Production L/S
1	Pipes and well at Tegalrejo	Intake facilities may be buried	18.19
2	Jeporo Spring	Intake facilities may be buried	5.23
3	Grenjengan Spring	Intake facilities may be buried	0.97
4	TukSongo Spring	Intake facilities may be buried	4.0
5	Ngrawan Spring	Intake facilities may be buried	26.0
6	Lempuyang Spring	Intake facilities may be buried	26.0
7	Kalitaman Spring	Intake facilities may be buried	25.0
8	Rekesan Spring	Pipes may break	4.0
9	Legowo Spring	Pipes may break	4.0

Source: PT Miranthi

In summary, the level of risk to the PDAM's intakes and distribution system from flood, or landslide under the baseline scenario varies based upon the location of each subsystem and the associated transmission infrastructure. Please see the summary results from the ARM Workshop presented in **Annex 4**.

2.3 WATER SUPPLY VULNERABILITY ASSESSMENT: CLIMATE CHANGE DRIVEN SCENARIO

Utilizing the results of the baseline scenario, the following section describes how the existing risks identified under the baseline may change as well as what new risks may emerge due to climate change. The first subsection describes the anticipated changes to the climate of Central Java and Semarang district, focusing on a **medium term timeframe (2030 to 2111)** under the **A2 Emissions Scenario**. The A2 Emissions Scenario was chosen because it correlates best with the study area and it is the most pessimistic of the scenarios. In addition to consulting existing literature on anticipated climate change impacts in the region, this report also utilized the MAGICC-SCENGEN climate change model scenario GCM (Global Climate Change Model) BCCRBCM2. The results were correlated with projections in the Indonesian Climate Change Sectoral Roadmap (ICCSR) of 2010. Groundwater projections were derived using weighted DRASTIC method based on the status of groundwater in 2011.

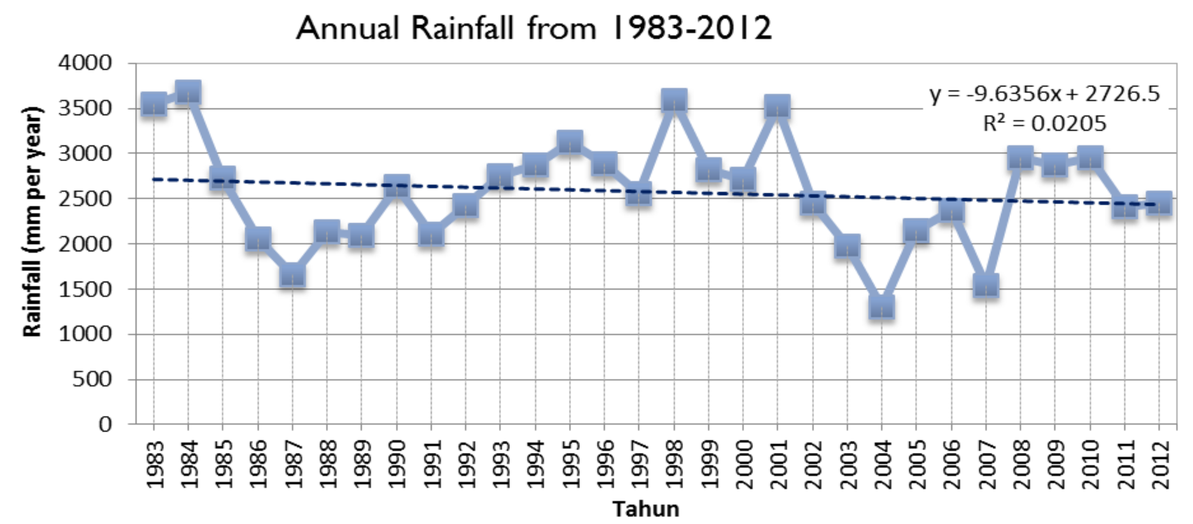
Notably, such climate change projections are to be interpreted as rough approximations, providing an indication of what *might* happen as opposed to what *will* happen. The selection of the emission scenario itself introduces wide variation, and it remains unclear the extent to which the A2 scenario will be representative over the future emissions trajectory. Thus, the reference to this models is meant as a tool to stimulate discussion, learning, and, action.

The second and third subsections of the Climate Change Driven Scenario then consider how risks identified under the baseline scenario may change as well as what new risks may be introduced. Key points of reference for the discussion include: (1) the "Water Supply Vulnerability Assessment for PDAM Semarang district, Central Java" as compiled by local partner PT Miranthi, (2) a stakeholder workshop implemented in November 2014, and (3) key information interviews and focus group discussions with PDAM and PEMDA representatives.

2.3.1 Climate Change in Semarang District, Central Java

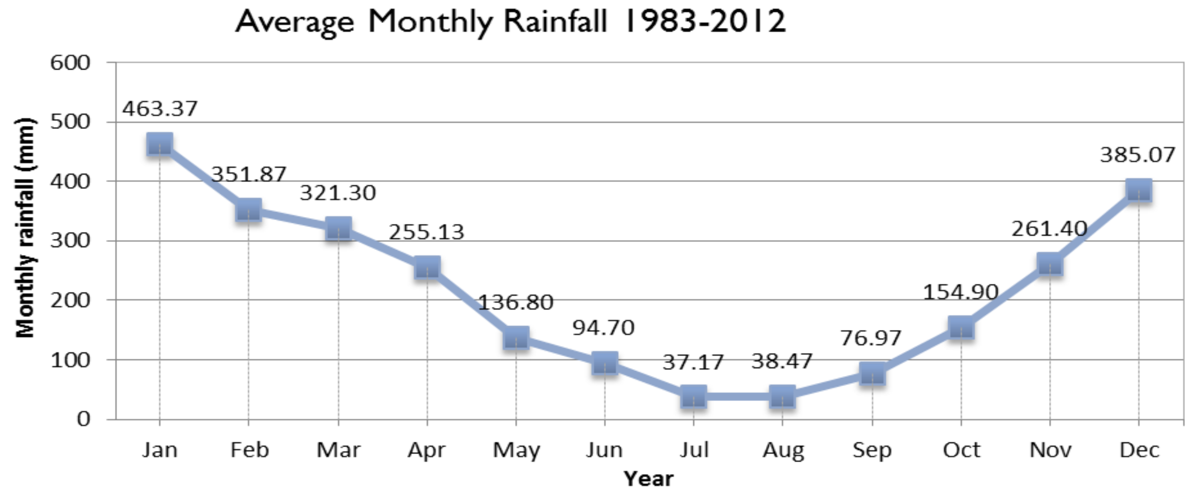
Current Conditions. As with other areas of Indonesia, Semarang district has a wet, tropical climate with essentially two seasons: wet and dry. The wet season generally lasts for about 4 months, from approximately December to March, while the dry season extends from June through October. The monthly average air temperature in Semarang district between 2001-2011 ranged from 26.9 to 29.4 degrees Celsius. Meteorology data was taken from BMKG's station at Getas, Semarang District.

Figures 7 and 8 present annual rainfall and average monthly rainfall for the period 1983 through 2012. During the period 1983 to 2012, annual rainfall in the district has ranged from 1300 mm to 3700 mm with a downward trend showing a decline of 5% over 30 years. Records at the Semarang BMKG Climate station showed that from 1985 to 2006, the average annual rainfall ranged from a low of 85 mm in 2004 to a high of 287 mm in 1993. The heaviest rainfall occurs in January and the lowest is in July.



Source: PT Miranthi

Figure 7: Annual Rainfall, Semarang District, 1983-2012.



Source: PT Miranthi

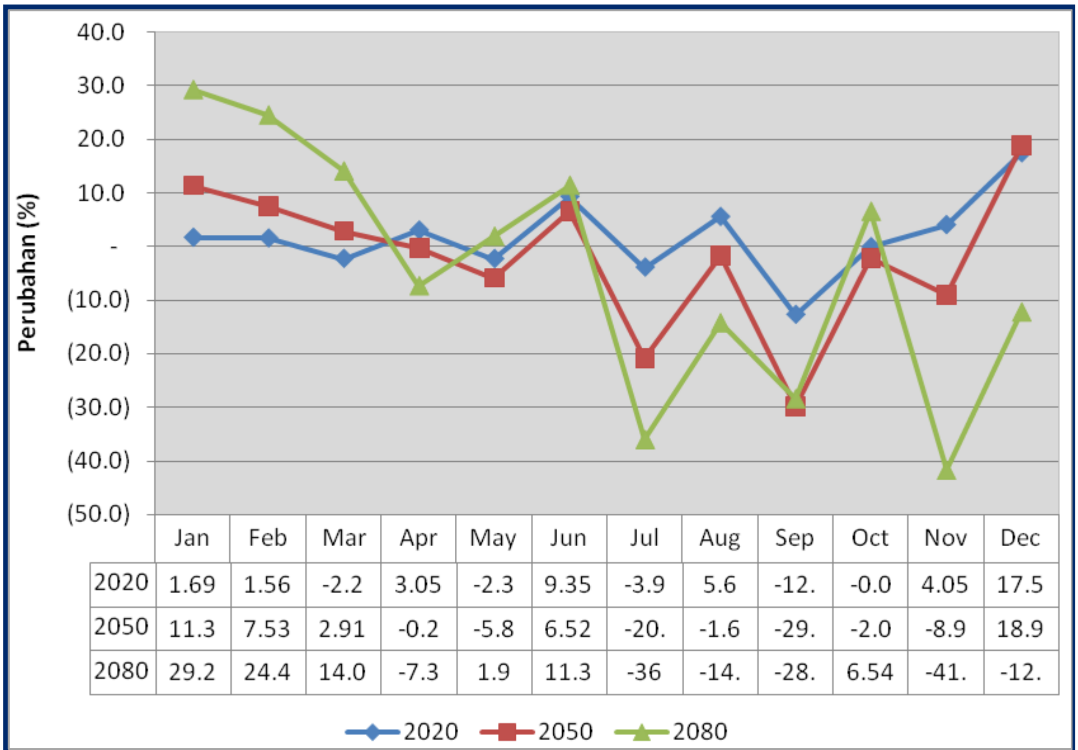
Figure 8: Average monthly Rainfall, Semarang District, 1983-2012

PT Miranthi has modeled a climate change scenario starting with analysis of reduction 5% of rainfall over the last 10 years using a Global Climate Model and assuming that emissions will continue at a high rate. The model yielded the following results:

Changes in Temperature. The results of the model suggest that by 2020, temperature will rise 0.56 degrees C over the baseline of 1990. By 2050, the increase will grow to 1.49 degrees, and by 2080 it will grow a total of 2.83 degrees. The effects of climate change include higher rate of evaporation in rivers, resulting in lower baseflow in dry season

Changes in Precipitation. December, January, and February are expected to be wetter than normal. Conversely, the ensemble shows the months of July, August, September—normally the driest of the year—to be even drier yet (except in 2080 when rainfall in November is abnormally low). While certainly not definitive, these model predictions support the overall expectation that climate change is likely to alter the *intensity* of rainfall, with more rain received over a shorter period of time, while, at the same time, dry periods extend for a greater duration. The results are shown in Figure 9.

To help understand the possible impacts of these changes, the PT Miranthi team created hydrological models using an assumption of a 5% decline in precipitation per decade. One notable conclusion was that drought-prone areas in the district would increase while the flow volumes of freshwater springs are likely to continue to decrease, with the declines being the greatest during the dry season.



Source: PT Miranthi

Figure 9: Percentage change in rainfall, in2020, 2050 and 2080.

2.3.2 Climate Change Scenario: Natural Assets

Using the above climate projections, historical records, and stakeholder input gained during the Asset Risk Matrix Workshop, PDAM Semarang's natural assets—which, according to the above discussion, are principally composed of fresh water springs and deep wells—face the following risks under the mid-century climate change scenario:

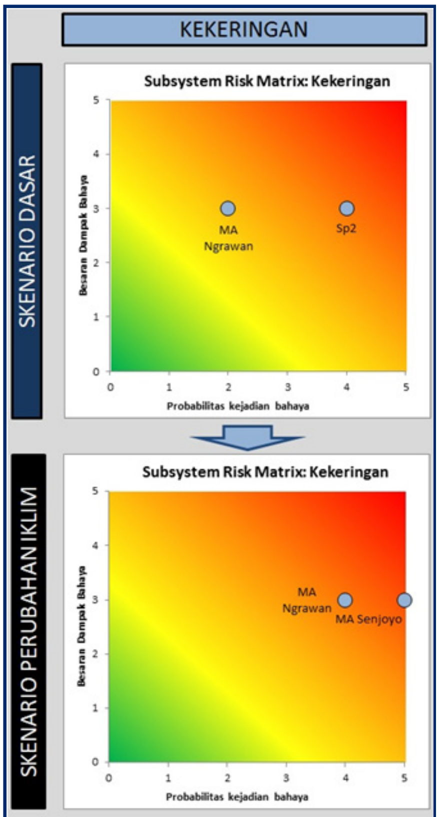
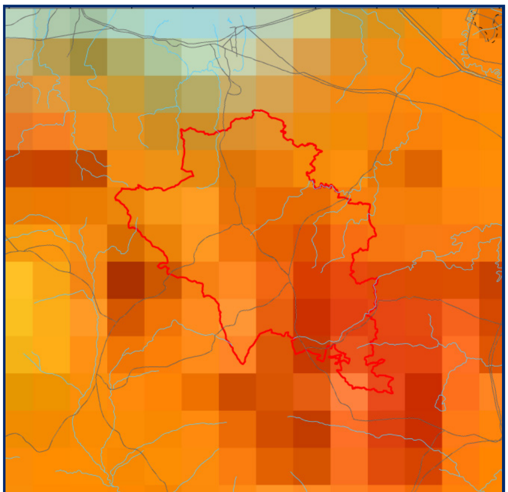


Figure 10: Drought Risk Analysis for Ngrawan and Senjoyo Spring.

- **Drought/Water Scarcity**: According to the Indonesian Climate Change Sectoral Roadmap, of 2010, Semarang District's vulnerability to drought is **very high**, as shown in Figure 11. Given the predicted shift in intensity of monthly rainfall—including longer dry seasons and more extreme but compact rainy seasons—the climate-change scenario indicates a **medium to high risk** to several of the natural assets of the PDAM. Specifically, more intense rains will lead to lower levels of infiltration and recharge and, ultimately, to lower flow volumes. Already at risk due to land-use change, the general consensus of stakeholders was that climate change would serve to elevate this risk. Senjoyo, Ngrawan, Lempuyang, and Ngablak Springs face a **high** risk of water scarcity, and Deep Well DPU faces a **medium** risk according to the participants in the vulnerability assessment workshop. Semarang district is fortunate in that its soils are usually sandy loam or sand which absorb water quickly and recharge the aquifer, but under the worst case the water table is expected to fall 5 meters over the next 20 years.
- **Flooding**. The greater intensity of precipitation events poses a **high risk** to Ngrawan Spring of flooding, and a **medium risk** to Lempuyang Springs under the climate change scenario. Given that the PDAM relies wholly on springs and deep wells, floods are unlikely to threaten the water quality of these sources.
- **Landslides**. Landslides pose a **high risk** to Ngrawan and Lempuyang Springs under the climate change scenario. Landslides also pose a low risk to Kalibening Springs.
- **Sea Level Rise**. There is no risk to the PDAM's natural assets from sea level rise under the climate change scenario.



Source: ICCSR, 2010

Figure 11: The map was created using the A2 scenario, or the high emissions scenario. The dark red areas indicate very high vulnerability to drought during the years 2025 to 2030.

As indicated under the baseline scenario, it will be important to monitor the impact of land use change in the upper watershed recharge areas. Given the predicted changes in precipitation patterns, maintaining absorption/infiltration levels will be critical to the long term sustainability of the fresh water springs in the district.

2.3.3 Climate Change Scenario: Physical Assets

Based upon the vulnerability study as well as the Asset Risk Matrix compilation workshop, the following levels of vulnerability were identified under the climate-driven scenario for the physical assets servicing the District of Semarang:

- **Drought/Water Scarcity**: There is a **<u>no risk</u>** of physical damages to the PDAM's water supply infrastructure due to drought. As noted under the baseline scenario, the PDAM does not have a history of citizen-induced damages to its infrastructure (pipeline network) during drought conditions.
- **Flooding**: Under the climate change scenario, increased intensity of storm events presents a **high risk** of flooding at Ngrawan Spring's transmission lines and pumps and **medium risk** to Lempuyang's intake. The risk to the Ngrawan intake is **medium**.
- **Landslides**: Due to the slope of the terrain in many areas of the district and more intense rainfall under the climate change scenario, there is a **<u>high risk</u>** of landslide at the Lempuyang Spring intake and at Ngrawan Spring's transmission lines and pumps, as shown in Figure 12. There is a **<u>medium risk</u>** of landslide to Ngrawan Spring's intake.
- **Sea Level Rise:** The PDAM's constructed assets remain both far enough inland and high enough in elevation to avoid exposure to sea level rise.

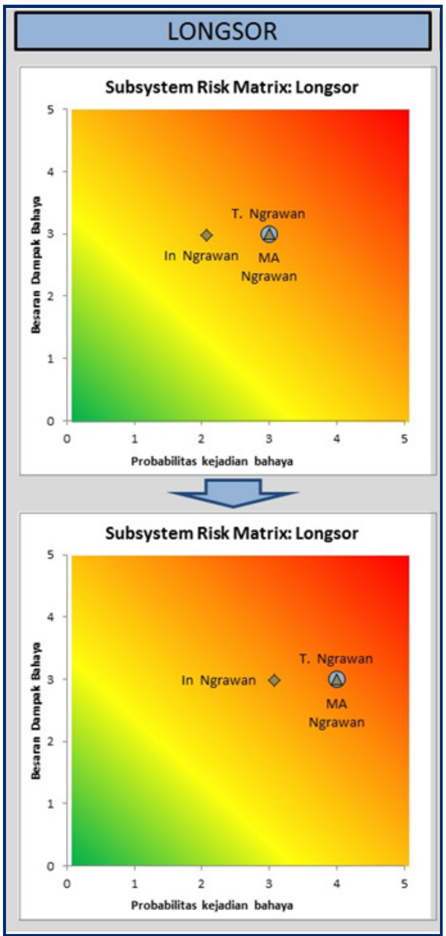


Figure 12: Landslide Analysis for Ngrawan natural & built assets.

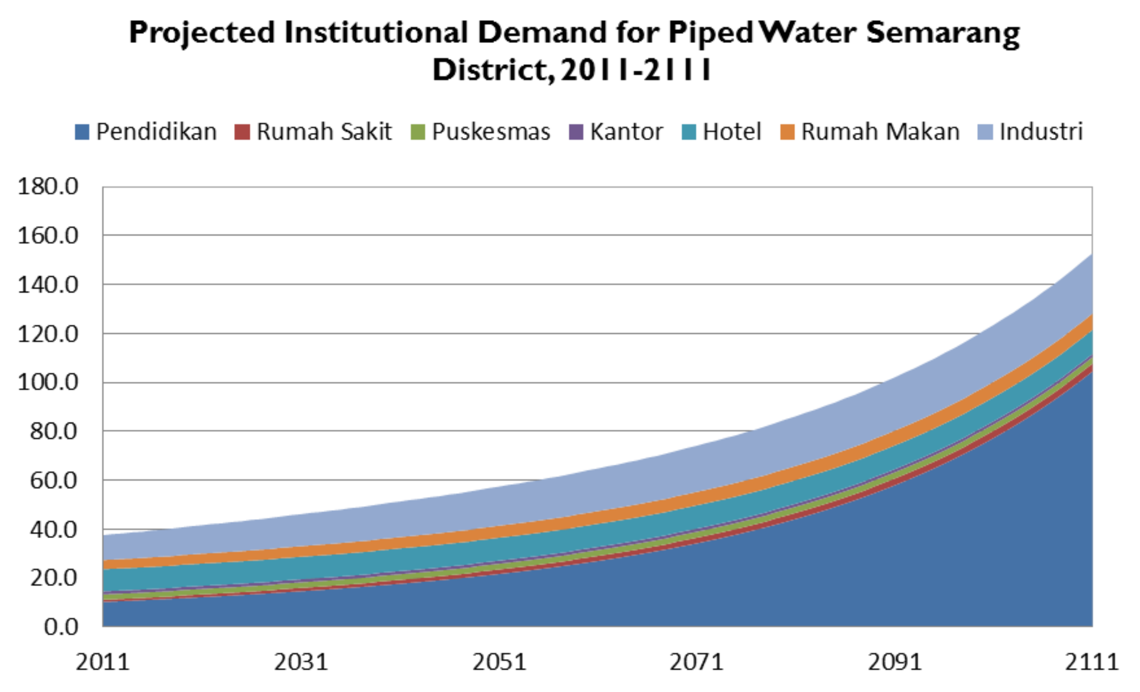
In summary, climate change, with increased intensity of rainfall, will worsen the existing threats to the PDAM's constructed infrastructure, particularly when it comes to flood and landslide hazards. Climate change is expected to introduce higher new threats to current constructed assets. As the PDAM considers the construction of new assets, it will be imperative that water utility managers consider these risks when planning the location and design for new infrastructure such as transmission lines and intakes. Please see the summary results from the ARM Workshop attached as **Annex 4**.

2.3.4 Climate Change Scenario: Limited Water Balance Analysis

To better understand the water balance faced by PDAM Semarang district, the PT Miranthi Research Team constructed several simplified models extending from the present through 2111 using results of expected changes to the local climate and the supply and demand for groundwater used by the PDAM. The research team assumed an average geometric annual population growth of 0.89% using consumption of 150 liters per day for household connections and 30 liters per day for public taps, resulting in a need for 3,615 liters per second to meet the demands of 2,957,185 people in Semarang district in 2111. Notable characteristics of the supply and demand analysis for Semarang district are as follows:

- The primary drivers behind increased demand are (1) **growth in the District's population** and (2) **expanded access to piped water** (which means that customers will use greater amounts of water per day). Given the recent growth of the local economy, however, it will also be important to consider how demand may begin to increase from other sectors such as industrial water users. As shown in Figure 13, growth in institutional demand is expected to accelerate exponentially.

- Related to the theme of economic growth of Semarang district combined with the aforementioned challenge of monitoring the quantity and quality of the Region's raw water assets, it is difficult to assess the overall available supply of water in the district. It is also difficult to discern how these assets are divided among the different types of users across the District for domestic, industrial, and farming needs.



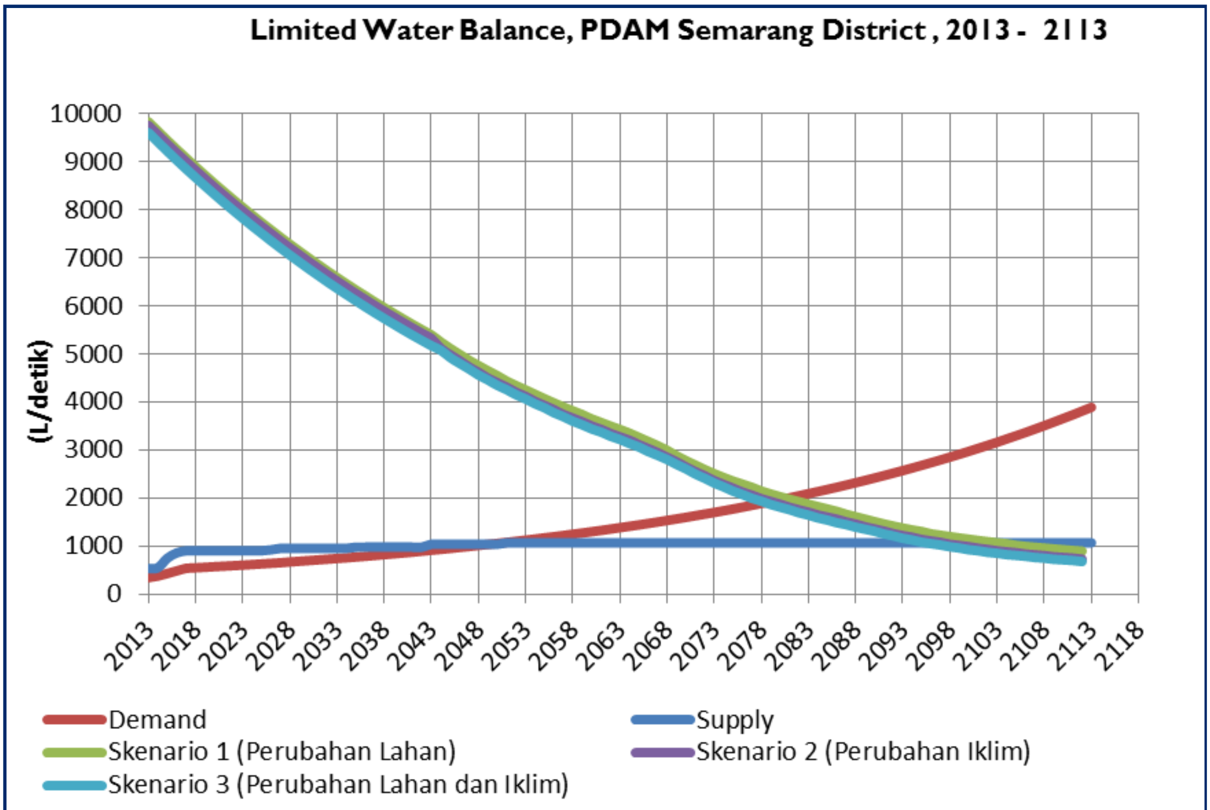
Source: PT Miranthi

Figure 13: Projected Institutional Demand for Piped Water.

- The existing sources of raw water possess capacity significantly above the current volume produced by the PDAM, meaning that the PDAM has natural assets available to continue to meet rising demand and grow its customer base in the short to medium term despite the climate change risks, but it will have to look for new sources in the medium term;
- Over the last 10 years total rainfall in Semarang District was reduced by about 5%, and the potential for water absorption fell by a significant amount. This trend is expected to accelerate with climate change
- Based on the assumption that no new sources of water will be found or developed, the available supply of current and planned sources of PDAM water is not expected to be overcome by demand from all users until about 2080.
- Climate change is expected to accelerate the decline of the water table which will reduce the rate of discharge from springs and possibly cause the disappearance of some production wells after the year 2029.
- The daily use of domestic customers through public hydrants is assumed to be only 30 liters per day. Domestic customers of piped water are assumed to use water a rate of 150 liters per day.

Figure 11 shows three scenarios for supply of groundwater for the PDAM:

- Scenario 1, reduction of 7% in infiltration rate due to change in land use
- Scenario 2, reduction of 12% in infiltration rate due to change in rainfall pattern
- Scenario 3, reduction of 19% in infiltration rate due to both rainfall pattern and land use change.



Source: PT Miranthi

Figure 14: Limited Water Balance for PDAM Semarang District.

Overall, it is clear that a more detailed analysis of supply and demand in Semarang district is needed in light of the risks posed by climate change. Such an analysis should be sure to take into consideration the needs of other users throughout the watershed.

3 CLIMATE CHANGE ADAPTATION PLANNING

3.1 APPROACH TO ADAPTATION PLANNING

According to the IPCC (2012) adaptation to climate change is the "process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities." Adaptation actions may take many forms, including the modification of existing plans (such as providing greater distance between a planned treatment facility and the adjacent river), "soft" adaptation actions (such as rehabilitating the watershed through tree planting), or "hard" adaptation actions (such as constructing a flood wall between the river and a treatment facility or storage unit). Where possible, PDAM managers should prioritize "no regrets" adaptation actions, which are those that deliver net benefits over the entire range of anticipated future climate and associated impacts (IPCC, 2012).

The process for identifying specific adaptation options is, in many ways, similar to the decision-making path for PDAM and local government investments more broadly. More specifically, after identifying geographic "hotspots"—i.e. key assets that are deemed highly vulnerable—decision-makers move from a "long-list" of actions down to a "short-list" of actions. Further, the short-list of actions is then assigned a level of priority in terms of response to be implemented immediately and those that will be planned for the medium or longer term. To facilitate this process, IUWASH held a series of stakeholder meetings from mid-2013 through early 2014 to construct a "long-list" of potential adaptation options for the identified hotspots that can be taken to boost the resilience of the PDAM's natural and constructed assets. Further, PDAM and local government representatives then discussed the costs and benefits of each potential action, using a series of criteria to identify a short-list of options and prioritize those options accordingly. The outcome of this process is described below.

3.2 VULNERABILITY HOTSPOTS

Following the vulnerability assessment process of the PDAM's natural and constructed assets, — which includes the PT Miranthi Baseline Report, a series of stakeholder meetings and workshops, and a synthesis by the IUWASH Climate Change Team—the following vulnerability hotspots were highlighted for further analysis and adaptation planning:

- **Mata Air Senjoyo (Natural Asset)** supplies about 31.84 liters per second to PDAM Semarang District. Neighboring PDAM Salatiga City, on the other hand, depends on Mata Air Senjoyo for 140 liters per second, almost half of its total raw water input. The discharge from MA Senjoyo appears to have declined about 13% between 2000 and 2004. In 2008, a study by the Faculty of Economics, University of Diponegoro, found that Air Mata Senjoyo already was supplying less than what was needed for agriculture, households, and the PDAMs. This steady downward trend has been of concern to the PDAM, especially during the dry months of the year. Mata Air Senjoyo is highly vulnerable to drought in the climate change scenario.
- **Mata Air Ngablak (Natural Asset),** currently supplies about 10 liters per second**,** down from about 40 l/s in 1987. Along with the other springs supplying Semarang District, it is vulnerable to drought, especially under the climate change scenario.
- **Mata Air Ngrawan and Mata Air Lempuyang (Natural Assets)** each produce about 26-30 liters per second. Both sources have high vulnerability to both landslide and drought under the climate change scenario, and the flow of water is significantly reduced during the dry season.

The Intake and Distribution Systems for Mata Air Ngrawan and Lempuyang (Built Assets) are vulnerable to risks of flood and landslide. The intake at Ngrawan Spring has been raised to protect it from the overflow of a river just above it, but the transmission line still has medium vulnerability to landslides. The intake for Lempuyang Spring is located just below an embankment holding up an irrigation canal, so the intake has medium vulnerability to flood and high vulnerablity to landslide under the climate change scenario.

In summary, *the vulnerability hotpots for PDAM Semarang district appear to be related mainly to vulnerability to drought for the natural assets and vulnerability to flood and landslide for built assets, suggesting mitigation measures aimed at reducing the rate of runoff and protecting or moving key infrastructure.*

3.3 LONG LIST OF ADAPTATION OPTIONS

A wide range of adaptation options exists to boost the resiliency of PDAM assets. As part of the adaptation planning process, IUWASH reviewed the different types of responses that the PDAM may consider for the vulnerability hotspots identified. Table 7 below provides an illustrative "long list" of climate change adaptation options.

Table 7: Long List of Adaptation Options

Adaptation Classifications	Specific Responses
Source Water Protection	Watershed Protection: Establishment of protected zones critical for water recharge or spring protection
	Aquifer recharge programs
	Farmer extension programs aimed at reducing soil erosion
	Improved waste collection and treatment
	Payment for Environmental Services
Water Efficiency and Demand Management	Non-Revenue Water Reduction
	Water meter maintenance and replacement
	Efficient water pricing (i.e. increasing block tariffs)
	Social marketing for consumer behavior change
	Consumer incentive programs (i.e. low-flow devices)
	Wastewater reuse for agriculture and industry
Infrastructure Options	Enhance/expand storage capacity through construction of new reservoirs
	Diversify water resources through construction of deep wells, new surface water intakes, and inter-basin transfers
	Check dams to slow runoff and facilitate aquifer recharge
	Increase access to improved urban sanitation systems to reduce pollution of upstream water sources and local groundwater
	Expanded wastewater treatment for water reuse in agriculture and industry
	Expand/upgrade urban drainage systems
	Construction of birms, dikes, or sea walls
	Relocation / strengthening water infrastructure subject to flooding
Information Management	Water Allocation Decision-Support Systems
	Hydrological / Meteorological Monitoring Stations
	GIS-Enabled Asset Management Systems
	Computerized Billing and Accounting

3.4 SHORT LIST OF ADAPTATION OPTIONS AND VULNERABILITY HOTSPOTS

Following the selection of the vulnerability hotspot and a review of the menu of adaptation options available, PDAM representatives and IUWASH then identified key criteria with which to compare and rank potential actions. These criteria were as follows:

- Cost of the proposed adaptation;
- Complexity, including technical complexity and coordination between stakeholders;
- Political support (and level of political action required);
- Speed of implementation; and
- Overall impact on the reduction of risk to the specific assets.

Table 8 below summarizes the short list of adaptation options discussed for the assets while also highlighting the hazards that the adaptation option will help to address. The full evaluation of adaptation options is attached as **Annex 5**.

Table 8: Prioritization of Adaptation Options using Multi-criteria Analysis

Asset	Priority Adaptation Options	Drought	Flood	Mudslide	Sea Level
Ngrawan Spring	Strengthen policies, including withdrawal of water surface water and ground water	*	*	*	*
	Installation and maintenance of infiltration wells	*	*	*	
	Protect infrastructure that is vulnerable to disaster		*	*	
	Establishment of disaster contingency fund	*	*	*	*
Senjoyo Spring	Aquifer recharge programs (raw water return activities)	*	*	*	*
	Payment for Environmental Services	*	*	*	
	Establish cooperation with neighboring PDAMs and local governments for sharing of water sources	*			
	Water resources research to better understand and map the location and characteristics of the aquifer	*	*	*	*
	Improve management of water resources: establish a forum to manage water resources/watershed	*	*	*	
Ngablak Spring	Program to return water to the source such as infiltration well	*	*	*	
	Install monitoring of surface and groundwater	*	*	*	
	Customers use basins or reservoirs	*	*		
	Monitoring and evaluation of adaptation steps	*	*	*	
Kalibening Spring	In regional plan establish a protection zone for protection of the freshwater spring source	*		*	
	Monitoring and evaluation of adaptation steps	*	*	*	
	Establish emergency disaster fund (government, PDAM)			*	
	Program to return water to nature, such as infiltration wells	*	*	*	
Ngembat Spring	Payment for environmental services	*	*	*	
	Regreening	*	*	*	
	Improve water resources management, such as establishment of a water users forum (Farmer Water Users Group)	*		*	
	Decision support system for allocation of water (including calculation of water resources and water balance)	*			

In addition to the above priority adaptation options identified by the PDAM and local government officials, IUWASH also recommended consideration of the following:

- **Strengthening and/or Repositioning of Key Transmission Lines:** In order to address the vulnerability of upstream transmission infrastructure, the PDAM may consider adding reinforcements to exposed pipeline networks, particularly for places that are in medium to high risk from landslides. Over the longer term, the PDAM may also consider moving these transmission mains altogether to a more secure and less flood-prone route.
- **Improved Asset Management:** The PDAM should be able to use its GIS-enabled asset management system to track critical infrastructure details such as: age, depreciated value, replacement cost, and historical damages. Full use of such a system would help to identify vulnerable assets and proactively plan for maintenance and/or repairs.
- **Water Resources Decision Support Systems**: In the absence of reliable stream flow data, ground water levels, and rainfall intensity records (i.e. hourly rainfall data), it will continue to be difficult for PDAM officials and local government officials to understand how the quantity and quality of their water resources are changing and how to best plan for the future. As such, incremental investments in automated hydrological and meteorological monitoring systems in cooperation with surrounding local governments could lead to more informed and effective water resources management decisions.

As described in greater detail in Chapter 4, some of the above adaptation actions have already commenced, particularly as concerns aquifer recharge programs, GIS implementation, and watershed management improvements.

4 ACTION PLAN

4.1 NEXT STEPS FOR IMPLEMENTATION OF ADAPTATION PLAN

Based upon the results of the water supply baseline study, the identification of vulnerability hotspots and completion of the asset risk matrix, the discussion and prioritization of adaptation options, the PDAM in conjunction with the local government have agreed to a series of short-term actions to be initiated with the coming six months. In accordance with the vulnerabilities highlighted above, the PDAM and respective Dinas will focus immediate efforts on the continuation and expansion of water resources protection activities in the upper catchment areas of the Kabupaten, specifically those related to the catchments for Ngrawanand Senjoyo Springs in the Salatiga sub-system, and Ngablak and Lempuyang Spring in the Ungaran sub-system.

Specific actions are as follows:

- **Action #1: Development of GIS Program:** after receiving GIS training, the PDAM used its own budget for its staff to develop GIS mapping of the piping network and its accessories. PDAM plans that all of its assets and customer locations will eventually be mapped based on GIS enabling better management of the assets, including those vulnerable to climate change-driven hazards.
- **Action #2: Development of Infiltration pond program:** through collaboration of IUWASH and Coca-Cola Foundation Indonesia (CCFI), the PDAM is helping construct infiltration ponds in the recharge area. Among other things, the ponds serve as artificial recharge reservoirs that feed the spring's aquifer. Communities are involved in the construction and they will take the lead in maintenance of ponds in the Kabupaten Semarang area.
- **Action #3: Musrenbangdes infiltration pond program:** Infiltration ponds are expected to be built through the Musrenbangdes local government-funded village planning program, not only to help improve recharge, but also to help address the local flooding problem. Desa Jethak and Desa Patemon of Kabupaten Semarang feel that the infiltration pond program can be replicated through Musrenbangdes.
- **Action #4: Cooperation with Senjoyo communities.** Kabupaten Semarang is taking the lead in a dialogue with communities living near Senjoyo Spring. They have hosted three stakeholder meetings attended by both PDAM Kabupaten Semarang and PDAM Salatiga City as well as the entities that are withdrawing water from the spring such as a textile factory, a military camp, and communities.
- **Action #5: SemarSalat:** As the water demand in the district is growing, Kabupaten Semarang is working to get additional raw water under the SemarSalat scheme, a system of cooperation between Semarang District and Salatiga City.

In addition to the above immediate actions by the local government and the water utility, several additional adaptation actions remain under discussion with the PDAM for the next 1-3 years. These include: additional strengthening of hydrological and meteorological monitoring to improve decision-making, the replacement of key aging infrastructure, and the fortification of above-ground pipelines in flood and landslide prone areas.

4.2 INTEGRATION INTO MEDIUM AND LONG-TERM PLANNING

In conjunction with the commencement of the implementation of immediate and short-term adaptation options, it is also important that the results of this assessment and planning exercise be integrated into the PDAM and local government's broader development planning. In other words, while the preparation of a specific "adaptation plan" makes sense as an initial step towards improved climate change adaptation planning, the more sustainable approach over the long term is that the results and, more importantly, the process itself, be included in existing planning mechanisms, namely, the PDAM's Corporate Plan and/or Annual Plan (RKAP) and the Local Government's annual and medium-term plans. Specific actions in this regard are:

- The PDAM will integrate the results of the Vulnerability Assessment and Adaptation Plan into the next revision of its 5 year corporate plan; and
- The Local Government is expected to establish a specific program and budgetary line items for improved water resources management in the upcoming Annual Work Plan and Annual Budget (APBD).

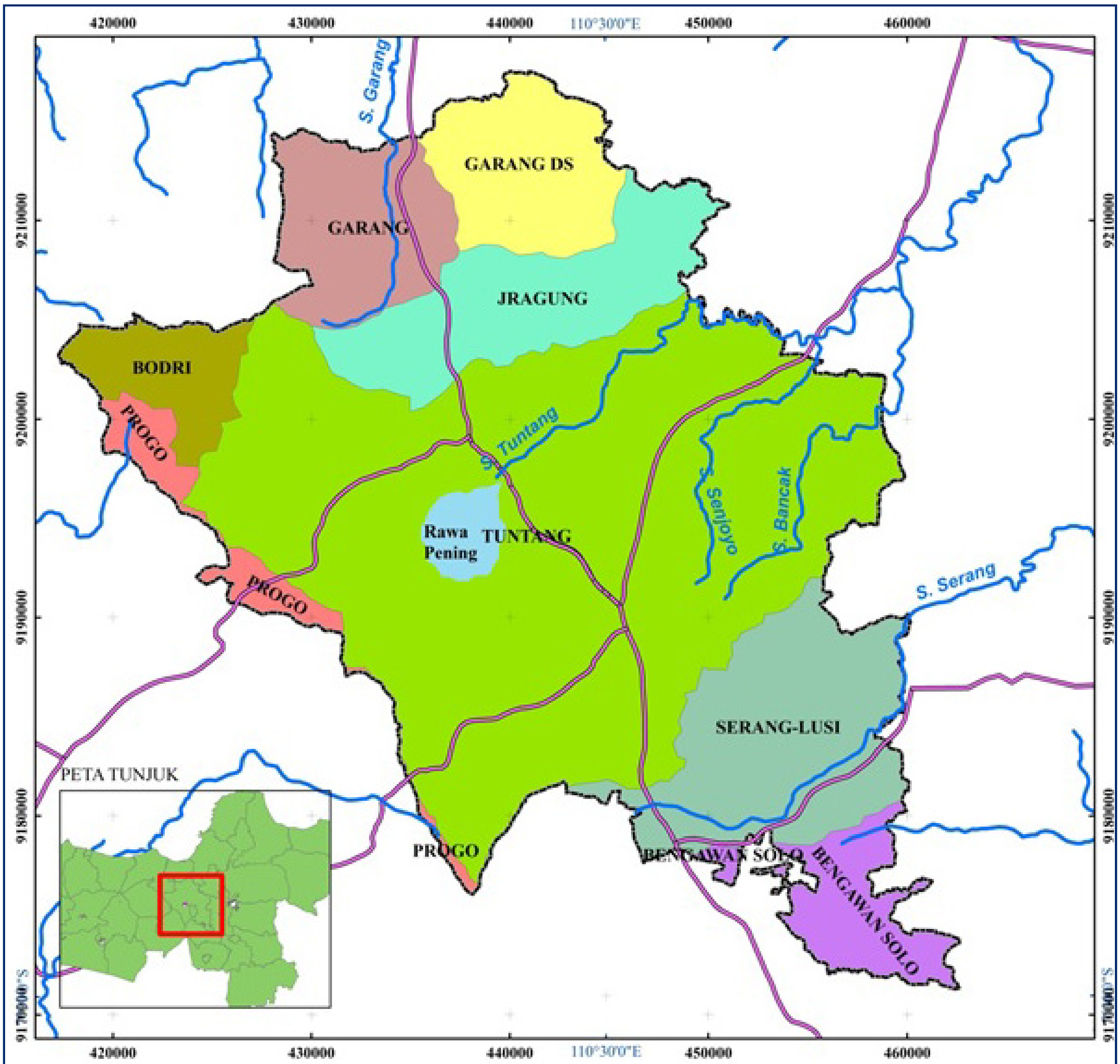
The integration of climate change vulnerability assessment and adaptation planning into the local planning documents will also support continuous learning and, where necessary, updating of adaptation approaches. There is still much that we do not know about how climate change will impact a specific location and the natural and built assets located therein. Thus, climate change adaptation is best approached on an iterative basis under the auspices of the local planning cycles, thereby ensuring that such plans are regularly updated based on the latest scientific knowledge and the evolving experiences and needs of the local communities.

ANNEXES

ANNEX 1: CHRONOLOGY OF VA & AP PROCESS

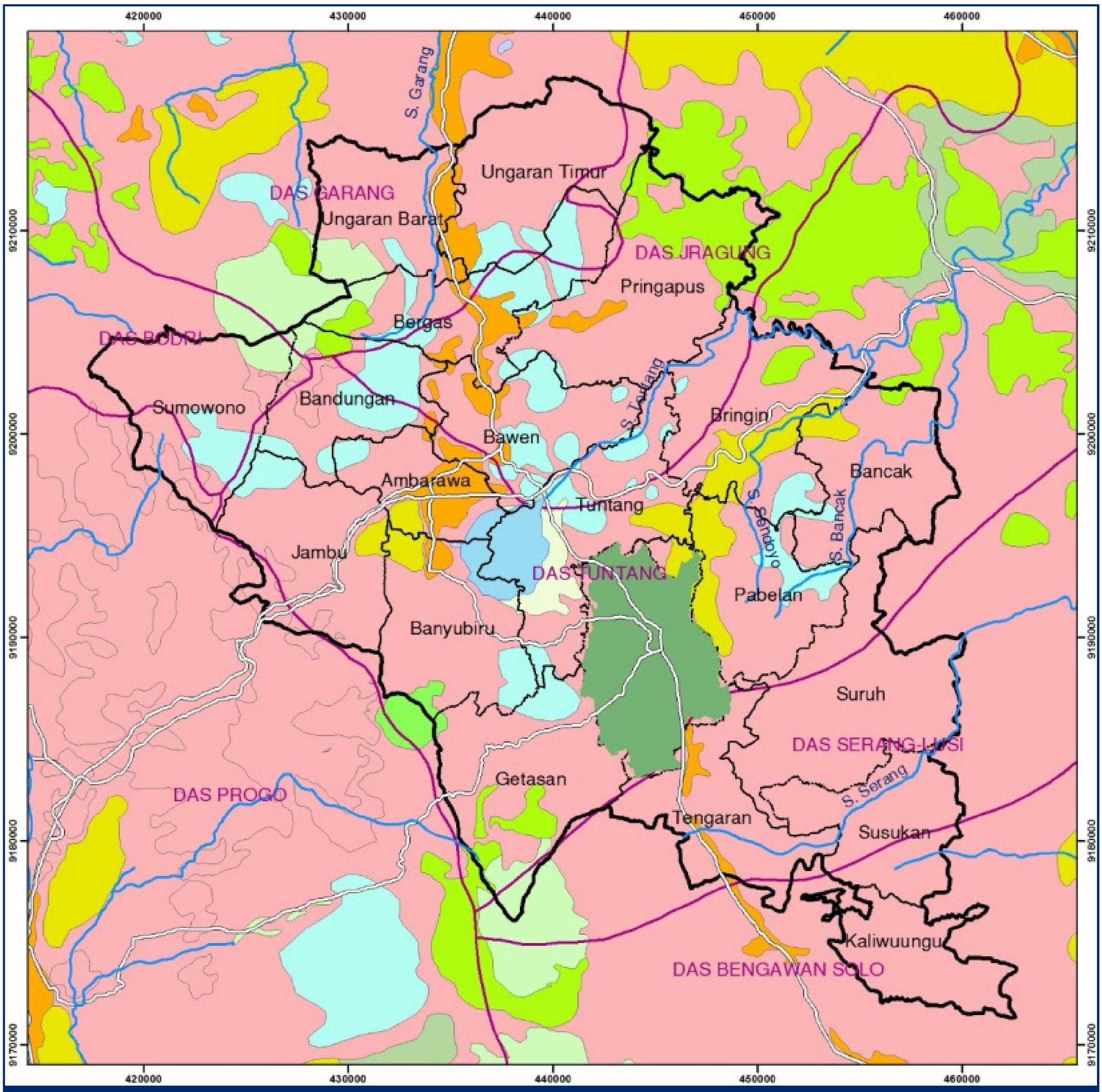
Date	Activity/Event	Major Output	Stakeholders
May 2012	Initial assessment: - Discussion with PDAM - Field survey of raw water sources used by PDAM	- Indication of declines in quantity of springs & deep well.PDAM recognized this fact. - Identified needs for CCVA study.	PDAM Kabupaten Semarang, IUWASH
November 2012	Selection of institution to conduct CCVA through tendering process	PT Miranthi qualified and was selected to conduct CCVA study	PT Miranthi, IUWASH
December 2012	Kick off meeting: Meeting and discussion among Kabupaten Semarang, IUWASH, and PT Miranthi	- Understanding of CCVA work activities to be undertaken - Agreement on schedule, data collection, and support of PDAM	PDAM, PT Miranthi, IUWASH
July 2013	Initial workshop on the CCVA study	Preliminary results of CCVA were discussed & items for revisions of CCVA were identified: water supply and demand, assets' vulnerability particularly on the raw water, and initial recommendation for adaptation	PDAM, Bappeda, Dinas PSDA, Dinas Pertambangan dan Energi, BLH, BPBD, Dinas Kehutanan, Dinas Pertanian, Satker PK-PAM Prov. Jateng, PT Miranthi, IUWASH
July 2013	Initial ARM workshop	Initial ARM were developed by PDAM and other key local government agencies	PDAM, Bappeda, DinasPSDA, Dinas Pertambangan dan Energi, BLH, BPBD, Dinas Kehutanan, Dinas Pertanian, Satker PK-PAM Prov. Jateng, PT Miranthi, IUWASH
September 2013	FGD on initial ARM and adaptation options development	Initial adaptation options were identified and discussed	PDAM, Bappeda, Dinas PSDA, Dinas Pertambangan dan Energi, BLH, BPBD, IUWASH
November 2014	Workshop on CCVA, ARM, and adaptation options	- Common understanding among PDAM and other stakeholders on Kabupaten Semarang's water supply's vulnerability - ARMsand adaption options were developed by PDAM and other key local government agencies	PDAM Kabupaten Semarang, PDAM Kota Salatiga, BPBD, Bappeda, Dinas PSDA, DPU, Balai Besar Wilayah Sungai (BBWS) Pemali-Juwana, LPPM Undip, PT Sarana Tirta Ungaran (STU), SPPQT, PT Miranthi, IUWASH

ANNEX 2: MAP OF WATERSHEDS IN SEMARANG DISTRICT



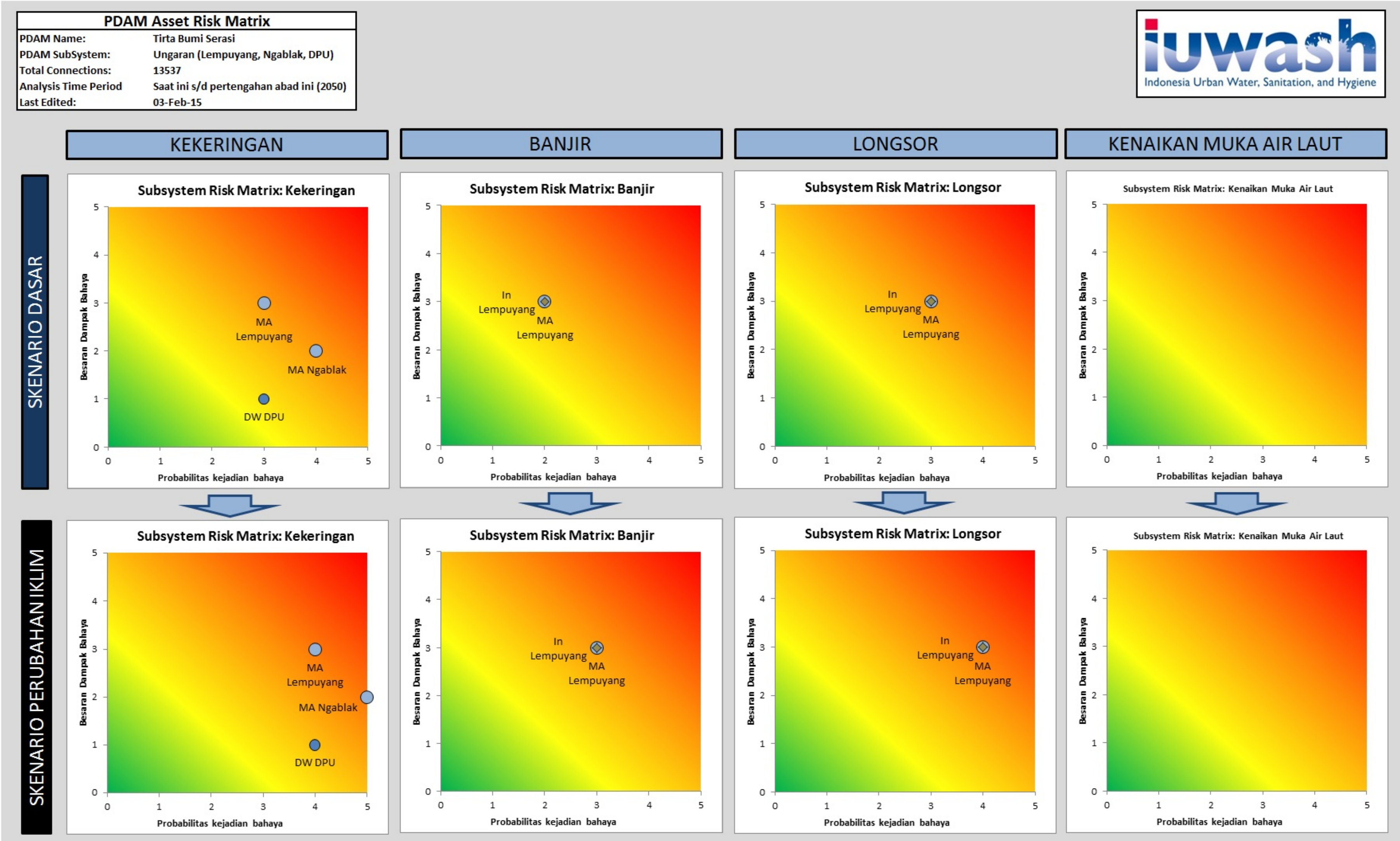
Semarang District includes portions of seven watersheds. The main watersheds are the Garang, Jragung, Tuntang, and Serang-Lusi watersheds.

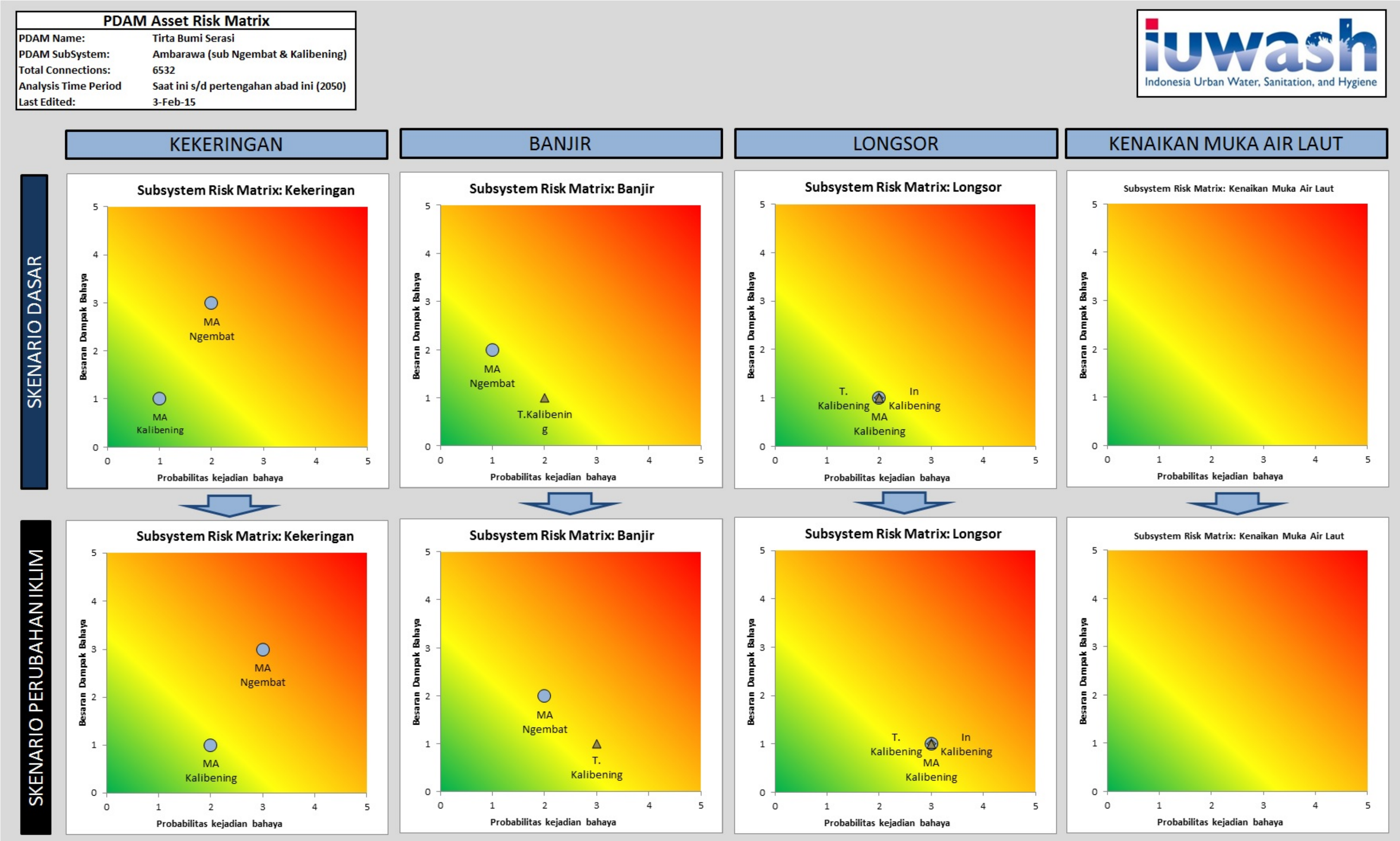
ANNEX 3: LAND USE MAP OF SEMARANG DISTRICT, 2003



Annex 3. Land use map of Semarang district. Dark gold area is settlements. Dark green area is Salatiga city. Yellow-green areas are rice paddy fields. Pink area is dryland agriculture. Dark blue area is Lake Rawapening. Light blue area is plantations. Two shades of green are forested areas.

ANNEX 4: ASSET RISK MATRIX BY SUBSYSTEM




PDAM Asset Risk Matrix
PDAM Name: Tirta Bumi Serasi
PDAM SubSystem: Ambarawa (sub Ngembat & Kalibening)
Total Connections: 6532
Analysis Time Period: Saat ini s/d pertengahan abad ini (2050)
Last Edited: 3-Feb-15
Indonesia Urban Water, Sanitation, and Hygiene
KEKERINGAN
BANJIR
LONGSOR
KENAIKAN MUKA AIR LAUT
SKENARIO DASAR
SKENARIO PERUBAHAN IKLIM
Subsystem Risk Matrix: Kekeringan
Subsystem Risk Matrix: Banjir
Subsystem Risk Matrix: Longsor
Subsystem Risk Matrix: Kenaikan Muka Air Laut
Besaran Dampak Bahaya
Probabilitas kejadian bahaya
MA Ngembat
MA Kalibening
T.Kalibenin g
T. Kalibening
In Kalibening

PDAM Asset Risk Matrix	
PDAM Name:	Tirta Bumi Serasi
PDAM SubSystem:	Salatiga (Ngrawan, Senjoyo)
Total Connections:	10385
Analysis Time Period	Saat ini s/d pertengahan abad ini (2050)
Last Edited:	3-Feb-15

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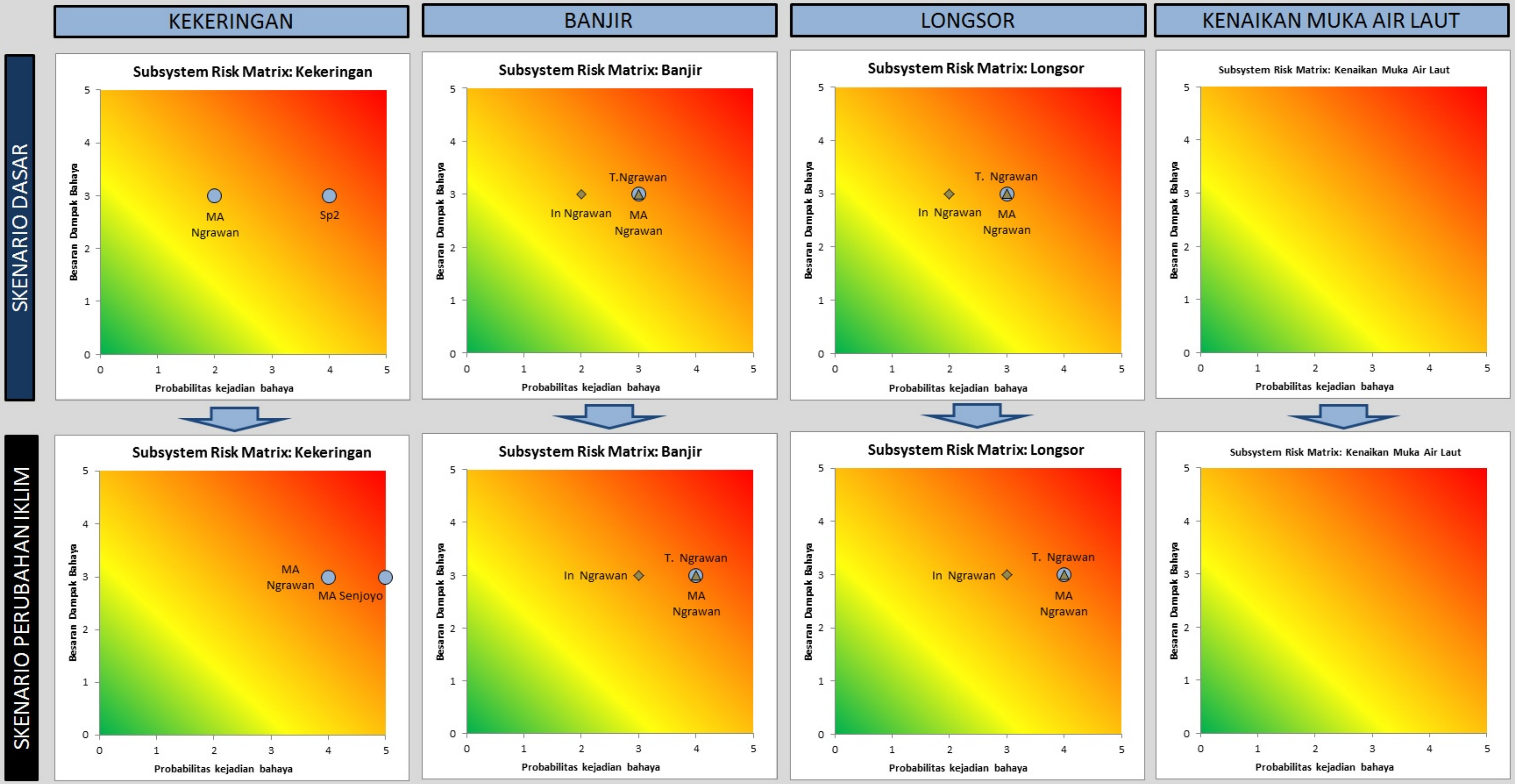

ANNEX 5: EVALUATION OF ADAPTATION OPTIONS

Pilihan Adaptasi Penyediaan Air Minum Kab. Semarang

Sumber/Unit/Sistem: Lempuyangan, Ungaran

Klasifikasi Adaptasi	Pilihan Adaptasi (Long List; silakan ditambahkan pilihan-pilihan aksi adaptasi lainnya, jika masih ada dan sesuai dengan profil ARM)	Bahaya yang diantisipasi				Total Skor
		Kekeringan	Banjir	Tanah Longsor	Kenaikan M. A. Laut	
Perlindungan Sumber Air	Perlindungan DAS: Ditetapkannya zona perlindungan wilayah imbuhan (untuk perlindungan m. air)	*	*	*		8
	Perbaikan tata kelola s.d. air: pembentukan forum/lembaga pengelola sumber daya air/forum DAS	*	*	*		10
	Memperkuat peraturan, termasuk izin pengambilan air tanah & air permukaan (PerDa, PerWal, PerBup, MoU kerja sama antarwilayah untuk perlindungan sumber air)	*	*	*		10
	Program pengembalian ke alam/pengisian akuifer, mis. sumur resapan, biopori	*	*	*		15
	Penyuluhan pertanian dengan tujuan mengurangi erosi tanah dan limpasan	*	*	*		14
	Perbaikan pengelolaan air limbah dan limbah padat (terutama di wilayah hulu)	*	*	*		7
	Pembentukan forum pemangku kepentingan di hulu: untuk menghindarkan/meminimalkan konflik	*				11
	Pembayaran jasa lingkungan (PP 37)	*	*	*		9
	Reboisai/penghijauan	*	*	*		13
	Analisa AMDAL terkait perijinan	*				9
Pilihan Infrastruktur	Sistem pengumpulan air hujan di tingkat masyarakat	*	*	*		0
	Penggunaan beberapa jenis sumber air baku (air permukaan, air tanah dalam, mata air), termasuk kerjasama antarwilayah/regionalisasi	*	*			0
	Meningkatkan akses terhadap sanitasi yang baik (untuk mengurangi/menghindari pencemaran sumber air), mis. dari cubluk menjadi septic tank	*	*	*		7
	Memperbaiki sistem drainase, mis. di sekitar infrastruktur SPAM agar terhindar dari pencemaran/genangan	*	*			0
	Pembuatan reservoir, meningkatkan kapasitas penyimpanan air	*	*			12
	Perkuatan infrastuktur yang rawan bencana, mis. thrust block untuk menghadapi longsor		*			0
	Pemindahan infrastruktur rawan bencana, mis. pipa transmisi		*	*		15
	Pengadaan truk tanki air untuk melayani wilayah/masyarakat rawan kekeringan			*		7
	Pemanfaatan idle capacity SPAM (rerating/uprating)	*				13

Pengelolaan/Efisiensi Konsumsi/Kebutuhan Air	Pengurangan tingkat kebocoran air (PDAM): teknis (penggantian jaringan lama/rusak)	*	*	*		8
	Pemeliharaan/penggantian meter air (lama/rusak)	*				14
	Penetapan tarif (progresif) yang mengarah pada penghematan penggunaan air	*				11
	Pemasaran sosial untuk perubahan perilaku pelanggan/pengguna air	*				14
	Efisiensi energi untuk mempertahankan tingkat pelayanan	*				12
	Penggunaan bak/tandon di pelanggan	*	*			13
	Mendorong industri untuk penggunaan sistem recycle	*		*		12
	Advokasi/regulasi untuk mengatur penggunaan air tanah	*		*		7
Perencanaan dan Pengelolaan Informasi	Sistem dukungan pengambilan keputusan untuk alokasi air (termasuk alat bantu perkiraan sumber daya air: water balance)	*	*	*		11
	Instalasi pemantauan hidrologi/meteorologi/air tanah	*	*	*		13
	Penerapan sistem akuntansi pencatatan & penagihan penggunaan air serta sistem akuntansi penyediaan air bersih/PDAM	*	*	*		13
	Penelitian sumber daya air, mis. untuk memahami lebih baik dan memetakan lokasi dan karakteristik akuifer dan sumber air baku lainnya	*	*	*		11
	Rencana pengelolaan bencana (contingency/emergency plan)	*	*	*		0
	Rencana pengamanan air (water security: ketersediaan/keberlanjutan)	*	*	*		11
	Monitoring & evaluasi langkah-langkah adaptasi	*	*	*		14
Pelimpahan/Antisipasi Risiko	Pembelian asuransi (properti) untuk bangunan dan sumber daya penting lainnya (mis. kendaraan operasional)	*	*	*		14
	Membentuk dana cadangan bencana (pemerintah, PDAM)	*	*	*		14
	Menyusun rencana dan/atau SOP darurat bencana (contingency plan), mis. bila ada banjir di lokasi sistem pemompaan	*	*	*		0

Pilihan Adaptasi Penyediaan Air Minum Kab. Semarang

Sumber/Unit/Sistem: : Ngembat, Ambarawa

Klasifikasi Adaptasi	Pilihan Adaptasi (Long List; silakan ditambahkan pilihan-pilihan aksi adaptasi lainnya, jika masih ada dan sesuai dengan profil ARM)	Bahaya yang diantisipasi				Total Skor
		Kekeringan	Banjir	Tanah Longsor	Kenaikan M. A. Laut	
Perlindungan Sumber Air	Rencana Detail Tata Ruang Kawaasan wilayah imbuhan, perlindungan m. air	*		*		12
	Perbaikan tata kelola s.d. air: pengutan forum/lembaga pengelola air (Perkumpulan Petani Air)	*		*		14
	Memperkuat peraturan, termasuk izin pengambilan air tanah & air permukaan	*		*		10
	Program pengembalian ke alam/pengisian akuifer, mis. sumur resapan, biopori	*	*	*		13
	Pembayaran jasa lingkungan	*	*	*		15
	Reboisai/penghijauan	*	*	*		14
Pilihan Infrastruktur	Memperbaiki sistem drainase, mis. di sekitar infrastruktur SPAM agar terhindar dari pencemaran/genangan		*	*		11
	Perkuatan infrastuktur yang rawan bencana, mis. thrust block untuk menghadapi longsor		*	*		11
	Pemanfaatan idle capacity SPAM (rerating/uprating)	*				10
Pengelolaan/Efisiensi Konsumsi/Kebutuhan Air	Pengurangan tingkat kebocoran air (PDAM): teknis (penggantian jaringan lama/rusak)	*				10
Perencanaan dan Pengelolaan Informasi	Sistem dukungan pengambilan keputusan untuk alokasi air (termasuk alat bantu perkiraan sumber daya air: water balance)	*				13
	Monitoring & evaluasi langkah-langkah adaptasi	*	*	*		14
Pelimpahan/Antisipasi Risiko	Membentuk dana cadangan bencana (pemerintah, PDAM)			*		12

Pilihan Adaptasi Penyediaan Air Minum Kab. Semarang

Sumber/Unit/Sistem: Ngrawan, Salatiga

Klasifikasi Adaptasi	Pilihan Adaptasi (Long List; silakan ditambahkan pilihan-pilihan aksi adaptasi lainnya, jika masih ada dan sesuai dengan profil ARM)	Bahaya yang diantisipasi				Total Skor
		Kekeringan	Banjir	Tanah Longsor	Kenaikan M. A. Laut	
Perlindungan Sumber Air	Rencana Detail Tata Ruang Kawaasan wilayah imbuhan untuk perlindungan m. air	*	*	*		12
	Perbaikan tata kelola s.d. air: pengutan forum/lembaga pengelola air (Perkumpulan Petani Air)		*	*		14
	Memperkuat peraturan, termasuk izin pengambilan air tanah & air permukaan			*		10
	Program pengembalian ke alam/pengisian akuifer, mis. sumur resapan, biopori	*	*	*		0
	Pembayaran jasa lingkungan	*	*	*		15
	Reboisai/penghijauan	*	*	*		14
Pilihan Infrastruktur	Memperbaiki sistem drainase, mis. di sekitar infrastruktur SPAM agar terhindar dari pencemaran/genangan		*	*		11
	Membangun tanggul		*			10
	Perkuatan infrastuktur yang rawan bencana, mis. thrust block untuk menghadapi longsor		*	*		11
	Pengamanan infrastruktur rawan bencana, mis. pipa transmisi		*	*		11
Pengelolaan/Efisiensi Konsumsi/Kebutuhan Air	Pengurangan tingkat kebocoran air (PDAM): teknis (penggantian jaringan lama/rusak)	*				10
Perencanaan dan Pengelolaan Informasi	Sistem dukungan pengambilan keputusan untuk alokasi air (termasuk alat bantu perkiraan sumber daya air: water balance)	*				13
	Rencana pengelolaan bencana (contingency/emergency plan)	*	*	*		0
	Monitoring & evaluasi langkah-langkah adaptasi	*	*	*		14
Pelimpahan/Antisipasi Risiko	Membentuk dana cadangan bencana (pemerintah, PDAM)			*		12

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