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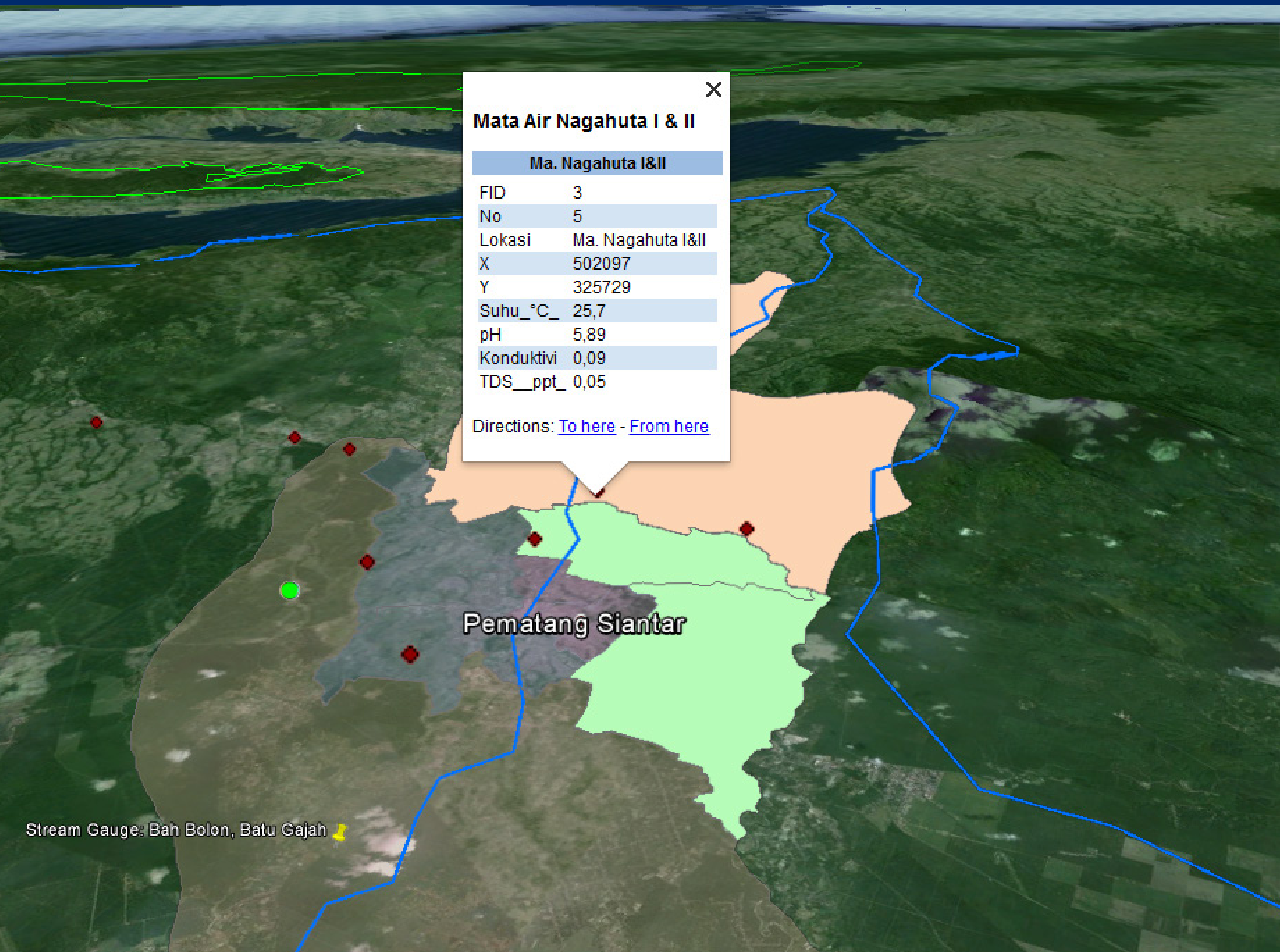
WATER SUPPLY VULNERABILITY ASSESSMENT AND ADAPTATION PLAN

PDAM PEMATANGSIANTAR 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.

Mata Air Nagahuta I and II are two fresh water springs (located in Kabupaten Simalungun) used by PDAM Pematangsiantar to supply water to the Northern Zone and Special Zone of the utility's service area (as indicated by the green and beige shading, respectively).

(Map View: Google Earth©)

USAID INDONESIA URBAN WATER SANITATION AND HYGIENE

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PDAM PEMATANGSIANTAR 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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Contract Number:	**AID-497-C-11-00001**
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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 the PDAM and the Local Government of Pematangsiantar City 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.

Importantly, the inputs and resulting conclusions do not represent a comprehensive assessment of climate change vulnerability for the PDAM, but are instead a first step towards achieving long-term resilience. Indeed, the underlying objective of the work described herein was to introduce the *process* of vulnerability assessment and adaptation planning to the PDAM, thereby stimulating a *dialogue* among stakeholders regarding existing vulnerabilities and how climate change may further impact the water utility in the years to come.

The content of the Water Supply Vulnerability Assessment and Adaptation Plan (VA&AP) was developed over a period of approximately 18 months with IUWASH technical assistance. Key steps in the process included the completion of a baseline water resources vulnerability study by the consulting firm PT. Geolexco, a series of workshops and focus group discussion with the PDAM and its stakeholders, and meetings with senior city officials. 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 Pematangsiantar City are concentrated in Nagahuta and Mual Goit spring areas. More specifically, the two springs have both exhibited vulnerability to decreased 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. Further, regarding the PDAM's built assets, the transmission line serving the Zona Tengah service area has experienced landslide events under the current climate scenario. Climate change is expected to further exacerbate the vulnerability of this infrastructure.

Based on these results, local stakeholders discussed a series of possible adaptation actions to reduce current risks and mitigate the longer term risks posed by climate change. Specific actions identified by the PDAM, local government, and IUWASH included:

- To ensure the continued contribution of the ground water replenishment initiative supported by the Coca-Cola Foundation and IUWASH, the PDAM will set aside funds for the maintenance of the infiltration wells constructed upstream of Nagahuta springs. Notably, two water meters were also installed at these springs to better monitor changes in flow levels over time;
- Building on the example in the Nagahuta catchment area, the Local Government (Badan Lingkungan Hidup) will construct the infiltration wells in several locations. In addition, BLH will also install "bio-pores" downstream in the Kota itself;

- To help address the threats facing the piping network, the PDAM will also plan and budget for the reinforcement of the transmission line carrying water from Habonaran spring to the Zona Tengah service area;
- As part of PDAM's effort in meeting the City's growing water demand, Kota Pematangsiantar (with support from the surface water management body Balai Wilayah Sungai II Sumatera) will collaborate with the neighboring Kabupaten Simalungun to obtain access to a new source of raw water, the Aek Nauli Spring; and
- In order to better track and manage the PDAM's constructed assets, the PDAM will evaluate how it may use geographic information systems (GIS) as part of its administrative systems. As a first step, PDAM staff will attend GIS training courses supported by IUWASH.

In conjunction with the commencement of the implementation of the above 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. Climate change adaptation is, ultimately, an iterative process that requires regular evaluation and adjustment in accordance with climate fluctuations, urban planning, and the changing needs of the local population.

On a final note, as part of the examination of future vulnerabilities to water supply service provision, an important conclusion was that the capacity of the PDAM's infrastructure itself represents a source of risk. Indeed, the PDAM's existing infrastructure is not able to serve all households within the service area. Regardless of the broader risks facing the natural and physical assets of the PDAM itself, then, one of the greatest constraints for service provision is whether investment in new infrastructure is able to keep pace with population growth.

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 Pematangsiantar** 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 2.1 and 2.2);
2. Consider how these risks may be increased by climate change by midcentury (Chapter 2.3);
3. Propose a portfolio of practical adaption actions that the PDAM and Local Government 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 18 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 consulting firm PT. Geolexco, a series of workshops and focus group discussion with the PDAM and its stakeholders, and meetings with senior city officials. 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 Pematangsiantar.

The underlying objective of the work described herein, then, was not to undertake a comprehensive vulnerability assessment, but rather to introduce the *process* of vulnerability assessment and adaptation planning to the PDAM, thereby stimulating a *dialogue* among stakeholders regarding existing vulnerabilities and how climate change may further impact the water utility in the years to come. 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 Pematangsiantar** is based upon an IUWASH document entitled, "**Climate Change Vulnerability Assessment and Adaptation Planning for Water Supply: Inception Report**" (available for download at http://iuwash.or.id/category/download-publication/technical-report/). Based upon emerging best practices in climate change adaption in the water sector, this document presents a 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 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 Pematangsiantar City.

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 Kick-off Meeting • Key Informant Interviews • Geospatial Analysis • PDAM Asset Risk Matrix
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 Business Plan • Project Feasibility Studies • M&E systems

As noted in Phases 1 and 2, an important aspect of the vulnerability assessment and adaptation planning (VA&AP) 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 Pematangsiantar, and the results are presented in the following chapters.

2 WATER SUPPLY VULNERABILITY ASSESSMENT

Chapter 2 of the Pematangsiantar Water Supply VA & AP Report summarizes the current state of the piped water supply system for Pematangsiantar City (Section 2.1) and then identifies the specific vulnerabilities of this system under current climate conditions (Section 2.2) as well as under a mid-century (2030 – 2050) climate change scenario (Section 2.3).

2.1 WATER SUPPLY CONTEXT

The following subsections provide an introduction to the water supply context for the City of Pematangsiantar, 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 treat, store, and deliver that water to its customers. These subsections are based upon the IUWASH-supported report by PT. Geolexco entitled "Water Supply Vulnerability Assessment for PDAM Pematangsiantar: Final Report" (also referred to as the "baseline study" and the "Geolexco report"), while also drawing from stakeholder consultations and other secondary data sources where noted.

2.1.1 Overview of PDAM Pematangsiantar

PDAM Tirta Uli Kota Pematangsiantar provides piped water service to the citizens of Kota Pematangsiantar, the second largest city in North Sumatra following Medan. The Kota has experience rapid urbanization and industrialization in the past decade, with a total population of 249,985 inhabitants within an area of 75.65 km2 (resulting in a population density of 3,304 persons/km2). As shown in Figure 1 below, the Kota as a whole is divided into eight sub-districts, namely Siantar Marihat, Siantar Marimbun, Siantar South, West Siantar, Northern Siantar, East Siantar, Siantar Martoba, and Siantar Sitalasari. Based on 2008 data, the population density is highest in the sub-districts of North Siantar, South Siantar, and Eastern Siantar. Notably, the population continues to grow steadily, averaging about 1.89% each year from 1997 through 2009. Population growth since 2010 is harder to determine given the absence of available data.

First established in 1976, PDAM Pematangsiantar is the official source of piped water for the Kota. As of 2012, the PDAM served approximately 72% of the service area within the city. In 2012, the PDAM distributed 709 liters per second of water, although more than 30% of this water was lost to non-revenue water. Notably, the PDAM also serves large areas to both the west and east of the city in the surrounding Kabupaten Simalungun. The map provided in **Annex 4** shows the four basic service areas of the PDAM. The table below summarizes the key characteristics of the PDAM and its service area for the most recent year of audited data:

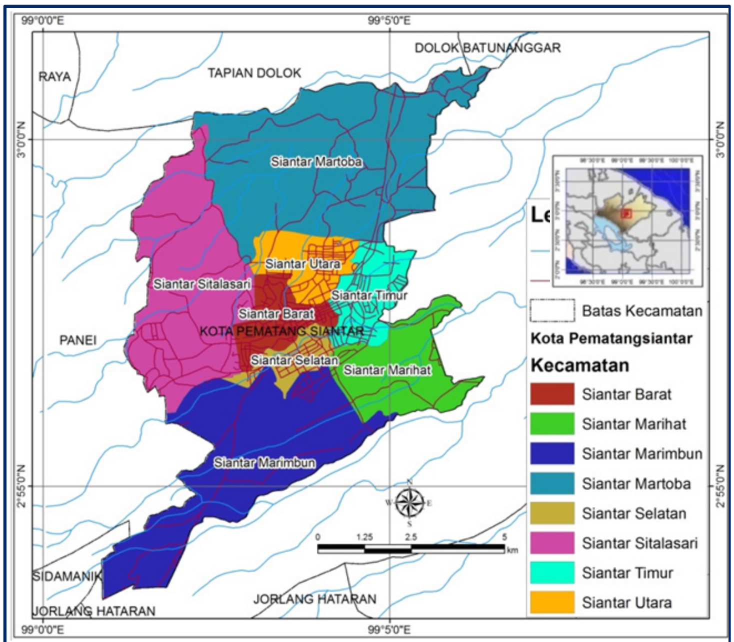


Figure 1: Pematangsiantar City, North Sumatra

Table 2: PDAM Pematangsiantar Characteristics

	Characteristic	2012	2011	2010
Customer	Number of Customers (as per Business Plan PDAM-BP)	57,489	55,231	53,841
	Coverage of Service Area (BP)	84 %	83%	82%
Technical	Total Water Produced (m3)	36,270,912	40,142,412	20,843,568
	Total Water Distributed	20,726,232	22,938,528	11,910,612
	Total Water Sold	15,130,152	17,203,884	8,932,956
	Non-Revenue Water (Technical) (BP)	30.4%	30.8%	31.7%
	Total Staff (BP)	462	X	X
Financial	Average Tariff (Rp. /m³) (BP)	1.585,32	X	X
	% Cost Recovery (BP)	91.1%	113.2%	104,3%
	Total Asset Value (BP)	43,921,242	34,700,898	33,019,132

2.1.2 Natural Assets of the PDAM

The "natural assets" of a PDAM consist of 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.

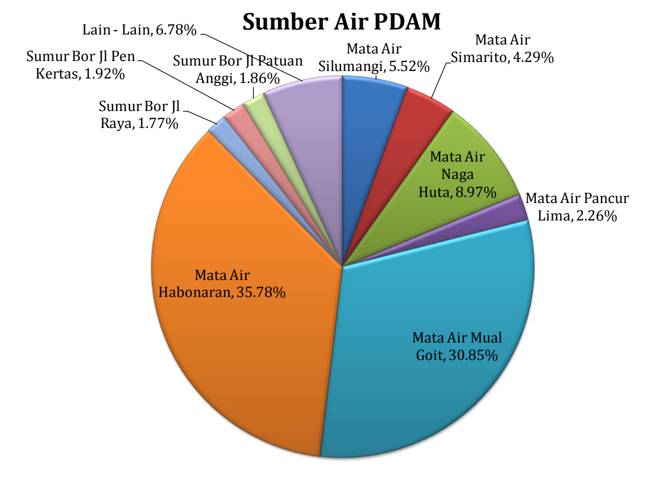


Figure 2: PDAM Pematangsiantar Raw Water Resources.

Raw Water Sources. PDAM Pematangsiantar derives its raw water solely from natural springs and deep wells. 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. As shown in the pie chart, the PDAM relies primarily on three major springs to supply water to the city:

- **Mata Air Habonaran** is the largest contributor of raw water to the PDAM, supplying about 36% of all of its water needs. Constructed in 1990, the majority of this water is routed to central and northern zones of Pematangsiantar. The spring itself is located southwest of the Kota (see photo in Figure 3), with a recharge area extending up to Lake Danau Toba. The total flow of the spring is about 288 liters per second, although this has dipped as low as 255 liters per second as recently as 2010. The PDAM is currently the only entity withdrawing water from the spring, which is not used for industrial or agricultural purposes;
- **Mata Air Mual Goit** is the second largest contributor of raw water to the PDAM, supplying about 31% of the total water needs, with the bulk of this water ultimately routed primarily to the southern service zone of the PDAM. Built in 1979, the spring is located directly south of Kota Pematangsiantar, and has a total capacity of 297 liters per second (although the PDAM only currently uses about 248 liters per second). The recharge area extends from the west side of the Kota across to the south. The PDAM is the only entity currently withdrawing water from the Mual Goit Spring; and

- **Mata Air Nagahuta** is the third major contributor of raw water resources to the PDAM, supplying about 10% of the total water required by its customers. With a capacity of about 110 liters per second, Nagahuta is located directly west of the city and primarily supplies water to the central service zone. The PDAM is currently the only user of this water supply. Note that there are actually four separate production units drawing from the Nagahuta spring: Nagahuta I and II were constructed in 1953 while Nagahuta III and IV were built in 1974.

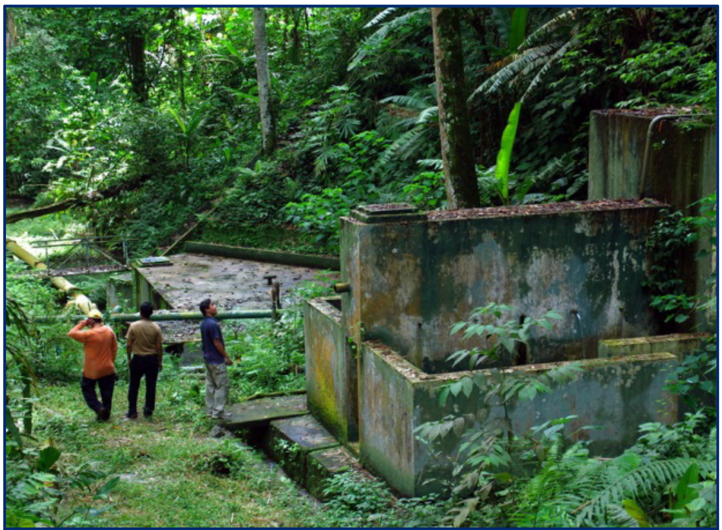


Figure 3: Mata Air Habonaran.

Taken together, the above springs supply almost 80% of the raw water for PDAM Pematangsiantar, and thus represent the PDAMs most important natural assets. As such, much of the vulnerability assessment conducted by IUWASH and its implementing partners focused on these critical assets. That said, the PDAM also utilizes an additional 4 fresh water springs as well as a total of 22 deep wells to meet the needs of the service area. The deep wells are of relatively small size, ranging from 1.4 to 34 liters per second. Figure 4 below shows the geographic distribution of the water sources.

Surrounding Watershed. The productivity and sustainability of the PDAM's raw water resources is closely linked to the characteristics of the surrounding watershed. Notably, given that the PDAM serves a city, very little of the surrounding watershed actually falls within the political jurisdiction of the Local Government of Pematangsiantar. Indeed, all of the PDAM's largest raw water sources are located outside of the Kota, meaning that the PDAM must work across administrative boundaries when it comes to managing and protecting these natural assets.

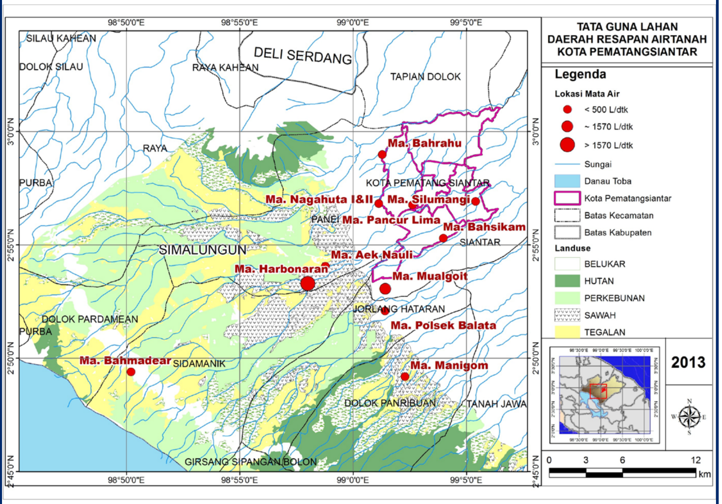


Figure 4: Raw Water Sources Utilized by PDAM Pematangsiantar.

Despite its small geographic area, the political jurisdiction of Pematangsiantar straddles two watersheds: the Hapal Watershed covers the northwestern portion of the Kota while the Bolon Watershed covers the southeastern section of the Kota (please see **Annex 2** for a map of the relevant watersheds). The majority of PDAM fresh water springs and deep wells are located in the Bolon Watershed.

Figure 5 below provides a glimpse of the current state of the upper catchment areas of the Hapal and Bolon Watersheds, with the dark green and light green shading representing the remaining mature and low-growth forest areas. As we can see, very limited areas of the watershed have retained significant forest coverage, with forest cover absent from nearly all areas immediately surrounding the PDAM's raw water sources. Instead, the upper catchments of both the Bolon Watershed and the Hapal Watershed are dominated by a mix of irrigated rice fields, plantations, and other farmlands. Rice paddies are particularly prevalent in the areas immediately surrounding the Kota boundaries as well as in the southern portion of the Kota itself. Such land-use characteristics put the PDAM's water resources at greater risk given that the lack of forest cover undoubtedly hampers recharge rates for valuable groundwater resources. Upper watershed degradation can also result in greater incidences of damaging floods and landslides.

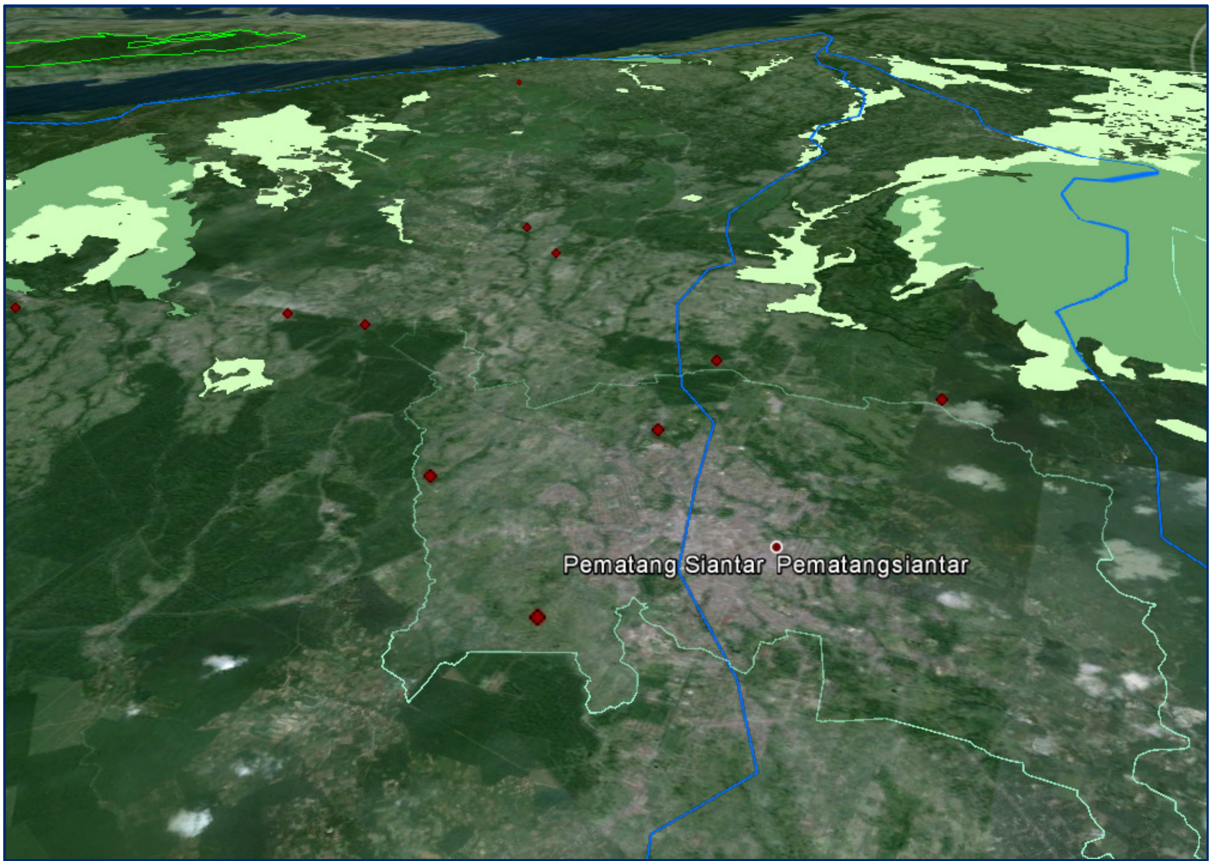


Figure 5: Forest Cover in the Upper Bolon and Hapal Watershed

The above image is looking Southwest of the City of Pematangsiantar. The blue lines represent the boundaries of the Bolon (on the left) and Hapal (on the right) Watershed, with key raw water sources marked by red diamonds. Further, dark and light green shading represents mature and low growth forest land, respectively. Unfortunately, as shown here, the upper watersheds contain limited forestland, which poses a threat to the effective recharge of groundwater resources.

2.1.3 Physical Assets of the PDAM

The physical or "constructed" assets of the PDAM include the intakes, the transmission pipelines, water treatment facilities, and storage and distribution facilities. These built assets allow the PDAM to obtain raw water from its natural assets and then treat, store, and transport clean water to its customers. The following table summarizes the key built assets of the PDAM, highlighting those that deliver/store the greatest volume of water and have the highest replacement value.

Table 3: Summary of PDAM Pematangsiantar Physical Assets

#	Assets Category	Location	Technical Details	Value at Acquisition/ hand over (IDR 2013)	Accumulated Depreciation (IDR 2013)	Book value (IDR 2013)
1	Land	Office, intake locations, storage location,	Raw water intake areas, office building, etc.	2,288,249,154.00	0.00	2,288,249,154.00
2	Raw water units	Incl. Nagahuta 1 & 2 springs areas	At spring: capturing facilities	2,444,209,211.00	1,836,552,689.95	607,656,521.05
3	Pumps	At PDAM's production facility	Incl. Chlorinator, hydrophore, electrical panel station	7,586,639,062.00	3,248,038,033.71	4,338,601,028.29
4	Trans-mission / distribution	Across all service area of PDAM	Piping, valves, and piping accessories	51,882,695,271.29	29,985,945,350.83	21,896,749,920.46
5	Water meter	Across all service area of PDAM	½-¾" pipe /meter size	8,634,360,027.32	6,652,025,184.86	1,982,334,842.46
6	Public taps	At PDAM's distribution network		14,612,617.00	14,612,617.00	0.00
7	Fire hydrants	At certain distribution network		10,051,720.00	9,564,338.10	487,381.90
8	Pipe bridge	At certain locations where pipeline crosses bridge	Incl. air valve	683,841,733.00	339,705,564.60	344,136,167.40
9	Office buildings	PDAM's office and production facilities	Head quarters and production facilities	3,366,147,829.00	1,393,103,284.65	1,973,044,544.35
10	Laboratory equipment	Laboratory building		47,913,391.00	42,163,780.03	5,749,610.97
11	Workshop equipment	Workshop area		311,942,913.00	221,154,740.52	90,788,172.48
12	Vehicles	Across PDAM's service area	Incl. operational vehicles, e.g. pick up truck	1,954,050,258.00	1,954,050,258.00	0.00
13	Office equipment	In PDAM's office and production facilities	Incl. furniture, etc.	3,311,752,006.00	2,902,835,811.33	408,916,194.67
	Total Assets			**82,536,465,192**	**48,599,751,653**	**33,936,713,538**

As indicated above, the majority of PDAM Pematangsiantar's physical assets consist of extensive transmission and distribution networks which deliver water to four overall service areas. The network relies primarily on gravity, using pipes ranging from 37.5 mm to 400 mm with a total length of about 640 kilometers. These pipes are made of multiple types of materials, including ACP, steel, PVC, and FGRP.

The PDAM also possesses 6 major reservoirs, ranging from 75 cubic meters to 2,250 cubic meters. By far the most significant reservoirs service the Mual Goit fresh water spring (with 1,500 cubic meters of storage capacity) and the Habonaran fresh water spring (with 2,250 cubic meters of storage capacity). The Mual Goit reservoir supplies water to the southern and central PDAM service areas while the Habonaran reservoir supplies water to the central and northern zones of the PDAM's service area.

The PDAM does not possess any secondary treatment facilities at this time, as the groundwater sources are of sufficient quality that minimal treatment is required. Combined with the reliance on gravity for the transmission of water, the absence of extensive treatment facilities represents a major cost savings for the PDAM.

On a final note, the PDAM faces a common problem in Indonesia in the form of aging infrastructure. Some of its spring systems and distribution pipes, for example, were originally constructed in the 1950s and 1970s. This is evidenced by the fact that more than 50% of the PDAM's transmission and distribution pipes are presently fully depreciated. While the intake facilities for the largest spring—Habonaran—were constructed in 1990, this still means that this infrastructure is nearly 25 years old.

Please see **Annex 5** for a schematic of the PDAM's constructed assets.

2.1.4 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.

Table 4 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 4: Natural Asset Monitoring Systems.

Topic	System/Equipment	Type of Data	Remarks
Precipitation, Temperature, and Wind Speed	1 post in Kab. Simalungun and 3 posts in the neighboring districts operated by BMKG	Daily rainfall, temperature, humidity, and wind speed recorded.	• installed by BMKG in 1970s (per interview with PDAM staff)
Stream Flow	- Bolon Watershed: 2 gauges in lower watershed. - Hapal Watershed: no stream stations.	Estimated flow in cubic meters per second (based upon water level)	• installed during 1995 to 2009 (from Puslitbang) for the Bolon River.
Spring Flow	Water meter; including 2 units installed at Nagahuta springs	Flow capacity	• installed in 2013 (the two water meter units in Nagahuta)
Deep Well Flow (Aquifer)	Water meter at deep well unit in Kota area	Flow capacity	• not functioning

Per the above table, there is only limited hydrological and meteorological data available in/around Kota Pematangsiantar 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. According to the Geolexco Report, there is a single Precipitation Monitoring Post ("Pos Hujan") in close proximity to Pematangsiantar, namely, the Pos Marihat which is located just to the south of the Kota in Kabupaten Simalungun (See map in Annex 6). There are three additional monitoring posts in the region (Pos Serangan, Pos Hayuraja, Kab. Mandailing Natal; and Pos Silinda, Kab. Serdang Bedagai), but these are somewhat distant from the PDAMs key water resources as well as at different elevations, making data comparisons difficult. The closest full Climatology Monitoring Station operated by BMGK is Stasiun Klimatologi Sampali, which is located in the City of Medan about 80 kilometers away.

Concerning stream flow measurement, there are two stream level stations on the Bolon Watershed according the Directorate of Water Resources at the Ministry of Public Works. Both are located well downstream of the Kota Pematangsiantar along the Bolon River. According to the Geolexco Report, data is available from one or both of these gauges for the period of 1995 to 2009. Notably, no stream flow measures are currently being taken for the neighboring Hapal River, however, as this is only "class two" stream.

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. Regarding tracking systems for constructed assets, PDAM Pematangsiantar 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 1 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 starting point for understanding how changes to the climate may alter the severity of these hazards in the years to come.

Key points of reference for the development of the baseline scenario include: (1) the "Studi Kerentanan Sumber Daya Air Daerah Pematangsiantar, Sumatera Utara" as compiled by local partner Geolexco, (2) stakeholder workshops implemented in May, 2013 and in January and February, 2014, and (3) key information from interviews and focus group discussions with PDAM and PEMDA representatives.

2.2.1 Baseline Scenario: Natural Assets

There are two basic risks to PDAM Pematangsiantar's natural assets: a decrease in the quantity of water available and the degradation of the quality of water from current sources. For a fresh water spring such as Mata Air Mual Goit, for example, the risk is that there may be insufficient water and/or that the quality of the water will be degraded by an external contaminant. Further, these specific risks may occur as a result of one or more hazards, including drought (water scarcity), flooding, landslides, and sea level rise. Utilizing the baseline

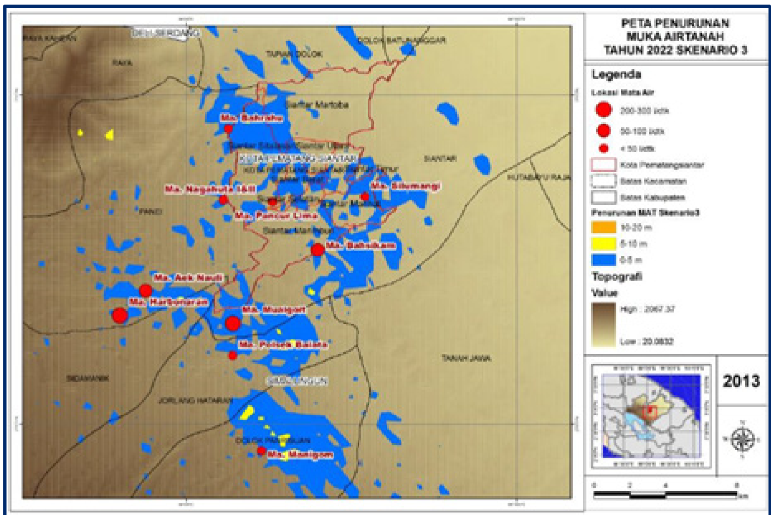


Figure 6: Model of Groundwater Levels and Recharge Rates

The above figure shows areas of probable decline in groundwater levels associated with a 50% decrease in the recharge rate of the watershed.

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 Kota Pematangsiantar:

- **Drought/Water Scarcity**. According to the Regional Disaster Management Agency (BPBD), the risk of water scarcity in Pematangsiantar due to drought is **low**. This is largely due to the fact that the Kota has historically received a relatively high amount of precipitation year round. The risk scores under the Asset Risk Matrix (ARM) are in line with this conclusion, as indicated in the summary table on Page 16 and the detailed analysis attached as **Annex 7**. Indeed, the stakeholders concluded that all of the natural assets that provide water to the four service zones were at a low risk of experiencing insufficient water quantity or poor water quality under the current conditions.

  That said, the vulnerability assessment performed by Geolexco did also show that decreases in the recharge rate of the surrounding aquifer can have a significant impact on the level of the ground water. The above figure, for example, shows how the groundwater level could decline if the aquifer recharge rate decreased by 50%. Thus, land-use change in the upper catchment will be important to monitor. For more details concerning the assumptions used in the projection, see Chapter 3 of the Geolexco Report.

- **Flooding**. According to BPBD the risk to the PDAM's natural assets from flooding is **low**. The principle exception to this risk level is a limited number of areas within the Kota itself where the Bolon River poses a medium threat to overflowing and damaging urban infrastructure (see map in Figure 8). This risk was also highlighted in the Asset Risk Management (ARM) Workshop in which participants identified the Bolon River at high risk of flooding. Indeed, the river has made headlines in local news outlets on multiple occasions in recent years for flooding residents in both Kota Pematangsiantar as well as Kabupaten Simalungun. It is important to note, however, that the Bolon River itself is *not* currently a natural asset that the PDAM relies upon for raw water, meaning such flooding events pose a low threat to the PDAM's raw water sources.

- **Landslides**. The risk of landslides under the baseline scenario is also considered to be **low** according to BPBD. The Kota and surrounding land are gently sloping, thereby limiting the probability of a landslide. While there is a degree of higher risk within the Kota itself, landslides pose minimal to no risk to the water quality or water quantity flowing from the PDAM's principle sources of raw water, which are largely groundwater sources outside the city.

- **Sea Level Rise**. There is **no risk** to the water quantity or water quality of the PDAM's natural assets from sea level rise. Seawater is unlikely to contaminate the deep wells currently used by the PDAM given that all raw water sources are located in the upper watershed more than 60 kilometers from the coastline.

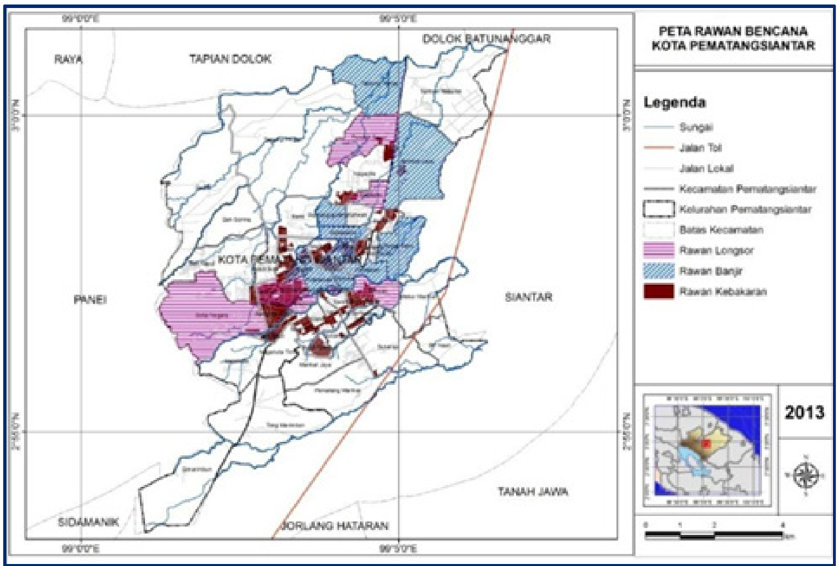


Figure 7: Risk Map of Kota Pematangsiantar.

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 any systematic monitoring systems for regular measuring of groundwater depth levels and spring flow levels. Thus, while the perception at the time of the study was that the fresh water springs still have sufficient capacity, the PDAM does not yet have the systems in place to look at trends over longer time horizons. In addition, the absence of more comprehensive precipitation and runoff monitoring, it is difficult to assess how changes in precipitation will impact both surface and groundwater sources. 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 flood, for example, could damage a treatment plant or an intake could be covered by a landslide 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 a **low 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 Pematangsiantar has not yet experienced purposeful damages to its water supply infrastructure during times of drought.
- **Flooding**: As noted above, per BPBD, major flooding in the Province of North Sumatra tends to be concentrated to the low lying coast areas. As such there is a **low risk** of major flooding events causing damage to the PDAM's physical assets, particularly the intakes, reservoirs, and transmission infrastructure located in the upper watershed of Kabupaten Simalungun. While localized flooding does remain a risk along the Bolon River which runs through the center of Kota Pematangsiantar, the PDAM's piping network near the river is primarily below ground and has not been significantly affected be flooding to date. This is also reflected in the preparation of the Asset Risk Matrix (ARM) where assets serving Zona Tengah were classified as low risk by stakeholders attending the workshop.
- **Landslides**: While BPBD has classified Pematangsiantar as low risk for landslides, the participants of the ARM Workshop identified the PDAM's physical assets serving Zona Tengah as facing a **medium risk** (see Figure 8 at right). Specifically, the transmission systems serving Zona Tengah were highlighted as at risk from landslides. This is based upon the fact that Zona Tengah is served from Habonaran spring where its transmission line runs through a landslide prone area.

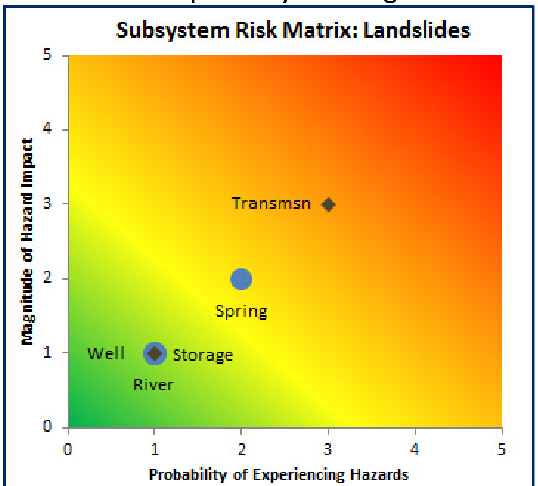


Figure 8: Landslide Risk for Assets in Zona Tengah under the Current Climate

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

In summary, there is an overall low level of risk to the PDAM's groundwater intakes-and storage infrastructure under the baseline scenario. The principle exception that deserves closer inspection going forward is the exposure of the transmission line infrastructure serving Zona Tengah to landslides from the surrounding terrain. Please see the summary results from the ARM Workshop included on page 16 as well as the detailed results in **Annex 7.**

2.2.3 Baseline Scenario: Supply and Demand Analysis

To better understand the supply and demand context faced by PDAM Pematangsiantar, the Geolexco research team constructed several simplified models extending from the present through about 2100. Notable characteristics of the supply and demand analysis for Pematangsiantar are as follows:

- The existing fresh spring sources of raw water possess capacity significantly above the current capacity, meaning that the PDAM has significant natural assets available to continue to meet rising demand in the medium term. Importantly, according to the Geolexco baseline report, there is minimal "competition" for these resources as most irrigation needs in the area are met from withdrawals from surface water, which the PDAM has yet to tap. This assumption could change, of course, as both the needs of the PDAM and farming communities expand over time, but such competition between sectors is unlikely to intensify any time in the near future.
- Per the graphic shown below (Figure 9), the projection of the supply of the PDAM's existing groundwater sources is projected to decline slightly over time. The Geolexco study developed this project using the assumption of reduced level of recharge due to changes in land use and a downward trend in local rainfall patterns over the past 30 years.
- The primary driver behind increased demand is growth in the Kota's population as can be seen from the manner in which the supply projection closely follows the population projection. Household connections are assumed to make up about 73% of the total demand, with the balance allocated to public hydrants, schools, hospitals, health clinics, offices, restaurants, and industry. Assuming that the supply from the existing fresh water springs remains stable (and that no other demands are placed on these resources), the PDAM will be able to continue to rely on these resources until approximately 2067.
- The most significant current constraint to meeting the demand of the local population is the capacity of the PDAM's infrastructure itself, which is not able to serve all households within the service area. **Regardless of the broader risks facing the natural and physical assets of the PDAM itself, then, arguably the greatest risk for service provision is the absence of in new infrastructure to expand coverage and keep pace with population growth.**

A more detailed explanation of the assumptions used to prepare the supply and demand analysis shown below is available in Section IV.2 of the Geolexco Report.

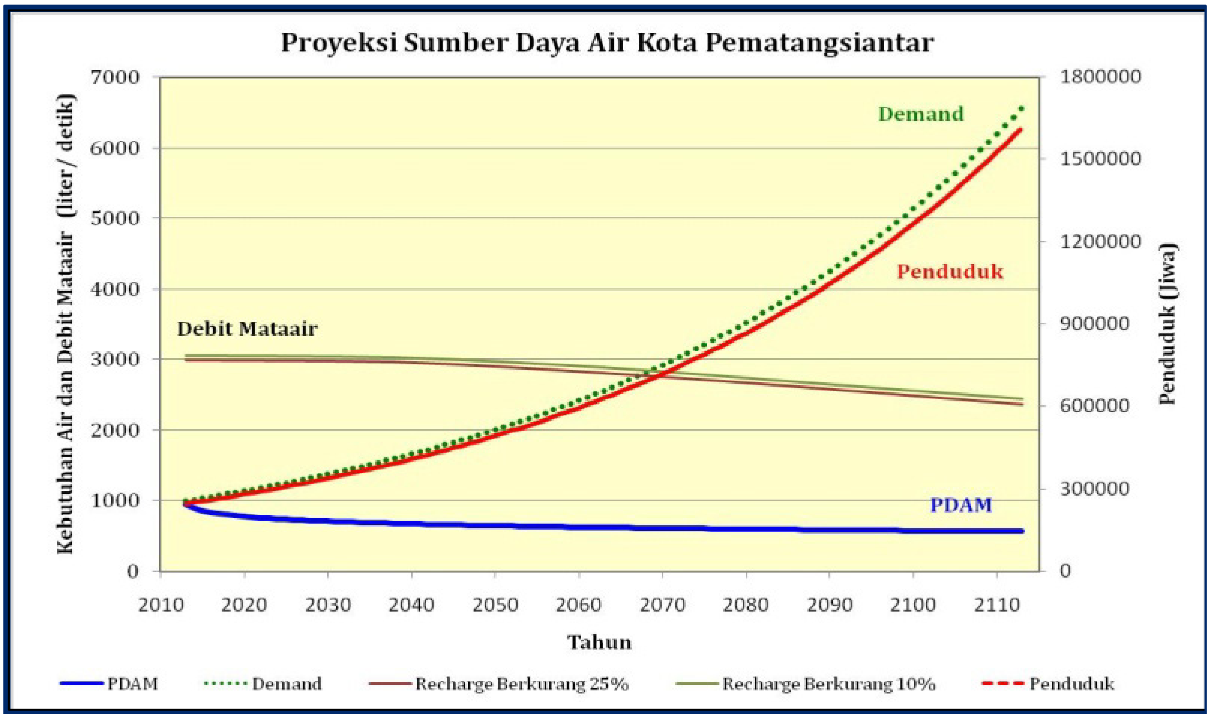


Figure 9: PDAM Production Capacity vs. Groundwater Capacity Supply vs. Projected Demand.

PDAM Asset Risk Matrix
PDAM Name: PDAM TIRTAULI
Risk Score Summary
Last Edited: Feb-14

iuwash — Indonesia Urban Water, Sanitation, and Hygiene

DATA ENTRY:

NATURAL ASSETS — **SUMMARY**

BASELINE SCENARIO

Category	Specific Risk	Zona Khusus River	Zona Khusus Spring	Zona Khusus Well	Zona Selatan River	Zona Selatan Spring	Zona Selatan Well	Zona Tengah River	Zona Tengah Spring	Zona Tengah Well	Zona Utara River	Zona Utara Spring	Zona Utara Well
Drought	Water Quantity/Quality Risks	na	0.80	na	0.20	0.80	na	0.20	0.20	0.20	na	0.80	na
Flooding	Water Quantity/Quality Risks	na	0.20	na	0.80	0.20	na	0.20	0.20	0.20	na	0.40	na
Landslides	Water Quality Risks	na	0.20	na	na	0.20	na	0.20	0.80	0.20	na	0.20	na
Sea Level	Water Quality Risks	na	na	na	na	na	na	na	na	na	na	na	na
	Sub Total by Asset	na	0.40	na	0.50	0.40	na	0.20	0.40	0.20	na	0.47	

Climate Change Scenario

Category	Specific Risk	Zona Khusus River	Zona Khusus Spring	Zona Khusus Well	Zona Selatan River	Zona Selatan Spring	Zona Selatan Well	Zona Tengah River	Zona Tengah Spring	Zona Tengah Well	Zona Utara River	Zona Utara Spring	Zona Utara Well
Drought	Water Quantity/Quality Risks	na	3.20	na	0.40	1.80	na	0.20	0.20	1.20	na	3.20	na
Flooding	Water Quantity/Quality Risks	na	0.80	na	1.20	0.20	na	1.80	0.80	0.20	na	0.80	na
Landslides	Water Quality Risks	na	0.20	na	0.80	0.40	na	1.80	1.80	0.20	na	0.80	na
Sea Level	Water Quality Risks	na	na	na	na	na	na	na	na	na	na	na	na
	Sub Total by Asset	na	1.40	na	0.80	0.80		1.27	0.93	0.53	na	1.60	

BUILT ASSETS — **SUMMARY**

BASELINE SCENARIO

Category	Specific Risk	Zona Khusus Intake	Zona Khusus Transmission	Zona Khusus Water Treatment	Zona Khusus Storage Facilities	Zona Selatan Intake	Zona Selatan Transmission	Zona Selatan Water Treatment	Zona Selatan Storage Facilities	Zona Tengah Intake	Zona Tengah Transmission	Zona Tengah Water Treatment	Zona Tengah Storage Facilities	Zona Utara Intake	Zona Utara Transmission	Zona Utara Water Treatment	Zona Utara Storage Facilities
Drought	Physical Damages to Infrastructure	na	na	na	na	na	na	na	na	na	na	na	0.20	na	na	na	na
Flooding	Physical Damages to Infrastructure	na	na	na	na	na	na	na	na	na	na	na	na	0.20	0.20	na	na
Landslides	Physical Damages to Infrastructure	na	na	na	na	na	0.20	na	na	na	1.80	na	0.20	na	0.20	na	na
Sea Level	Physical Damages to Infrastructure	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Sub Total by Asset	na	na	na	na	na	0.20	na	na	na	1.80	na	0.20	0.20	0.20	na	na

Climate Change Scenario

Category	Specific Risk	Zona Khusus Intake	Zona Khusus Transmission	Zona Khusus Water Treatment	Zona Khusus Storage Facilities	Zona Selatan Intake	Zona Selatan Transmission	Zona Selatan Water Treatment	Zona Selatan Storage Facilities	Zona Tengah Intake	Zona Tengah Transmission	Zona Tengah Water Treatment	Zona Tengah Storage Facilities	Zona Utara Intake	Zona Utara Transmission	Zona Utara Water Treatment	Zona Utara Storage Facilities
Drought	Physical Damages to Infrastructure	na	na	na	na	na	na	na	na	na	na	na	0.20	na	na	na	na
Flooding	Physical Damages to Infrastructure	na	na	na	na	na	na	na	na	0.40	na	na	0.20	0.20	0.20	na	na
Landslides	Physical Damages to Infrastructure	na	na	na	na	na	0.80	na	na	0.40	5.00	na	0.80	na	0.80	na	na
Sea Level	Physical Damages to Infrastructure	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
	Sub Total by Asset	na	na	na	na	na	0.80	na	na	0.40	5.00	na	0.40	0.20	0.05	na	na

Figure 10: Risk Score Summary for Baseline and Climate Change Scenario

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 North Sumatra and Kota Pematangsiantar, focusing on a **medium term timeframe (2030 to 2050)** under the **A2 Emissions Scenario**. In addition to consulting existing literature on anticipated climate change impacts in the region, this report also utilized statistically downscaled projections from the Climate Wizard, a collaborative effort between the World Bank and The Nature Conservancy. More specifically, an ensemble of five global climate circulation models was run for North Sumatra, with the ensemble average used to inform the discussion below. The specific GCMs used were as follows:

- CGCM3.1 (T47) Model 2
- CNRM-CM3
- GFDL-CM2.0
- GFDL-CM2.1
- IPSL-CM4

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 these 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 "Studi Kerentanan Sumber Daya Air Daerah Pematangsiantar, Sumatera Utara" as compiled by local partner Geolexco, (2) a series of stakeholder workshops implemented during late 2013 until early 2014, and (3) key information interviews and focus group discussions with PDAM and PEMDA representatives.

2.3.1 Climate Change in Pematangsiantar, North Sumatra

Current Conditions. Table 5 below summarizes the current climate conditions for Pematangsiantar, North Sumatra, including temperature, rainfall, and evapotranspiration averages, highs, and lows.

Table 5: Summary of Weather Conditions in Pematangsiantar, North Sumatra

Parameter	Average	High	Low
Temperature	25.57	32.58 (Jun)	21.16 (Feb)
Precipitation	193.5 mm/mnth	826 mm (May 2006)	16 mm (Feb 1987)
Wind Speed	9.48 km/hr	25.44 km/hr	0.29 km/hr
Humidity	90.9%	98.13% (Apr)	72.71% (May)
Evapotranspiration	3.83 mm	6.17 mm (Sep)	2.39 mm (Dec)

It is important to note that Pematangsiantar generally has two "peaks" in precipitation levels during the year. The first peak comes in March through May, while the second comes September through December. As such January, February, June, July, and August are generally the driest months of the year. Such a rainfall pattern is caused by the Kota's position near the equator and is associated with the summer and winter equinox when temperatures tend to increase and the atmospheric pressure tends to decline.

Changes in Temperature. Average temperatures are expected to increase in the Province of North Sumatra by 2 to 3 degrees Celsius by mid-century. According the model ensemble referenced above, the average daily low temperature in the Pematangsiantar area will increase by approximately 2.5 degrees Celsius (over the baseline of 1960-1990), while the average daily high temperature will increase by about 2 degrees Celsius. The statistical confidence in these projections is high.

Changes in Precipitation. According to the model assemble, on an annual basis, precipitation levels are expected to decrease by about 125+ mm (See Figure 12 at right, with the general proximity of Pematangsiantar indicated by the oval). This decrease is unlikely to be equally spread across the year. Indeed, some months may be noticeably drier while other may actually be wetter. Figure 13 at right, for example, shows that the drop is expected to be more exaggerated in February, possibly by as much as 30 mm. As noted previously, February is already one of the drier months of the year in Pematangsiantar.

The results of the model ensemble also correlate well with the analysis compiled for the 2010 Indonesian Climate Change Sectoral Roadmap (ICCSR) which includes a water scarcity risk map for the period of 2025-2030. The area of Pematangsiantar is located in a region where the drought risk ranges from medium to high (see page 83 of the Geolexco report).

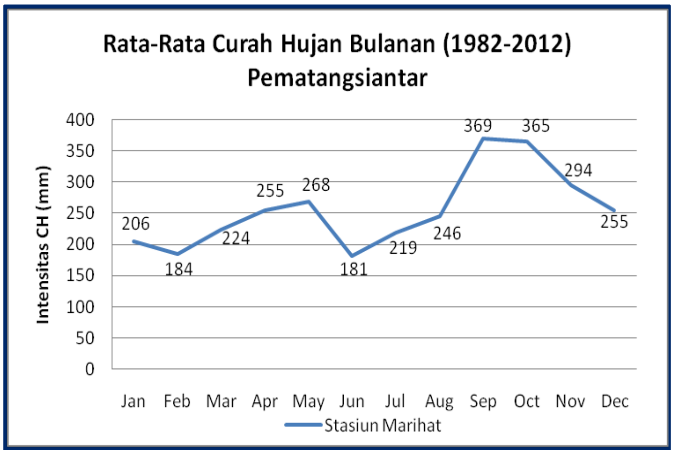


Figure 11: Average Monthly Rainfall in Pematangsiantar from 1982 to 2012.

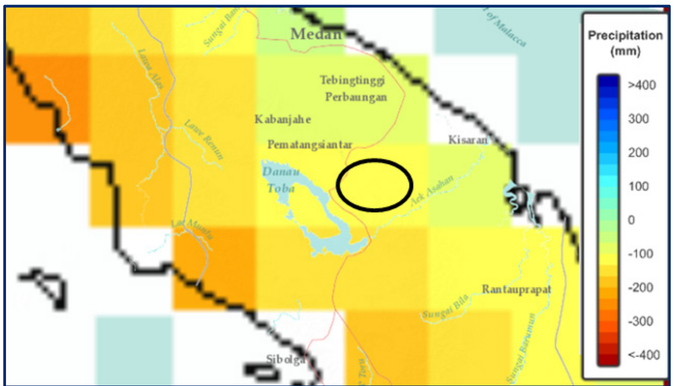


Figure 12: Change in Annual Precipitation by Mid-Century.

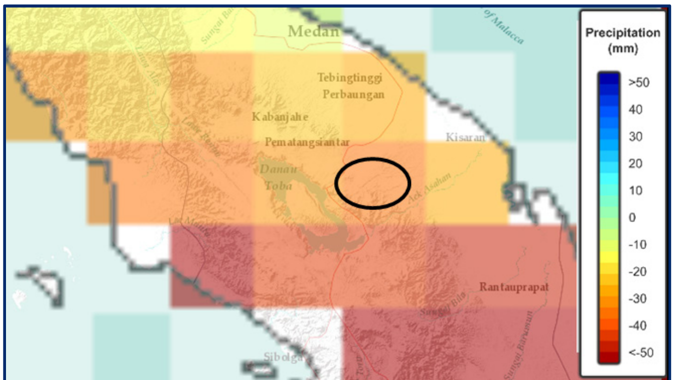


Figure 13: Change in February Precipitation by Mid-Century.

Further, while not definitive, observed trends at the Marihat Rainfall Monitoring Post outside of Kota Pematangsiantar support the projections in rainfall reduction in terms of continuing a trend that is already being observed. Figure 14 below, for example, shows an overall decline in the average rainfall over the course of the past 30 years from one decade to the next.

In addition to changes in the *volume* of rainfall, climate change is also like 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. Figure 15 visualizes this trend.

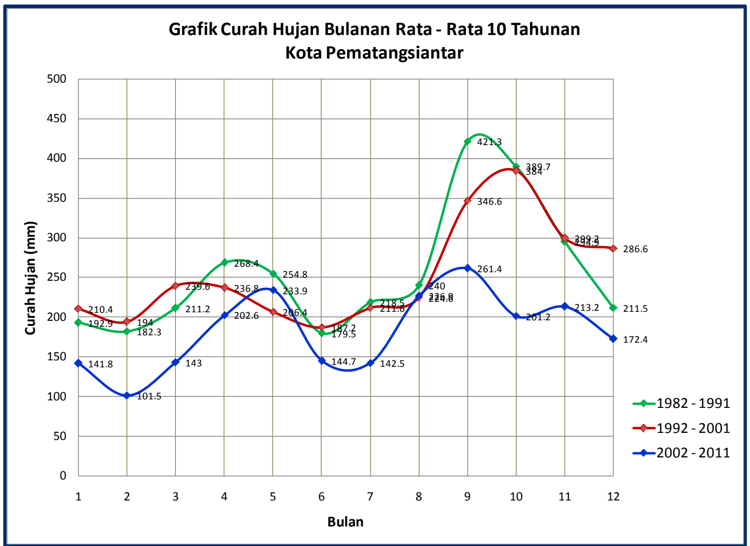


Figure 14: Average Monthly Rainfall Over Three Decades.

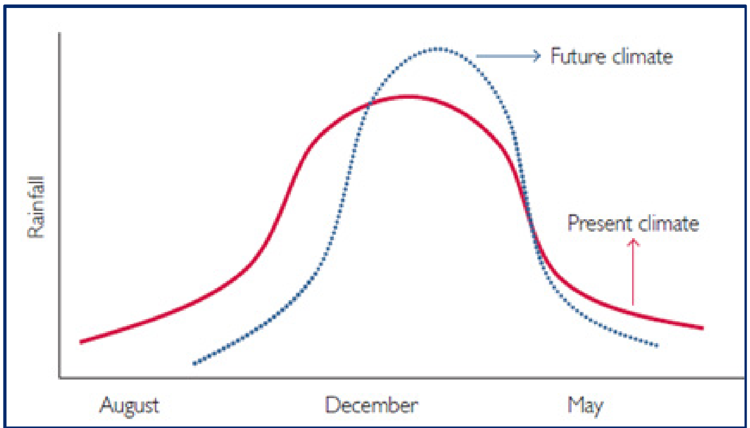


Figure 15: The Shifting Precipitation Landscape.

As noted in the Geolexco report, such changes can have a significant impact on the amount of infiltration and aquifer recharge that takes place. Importantly, the reduction in infiltration brought on by more intense storm events and reduced precipitation will only be exacerbated by land use changes in the upper watershed. Indeed, the conversion of forest land to other uses will increase the amount of water that is lost to runoff. The schematic on page 79 of the Geolexco report aptly illustrates how changes in the volume of rainfall, temporal distribution of rainfall, and land use patters can combine to have a detrimental impact on the availability of local water resources.

By combining the model results, field observations, and broader climate research, then, it appears that *overall levels of precipitation for Kota Pematangsiantar are likely decline moderately while intra-annual variations (month-to-month variations) are likely to become more extreme.*

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 Pematangsiantar'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:

- **Drought/Water Scarcity**: Given the predicted decreases in average monthly rainfall, the climate-change scenario indicates a **medium risk** to several of the present natural assets of the PDAM. The stakeholder workshop noted that this risk was higher for the natural assets serving the Special Zone as well as the Northern Zone of the franchise area, including Mata Air Nagahuta (1-4), Mata Air Silumangi, Mata Air Simarito, and Mata Air Bah-Rahu. Mata Air Nagahuta I and II were specifically noted as facing a higher probability of risk than many of the other sources of raw water for the PDAM. Figure 16 below highlights the declining flow volume from these two springs since 2008.

- **Flooding**. The greater intensity of precipitation events poses a **low risk** to the natural assets of the PDAM. 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 **low risk** to the quantity and quality of natural assets under the climate change scenario given that landslides are unlikely to reduce the quantity of spring or well water available. Landslides will also not impact the water quality of the groundwater sources used by the PDAM.

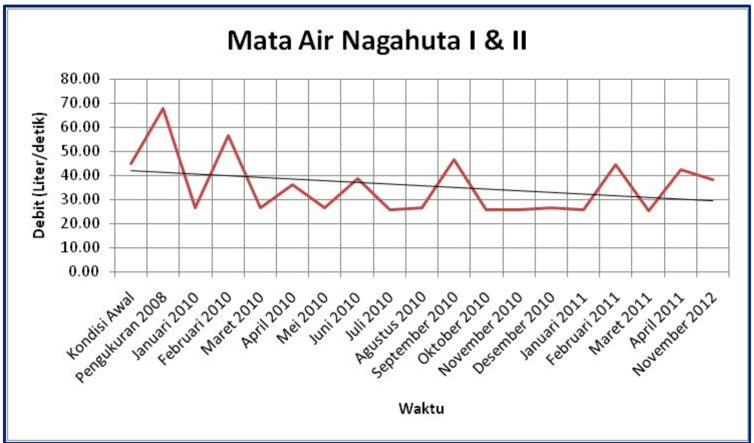


Figure 16: Flow Trend for Mata Air Nagahuta I & II

- **Sea Level Rise**. There is **no risk** to the PDAM's natural assets from sea level rise under the climate change scenario given the considerable distance to the coast.

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 located in the Bolon and Hapal Watersheds.

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 Kota Pematangsiantar and the surrounding regions of Kabupaten Simalungun:

- **Drought/Water Scarcity**: There is a **low risk** 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**: Given the likelihood of the increased intensity of storm events, flooding may present a **low to medium risk** to the PDAM's physical assets in a limited number of locations. Several locations of deep wells within the Kota, for example, have experienced flooding in recent years, although the extent is not substantial in terms of duration and area.
- **Landslides**: While BPBD classified Pematangsiantar as low risk for landslides overall, the participants of the ARM Workshop identified the PDAM's physical assets serving Zona Tengah as facing a **high risk** under the climate change scenario. Specifically, the transmission systems serving Zona Tengah were highlighted as facing an

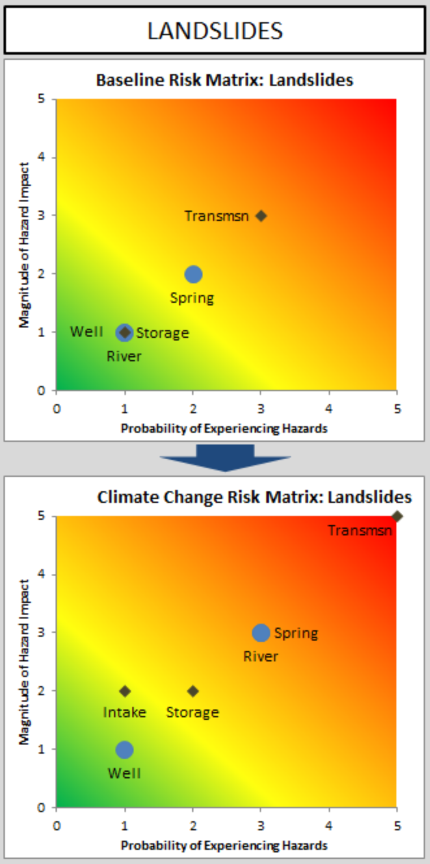


Figure 17: Landslide Risk Matrix for Zona Tengah

elevated risk beyond the baseline scenario (See Figure 17). Even under current the current climate scenario the transmission line serving Zona Tengah has been damaged several times due to landslides; more intense rainfall patterns associated with climate change will only worsen this condition.

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

In summary, climate change will worsen the existing threats to physical assets serving the Central Zone, but is not expected to introduce threats to new physical assets. As the PDAM considers the construction of new assets, however, it will be imperative that water utility managers consider these risks when planning for new infrastructure such as transmission lines and intakes. Please see the summary results from the ARM Workshop in Figure 10 above as well the detailed results attached as **Annex 7**.

2.3.4 Climate Change Scenario: Supply and Demand Analysis

The baseline supply and demand analysis included under Section 2.2.3 showed that the existing sources of raw water possess capacity significantly above the current volume produced by the PDAM, meaning that the PDAM has significant 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. Indeed, the immediate constraint to meeting the water demands of the local populace is the supply infrastructure of the PDAM itself. That said, the baseline analysis performed by Geolexco (see Figure 9) also showed a modest decline in groundwater sources due to a combination of land use change and a downward trend in local rainfall patterns over the past 30 years. Based on this current trend combined with the likelihood of more intense storm events, it appears likely that the intersection of available supply and rising demand may shift to a sooner point in time (i.e. prior to 2067). How large this shift may be is difficult to say at this juncture given the level of uncertainty that remains in how local precipitation patterns will actually change by mid-century.

Overall, it is clear that a more detailed analysis of supply and demand in Pematangsiantar is needed in light of the risks posed by climate change. Such an analysis should adopt an integrated approach, being sure to take into consideration the needs of other users throughout the broader Bolon and Hapal Watersheds. It is particularly important that demands for irrigation be factored into the analysis, noting the need to both feed more people as well as cope with higher temperatures and greater rates of evapotranspiration.

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 Geolexco 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 Nagahuta (Natural Assets):** With a total volume of 72 liters per second, the Nagahuta fresh water springs represent a significant source of water for the Northern Zone and Simalungun Zone of the PDAMs service area. In recent years, the PDAM has also observed noticeable decreases in the flow capacity of these springs, particularly Nagahuta I and Nagahuta II. While much of this decline is likely due to land use change, climate

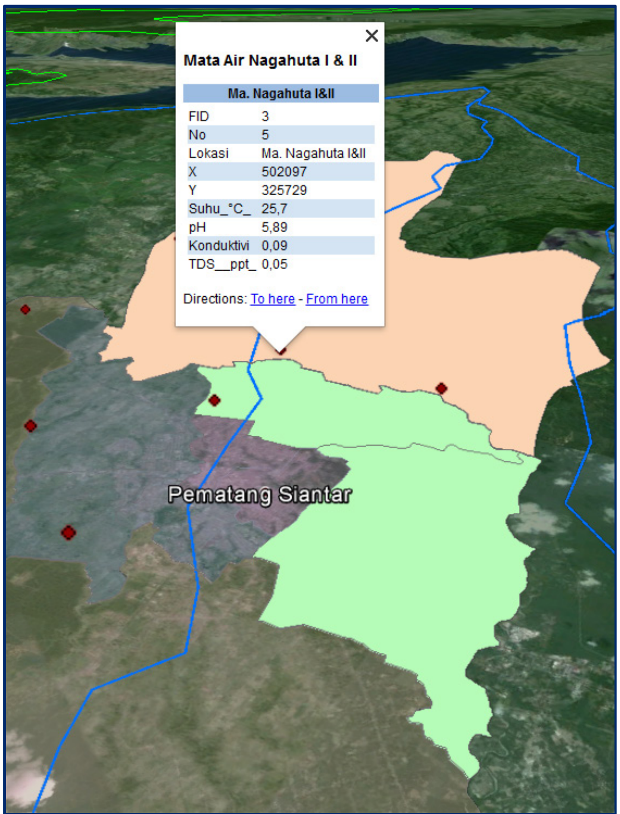


Figure 18 18: Mata Air I and II
MA Nagahuta I and II supply water to the Northern and Special Zones (green and beige, respectively) of the PDAMs service area.

change will only lessen the rate of recharge of this valuable natural asset. Figure 19 above shows the location of these springs just outside of the western edge of the Pematangsiantar boarder.

- **Mata Mual Goit (Natural Assets):** With a current capacity of 248 liters per second, the Mual Goit spring serves the Southern Zone the PDAMs service area. While not as severe as Nagahuta, the PDAM has observed a degree of reduced flow form this spring, especially during the dry season. The PDAM believes that the decline in flow is likely due to land use change, but that, when coupled with climate change, the condition of the spring may worsen yet.
- **The Transmission Systems Serving the Central Zone (Built Assets)**: Given the past history of landslide damages to these assets combined with their estimated replacement value, it is clear that this infrastructure remains highly vulnerable to future storm events. The transmission line delivers water from Habonaran spring to the Central Zone. These vulnerabilities were also highlighted by stakeholders under both the baseline and the climate change scenarios.

In summary*, the vulnerability hotpots for PDAM Pematangsiantar appear to be focused on a select group of fresh water springs and a limited section of the transmission line in the upstream.*

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 6 below provides an illustrative "long list" of climate change adaptation options.

Table 6: 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 7 below highlights the highest scoring adaptation options according to the evaluations completed by stakeholders for the respective service areas of the PDAM. Notably, many adaptation options were found to be applicable across different assets and service areas. The full evaluation of adaptation options is attached as **Annex 8**.

Table 7: Prioritization of Adaptation Options using Multi-criteria Analysis.

Assets	Priority Adaptation Options	Drought	Flood	Mudslide	Sea Level
Central Service Zone (MA Mual Goit)	Watershed protection, including establishment of protected recharge zones	*	*	*	
	Establish forum with upstream stakeholders to minimize conflict over water resources	*			
	Installation and maintenance of infiltration wells upstream	*	*	*	
	Water-use efficiency incentives for customers	*			
	Develop disaster early warning systems	*	*	*	
	Monitoring and evaluation of adaptation options	*	*	*	
Northern Service Zone (Nagahuta)	Improving water resources governance by establishing forums / water management institutions	*	*	*	
	Aquifer recharge program to increase groundwater	*	*	*	
	Establish forum with upstream stakeholders to minimize conflict over water resources	*			
	Payment for environmental services	*	*	*	
Southern Service Zone	Improving water resources governance by establishing forums / water management institutions	*	*	*	
	Agricultural extension in order to reduce soil erosion and runoff	*	*	*	
	Rainwater collection system at the community level	*	*	*	
Special Service Zone (MA Silumangi)	Development of infiltration wells upstream of spring	*	*	*	
	Agricultural extension in order to reduce soil erosion and runoff	*	*	*	
	Establish forum with upstream stakeholders to minimize conflict over water resources	*			
	Examination of irrigation channels to slow runoff and aid aquifer recharge	*	*	*	
	Increasing access to improved sanitation (to reduce / avoid contamination of water sources)	*			
	Behavior change campaigns to improve water usage practices of customers	*			
	Improved billing and accounting system for PDAM	*			
	Purchase property insurance for buildings and other essential assets	*	*	*	

Building on as well as 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 transmission infrastructure, the PDAM may consider adding reinforcements to exposed pipeline networks, particularly for places identified by stakeholders as highly susceptible to landslides. Over the longer term, the PDAM may also consider moving these transmission mains altogether to a more stable route.
- **Improved Asset Management:** At present the PDAM does not utilize a GIS-enabled asset management system to track critical infrastructure details such as: age, depreciated value, replacement cost, and historical damages. Adopting 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, watershed management improvements, and water resources monitoring.

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.

Specific actions are as follows:

- **Action #1:** Significant resources have been dedicated already to the installment of infiltration wells in the upper reaches of the sub-watershed surrounding the Nagahuta Spring (see Figure 19). To help sustain this investment, the PDAM will budget funds for maintenance costs for the infiltration wells. The maintenance is deemed important to make sure that the wells are functioning satisfactorily, e.g. helping to improve the infiltration rate upstream of the Nagahuta springs area.

Figure 19: The Construction of an Infiltration Wells above Mata Air Nagahuta.

- **Action #2:** Building on the aquifer recharge work started near the Nagahuta Spring, the Local Government (Badan Lingkungan Hidup-BLH) will also construct infiltration wells in several locations. In addition, BLH will also install "bio-pores" in downstream areas within the City itself.
- **Action #3:** As part of PDAM's effort in meeting the City's growing water demand, PDAM Pematangsiantar—through the City administration and support from the surface water management body (Balai Wilayah Sungai II Sumatera)—will collaborate with the neighboring Kabupaten Simalungun to access a new raw water source. Specifically, the PDAM will be granted access to fresh water from the Aek Nauli Spring in the amount of approximately 60 liters per second.
- **Action #4**: The PDAM will more diligently monitor the flow levels of the targeted fresh water springs to ensure the compilation of robust historical data and thereby provide an improved baseline of data for future analytical needs and decision-making. The effort to improve the collection of hydrological data has indeed already begun with assistance from IUWASH in the form of the procurement and installation of two water flow meters for Nagahuta Spring.
- **Action #5:** To help address the threats facing the piping network, the PDAM will also plan and budget for the reinforcement of the transmission line carrying water from Habonaran spring to the Zona Tengah service area;
- **Action #6**: In order to better track and manage the PDAM's constructed assets, the PDAM will evaluate how it may use geographic information systems (GIS) as part of its administrative systems. As a first step, PDAM staff will attend GIS training courses supported by IUWASH.

4.2 INTEGRATION INTO MEDIUM AND LONG-TERM PLANNING

In conjunction with the commencement of the 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 Business 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 establish a specific program for the maintenance and expansion of the infiltration wells under its RKAP 2015;
- The PDAM will integrate the results of the Vulnerability Assessment and Adaptation Plan during the next revision of its five-year business plan; and
- The Local Government will establish a specific program and budgetary line item for improved water resources management in the upcoming Annual Work Plan and Annual Budget (APBD).

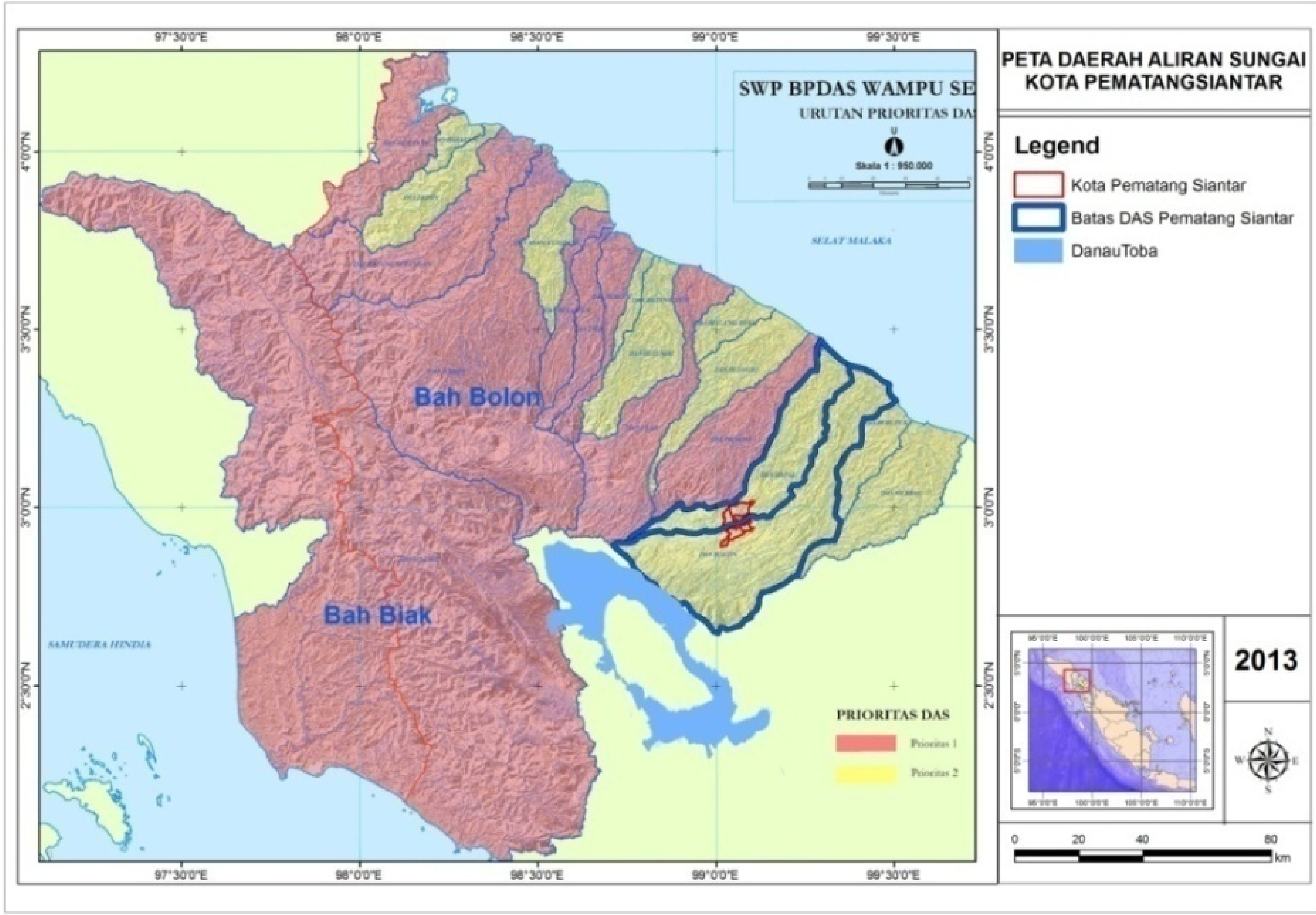
The integration of the climate change vulnerability assessment and adaptation planning into the local planning documents will also support continuous learning and, where necessary, updating of adaptation approaches. There is still much that we do not know about how climate change will impact a specific 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

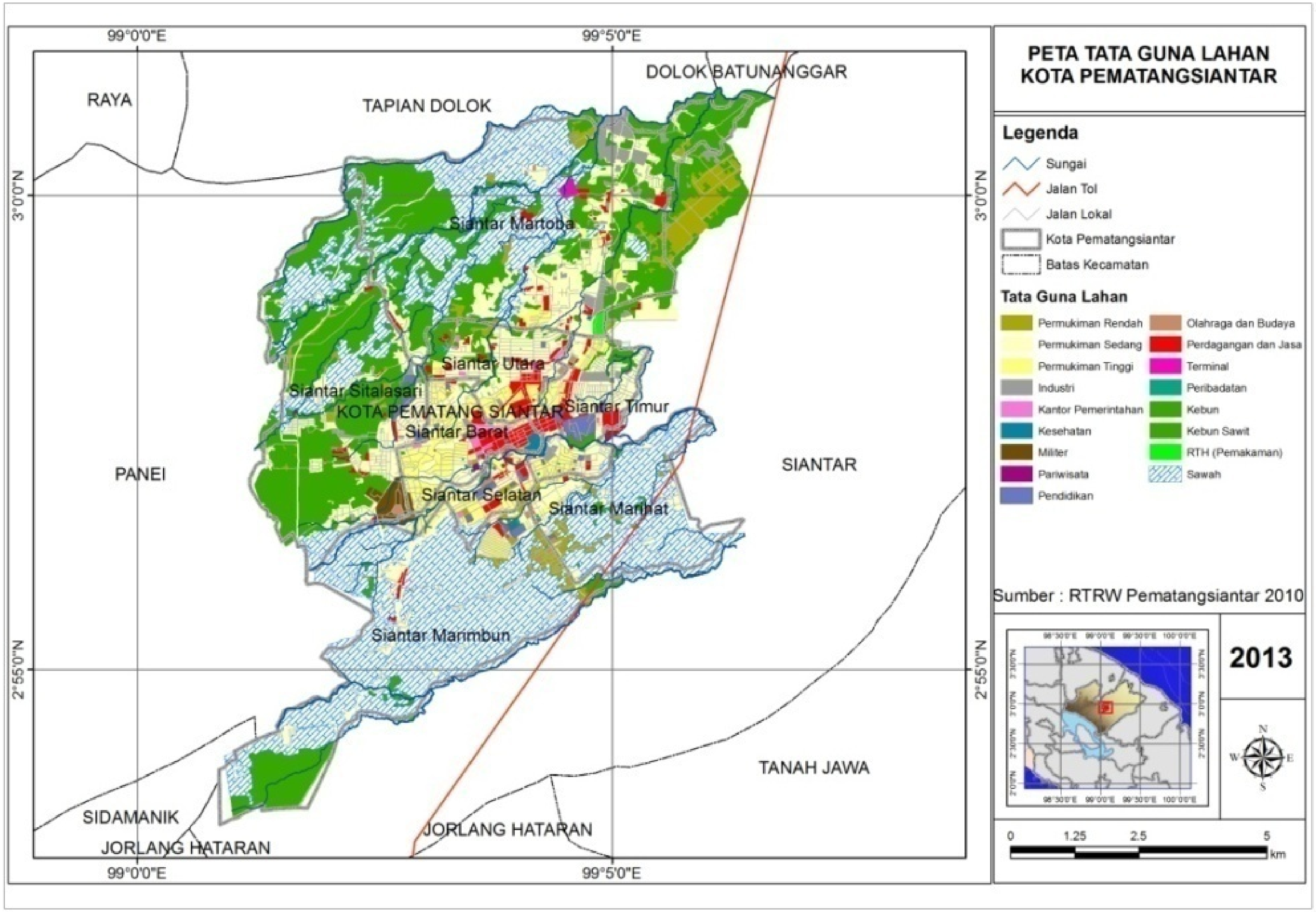
ANNEX 1: CHRONOLOGY OF VA & AP PROCESS

Date	Activity/Event	Major Output	Stakeholders
August 2011	Initial assessment: - Discussion with PDAM - Field survey of raw water sources used by PDAM	- Indication of drops in flow/ quantity of springs. PDAM recognized this condition.	PDAM, IUWASH
October 2012	Selection of institution to conduct CCVA through tendering process	PT. Geolexco International qualified and was selected to conduct CCVA study	PT. Geolexco International, IUWASH
May 2013	Workshop on the CCVA study: Results of study were discussed with stakeholders	CCVA study presenting dynamics of water supply and demand, vulnerability, and initial adaptation options addressing vulnerability. Note: completion of the CCVA study in October 2013	PDAM, local stakeholders, PT. Geolexco International, IUWASH
January 2014	Stakeholders workshop on ARM	ARM were developed by PDAM and other key local government agencies	PDAM, BPBD, Bappeda, Dinas SDA, Dinas Kehutanan, Dinas Pertanian, BLH, Dinas Tarukim Prov. Sumut, IUWASH
February 2014	Stakeholders workshop on adaptation options development	- Common understanding that Pematangsiantar should address water resources issues particularly related to climate change - Adaption options were developed by PDAM and other key local government agencies	PDAM, BPBD, Bappeda, Dinas PSDA, Dinas Kehutanan, Dinas Pertanian, BLH, Dinas Tarukim Prov. Sumut, IUWASH
June 2014	Serial discussions with decision makers on priority/action plan of adaptation actions	Adaptation actions that will be implemented by PDAM and local government agencies	PDAM, BPBD, Bappeda, Dinas PSDA, Dinas Kehutanan, Dinas Pertanian, BLH, Dinas Tarukim Prov Sumut, IUWASH

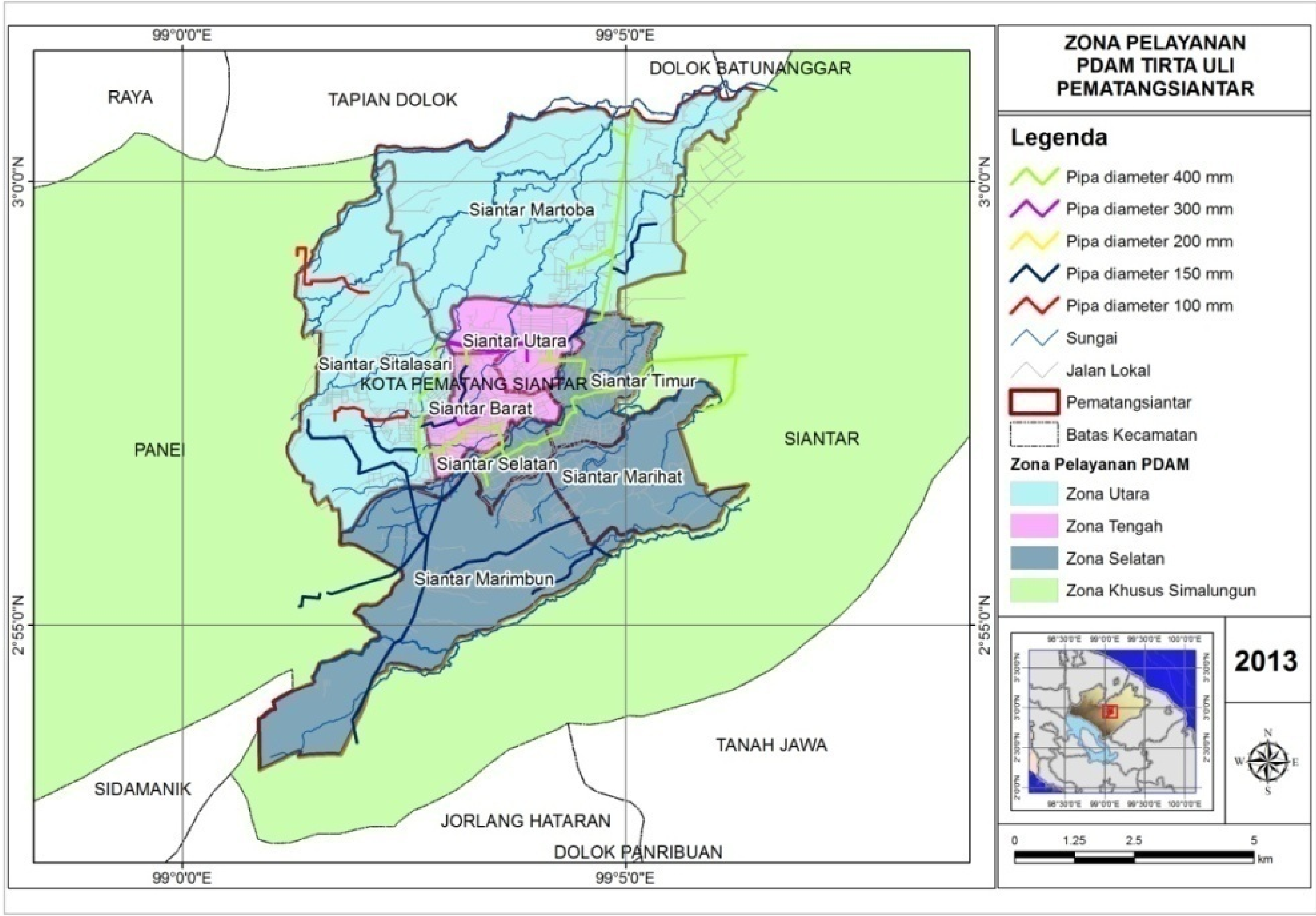
ANNEX 2: MAP OF WATERSHEDS IN PEMATANG SIANTAR



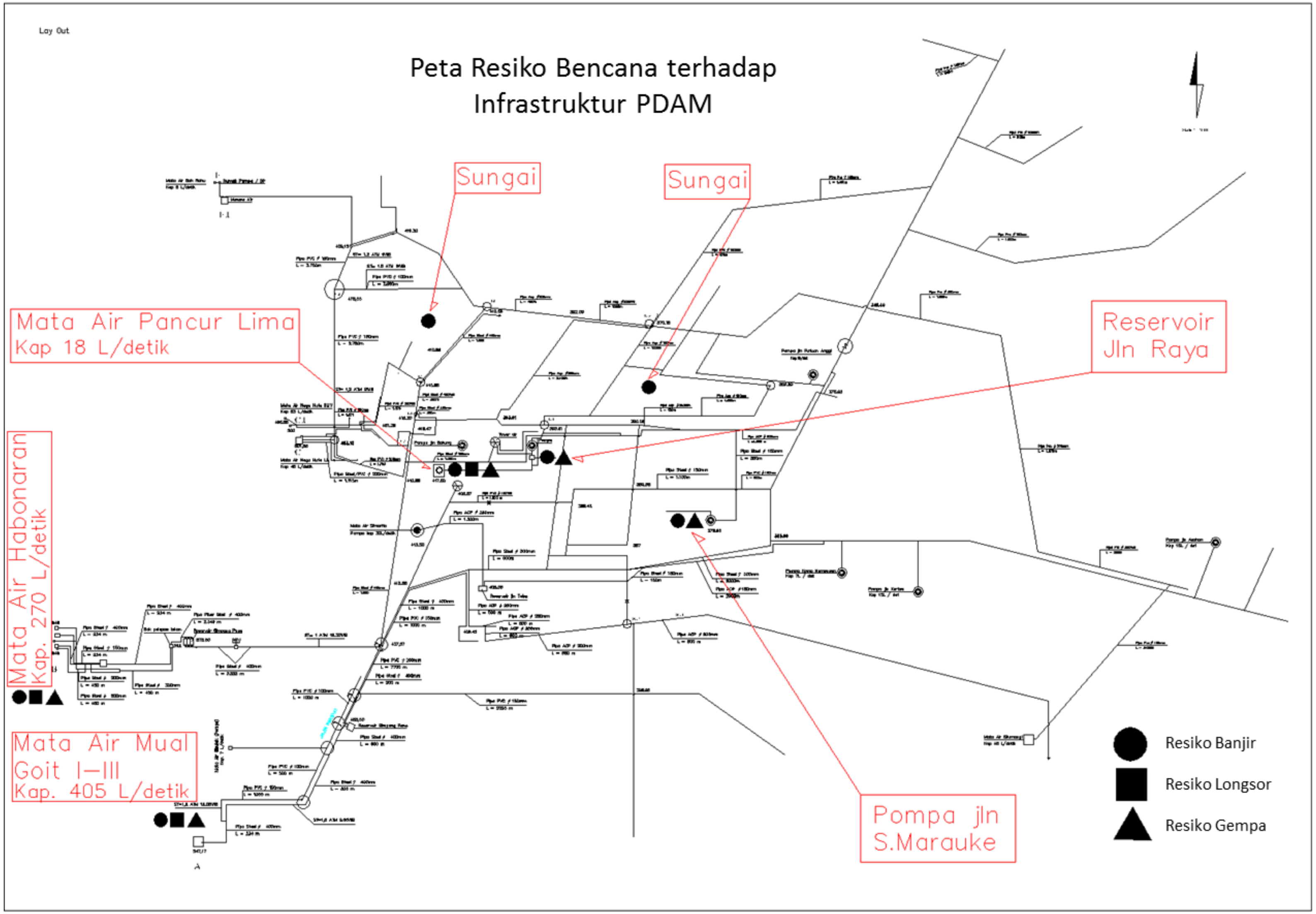
ANNEX 3: LAND USE MAP OF WATER RESOURCE RECHARGE AREAS



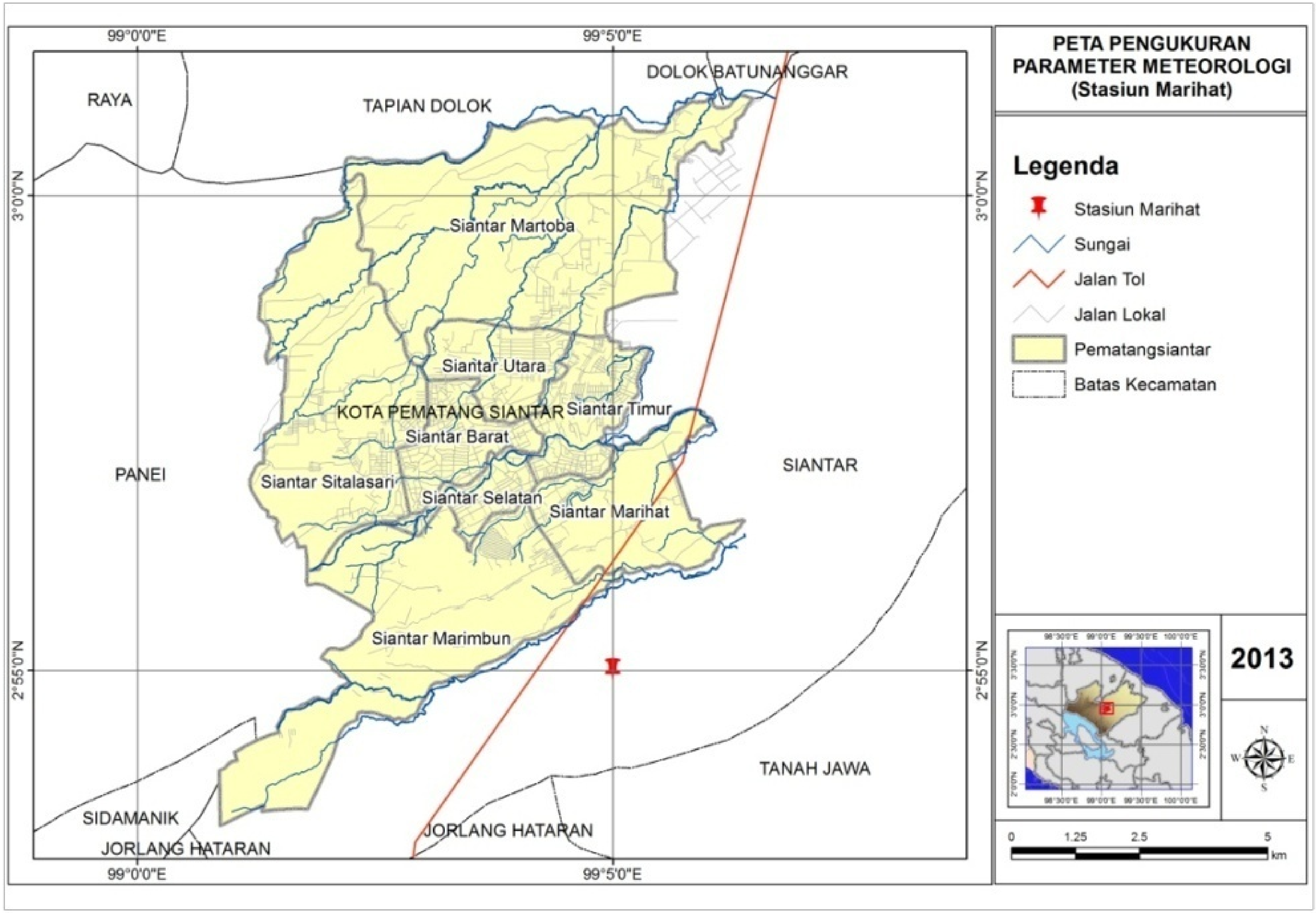
ANNEX 4: SERVICE AREAS OF PDAM TIRTA ULI PEMATANGSIANTAR



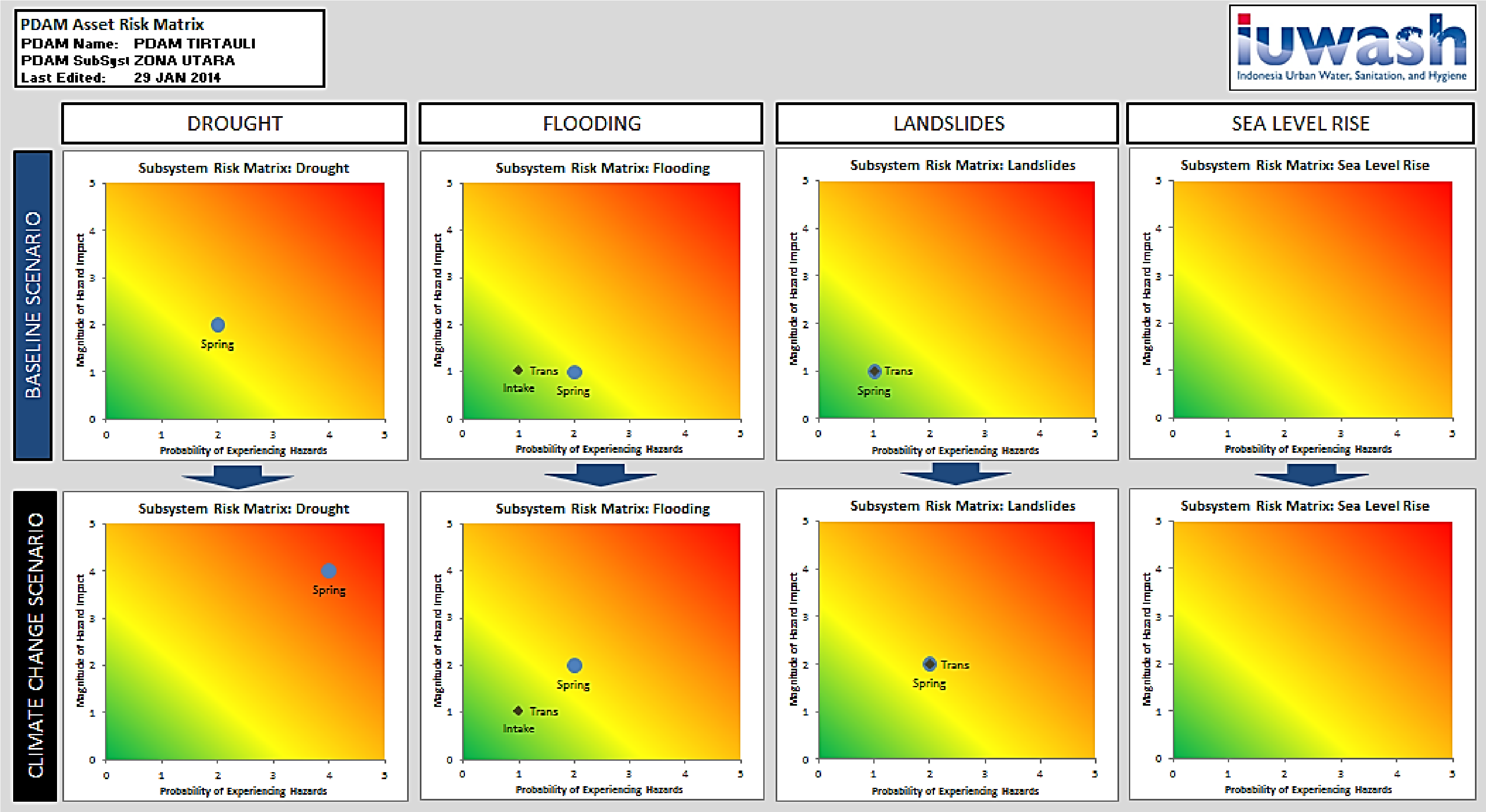
ANNEX 5: SCHEMATIC OF RISKS FACING PDAM'S INFRASTRUCTURE

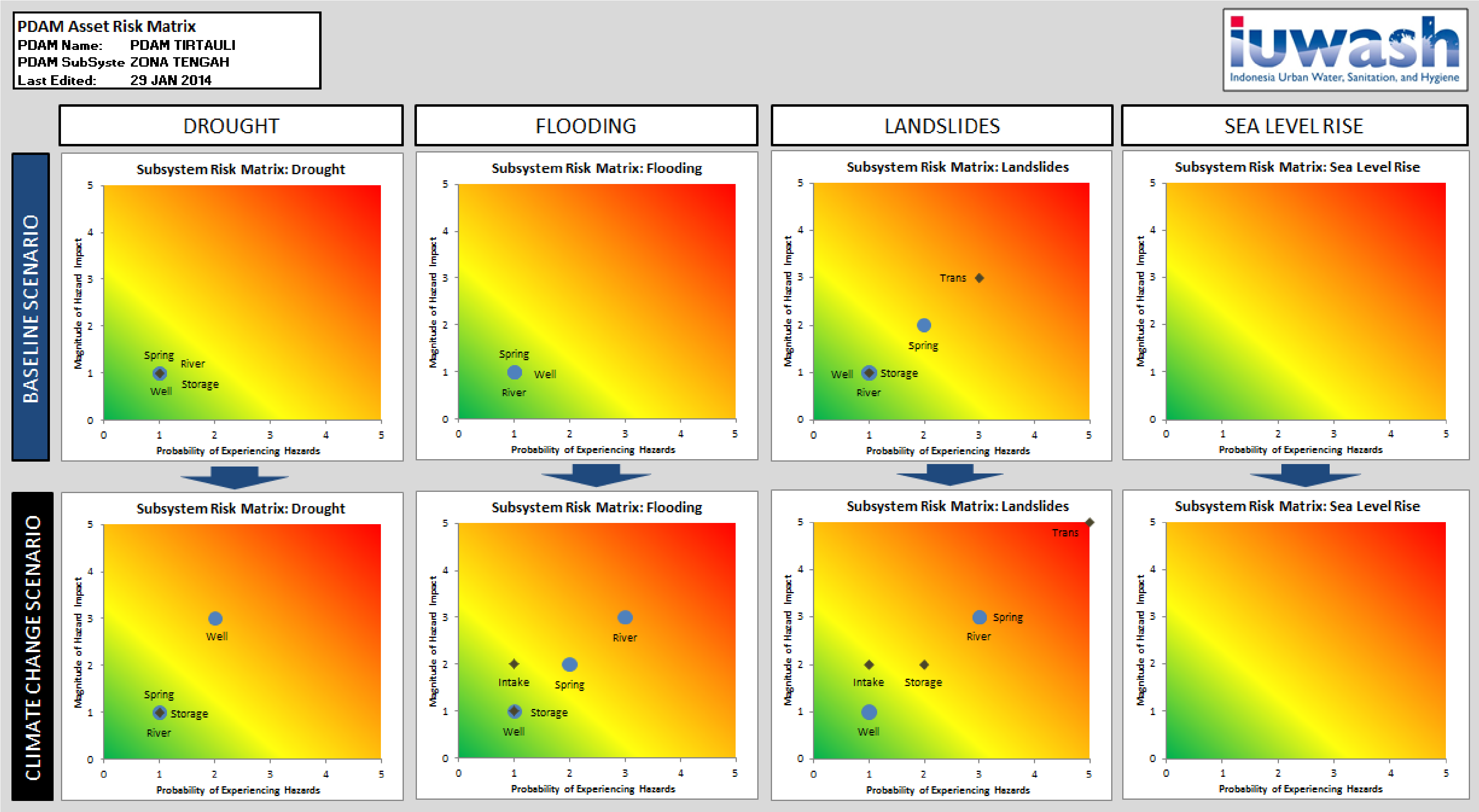


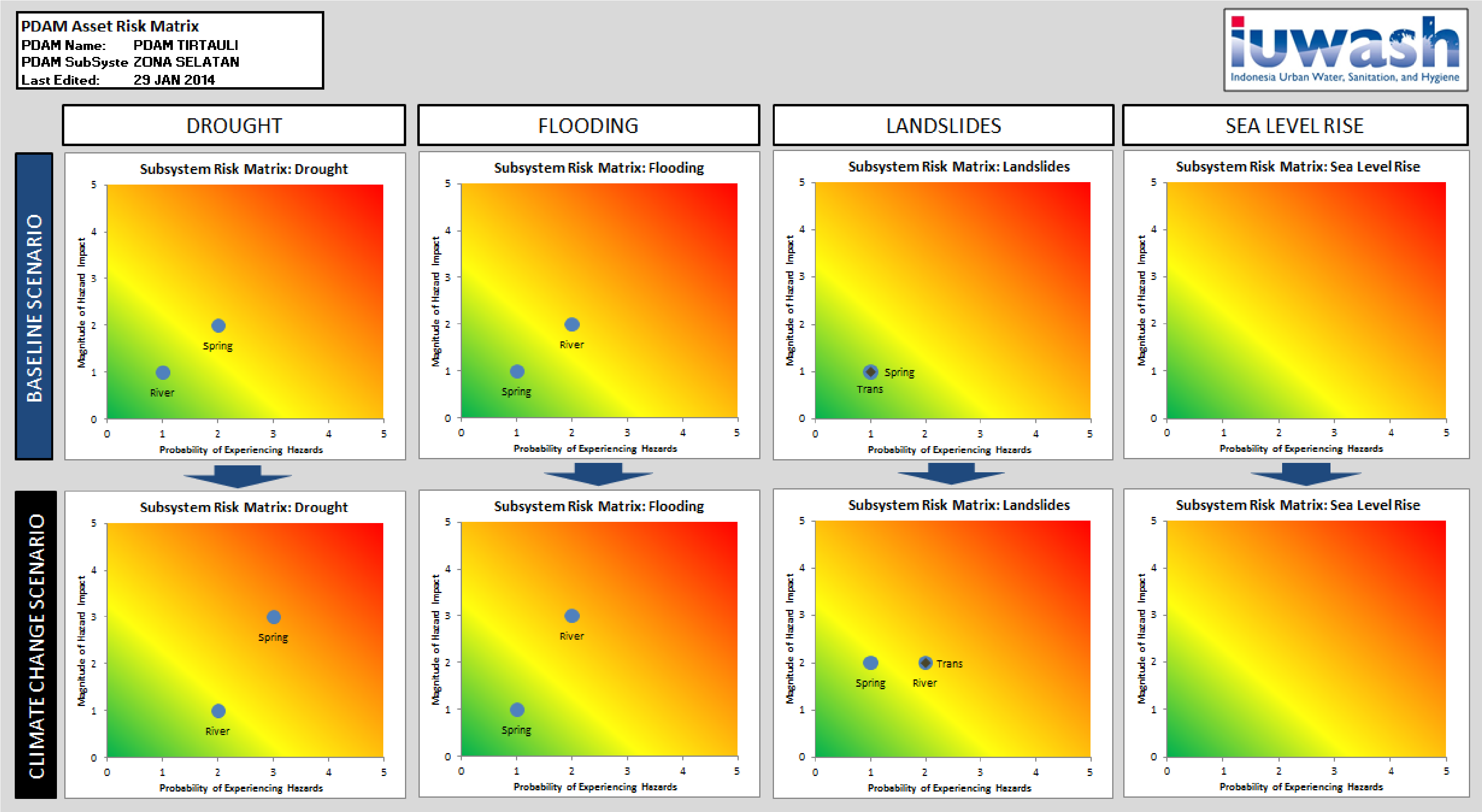
ANNEX 6: MAP OF LOCATION OF METEOROLOGICAL STATION



ANNEX 7: ASSET RISK MATRIX BY PDAM SERVICE AREA




PDAM Asset Risk Matrix
PDAM Name: PDAM TIRTAULI
PDAM SubSyste ZONA TENGAH
Last Edited: 29 JAN 2014
iuwash
Indonesia Urban Water, Sanitation, and Hygiene
DROUGHT
FLOODING
LANDSLIDES
SEA LEVEL RISE
BASELINE SCENARIO
CLIMATE CHANGE SCENARIO
Subsystem Risk Matrix: Drought
Subsystem Risk Matrix: Flooding
Subsystem Risk Matrix: Landslides
Subsystem Risk Matrix: Sea Level Rise
Magnitude of Hazard Impact
Probability of Experiencing Hazards
Spring
River
Well
Storage
Trans
Intake


PDAM Asset Risk Matrix
PDAM Name: PDAM TIRTAULI
PDAM SubSyste ZONA SELATAN
Last Edited: 29 JAN 2014
iuwash
Indonesia Urban Water, Sanitation, and Hygiene
DROUGHT
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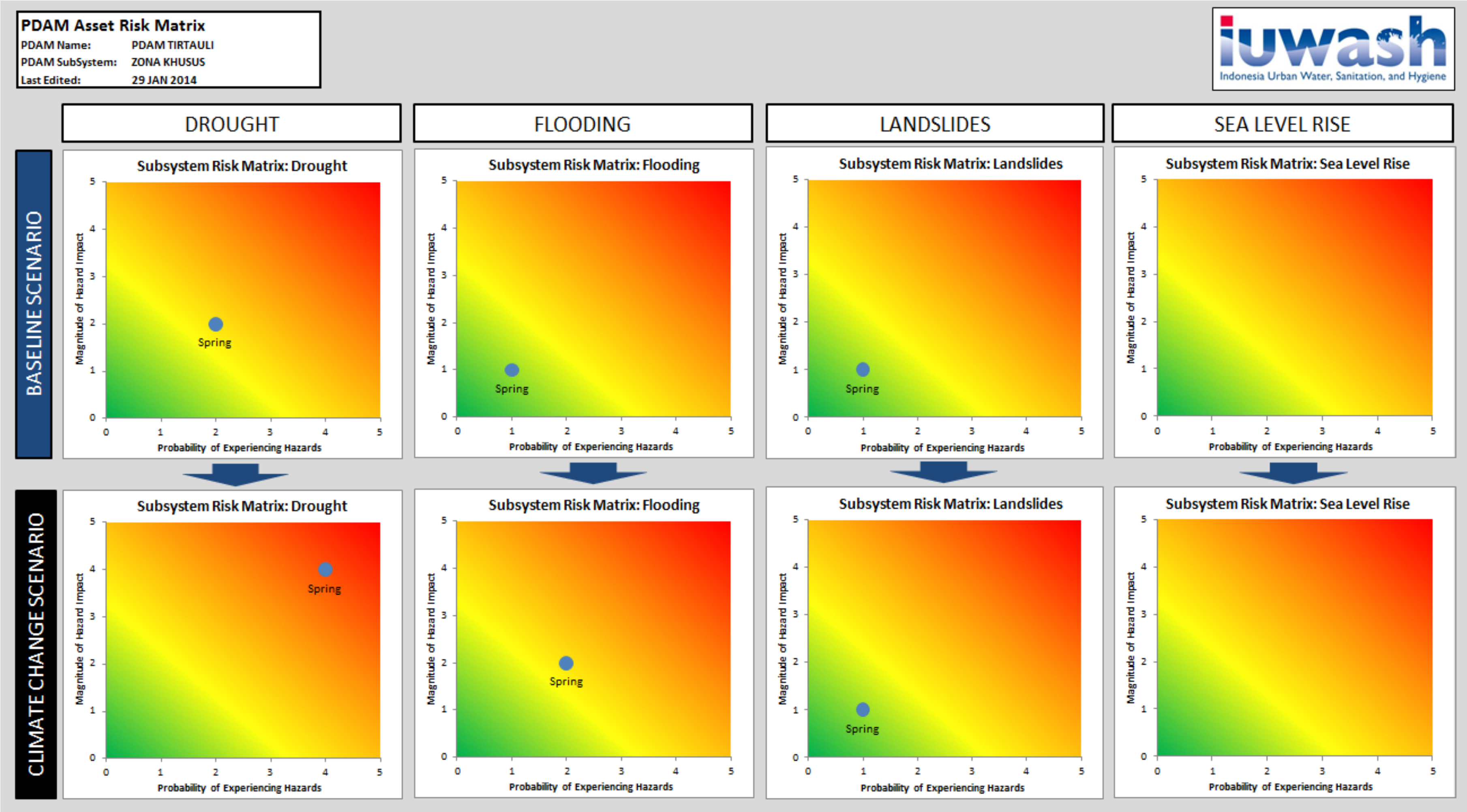
BASELINE SCENARIO
CLIMATE CHANGE SCENARIO
Subsystem Risk Matrix: Drought
Subsystem Risk Matrix: Flooding
Subsystem Risk Matrix: Landslides
Subsystem Risk Matrix: Sea Level Rise
Magnitude of Hazard Impact
Probability of Experiencing Hazards
Spring
River
Trans


PDAM Asset Risk Matrix
PDAM Name: PDAM TIRTAULI
PDAM SubSystem: ZONA KHUSUS
Last Edited: 29 JAN 2014
DROUGHT
FLOODING
LANDSLIDES
SEA LEVEL RISE
BASELINE SCENARIO
CLIMATE CHANGE SCENARIO
Subsystem Risk Matrix: Drought
Subsystem Risk Matrix: Flooding
Subsystem Risk Matrix: Landslides
Subsystem Risk Matrix: Sea Level Rise
Magnitude of Hazard Impact
Probability of Experiencing Hazards
Spring

ANNEX 8: EVALUATION OF ADAPTATION OPTIONS

Climate Change Adaptation Options for Kota Pematangsiantar Water Supply
Water Source & Zone: Mual Goit (Zona Tengah)

Adaptation Classifications	Options of Adaptation Actions	Anticipated Hazard				Selection Criteria					Total Score
		Drought	Flood	Landslide	Sea Water Level Rise	Cost	Complexity (technical, coordination, etc.)	Political Aspect	Speed of Implementation	Benefit	
Water Source Protection	Installation and maintenance of infiltration wells upstream	*	*	*		3	3	3	3	2	14
	Watershed protection, including establishment of protected recharge zones	*	*	*		3	3	3	3	2	14
	Strengthen regulatory aspect, including groundwater and surface water extraction permits	*				3	2	1	3	3	12
	Establish forum with upstream stakeholders to minimize conflict over water resources	*				3	3	1	3	3	13
	Payment for Environmental Services	*	*			3	2	1	3	3	12
Infrastructure Options	Diversify water resources through construction of deep wells, new surface water intakes, inter-basin transfers, incl. cross jurisdiction cooperation (regionalization)	*	*			1	1	1	1	3	7
	Increase access to improved sanitation systems to reduce pollution of upstream water sources and local groundwater	*	*			3	3	1	3	2	12
	Expand/upgrade/improve drainage systems	*	*			2	2	1	3	2	10
	Construction of berms, dikes, or sea walls for infrastructure vulnerable to risk, e.g. landslide		*			2	2	1	3	2	10
	Relocation/strengthening water infrastructure subject to flooding, including raising pumping stations and well heads, constructing aprons for bore-wells		*	*		1	2	3	3	2	11
Water Demand Management/ Efficiency	Water leakage reduction, including repair/replacement of aging piping	*	*			1	1	3	2	3	10
	Water meter maintenance and replacement		*			1	1	3	3	2	10
	Social marketing for consumer behavior change		*	*		2	2	1	3	3	11
	Water-use efficiency incentives for customers	*				2	3	3	3	3	14
	Use of storage at customer	*	*			2	3	3	3	1	12
Planning and Information Management	Water Allocation Decision-Support Systems (including forecasting tools for water resources)	*				1	1	2	3	3	10
	Installation of Hydrological / Meteorological / Groundwater Monitoring Stations	*	*	*		1	1	3	2	3	10
	Computerized Billing and Accounting					1	1	3	2	3	10
	Water resources research to, for example, better understand and map the location and characteristics of aquifers	*	*			2	2	3	2	2	11
	Develop disaster early warning systems	*	*	*		2	2	3	3	3	13
	Disaster Management Plans		*	*		2	3	2	3	2	12
	Water Safety Plans	*	*	*		1	2	2	3	2	10
	Monitoring and evaluation of adaptation options	*	*	*		3	3	3	3	1	13
Risk Transfer	Establishment of government and PDAM disaster reserve fund		*	*		3	3	1	3	2	12

Climate Change Adaptation Options for Kota Pematangsiantar Water Supply
Water Source & Zone: Nagahuta (Zona Utara)

Adaptation Classifications	Options of Adaptation Actions	Anticipated Hazard				Selection Criteria					Total Score
		Drought	Flood	Landslide	Sea Water Level Rise	Cost	Complexity (technical, coordination, etc.)	Political Aspect	Speed of Implementation	Benefit	
Water Source Protection	Installation of infiltration wells upstream	*		*		3	1	3	3	3	13
	Watershed protection, including establishment of protected recharge zones	*		*		3	3	3	2	2	13
	Improving water resources governance by establishing forums/ water management institutions	*	*	*		3	3	3	2	3	14
	Strengthen regulatory aspect, including groundwater and surface water extraction permits	*		*		2	1	1	2	3	9
	Aquifer recharge program to increase groundwater	*	*	*		3	3	3	2	3	14
	Agricultural extension in order to reduce soil erosion and runoff	*		*		3	2	3	2	2	12
	Improved wastewater collection and treatment and solid waste management	*		*		1	1	3	1	3	9
	Establish forum with upstream stakeholders to minimize conflict over water resources	*				3	3	3	3	2	14
	Payment for environmental services	*	*	*		3	3	3	3	2	14
Infrastructure Options	Rainwater collection system at the community level	*		*		1	1	3	1	3	9
	Increase access to improved sanitation systems to reduce pollution of upstream water sources and local groundwater	*		*		2	1	2	2	3	10
	Expand/upgrade/improve drainage systems	*		*		1	2	3	2	3	11
	Increase storage capacity (reservoirs, artificial lakes, etc.)	*		*		1	2	3	3	3	12
	Strengthening water infrastructure subject to hazard such as landslide	*		*		2	2	3	3	3	13
Water Demand Management/ Efficiency	Water leakage reduction, including repair/replacement of aging piping	*		*		1	2	3	3	3	12
	Water meter maintenance and replacement	*		*		1	2	3	3	3	12
	Efficient water pricing (i.e. increasing block tariffs; progressive tariff)	*		*		2	1	1	1	3	8
	Water-use efficiency incentives for customers	*		*		2	2	1	3	3	11
	Use of storage at customer	*		*		2	2	1	3	3	11
Planning and Information	Water Allocation Decision-Support Systems (including forecasting tools for water resources)	*		*		2	2	3	3	3	13
	Installation of Hydrological / Meteorological / Groundwater Monitoring Stations	*		*		2	2	3	3	3	13
	Computerized Billing and Accounting	*		*		2	2	3	3	3	13
	Develop disaster early warning systems	*		*		2	2	3	3	3	13
	Disaster Management Plans	*		*		2	2	3	3	3	13
	Water Safety Plans	*		*		2	2	3	3	3	13
	Monitoring and evaluation of adaptation options	*		*		2	2	3	3	3	13
Risk Transfer	Purchase of property insurance for buildings and other key assets (i.e. vehicle fleet)	*		*		2	2	3	3	3	13
	Establishment of government and PDAM disaster reserve fund	*		*		2	2	1	3	3	11

Climate Change Adaptation Options for Kota Pematangsiantar Water Supply
Zone: Zona Selatan

Adaptation Classifications	Options of Adaptation Actions	Anticipated Hazard				Selection Criteria					Total Score
		Drought	Flood	Landslide	Sea Water Level Rise	Cost	Complexity (technical, coordination, etc.)	Political Aspect	Speed of Implementation	Benefit	
Water Source Protection	Watershed protection, including establishment of protected recharge zones	*	*	*	*	1	2	3	2	3	11
	Improving water resources governance by establishing forums/ water management institutions	*	*	*	*	3	3	3	2	3	14
	Strengthened regulatory environment, including groundwater and surface water extraction permits	*	*	*	*	2	2	2	2	3	11
	Aquifer recharge program to increase groundwater	*	*	*	*	2	2	3	2	3	12
	Agricultural extension in order to reduce soil erosion and runoff	*	*	*		2	3	3	3	2	13
	Improved wastewater collection and treatment and solid waste management	*	*	*		2	2	3	2	3	12
	Establish forum with upstream stakeholders to minimize conflict over water resources	*				3	2	2	2	3	12
	Payment for environmental services	*	*	*	*	2	2	2	2	2	10
Infrastructure Options	Rainwater collection system at the community level	*	*			2	2	3	3	3	13
	Diversify water resources through construction of deep wells, new surface water intakes, inter-basin transfers, incl. cross jurisdiction cooperation (regionalization)	*	*	*	*	2	1	2	2	3	10
	Increase access to improved sanitation systems to reduce pollution of upstream water sources and local groundwater	*	*			1	1	3	2	3	10
	Wastewater reuse/recycling for agriculture and industry	*	*			2	1	3	1	3	10
	Expand/upgrade/improve drainage systems	*	*		*	2	2	3	2	3	12
	Increase storage capacity (reservoirs, artificial lakes, etc.)	*	*			1	2	3	2	3	11
Water Demand Management/ Efficiency	Water leakage reduction, including repair/replacement of aging piping	*	*	*		1	2	3	2	3	11
	Water meter maintenance and replacement					2	2	3	2	3	12
	Efficient water pricing (i.e. increasing block tariffs; progressive tariff)					2	1	2	1	3	9
	Social marketing for consumer behavior change	*				1	1	2	1	3	8
Planning and Information Management	Water Allocation Decision-Support Systems (including forecasting tools for water resources)	*	*	*	*	1	2	3	1	3	10
	Installation of Hydrological / Meteorological / Groundwater Monitoring Stations	*	*	*	*	1	2	3	2	3	11
	Computerized Billing and Accounting	*	*	*	*	1	2	3	2	3	11
	Water resources research to, for example, better understand and map the location and characteristics of aquifers	*	*	*	*	1	2	3	3	3	12
	Develop disaster early warning systems	*	*	*	*	2	2	3	2	3	12
	Disaster Management Plans	*	*	*	*	2	2	3	2	3	12
	Water Safety Plans	*	*	*	*	2	1	3	2	3	11
	Monitoring and evaluation of adaptation options	*	*	*	*	2	2	3	2	3	12
Risk Transfer	Purchase of property insurance for buildings and other key assets (i.e. vehicle fleet)	*	*	*	*	2	2		2	3	9
	Establishment of government and PDAM disaster reserve fund	*	*	*	*	2	2		2	3	9

Climate Change Adaptation Options for Kota Pematangsiantar Water Supply
Source & Zone: Mata Air Silumangi (Zona Khusus)

		Anticipated Hazard				Selection Criteria					
Adaptation Classifications	Options of Adaptation Actions	Drought	Flood	Landslide	Sea Water Level Rise	Cost	Complexity (technical, coordination, etc.)	Political Aspect	Speed of Implementation	Benefit	Total Score
Water Source Protection	Development of infiltration ponds upstream of spring	*	*	*		3	3	3	3	2	14
	Watershed protection, including establishment of protected recharge zones	*	*			1	1	1	1	2	6
	Strengthened regulatory environment, including groundwater and surface water extraction permits	*	*			2	3	2	2	3	12
	Agricultural extension in order to reduce soil erosion and runoff	*	*	*		3	3	3	3	2	14
	Establish forum with upstream stakeholders to minimize conflict over water resources	*				3	3	3	3	2	14
Infrastructure Options	Examination of irrigation channels to slow runoff and air aquifer recharge	*	*	*		3	3	3	3	2	14
	Increasing access to improved sanitation (to reduce/avoid contamination of water sources)	*				3	3	3	3	2	14
	Expand/upgrade/improve drainage systems	*	*			1	1	3	3	3	11
	Increase storage capacity (reservoirs, artificial lakes, etc.)	*	*			2	2	3	2	3	12
Water Demand Management/ Efficiency	Water leakage reduction, including repair/replacement of aging piping	*	*			1	1	3	1	3	9
	Water meter maintenance and replacement	*				2	2	3	2	3	12
	Efficient water pricing (i.e. increasing block tariffs; progressive tariff)	*				2	3	1	3	3	12
	Behavior change campaign to improve water usage practices of customers	*				3	3	3	3	3	15
	Energy Efficiency measures to maintain service provision with reduced energy costs	*				1	1	3	1	3	9
	Water-use efficiency incentives for customers	*				1	2	3	3	1	10
	Use of storage at customer	*	*			1	2	3	3	3	12
Planning and Information Management	Water Allocation Decision-Support Systems (including forecasting tools for water resources)	*	*			1	1	1	2	3	8
	Installation of Hydrological / Meteorological / Groundwater Monitoring Stations	*	*			1	2	3	2	3	11
	Computerized Billing and Accounting	*				3	3	3	2	3	14
	Water resources research to, for example, better understand and map the location and characteristics of aquifers	*	*			1	1	3	2	3	10
	Develop disaster early warning systems	*	*			3	1	3	3	1	11
	Disaster Management Plans	*	*			3	1	3	2	3	12
	Water Safety Plans	*	*			1	2	3	2	2	10
	Monitoring and evaluation of adaptation options	*	*			1	2	3	2	2	10
Risk Transfer	Purchase property insurance for buildings and other essential assets	*	*	*		2	3	3	3	3	14
	Establishment of government and PDAM disaster reserve fund	*	*			3	3	3	2	2	13

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