Climate Change Risk and Adaptation Assessment

Greater Malang

Sectoral Report
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Climate Change Risk and Adaptation Assessment for the Water Sector – Greater Malang

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Climate Risk and Adaptation Assessment for the Water Sector - Greater Malang

Draft Final Report

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I INTRODUCTION

1.1 Background

Indonesia is strongly exposed to climate change. With over 17.000 islands, the rising sea level, changes in precipitation and extreme climate events are a major issue. Climate projections indicate that the mean wet-season rainfall will increase across most of Indonesia, especially in regions located south of the equator such as Java and Bali. At the same time, the length of the dry season is expected to increase. Moreover, an increase in the intensity and frequency of extreme events like El Nino, which have caused major droughts and fires in Indonesia, is already noticeable in the Asian region. The risk of floods during the rainy season and drought in the dry season is therefore likely to increase. This will particularly impact water resources, agriculture and forestry, fishery as well as health and infrastructure. Land subsidence, sea level rise, floods, droughts, landslides and forest fires already cause considerable damage in Indonesia. Adaptive measures can mitigate damage and avoid aggravating impacts of natural disasters.

Therefore, the necessity for adaptation measures at national and local levels is rapidly emerging as central issue in the debate around policy responses to climate change. In order to prioritize, design and implement interventions to adapt to climate change, it is essential to adopt a coherent set of approach, framework and methodologies for examining vulnerability and adaptive capacity.

1.2 Problem Statement

Many vulnerability studies, while being effective in raising awareness to the possible effect of climate change on a general level, have limited effectiveness in providing local scale guidance on adaptation. Methods and tools for vulnerability studies at the provincial/local level are different from the ones used on national and global scales. To effectively formulate adaptation strategies at the province level, it is proposed to apply "meso level-multi sectoral approach" (MsLMSA) which means assessing vulnerability at the meso-level but considering the multi sectoral impacts of climate change e.g. water, agriculture and coastal / marine sectors. An appropriate approach has been developed and applied on Lombok Island and is the first MsLMSA based vulnerability study in Indonesia. The study result is very promising and it is necessary to be replicated in other region in Indonesia.

Moreover, a shifting political system from centralized to decentralized structures urgently requires and challenges an increasing role of local governments (district/city) to initiate local level activities in climate change adaptation. Therefore, the vulnerability assessment on climate change and integration of its result into local development planning also becomes essential. Thus, the MsLMSA based vulnerability study in Lombok Island was developed and conducted on provincial level (“meso level-multi sectoral approach” or McLMSA). Mainstreaming of V-A into development policies can follow two approaches, the first one directly influencing the preparation of the local mid-term development plan (RPJM) and integration of the annual sectoral plans. Given that the preparation of the RPJM depends on the election cycle of the local governments, the project will prepare both the input for the *forthcoming* RPJMs and the annual sectoral plans as *immediate* contribution.

Furthermore, the new Indonesian environmental law has just been approved by the parlament and signed by the president (September/October 2009), which outlines the framework for climate change mitigation and adaptation issues, however the technical and operational guidelines still have to be developed. This project will develop the strategy and action and implementing it in the field, which can be taken as a model for technical and operational guideline development.

1.3 Objectives

The global objective of the project is to further develop and replicate the nationally approved V-A methodology, to develop adaptation strategies on local levels and to secure implementation by adequate budgeting and financing, including the development of innovative financing and policy instruments in Greater Malang. In this study, Greater Malang consists of regions of Batu City, Malang City, and Malang District.

To achieve this global objective the following objectives shall be achieved:

a. To enhance awareness on climate change impact and its management for regional/local government and stakeholders.

b. To further develop, replicate and apply methods and tools, which have been applied in Lombok Island (NTB Province) to Malang Greater, The Greater Malang City, and Greater Malang in order to assess climate change vulnerability and design adaptation strategies as well as to integrate its result into regional/local development planning.

c. To mainstream adaptation to climate change into regional/local development planning.

d. To build capacity of stakeholders related to vulnerability and adaptation issues on the local level.

e. To streamline aspects of climate change adaptation and disaster preparedness

f. To support and provide input to national level policy making and development planning, especially with a view to support local level adaptation strategies and planning.

g. To develop the capacity of local government in fiscal and financial areas and increase their capability in accessing national and international sources of fund. The financial mechanism should be developed in the context of the Indonesia Climate Change Trust Fund (ICCTF) investment window on adaptation and resilience, thereby providing the mechanism to the ICCTF, which local governments can use to access funds.

1.4 Scope of the Assessment

The scope of the assessment is vulnerability assessment (V-A) for the water sector in Greater Malang according to the "micro level-multi sectoral approach" (McLMSA) and – on this basis – formulate an appropriate adaptation strategy with precise adaptation options, which is endorsed by the local authorities. The assessment is worked in close collaboration with others experts of the scientific team.

The scope of the V-A for the water sector in more detail includes activities as follow:

a. Develop the conceptual framework and step by step easy to use methods for assessing climate risk on water sector and identification of data needs based on above methods to be completed for Greater Malang;
b. Collection, analysis and synthesis of the data for the water sector which cover surface water and groundwater, according to the methods mentioned above for Greater Malang;
c. Analysis of climate hazards and vulnerability of the water sector to the hazards for Greater Malang in collaboration with other experts within the scientific team;
d. Synthesis of climate risk for the water sector (in collaboration with the other experts within the scientific team) of Greater Malang;
e. Formulation of adaptation strategies on water sector in response to climate change for Greater Malangin collaboration with the local parliament, government and administration and other relevant stakeholders or institutions;
f. Facilitation of the mainstreaming process of the adaptation strategies into the local Development Policies for Greater Malang;
g. Provide input of water sector into the climate change adaptation and vulnerability database to be used by local governments and stakeholders of Greater Malang.

II GENERAL DESCRIPTION, WATER SECTOR, AND CLIMATE CHANGE ISSUES OF MALANG REGION

2.1 Regional Descriptions

Selection of the Greater Malang as a study area of Climate Change Risk and Adaptation Assesment (CRAA) on Water Sector were based on its role as a part of Brantas’ River. This river, along 320 Km empties into Java Sea and Madura Strait, with catchment area of 12,000 km^2 or 25% of East Java area (Jasa Tirta I, 2011). The amount of population in the Greater Malang with high dependence of water is about 3.349.503 people.

The use of water resources of the Brantas river consists of irigation about 340,000 Ha, poweplant with power capacity 239 MW, raw water supply for domestic use 240 million m^3, industry needs 135 $million^3$, and aquaculture about 15,000 Ha.

2.1.1 Location, Administrative, and Population

The Greater Malang consists of three administrative areas as part of Brantas’ upstream,: Malang District, Malang City, and Batu City (Figure 2.1). Malang District is located geographically at $112^0$17’12.25”- $112^0$57’28.17” east meridian and $7^0$45’41.86”- $8^0$27’53.58” south latitude with area 3,519 square kilometer (East Java in Numbers 2009). While, Batu City in north of Greater Malang located at $112^0$28’19.72”- $112^0$35’26.68” east meridian and $7^0$43’58.71”- $7^0$56’28.28” south latitude with area 189 square kilometer. Malang City, center of Greater Malang, is geographically located at $112^0$34’39.11”- $112^0$40’37.12” east meridian and $7^0$55’11.05”- $8^0$1’59.65” south latitude with an area about 110 square kilometer.

Based on data East Java in Numbers 2009, Malang District consists of 33 sub-districts (Malang District in Numbers 2009) with 12 villages (*kelurahan*) and 378 villages (*desa*), which 117 spread in urban and 273 in rural area. Malang City is divided into five sub-districts with 57 village where 54 spread in urban area and three in rural area. Batu City is divided into three district with 24 villages where 12 spread in urban area and 12 in rural area.

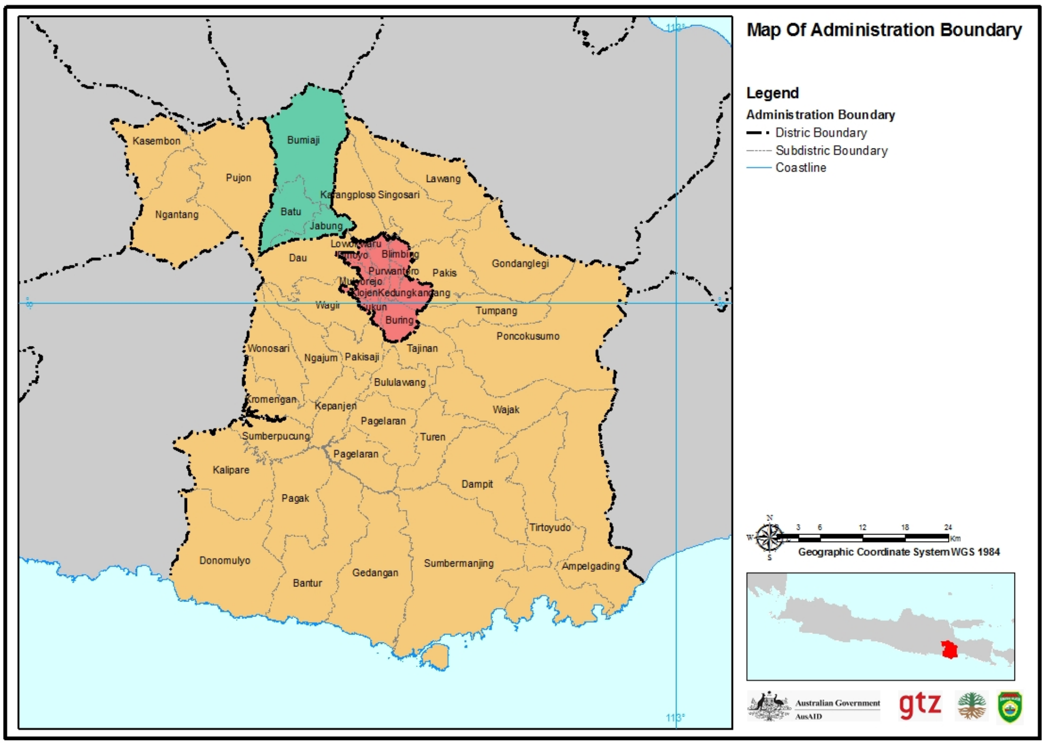


Figure 2. 1 Administration area of Greater Malang is consisting of Malang District (orange/brown colored area), Malang City (red area), and Batu City (green area).

The total population and its distribution, density, and growth are among the important parameters in water sector assessment. Based on the BPS (*Biro Pusat Statistik,* 2010), existing population of Malang District in 2008 is 2,413,779 peoplewith density of 810 people/km^2. Meanwhile, Malang City's population in 2008 is 816,637 people with density of about 7,420 people/km^2. Batu City has population about 119,087 people in 2008 with density of 925 people/km^2.Total number of population in Malang District is a second largest in East Java Province after Surabaya City. With a vast amount of area, Malang District has lower population density compared with Malang City or Batu City.

Growth rate of Malang District population based on 2000 census is about 0.67% per year. Region with highest growth rate of population is Pakis Sub-district with growth rate 2.07%, while the lowest is Ngajum Sub-district by -6.23%. Largest amount of population is located in Singosari Sub-district with139,594 people (2000), while the largest population density is Kepanjen Sub-Districts with 2,019 people/km^2. Malang City has growth rate 0.55% per year. Region with the highest population growth is Kedungkandang Sub-district with 2.72% and the lowest is Klojen Sub-districtabout -1.96%. The largest amount of population is located in Sukun Sub-district with 162.094 people (2000) 13,307 people/km^2. The largest amount of population in Batu City is located in Batu Sub-district 84.829 people. Batu Sub-district also has the highest density of population with 1,866 people/km^2.

2.1.2 Land Use

Changes in land use from natural area into built-up area, which often found in urban region, will reduce the infiltration capacity of surface water into the ground. These changes in land use will also be accompanied with increase in water demand, and the balance of water budget becomes greater in the demand side. Such change of land use will also increase the risk of flood events and extent the present of degraded area caused by erosion, which resulted in increasing river sedimentation. Hence, the existing land use and the prediction of its change in the future have to be considered in the assessment.

For the purpose of this study, land use map of Malang Region is already produced by GIS team. This map used raw data of landuse map of Malang City, Malang District, and Batu City for the year of 2009. Based on those data, using assumption that there is no significant of land use change from 2009 to 2010, as “land use map of Malang District 2010” (Figure 2.2)

In this map, the land use of Greater Malang is divided into 23 groups.Which then classified into ten groups based on the dominant of distribution area (See Figure 2.2). Those ten groups are: 1) dense forest (dark green colored), 2) bushes (light-green colored); 3) /dry-land agriculturee (light-pink colored), 4) fish pond (sky blue colored); 5) dry land agriculture (dark pink colored), 6) mangrove (lime colored), 7) plantation (dark red colored), 8) built up area or settlement (rose colored), 9) mixed farm (dark aqua colored), and 10) water body (light blue colored).

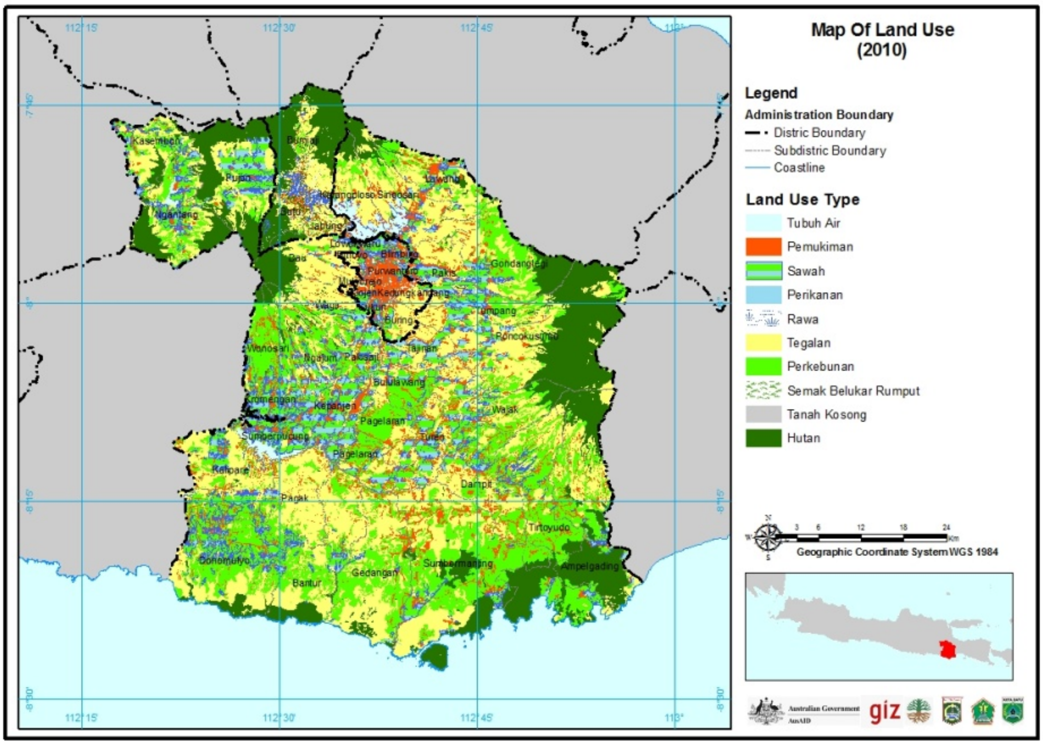


Figure 2. 2 Land use map of The Greater Malang Region, 2010
(*Source*: GIS team)

2.1.3 Economic Growth and Development

Economic growth is one of the indicators for regional development. Center of Statistic Office (BPS) counts a change in Regional Gross Domestic Product (RGDP), which shows economic activity on real sector in region and time. Economic growth of Province East Java in 2008 is 5.90%. Economic growth of Malang City in 2008 is 6.02%. Meanwhile, in 2008 growth economic of Malang District is 5.76%.

2.2 General Description of Water Sector

Description of water sector is important for providing information on current water resources including its quantity and quality, spatial and temporal distribution, and utilization; problem on water resources, including current hazards and vulnerability; and strategic issues on water sector in The Greater Malang. This water sector description is produced on the basis of field observation data and results of previous studies (secondary data). The data from field observation is used to update the secondary data. The previous studies concerning water sector of Greater Malang are:

1) Hydrogeological mapping of Indonesia, 1:250,000 scale, sheet X, Kediri, P. Jawa, by Center for Environmental Geology (CEG), Geological Agency (GA), 1984;
2) Hydrogeological mapping of Indonesia, 1:100,000 scale, sheet 1608-1, Malang, P. Jawa, by Center for Environmental Geology (CEG), Geological Agency (GA), 1998;
3) Secondary data from related institution/unit/offices in Malang District, Malang City, and Batu City consists of spring inventory, agency of water resource and energy, and regional water company (PDAM).

Water availability in Greater Malang region consists of water surface, ground water, and springs. Surface water is water with a source in surface of land such as river, lake, reservoir, and springs.

2.2.1 Surface Water

The Brantas as a main river and as water provider in the center of East Java has its sources from a complex of springs located in the Greater Malang area. Based on inventory of Water Resource and Energy Agency Batu City in 2005, Batu City has 11 springs with total capacity of about 78.37 litre/seconds.

Figure 2.3 shows the decrease of well water debit of the PDAM in the Malang City with the exception of the Supit Urang well.

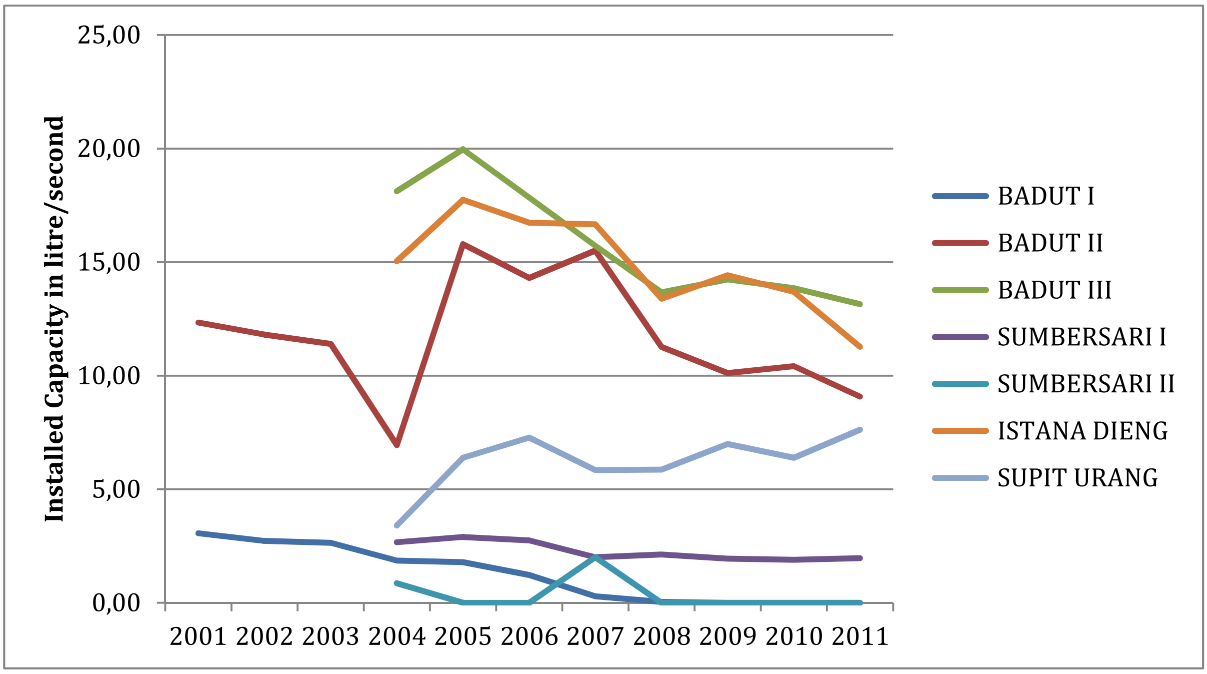
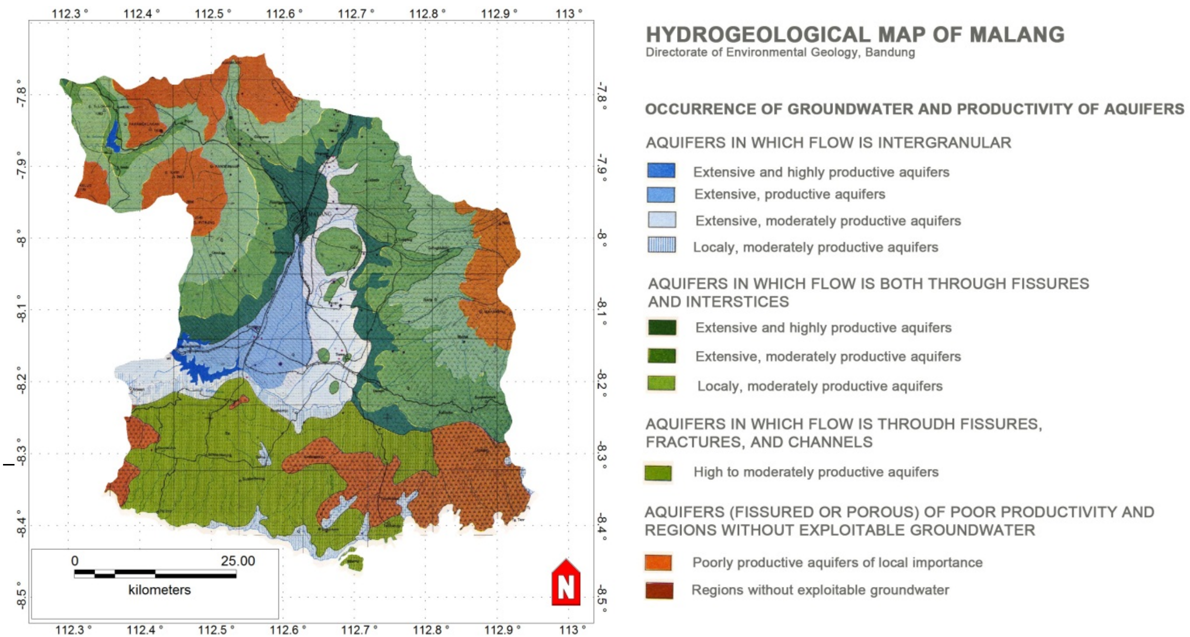


Figure 2. 3 Decrease of debit Wells water debit of Regional Water Company in the city of Malang

2.2.2 Groundwater

Groundwater is found in aquifers, which have capability of both stroring and transmitting groundwater (Schwartz and Zhang, 2003). An aquifer is defined formally as a geologic unit that is sufficiently permeable to supply water to a well.

Based on occurrence of groundwater, the Greater Malang can be divided into four systems of aquifers depend on its lithology as media(Figure 2.4). Those four systems are: 1) Aquifers in which flow is intergranular in the porous media was illustrated in blue; 2) Aquifers in which



flow is both through fissures and interstices in the slope of strato-volcanoes were illustrated in green; 3) Aquifers in which flow through fissures, fractures, and channels were illustrated in pale green;and 4) Aquifers of poor productivity and regions without exploitable groundwater were illustrated in brown.

Figure 2.4 Map of Groundwater Potential of The Greater Malang.

(Source: CEG, GA, 2009)

Based on the occurence of groundwater and productivity of aquifers, darker color shows the higher productivity of groundwater than lighter color in blue and green.Along the valley of Brantas River, the pontential groundwater is high. Malang's Hidrogeology generally consists of mid-high productivity at slope side into valley plain between mountains. Aquifers contuinity is mid-high with debits of wells could reach 50 litre/seconds.

2.2.3 Water Quality and Water Use

The groundwater quality is observed by the Enviromental Agency of Malang District. This observation is conducted in location of wells that proposed water discharge permit to Energy and Mineral Resource Office of Malang District. Locations for water quality measuerement covered area of sub-districts of Kepanjen, Karangploso, Bantur, and Jabung. Measurement result shows that groundwater quality in Malang Region, in general has meet standard of regional water quality.

The usage of surface and groundwater can be divided into instream and offstream use (Deming, 2002). Water use related to human use is belong to offstream use. This use can be divided into four broad categories: (1) domestic and commercial use; (2) industrial and mining; (3) thermoelectric; and (4) agriculture (irrigation and livestock). Based on data from East Java drink water company in Malang Region year 2001, the largest water use is from domestic use of about 93.99%. The percetage for commercial and industrial use is 2.81%. For Batu City, fresh water used mostly for non-domestic consumption with numbers as 90.57%.

2.3 Current Hazards and Vulnerabilities of Water Sector

Water sectors hazards happening in Malang area is a declination of water availability, especially fresh water. Experts for Water Resource Conservation Study Brawijaya University, Prof. Mohammad Bisri, said that water reserve in Malang City has reduced on the since last 20 years. Water recharge area fas become only 10 percent left (Radja op.cit. Bisri, 2011). This condition mainly as a result of change in land use for settlement and comercial area.

Most of population in Malang area use dug wells as a source of fresh water. When dry season, dug wells that take ground water is affected so that causing decrease in water level until some of wells dry. This condition will cause an effect of fresh water crisis. Affected regions are in the south of Malang District, which consists of four sub-districts namely Sumbermanjing Wetan, Pagak, Gedangan, and Kalipare. As whereas consists of Sukun and Belimbing sub-districts in the Malang City.

2.3.1 Floods

Jasa Tirta I record 6 (six) floods in the Brantas water catchment area that have a large impact on period of 2002-2006.

1) Floods in Lesti sub-district, Malang District on January 29, 2002 with collateral damage of 40 houses, seven bridges, and damaged observation tools.
2) Floods in Metro sub-districts, Malang district on December 8, 2002 with collateral damage of three units irigation dam with casualties one person,
3) Floods in Sumberbrantas, Batu on February 3, 2004 with collateral damage of 11 houses, one dam, three bridges, and livestock drifted away.
4) Floods in Brantas Hulu sub-districts, Malang city on February 3, 2004 with collateral damage of three houses, three bridges, and rupture of Water Company pipeline.
5) Floods in Pait sub-districts, Malang district on January 24-25, 2006 with collateral damage one bridge.
6) Floods in Seloatep sub-districts on January 24-25th 2006, with collateral damage of 36 houses and two Dams.

2.4 Strategic Issues of Water Sector, Climate Change, and Development

The Greater Malang which is located in the upstream of Brantas River has a big responsibility to maintain the water supply capacity. Development of the urban areas in the upstream will push the landuse change which has consequence to the balance of water availability. Due to landuse change, the catchment area will decrease which has a main impact that more run off reducing the availability of groundwater, and springs dry.

Another impact of the development of urban area in the upstream will increase the water demand. affect other sector such as agriculture, economy and health.

Water availability as a part of hydrological cycle is affected by the climate. The climate change will increase the uncertainty of the water distribution.

III METHODOLOGY OF ASSESSMENT

3.1 Framework of the Assessment

In this sub-chapter, we express in short the context of methodology and general framework used in the Climate Risk and Adaptation Assessment for Water Sector. However, apart from the explanation of methodology and general framework below, there are also assumptions and problem simplification.

The main framework of this study is shown in Figure 3.1.

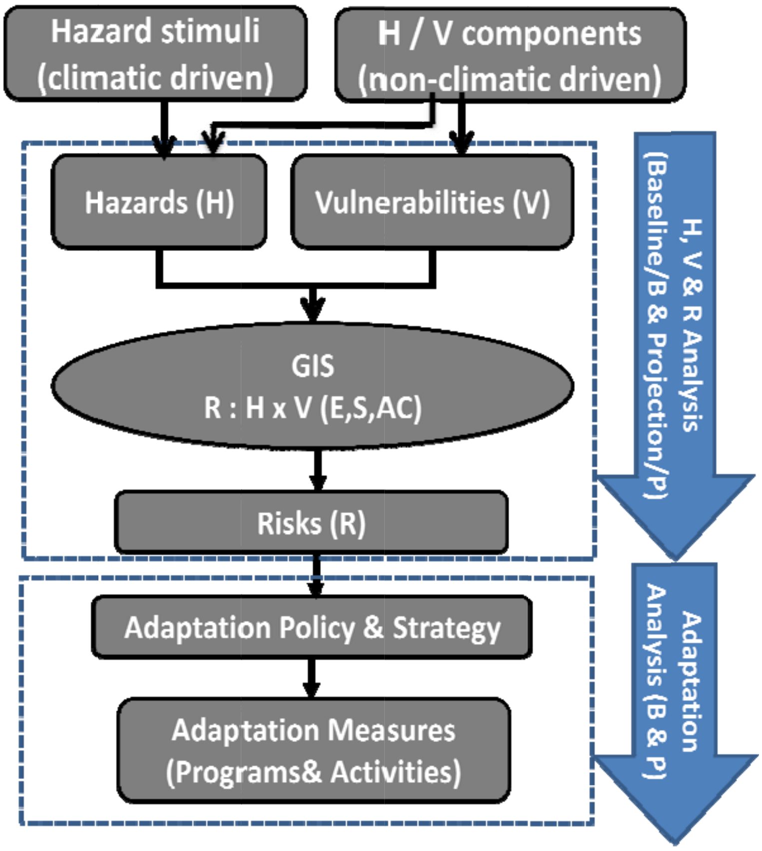


Figure 3. 1 Main framework for the climate change risk and adaptation assessment applied in this study.

Note: Main hazard stimuli (climatic drivers) are temperature increase and precipitation variability. R is risk, H is hazard, V is vulnerability, E is exposure, S is sensitivity, AC is adaptive capacity;

Assumptions about future trends are needed to show how the driving force on water sector is assumed to happen on the projection period. Thus, there are two assumptions, climatic drivers and non-climatic drivers. Assumptions about future trends in climatic driver are needed to limit the main stimuli from the climatic components affecting future water sector. As stated in the AR4, assumptions about future trends in non-climatic drivers are necessary in order to assess the vulnerability of freshwater systems to climate change, and to compare the relative importance of climate change impacts and impacts due to changes in non-climatic drivers.

3.2 Assumptions about future trends

3.2.1 Climatic drivers

As stated in the AR4, the most dominant climatic drivers for water availability are precipitation, temperature, and evaporative demand. The three drivers are also valid for the water condition of the Greater Malang. Precipitation involved in the climate change impact projection to water sector in The Greater Malang is the monthly precipitation. But, for several cases, if the data is available, daily precipitation is also used.

The temperature stimulus is also assumed important in determining the future water condition on The Greater Malang. The temperature data is obtained from the climate sector study; in this context it is also assumed to include sea level rise impact. The evaporative demand, due to the unavailability of ground level solar radiation data, atmospheric humidity, and wind speed, is assumed could be approached by only using temperature data. Another assumption is that for all of The Greater Malang, there is only one climatic data (Temperature T; and Precipitation CH) which comes from one observational station located on the island. In other words, it is assumed that there is no spatial variation in the temperature and precipitation of The Greater Malang.

3.2.2 Non-climatic drivers

As stated by the IPCC in AR4, water resources, both in quantity and quality, are influenced by land-use change, the construction and management of reservoirs, pollutant emissions, and water and wastewater treatment. Also, as stated in the AR4, water use is driven by changes in population, food consumption, economic policy (including water pricing), technology, lifestyle, and society's views of the value of freshwater ecosystems. In short, the availability and functions of water are very influenced by non-climatic drivers.

3.2.2.1 Population

Furthermore, it is important to calculate the population of each house to gain the spatial population density distribution in a more reliable condition in the baseline period. In this assessment, the population of each house is obtained based on the following assumptions: 1) population of each house is the same in a village; and 2) a house is a building with an area less than 500 m^2.

In the projection condition (2030), the general assumption is that population distribution will be distributed following the development of regions. The development can be indicated by road planning and is limited by the settlement planning. The development assumptions are:

1) population growth only happened in regions of settlement planning; 2) the existence of roads shows that the settlement is ready to be developed; and 3) population growth level is determined by the current population density.

3.2.2.2 Landuse

Land-use type strongly influences the level of risk. Current land-use as a baseline is based on the 2008 land-use from the BAPPEDA of Batu City, Malang City, and Malang District. Meanwhile, the 2030 land-use condition is taken from the 2030 Spatial Planning of those regions.

3.2.2.3 Role of Infrastructure

Natural disasters or impacts of climate change often cause great collateral damage. This happened if there are important infrastructures. The amount of this damage is difficult to measure but very real. As an example, if a landslide occurred on a road, then every activity on the road, such as public transportation and economy, cannot be continued.

Future infrastructure condition is difficult to project, but it can be assumed based on the 2030 Spatial Planning. The infrastructure classes are uniformed by using the type of infrastructures in the 2030 Spatial Planning.

3.2.2.4 Water Demand

The performance of water supply gets worse by higher water demand. The higher water demand can lead to shortage of water supply. Hence, water demand is an indicator which will be used to analyze the vulnerability and hazard of water shortage.

Water demand is analyzed from two components, they are population or domestic water needs and non-domestic water needs. Non-domestic water need was divided into agriculture and plantation. Based on the standard of WHO, domestic water needs is 150 liter/person/day and non-domestic water needs is around 9,000-14,000 m^3/year/ha (*FAO*). It is also difficult to predict the water demand in 2030 because of, among others, difficulty in establishing the projection of future industries built in Greater Malang. But based on the 2030 Spatial Planning of both of Malang Municipality or City and Batu City, the location of industries has been clearly depicted. The areas of industries in the 2030 Spatial Planning are assumed to be the areasof industries in 2030.

3.2.2.5 Water Sources

The impact of climate change to water availability will be felt by people according to the amount of water sources utilized. The higher the dependence of the water sources to climate, the bigger the impact of climate change felt. Water source, especially surface water and shallow groundwater of unconfined aquifer are sensitive to temperature rise and precipitation variability.

Water sources information used by the local people is obtained from the 2008 survey of village potency (*Survei Potensi Desa, 2008*). Based on the data, there are five water sources utilized by the population in Greater Malang: *1)tape/bottle water (drinking water company services), 2) drilled water, 3) dugwell, 4) spring, 5) river/lake, 6) rainwater, and 7) others.*Water Resources in Greater Malang was dominated by dugwell. In Malang City, most of the population in Malang City has used tape/bottle water.

3.2.2.6 Population Welfare

Other than government programs, society also plays a role in minimizing the impact of disasters or impact of climate change. This is what we address as adaptive capacity that will reduce the vulnerability. But the involvement of adaptive capacity of society is very depended on the ability or capacity of society itself. This ability or capacity of society is assumed could be approached from analysis of the social welfare condition.

In this study, assumption for social welfare is that its value can be considered from two sides, house types and society's income. With this assumption, the social welfare can be counted temporally (baseline and projection conditions) and drawn spatially. Currently, house types and society's income are based on the existing data. In the projection, social welfare is not included due to government program that assumed has the performance of maximum condition.

3.3 Method of Hazards Analysis

In general, method for identifying climate change hazards on water sector is conducted by analyzing the direct hazards or climatic potential of hazards with physical potential hazards using a suitable approach or analytical method for each related hazard, respectively. Based on the strategic issues of water sector, climate change, and development in The Greater Malang (see Chapter 2, sub-chapter 2.4 of this report), there are 3 hazards of climate change to water sector. These hazards, from the less important to the most important are water shortage, floods, and landslides. The direct hazards involved in the analysis are the results of climate projection of temperature and precipitation. Meanwhile, the physical potential hazards are any non-climatic drivers that is decreasing water availability or increasing the probability of floods or landslides, such as land-use change.

In more specific, hazards in this research are the result of hydrology modeling within the framework as shown in Figure 3.2. The hydrology models are derived to determine water availability, floods, and landslides. Climate data, baseline and projection, is used as an input in the hydrology model, i.e. precipitation and temperature data.

Hydrology model using secondary data is needed to verify the result of the model by fitting the hydrology condition, both in baseline and projection. Similar framework can be drawn for the groundwater modeling to identify climate change impacts to groundwater sources or groundwater recharge, especially groundwater in unconfined aquifer or shallow aquifer.

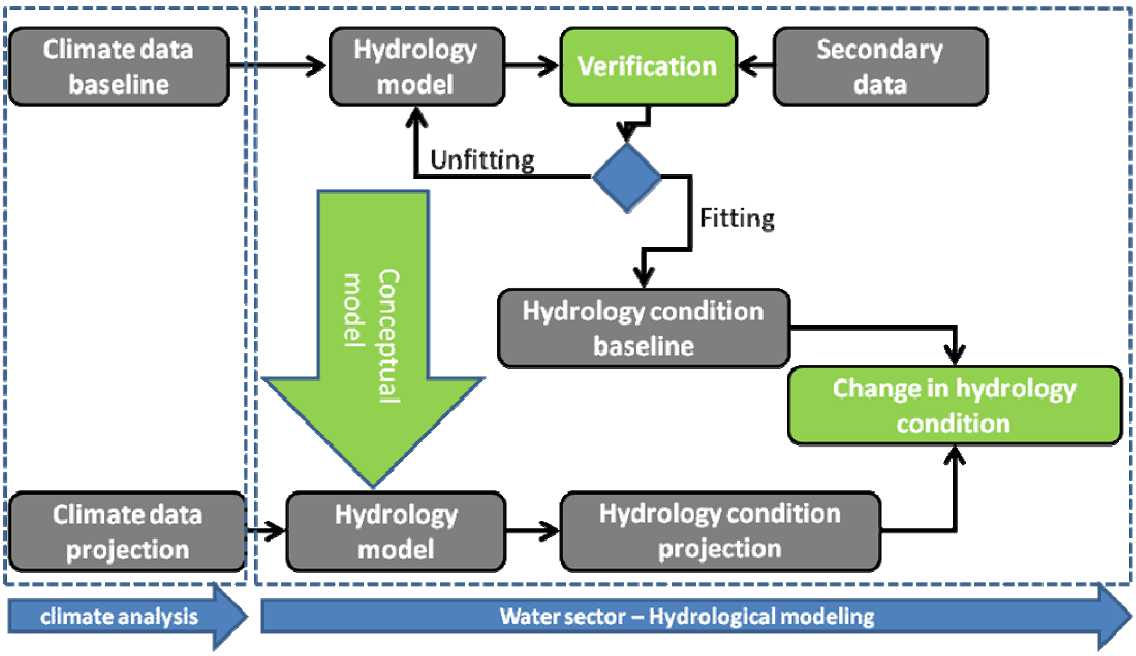


Figure 3. 2 Framework to determine climate change impacts to water sources (surface water). Similar framework can be implemented to groundwater.

Using the framework in Figure 3.2, all these hazards are modeled and fitted to both baseline and projection by following the hydrology and groundwater modeling. The names and/or processes of these modeling are explained in Figure 3.3.

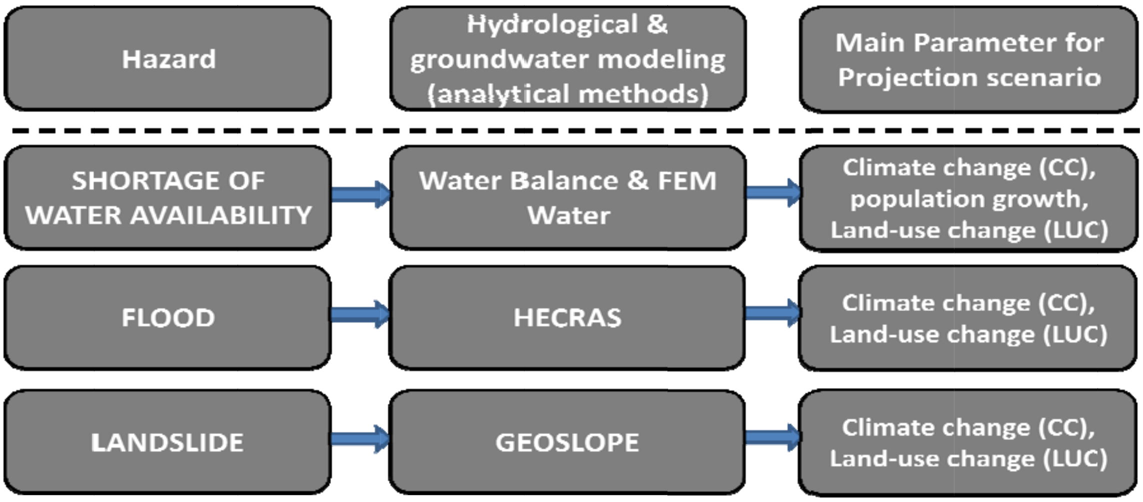


Figure 3. 3 Processes of modeling water sector into projection scenarios in climate change model.

General availability of data or data used in hazard analysis on water sector is presented in Table 3.1.

Table 3. 1 List of data used, sources, and user or related analysis

No.	Data Used	Data Sources	User (Analysis Tool)
1	Rainfall (mm/hour)	Science basis team	HEC-RAS (WMS)
2	Rainfall (mm/month)	Science basis team	Water balance,FEM Water
3	Temperature	Science basis team	HEC-RAS, Water Balance
4	Land-use	GIS team	HEC-RAS, FEM Water, Water Balance
5	Soil/rock type	GIS team	GeoSlope, FEM Water
6	Geology/geological cross-section	GIS team	HEC-RAS, Water balance, FEM Water
7	Recharge areas	GIS team	HEC-RAS, Water balance, FEM Water
8	Water usage areas	GIS team	FEM Water
9	Water table (groundwater)	GIS team	FEM Water
10	DEM	GIS team	HEC-RAS, GeoSlope, Water balance, FEM Water

11	Debit (river, groundwater)		HEC-RAS, Water balance

3.3.1 Method of water shortage hazard analysis

The hazard of shortage of water availability, or in simply, water shortage hazard (WS hazard) is analyzed based on direct climate change impact and physical potential hazard. The direct impact is the analysis results of climate scientific basis. The results consist of projection of temperature and precipitation. The physical potential hazards are water demand and quantity of water in watershed unit.

Water availability is the amount of available water that can be utilized. Water availability in nature is affected by climate variability and climate change.On the other hand, water availability in nature is also affected by human activities. Even sometimes, human activities have a great deal in the decreasing water availability. Based on these facts, water shortage can be interpreted as “the decreasing amount of water both naturally or due to human utilization”. If the amount of decrease is equal to the average amount of water we can say that there will be water crysis.

Water potential can be approached by using the water balance method. The general form of water balance equation is: **P = Ea + ΔGS + TRO**

Precipitation (P) will be used for evapotranspiration (Ea), surface run off (TRO), and then stored in the ground (**ΔGS).** The amount of water utilized directly by society is the surface run off or often called total runoff (TRO). Total runoff consists of Direct Run Off which is directly flowed on the surface when raining, base flow which becomes the run off of river bed through springs, and storm run off which is a run off on the unsaturated zone when the rain has a value of 5 – 10%.

The evapotranspiration in the formula mentioned above is calculated using Blaney-Criddle formula with modification. The formula based only on temperature (T) data. The formula with modification is taken because of the available data, for calculating evapotranspiration, spatially and temporally, is only temperature data.

Water balance calculation is best used in the watershed unit and monthly time series. The hazard analysis is based on the availability value in a watershed. The surface water availability value in a watershed is seen from the total run off value. Meanwhile, the current water shortage can be seen based on the changing value of total runoff cumulative probability 50 % ($TRO_{CDF50\%}$) in current period to the condition of total runoff cumulative probability 50 % ($TRO_{CDF50\%}$) in the baseline period. Meanwhile, the value of water shortage in the projection condition is the decreasing total runoff cumulative probability 50 % ($TRO_{CDF50\%}$) in the projection to the value of total runoff cumulative probability 50 % ($TRO_{CDF50\%}$) condition. The Baseline condition is defined as the condition of 1960 – 1990, current condition (or “baseline” with “b” in small letter)1990 – 2020, and projection condition is the condition of 2000 – 2030.

In this study, WS hazard is defined as decreasing water availability (DoWA) plus the value of water demand (WD) and divided by total water availability in Baseline condition ($Q_{Baseline}$ or $Q_{1960\text{-}1990}$) in watershed unit as expressed in the following formulation:

$$Water\ Shortage\ Hazard\ (WS\ Hazard) = \frac{(DWA + WD)}{Q_{Baseline}}$$

The DoWA (decreasing water availability) and total water availability in Baseline condition ($Q_{Baseline}$) are calculated using the method of water balance analysis. The TRO here is an important tool for calculating the DoWA and $Q_{Baseline}$. Cumulative distribution frequency (CDF) analysis, as illustrated in Figure 3.5, is used to further calculate the total runoff (TRO) data which is obtained from the water balance analysis. By application of the CDF methode it is possible to determine value of TRO which can generate the water shortage as the TRO below 50% on CDF graphic (see sample on Figure 3.5) denote the value.

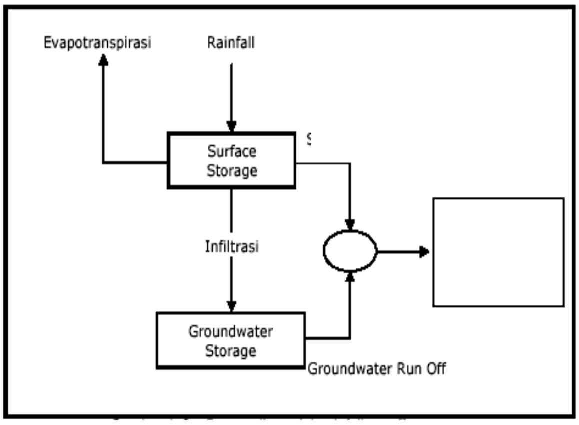


Figure 3.4 Conceptual framework of water balance analysis. The total run off or TRO = direct run off (DRO or surface run off + Groundwater run off

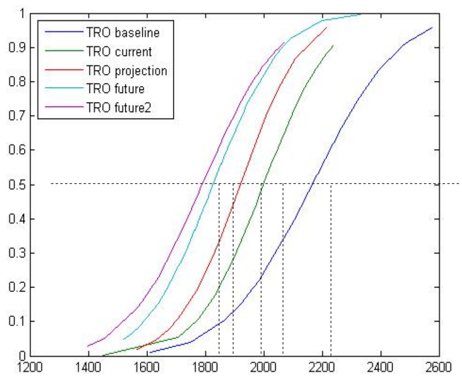


Figure 3.5 Illustration of cumulative frequency distribution (CDF 50%) for TRO baseline (1960-1990), TRO current (1991-2020), TRO proyeksi (2010-2030), TRO future (2031-2060) & TRO future2 (2061-2090)

Furthermore, the DoWA (decreasing water availability) is formulated as the probability of water decrease compared to normal condition (Baseline condition, or 1960-1990). The value of 50% TRO is taken as reference, while the value below 50% TRO indicates decreasing water availability. Hence, the DoWA in the formula mentioned above are :

(1) the difference between TRO of Baseline condition ($TRO_{Baseline}$) and TRO of current condition ($TRO_{current}$), or $DWA_{baseline} = TRO_{Baseline} – TRO_{current}$ for baseline or current condition; and

(2) the difference between TRO of current condition ($TRO_{current}$) and TRO of projection condition, or $DoWA_{projection} = TRO_{current} – TRO_{projection}$ for projection condition.

Finally, the DoWA is also influenced by water demand (WD). The higher the water demand, the bigger the magnitude of the hazard. The WD is calculated spatially based on the total population and industry for the baseline period; and based on population and type of land-use for the projection period. WD analysis uses standard water demand for each component of water user and assumptions as mentioned in section 3.1 and presented in Table 3.2 and Table 3.3 below. From the formula of WS hazard, it is clear that the unit of WS hazard is watershed or water catchment area.

Table 3. 2 Standard of water need for domestic use

Total population (household)	Connection to House	Connection to Public Facility	Water Demand in Average (m^3/day/person)
>1000	0.21	0.30	0.174
500 – 1000	0.17	0.30	0.170
100 – 500	0.15	0.30	0.126
20 – 100	0.90	0.30	0.78
0 – 20	0.60	0.30	0.54

Table 3. 3 Standard water needs in 2030 based on land-use

Land-use Types	Water Demand (m^3/day/ha)
Industries	50
Trades and services	40
Airports	40
Hospitals	30
Governmental offices	25
Religious places	25

3.3.2 Method of flood hazard analysis

Flood hazard model is using rational method. Flood hazard is modeled in two conditions or period, baseline and projection conditions or period. Flood hazard is determined based on the trend increasing of runoff in existing, baseline and projection.

- Identified Coefficient Runoff

  The runoff influenced by coefficient runoff of land use that has typical range 0.01 – 1. It must be assigned to every cell in the active grid. The assessment is using land use existing data from RBI Bakosurtanal and land use for regional development planning (RTRW).

Table 3. 4 Values of Runoff Coefficient (C) for Rational Formula

Land Use	C	Land Use	C
Business: Downtown areas Neighborhood areas	 0.70 - 0.95 0.50 - 0.70	***Lawns:*** Sandy soil, flat, 2% Sandy soil, avg., 2-7% Sandy soil, steep, 7% Heavy soil, flat, 2% Heavy soil, avg., 2-7% Heavy soil, steep, 7%	 0.05 - 0.10 0.10 - 0.15 0.15 - 0.20 0.13 - 0.17 0.18 - 0.22 0.25 - 0.35
Residential: Single-family areas Multi units, detached Munti units, attached Suburban	 0.30 - 0.50 0.40 - 0.60 0.60 - 0.75 0.25 - 0.40	***Agricultural land:*** *Bare packed soil* *Smooth *Rough *Cultivated rows* *Heavy soil, no crop *Heavy soil, with crop *Sandy soil, no crop *Sandy soil, with crop *Pasture* *Heavy soil *Sandy soil Woodlands	 0.30 - 0.60 0.20 - 0.50 0.30 - 0.60 0.20 - 0.50 0.20 - 0.40 0.10 - 0.25 0.15 - 0.45 0.05 - 0.25 0.05 - 0.25
Industrial: Light areas Heavy areas	 0.50 - 0.80 0.60 - 0.90	*Streets:* Asphaltic Concrete Brick	 0.70 - 0.95 0.80 - 0.95 0.70 - 0.85
Parks, cemeteries	0.10 - 0.25	Unimproved areas	0.10 - 0.30
Playgrounds	0.20 - 0.35	Drives and walks	0.75 - 0.85
Railroad yard areas	0.20 - 0.40	Roofs	0.75 - 0.95

- Identified extreme rainfall

Runoff analysis identified amount of extreme rainfall that occurs in the real time of flood events, extreme rainfall in the baseline condition and magnitude of increasing of extreme rainfall in the projection condition.

The Baseline condition is 20 previous years in 1990 – 2010 and the projection condition based on government planning is 2011 – 2030. The observation rainfall data showed rainfall extreme occurs in November 2003 with daily maximum rainfall in 312 mm, while monthly maximum rainfall occurs in December 2007 with 1159 mm. The daily maximum rainfall located in Brantas watershed.

Baseline monthly maximum rainfall data analyzed showed to increase 42 – 110 % in the projection condition (Figure 3.6). Based on rainfall analyzed, the increasing maximum extreme rainfall will be occured in Lesti watershed.

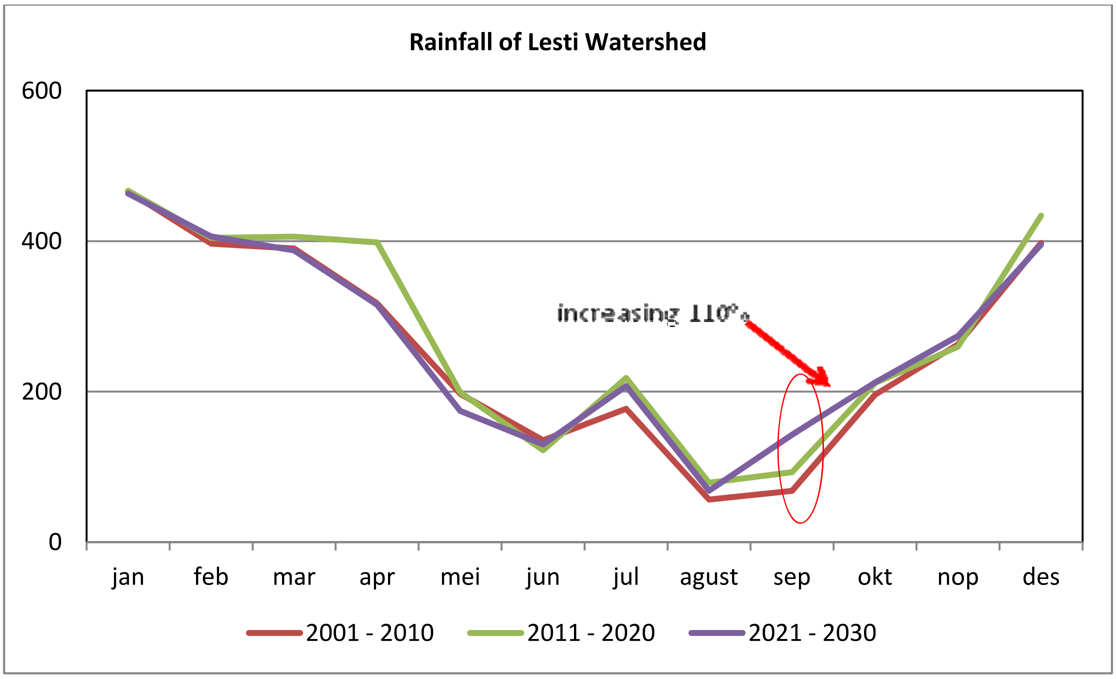


Figure 3. 6 Extreme Rainfall in Lesti watershed

- Runoff

Runoff is analyzed with rational method. The Rational Method is usually expressed in terms of the following equation:

$Q = c . i . A$

Where:

Q is the peak flow in m^3/hr,

C is the runoff coefficient of land use (dimensionless), I is rainfall intensity (m/hr)

A is area of watershed in m^2,

Runoff coefficients and loading factors were assigned to various land-use types within the watershed areas.

In this assessment the step first for the runoff analysis is determining runoff value for areas (villages) that have flood historical data. The second, based on extreme rainfall distribution analysis in baseline condition, the assessment will be determined the extreme runoff for baseline condition (1990 – 2010). The last, based on the magnitude of extreme rainfall from baseline to projection condition and land use change of RTRW, the amount of runoff projection will be knew. The runoff value will be determined the hazard levels.

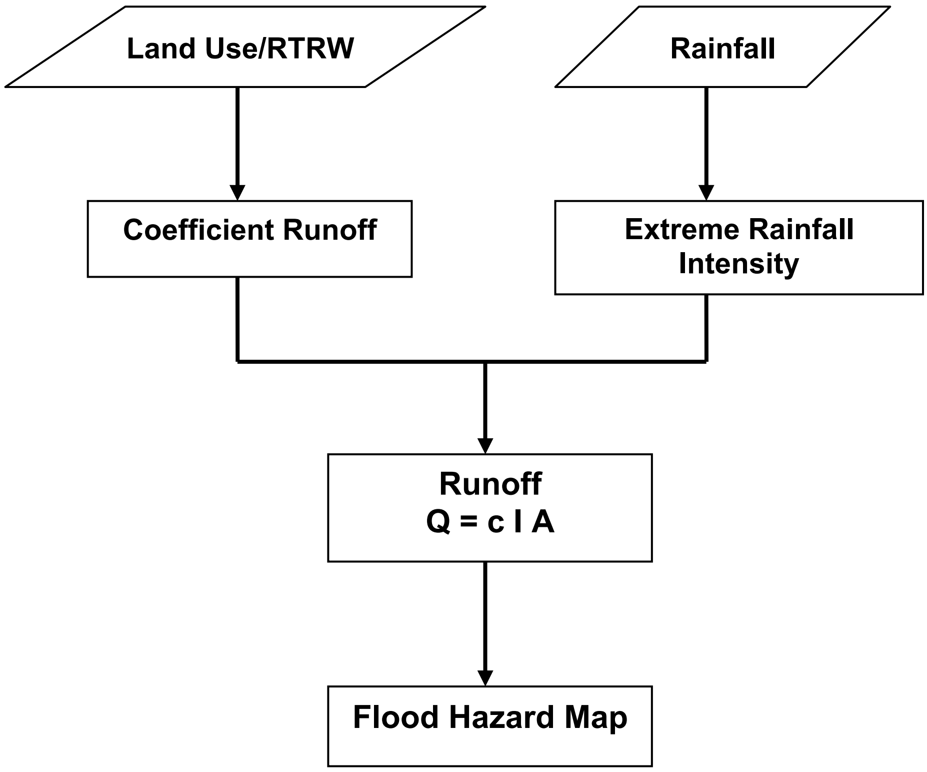


Figure 3. 7 Framework of flood risk assessment

3.3.3 Method for Landslide Hazard Analysis

Landslide hazard are usually trigerred by rainfalls as a climatic driven factor, geology, soil type, and slope. Several methods have been used to integrate the characteristics of extreme rainfall into the slope stability analysis. Climate change indicates a trend of rainfall change that is a one of landslide triggering factors. Landslide hazard assessment is analyzed by

Geographical Information Systems (GIS) method. The assessment techniques are used deterministic and statistical approaches. Deterministic approaches based on stability model that analyzed by Geostudio application, while statistical approach is used for weighting of landslide trigger factors. The method of statistical analysis to generate landslide hazard show at figure 3.8 below.

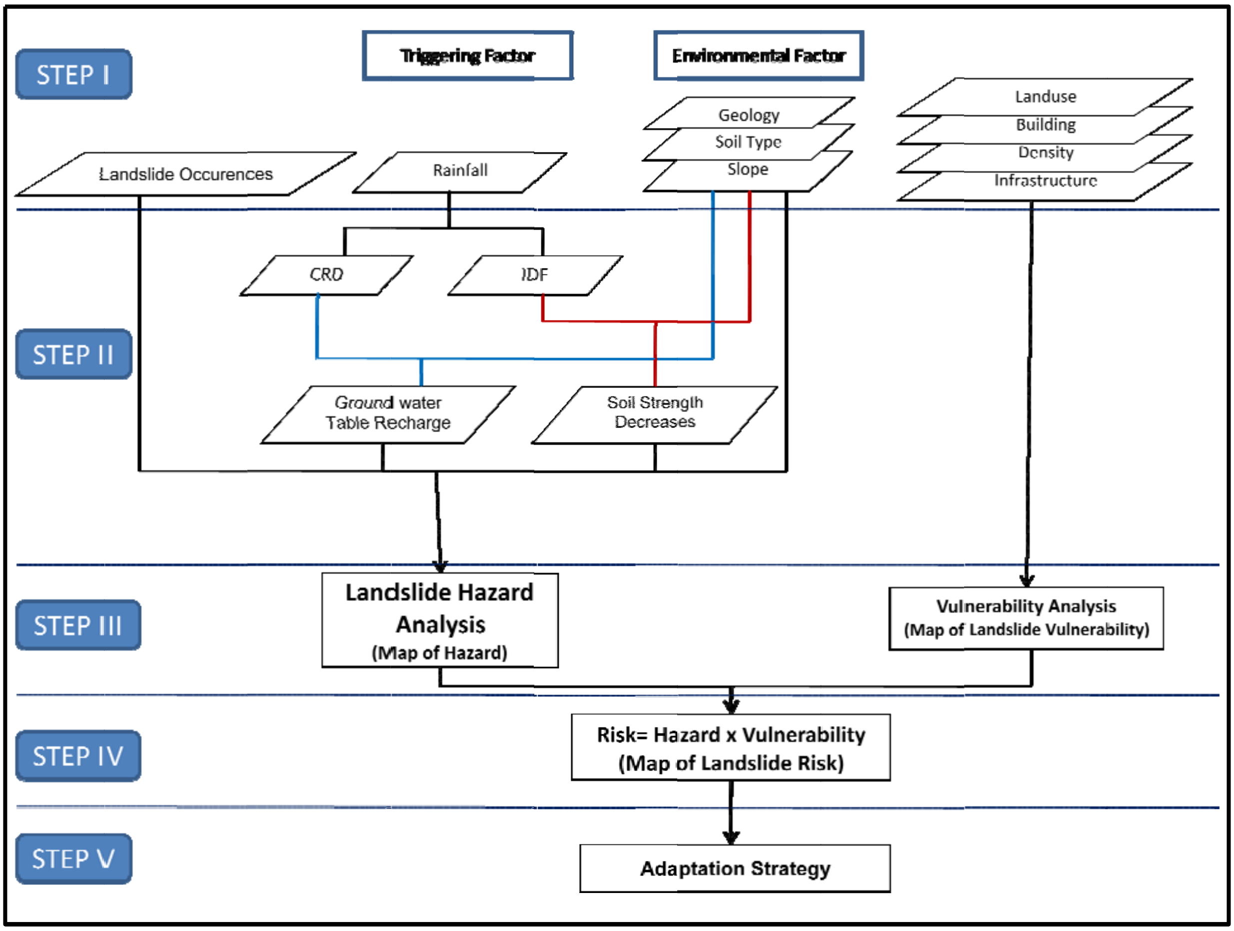


Figure 3. 8 Framework of landslide risk assessment

1. Landslide Occurrences Analysis

Mineral and Energy department of East Java Province had been identified 175 of landslide occurrences that spread in the Greater Malang Area where 47 of landslide occurrences were located in Konto watershed (Appendix B). The landslide occurrences are one of landslide hazard assessment indicators which will be analyzed by deterministic approach. According it, the landslide hazard will be analyzed by slope stability analysis that calculated a safety factor.

The slope condition will be declared as technically safety slope if index of safety factor > 1.5, while the construction will be declare unsafe if index of safety factor < 1.5. Landslide will be occurred if the safety factor < 1. The safety factors of landslide existing occurrences will be weighted as a baseline condition of landslide hazard.

In the projection condition, safety factor index will be influenced by ground water table recharge and soil strength decreases factors. The ground water table recharge will be analyzed by Cumulative Rainfall Departure method which strongly influenced rainfall and specific yield of soil, while the soil strength decreases will be calculated by Intensity Duration Frequency analysis.

a. Ground Water Table Recharge Analysis

The cumulative rainfall departure (CRD) method, based on the water-balance principle, is often used for mimicking of water level fluctuations. Because of its simplicity and minimal requirement of spatial data, the CRD method has been applied widely for estimating either effective recharge or aquifer storativity. The CRD value has a linier relationship with a monthly water level change. Ground water table recharge is analyzed into 2 conditions that are baseline and projection. The baseline condition determined in 1980 – 2011 period, and the projection in 2012 – 2030 period. Based on the result of CRD analysis, the highest of baseline water table recharge is occurred in the year of 2003 of 18 mm. in the projection condition, it will be occurred in the year of 2020 and 2029 with 20 mm and 19 mm.

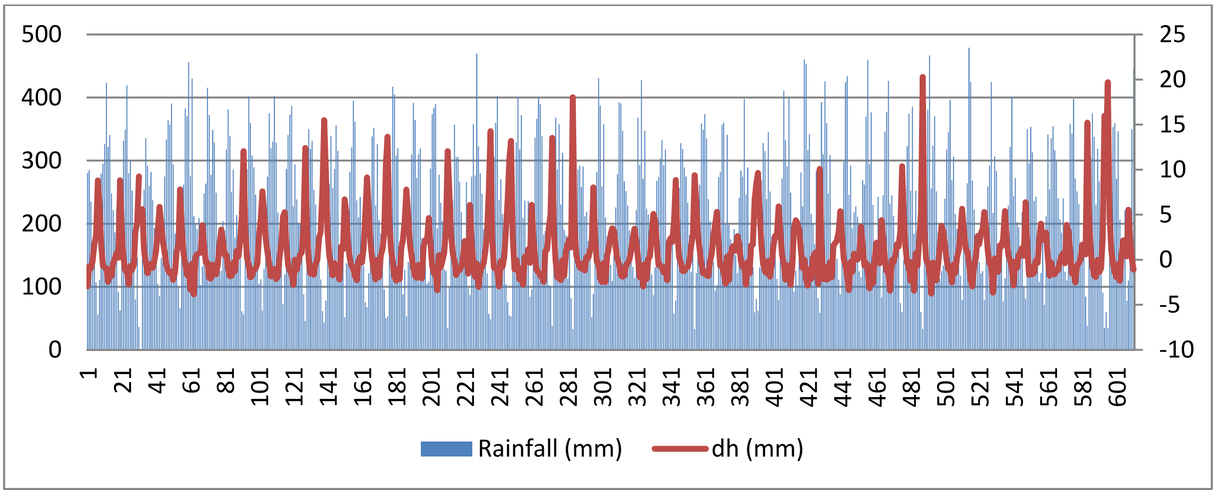
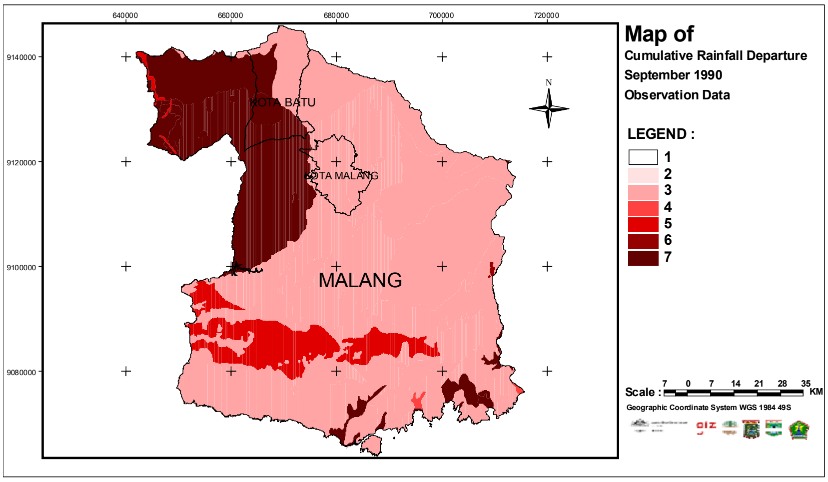


Figure 3. 9 One of CRD and GWT (long: 112.75; lat: -8.25) from 1980 – 2030 at malang tuf geology

The value of ground water table recharge will be distributed into spatial map of the Greater Malang that shown in figure 3.10



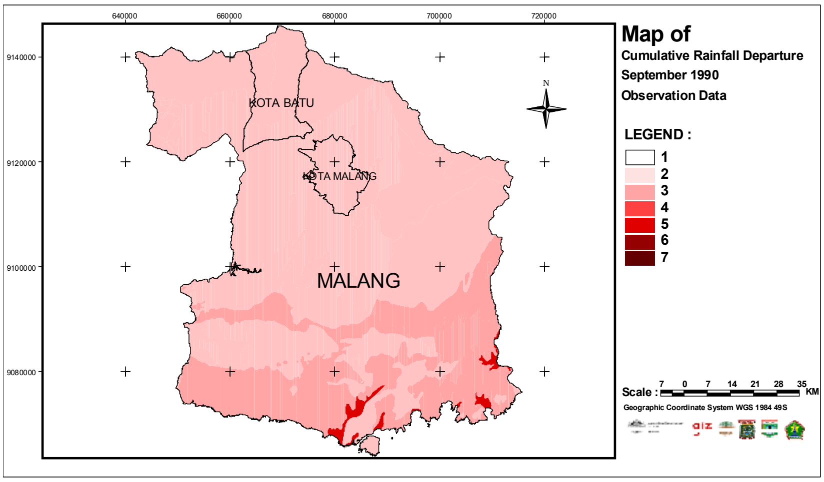


Figure 3. 10 (a) GWT of september 1990 using observation data, (b) GWT of September 1990 using simulation data (IPCC)

The result of ground water table recharge analysis will be divided into 7 levels that representing ground water table recharge scales which have probability to trigger landslide occurrence. The highest level of GWT is identified the highest probability to trigger landslide hazard.

b. Soil Strength Decrease Analysis

The soil strength decrease analysis identified intensity and duration of rainfall that affecting cohesion decrease. The analysis is using relation curve between intensity duration frequency of rainfall, hydraulic conductivity function, and soil water character curve. Based on the result of soil strength decrease analysis, in the one of landslide location, Waturejo village of Kasembon sub-district, the landslide will be occurred if the soil cohesion decreases when the intensity of rainfall has 21.38 mm/hour of > 1 hour duration rainfall. Based on it, in the projection condition, the landslide occurrences will be the worst.

2. The Environment Trigger Analysis

Besides rainfall factor, landslide hazard also triggered by geology and slope factors. According to the geology map of the Greater Malang, it shows the composition of rocks that are young vulcanic rocks, sedimentary rocks, porosity rocks, and old vulcanic rocks which formed at early Plistosen to end Holosen age . Geology type can be triggering landslide occurrence due to the physical and structure of geology. Based on it, the lithology is divided into 45 levels due to erosion rate that are very high, high, moderate, low, and very low which

Furthermore, the slope is the highest factor of landslide trigger. Based on digital elevation model (DEM), the Greater Malang region lies in the slope of 0^0 to more than 90^0. The slope map is divide into 6 classes which the highest class will be represented the highest slope

3. Landslide Hazard Assessment

The result of landslide occurrences and the environment trigger analysis have to export to GIS. Landslide hazard is divided into 5 levels that are very low, low, moderate, high, and very high. The landslide hazard assessment will be producing 2 maps that are landslide hazard map in the baseline and projection conditions. The landslide hazard baseline map is representing landslide hazard existing while the projection map is a combination weighting of all of landslide trigger factors that are landslide occurrence, potential landslide occurrence, geology, and slope factors.

3.4 Method of Vulnerability Analysis

Vulnerability is defined as a function of the character, magnitude, and rate of climate change as well as the degree of variation to which a system is exposed, its sensitivity, and its adaptive capacity (Affeltranger, et al, 2006 as quoted in Suroso, D.S, 2008). Thus, the components of vulnerability consist of exposure (E), sensitivity (S), and adaptive capacity (AC). The function initially is a multiplication between E with S factors and divided by AC factor as in the following formula: V = (E x S)/AC. The formula means vulnerability to a certain hazard is strengthened by its exposure and its sensitivity and decreased by its adaptive capacity. In this assessment, the function of V = (E x S)/AC is *pseudo* multiplication, because, in practice, the vulnerability (V) is gained from addition between the exposure (E) component with the sensitivity (S) component and reduced by adaptive capacity (AC) component.

Several sub-sections below explain the method of vulnerability assessment in facing hazard used in this study. The hazard which has been identified in previous chapter are water shortage, floods, and landslides. Hence, there are three type of vulnerabilities: vulnerability to water shortage hazard, vulnerability to flood hazard, and vulnerability to landslide hazard. The scopes of the explanation including method of identification and selection of vulnerability components as well as indicator of each components, method of assessment of water shortage vulnerability as well as method of flood vulnerability assessment and landslide vulnerability assessment; and method of analyzing and weighting each component of vulnerability.

In this study, we also implement dynamic vulnerability. Meaning, indicators of each vulnerability components are dynamic. To obtain the vulnerability results in a more reliable projection condition, an analysis of change of vulnerability indicators from baseline condition to projection condition is needed, both its number and distribution. Several analysis methods are needed to approach this dynamic vulnerability.

3.4.1 Method of vulnerability components identification and selection

In this step, we identify the vulnerability components E, S, and AC through each of its indicators for every hazard. Sources of identification are some related IPCC's publications, and previous study results in Indonesia, and discussions between experts in this VA Malang Greater study, also the results of focus group discussions with stakeholders from the government of Malang Greater.

Next, we select from the identification results based on certain criterions to determine final vulnerability indicators and components. The criterions are:

(1) The level of significant relation between indictors and hazards reviewed where the strongest significance will be chosen;

(2) Indicators have enough availability or its data can be calculated, both temporal (baseline and projection) and spatial, based on its available data parts; and

(3) Indicators are not yet involved in the analysis of hazard.

The next step is to map the indicators into one of the components of vulnerability: exposure, sensitivity, and adaptive capacity. Then followed by calculating the quantity, mapping the distribution, and weighting the vulnerability components based on its indicators in the baseline and projection period.

3.4.2 Method of assessment of water shortage vulnerability

Based on the benchmarking to literature studies (AR4 IPCC, ICCSR, VA Lombok, etc.) we obtained that indicators with strongest relation with the water shortage hazard are water availability, water demand, water sources as a part of water availability, water quality, population welfare, PDAM network as community's access to clean water source, local government's policies and programs on water management, initiatives and role of local community on water conservation, landslides, water sources damages, etc.

Based on the three criterions that have been mentioned above, we identify the vulnerability indicators for water shortage hazard, which are: population, land use, water demand, water resources used by inhabitant people, role of infrastucture and social welfare. These indicators wil be fixed in Chapter V of this study with each data sources presented in Table 3.6 below.

Table 3. 5 Indicators and sources of their data for water shortage vulnerability

Indicators	Data
Water Demand	• Population Census of Malang Greater , 2010 • Landuse 2008 • *Rencana Tata Ruang*Malang Greater, 2030
Water sources	• National Census, 2007
Population Welfare	• House type, Capital Income (Field survey, National Census, 2007)

Based on Table 3.6, methods used in the assessment of water shortage vulnerability are:

1) Calculating and mapping of water demand

Water demand (WD) is calculated based on the water needs of every water user, they are society, industries, etc. The difference of WD used as vulnerability components with WD in the hazard analysis is that the WD in the vulnerability is calculated per grid or distribution per grid with grid area = 100 m x 100 m or 1 hectare; while the WD in the hazard analysis is calculated per watershed unit.

Society's WD is calculated based on current population for the baseline and based on 2030 population for the projection condition. At first, water needs standard used is 144 liter/person/day for the baseline condition. After processed based on the classification of total households, the standard is modified into as in Table 3.2. For the projection condition, society's WD is calculated based on the projection of 2030 population. Population growth here uses values from BPS. Meanwhile, the water needs standard of the projection is assumed the same with the standard of baseline period (Table 3.2).

Society's WD calculation per grid with grid area of 1 hectare or 10.000 m^2, needs an approach to estimate the distribution of population density more reliably for both baseline and projection period. For the baseline period, we need the calculation of population distribution per every household in each village and the number of houses per grid area. In the projection period, we need data on 2030 spatial plan to calculate population development and its distribution in the same grid area. Thus, we use assumptions as discussed in sub-section 3.1.2 1) above, for both baseline and projection period. Findings of this population density distribution per grid method and its results are one of the results of this climate risk and adaptation study on Malang Greater Provinve which will be further discussed in Chapter 5.

Calculation and mapping of industries' and other's WD is based on the approach of land=use condition and standard water needs for every land-use. In the baseline condition, the number and distribution of land-use is obtained from the land-use map of Malang Greater Provinve of 2008, while the standard water needs per land-use unit is as shown in Table 3.3.

In the projection period, the land-use condition is determined by 2030 land-use approach derived from 2030 Spatial Planning of Malang Greater. The standard of water needs per land-use unit for the projection period is assumed the same with the standard water needs for every type of land-use in the baseline period (Table 3.3).

2) Calculating and mapping of water sources

Water sources are various sources of water that are used by population in Malang Greater for the baseline and projection periods. For the baseline, the calculation and mapping of water sources data is obtained from the 2008 survey of village potency (*Survei Potensi Desa, 2008*). Report of the survey consists of the data of each source of water used by people and its distribution in village as unit of distribution.

In the projection condition, based on the assumption that 90% of Malang Greater Provinve will be served by PDAM network, it is clear that 90% of water sources in every village are taken from PDAM service. Hence, map of this water source will follow the map of PDAM service networking. Here, the contribution of the others sources, which are 10% of total water source in the projection are neglected.

3) Calculating and mapping of water quality

Based on literature studies, swamp water on Kalimantan and its surrounding has a bad quality because possibly it contains iron or has a high acidity. Based on the data of water sources used by public, in Malang Greater, there are still people using river water, wells, and springs for its daily use. In the regions near swamps or regions which are previously swamps there are possibilities that the water quality from those three sources is contaminated by low quality swamp water. Meanwhile, in the projection period where there will be a decrease of water supply, swamp water may likely used by the public as a source of water.

The next method of this water quality vulnerability indicators study begins with extracting samples or checking other secondary sources of water. These water samples then tested at a laboratory to ensure its level of quality. The next step after the quality of water is obtained, is determining the source of water which fulfills the criterions to be a vulnerability component indicator.

The final step is to calculate the spatial distribution of these selected sources of water. To determine the distribution of swamp area, for instance, we can use an observational method with the help of Landsat ETM7 images of 2003 with the assumptions that has been mentioned in previous sub chapter. Other significant sources to water quality may also be calculated and mapped based on its distribution. In the projection period we assume that water quality is not significant as a vulnerability indicator because in 2030 it is assumed that PDAM's water service with a quality fulfilling the standard drinking water has reach 90% of the total population, and the 10% left can be ignored.

4) Calculating and mapping of PDAM's service network

Based on data availability, the reliable method to calculate and map PDAM's service network is by using the approach of population served by PDAM. Thus, we calculate the population percentage served by PDAM with its service network map in the baseline or current condition (2010) and projection period (2030).

5) Calculating and mapping of social welfare

As assumed before, social welfare is stated by two sub-indicators, they are type of house and population income. Hence, the calculation method of house type is based on the house type in every village through field surveys. Meanwhile, the calculation method of population income is done by analyzing data from the 2007 National Census. With these two methods, house type and population income can be calculated and mapped for each village unit. The two methods are calculation and mapping of social welfare for the baseline period (2010).

For the projection period, this social welfare is assumed not contributing to reducing the vulnerability. It is because of the government program to mitigate water shotage is assumed in maximum condition that is 90% PDAM service target is achieved.

3.4.3 Method of flood vulnerability assessment

Based on the existing literature references, we obtain a number of alternative indicators with strong relation to floods hazard. These indicators are: population density, land-use, watershed degradation, slope, rock type and its ability to absorb water, role of infrastructure, population welfare, and government program.

Based on the same criterions that have been applied in selecting the indicators of water shortage vulnerability, we can identify vulnerability indicators to floods hazard: population, density, land-use, role of infrastructure, population welfare, and government program as shown in Table 3.7. These will be fixed in Chapter V.

Table 3. 6 Indicators and sources of their data for flood vulnerability

Indicators	Data
Population Density	Population Census of Govt. of Malang Greater 2010
Land-use	Land-use 2008 (Malang Greater with modification)
Role of Infrastructure	PDAM Malang Greater 2005 and Landuse 2008
Population Welfare	House type, Capital Income (Field survey; National census, 2007)
Government Program	Infrastructures (Public Work Agency, Malang Greater Provinve, 2008)

Based on Table 3.7, two of the indicators are the same with the indicators previously used in the assessment of water shortage vulnerability, such as: population density (used in the calculation of water needs), and population welfare. Below are the assessment methods in detail for the floods hazard indicators.

1) Calculating and mapping of population density

The population density data used as the indicator of floods vulnerability is the same with the population density data calculated in the analysis of water needs in the assessment of water shortage vulnerability. In principal, the method of this population density study is calculating and mapping the population distribution as realistic as possible. The method has been discussed in the explanation of water demand indicator.

2) Calculating and mapping of land-use

To calculate and map the land-use type, we acquire sufficient data from the local government. The data includes: the 2008 land-use from the BAPPEDA of Malang Greater Provinve for the baseline period and 2030 land-use of the Spatial Planning of Malang Greater Provinve for 2030 with the assumption that have been mentioned in sub-sub chapter. The next needed study is to assess the data further to group the land-use based on the uniform land-use unit between baseline and projection period. This step is needed considering the difference of grouping between 2008 land-use and 2030 land-use.

3) Calculating and mapping of role of infrastructure

Role of infrastructure here, as mentioned in the assumptions, is infrastructures useful in preventing floods or overcoming impacts of floods. An example of this role is reservoirs used as floods reducer besides its function as water storage, and which is useful as clean water supplies for society suffered from the flood. Assessment in this case is in the form of calculating and mapping infrastructures useful to prevent floods and accelerate recovery from floods impacts. Data used include: current infrastructure data of PDAM's service and 2008 land-use map for the baseline period. For the projection period the same assessment will be done using the 2030 Spatial Planning. With the assumptions, the infrastructure classes can be assessed by its roles to floods.

4) Calculating and mapping of government program

As stated in the assumption about future trends, the government programs are any treatment from the government to handle landslides to government facilities and important infrastructures which suffered from floods. Those government programs are for the baseline period. Hence, the methods that will be done here are assessing the location of government program related to floods that has been implemented or planned to be acted in the next couple of years and drawing their magnitude and distribution on the map.

Meanwhile, for the projection period, it is assumed that the role of government program in the projection is in the maximum condition. It means that government program in anticipating flood in the projection period will cover all areas of Malang Greater Provinve. Being in this assumption, the method for calculating and mapping the government program for the projection period can easily be done by tracing the location of the landslide in the projection period.

5) Calculating and mapping of social welfare

The social welfare indicator for floods is as the social welfare indicator for the water shortage vulnerability. Hence, the method used to calculate and map the social welfare in this floods vulnerability is the same with the method of study of the social welfare in the water shortage vulnerability.

3.4.4 Method of landslide vulnerability assessment

Using the same method as in benchmarking the alternative indicators to water shortage and flood vulnerability, for vulnerability to landslides, there are several vulnerability indicator options: population, density, land-use, watershed's critical level, slope, rock type andits ability to filtrate water, ground water surface, roads position to hills, role of infrastructure, settlement distribution, population welfare, government program, etc.

Based on the criterions used, we can identify indicators for landslides vulnerability as population, density, land-use, role of infrastructure, population welfare, and government program (Table 3.8). These temporary indicators will be fixed in Chapter V.

Table 3. 7 Indicator and sources of their data for landslide vulnerability

Indicator	Data
Population Density	Population Census Govt.Malang Greater 2010
Landuse	Landuse 2008 (Government of Malang Greater, with modification)
Role of Infrastructure	PDAM Malang Greater 2005 and Landuse 2008
Population Welfare	House type; Capital Income (Field survey, National census, 2007)
Government Program	Roads (Public Work Agency, Malang Greater, 2008)

Vulnerability indicators to landslides and its sources (Table 3.8) are the same with the indicators and its sources used in the assessment method of flood vulnerability as in Table 3.8. This is due to data availability which prevents landslides vulnerability indicators to acquire more complete data.

Based on the comparison of Table 3.7 and Table 3.8, methods used in the vulnerability assessment to landslides are the same as the calculation and mapping methods of vulnerability to floods. In this case, we don’t need another discussion on the assessment of vulnerability to landslides.

3.5 Method of Risk Analysis

Following the definition of Risk (R) as function of Hazard (H) and Vulnerability (V) or R = f (H,V), risk analysis conducted after hazards and vulnerability have been identified by using GIS method. In this study, the function (f) is addition rather than multiplication or R = H + V. Using weighting method and GIS analysis, risk map of every hazard and vulnerability to the related hazard is produced.

IV ANALYSIS OF HAZARD DUE TO CLIMATE CHANGE

4.1 Direct impact of climate change related to water sector

The increasing temperature and precipitation variability are among the direct impacts of climate change. In water sector, temperature and precipitation are the main agent that determines natural water supply. Temperature projection, based on GCM output, results the model matched the temperature trend during the last 25 years, which signifies the effect of global warming as shown in Figure 4.1 (Hadi et al, 2011).

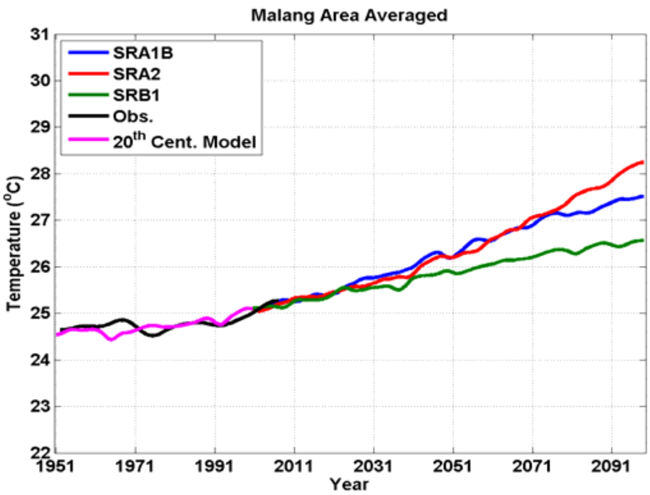


Figure 4. 1 The GCM output based projected temperature of Malang for the 21st century with an extension back to 1951 (20th century). Data has been smoothed to show only the long-term trend (Hadi et al, 2011).

Temperature T during the projection period experiences an increase in all scenarios. Climate projection results until 2030s show tendency of increasing average temperature as high as 1ºC for all scenarios (B1, A1B, and A2). ***Source*****: Hadi et all, 2011)**

All projection scenarios shows projected almost similar temperature trend until 2030 with an increase of about 1°C compared to the 1961-1990 baseline period. Based on IPCC model, the temperature will further increase by about 2°C until the end of the 21st century with A1B and A2 scenarios. In this study, evaporative demand is calculated by using Blanney-Criddle formula in water balance analysis. The significant temperature rise will trigger significant impact in evapotranspiration rise. This rise will be followed by decreasing TRO – caused by non climatic factor – which will cause water shortage hazard.

Meanwhile, the monthly average precipitation (CHavm) on the projection is varying but in general it shows trend of decreasing trend in the period 2011-2030. As in the scientific basis analysis, CHavm in the projection period of 2011-2030 actually experiences variability or up and down in the period of 5 to 10 years. But the general trend of CHavm in the projection period of 2011-2030 is decreasing.

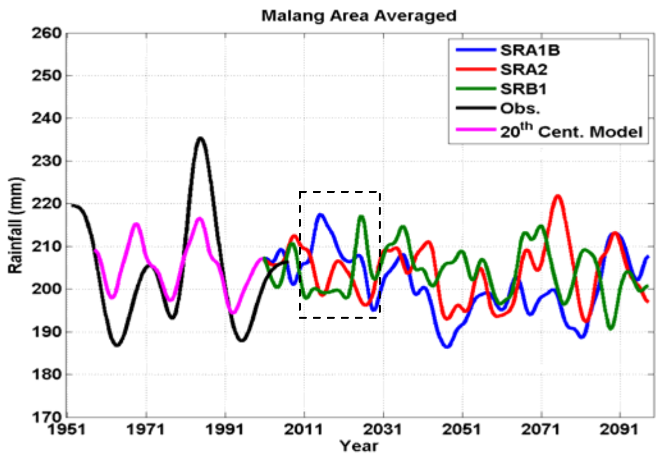


Figure 4. 2 Average rainfall increase pattern on Malang Area in 1951–2010, observation (black) and 20th century model (pink); SRA1B (2011-2091) scenario (blue), SRA2 (red), and SRB1 (green) from climate analysis (Hadi et al, 2011).

In the box, 2011–2030 projection shows precipitation variability with general trend of decrease, consistent for all scenarios with an exception with SRB1 scneario. The lowest decrease in scenario SRA1B of 2021-2030 period. There is a trend of interdecadal decrease in 2040-2050 and 2075-2085 although the decrease is not as low as the 1961-1970 period.

4.2 Water Shortage Hazard

Water shortage hazard is formulated as the probability of decreasing water supply in the normal condition, stressed by the condition of water demand, compared to the water supply of normal condition. The normal condition is assumed as 1960-1990 (Baseline).

The main indication of water shortage hazard is the tendency of decreasing precipitation as stated by the results of climate analysis, where 1960-2030 precipitation fluctuated, but had a decreasing trend (see Figure 4.2). The consistent temperature rise since the baseline period is predicted to increase potential evapotranspiration (ET) ensuring the threat of natural water supply.

The next indication is the increasing population and landuse change in Malang, which increase needs of water. This is the contributing factor which is not driven by climate change impact. Water needs increase will rise and stress the hazard.

Next we study the hazard components influenced by non climatic drivers, which are water needs per watershed and water supply in the baseline condition as comparison of the water shortage hazard. The last part of this chapter will discuss the calculation results and mapping distribution of water shortage hazard in the Greater Malang along with its weight.

4.2.1 Climatic drivers of water shortage hazard

Based on the climate data in Appendix 3.1, we analyze Potential Evapotranspiration (ET) and water balance which produced Total Runoff (TRO), Base Flow (BF), Direct Runoff

(DRO) and Storm Runoff (SRO) data in mm/year from 1960-2100. The analysis results water balance of the Greater Malang as shown in Figure 4.3 and 4.4.

It can be seen from Figure 4.3 that the decreasing trend is greater along with time (year) for the following variables: Total Runoff (TRO, green), infiltration (IF, tosca green), Direct Runoff (DRO, yellow green), and Base Flow (BF, purple) from 1960 to 2080. The decreasing variables that are the indicators of water availability shortage are variables of TRO, IF, DRO, and BF. These curves are proves of future water shortage hazard, beside the decreasing CH trend and temperature rise.

The decrease in water availability is calculated from water balance. The main factor for the water balance calculation is landuse data. Landuse change of forestry and vegetation contributed in water distribution, which flows on land surface or infiltrate into soil and rock. Considerated land use change that influence calculation were shown in Figure 4.3 and 4.4.

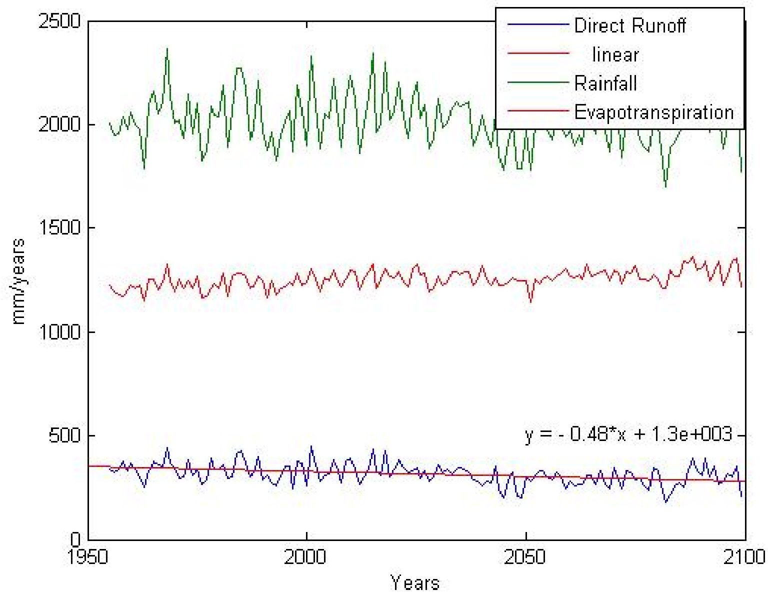


Figure 4. 3 Direct Runoff calculated without landuse change. It shows the decreasing annually about 0.48 mm.

Calculation results of water balance for periods 1961-2100 without considering change in landuse shows the tendency of decrease of runoff. Two scenarios of land use change results different runoff values. Calculation of water balance without change in land use consideration results runoff values that decrease 0.48 mm every year as shown in Figure 4.3. Calculation of water balance with change in land use results runoff values that increase 2.8 mm every year as shown in Figure 4.4.

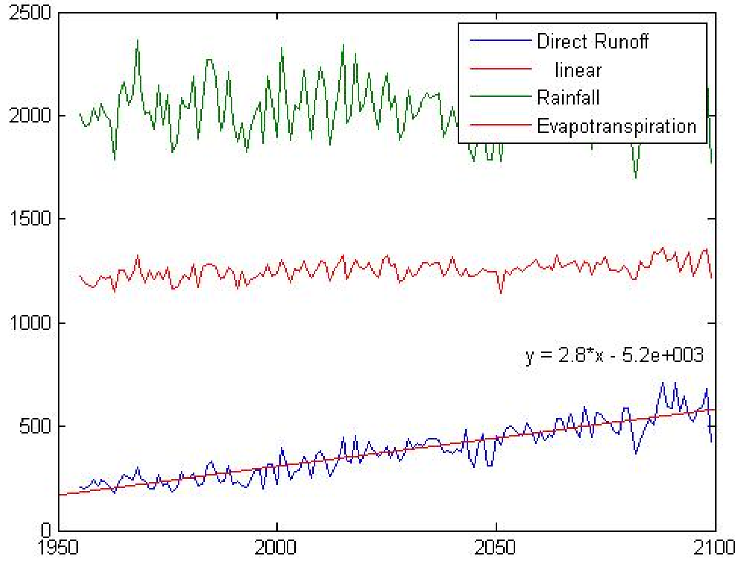


Figure 4. 4 Direct Runoff calculated with landuse change scenario. It shows the increasing annually about 2.8 mm.

Process of evapotranspiration, which evaporates water back to the atmosphere, is reducing factor that contribute for reduce of water availability. Because of evapotranspiration, evaporated water increases 0.5 mm every year as depicted in Figure 4.5. This event is hugely influenced by surface temperature that reach 1°C in 2100 compared with 1961 period. In period interval, variance of decrease-increase of evapotranspiration reaches 50 mm. The maximum increase that corelate with increase of air temperature occurred in interval of 1961-1970, 2010-2030, and 2080-2100. The minimum evapotranspiration value occurred at the beginning of 1960 and 2050. Tendency of evapotranspiration variance increases in harmony with the rise of air temperature.

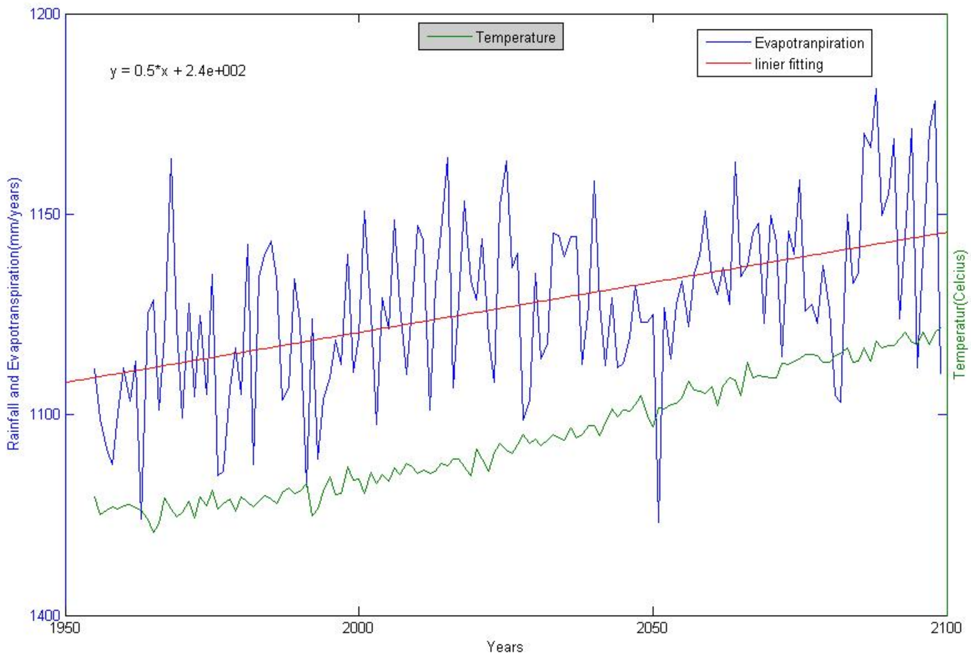


Figure 4. 5 Blue: magnification of ET (mm/year) vs time (1960-2090). Red: linier regression of ET vs year, with equation y = 0.5x + 2.4 * 10^2

Figure 4.5 shows an enlarged evapotranspiration (ET) trend to show the increasing ET from year to year. The linier line formulation, y = 0.5*x + 2.4e+002 or y = 0.5x + 2.4 * 10^2 is the linier regression from the evapotranspiration (ET) curve where y is the evapotranspiration in mm/year and x is year, from 1960 to 2090. Evapotranspiration is the amount of water evaporates from Malang from 1960 to 2090, and increasing trend means decreasing water supply.

Influence of rise in evapotranspiration value would enlarge water distribution reducing factor, whether flows above or below land surface. Amount of water flows is represented by Total Runoff (TRO) value. The previous water balance calculation shows different direct runoff value on land surface for two condition as a cause of land use change, then Total Runoff show a tendency for decreasing value for those two condition (Figure 4.6 and 4.7).

For a calculation without land use change consideration, total runoff shows linear decreasing value 1.05 mm per year with average total decrease in periods 1961-2100 reaches 150 mm. Meanwhile, calculation with land use change shows total runoff decrease linearly 1.1 mm per year. This condition shows significant influence from land use change toward water availability in Greater Malang region.

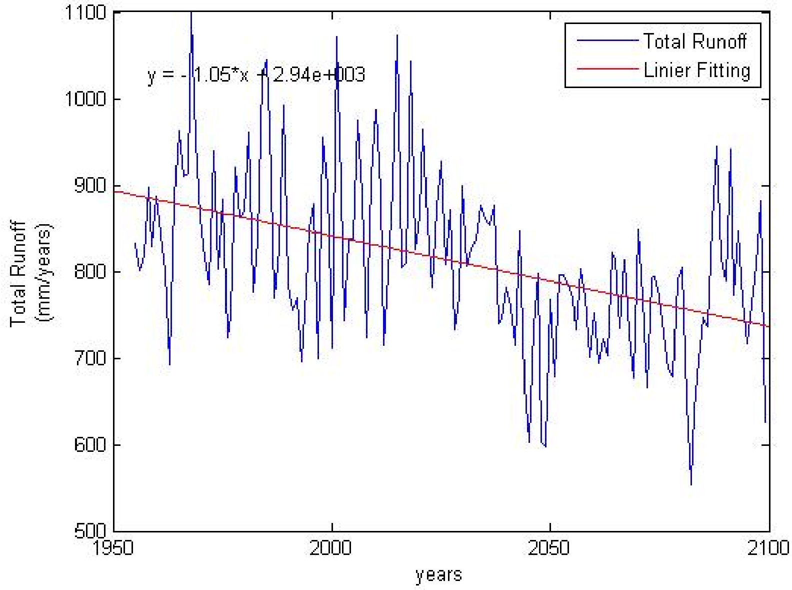


Figure 4. 6 Total Runoff calculated without landuse change. It shows the decreasing annually about 1.05 mm.

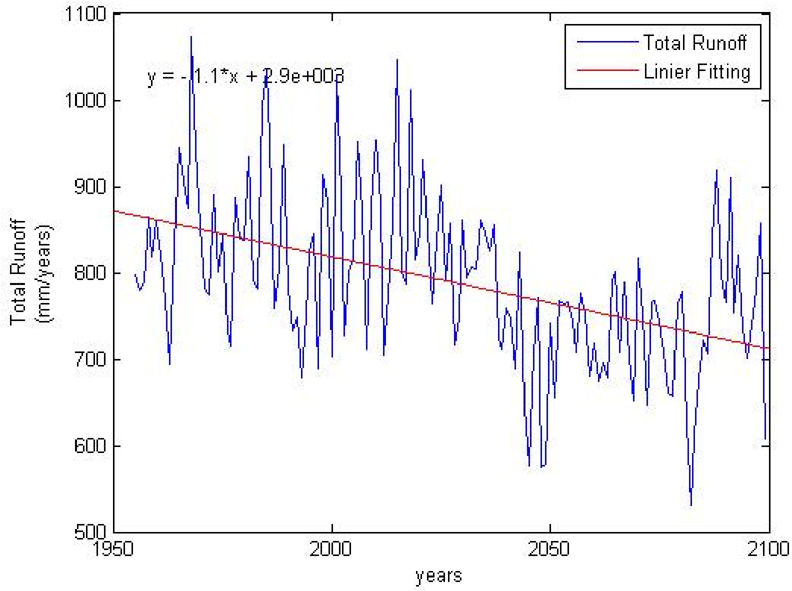


Figure 4. 7 Total Runoff calculated with landuse change scenario. It shows the decreasing trend annually about 1.1 mm.

4.2.2 Non-climatic drivers of water shortage hazard

The indicator of non-climatic drivers of water shortage hazard is defined by water demand. There were two parameters used to calculate water demand in Malang Region, which are population numbers and landuse change. Number of population is used to calculate domestic water demand using the standard of 150 liters per day (source: FAO).

For non-domestic water demand, the numbers are calculated based on the amount of total area of land coverage of agriculture, plantation, and industry using standard water needs of each land use.

At baseline condition, largest water demand or water need in Malang is concentrated at Malang City region (Figure 4.9). There were five clasification for every water need value based on area size, those clasification are: (1) 0-40,000 m^3/years/Ha; (2) 40,001-80,000 m^3/years/Ha; (3) 80,001-120,000 m^3/years/Ha; (4) 120,001-160,000 m^3/years/Ha; and 160,001-200,000 m^3/years/Ha.

The water need values are distributed evenly in high population regions such as valley between mountains. In average, the largest water need occurred in the interval of 40,001-80,000 m^3/years/Ha. Population’s water need increases at the projection condition, indicated by increase of color intensity that moving towards red color in the maps (from Figure 4.8 to Figure 4.9) with distribution goes to the north and south directions.

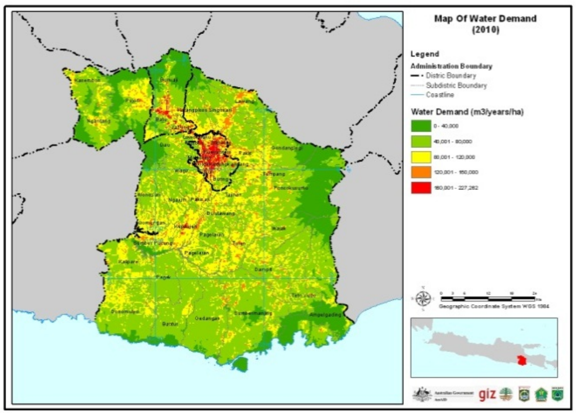


Figure 4. 8 Map of water demand per Sub-district unit, for the baseline/current period.

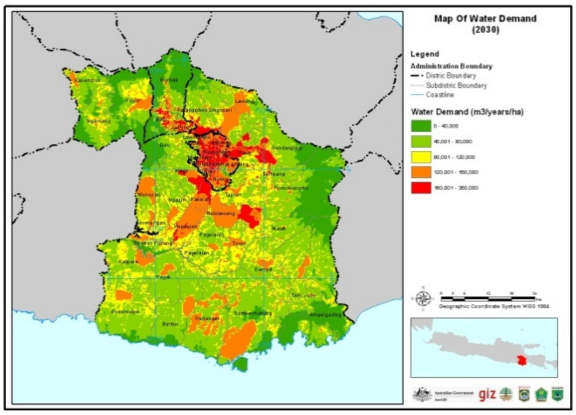


Figure 4. 9 Map of water demand per Sub-district unit, for the projection period.

As based on the watershed, the largest water demand of Greater Malang at baseline condition is clasified more than 12 million m^3/month at east watershed (Amprong and Bango) and west of Greater Malang (Figure 4.11). Meanwhile, at projection condition water demand based on watershed could increase at the center of Greater Malang watershed (Figure 4.12).

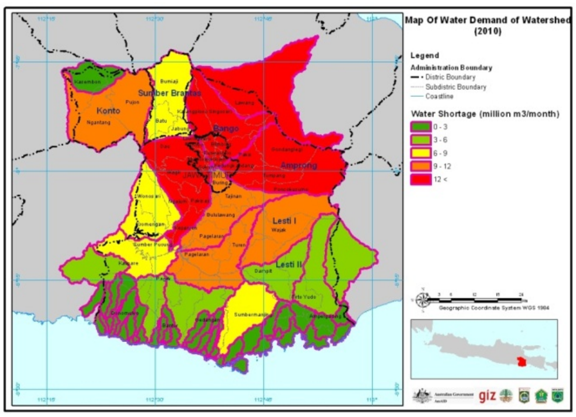


Figure 4. 10 Map of water demand per

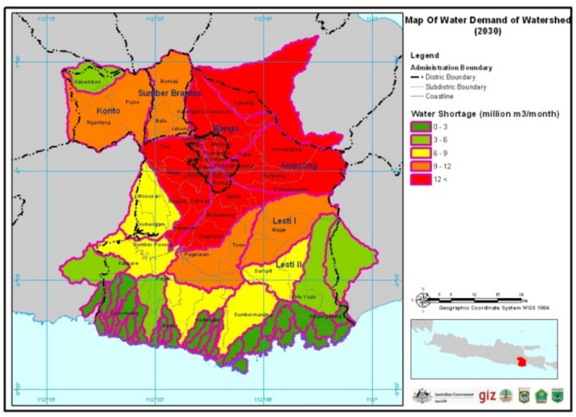


Figure 4. 11 Map of water demand per

watershed, for the baseline/current period. **watershed, for the projection period.**

4.2.3 Figure of water shortage hazard

As in Chapter 3, water shortage hazard or hazard of decreasing water supply in this study is formulated as the probability of decreasing water amount from the normal condition which will be worsen by the water demand. The probability is approached by the analysis of CDF to TRO in the 50% CDF. The analysis of CDF has shown that the TRO 50% CDF tendency to decrease consistently from the baseline (1960-1990), current (1991-2020), and projection (2010-2030), even continued to future (2090, see Figure 4.6). In its implementation, the amount of water shortage and water demand per district as hazard indicators are then compared to the water amount of normal condition, the baseline condition of 1960-1990. So, the form of water shortage hazard (WSH) is obtained from overlaying the decreasing of water availability (DoWA) with the water demand (WD) and compared to the water amount in the baseline condition ($Q_{Baseline,1960-1990}$). Mathematically, it can be approached with **WSH = [(DoWA + WD)/ $Q_{Baseline,1960-1990}$] with watershed unit. At WSH baseline defined as $WSH_{baseline}$ = [($DoWA_{baseline}$ + $WD_{baseline}$)/ $Q_{Baseline,1960-1990}$], Meanwhile WSH projection defined as $WSH_{projection}$ = [($DoWA_{projection}$ + $WD_{projection}$)/ $Q_{Baseline,1960-1990}$].** From this approach, and the temporary results of sub-chapter 4.2.1 on decreasing water availability and sub-chapter on water demand (Figure 4.9 and Figure 4.10), we can create the map of water shortage hazard below (Figure 4.11 and Figure 4.12).

Hazard level of decrease in water availability in the Malang Region generally is dominated by moderate-high hazard level. Moderate hazard level is distributed around the Malang City from west, north, into south. Higher hazard level is located at west, east and moving towards south that morphologically is a valley or mountain.

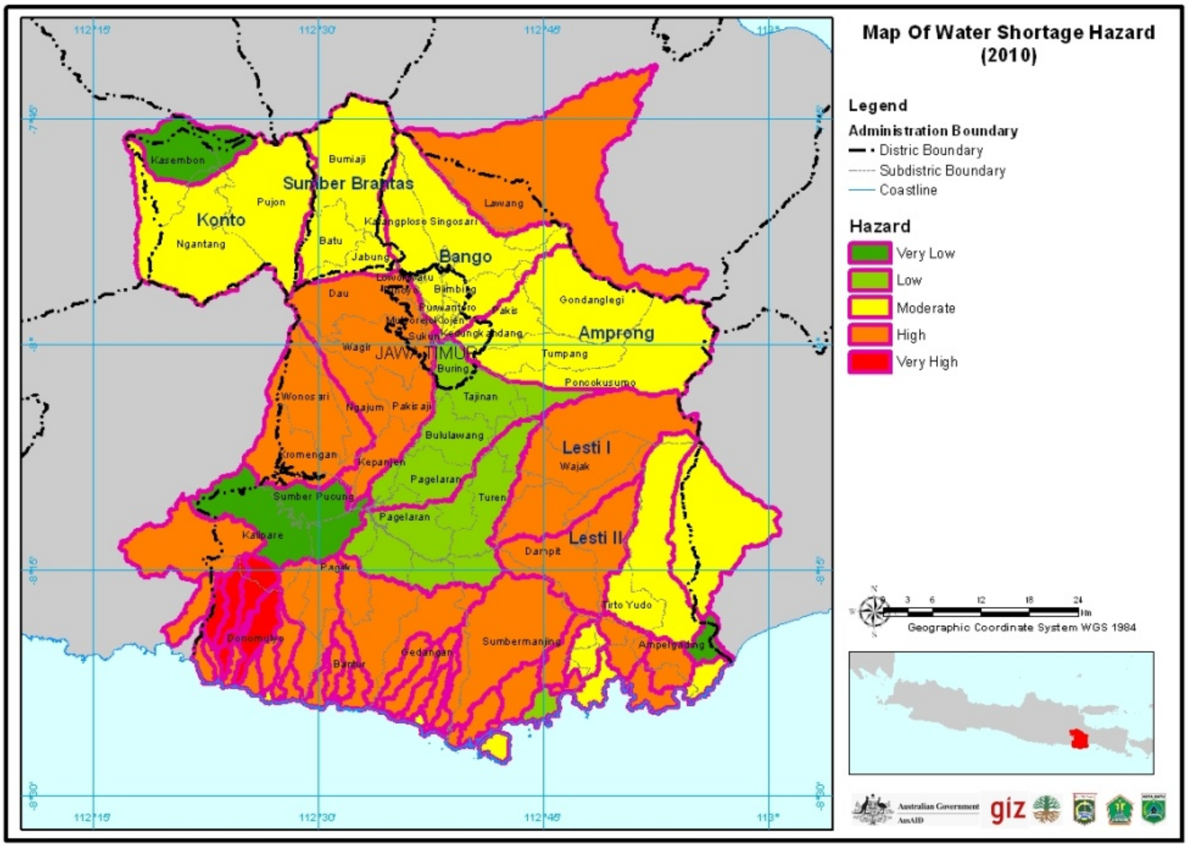


Figure 4. 12 Map of water shortage hazard in the baseline condition

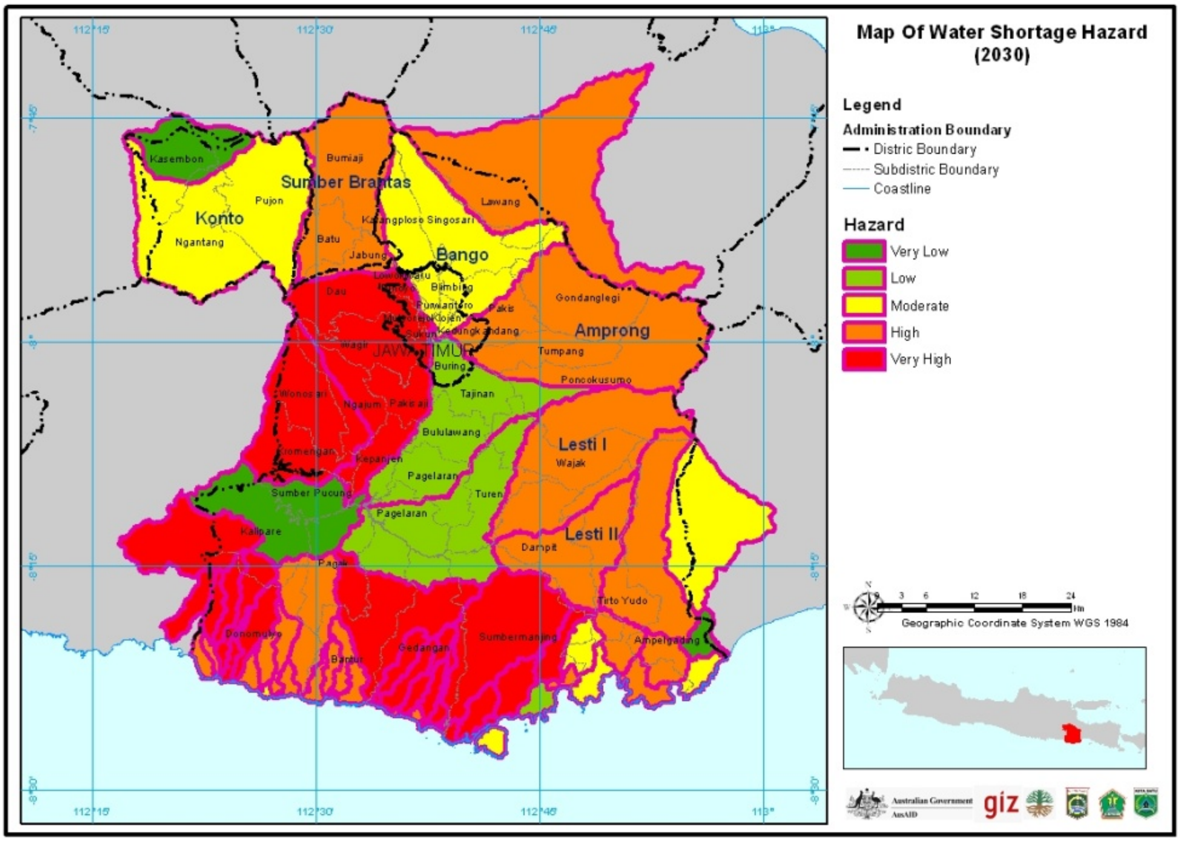


Figure 4. 13 Map of water shortage hazard in the projection condition

Table 4. 1 Water shortage hazard and its distribution in the watershed for current period and projection period

Level of WS[1] Hazard	Current (baseline), 2010 (As seen in Figure 4.12)					
	DoWA[2] current-baseline (m³/month)	WD[3] 2010 (m³/month)	WA2010 (m³/month)	% WS	Watershed	Regency
Very High	494575.79	9716490.84	4820417.32	2.49	Donomulyo	Malang Regency
High	12267816.09	191816470.59	121790999.88	47.36	Lesti I, Lesti II, west of Kalipare, Bantur to Sumbermanjing, Ampelgading; Lawang, Dau to Kromengan	Malang City, Malang Regency
Moderate	7570055.39	135242712.12	117956202.88	34.22	Konto, SumberBrantas, Bango, Amprong, east of Tirtoyudo, small part between Sumbermanjing and Ampelgading	Batu City, Malang City, Malang Regency
Low	10424687.55	106659197.24	49720702.13	10.27	From Buring to Pagelaran and Turen	Malang City, Malang Regency
Very Low	17304500.57	22025425.20	195122920.14	5.65	Kesamben, SumberPucung	Malang Regency
Level of WS[1] Hazard	Projection, 2030 (As seen in Figure 4.13)					
	DoWA[2] projection-baseline (m³/month)	WD[3] 2030 (m³/month)	WA2030 (m³/month)	% WS	Watershed	Regency
Very High	9067071.02	139118136.17	63591647.80	26.6	Dau to Kromengan; from Kalipare to Donomulyo, from Bantur to Sumbermanjing,	Malang City, Malang Regency
High	8106292.34	169368515.50	111984389.80	40.13	SumberBrantas, Amprong, Lesti I, Lesti II, between Tirtoyudo and Ampelgading	Batu City, Malang City, Malang Regency
Moderate	5074726.27	85199199.49	67047872.04	17.79	Konto, Bango, east of Lesti II, between Sumbermanjing and	Malang City, Malang Regency

					Tirtoyudo	
Low	10424687.55	63548438.58	106649805.71	10.27	Buring to Pagelaran	Malang City, Malang Regency
Very Low	26798025.73	23661927.90	185629394.97	5.65	Kesamben, SumberPucun g	Malang Regency

4.3 Flood Hazard

Flood hazard assessment identified the amount of runoff that affects flood events. Based on watershed delineation, Greater Malang has 12 main watersheds consist of Konto, Upstream of Brantas, Bango, Amprong, Lesti, Glidik, Panguluran, Barek, Kondang Merak, Donowari, Lahor and Metro.

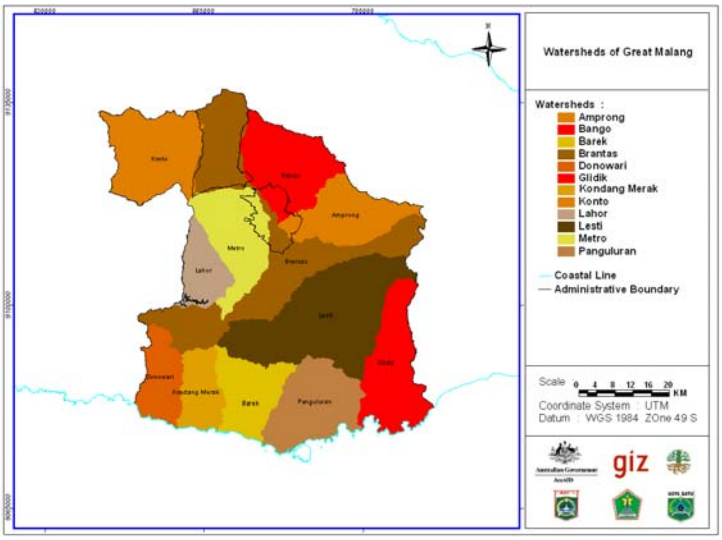


Figure 4. 14 Watershed Map of Malang Raya

Based on the flood historical data of Dinas Pengairan of Malang district, the flood events was located in 8 villages in the year of 2001. There are Pujiharjo, Purwodadi, Lebakharjo, Peniwen, Ngabab, Gading Kembar, Argosari, and Purworejo. The villages are located in the 6 districts. In the following year, the flooding areas increase to 9 villages in the 11 sub-districts. The Most of inundation area occured in the South Malang area (Figure 4.15).

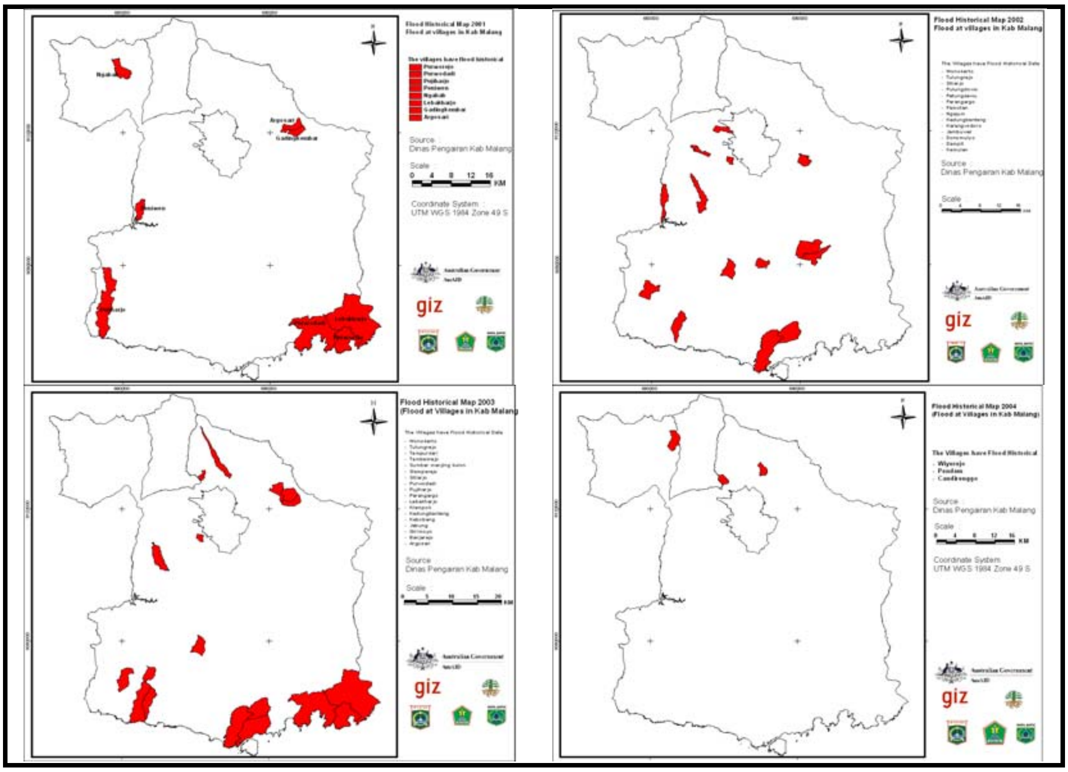


Figure 4. 15 Flood Historical Map of Kab Malang (2001 – 2004)

Flood hazard is classified based on the amount of runoff in 5 levels. There are Very Low (VL), Low (L), Moderate (M), High (H), and Very High Hazard (VH). In the baseline condition based on extreme runoff, Malang City has the largest very high potential flood hazard area. Meanwhile in the projection condition, Malang District has the largest very high potential flood hazard area.

Table 4. 2 Potential Flood Hazard Area

Hazard Level	Malang District		Malang City		Batu City	
	Baseline (km^2)	Projection (km^2)	Baseline (km^2)	Projection (km^2)	Baseline (km^2)	Projection (km^2)
Very Low	4101.87	18317.75	34.94	2.00	180.14	154.49
Low	439.02	787.49	37.65	9.54	2.33	7.43
Moderate	143.14	268.66	15.65	8.68	16.09	0.40
High	30.32	213.06	15.77	11.26	0.02	27.16
Very High	4.52	261.15	5.96	78.32		6.65

In baseline condition, very high hazard level covers mostly residential and built up area. Meanwhile in projection, very high hazard level covers residential area, commercial and services area, industrial area, airport and public facility.

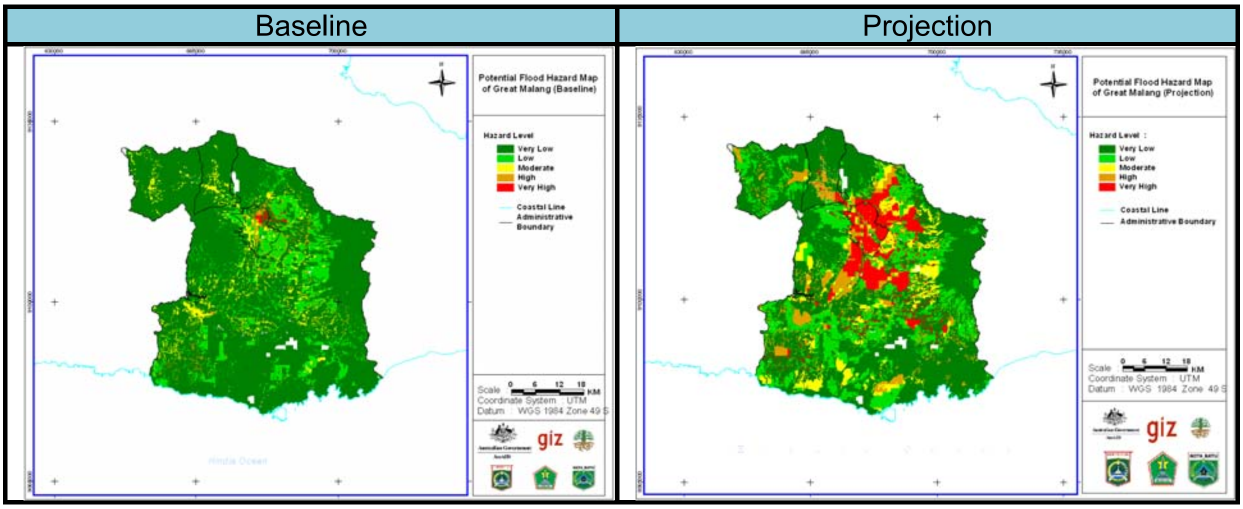


Figure 4. 16 Flood Hazard of Great Malang

Flood hazard model has been analyzed base on watersheds as follows.

4.3.1. Konto

Konto watershed is located in the Malang District. The catchment area of the Konto watershed is 347.881 km^2. Most of catchment area is covered by forest, agriculture land, dry-land agriculture and paddy field. In the baseline condition, the watershed has 3 levels of hazard that are Very Low, Low and Moderate. The flood hazard area will increase in the projection to 4 levels of hazard.

Table 4. 3 Hazard Level of Konto Watershed

Hazard Level	Baseline	Projection
Very Low	327.70	228.30
Low	0.94	85.78
Moderate	16.02	1.74
High		28.63

Extreme daily rainfall occured in the 22^{th} of November 2003 with 206.03 mm while extreme monthly rainfall occured in December 2007 with 884.99 mm. In the projection condition, flood hazard area will be 42% more extreme than the baseline condition that will cover mostly residential area.

Baseline	Projection

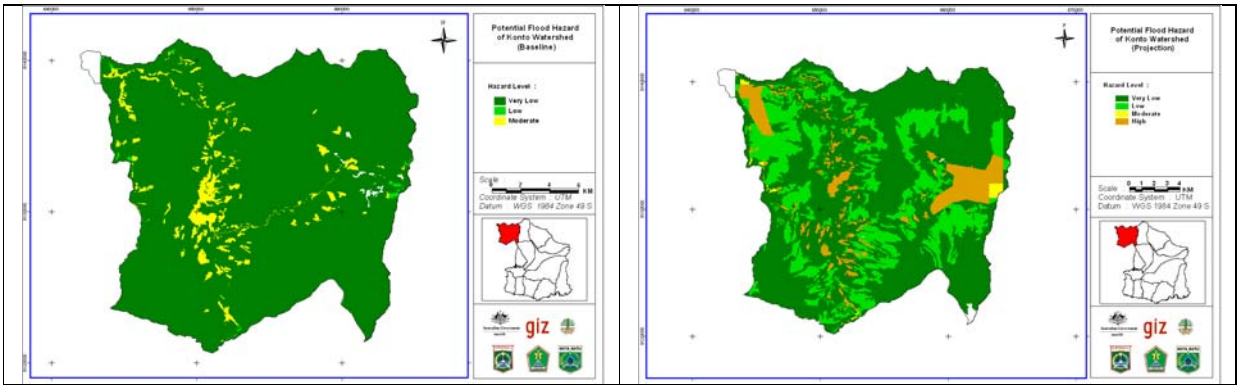


Figure 4. 17 Flood Hazard of Konto Watershed

4.3.2. Upstream of The Brantas River

Upstream of the Brantas watershed crosses to through Batu City, Malang City, and Malang District. It has 667.51 km^2 of catchment area that covers mostly dry-land agricultures, paddy field and plantation. Extreme daily rainfall was 312 mm that occured in November 2003, while extreme monthly rainfall was 1159 mm in December 2007. Based on rainfall projection data (AR4), compared to the baseline condition will be increasing sharply 74 % in the projection condition.

In the baseline condition, upstream of the Brantas watershed has 5 levels of hazard that are very low, low, moderate, high and very high. In the projection condition, the watershed will have 5 levels of hazard and flood hazard will be larger than the baseline condition.

Table 4. 4 Hazard Level of Brantas Watershed

Hazard Level	Baseline (Km^2)	Projection (Km^2)
Very Low	504.72	342.66
Low	90.57	132.84
Moderate	58.85	27.27
High	14.06	72.78
Very High	0.10	90.88

In the baseline condtion, very high and high level of flood hazard area cover mostly of residential and built uparea. Meanwhile in the projection, very high and high level of hazard will spread in public facility, residential area, industrial area, commercial and services area.

Baseline	Projection

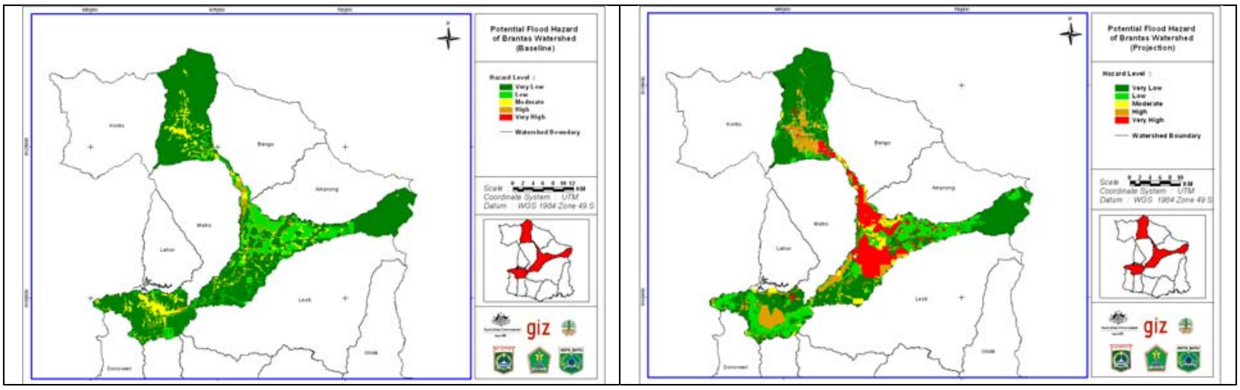


Figure 4. 18 Flood Hazard of Brantas Watershed

4.3.3. Bango

Bango watershed has 321.38 km^2 of catchment area that is covered mostly dry-land agricultures, paddy fields and residential area. Daily extreme rainfall was 312 mm that occured in November 2003, while monthly extreme rainfall was 1037 mm in Januari 2010. In the projection condition, extreme rainfall will be increasing about 67% than the baseline condition. Based on spatial planning 2030, Bango watershed will be covered mostly dry-land agricultures, residential area, industrial & warehousing area, Airport, commercial & services area, and military area.

Table 4. 5 Hazard Level of Bango Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	228.58	127.16
Low	52.38	51.67
Moderate	9.86	31.52
High	11.23	25.10
Very High	10.32	77.22

In the baseline and projection condition, Bango watershed has 5 levels of hazard. There are Very Low, Low, Moderate, High and Very High. Very High and High level of hazard covered mostly main infrastructure such as industrial area, commercial and services area, airport, and military area, which could strongly affect to economic activities in Malang District and Malang City.

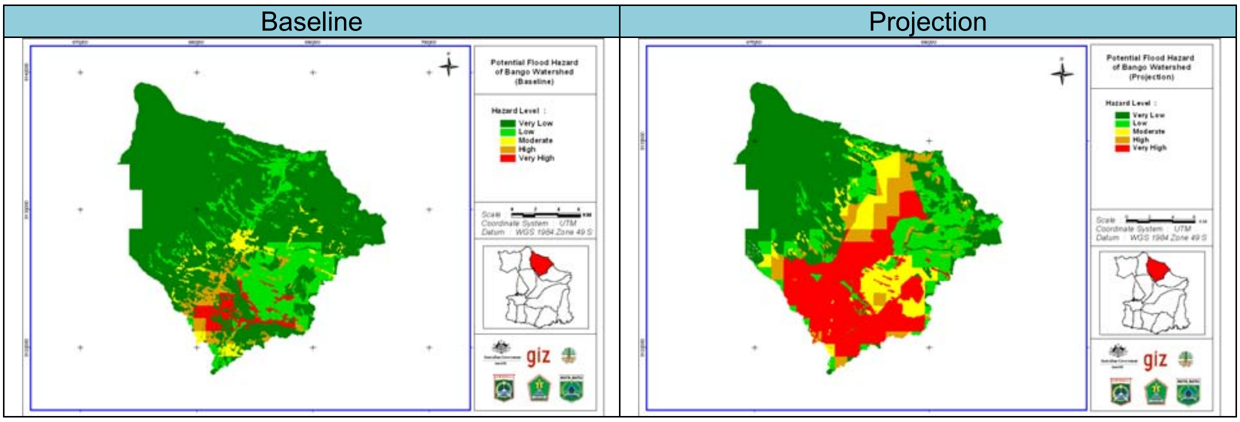


Figure 4. 19 Flood Hazard of Bango Watershed

4.3.4. Amprong

Amprong watershed has 255.547 km^2 of catchment area that is covered by most of dry-land agricultures, plantation and forest. In projection, based on spatial planning of Great Malang, Amprong watershed will be covered most by dry-land agricultures, plantation, protected forest, residential area and main infrastructure such as industrial, commercial and services area and public facility.

Extreme daily rainfall was 261.64 mm in November 2003 meanwhile extreme monthly rainfall occured in December 2002 with 907.21 mm. Based on AR4 Projection with scenario SRA1B, extreme rainfall of Amprong watershed will be increasing sharply of 93% from baseline condition.

Table 4. 6 Hazard Level of Amprong Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	168.79	119.46
Low	67.96	44.31
Moderate	7.43	41.45
High	10.82	0.16
Very High	0.05	49.06

In baseline condition, high level of flood hazard covered most of residential area. Meanwhile in projection condition, Very High Level of flood hazard will cover residential area and industrial and warehousing area.

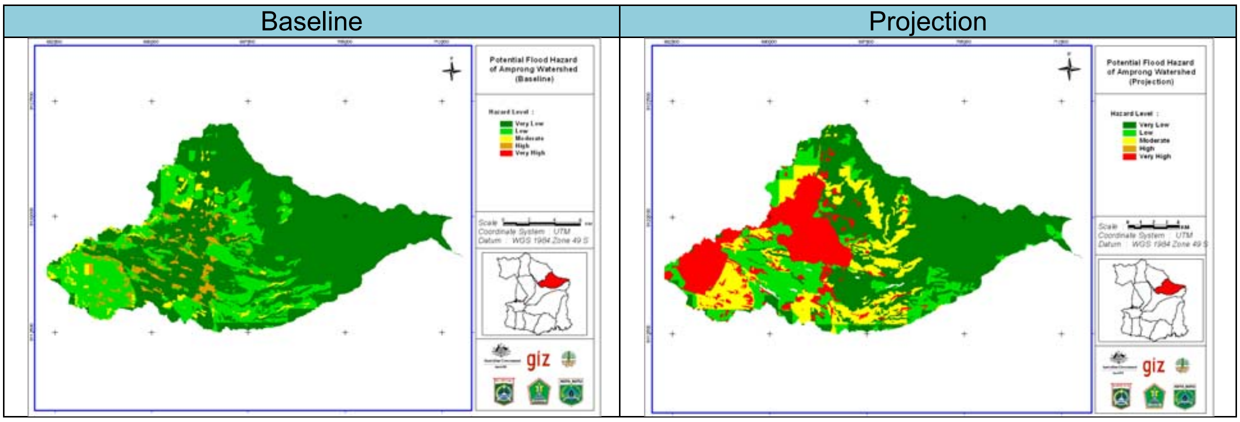


Figure 4. 20 Potential Flood Hazard of Amprong Watershed

4.3.5. Lesti

Lesti watershed is the largest watershed in the Greater Malang with 602.336 km^2 of catchment area which is covered by most by dry-land agricultures, agriculture land and residential area. Daily extreme rainfall of Lesti watershed occured in November 2003 with 161.15 mm, while extreme monthly rainfall occured in December 2007 with 1021.2 mm. Based on spatial planning of Great Malang, the watershed will be covered mostly by dry-land agricultures, agriculture land, residential area, protected forest, paddy fields, and industrial and warehousing area.

In the Baseline condition, Lesti watershed has 4 levels of hazard that are Very Low, Low, Moderate, High level. Meanwhile in the projection condition, the levels of hazard would be higher to 5 levels. It is caused by land use change and increasing extreme rainfall of 110%.

Table 4. 7 Hazard Level of Lesti Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	452.33	274.21
Low	104.81	173.07
Moderate	38.02	62.45

High	1.21	20.93
Very High	-	65.66

In baseline condition, high levels of hazard covered residential area. Meanwhile in projection condition very high and high level of hazard will cover residential area and industrial and warehousing area.

Baseline	Projection

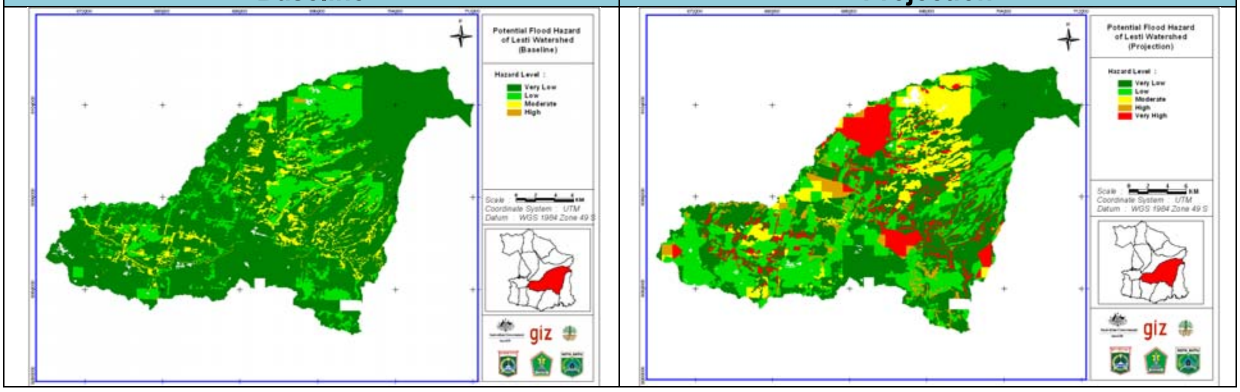


Figure 4. 21 Flood Hazard of Lesti Watershed

4.3.6. Glidik

Glidik watershed covers mostly forest, agriculture land, shrubs, dry-land agricultures and residential area. Based on spatial planning of Great Malang, Glidik watershed will be coveres by protected forest, agriculture land, dry-land agricultures, residential area, paddy fields, ponds and swamp. Glidik watershed has 309.673 km^2 of catchment area.

Extreme daily rainfall of Glidik watershed was 139.97 mm that occured in December 2007, while extreme monthly rainfall occured in December 2002 with 853.79 mm. According to AR4 projection with scenario SRA1B, extreme rainfall will be increasing at 70 % from the baseline condition.

In the baseline condition, Glidik watershed has 3 levels of hazard that are Very Low, Low, and Moderate level. Low and Moderate level will be increasing sharply in projection condition. It makes 4 levels of hazard in the projection condition.

Table 4. 8 Hazard Level of Glidik Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	276.58	240.92

Low	29.06	50.71
Moderate	2.13	3.07
High		13.15

In baseline condition, Moderate level of hazard covered residential area. Meanwhile in projection condition High level of hazard will cover residential area.

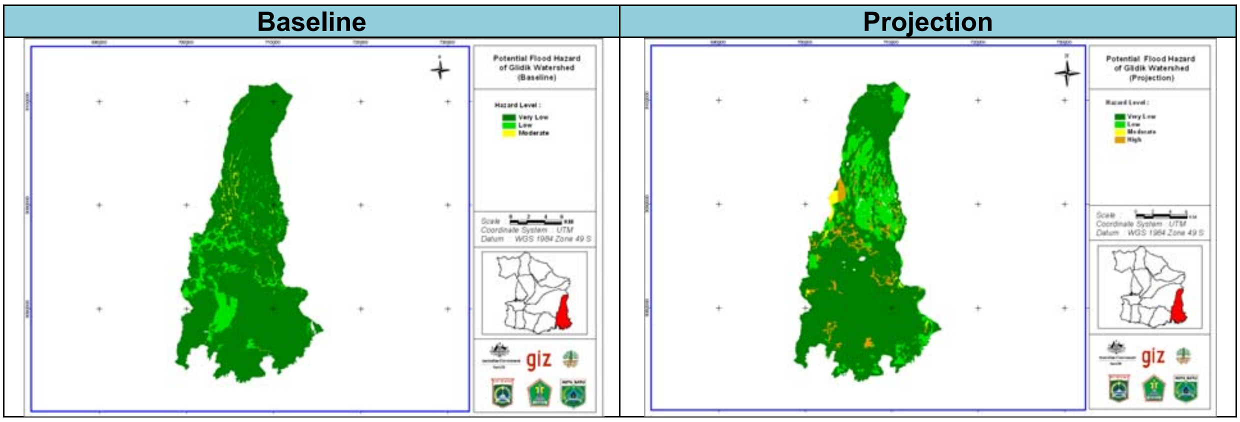


Figure 4. 22 Flood Hazard of Glidik Watershed

4.3.7. Panguluran

Panguluran watershed is located in the south of Greater Malang. Panguluran watershed has 300.671 km^2 of catchment area that mostly covers agriculture land, forest, residential area and dry-land agricultures. Based on spatial planning, mostly area of Panguluran watershed will be covered by agriculture land, dry-land agricultures, industrial and warehousing area, protected forest, residential area, etc. Extreme daily rainfall of Panguluran watershed was 147.61 mm that occured in December 2007. Meanwhile extreme monthly rainfall is 1005.1 mm that occurs in September 2010.

In the baseline condition, Panguluran watershed has 3 levels of hazard that are Very Low, Low and Moderate level. In the projection condition, the level of hazard and hazard area will be increasing due to land use change and increasing of extreme rainfall of 60 % from baseline condition.

Table 4. 9 Hazard Level of Panguluran Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	245.11	209.12
Low	37.37	41.31

Moderate	4.97	19.86
High		17.89

In the baseline condition, the highest level of hazard is Moderate level that covers residential area. Meanwhile in projection condition, Level of hazard will be increase to 4 levels which the highest level of hazard is High Level that will cover residential area and Industrial and warehousing area.

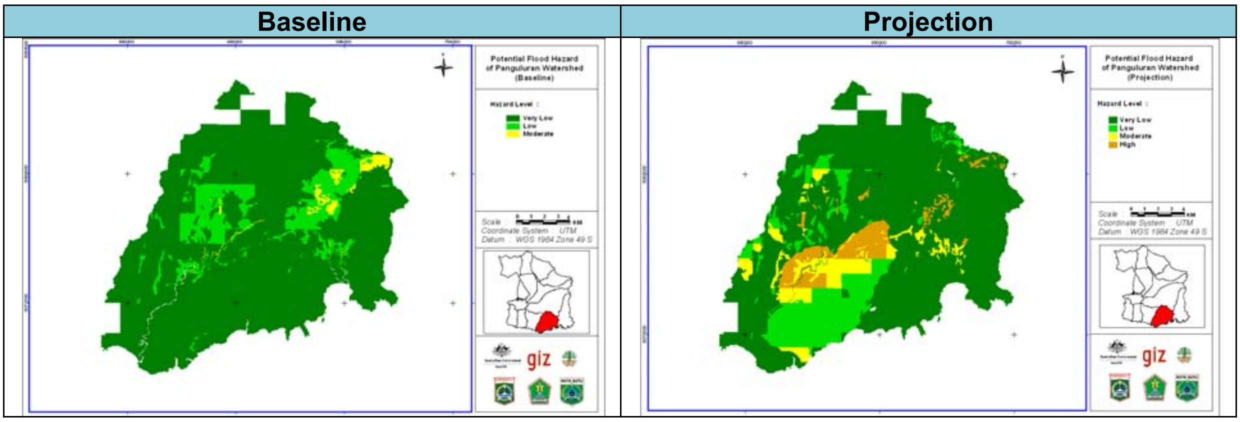


Figure 4. 23 Flood Hazard of Panguluran Watershed

4.3.8. Barek

Barek watershed has 214.822 km^2 of catchment area that mostly covered by dry-land agricultures, agriculture land, forest, residential area, etc. Meanwhile based on spatial planning, barek watershed will be covered by dry-land agricultures, agriculture land, residential area, industrial and warehousing area, commercial and services area. Extreme daily rainfall of Barek watershed was 185 mm while extreme monthly rainfall was 879.3 mm. The extreme rainfalls occured in December 2007.

Table 4. 10 Hazard level of Barek Watershed

Hazard Level	Baseline **(km^2)**	Projection **(km^2)**
Very Low	202.75	121.30
Low	10.95	74.58
Moderate	0.49	17.77
High		0.82

Moderate level of hazard in the baseline condition would cover residential area, while Moderate and High level of hazard area in the projection condition will cover residential area and industrial and warehousing area.

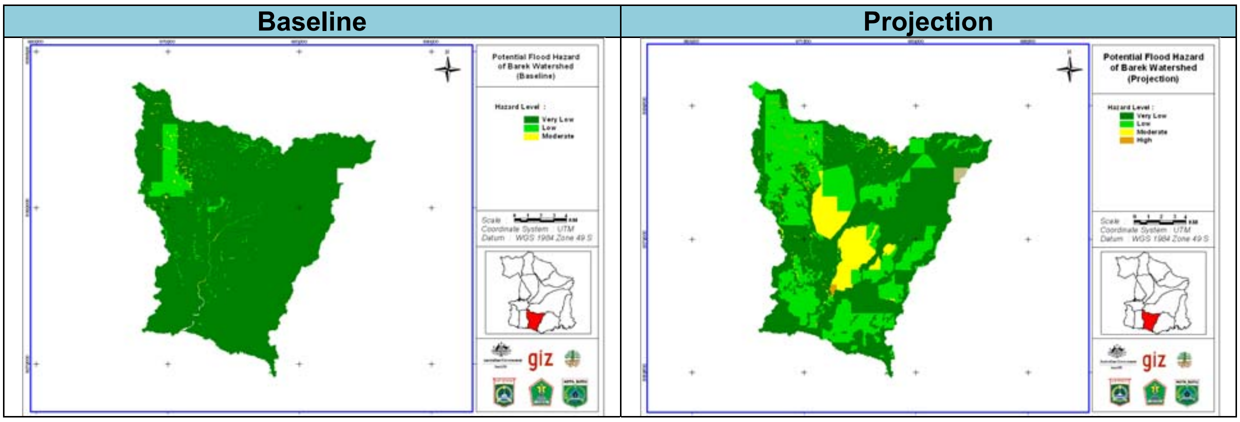


Figure 4. 24 Flood Hazard of Barek Watershed

4.3.9. Kondang Merak

Kondang Merak watershed has 147.155 km^2 of catchment area that mostly covers agriculture land, dry-land agricultures, paddy fields, residential area. Extreme daily rainfall of Kondang Merak watershed was 230.50 mm in December 2007 while extreme monthly rainfall was 820.18 that occured in December 2004. In projection condition, extreme rainfall will increase of 50 % from baseline condition. Based on spatial planning, Kondang Merak watershed will be covered by agriculture land, dry-land agricultures, protected forest, paddy fileds, residential area and swamp.

Table 4. 11 Hazard Level of Kondang Merak Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	118.23	84.47
Low	22.75	23.87
Moderate	1.05	30.80
High	4.82	2.03
Very High	0.02	5.89

In baseline condition, high and very high level of hazard covered residential area and agriculture land. Meanwhile in projection condition, high and very high level of hazard will cover residential area.

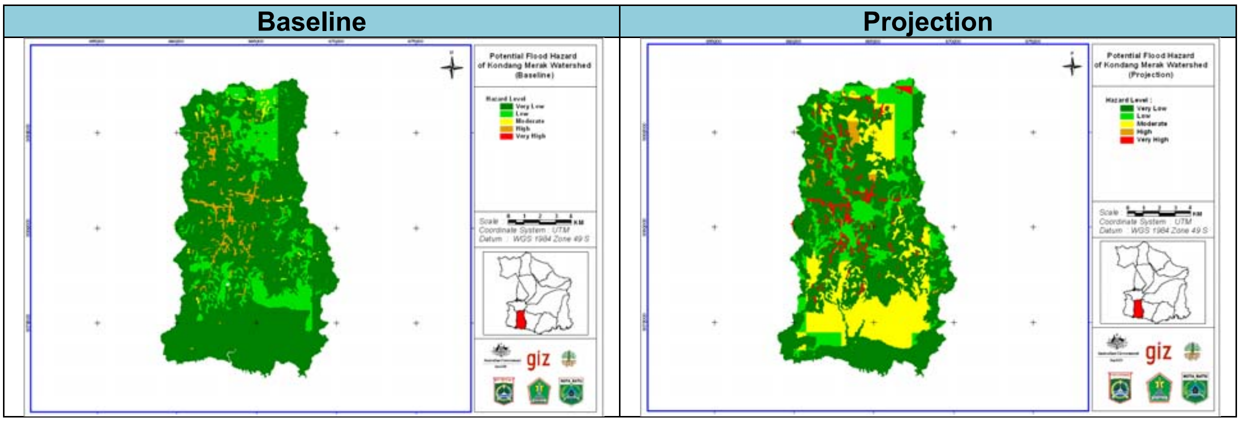


Figure 4. 25 Flood Hazard of Kondang Merak Watershed

4.3.10. Donowari

Donowari watershed has 164.443 km^2 of catchment area that is covered by agriculture land, paddy fields, dry-land agricultures, residential area, shrubs and forest. Based on spatial planning of Greater Malang (RTRW), Donowari watershed will be covered by agriculture land, dry-land agricultures, residential area, paddy fields, protected forest and swamp.

Extreme daily rainfall of Donowari watershed was 288.94 mm in November 2003, meanwhile extreme monthly rainfall was 904.11 mm that occured in December 2004.. In projection condition, the hazard area will increase significantly due to land use change and increasing of extreme rainfall of 47% than baseline condition.

Table 4. 12 Hazard Level of Donowari Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	130.73	92.96
Low	19.13	43.30
Moderate	11.11	6.42
High	3.10	15.73
Very High	0.05	5.49

In baseline condition, High and Very High level covered residential area. In projection condition, residential area also would be covered by High and Very High level of flood hazard.

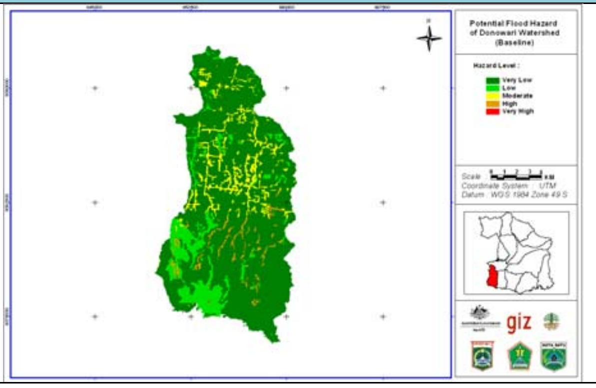
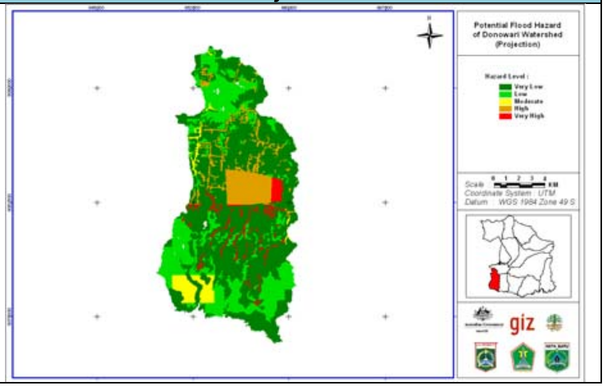
Baseline	Projection
	

Figure 4. 26 Flood Hazard of Donowari Watershed

4.3.11. Lahor

Mostly area of Lahor watershed is covered by agriculture land, paddy fields, residential area, dry-land agricultures, forest, and shrubs. The watershed has 144.883 km^2 of catchment area. Extreme daily rainfall for this watershed occured in November 2003 was 238.67 mm, while extreme monthly rainfall was 1100.7 mm that occured in December 2007. Based on scenario SRA1B of AR4 projection in projection condition, extreme monthly rainfall will be increasing of60% from baseline condition.

Based on spatial planning of Greater Malang, Lahor watershed will be covered by mostly residential area, agriculture land, paddy fields, dry-land agricultures and protected forest.

Table 4. 13 Hazard Level of Lahor Watershed

Hazard Level	Baseline **(km^2)**	Projection **(km^2)**
Very Low	127.25	86.11
Low	10.41	17.13
Moderate	6.75	21.98
High	0.002	18.55
Very High		0.65

The levels of hazard and potential hazard area will increase significantly in projection condition. It is caused byland use change and increasing of extreme rainfall.

Baseline	Projection

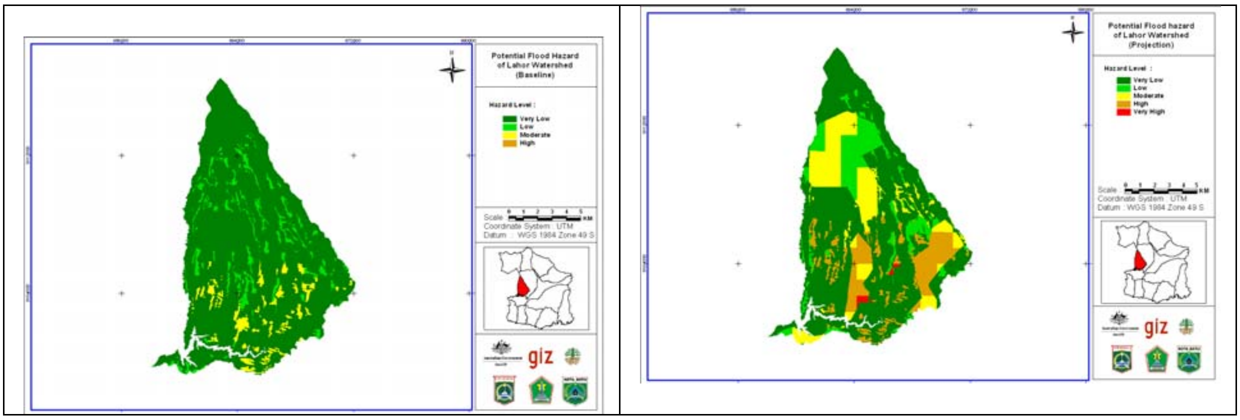


Figure 4. 27 Flood Hazard of Lahor Watershed

The highest level in baseline condition covered residential area, meanwhile in projection condition the highest level also will cover residential area.

4.3.12. Metro

Metro watershed is located in Malang District and Malang City. Metro watershed has 280.457 km^2 of catchment area that is covered by dry-land agricultures, paddy fields, agriculture land, residential and built up area, shrubs and forest. Meanwhile based on spatial planning, mostly area of this watershed will be covered by dry-land agricultures, residential area, protected forest, industrial and warehousing area, agriculture land, paddy fields, green open space, commercial and services area, public facility and military area.

Extreme daily rainfall was 259.96 mm that occured in November 2003 and extreme monthly rainfall occured in December 2007 with 1241.3 mm.

Table 4. 14 Hazard Level of Metro Watershed

Hazard Level	Baseline (km^2)	Projection (km^2)
Very Low	227.74	114.83
Low	32.53	64.05
Moderate	19.79	13.50
High	1.16	34.59
Very High		53.17

The highest level in baseline condition covers residential area, meanwhile in projection condition will cover residential area and industrial and warehousing area. The highest level area will be increasing sharply that caused land use change and increasing of extreme rainfall to 80 % from baseline condition.

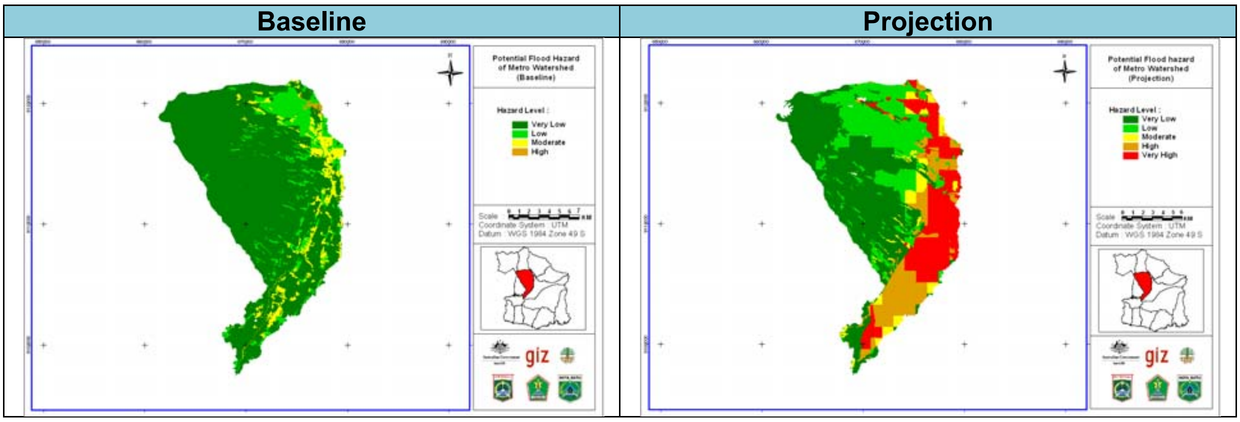


Figure 4. 28 Flood Hazard of Metro Watershed

4.4 Landslide Hazard

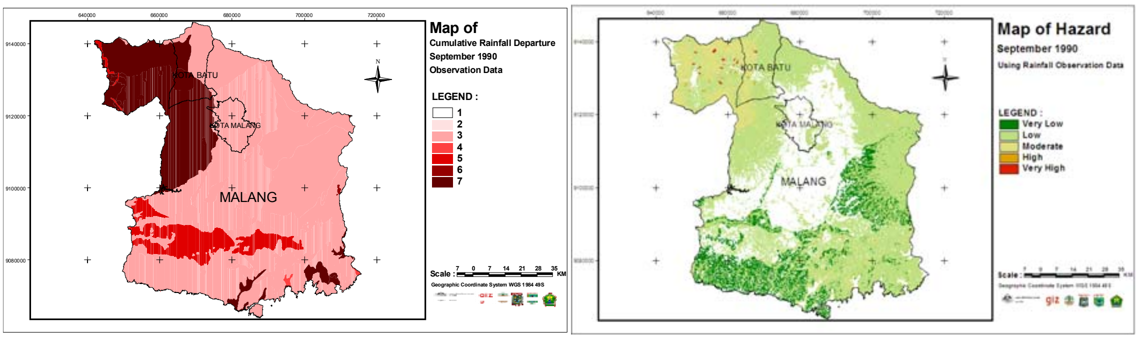
Landslide hazard map is generated based on the observation data and it analyzed using Geographical Information System (GIS) approach. Those observation data i.e. landslide existing, slope, lithology and groundwater table are need to be modified as a layer in GIS analysis. Each layer is a parameter that caused landslide, but because each layer providing a different effect on the landslide, the weighting process is required. In our framework, different weightings can be assigned to each layer, and unrealistic landslide hazard on flat slope (0^o – 3^o) is eliminated by proposing a filter function.

Landslide hazard map is generated based on the observation data and it is analyzed using Geographical Information System (GIS) approach. Those observation data i.e. existing landslide, slope, lithology and groundwater table need to be modified as layers in GIS analysis. Each layer is a parameter that caused landslide, however as each layer provides a different effect on the landslide, the weighting process is required.

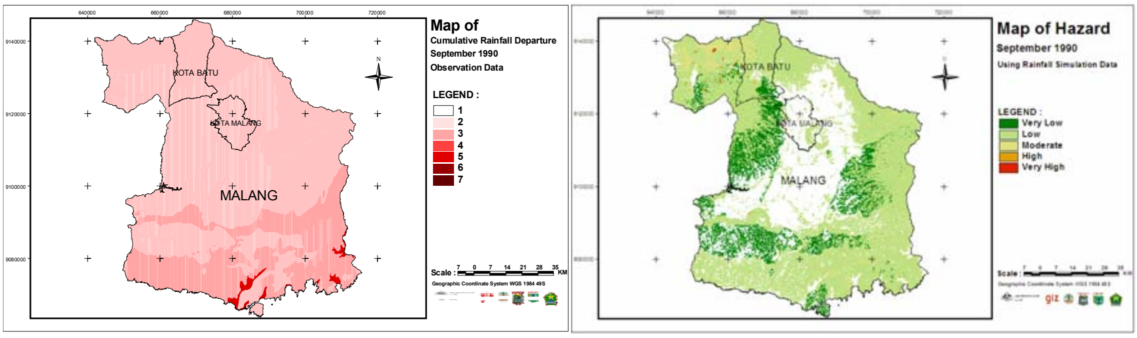
4.4.1 Analysis of Simulation and Observation of Rainfall Data

Decrease in slope stability as the cause of landslide affected by rising groundwater as result of infiltration. The rate of infiltration would be depends on duration, frequency and intensity of rainfall. In this research, change the groundwater table due to precipitation is modeled by using the Cumulative Rainfall Departure (CRD) Method. CRD as climate driven modeling in climate change is to use rainfall data on baseline condition (1980-2011) and projection condition (2012-2030) that is taken from the result of science basis modeling. To provide the impact of climate change on landslide hazard, that is rainfall variability in the projection, the changing of groundwater table is generated by using CRD method. rainfall data of science basis modelling, consist of two different sources, they are from observation and simulation data, where observation data are collected from 46 rain-gauge of local resources (government and private) that spread in Greater Malang for 30 years (1980-2011), meanwhile simulation data collected from IPCC, for baseline (1980-2011) and projection (2012-2030). Figure 1 below show the the changing of groundwater and its hazard of both different sources.

Decrease in slope stability as the cause of landslide is affected by rising groundwater as result of infiltration. The rate of infiltration would depend on duration, frequency and intensity of rainfall. In this research, change of the groundwater table due to precipitation is modeled by using the Cumulative Rainfall Departure (CRD) Method. CRD as climate driven modeling in climate change is to use rainfall data on baseline condition (1980-2011) and projection condition (2012-2030) that is taken from the result of science basis modeling. To provide the impact of climate change on landslide hazard, that is rainfall variability in the projection, the changing of groundwater table is generated by using CRD method. Rainfall data of science basis modelling consist of two different sources: observation and simulation data. Observation data is collected from 46 rain-gauges of local resources (government and private) that spread in the Greater Malang for 30 years (1980-2011), meanwhile simulation data is collected from IPCC model, for baseline (1980-2011) and projection (2012-2030). Figure 4. 29 shows the changing of groundwater table and its hazard of both different sources.



(a)



(b)

Figure 4. 29 (a) ground water table recharge map and hazard baseline map of september 1990 using observation data, (b) ground water table recharge map and hazard baseline map of september 1990 using simulation data (IPCC)

Both of the maps show the differences between hazard map using observation data at september 1990 and hazard map using simulation data at september 1990. hazard map using observation data at september 1990 looks higher at northern part, it show the moderate level at that area, include some part at batu city, then very low level looks at southern part, and some at eastern part, but the rest is low level with total area 1.903.650.000 m^2. Meanwhile, hazard map using simulation data at september 1990, looks different, at southern part very low level and low level dominate, while at southern part, the composition between very low and low level looks different from hazard map using observation data at september 1990, as shown at figure 3. Table 1 below, show very high at hazard map using observation data at september 1990 with total area 4.880.000 m^2 is bigger than hazard map using simulation data at september 1990 with total area 1.290.000 m^2, as lited in table 1.

Both of the maps show the differences between hazard map using observation data in September 1990 and hazard map using simulation data in September 1990. Hazard map using observation data in September 1990 was higher in northern part of Greater Malang that was the moderate level, including some parts of Batu City. Meanwhile, hazard map using simulation data in September 1990 was different in which the nothern part of Greater Malang which was dominated by very low and low levels. Table 4.15 shows that very high hazard using observation data in September 1990 with the total area of 4.880.000 m^2 was bigger than the one that using simulation data in September 1990 with total area 1.290.000 m^2.

Table 4. 15 Comparison of Total Area of Hazard Level between Simulation and Observation Data

Hazard Level	Hazard (m^2)	
	Simulation	Observation
Very Low	450.950.000	387.390.000
Low	2.024.290.000	1.903.650.000
Moderate	100.550.000	284.750.000
High	11.550.000	7.960.000
Very High	1.290.000	4.880.000

Related to ground water table (GWT) recharge map at figure 1, as climatic drive factor, hazard at each map change recording to it ground water table (GWT) recharge map as one of the hazard map input. At northwest part of hazard baseline map of september 1990 using observation data looks at higher level of hazard, just similar to ground water table (GWT) recharge map using observation data. ground water table (GWT) recharge map as one climatic factor to drive the landslide hazard.

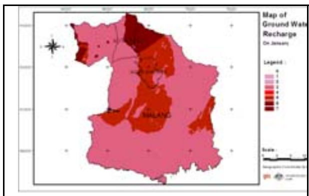
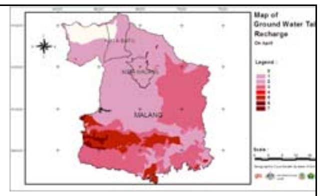
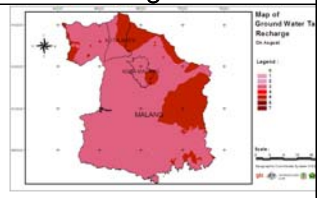
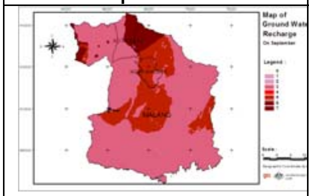
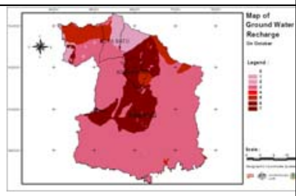
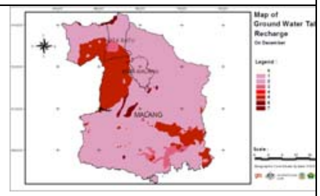
4.4.2 Landslide Hazard on Greater Malang

As known, duration, frequency, and intensity of rainfall in Indonesia are different to each seasons, where there are 2 (two) seasons, they are rainy seasons usually on October-May, while dry seasons usually on April-October. But, related to climate changes that impact to changes of uncertainty rainfall role and seasons. Hence, the landslide hazard model could be used for the projection of future landslides by providing a monthly scenario of rainfall projection, distribution that given. Table below shows, monthly ground water table recharge on January to December.

As known, duration, frequency, and intensity of rainfall in Indonesia are seasonally different. Hence, the landslide hazard model could be used for the projection of future landslides by providing monthly scenarios of rainfall projection. Table 4.16 shows monthly Ground Water Table Recharge from January to December.

Table 4. 16 Monthly Ground Water Table Recharge of Greater Malang

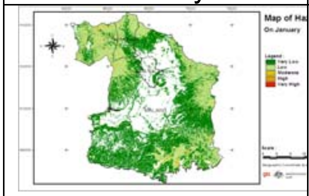
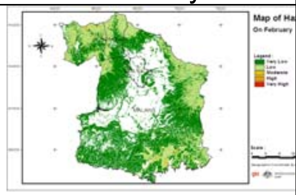
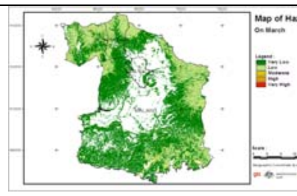
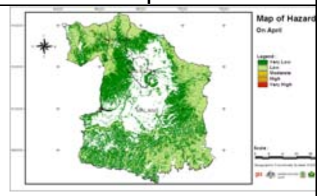
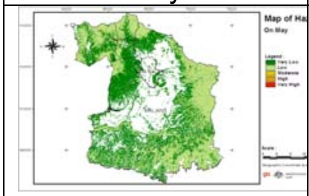
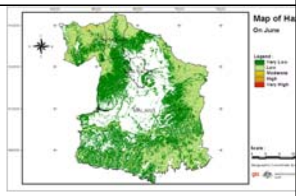
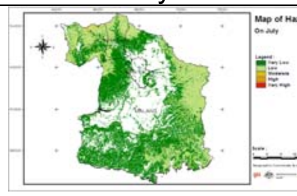
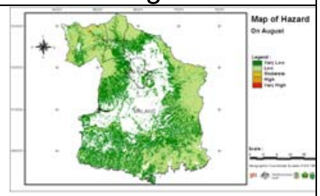
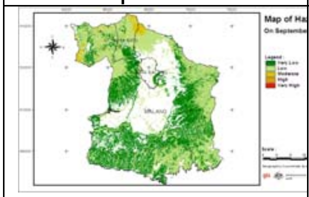
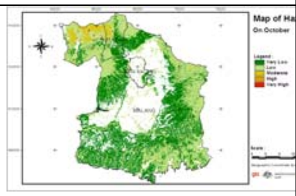
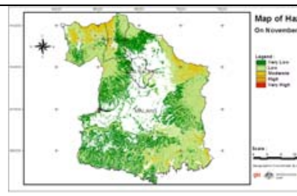
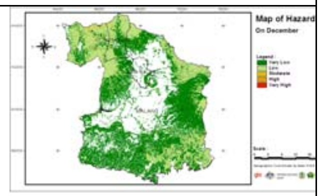
January	February	March	April

			
May	June	July	August
			
September	October	November	December
			

Comparison of the monthly ground water table recharge, as shown in table above, where ground water table increasing on January, August, September, October, and November, while it is decreasing in February, March, April, May, June, and July. Ground water table recharge map, give a contribution on Landslide Hazard Map, as shown in table 3 (three) and 4 (four) below, The level of hazard is estimated by using quartile of probability range of ground water table change. The level can be divided in to 5 levels that are very low, low, moderate, high and very high. The area of landslide hazard level shown in Table 4.10

Monthly ground water table recharges (table 4.16) are increasing in January, August, September, October, and November, while they are decreasing in February, March, April, May, June, and July. Ground water table recharge contributes to Landslide Hazard, as shown in table 4.17 and 4.18, The level of hazard is estimated by using quartile of probability range of ground water table change. The level then can be divided into 5 levels: very low, low, moderate, high and very high. The monthly landslide hazard map shown in Table 4.17.

Table 4. 17 Monthly landslide hazard of the Greater Malang

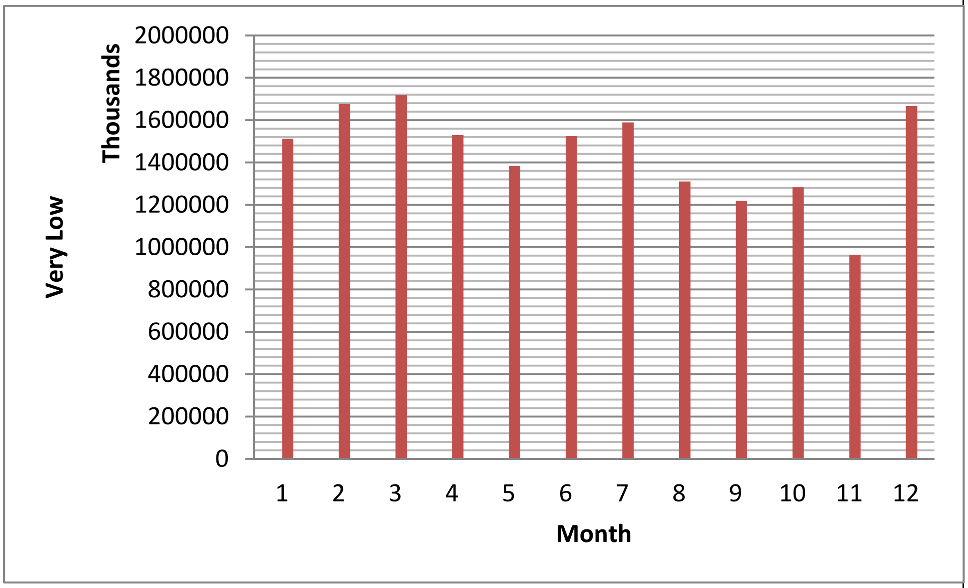
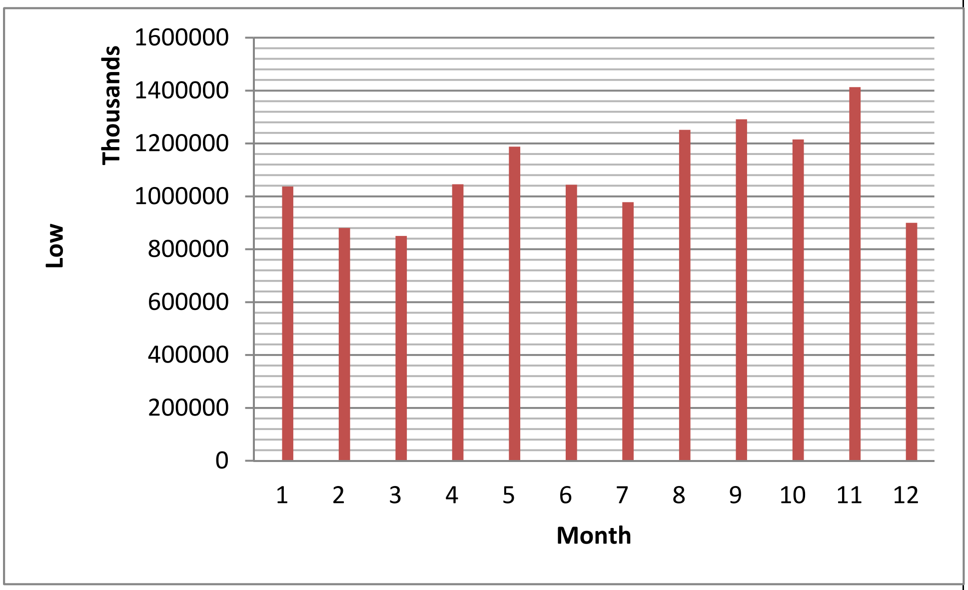
January	February	March	April
			
May	June	July	August
			
September	October	November	December
			

It can be seen in the hazard level area, for very high landslide hazard level, the area are varied from 6.020.000 m^2 to 1.240.000 m^2, it is higher on October and November. While, for high landslide hazard level, the area are varied from 11.600.000 m^2 to 6.420.000 m^2, it is higher on January to August. And for moderate landslide hazard level, the area are varied from 199.430.000 m^2 to 540.000 m^2, it is higher on November. Based on its level, November are one of the highest landslide hazard probability.

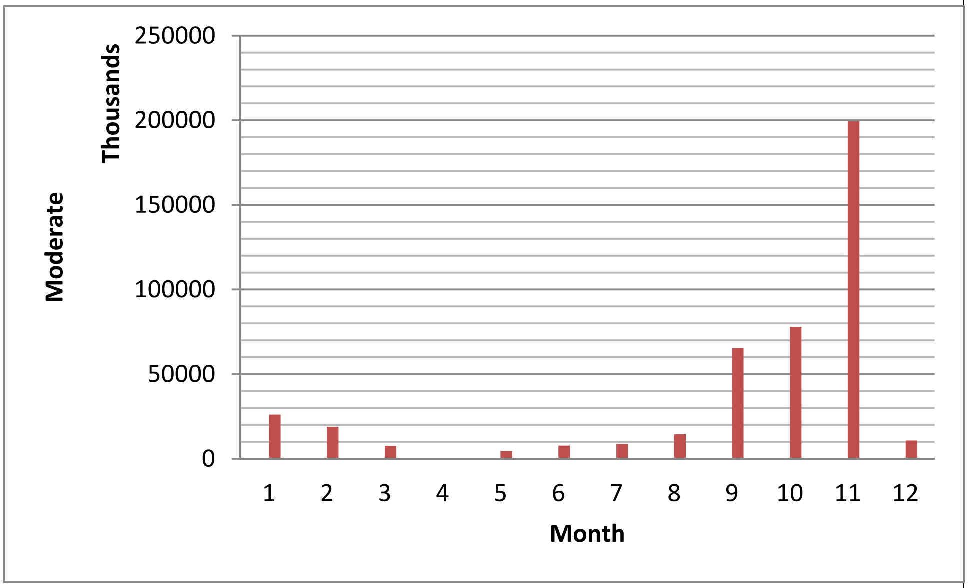
Very high landslide hazards are varied from 6.020.000 m^2 to 1.240.000 m^2 and higher in October and November, while high landslide hazards are varied from 11.600.000 m^2 to 6.420.000 m^2 and higher from January to August. Landslide hazard probability in November is the highest.

Table 4. 18 Monthly level of landslide hazard of Greater Malang

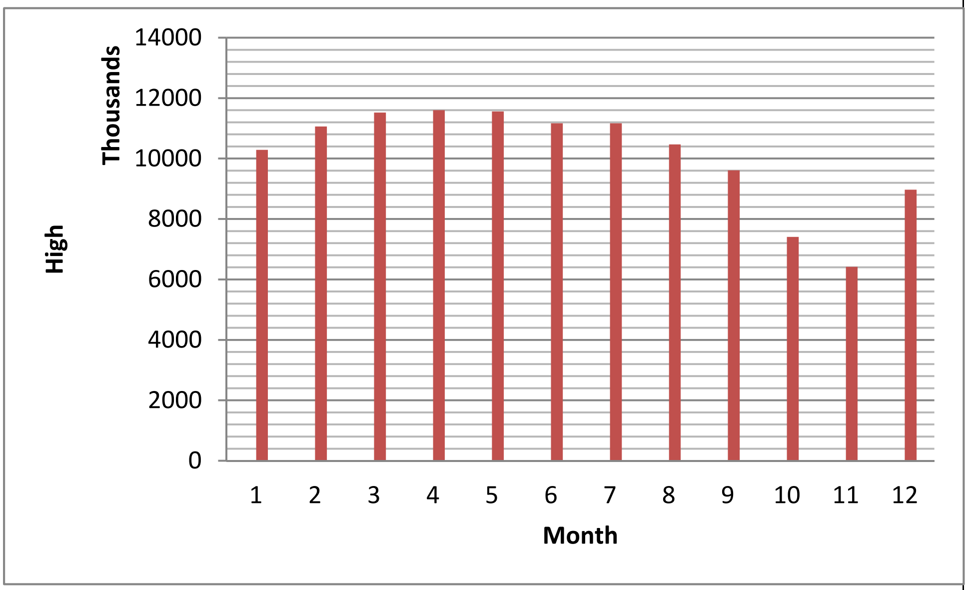
Hazard Level	Area (km^2)

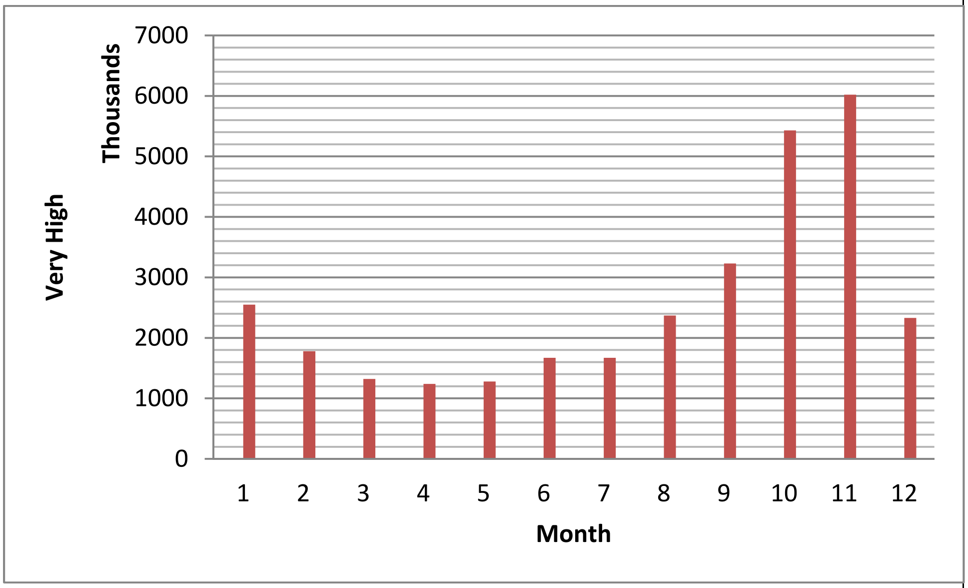
Very Low	Thousands Very Low 2000000 1800000 1600000 1400000 1200000 1000000 800000 600000 400000 200000 0 1 2 3 4 5 6 7 8 9 10 11 12 Month
Low	Thousands Low 1600000 1400000 1200000 1000000 800000 600000 400000 200000 0 1 2 3 4 5 6 7 8 9 10 11 12 Month

Moderate



High



Very High	

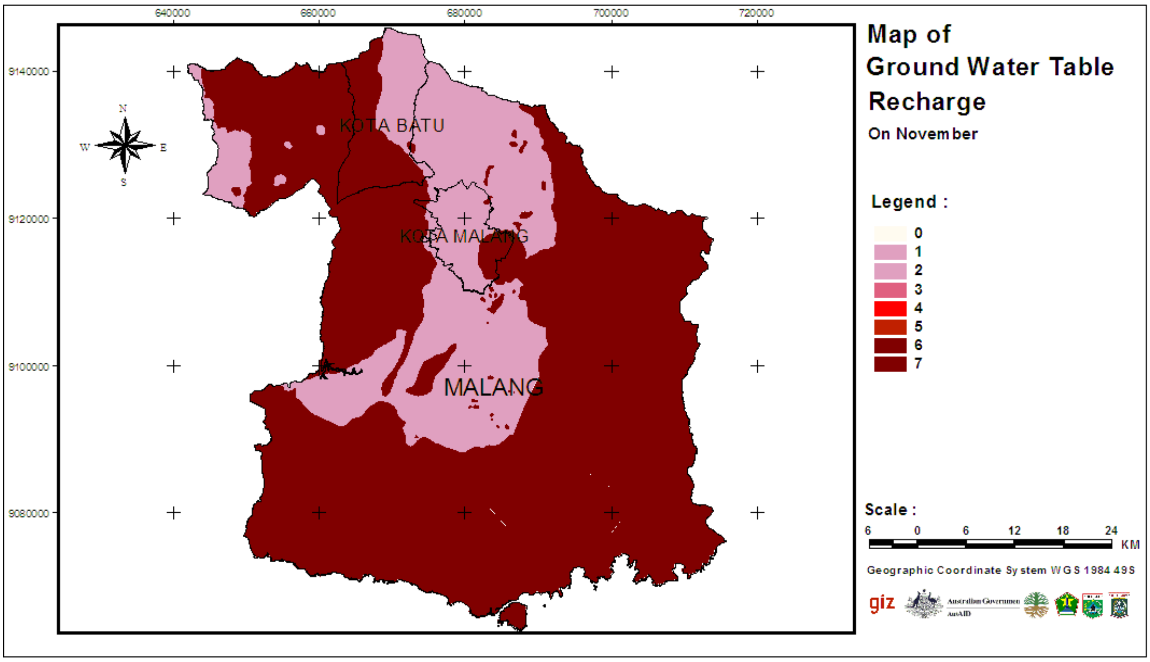


Figure 4. 30 Map of ground water table (GWT) recharge projection (2012-2030)

Based on hazard analysis, June has the highest probability of landslide hazard which the detailed explaination is shown in figure 2 below. It shows map of ground water table (GWT) recharge projection (2012-2030), where the highest weighting level show at almost part of greater malang, and it is lower at middle part, that will drive to hazard landslide map.

As seen in figure 4.31, the landslide hazard area where the largest hazard area on the very low level with 963.590.000 m^2 and low level 1.412.770.000 m^2 with then followed by moderate, high, and very high level.

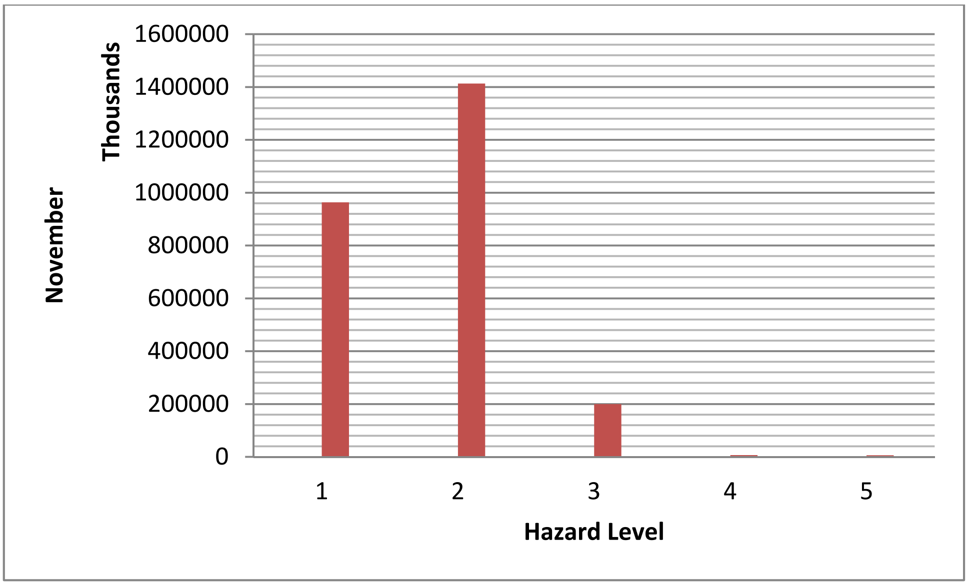


Figure 4. 31 Greater Malang landslide hazard projection map

Furthermore, the result of hazard analysis is cross-checked to administrative map of Greater Malang. It is shown the location of landslide hazard where is occurred in Malang, Malang City and Batu City.

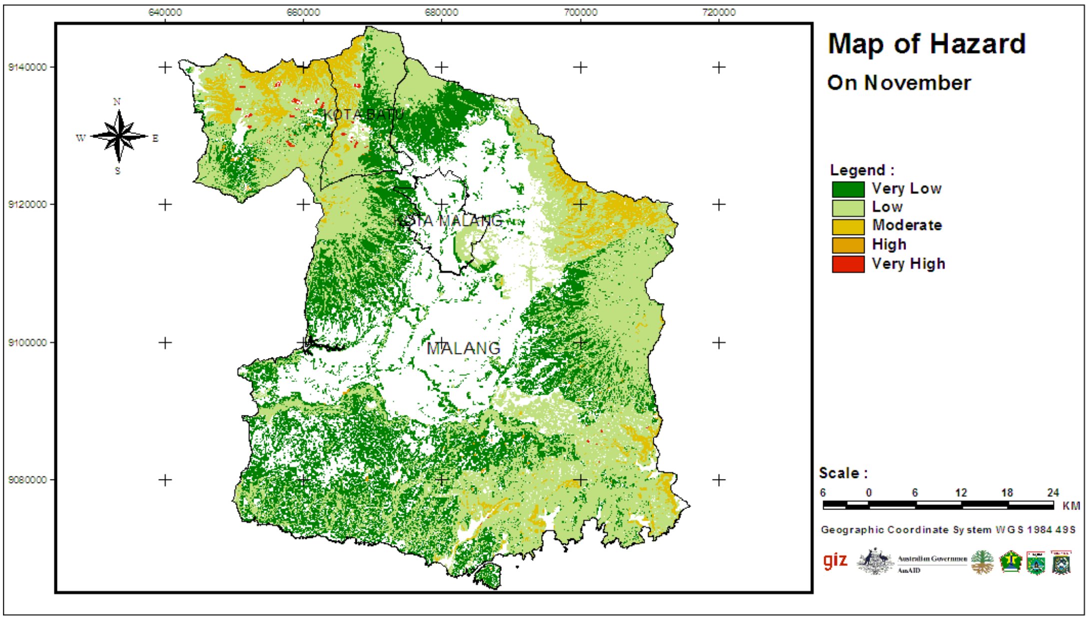
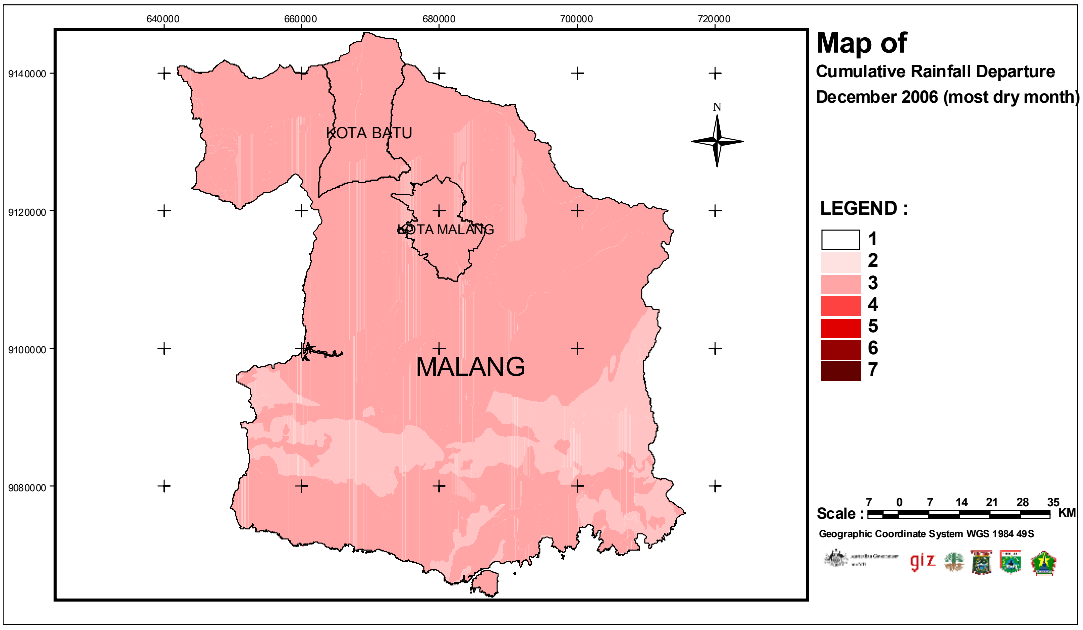


Figure 4. 32 Greater Malang landslide hazard projection map

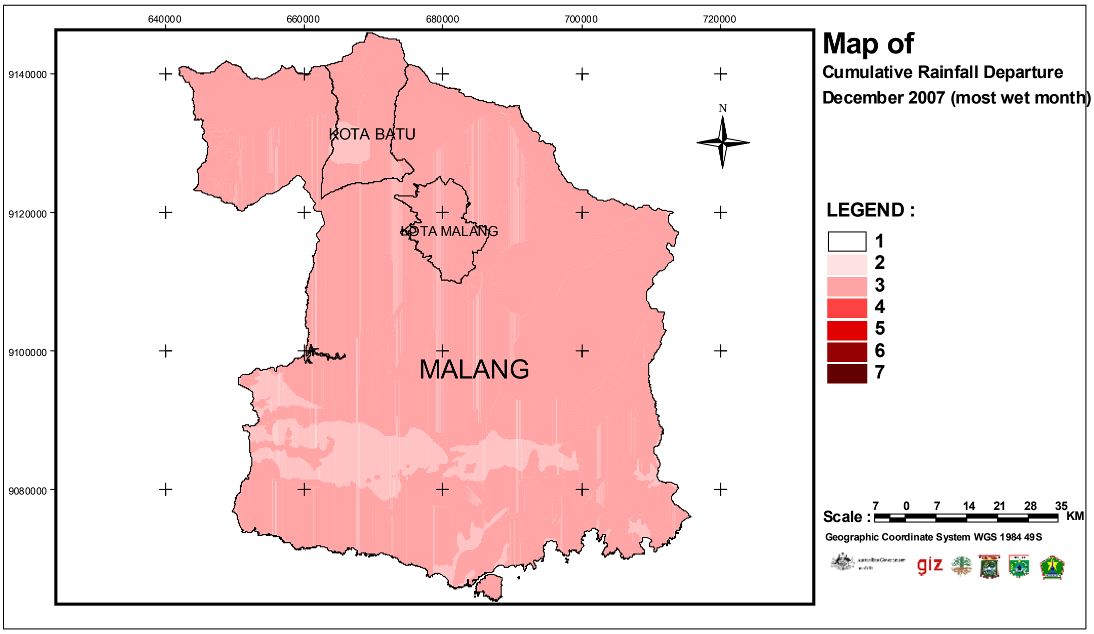
Malang district as the biggest part of Greater Malang have a complete hazard level, where at south west consist of moderate level, and high to very high level spotted at several place as seen in figure 4.32 Batu city have a very low to high hazard level, where at west part dominated with moderate level and high level spotted. While Malang city with a very low and low level.

4.4.3 Analysis of Most Dry And Most Wet Month From Recording Data

This study, are including into baseline condition analysis, where it is using observation data as explained before, on December 2006 as the most dry month and December 2007 as the most wet month, and the record are using rainfall data of Perum Jasa Tirta. Ground water table (GWT) recharge map analysis using cumulative rainfall departure (CRD) map as climatic driven factor, one more time shows that hazard at each map change recording to it ground water table (GWT) recharge map as one of the hazard map input, as seen in figure 4.33. Ground water table (GWT) recharge map of december 2006 as the most dry month, ground water table (GWT) recharge map of December 2007 as the most wet month, drive to landslide hazard map at that time.



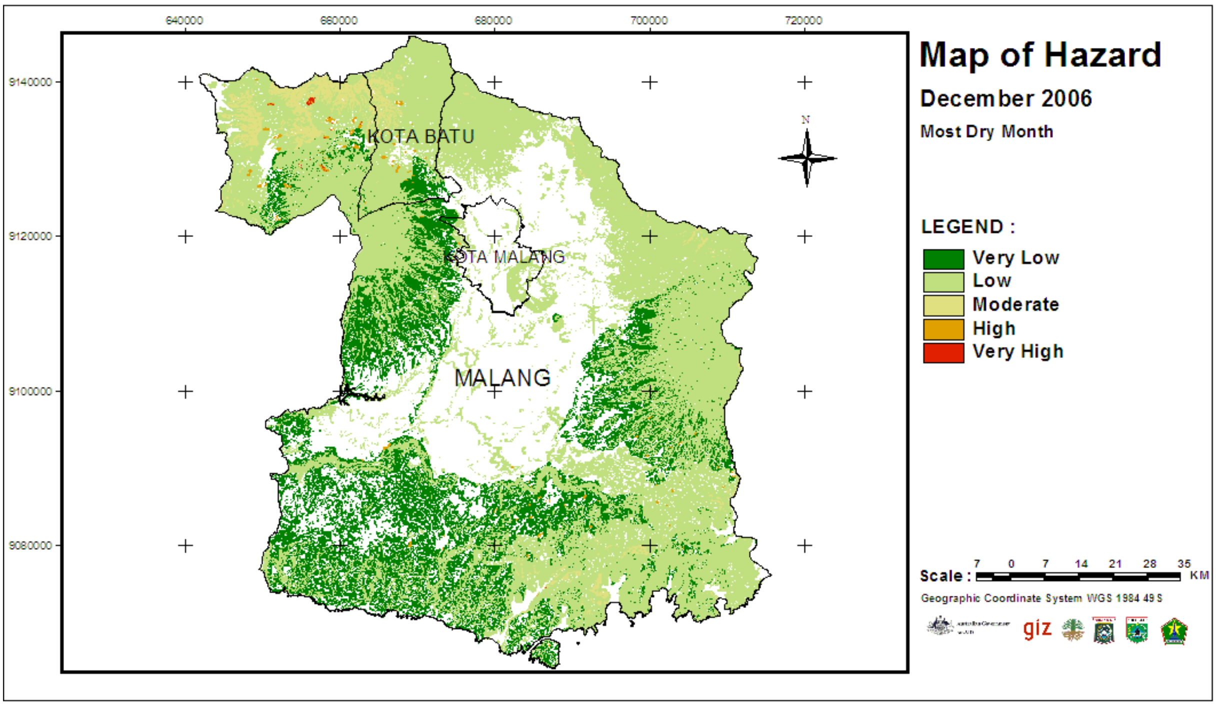
(a)



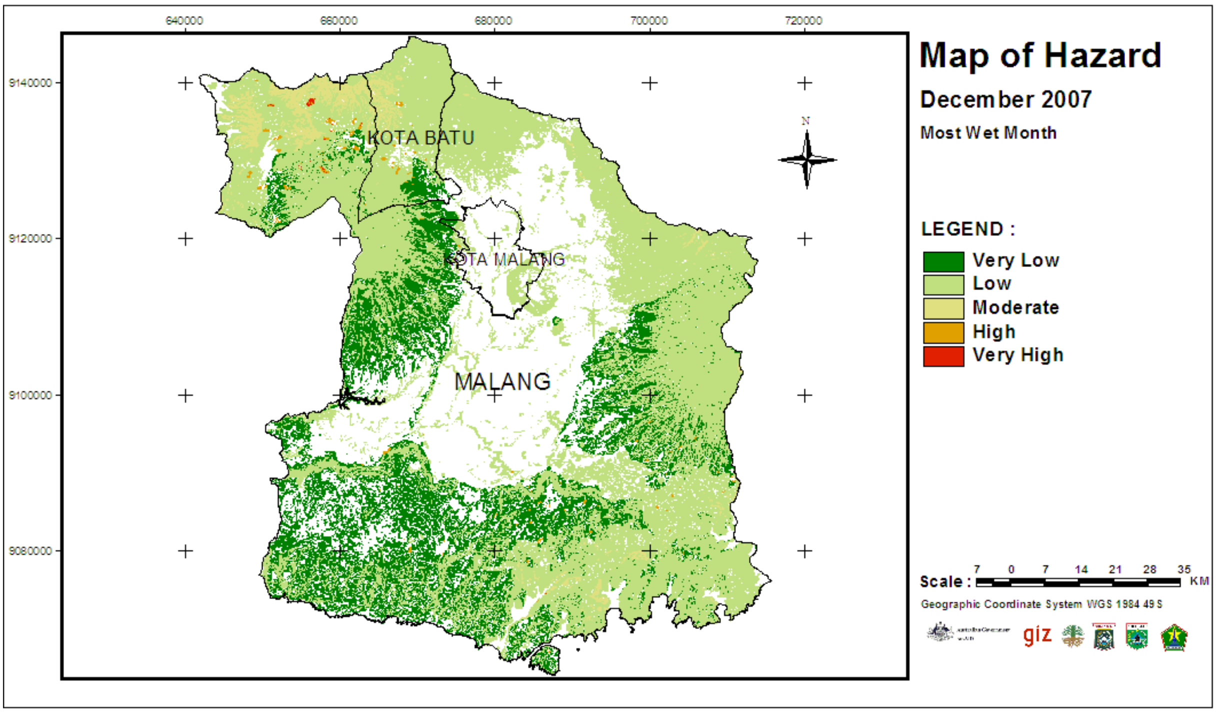
(b)

Figure 4. 33 (a) ground water table (GWT) recharge map of december 2006 as the most dry month, (b) ground water table (GWT) recharge map of December 2007 as the most wet month

As seen in figure 4.33, map ground water table (GWT) recharge map of december 2006 as the most dry month, ground water table (GWT) recharge map of December 2007 as the most wet month looks doesn't have significant differences. At southeast part of map ground water table (GWT) recharge of december 2006 as the most dry month looks there are some differences at some part, while at Batu city of map ground water table (GWT) recharge of December 2007 as the most wet month looks different from map of ground water table (GWT) recharge of december 2006 as the most dry month. Figure 6 below show hazard baseline map of december 2006 as the most wet month and hazard baseline map of december 2007 as the most dry month that related to ground water table (GWT) recharge map in figure 5 as one of the hazard map input.



(a)



(b)

Figure 4. 34 (a) : Hazard Baseline Map of december 2006, as the most wet month (b) : Hazard Baseline Map of december 2007 as the most dry month

The same like figure 4, there are no significant differences between baseline map hazard of december 2006, as the most wet month and baseline map hazard of december 2007 as the most dry month. As listed in table 5 below, the differences of both hazard map, about 1 km^2

and just seen at very low to high level, while at very high level does not have differences to each other.

Table 4. 19 Total area for each hazard level of hazard december 2006 and december 2007

Rank	Hazard (m^2)	
	Dec 2006	Dec 2007
	most dry month	Most wet month
Very Low	1.219.690.000	1.218.450.000
Low	2.431.320.000	2.432.560.000
Moderate	95.300.000	94.990.000
High	17.720.000	18.030.000
Very High	1.130.000	1.130.000

V ASSESSMENT OF VULNERABILITIES TO CLIMATE CHANGE

5.1 Identification of Vulnerability Component

The overall vulnerability in water sector of Greater Malang components are described in the following sections.

5.1.1 Population Density

Population density in a location of hazard determines its level of vulnerability. Greater Malang has a relatively high population density especially in Malang City and Batu City. In 2008, total population of Greater Malang was 3.349.503 people which consists of total population of Malang City was 816,637 people, total population of Batu City was 119,087 people, and total population of Malang District was 2,413,779 people. Meanwhile, Its population density in average was 786 persons/km^2 which consists of population density in average for Malang City, Batu City, and Malang District respectively are 7,420 persons/km^2, 925 persons/km^2, and 810 persons/km^2. Its population growth in 2005-2010 period is 0.55% %/year; meanwhile projection of population growth for 2020-2025 period is 0.67%/year (BPS, 2011).

The population density analysis in the current condition is based on the population per sub-district from 2008 Pondes. Meanwhile, the analysis of population density in the projection condition is based on the population growth as in the Greater Malang's RTRW. The growth ratio for each sub-district in a district is assumed to be the same. Figure 5.1 and Figure 5.2 show the population density on the current condition and projection condition.

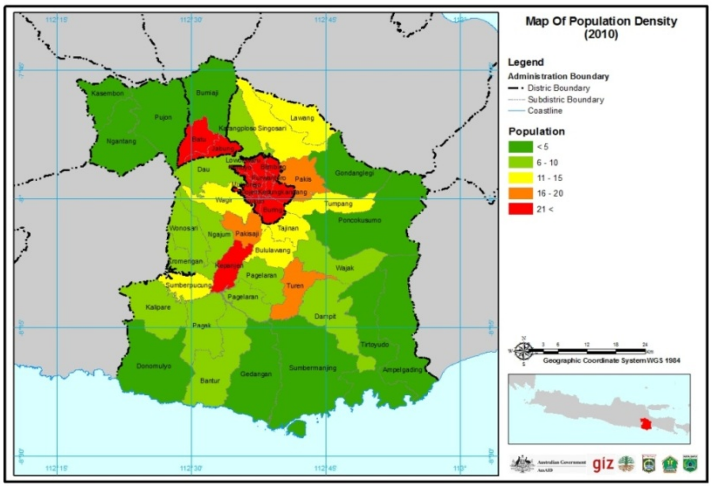


Figure 5. 1 Population density in gerater Malang at baseline periode.

Population density reaches maximum value at number of200 persons/km2. If more than 200 persons/km2, it will be assumed to be at maximum value.

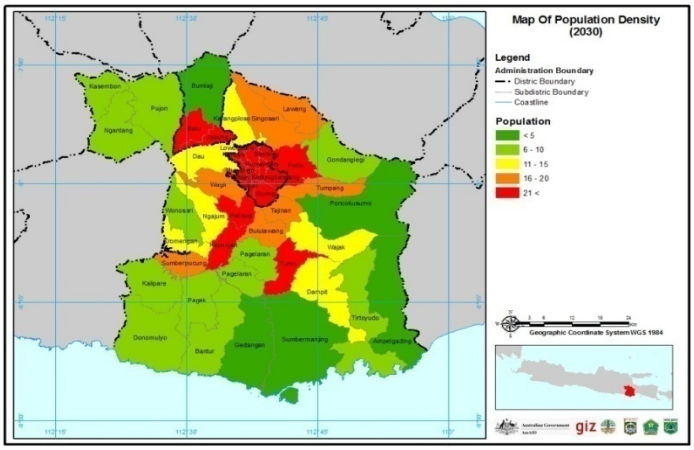


Figure 5. 2 Population density in gerater Malang at projection periode

For every hazard on floods and landslide there were a given value. For water shortage hazard, the value is converted from population density into water needs value.

5.1.2 Landuse

Land use type determines the level of vulnerability.The available landuse data is from year 2008, while baseline period in this study is year 2010. Thus, landusedata of year 2008 is assumed as landuse of baseline period, while data for projection landuse is based on the Spatial Planning year 2030(*RTRW 2030)*. Both data of landuse maps are obtained from the BAPPEDA of each government of Malang City, Batu City, and Malang District. To gain the validity of information from those landuse maps in the vulnerability analysis, some assumptions are applied: landuse is considered based on theirs economic value during floods and landslides events; and based on water needs value for water shortage. Those assumptions for baseline periode are presented in Table 5.1 below.

Table 5. 1 Landuse types and assumptions of its value for calculating the vulnerability of landuse to climate change in water sector (forflood and landslidehazard), baseline condition

Landuse Types forYear 2008 (Baseline)	Assumptions of Landuse Value
Settlement (*Pemukiman*)	10.0
Fishery (*Perikanan*)	5
Paddy field(*Sawah*)	5
Plantation (*Perkebunan*)	2
Dry land agriculture(*Pertanian Lahan Kering*)	1.0
Bush, grass, waste land (*Semak Belukar, Rumput, Tanah Kosong*)	0.5
Forest (*Hutan*)	0.1
Swamp & water body (*Rawa dan tubuh air*)	0

Techical term or terminology in every district/city is different each other, so it is neccesary to standardize those terms or terminologies used in this study. This standards is used for spatial planning in year 2030 (projection) that easily compared with spatial planning year 2008 (baseline). Table 5.2 shows the standardized spatial planning and its comparison with spatial planning in Malang District, Malang City, and Batu City. Meanwhile, an assumption of each economy value in projection periode is presented in Table 5.2.

Table 5. 2 Land use in standadized spatial planning (spatial planning in 2030) with its proportionality to the spatial planning of Malang District, Malang City and Batu City respectively

Land use in Standadized Spatial Planning	Land use in Spatial Planning of Malang District	Land use in Spatial Planning of Malang City	Land use in Spatial Planning of Batu City
Airport (*Bandara*)	Airport (*Bandara*)		
Public facilities (*Fasum Fasos*)		Public facilities (*Fasum Fasos*)	Public facilities (*Fasilitas Umum*)
Industrial and warehousing region (*Kawasan Industri dan Pergudangan*)	Industrial region/ Development of industrial region (*Kawasan Industri/ Pengembangan Kawasan Industri*)	Industrial and warehousing region (*Kawasan Industri dan Pergudangan*)	Industrial and warehousing (*Industri dan Pergudangan*)
Military region (*Kawasan Militer*)		Military region (*Kawasan Militer*)	Defense & security region (*Kawasan Pertahanan & Keamanan)*
Tourism region (*Kawasan Pariwisata*)			Tourism region (*Kawasan Pariwisata*)
Settlement region (*Kawasan Pemukiman*)	Settlement / urban settlement (*Pemu-kiman / Pemukiman Perkotaan*)	Settlement region (*Kawasan Pemukiman*)	Housing (*Perumahan*)
Trade and service region (*Kawasan Perdagangan & Jasa*)	Coomercial region (*Kawasan komersial)*	Trade and service region (*Kawasan Perdagangan & Jasa*)	Trade and service (*Perdagangan & Jasa*)
Fishery (*Perikanan*)	Fishery (*Perikanan*)		
Plantation (*Perkebunan*)	Plantation (*Perkebunan*)		Agriculture (*Pertanian*)
Irrigated paddy field (*Sawah Irigasi*)	Irrigated paddy field (*Sawah Irigasi*)		
Rainy paddy field (*Sawah Tadah Hujan*)	Rainy paddy field (*Sawah Tadah Hujan*)		
Dry-land agriculture (*Tegalan*)	Dry-land agriculture (*Tegalan*)		
Protected forest (*Hutan lindung*)	Protected forest (*Hutan lindung*)		Protected forest (*Hutan lindung*)
Production forest			Production forest (*Hutan*

Land use in Standadized Spatial Planning	Land use in Spatial Planning of Malang District	Land use in Spatial Planning of Malang City	Land use in Spatial Planning of Batu City
(*Hutan produksi*)			*produksi*)
Swamp forest (*Hutan Rawa*)	Swamp forest (*Hutan Rawa*)		
Green open space (*Ruang Terbuka Hijau*)		Green open space (*Ruang Terbuka Hijau*)	Green open space (*Ruang Terbuka Hijau*)
Locally protected region (*Kawasan Lindung Setempat*)		Locally protected region (*Kawasan Lindung Setempat*)	River demarcation/ Higg voltage demarcation (*Sempadan sungai/ Sempadan Sutet*)
Grand forest garden (*Taman Hutan Raya)*			Grand forest garden (*Taman Hutan Raya)*
Lake/dam (*Danau/waduk*)	Lake/dam (*Danau/waduk*)		

Table 5. 3 Landuse types and assumptions of its value for caculating the vulnerability of landuse to climate change in water sector (for flood and landslide), projection condition (2030).

Landuse in combined Spatial Planning	Landuse Value
Airport (*Bandara*)	10
Public facilities (*Fasum Fasos*)	10
Industrial & warehousing region (*Kawasan Industri dan Pergudangan*)	10
Military region (*Kawasan Militer*)	10
Tourism region (*Kawasan Pariwisata*)	10
Settlement region (*Kawasan Pemukiman*)	10
Trade and service region (*Kawasan Perdagangan & Jasa*)	10
Fishery (*Perikanan*)	5
Plantation (*Perkebunan*)	2
Irrigated paddy field (*Sawah Irigasi*)	5
Rainy paddy field (*Sawah Tadah Hujan*)	2
Dry-land agriculture (*Tegalan*)	1
Protected forest (*Hutan Lindung*)	0.1
Production forest (*Hutan Produksi*)	0.1
Swamp forest (*Hutan Rawa*)	0.1
Green open space (*Ruang Terbuka Hijau*)	0.1
Locally protected region (*Kawasan Lindung Setempat*)	0.1
Grand forest garden (*Taman Hutan Raya)*	0.1

Landuse in combined Spatial Planning	Landuse Value
Lake/dam (*Danau/waduk*)	0

The maximum economical value of landuse is Rp 10 Million/m^2. The values in Tabel 5.1 and 5.3 also will be normalized according to the maximum economical value.

Based on the criterias, data, and assumptions as in Table 5.1 and 5.3, we can create a weighting of landuse vulnerability for the current baseline condition and projection condition for floods and landslides, as depicted in Figure 5.3 and Figure 5.4.

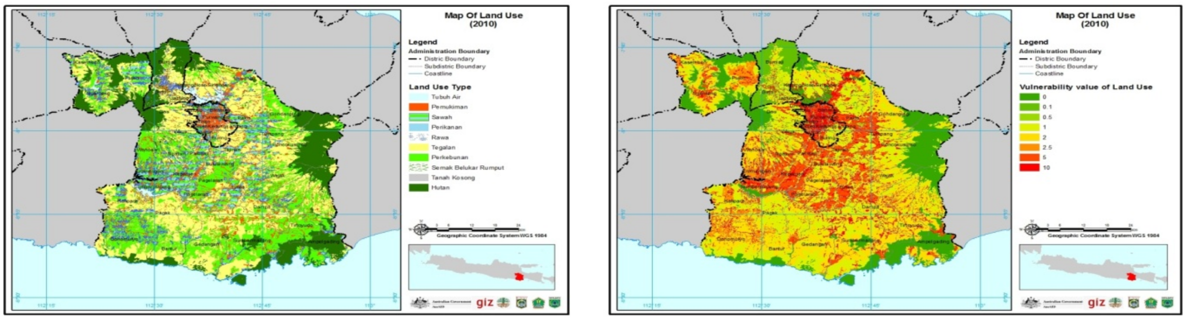


Figure 5. 3 Vulnerability of landuse at baseline condition land use type (*left*)

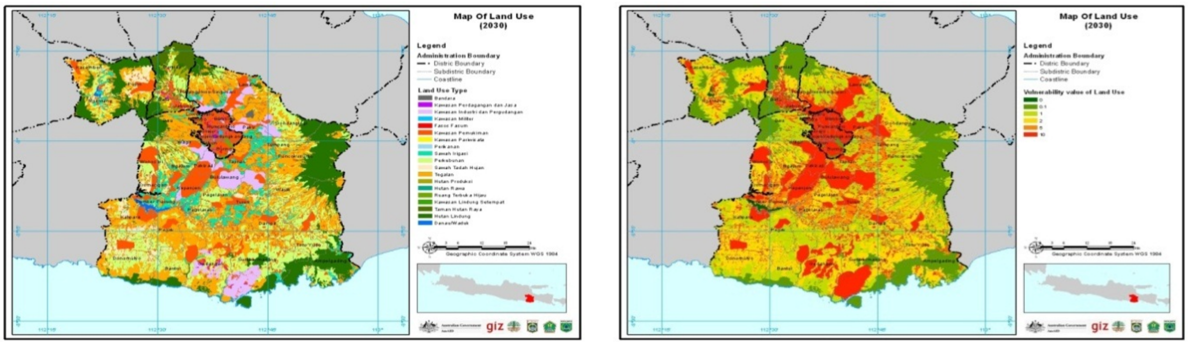


Figure 5. 4 Vulnerability of landuse at projection condition (2030) land use type (*left*)

5.1.3 Role of Infrastructure

Hazard often caused great collateral damages or risks for vulnerable area, especially if it occured in important infrastructures. For example, if a landslide occurred on a road, then every activity on the road cannot be conducted.

Road network is the important infrastructure which determines the level of vulnerability to climate change. The source of road data includes is the RTRW (spatial planning) of each district/city both for baseline and projection period. For the baseline condition, the map represents the existing function of road, while for the projection condition the map is assumed as road infrastructures for the 2030. Figure 5.5 is map of infrastructure in projection period (spatial planning of 2030).

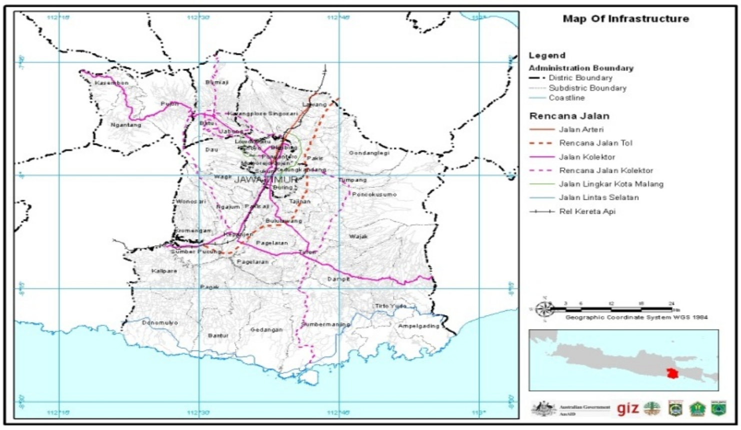


Figure 5. 5 Map of Infrastructure of Malang City, Batu City and Malang District in projection periode (2030), taken from the 2030's spatial planning

Roads also have larger role for opening access from one location to another. Thus, the weighting role of the infrastructure can also be based on each function of the roads (Table 5.4).

Table 5. 4 Values for each road for the weighting component of infrastructure vulnerability

Type of Road	Value
Rail Roads	3 x roads length each grid (1km^2)
Arterial Roads	3 x roads length each grid (1km^2)
Collector Roads	2 x roads length each grid (1km^2)
Local Roads	1 x roads length each grid (1km^2)

Based on the data and approach, also form the above assumptions, we obtain the map of road infrastructures for the baseline and projection conditions as in Figure 5.6 and 5.7.

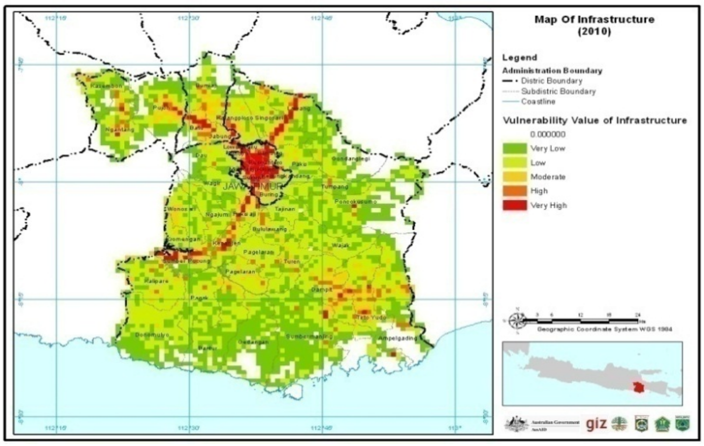


Figure 5. 6 Map of infrastructure vulnerability in Greater Malang at baseline (2010) period with level of vulnerability from very high (red), high (orange), moderate (yellow), low (light green) and very low (green)

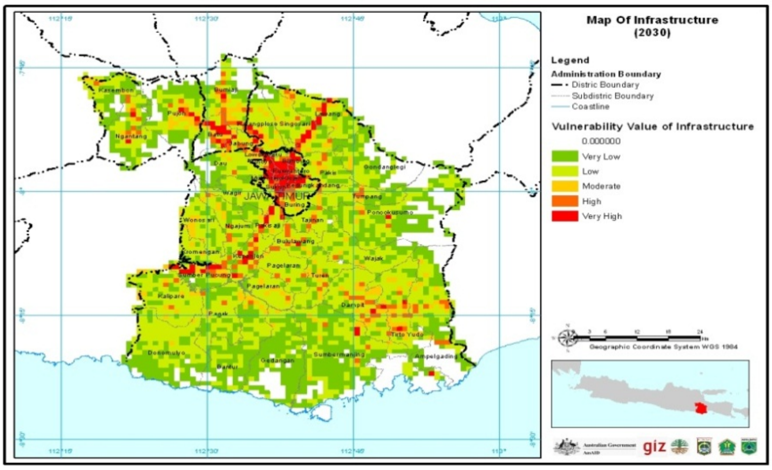


Figure 5. 7 Map of infrastructure vulnerability in Malang Greater at projection period (2030) with level of vulnerbality from very high (red), high (orange), moderate (yellow), low (light green) and very low (green)

5.1.4 Water Demand

Water demand is an indicator used to analyze water shortage. Water shortage is worsen by higher water demand. The level of water demand is analyzed from two components: people or domestic water need and landuse's water needs. Based on the standard of FAO, people's water needs is 150 liter/person/day or 0.15 m3/person/day.

The landuse water need is divided into four groups based on standard of FAO that comparable with landuse condition in greater Malang condition. The four groups are (Table 5.5): paddy field with a need of 14,000 m^3/ha/year, plantation with a need of 10,000 m3/ha/year; dry land agriculture which has a water need of 9,000 m^3/ha/year, and forest which has a water need of 5,000 m^3/ha/year.

Table 5. 5 Water demand assumption depending on landuse

Landuse types	Water demand (m^3/ha/year)
Paddy field or Rice field	14,000
Plantation	10,000

Dry land agriculture	9,000
Forest	5,000

Source: FAO, 2010

In this study, water need of industries is not involved considering its low water need, as to be considered insignificant. Based on the above assumptions, we obtained the water demand distribution for greater Malang in baseline and projection periode as presented in Figure 5.7 and 5.8.

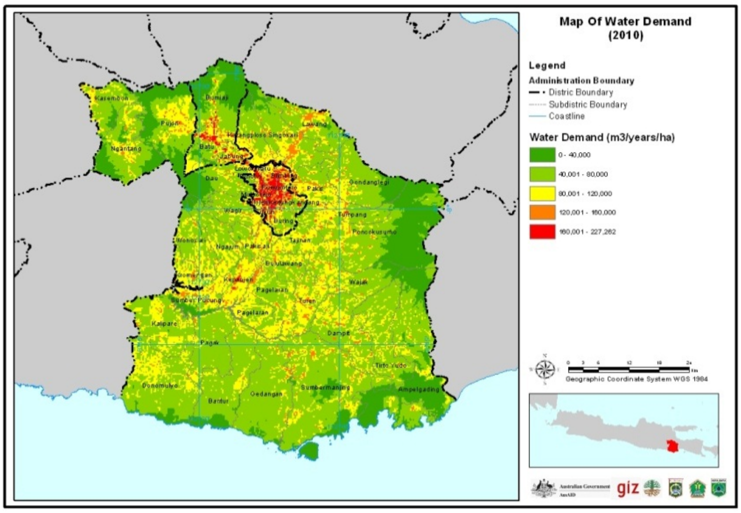


Figure 5. 8 Map of total water need (water demand) in greater Malang in baseline period (2010)

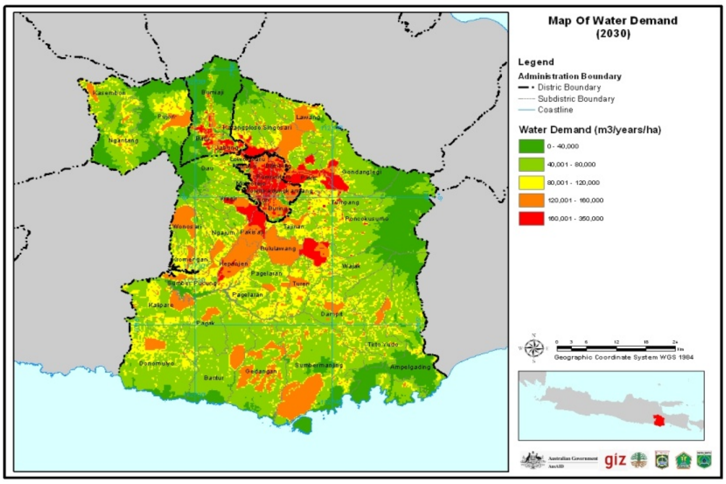


Figure 5. 9 Map of total water need (water demand) in greater Malang in projection period (2030)

5.1.5 Water Sources

The impact of climate change to water availability depends on the amount of water sources utilized. The higher the dependence of water sources to climate, the bigger the impacts of climate change. So, the water sources are a part of vulnerability component to the hazard of climatic change, especially water shortage hazard.

Data of utilized water sources is obtained from 2008 Village Potential (*National Cencus, 2008*). Based on the data, there are 7 water sources utilized in greater Malang as follows: 1) Instalation water or bottling/packing water, 2) pumping water, 3) well, 4) spring, 5) river/lake 6) rain water, and 7) others.

To obtain the weighting values for the water sources, along with its spatial distribution for the baseline and projection, we use the following assumptions:

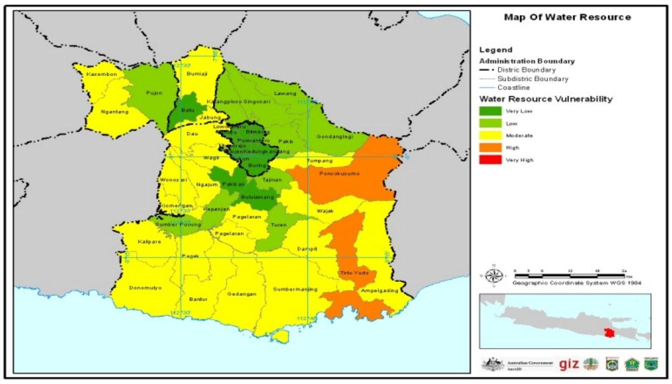
- Unit of weighting is sub-distric (*kecamatan*) where each sub district is averaged from thevillage's water source in that sub district;
- Each vulnerability weighting is as in Table 5.6;
- On the projection conditions (2030), it is assumed that all water sources in greater Malang is in the form of instalation water or bottling/packing water (water from PAM or bottled water). This means that the weight value of water source is assummed to be 1 or the maximum value or the lowest vulnerability;

Table 5. 6 Each weighting value for each water source

Type of Water Source	Weighting ofWater Source
Instalation water or bottling/packing water	1
Pumping water	2
Well	3
Spring	4
River/lake	5
Rain water	6
Others	7

Based on the assumptions and weighting above, we obtain the picture of vulnerability level of water sources and its spatial distribution in Greater Malang. Figure 5.10 shows the level of vulnerability of water sources in the baseline period.

Figure 5. 10 Vulnerability of water source at baseline period



5.1.6 Population Welfare

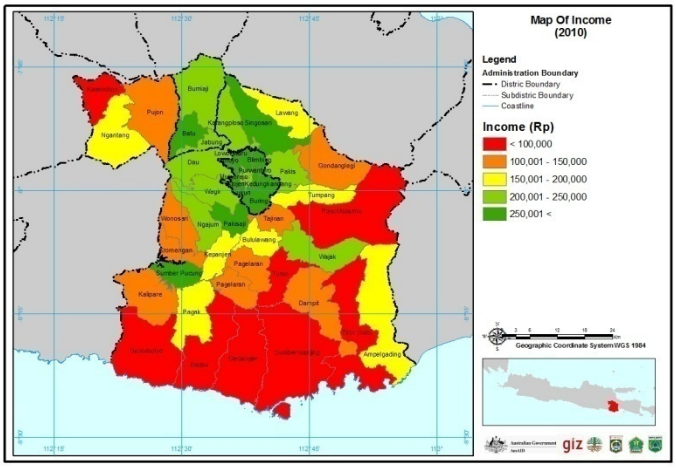
Population welfare or social welfare is used to represent the involvement of society in minimizing impacts of disasters. In this study, it is is measured based on population's income or income/capita.

The income data is obtained from the 2007 National Census. In the analysis, the data is then averaged from Rp 250,000.00 to Rp 1000,000.00.Several assumptions used in the analysis are:

- The lower the income, the larger the vulnerability to climate change;
- In the projection condition, it is assumed that the vulnerability of welfare component is on the lowest condition or value 1; which means that in 2030 we assumed that the population can handle climate change well enough.

Based on the data and assumptions mentioned above, we obtain the picture of vulenarbility of population welfare in greater Malang as in Figure 5.11.

Figure 5. 11 Vulnerability of population welfare at baseline condition



5.2 Overview of Water Sector Vulnerability

As stated in Chapter 3, vulnerability in this study is defined as a function of character, magnitude, and rate of climate change hazards and a variation of exposure, sensitivity, and adaptive capacity from the system to the hazards. Hence, there are two affecting factors, they are: climate change identified hazard type; and the components of vulnerability based on the hazard.

Based on the identified hazard, there are three vulnerabilities of water sector to climate change in this study. The three vulnerabilities are vulnerability to water shortage, vulnerability to floods, and vulnerability to landslides. Next, each vulnerability component is analyzed based on its population density, landuse, role of infrastructure, water demand, water source, and population welfare.

5.2.1 Vulnerability to water shortage

Vulnerability to water shortage can be defined as vulnerability from the combination of its vulnerability compnents to water shortage hazard. Water shortage hazard has been identified as in Chapter 3. The vulnerability to water shortage consists of 3 components and 3 indicators: water demand as indicator of its exposure component, water sources as indicator of its sensitivity components, and population welfare as indicator of its adaptive capacity component. Table 5.7 shows the vulnerability components to water shortage along with its indicators and weighting in the GIS analysis.

Table 5. 7 Components and indicators of vulnerability to water shortage

Components	Indicators	Sub Indicators	Ratio
Exposure	Water Demand	Population water demand	0.5
		Landuse water demand	
Sensitivity	Water Resource	Instalation water; or bottling or packing water; pumping water, well, spring; river/lake, rain water; others water resources.	0.32
Adaptive Capacity	Population Welfare	Society's income	0.18

Based on previous analyses on water demand, water sources, and population welfare with GIS analysis referencing to the framework of Table 5.7, we produce the map of vulnerability to water shortage hazard for the baseline and projection periods in Figure 5.12 and 5.13.

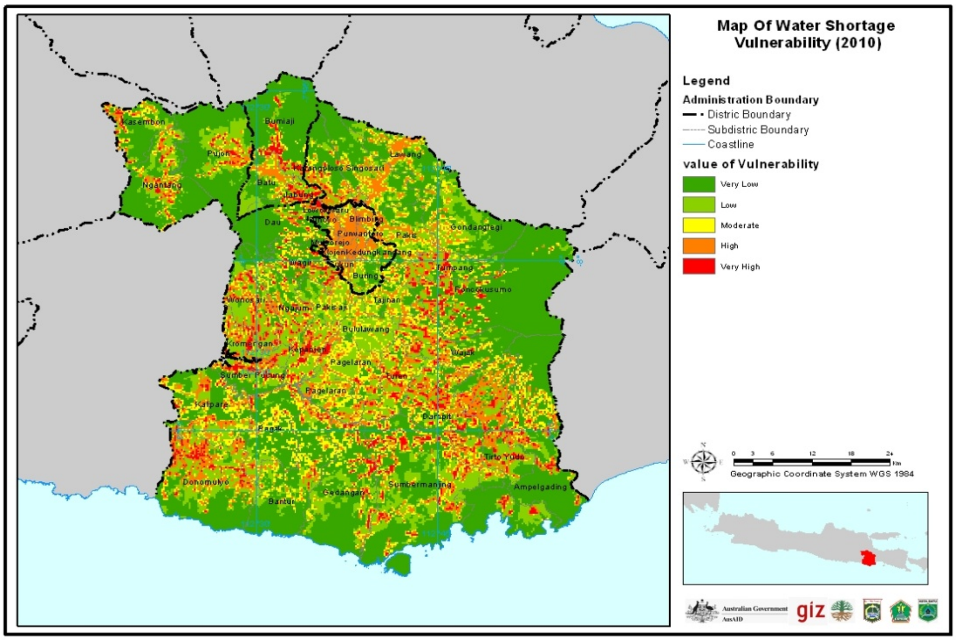


Figure 5. 12 Vulnerability to water shortage hazard at baseline condition (2010).

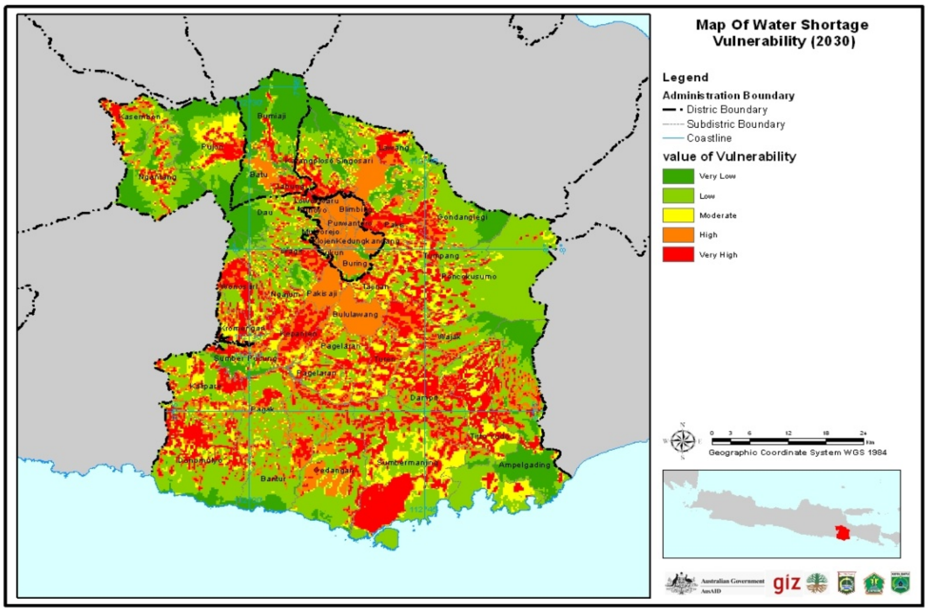


Figure 5. 13 Vulnerability to water shortage hazard at projection condition (2030).

As shows in Figure 5.12 and 5.13, generally, the vulnerability of greater Malang to water shortage hazard is varying from very low to very high in both periods. But it shows that in baseline period, dominance vulnerability rate is on urban area or valley morphology, and low vulnerability in rural area or hills morphology; and in projection period, that vulnerability rate change from dominance high to very high vulnerability. In general, the vulnerability condition of greater Malang to water shortage hazard is increasing from the baseline to the projection period from dominantly moderate vulnerability to high- very high vulnerability. Here, the most dominant component that contributes high level of vulnerability is water demand component. By looking at the map of watersheds as in Chapter 4, the regions that experience significant increase of vulnerability from the baseline to the projection period for each watershed is shown in Table 5.8.

Table 5. 8 Vulnerability change to water shortage hazard from the baseline (2010) to the projection (2030) period

No.	District/City	Sub-District	Vulnerability Level	
			Baseline Condition	Projection Condition
1.	Malang City	Blimbing	Mostly high	All region of the district is high .
		Purwantoro	Mostly high	All region of the district is high .
		Kedungkandang	Part (up to 50%) of the region is high. and the other part is low to very low	Mostly high; a small part in the south of the region is low
		Buring	Mostly low v to very low; some small region of moderate.	Mostly high; a small part in the south of the region is low
		Sukun	Mostly moderate to high; some small region of low.	Mostly high; some small region of moderate to low.
		Klojen	Mostly moderate to high; some small region of low.	Mostly high; some small region of moderate to low.
		Mulyorejo	Mostly moderate to high; some small region of low.	Almost all region of the district is in high.
		Dinoyo	Mostly low to very low; some small region of moderate.	Almost all region of the district is in high.
		Lowokwaru	Up to 50% of the region is high; in the other part of the region is moderate to low	Almost all region of the district is in high.
2.	Batu City	Jabung	Mostly high v to very high; some small region of moderate.	Almost all region is very high to high
		Batu	High to moderate in the north and low to very low in the south	Mostly high in the north region and low in the south
		Bumiaji	Mostly low to very low in the middle to the north; some small region of high to very high in the middle to the south	Mostly low in the middle to the north; some significant area of high to very high in the middle to the south
3.	Malang District	Karangploso	Mostly very low except in the south region with moderate to high	The south region becomes dominantly very high
		Singosari	Mostly very low to low. Some small part in the middle-south of the region	Mostly low. Some significant part in the middle-south of the

No.	District/City	Sub-District	Vulnerability Level	
			Baseline Condition	Projection Condition
			is moderate to high.	region is high.
		Lawang	Mostly very low to low. Some small part in the middle of the region is moderate to high.	Mostly low. Some significant part in the middle of the region is high.
		Gondanglegi	Almost all region is very low to low except a small part in the west is high to moderate	The west area significantly become very high-high. The others area is low to very low
		Pakis	Mostly low to moderate. Some small area of high in the middle	Almost all region is very high to high except north part low to moderate
		Tumpang	High to moderate in the middle region and low to very low in the others region	The middle region become very high to high v; & the others become low to moderate
		Poncokusumo	Mostly very low, except some scattered area in the west which moderate to very high	Mostly low, except the scattered area in the west which moderate to very high v become wider
		Ampelgading	Mostly very low, except some scattered area in the south which mostly moderate	Mostly low, except the scattered area in the south which high to very high
		Tirtoyudo	Scattered area ranges from low to very high where the dominant area are moderate to high	Scattered area ranges from low to very high where the dominant area are high to very high
		Wajak	Scattered area ranges from low to very high where the dominant area are moderate to high	Scattered area ranges from low to very high where the dominant area are high to very high.
		Tajinan	Scattered area ranges from low v to very high	Scattered area ranges from low v to very high.
		Batulawang	Scattered area ranges from low v to very high	Almost all region is high
		Turen	Scattered area ranges from low v to very high	Scattered area ranges from low v to very high & mostly is very high.
		Dampit	Scattered area ranges from low to very high	Scattered area ranges from low v to very high v & mostly is very high v.
		Sumbermanjing	Mostly low to very low especially in the middle with some scattered area of medium to very high	The area of low to very low become more limited in the middle. Some significant area in the south is very high
		Gedangan	Mostly very low to low, except some scattered area in the north which mostly moderate	Mostly high to very high. Low to very low rested in the south of region
		Pagelaran Utara	Scattered area ranges from low to high, but low v is dominant	The same pattern of scattered area but very high area become wider
		Pagelaran Selatan	Scattered area ranges from low to high	The same pattern of scattered area but very

No.	District/City	Sub-District	Vulnerability Level	
			Baseline Condition	Projection Condition
				high v become wider
		Bantur	Dominantly low with some scattered area of moderate ton high	Low vulnerability still dominant but moderat to high v become wider
		Kepanjen	Scattered area ranges from low v to very high	Almost all region is very high v.
		Pakisaji	Scattered area ranges from low v to high	Almost all region is high, except in northwest
		Ngajum	Scattered area ranges from low to very high, the dominant is low	Scattered area ranges from low to very high, dominantly low but very high area become wider
		Kromengan	Scattered area ranges from low to very high.	Almost all regions is very high.
		Sumberpucung	Moderate to very high in the middle-north region; mostly low in the south	The middle-north region becomes dominantly very high
		Pagak	Mostly very low to low, which scattered area of dominantly moderate	Mostly low, the scattered area which is dominantly very high becomes wider
		Donomulyo	Mostly very high to moderate ind the middle-west region; and low to moderate in the south	The middle-west become dominantly very high; the south becomes low with some scattered of high to very high
		Kalipare	Mostly very low with some scattered area of mostly moderate	Mostly low with the scattered area becomes mostly very high
		Wonosari	Scattered area ranges from low to very high.	Area of very high becomes dominant especially in the middle to the nortwest of region
		Wagir	Scattered area ranges from low to very high.	Area of very high becomes dominant
		Dau	Mostly very low. Some scattered area of mode-rate tohigh in the east	Scaterred are with dominantly very high in the east becomes wider
		Pujon	Mostly very low to low; some small area of moderate to very high in the middle-east of the region	The area in middle-east become wider which mostly very high; the area of low to very low become smaller
		Ngantang	Mostly very low to low; some small area of moderate to very high v in the middle of the region	The area in middle-east become wider which mostly very high; the low to very low area become smaller
		Kasembon	Mostly very low to low; some small area of moderate to high in the north-east of the region	The area in the north-east becomes wider which mostly very high.

Note: v = vulnerability; Watershed: is the main watershed which consists of some small watersheds

(1) The baseline condition of water shortage vulnerability

In the baseline period, the most vulnerable areas to water shortage wich indicated by highest rank of vulnerability and widest total area in the district unit are Jabung, Batu and Bumiaji in Batu City; and Pujon, Ngantang, Donomulyo, Dampit, Kepanjen, Sumbermanjing, Gedangan, Dampit, Turen, Tirtoyudo, Tumpang, and Poncokusumo in Malang District.

Meanwhile, the widest area with the high level of vulnerability can be considered as the next to the most vulnerable areas. These areas in sub-district unit in baseline period, among others, are Blimbing, Purwantoro, Klojen (Malang City); Batu (Batu City); and some other districts in Malang District.

(2) The projection condition of water shortage vulnerability

In general, vulnerability pattern of the projection period (2030) is continuing the pattern in baseline period (2010). As shown in Table5.8, in general, the vulnerability is changing to be higher vulnerability. There are three patterns of change from the baseline to the projection, which are: (1) change from a level into one higher level of vulnerability, (2) change into two levels higher, and (3) change into three levels higher.

In the **one vulnerability level higher**, there are 4 categories of regions:

1) **High** vulnerability regions change into **very high** vulnerability regions, in example: in sub-dictricts of Pujon, Lawang, Dampit, Ampel Gading (Malang District), and Batu, Bumiaji, and Jabung (Batu City).
2) **Moderate** vulnerability regions change into **high** vulnerability regions, such in sub-districts of Blimbing, Lowokwaru, Dinoyo, etc (Malang City); Batu, Bumiaji, and Jabung (Batu City); Karangploso, Singosari, Ampelgading, Dampit, Sumbermanjing, Gedangan, Batulawang, Pakisaji (Malang District).
3) **Low** vulnerability regions change into **moderate** vulnerability regions, for examples are sub-districts of Pujon, Gondanglegi, south Tirtoyudo, Sumbermanjing, Gedangan, Bantur, Pagak, Kalipare, Donomulyo, Pagelaran (Malang District).
4) **Very low** vulnerability change into **low** vulnerability regions, for examples are sub-districts of Bumiaji (Batu City); Karangploso, Singosari, Lawang, Gondanglegi, Tumpang, Poncokusumo, Ampelgading, Tirtoyudo, Sumbermanjing, Gedangan, Donomulyo, Pagak, Sumberpucung, Pakisaji, Dau, Pujon (Malang District).

For the second pattern, change into **two vulnerability levels higher**, there are three categories:

1) **Moderate** vulnerability level change into **very high**. This pattern, for examples consists of sub-districts of Batu, Bumiaji, and Jabung (Batu City); Karangploso, Lawang, Pakis, west Gondanglegi, Tumpang, Tajinan, Wajak, Turen, Dampit, central-north Tirtoyudo, Pagelaran, Pagak, Gedangan, Donomulyo, Kalipare (Malang District)
2) **Low** vulnerability level change into **high** vulnerability, as shown in part of sub-districts of: Karangploso, Lawang, Tumpang, Poncokusumo, Ampelgading, Sumbermanjing, Bantur, Donomulyo, Pagak, Pagelarang (Malang District)
3) **Very low** vulnerability level change into **moderate** vulnerability, for example part of sub-districts of : Ampelgading, Gedangan, Sumbermanjing, Tirtoyudo, Pagak, Kepanjen, Ngajum, Kromengan, Pujon (Malang District)

For the third pattern, change **into three vulnerability levels higher**, there are two categories:

1) **Low** vulnerability regions change into **very high** vulnerability, as clearly shown in part of sub-districts of: Sumbermanjing, Gondangdia, Lawang, Dampit, Donomulyo, Pagak, Sumberpucung, Wonosari, etc (Malang District)
2) **Very low** vulnerability regions change into **high** vulnerability, such as in some areas of sub-districts of: Buring (Malang City); Jabung, Batu (Batu City); Singosari, Lawang, Poncokusumo, Gedangan, Bantur, etc (Malang District).

Regions which need to focus in reference to adaptation, based on the distribution of high to high vulnerability level and its changes are: 1) the whole Malang City region; 2)the center to southern of Batu City region; 3) the upper or northern Malang District Region (Kasembon, Pujon, Ngantang, Karangploso, Lawang, south Singosari; middle of Malang District (Pakis, Gondanglegi, Tumpang, west Wajak, Batulawang, Pakisaji, Kepanjen, Kromengan,Turen, Sumberpucung); and the lower or south of Malang District (Dampit, center of Ampelgading, south of Sumbermanjing, Gedangan, Bantur, Donomulyo, Pagak, Kalipare).

As in the baseline condition, the vulnerability analysis for the projection period did not involve other vulnerability components such as water quality and water infrastructures due to its unavailable projection data. The vulnerability condition will be a little different and will worsen several regions if the water quality and infrastructures are involved.

5.2.2 Vulnerability to floods

Vulnerability to floods can be defined as vulnerability from the combination of its components to floods hazard. Floods hazard has been identified in chapter four. The vulnerability to floods consists of three components and four indicators: population and landuse as indicators of its exposure component; role of infrastructure as indicator of its sensitivity components, and population welfare as indicator of its adaptive capacity component. Table 5.9 shows the vulnerability components along with its indicators and weighting from the GIS analysis.

Table 5. 9 Components and Indicators of vulnerability to flood

Components	Indicators	Sub-indicators	Weighting
Exposure	Population density	Population and population growth per sub-district	0.53
	Landuse	Landuse as in regional planning	0.23
Sensitivity	Role of infrastructure	Road infrastructure	0.18
Adaptive Capacity	Population Welfare	Population's income	0.06

Based on previous analyses on vulnerability components to floods, with the GIS analysis refering to the framework as in Table 5.8 above, we produce maps of water vulnerability to floods for the baseline period and projection period, shown in Figure 5.14 and 5.15.

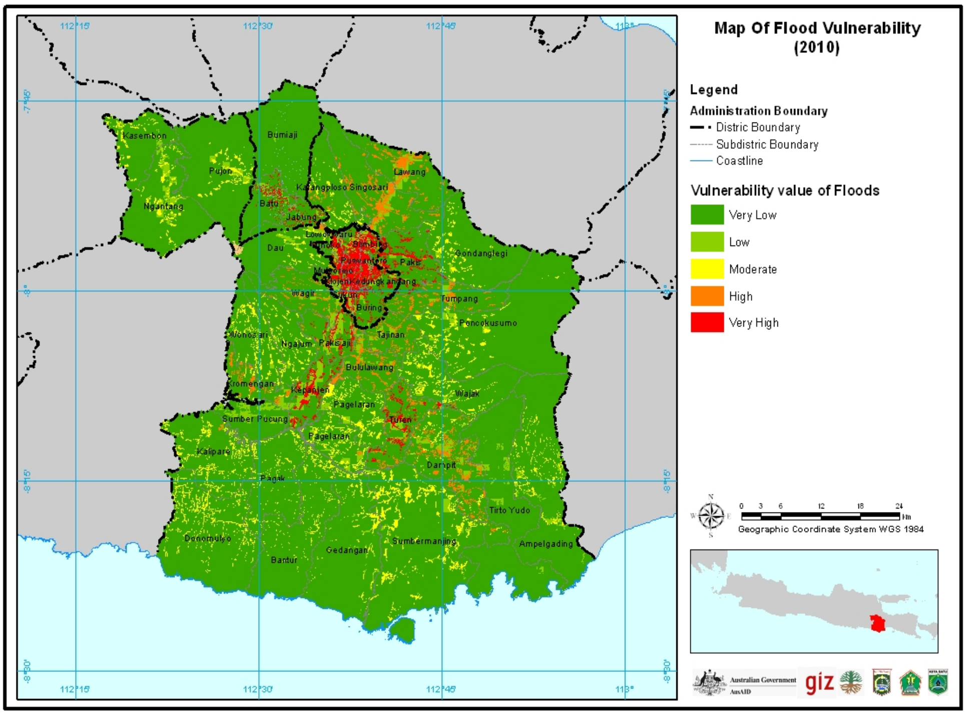


Figure 5. 14 Vulnerability to flood hazard at baseline period (2010)

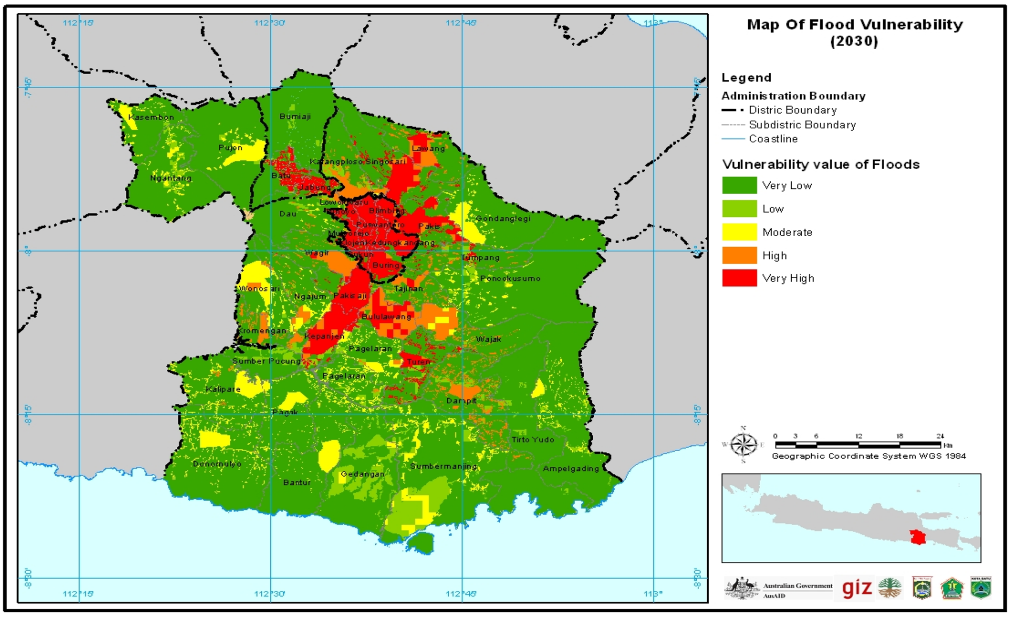


Figure 5. 15 Vulnerability to flood hazard at projection period (2030)

As in Figure 5.14 and 5.15, in general, the vulnerability to floods consists from the very high level to very low level of vulnerability in both periods. Here, landuse component and population component are the dominant components that contribuite to the total vulnerability for the flood hazard. Meanwhile, the less dominant to contribute to the total vulnerability of flood hazard is the role of infrastructure.

Generally, the vulnerability condition of greater Malang to floods increases from the baseline period (2010) to the projection period (2030). By refering to the map of Greater Malang, the regions which will experience significant increase of vulnerability level in every district unit are presented in Table 5.10.

Table 5. 10 Vulnerability change to floods hazard from the baseline to the projection condition

No.	District/City	District	ChANGE IN Vulnerability Level	
			Baseline Condition	Projection Condition
1.	Malang City	Blimbing	Mostly very high	All region of the district is very high.
		Purwantoro	Mostly very high	All region of the district is high .
		Kedungkandang	Mostly very low. Some small areas in the west are low to very high	Mostly very high. A significat part in the south is very low to low
		Buring	Mostly low to very low; some scattered small areas of high.	Mostly very high. Some small areas in the south are low.
		Sukun	Low to very high.	Almost all region is very high.
		Klojen	low to very high.	All regio is very high.
		Mulyorejo	Almost all regions is very high.	All regio is very high.

		Dinoyo	Very low to low except in east parts are moderate to very high.	Almost all region of the district is in very high.
		Lowokwaru	Mostly low to moderate; a small part in the west-south is very high.	All regio is very high.
2.	Batu City	Jabung	Mostly very low. Some scattered areas of low to high.	Almost all region in the center-south east parts are very high
		Batu	Mostly very low. Some scattered areas of low to high.	Almost all regions in the center-north parts are very high.
		Bumiaji	All region is in very low.	Some small areas in the center are low.
3.	Malang District	Karangploso	Mostly very low except some scattered areas of moderate to high.	The south-center region becomes high
		Singosari	Mostly very low except a significant area in south region and some scattered area in center to the north region are high	The high in the south region and scattered area in the center region become very high and the area become wider.
		Lawang	Mostly very low except a significant area in center region and some scattered area in the center to the north region are high	The high in the center to the north region become very high and the area become wider
		Gondanglegi	Almost all region is very low except some small scattered areas in the wwest region are moderate	The scattered area of moderate in the west region become unity and significant area. The others area are still low.
		Pakis	Some scattered areas in the center region are high. The others region are low	The very high. area become wider. Also, some area of high. becomes dominant area.
		Tumpang	Mostly very low to low except a significant area in center region is high and some scattered areas are low to very high	The high in the center region become very high and wider. The scattered areas of low to very high vstill present
		Poncokusumo	Mostly very low except some scattered areas in the west region are moderate to low	The pattern and area of are not changing significantly except in the soutwest region
		Ampelgading	Mostly very low except some scattered areas from the north to the south region are moderate.	The pattern and area of vulnerabilities are not changing significantly except in the center become wider
		Tirtoyudo	Almost all region is very low.	Mostly very low; some regios are low.
		Wajak	Mostly very low to low except some scattered areas in the center-west region are moderate.	Mostly still very low to low, the scattered areas of moderate become wider and some are become high.

Tajinan	Mostly very low except some scattered areas are moderate to high.	Some of the scattered areas become unity and wider and some of its area become very high
Batulawang	Mostly very low to low with some scattered areas of moderate to very high	Almost all region is in very high to high
Turen	Mostly very low to low with some scattered areas of moderate to very high	Up to 50% of total area is very high, distributed in all region, especially in the center.
Dampit	Mostly very low to low with some scattered areas of moderate to high	Scattered areas of high in the center becomes unity and wider
Sumbermanjing	Mostly very low. Some scattered areas of moderate	Mostly low to very low . Some scattered areas of moderate
Gedangan	Mostly very low to low	Mostly very low to low with some scattered areas of moderate in the soutwest region and northeast region
Pagelaran Utara	Mostly very low with some scattered areas of moderate v	The scattered areas of moderate become wider and the rank of some of the area are high.
Pagelaran Selatan	Mostly very low with some scattered areas of moderate	The scattered areas of moderate v become wider and the rank of some of the area are high.
Bantur	Almost all region is low except in the north is some scattered areas of moderate	Mostly very low to low. A significat wide of moderate in the center region
Kepanjen	Mostly very low to low with some scattered areas of very high in the center region	Amost all region is very high with some scattered areas of high
Pakisaji	Mostly very low to low with some scattered areas of very high	All region is very high
Ngajum	Mostly very low with scattered areas of low to moderate	Very low still dominant. Scattered areas become wider with the rank are low to very high
Kromengan	Mostly very low v with scattered areas of low to high	The scattered areas of moderate to high become wider.
Sumberpucung	Mostly very low to low.	Mostly very low to low, some scattered areas of moderate v in the south
Pagak	Mostly very low to low	Not much chage, except a significat area of moderate in the center
Donomulyo	Mostly very low to low with some scattered areas of moderate	The scattered areas of moderate become wider
Kalipare	Mostly very low to low	The scattered areas of

			with some scattered areas of moderate	moderate become wider
		Wonosari	Mostly very low to low with some scattered areas of moderate	The scattered areas of moderate become wider and the rank of some of the areas are high
		Wagir	Scattered area ranges from low to very high.	Area of very high becomes dominant
		Dau	Mostly very low. Some scattered area of moderate in the east	The scaterred areas become very high to moderate.
		Pujon	Mostly very low. Some scattered area of moderate in the east	The scaterred areas of moderate become wider
		Ngantang	Mostly very low. Some scattered area of moderate in the east	The scaterred areas of moderate become wider
		Kasembon	Mostly very low. Some scattered area of moderate in the east	The scaterred areas of moderate become wider

Note: v = vulnerability;

(1) The baseline condition of flood vulnerability

In the baseline period (2010), the highest vulnerability area to flood hazard is found dominatly in almost in the whole area of Malang City and ranked by very high vulnerability. Other regions with very high vulnerability level in the baseline period are: 1) some parts of Batu sub-district and Jabung sub-district (Batu City), 2) southern parts of Karangploso and Singosari, and center part of Lawang (Malang District); 3) almost all region of Pakis district, Pakisaji, and Kepanjen district (Malang District); 4) parts of Batulawang and Turen (Malang District); and 5) some small parts of Tajinan, Tumpang, and Wagir district (Malang District).

The area of high vulnerability in baseline periode is distributed mostly in Malang District regions. The regions are: 1) southern part of Karangploso, Singosari, Lawang, and Wagir sub-district; 2) a significant areas in Batulawang, Tajinan, and Wajak sub-district; and 3) center to southeren part of Dampit sub-district, center part of Kromengan and Wonosari sub-district.

Another vulnerability level in Greater Malang is the moderate vulnerability. This level of vulnerability is scatteredly distributed in Greater Malang almost in each sub-district such as in Buring (Malang City); Pujon, Ngantang, Kasembon, Gondanglegi, Poncokusumo, Wajak, Ampelgading, Dampit, Sumbermanjing, Pagelaran, Kapanjen, etc (Malang District).

The vulnerability condition in the baseline period as mentioned before were based only on 4 vulnerability indicators: population density, landuse, role of infrastructure, especially road infrastructures, and social welfare as represented by income per person. But, actually there are several other components which are not involved in the analysis due to unavailable data such as: water infrastructures (dams, irrigations), watersheds' rate of damage, or conversion rate from forests to fields, etc. This condition causes several vulnerability level distribution to be unexposed clearly. For example, if the rate of land conversion is included in the analysis, then the map of vulnerability will not be as shown in Figure 5.12.

(2) The projection condition of flood vulnerability

The vulnerability conditiont floods in the projection period (2030) changes significantly compared to the baseline period (2010) where it, generally, becomes more vulnerable. Regions which become more vulnerable in the projection period are: 1) the whole region of Malang City; 2) most part of Batu City region, especially center to southern part (parts of Batu district and Jabung district); 3) wide parts of regions of following sub-districts in Malang District: Karangploso, Singosari, Lawang, Pakis, Pakisaji, Kepanjen, Batulawang, Turen, Wagir, and Wajak; 4) some significant to small parts of regions of following sub-districts of Malang District: Tumpangm Dampit, Ngajum, Kromengan, Wonosari, and Tajinan. The rank of vulnerability in those regiosn is vary from very high vulnerability to high vulnerability.

Generally, there are two important patterns of change in the rank of vulnerability from the baseline period to the projection period, that is: (1) pattern change of one level higher, and (2) change of two level higher.

For the first pattern, that is **one level more vulnerable**, there are 4 categories:

1) **High** vulnerability level change into **very high** level, for example: some part in center of Malang City, south of Singosari sub-district and center of Lawang sub-district (Malang District);
2) **Moderate** vulnerability change into **high** vulnerability, such as som regiosn in sub-district of Tumpang, Dampit, Kepanjen (Malang District);
3) **Low** vulnerability change into **moderate** vulnerability. This pattern for example: west of Gondanglegi sub-district, center of Pujon district, center of Bantur district, north Donomulyo sub-district;
4) **Very low** vulnerability change into **low** vulnerability as in several parts of Sumbermanjing sub-district, Gedangan sub-district.

For the second pattern of change, that is **two level more vulnerable**, there are 3 categories:

1) **Moderate** vulnerability change into **very high** vulnerability. This patteren shown, for example, in: some parts of center Malang City, some parts of sub-districts of Kepanjen, Tumpang, Tajinan (Malang District);
2) **Low** vulnerability change into **high** vulnerability. This patteren fFor example are: several small areas in south Malang City (Buring, Kedungkandang); some significat parst of Jabung and Batu sub-district (Batu City); some parts of sub-districts of Wagir, Kepanjen, Dampit, Lawang, Singosari, Karangploso;
3) **Very low** vulnerability change into **moderate** vulnerability, as in several parts of sub-districts of Gondanglegi, Ampelgading, Sumbermanjing, Gedangan, Bantur, Donomulyo, Pagak, Kalipare, Wonosari, Pujon, Kesambon (Malang District).

From the analysis, we can conclude that the lowest level of vulnerability in the projection period is the very low vulnerability, while the highest level is the very high vulnerability. Meanwhile, we also obtain that the distribution of vulnerability level to floods can be said to be distributed evenly, from the lowest to the moderate. Only the high and very high level of vulnerabilities which are relatively less wide. Also from the analysis, the regions which need attention due to its very high to moderate distribution rank of the vulnerability, include: 1) the whole region of Malang City; 2) most part of Batu City region, especially center to southern part (parts of Batu district and Jabung district); 3) wide parts of regions of following districts in Malang District: Karangploso, Singosari, Lawang, Gondanglegi, Pakis, Pakisaji, Kepanjen, Batulawang, Turen, Wagir, Wajak, Wonosari; and 4) some significant to small parts of regions of following sub-districts of Malang District: Tumpang, Dampit, Sumbermanjing, Gedangan, Bantur, Donomulyo, Kalipare, Pagak, Pagelaran, Ngajum, Kromengan, Wonosari, and Tajinan.

5.2.3 Vulnerability to landslides

Vulnerability to landslide can be defined as the vulnerability produced from the combination of function of its vulnerability components to landslides hazard. Landslides hazard has been identified in Chapter 4. The vulnerability components along with its indicators and weighting are presented in Table 5.11.

Table 5. 11 Components and its indicators of vulnerability to landslides

Components	Indicators	Sub-indicators	Weighting
Exposure	Population density	Population and population growth per sub-district	0.54
	Landuse	Landuse as in regional planning	0.22
Sensitivity	Role of infrastructure	Road infrastructure	0.18

Adaptive Capacity	Population Welfare	Population's income	0.06

The vulnerability indicators of landslides are identiical with the indicators of floods. Hence, the weighting can also be identical. Based on the previous analysis, we produce the following maps of vulnerability to landslides in the baseline and projection periods in Figure 5.16 and 5.17.

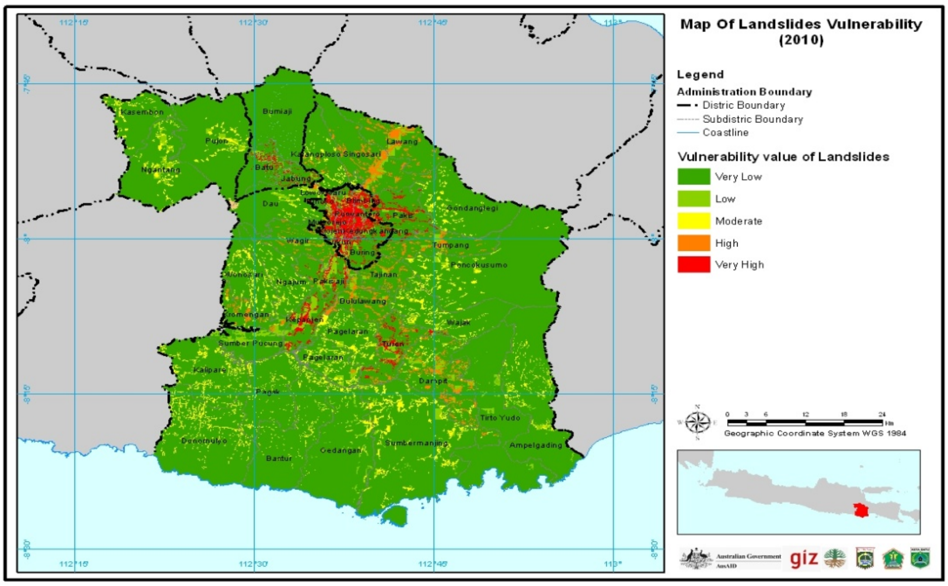


Figure 5. 16 Vulnerability to landslide hazard at baseline condition (2010)

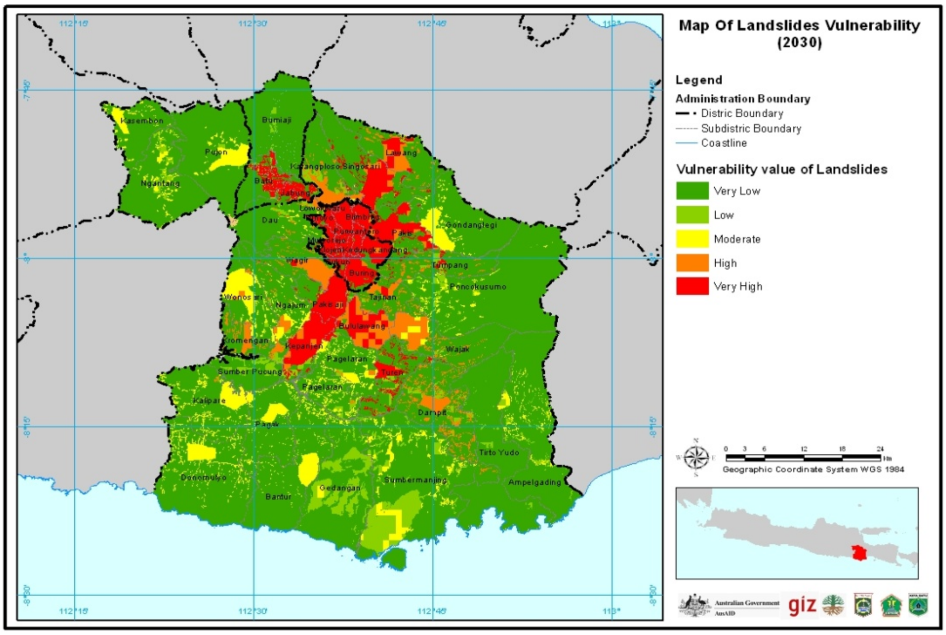


Figure 5. 17 Vulnerability to landslide hazard at projection condition (2030)

Due to the identical vulnerability indicators between landslides and floods, then generally, the vulnerability level of landslides and its distribution are also identical with the floods, as well as its vulnerability condition in the baseline and projection periods.

VI ASSESSMENT OF RISK TO CLIMATE CHANGE

6.1 Identification of Climate Change Risk on Water Sector

The risk of climate change, magnitude and spatial distribution is determined by its level of hazard and vulnerability. This study assesses the risks of hazard of: watershortage, floods, and landslides.

As it has been stated in the assessment method (Chapter 3), risk is a function of hazard and vulnerability (Affeltranger, et.al, 2006). Practically, the risk is drawn in a map to see its distribution for minimum of two periods, baseline and projection, so we can see the risk temporally and spatially. The map consists of overlay of two maps previously produced, map of hazard and map of vulnerability for each hazard. Here, risk level is classified into 5 levels; from low risk to very high risk.

6.2 Water Shortage Risk

Water shortage risk is a function of water shortage hazard and vulnerability. Water shortage hazard consists of natural water supply component and increasing water needs per district unit as shown in Figure 4.9 and Figure 4.10, Chapter IV. Meanwhile, the vulnerability consists of water demand component per grid area of 100 x 100 m^2, water resources, and social welfare. The map of water shortage risk is shown in Figure 6.1 and Figure 6.2.

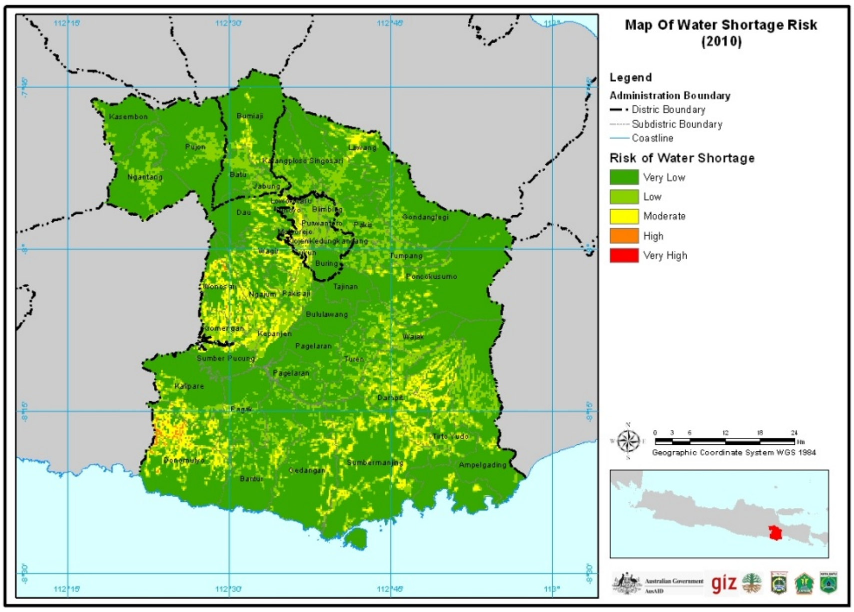


Figure 6. 1 Water Shortage Risk Map of Greater Malang in baseline.

Generally, risk of decresase of water availability in Greater Malang Region at baseline condition has low level to very low level.

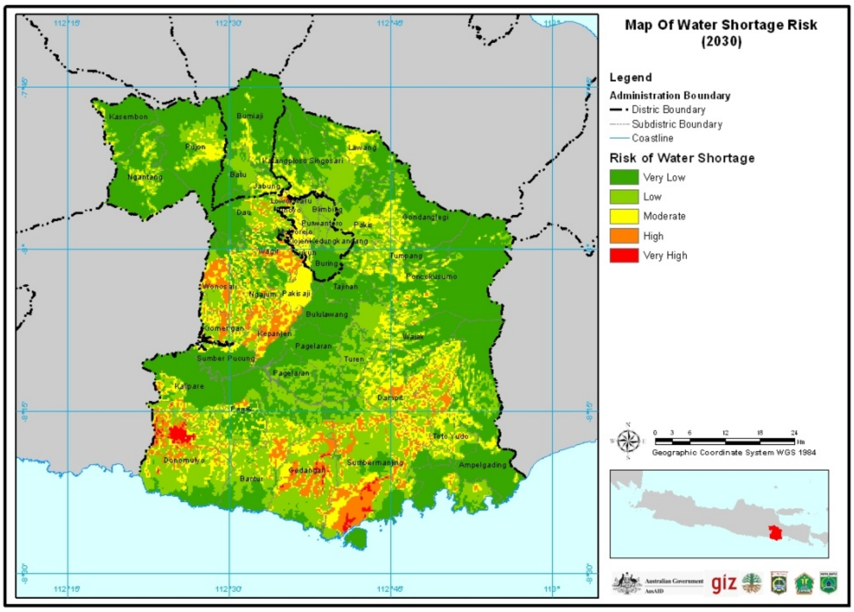


Figure 6. 2 Water Shortage Risk Map of Greater Malang in projection.

Risk of decrease of water availability has increase in southern region.

From the figures above we can see that the water shortage risk in Greater Malang is relatively low in the baseline. In the projection period, there is a slight increase of low to high risks and an increase of area of medium and high risks, compared to previous period.

At baseline condition, there is no very high risk of decrease of water availability in Greater Malang Region. Different with projection condition, risk level of very high for decrease of water availability is found in southern area of Malang municipal. Increase of risk with large distribution found in Malang municipal region, while in Batu City and Malang City region occuring not dominant increase.

The characteristics of each risk level in baseline period are shown in Table 6.1 below. Meanwhile in the projection period, the condition of water shortage risk and its risk levels are shown in the following Table 6.1.

Table 6. 1 Water shortage (WS) risks and their distribution in each district/municipality in baseline period (2010)

Level of WS[1)] Risk	Watershed	District/City : Sub-District	Description of the Risk
Very High		-	-
High	IIA, IIIA	Malang Municipal: Donomulyo, Wonosari, Tirtoyudo	• Decrease on water availability as a cause of climate factor • Increase in water availability as a cause of concentration of settlement.

Moderate	IIA, IIC, IIIA, IIIB	Malang municipal: all sub-districts except Pagak, Pagelaran, Bululawang, Tajinan, Gondanglegi, Pakis, Singosari, Karangploso, Pujon, Ngantang, and Kasembon	• Decrease on water availability as a cause of climate factor • Increase in domestic water demand and change in land use.
	IA	Batu City: Bumiaji	
	IIC	Malang City: Dinoyo, Mulyorejo, Sukun	
Low	IB, IC, IIA, IIB, IIC, IIIA, IIIB, VA, VC	Malang Municipal: all sub-districts except Bululawang and Tajinan	There's no significant risk
	IA	Batu City: Bumiaji, Jabung, & Batu	
	IB, IC, IIA	Malang City: dominantly in Lowokwaru, Blimbing, Purwantoro, Klojen, and Kedungkandang sub-districts	
Very Low	IB, IC, IIA, IIB, IIC, IIIA, IIIB, IV	Malang Municipal: Bululawang, Tajinan	There's no significant risk
	IA	Batu City: Bumiaji, Jabung, Batu	
	IIB	Malang City: Buring	

Table 6. 2 Water shortage (WS) risks and their distribution in each district/municipality in projection period (2030)

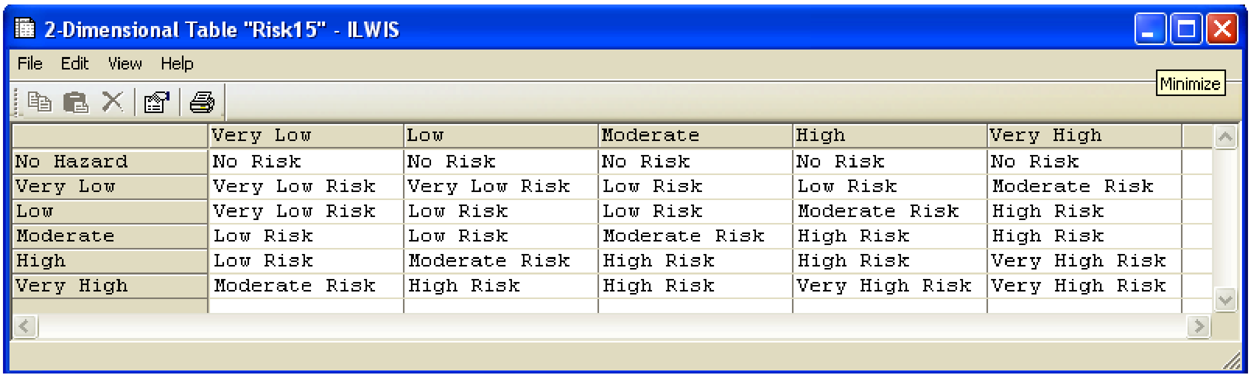
Level of WS[1)] Risk	Watershed	Municipal/City : Sub-District	Description of the Risk
Very High	IIIA, IIIB	Malang Municipal: Donomulyo, Gedangan, Sumbermanjing	• Decrease on water availability as a cause of climate factor • Increase in water availability as a cause of concentration of settlement.
High	IIA, IIC, IIIA, IIIB	Malang Municipal: Donomulyo, Kalipare, Pagak, Bantur, Gedangan, Sumbermanjing, Dampit, TirtoYudo, Dampit, Poncokusumo, Kromengan, Wonosari, Ngajum, Kepanjen, Dau, Wagir	• Decrease on water availability as a cause of climate factor • Increase in domestic water demand and change in land use.
Moderate	IB, IC, IIA, IIC, IIIA, IIIB	Malang Municipal: all sub-districts except Singosari, Bululawang, Tajinan, Pagelaran,	• Decrease on water availability as a cause of climate factor
	IA	Batu City: Bumiaji, Jabung	

	IIC	Malang City: Dinoyo, Oro-oro Dowo, Sukun, Mulyorejo, Klojen	
Low	IB, IC, IIA, IIB, IIC, IIIA, IIIB, V	Malang Muncipal : all sub-districts except Bululawang	There's no significant risk
	IA	Batu City: Bumiaji, Jabung, Batu	
	IB, IC, IIB	Malang City: Kedungkandang, Lowokwaru, Blimbing, Purwantoro	
Very Low	IB, IC, IIA, IIB, IIC, IIIA, IIIB, IV	Malang Municpal: all sub-districts except Kromengan, Wonosari	There's no significant risk
	IA	Batu City: Bumiaji, Jabung, Batu	
	IIB	Malang City: Buring	

Generally, the risk area of projection period is wider than in the baseline period. The distribution includes new areas which previously are not in risk. The increasing risk is caused by the decreasing water supply due to decreasing precipitation trend and increasing evapotranspiration and water needs.

6.3 Floods Risk

Risk level map is resulted from 2 Dimensional Table analyze between hazard level and vulnerability level by ILWIS (Integrated Land and Water Information System) application (Figure 6.3).



	Very Low	Low	Moderate	High	Very High
No Hazard	No Risk	No Risk	No Risk	No Risk	No Risk
Very Low	Very Low Risk	Very Low Risk	Low Risk	Low Risk	Moderate Risk
Low	Very Low Risk	Low Risk	Low Risk	Moderate Risk	High Risk
Moderate	Low Risk	Low Risk	Moderate Risk	High Risk	High Risk
High	Low Risk	Moderate Risk	High Risk	High Risk	Very High Risk
Very High	Moderate Risk	High Risk	High Risk	Very High Risk	Very High Risk

Figure 6. 3. 2 Dimensional Table analyze between hazard level and vulnerability level by ILWIS (Integrated Land and Water Information System) application

Flood risk assessment is divided into 5 levels. There are Very Low Risk, Low Risk, Moderate Risk, High Risk, and Very High Risk. In the baseline condition, Greater Malang has 5 levels of risk which residential has High Risk level. Meanwhile in the projection condition, risk area of Greater Malang will be larger than baseline condition that due to land use change as indicated by spatial planning.

Table 6. 3 Flood Risk Area of Great Malang

Risk Level	Batu City		Malang City		Malang District	
	Baseline (km^2)	Projection (km^2)	Baseline (km^2)	Projection (km^2)	Baseline (km^2)	Projection (km^2)
Very Low	179.38	160.68	57.22	6.88	3059.36	2494.50
Low	11.68	7.75	3.14	3.80	177.58	347.08
Moderate	1.59	2.71	4.03	1.30	97.15	104.59
High	3.32	0.70	25.55	9.00	66.90	228.36
Very High	0.001	24.14	20.53	89.48	7.71	233.21

In baseline condition, the highest risk was experienced by Malang city as 18.67 % of Malang City area was rated as very high risk. Meanwhile in projection condition, almost all the Malang City (80.23 %) area will be facing very high flodd risk.

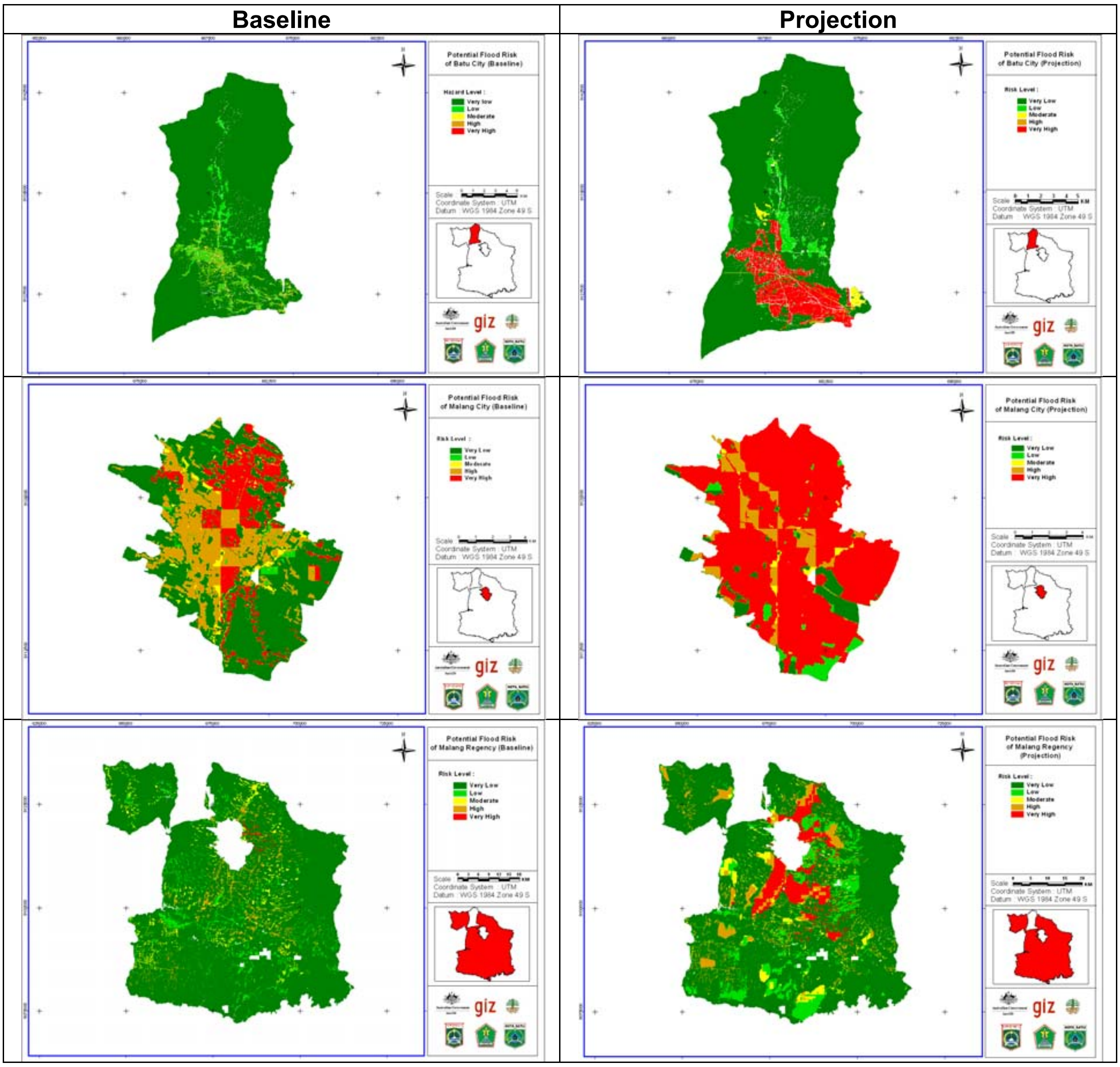


Figure 6. 4 Flood Risk at cities/district in Great Malang

Flood Risk analysis has been done for 12 watersheds in the Greater Malang as follows.

6.3.1. Konto

In baseline condition, Konto watershed has 3 levels of risk that are Very Low, Low, and Moderate Risk. Meanwhile in projection condition, there have 4 levels of risk that are Very Low, Low, Moderate and High risk level. The largest level area of risk will be dominated by Very Low risk level that has 321.16 km^2 in baseline condition while in projection condition with 309.2

Baseline	Projection

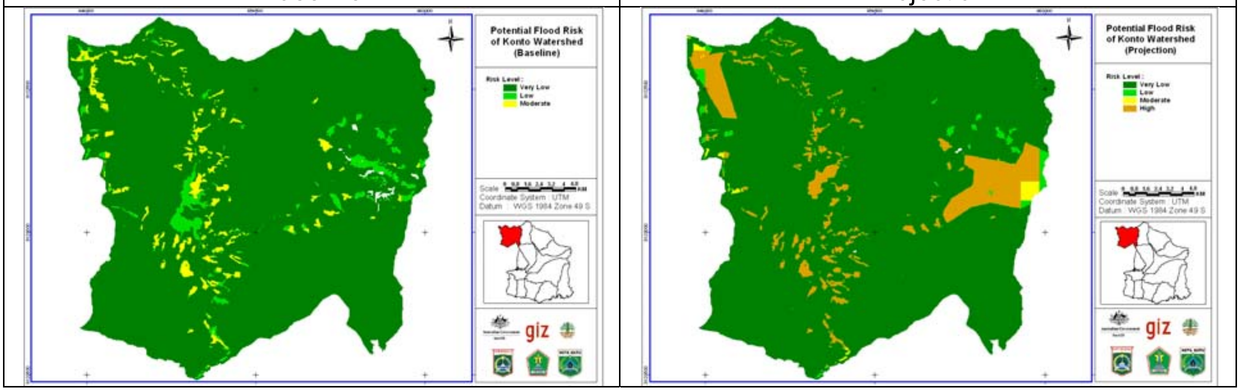


Figure 6. 5 Potential Flood Risk of Konto Watershed

The three level of risk in baseline condition will be decrease risk area in projection condition but the risk area will be increase 27.49 km^2 to High Risk level area. In baseline condition, Very Low Risk level area mostly covered forest and dry-land agricultures but in projection condition mostly would be covered protected forest and dry-land agricultures. Based on spatial planning most of forest area would be change to protected forest according the location of Konto watershed is upstream area.

Low, Moderate and High Risk level area in projection condition would be covered most of residential area.

Table 6. 4 Flood Risk Area of Konto Watershed

Risk Level	Baseline		Projection	
	Area	Land Use	Area	Land Use

	(km²)		(km²)	
Very Low	321.16	Shrubs Building Forest Agriculture land residential swamp grass paddy fields dry-land agricultures	309.20	lake protected forest Production Forest wetland/swamp forest residential Plantation paddy field green forest dry-land agricultures
Low	12.21	shrubs forest Agriculture land residential swamp grass paddy fields dry-land agricultures	5.56	lake protected forest residential Plantation paddy field dry-land agricultures
Moderate	10.16	shrubs forest Agriculture land residential grass paddy fields dry-land agricultures	1.89	lake protected forest residential Plantation paddy field dry-land agricultures
High			27.49	lake protected forest residential Plantation paddy field dry-land agricultures

6.3.2. Upstream of The Brantas River

In baseline condition, the Very low risk level area has the largest risk area with 565.23 km^2 that mostly covered paddy fields and dry-land agricultures while the smallest area is Very High level of risk with 6.11 km^2.

In projection condition, Very Low, Low and Moderate area would be decrease but High and Very High level of risk areas would be increase sharply.

Baseline	Projection

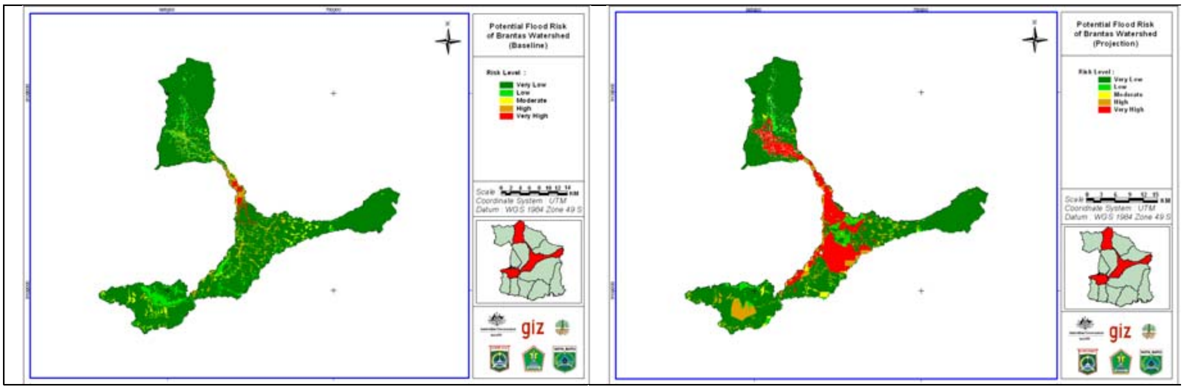


Figure 6. 6 Flood Risk of Upstream of The Brantas River

In baseline condition, the low level of risk mostly covers paddy fields and dry-land agricultures. Meanwhile in middle and high level of risk mostly cover residential area. In projection condition, the very high risk level area would be covered residential area, industry area, commercial and services area, and military area.

Table 6. 5 Flood Risk Area of Upstream of The Brantas River

<table>
<tr><th rowspan="2">Risk Level</th><th colspan="2">Baseline</th><th colspan="2">Projection</th></tr>
<tr><th>Area (km^2)</th><th>Land Use</th><th>Area (km^2)</th><th>Land Use</th></tr>
<tr><td>Very Low</td><td>565.23</td><td>shrubs
Building
Forest
Agriculture land
residential
Swamp
Grass
Paddy Field
dry-land agricultures</td><td>455.39</td><td rowspan="3">Lake/Pond
Public Facility
Protected Forest
Production Forest
Wetland Forest
Industry Area
Military Area
Tourism Area
Residential
Commercial and Services Area
Plantation
Green Open Space
Paddy Field
Green Forest
Dry-land agricultures</td></tr>
<tr><td>Low</td><td>50.20</td><td>shrubs
Building
Forest
Agriculture land
residential
Swamp
Grass
Paddy Field
dry-land agricultures</td><td>39.05</td></tr>
<tr><td>Moderate</td><td>19.52</td><td>Shrubs
Building
Agriculture land
residential
Grass
Paddy Field
dry-land agricultures</td><td>13.61</td></tr>
</table>

High	23.61	Shrubs Building Agriculture land residential Grass Paddy Field dry-land agricultures	43.93	
Very High	6.11	Shrubs Building Agriculture land residential Grass Paddy Field dry-land agricultures	110.11	

6.3.3. Bango

In the projection condition, Very High Risk area would increase sharply than the baseline condition.

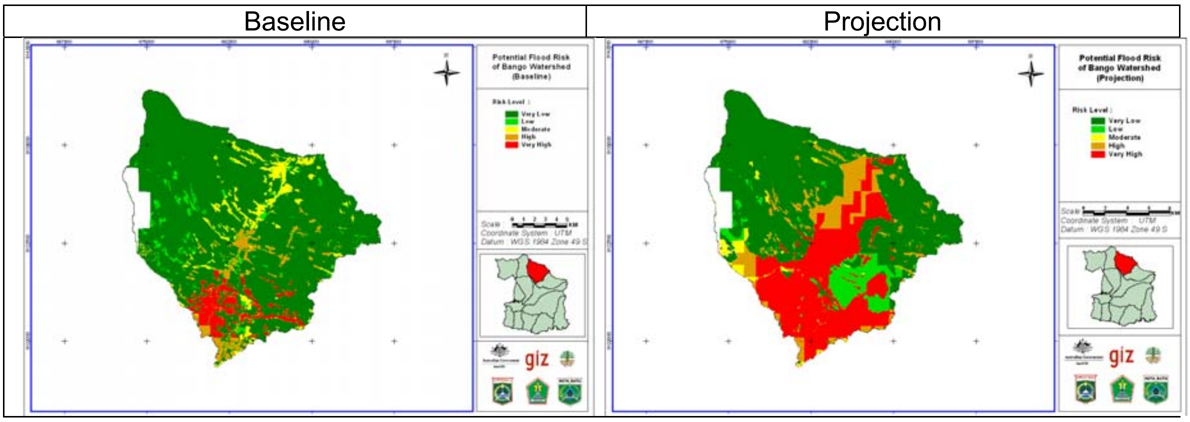


Figure 6. 7 Flood Risk of Bango Watershed

In baseline condition, the risk areas mostly cover residential area. Meanwhile in projection condition, Very Low level would be covered most of dry-land agricultures, plantation, paddy field and protected forest. Meanwhile in the others level would be covered mostly military area, industry area and residential area. The highest risk of place is airport because it is the main transportation infrastructure in Greater Malang.

Table 6. 6 Potential Flood Risk Area of Bango Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low	252.17	Paddy Field Dry-land agricultures	164.80	Protected Forest Plantation Paddy Field

				Dry-land agricultures
Low	11.76	Residential Paddy Field	22.21	Dry-land agricultures Residential Industry Area
Moderate	18.36	Residential	6.95	Military Area Industry Area Residential
High	13.12	Residential	30.20	Military Area Industry Area Residential
Very High	17.48	Residential	89.41	Airport Public Facility Industry Area Residential

6.3.4. Amprong

In baseline condition, Amprong watershed has 5 levels of risk that are Very Low, Low, Moderate, High and Very High Risk. In projection condition, there have 5 levels of risk with larger area. The Very Low level area would be decrease significantly but the Low, High and Very High level areas would be increased sharply in projection condition.

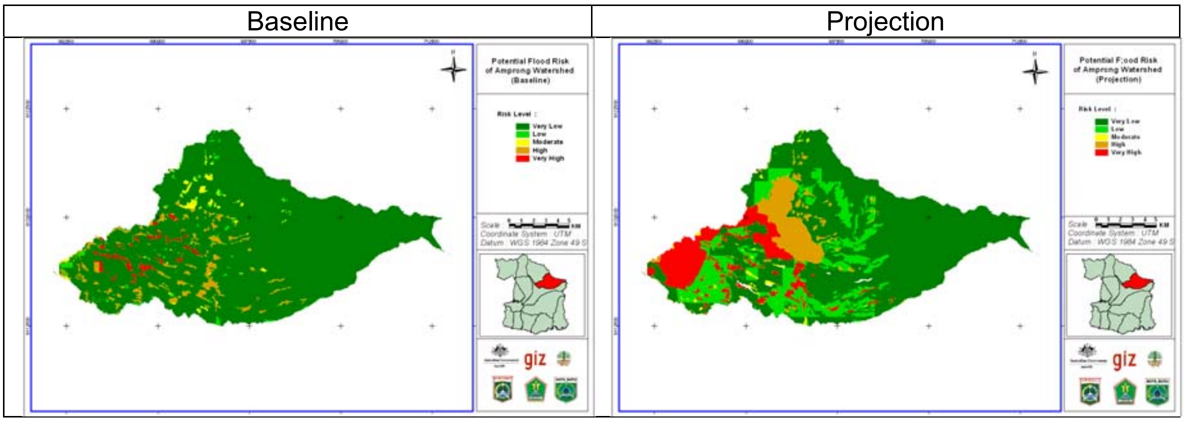


Figure 6. 8 Flood Risk of Amprong Watershed

In baseline condition, the very low level area covers mostly dry-land agricultures, paddy fields, agriculture land, forest and shrubs. At the same time, the low, moderate, high and very high level mostly cover residential area. Meanwhile in projection condition, the very low and low level areas would be covering mostly protected forest, dry-land agricultures and paddy fields. The others level of risk would be cover residential area and industry area.

Table 6. 7 Potential Flood Risk Area of Amprong Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use

Very Low	231.45	Dry-land agricultures Paddy field Agriculture land Forest Shrub	155.09	Protected Forest Plantation Dry-land agricultures Paddy Field Green Open Space
Low	5.88	Residential Dry-land agricultures	47.49	Dry-land agricultures Paddy Field
Moderate	3.75	Residential	3.19	Residential Industry Area
High	10.28	Residential	21.45	Industry Area Residential
Very High	3.65	Residential	27.19	Residential Industry Area

6.3.5. Lesti

In baseline condition, Lesti watershed has 4 levels of risk that are Very Low, Low, Moderate and High level. Meanwhile in projection condition, the levels of risk would be increase to Very High level of risk. At the same time thr risk level area would be wider than baseline condition except the Very Low Risk level occurs to decrease risk area.

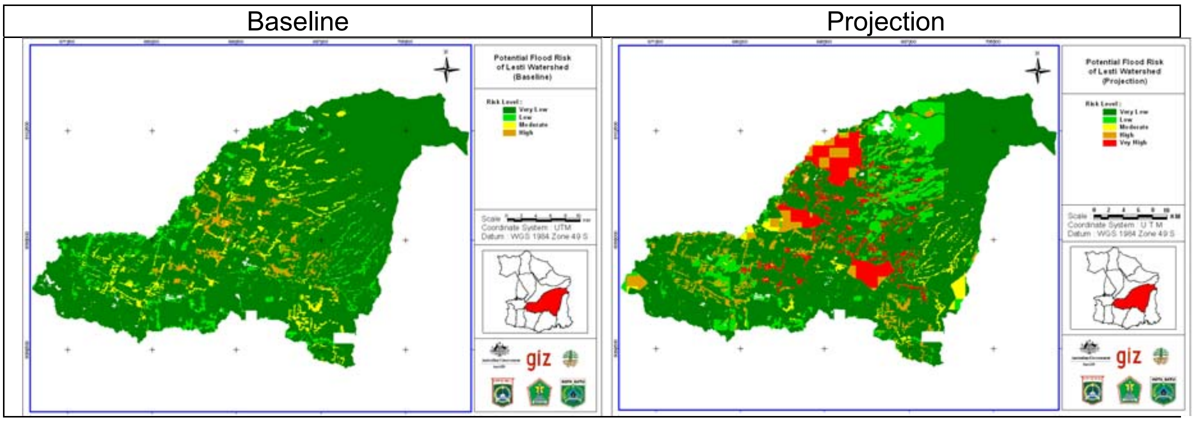


Figure 6. 9 Flood Risk of Lesti Watershed

Most of risk area of baseline condition is very low risk that covers dry-land agricultures, agriculture land, plantation, forest and paddy fields. And the others level of risk would be covered residential area. As well as baseline condition, the very low risk area would be covered most of dry-land agricultures, plantation, paddy field and protected forest area. Meanwhile the moderate, high and very high risk level would be covered residential area and industry area.

Table 6. 8 Potential Flood Risk Area of Lesti Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use
Very Low	516.15	Dry-land agricultures Agriculture land Plantation Paddy Field Forest Shrubs	423.82	Dry-land agricultures Plantation Paddy Field Protected Forest
Low	38.45	Residential	73.38	Dry-land agricultures Paddy Field
Moderate	25.32	Residential	18.08	Residential
High	16.29	Residential	34.85	Residential Industry Area
Very High			45.36	Residential Industry Area

6.3.6. Glidik

Glidik watershed has 3 levels of risk in baseline condition that are Very Low, Low and Moderate level. In projection condition, the risk level of Glidik watershed would be increase to 4 levels that are Very Low, Low, Moderate and High level of risk.

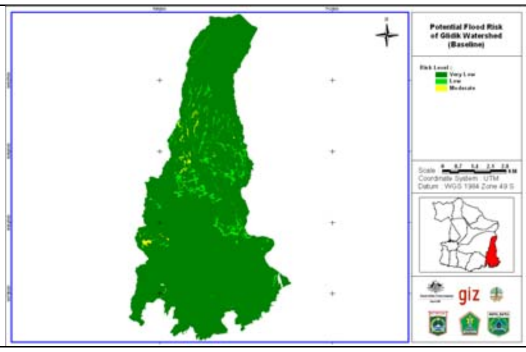
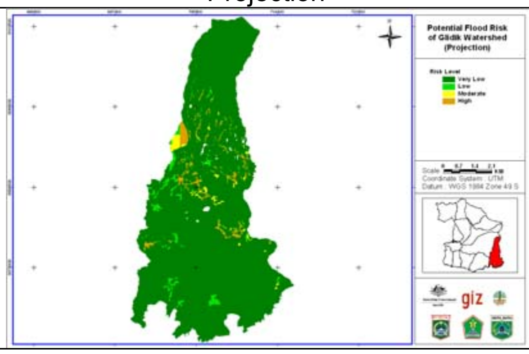
Baseline	Projection
	

Figure 6. 10 Flood Risk of Glidik Watershed

In baseline condition, the very low risk level has the largest risk area with 295.82 km^2 that mostly cover forest, dry-land agricultures, shrubs, plantation and residential area. At the same time the low and moderate risk level would be cover residential area. Meanwhile in projection condition, the very low risk level would be decrease to 288.23 km^2 that covers protected forest, plantation and dry-land agricultures. The others level of risk would be covered residential area.

Table 6. 9 Potential Flood Risk Area of Glidik Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use
Very Low	295.82	Forest Dry-land agricultures Shrubs Plantation Residential	288.23	Protected Forest Plantation Dry-land agricultures
Low	10.22	Residential	8.85	Residential
Moderate	1.46	Residential	3.49	Residential
High			6.92	Residential

6.3.7. Panguluran

In baseline projection, Panguluran watershed has 4 levels of risk that are Very Low, Low, Moderate and High level which the very low level as the largest risk area with 263.29 km^2. In projection condition, the very low risk level area would be decrease to 207.63 km^2 while the others level of risk would be increase sharply area of risk.

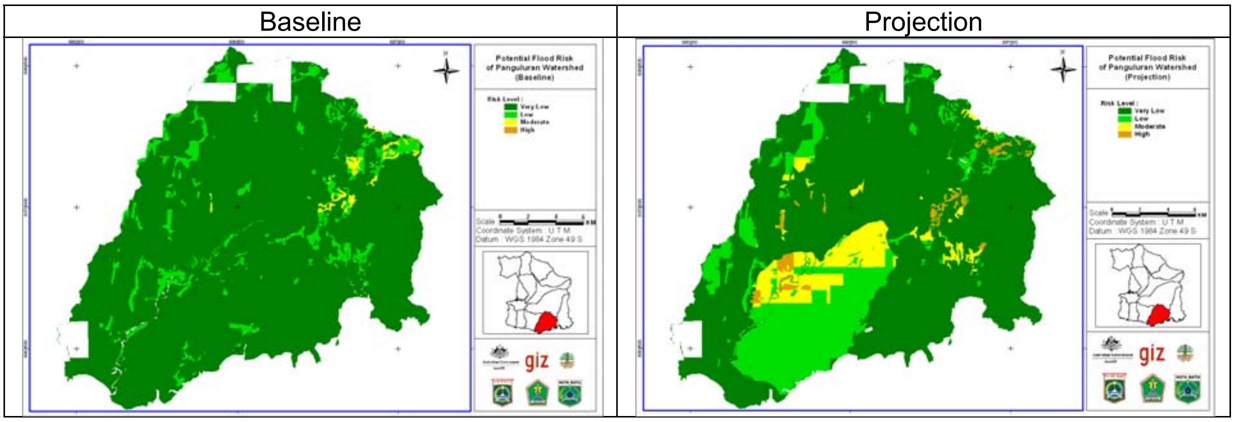


Figure 6. 11 Flood Risk of Panguluran Watershed

In baseline condition, the very low risk level covers most of forest, plantation, dry-land agricultures, shrubs and residential area. The others level of risk cover residential area. Meanwhile in projection condition, the Very Low risk level would be covered protected forest, plantation and dry-land agricultures but in the low risk level area has industry area, commercial and services area, and residential area. Industry and residential area have the highest risk.

Table 6. 10 Potential Flood Risk Area of Panguluran Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use
Very Low	263.29	Forest Plantation Dry-land agricultures Shrubs Residential	207.63	Protected Forest Plantation Dry-land agricultures
Low	21.73	Residential	56.27	Industry Area Residential Commercial and services Area
Moderate	2.39	Residential	19.63	Industry Area Residential
High	0.07	Residential	4.38	Industry Area Residential

6.3.8. Barek

In baseline and projection condition, Barek watershed has 4 levels of risk that are Very Low, Low, Moderate and High level. In baseline condition the High Risk level has the smallest risk area with 193.66 m^2 that covered residential area. In projection condition, the low, moderate and high risk level would be increase sharply risk area.

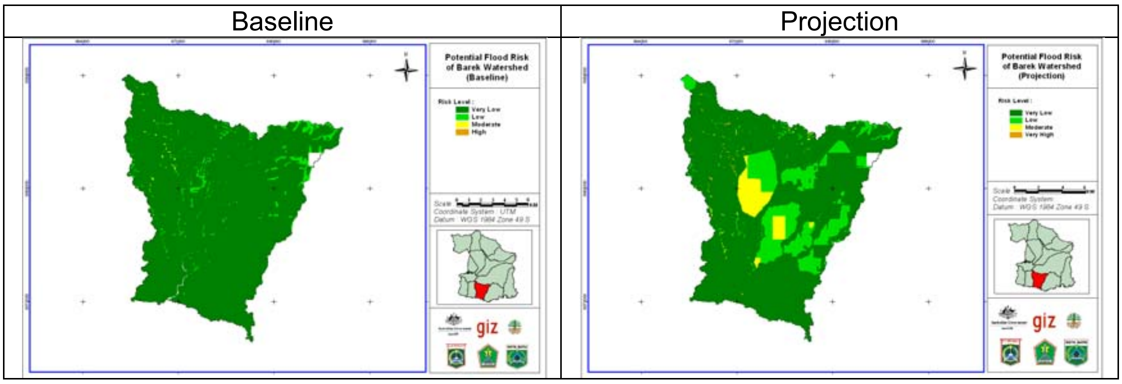


Figure 6. 12 Potential Flood Risk of Barek Watershed

In baseline condition, the very low risk level mostly covers dry-land agricultures, forest, agriculture land and shrubs. At the same time the others level of risk cover residential area. Meanwhile in projection condition, the risk area of very low level would be covered dry-land agricultures, plantation, protected forest, residential and industry area. The others level of risk would be covered residential and industry area.

Table 6. 11 Potential Flood Risk Area of Barek Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use
Very Low	206.31	Dry-land agricultures Forest agriculture land shrubs	167.45	Dry-land agricultures Plantation Protected Forest Residential Industry Area
Low	7.09	Residential	36.35	Residential Industry Area
Moderate	0.23	Residential	9.75	Residential Industry Area
High	0.0002	Residential	0.30	Residential

6.3.9. Kondang Merak

Kondang Merak watershed has 4 levels of risk that are Very Low, Low, Moderate and High risk level. In baseline condition, the risk area of very low risk level is 139.48 km^2 that would be decrease to 106.3 km^2 in projection condition. Meanwhile the low risk level would be increase sharply almost 13 higher to 34.72 km^2.

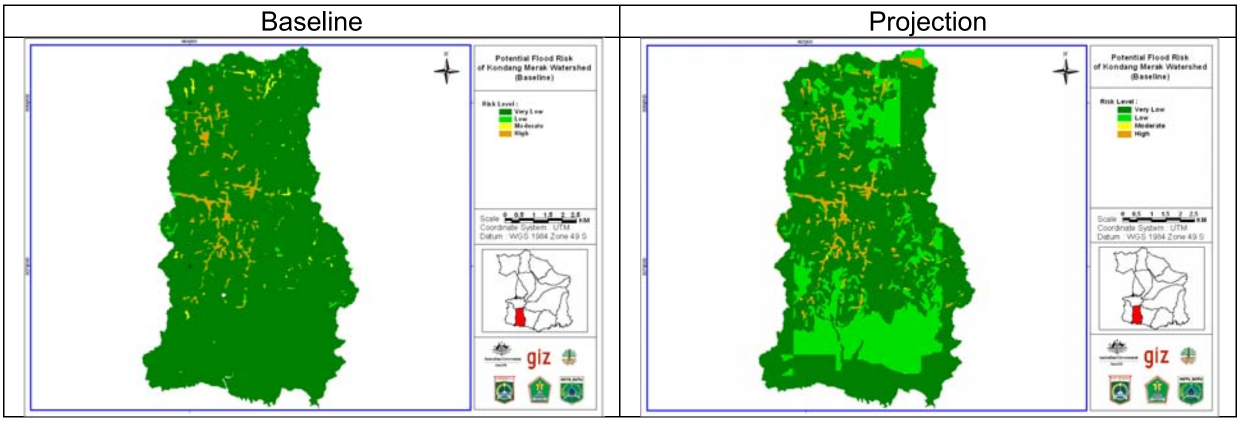


Figure 6. 13 Potential Flood Risk of Kondang Merak Watershed

In baseline condition, the very low risk level area mostly covers agriculture land, forest, dry-land agricultures and paddy fields while the low, moderate, and high risk level areas mostly cover residential area. In projection condition, the largest risk area located in plantation area because 3 levels of risk at this area but the highest risk area covers residential area with 5.24 km^2.

Table 6. 12 Potential Flood Risk Area of Kondang Merak Watershed

Risk Level	Baseline		Projection	
	Area (km2)	Land Use	Area (km2)	Land Use
Very Low	139.48	agriculture land forest dry-land agricultures paddy field	106.30	Plantation Protected Forest dry-land agricultures paddy field
Low	2.48	agriculture land residential	34.72	dry-land agricultures residential
Moderate	0.80	residential	0.79	residential plantation
High	4.16	residential	5.24	residential

6.3.10. Donowari

In baseline and projection condition, Donowari watershed has 4 levels of risk that are Very Low, Low, Moderate, High and Very High level. Some of risk level area would be decrease area in projection condition but the others level will increase such as the Very High level that increases 10 more wider than baseline condition.

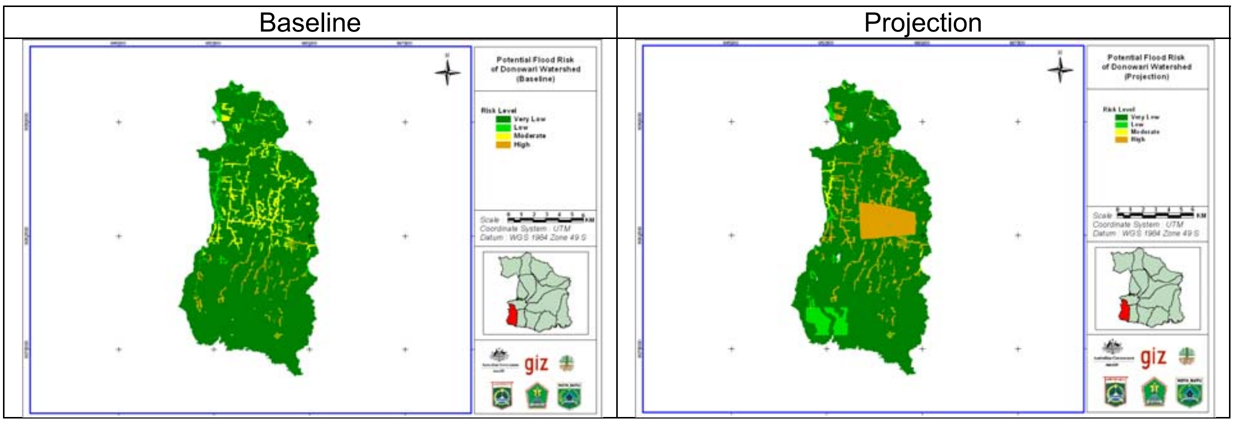


Figure 6. 14 Potential Flood Risk of Donowari Watershed

In baseline condition, most of risk area located in residential area because it has 3 levels of risk such as Low, Moderate and High risk level. Meanwhile the Very Low risk level covers agriculture land, dry-land agricultures, paddy fields and shrubs.

In projection condition, the place of highest risk is residential area because 3 levels of risk located at this area. At the same time, the very low risk level would be covered plantation, dry-land agricultures, paddy field and protected forest.

Table 6. 13 Potential Flood Risk Area of Donowari Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use
Very Low	145.33	agriculture land dry-land agricultures paddy field shrubs	132.90	Plantation Dry-land agricultures Paddy Field Protected Forest
Low	6.52	Residential agriculture land	9.61	Residential Dry-land agricultures
Moderate	9.49	Residential	1.68	Residential
High	2.63	Residential	20.06	Residential

6.3.11. Lahor

In baseline condition, Lahor watershed has 4 levels of risk that are Very Low, Low, Moderate and High level. Meanwhile in projection the level of risk will be increasing to 5 levels of risk that are Very Low, Low, Moderate, High and Very High level. The very low risk level area has decreasing 27 % of risk area while the moderate and high risk level will be increasing significantly in projection condition.

Baseline	Projection

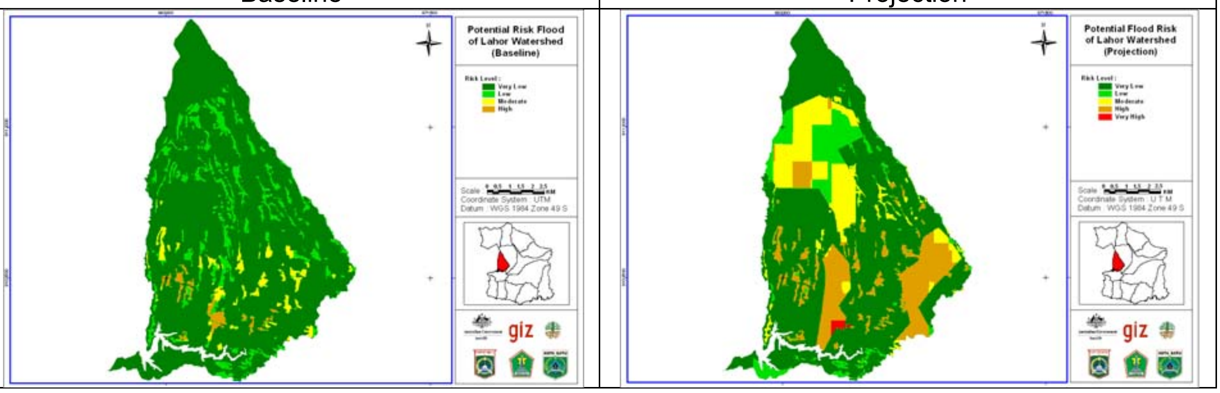


Figure 6. 15 Potential Flood Risk of Lahor watershed

In baseline condition, the very low risk level covers agriculture land, paddy fields, dry-land agricultures and forest but the low, moderate and high risk level cover residential area. In projection condition, the place of highest risk is residential area because 38 % of risk area would be located at this area while the remaining 62 % of risk area will be cover most of plantation, paddy fields, dry-land agricultures and protected forest.

Table 6. 14 Potential Flood Risk Area of Lahor Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use
Very Low	122.94	Agriculture Land Paddy Field Dry-land agricultures Forest	89.46	Plantation Paddy Field Dry-land agricultures Protected Forest
Low	14.81	Residential Agriculture Land	14.16	Residential
Moderate	4.24	Residential	18.13	Residential
High	2.26	Residential	22.09	Residential
Very High			0.44	Residential

6.3.12. Metro

In baseline and projection condition, Metro watershed has 5 levels of risk that are Very Low, Low, Moderate, High and Very High level. The Very Low risk level has the largest risk area with 236.14 km^2 that will decrease to 158.24 km^2 in projection condition while the very high risk level will be increasing sharply risk area more 80 wider than baseline condition because the very high risk level located in central of Malang District.

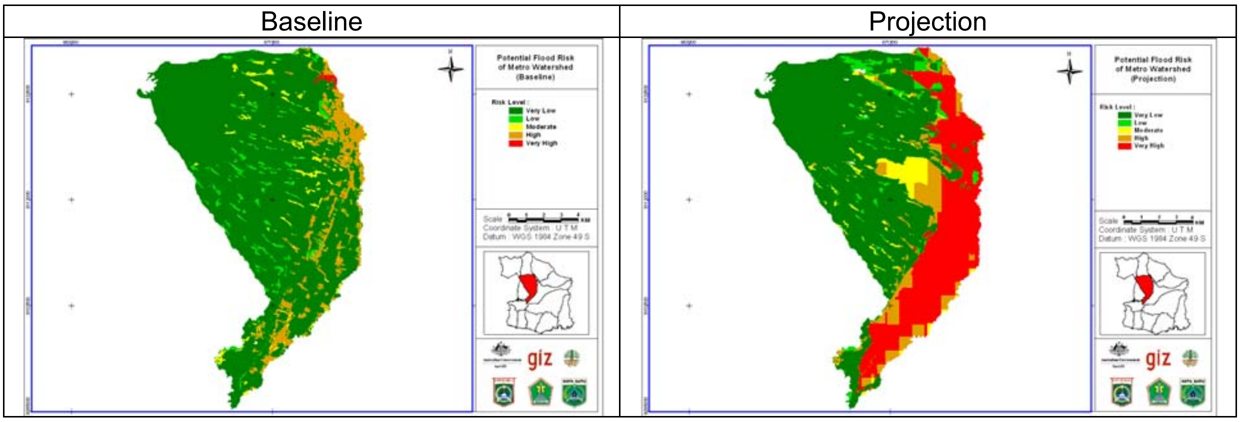


Figure 6. 16 Potential Flood Risk of Metro Watershed

In baseline condition, residential area is the place of highest risk because 4 levels of risk located at this area that are Low, Moderate, High and Very High level of risk while the very low risk level covers dry-land agricultures, paddy fields, agriculture land, forest and shrubs.

In projection condition, the places of highest risk are residential, industry area and public facility because these areas covered by high and very high risk level.

Table 6. 15 Potential Flood Risk Area of Metro Watershed

Risk Level	Baseline		Projection	
	Area (km^2)	Land Use	Area (km^2)	Land Use
Very Low	236.14	Dry-land agricultures Paddy Fields Agriculture Land Forest Shrubs	158.24	Dry-land agricultures Protected Forest Plantation Paddy Field Green Open space
Low	11.08	Residential Dry-land agricultures	10.60	Residential Dry-land agricultures Paddy Field Green Open space
Moderate	7.70	Residential	11.77	Residential Industry Area
High	23.45	Residential	22.18	Residential Industry Area Public Facility
Very High	0.89	Residential	76.25	Residential Industry Area Public Facility

6.4 Landslide Risk

Landslide risk analysis includes the cross-correlation of the hazard analysis which triggered by existing historical landslide, slope, geology, and ground water table recharge, and the vulnerability analysis which indicated by population density, land use, role of infrastructure, and population welfare, i.e. **Hazard x Vulnerability = Risk**.

6.4.1 Risk Level Mapping

Risk assessment performs the estimation of the level of risk in accordance to the levels of hazard and vulnerability by using relation table in

HAZARD	VULNERABILITY					
		Very Low	Low	Moderate	High	Very High
	Very Low	**VL**	**VL**	**L**	**L**	**M**

	Low	VL	L	L	M	H
	Moderate	L	L	M	H	H
	High	L	M	H	H	VH
	Very High	M	H	H	VH	VH

Figure 6. 17 6 belows, where it is divided into 5 levels, they are very low, low, moderate, high and very high.

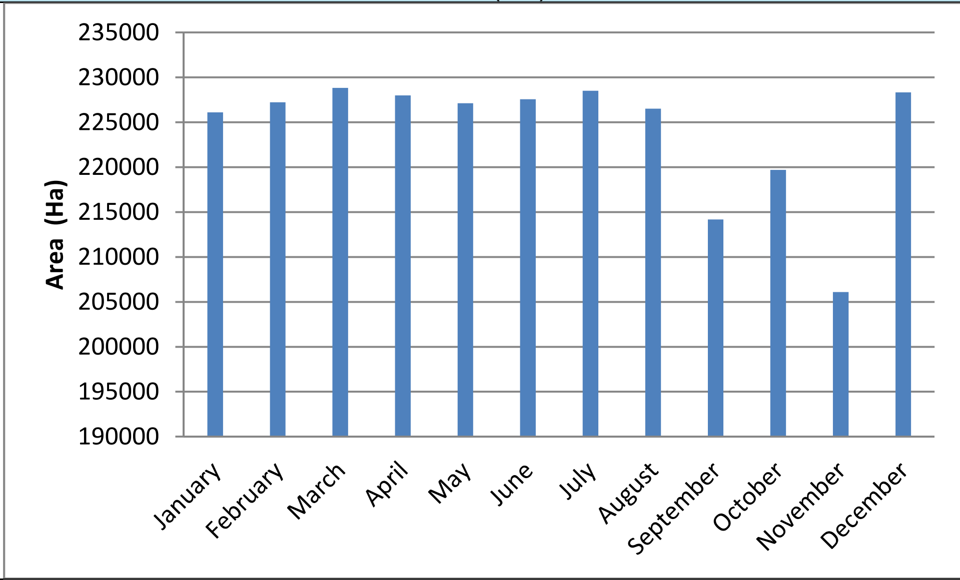
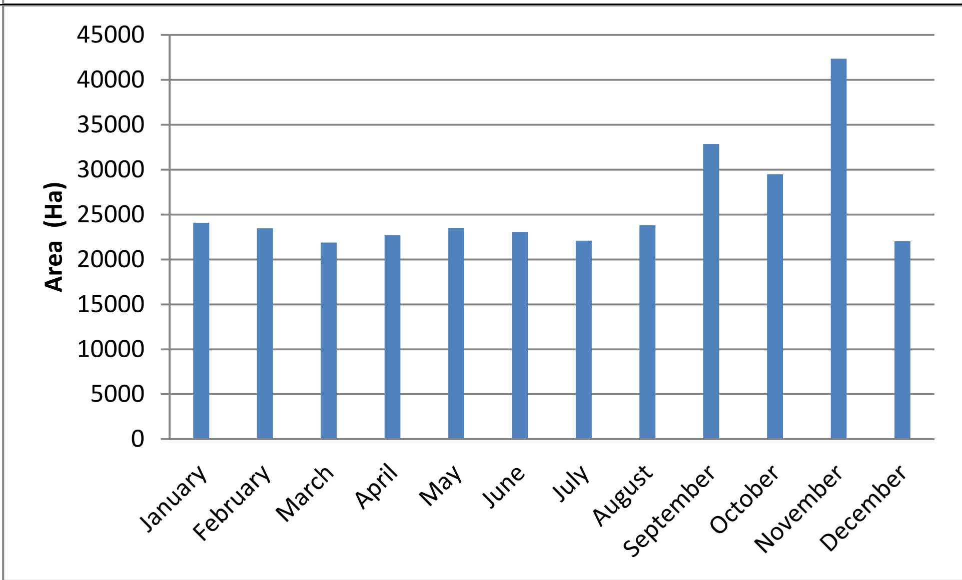
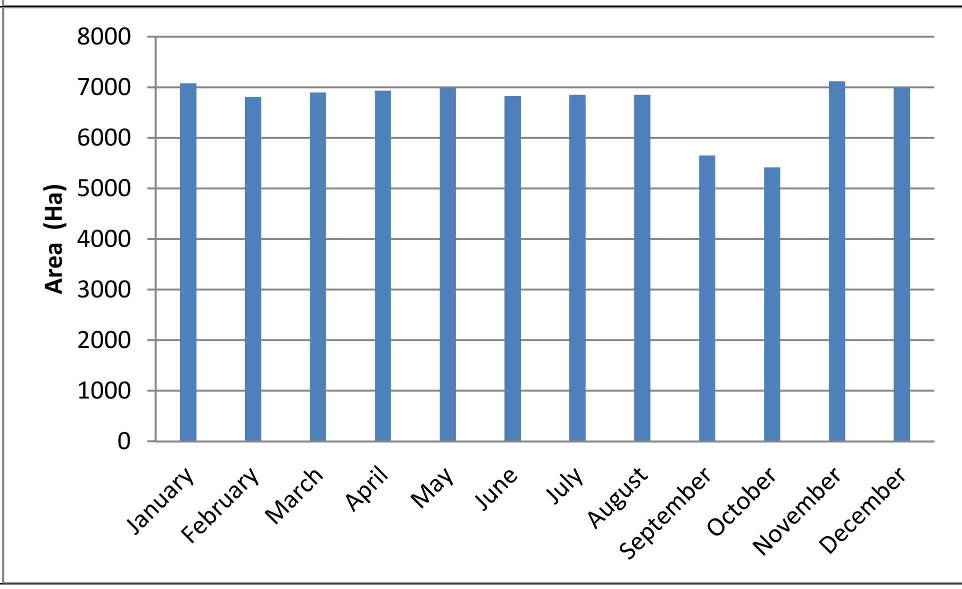
		VULNERABILITY				
		Very Low	Low	Moderate	High	Very High
HAZARD	Very Low	VL	VL	L	L	M
	Low	VL	L	L	M	H
	Moderate	L	L	M	H	H
	High	L	M	H	H	VH
	Very High	M	H	H	VH	VH

Figure 6. 17 Scheme for estimate the risk level

Based on the figure 6.16 above and monthly hazards, monthly landslide risks are produced as shown in Table 6.15 below.

Table 6. 16 Monthly landslide risk of Greater Malang

Risk Level	Area (Ha)

<table>
<tr><th>Risk Level</th><th>Area (Ha)</th></tr>
<tr><td>Very Low</td><td>
</td></tr>
<tr><td>Low</td><td>
</td></tr>
<tr><td>Moderate</td><td>
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</table>

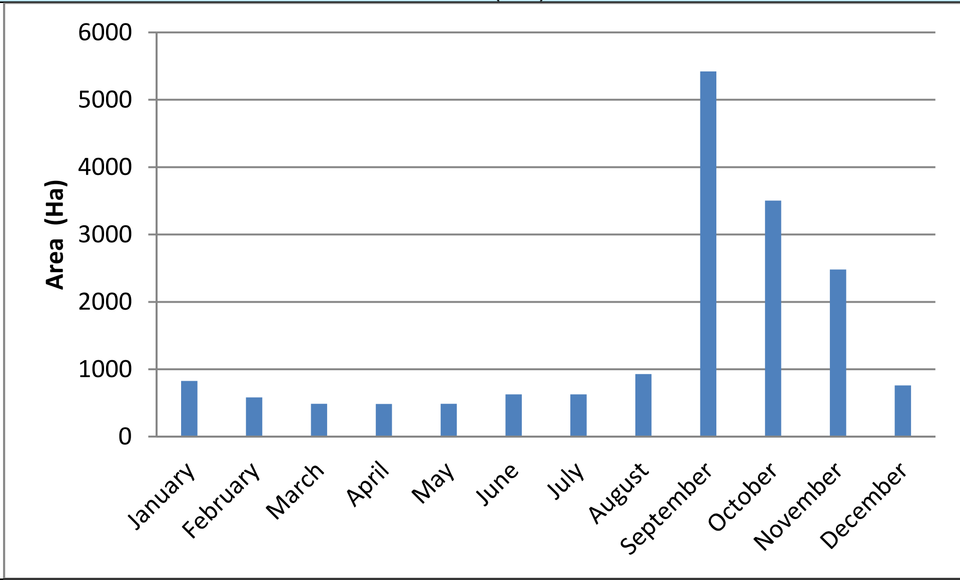
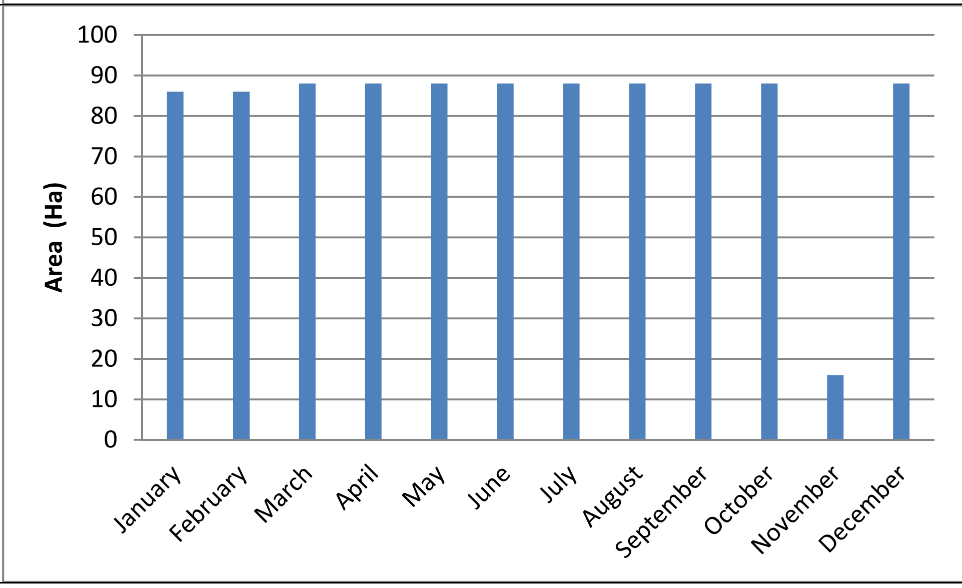
Risk Level	Area (Ha)
High	
Very High	

Table 6.15 shows that the high level of landslide hazard in September has the highest area (5.420 Ha) and for the very high level spreads over 88 Ha area. The spatial distribution of risk areas for baseline (2011) and projection (2030) in September is shown in Figure 6.17.

Baseline condition

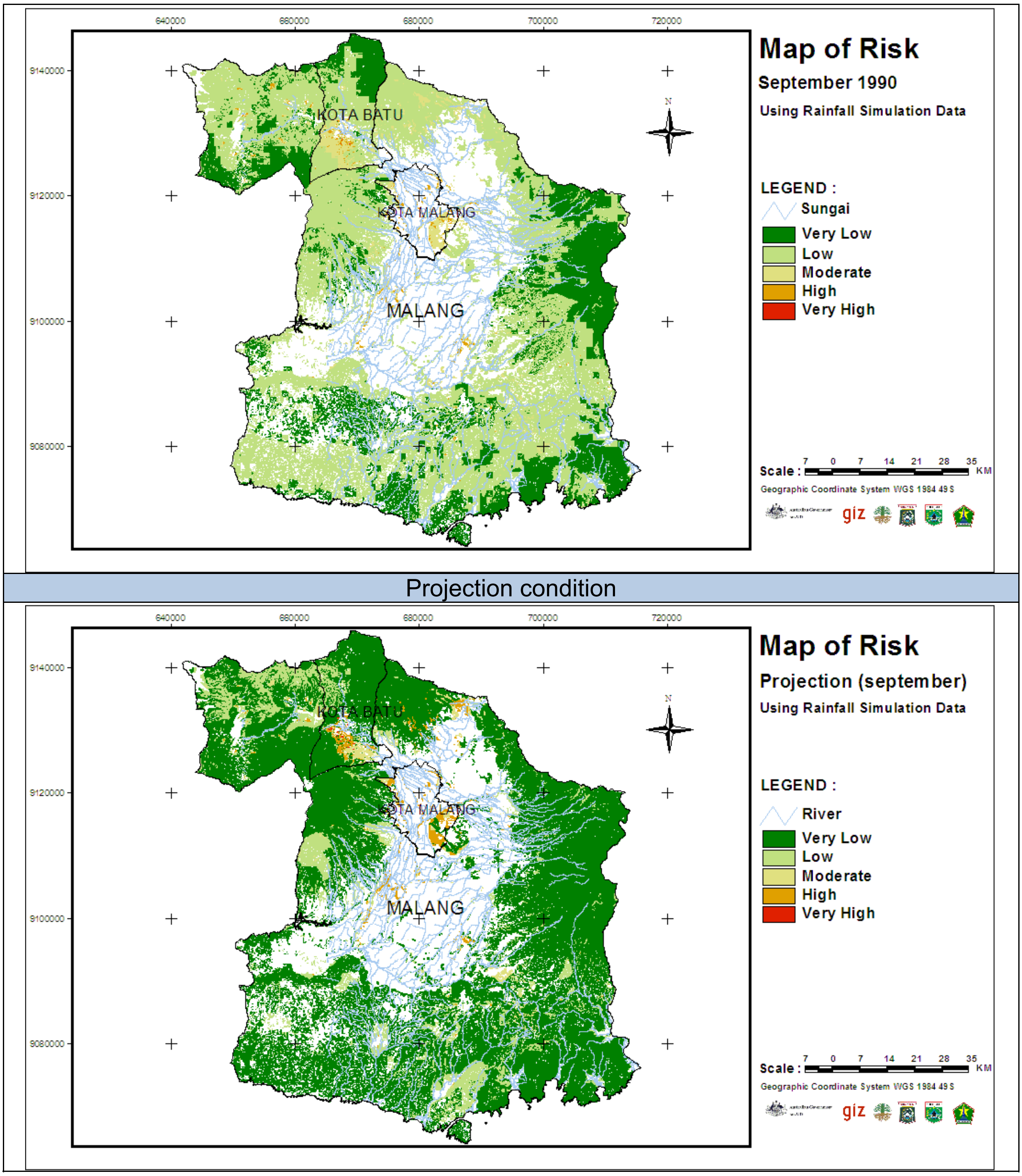


Figure 6. 18 Landslide risk map for baseline condition and for projection condition

As seen in Figure 6.17, the risk areas for high and very high levels will increase significantly from baseline to projection (see Table 6.17).

Table 6. 17 Risk map area for baseline and Projection

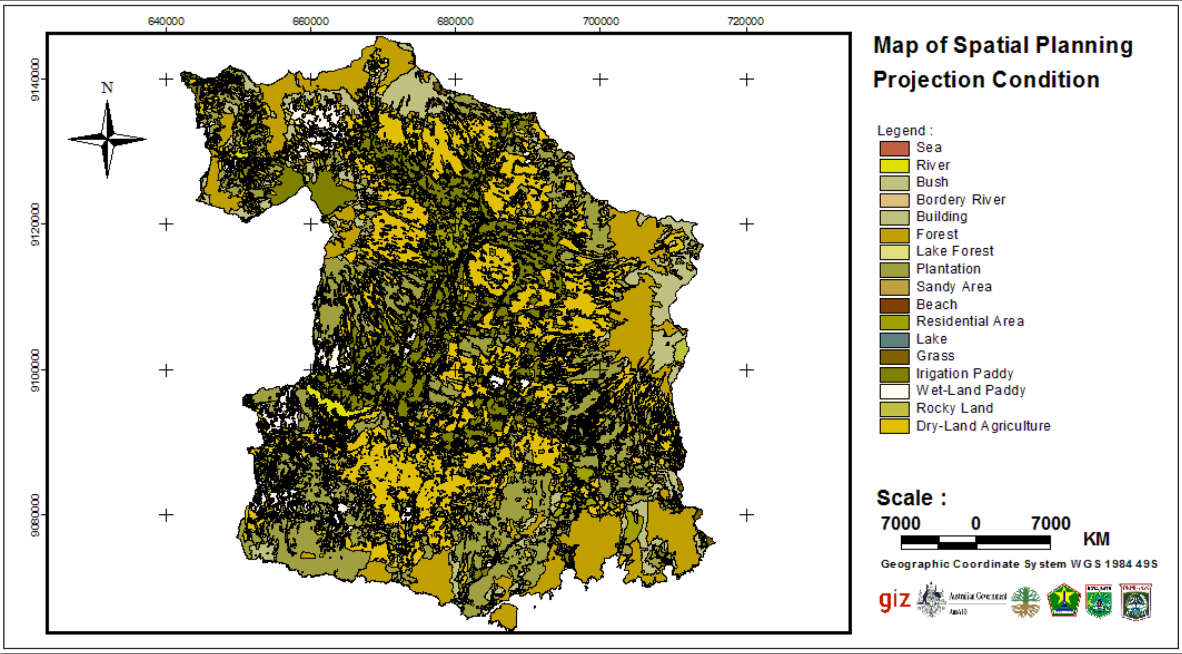
Level	Risk (Km^2)	
	Baseline	Projection

Very Low	792,590.00	2,141,700.00
Low	1,657,270.00	328,540.00
Moderate	115,720.00	56,510.00
High	20,620.00	54,200.00
Very High	0.19	0.88

6.4.2 Risk Map in Spatial Planning

Figure 6.19 shows the land use of the Greater Malang for baseline (2011) and projection (2030). The results of an overlay between landslide risk map and land use map are as follows. For the baseline condition, very high level occured in built-up area (3.352,39 m^2), Plantation (45.934,96 m^2), residential (111.493,88 m^2), and Irigation paddy (27.890,22 m^2). While, for the projection condition, very high level would occur in Social and Public facilities (15.634,89 m^2), Protected Forest (60,78 m^2), industrial and warehouse (2,908.91 m^2), tourism area (41.603,05 m^2), Plantation area (3.673,96 m^2), Trade and service area (70.600,75 m^2), Residential area (624.679,50 m^2), green open space (19.507,86 m^2), and border river (13.654,42 m^2).

Baseline condition



Projection condition

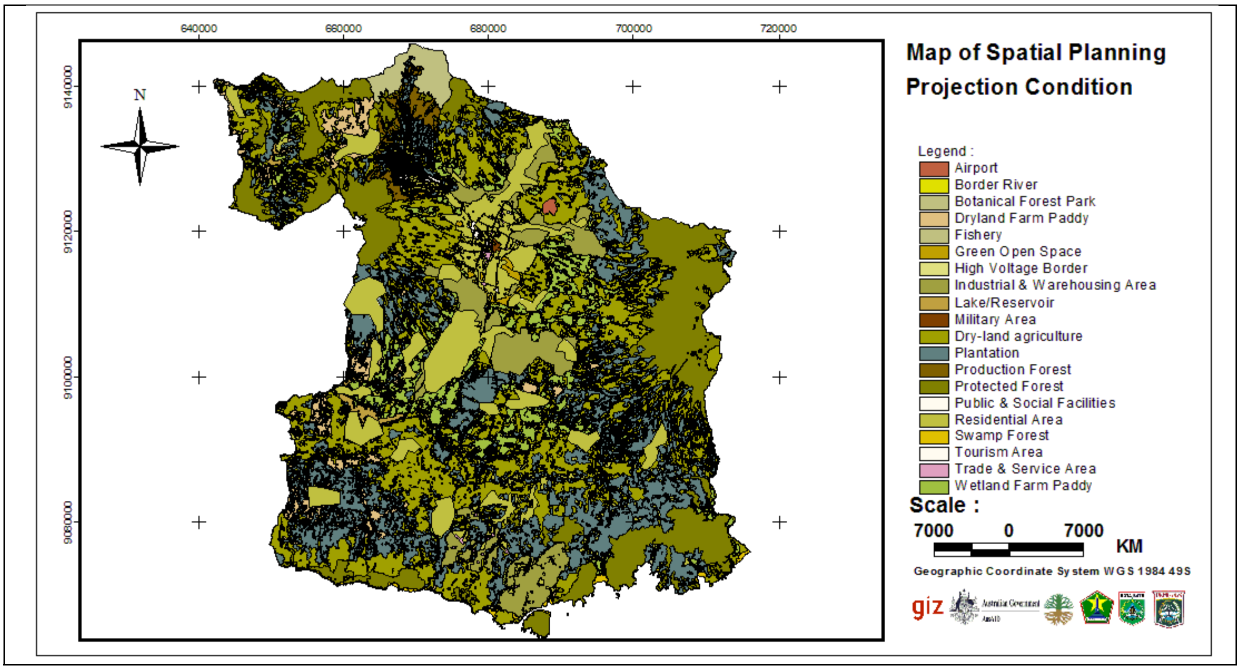


Figure 6. 19 Landuse map of projection condition

More detailed information area can be seen in Table 6.17 and 6.18.

Table 6. 18 Landslide area (landuse) of risk map for baseline condition using rainfall simulation data

Landuse	Area (m^2)				
	Very Low	Low	Moderate	High	Very High
River	655.259,93	3.289.474,23	603.853,69	92.870,90	
Bush	125.908.185,89	151.358.532,98	8.345.739,64	2.510.593,18	346,19
Border River	74.726,60	36.163,88			
Building	907,89	30.071,14	50.183,59	34.882,79	3.352,39
Forest	292.006.761,83	152.488.749,35	2.282.885,97	704.551,56	
Lake Forest	616.861,67	31.343,55			
Plantation	171.348.633,04	531.360.208,34	23.306.348,15	3.143.905,21	
Sandy Area	15.406,38	3.480,33			
Beach	4.983,04				
Residential Area	14.156.372,19	118.715.641,02	29.985.079,11	9.825.251,24	111.493,88
Lake	254.517,77	2.607,57			
Grass	1.549.644,79	14.647.745,83	1.149.569,84	288.561,43	2.198,89
Irigation Paddy	9.901.938,04	90.243.329,21	30.195.872,45	4.504.321,58	27.890,22
Wet-Land Paddy	8.968.992,21	59.742.134,12	1.724.484,97	1.417.774,60	
Rocky Land	4.513.415,83	616.901,90	15.273,55		
Dry-Land Agriculture	116.738.460,74	526.944.703,33	45.233.410,72	7.440.136,78	45.934,96

Table 6. 19 Landslide area (landuse) of risk map for projection condition using rainfall simulation data

Landuse	Area (m^2)				
	Very Low	Low	Moderate	High	Very High
Airport	33,952.03	76,075.77		33,952.03	
Lake/Reservoir	405,459.27	3,914,457.16	62,080.15	23,290.11	
Public and Social facilities	843,162.11	1,136,106.52	418,219.60	731,500.95	15,634.89
Protected Forest	53,026,162.32	538,528,454.37	1,008,604.12	198,775.63	60.78
Production Forest	2,877,931.97	30,267,031.54	99,940.85	201,613.99	
Swamp Forest	68,800.07	2,015,384.60			
Industrial and Warehouse	56,500,404.07	37,853,842.04	7,401,945.32	5,115,752.71	2,908.91
Tourism Area	3,240,948.36	3,658,329.76	1,059,614.45	2,129,005.24	41,603.05
Military Area	6,839.16	6,839.16		63,976.14	
Plantation	45,669,965.00	611,566,081.73	4,266,649.85	1,004,521.34	3,673.96
Trade and Service Area	1,167,889.25	1,344,329.98	347,344.92	1,198,540.07	70,600.75
Fishery	10,395.22	93,704.59			
Residential Area	174,701,835.94	135,951,923.53	31,907,760.02	37,976,517.27	624,679.50
Green Open Space	4,513,052.18	2,682,332.01	407,502.48	835,077.65	19,507.86
Wetland Farm Paddy	21,347,284.74	110,573,278.49	1,555,284.47	774,153.34	
Border River	888,217.06	3,798,611.91	373,334.68	375,815.88	13,654.42
Botanical Forest Park	5,572,717.14	44,339,769.66			
Dry-Land Agriculture	40,637,083.32	721,874,599.04	4,340,045.68	1,902,608.63	

VII. ADAPTATION STRATEGY ON WATER SECTOR

7.1 General Concept and Principles

Adaptation to water risk must be a part of Integrated Water Resources Management (IWRM). In this adaptation, climate change supposes to be one of the basic considerations in managing water, as in developing water supply infrastructures, etc. As stated in the AR4, IWRM should be an instrument to explore adaptation measures to climate change. The indicators of the IWMR as stated in the AR4 are: capturing society's views, reshaping planning processes, coordinating land and water resources management, recognizing water quantity and quality linkages, conjunctive use of surface water and groundwater, protecting and restoring natural systems, consideration of climate change, and omitting the impediments to the flow of information.

However, to implement the IWRM in Greater Malang as well as in many regions in Indonesia there are still many constraints. The constraints come from, among others, unavailability of data, lack of local government involment, and confussion about the division of authority. For example, the duty and authority of Public Works do not include the maintenance of water sources and water infiltration zones. IWRM steps are different in each region because of different natural characteristics and social cultures. Some adaptation options from AR4 are presented in Table 7.1, while Table 7.2 is an example of adaptation technologies for water supplies from UNFCCC.

Table 7. 1 Some adaptation options for water supply and demand (*Source*: the AR4)

Supply-side	Demand-side
Prospecting and extraction of groundwater	Improvement of water-use efficiency by recycling water
Increasing storage capacity by building reservoirs and dams	Reduction in water demand for irrigation by changing the cropping calendar, crop mix, irrigation method, and area planted
Desalination of sea water	Reduction in water demand for irrigation by importing agricultural products, i.e., virtual water
Expansion of rain-water storage	Promotion of indigenous practices for sustainable water use
Removal of invasive non-native vegetation from riparian areas	Expanded use of water markets to reallocate water to highly valued uses
Water transfer	Expanded use of economic incentives including metering and pricing to encourage water conservation

Table 7. 2 Example of adaptation technologies for water supplies (*Source*: UNFCCC, 2006)

Use category	Supply side	Demand side
Municipal or domestic	• Increase reservoir capacity	• Use "grey" water

		• Desalinate • Make inter-basin transfers	• Reduce leakage • Use non-water-based sanitation • Enforce water standards
Industrial cooling		• Use lower-grade water	• Increase efficiency and recycling
Hydropower		• Increase reservoir capacity	• Increase turbine efficiency
Navigation		• Build weirs and locks	• Alter ship size & frequency of sailings
Pollution control		• Enhance treatment works	• Reduce effluent volumes
		• Reuse and reclaim materials	• Promote alternatives to chemicals
Flood management		• Build reservoirs and levees	• Improve flood warnings
		• Protect and restore wetlands	• Curb floodplain development
Agri-culture	• Rain-fed	• Improve soil conservation	• Use drought-tolerant crops
	• Irrigated	• Change tilling practices	• Increase irrigation efficiency
		• Harvesting rainwater	• Change irrigation water pricing

Adaptation options in the tables can be grouped into two types of adaptation, hard adaptation and soft adaptation. Hard adaptation is physical adaptation, such as building reservoirs and other physical structures to adapt. Soft adaptation includes development of regulations, early warning system for floods, capturing society's views, etc. Some main adaptation principle from the AR4 (Table 7.1) or UNFCCC (Table 7.2) are uneasy to implement in Greater Malang due to lack of financial resources, technological resources, and human resources.

7.2 Adaptation for water shortage risk

7.2.1 Zoning for adaptation measurement

The adaptation strategies are divided into five main zones. These zones are classified based on watershed area. All rivers flow throughout region of Greater Malang can be grouped into more than 50 watersheds including several small watersheds (total areas < 10 km2) in the southern part of the region, medium watersheds (total area between 10 km2 – 25 km2), and large watersheds (total area > 25 km2) as presented in Figure 7.1. There are several rivers in Greater Malang do not flow into Brantas River.

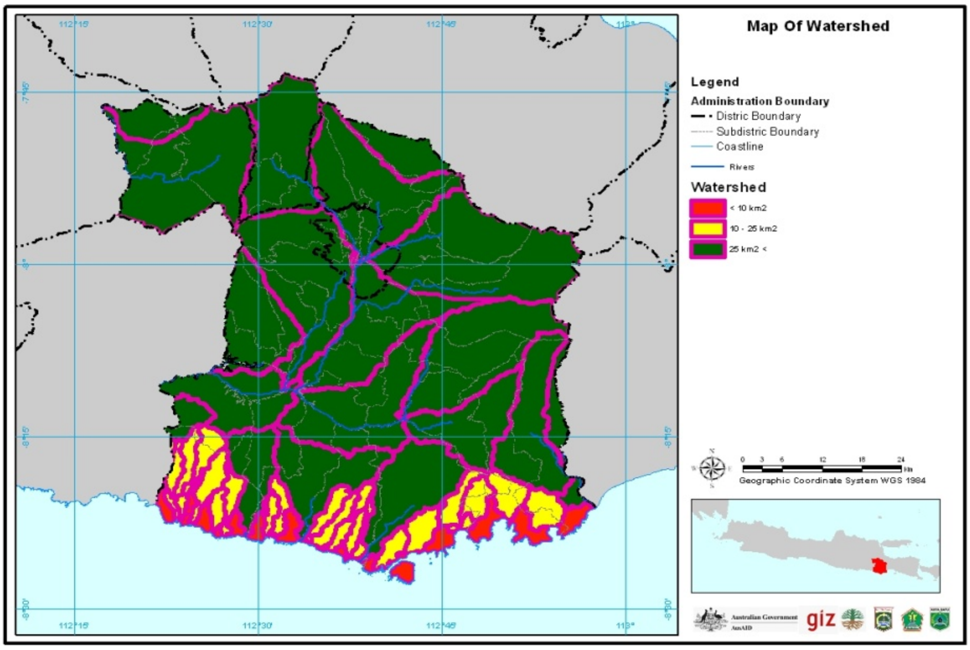


Figure 7. 1 Watershed Map of Greater Malang.

Others basis for determining adaptation zone in Greater Malang are the distribution pattern and the level of water shortage hazard. The land elevation and the existing watershed classification the Agency of Brantas Watershed Management or *Balai Pengelolaan DAS Brantas/ BP DAS Brantas* are also used as basis in this zoning for the adaptation. Based on those basis mentioned above, the Greater Malang is divided into 5 (five) zones. Further, these five zones are divided into several sub zones, except Zone IV. Therefore, we have 12 (twelve) zones for the adaptation in Greater Malang as follows: Zone IA, Zone IB, Zone IC, Zone IIA, Zone IIB, Zone IIC, Zone III, Zone IVA, Zone IVB, Zone VA, Zone VB, and Zone VC (Figure 7.2).

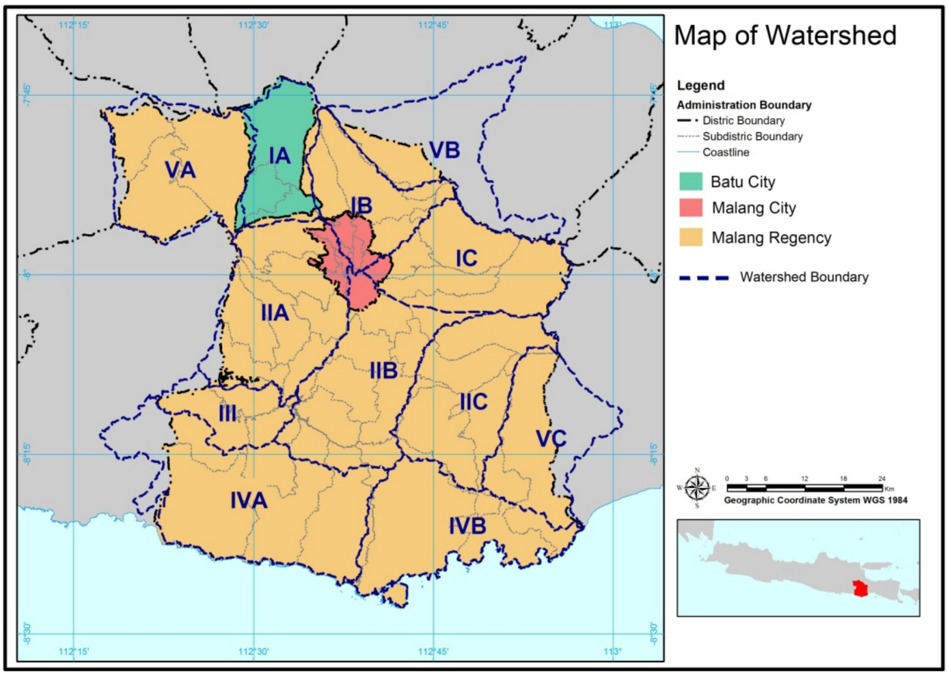


Figure 7.2 Tweleve zones for adaptation to water shortage risk in Greater Malang

The Zone IA is the Sumber Brantas Watershed which is located in the upstream of Greater Brantas Watershed. The Zone IB is the Bango Watershed which covers the northern part of Malang City region. The Zone IC is the Amprong Watershed located in eastern of Malang city. The Zone IIA is west part of Metro-Lahor-Melamon Watershed located western side of Malang City and including Kapanjen, the capital of Malang District. The Zone IIB is east part of the Metro-Lahor-Melamon Watershed. Zone IIC is Lesti Watershed. Zone III is region of Soetami dam. This zone is separated from other zone because of its special function as area of the biggest dam in the Brantas Watershed.

The Zone IVA (western south coast watershed) and IVB (eastern south coast watershed) located respectively in west side and east side of coastal region of south Malang District. These two zones are not part of the greater Brantas Watershed. The Zone VA, Zone VB, and Zone VC are small zones which are separated from other zones because they are not part of greater Brantas Watershed. The Zone VA, Konto watershed, is the biggest one which is located in western Batu City. The Zone VB mostly is located in Lawang sub-district. The zone VC is located mostly in Ampelgading sub-district.

Five adaptation zones to decrease of water supply in Greater Malang are like:

1. Zone I is located in the upstream of northern Brantas river as the center of Batu city's activities and the north of Malang city. This zone is divided into three sub-zone: Sumber Brantas, Bango and Amprong.

2. Zone II is a part of Malang city and Malang district activities's center. This zone is projected to have land cover changes to accommodate the increasing of activity intensity.
3. Zone III is the Metro-Lahor-Lemon sub-watershed as a part of the Soetami Dam. This zone is characterized as important of water supplier.
4. Zone IV is located in the south of Malang and it is not a part of Brantas Hulu watershed that flows directly to Indonesia Ocean. This zone is projected to experience water shortage risk.
5. Zone V is also not the part of BrantasHulu sub-watershed.

Table 7.3 Zoning of Adaptation of Water Water Shortage Risk

ZONE	City / District Area	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK I IN PROJECTION PERIOD	Adaptation Option For Strategy
IA, Sumber Brantas sub watershed	Batu, Jabung, Bumiaji (Batu City)	• Mostly green areas as recharge areas for downstream region, separated by spring • Relatively unchanged of Land use • Spring as main water sources	- The hazard is increasing one level to high in 2030 - DoWA is relatively unchanged arround 652,999.25 m^3/month - The vulnerability is increasing to high - In the center part of Batu,several areas risk are increasing up two level from very low to moderate affected by increasing of water demand	• Reforestation/Afforestation • Implementation of water resource conservation (supply side) • Implementation of low impact development (LID), i.e.: maximize recharge area, increase water infiltration with special vegetation and land structuring, decreasing impermeable layer of land, conserve land function in holding and recharging water;
IB, Bango watershed,	Karangploso, Singasari, north Pakis, south	• Mostly urban area • Recharge & discharge area	- The hazard is moderate. - DoWA is relatively	• Lower region or urban area (Malang city and its surrounding area) through

ZONE	City / District Area	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK I IN PROJECTION PERIOD	Adaptation Option For Strategy
part of Amprong-Bango (Ambang) sub watershed	Lawang (Malang District); east Lowokwaru, Blimbing, Purwantoro, east Klojen, and northern part of Kedungkandang (Malang City)	(groundwater) • Mostly built-up area • Higher Water demand but reltively fulfilled by the PDAM and groundwater	unchanged arround 3,226,867.05 m^3/month - The vulnerability are very low to high and it is increasing from 2010 to 2030 - The causes of the increasing risk are increasing water demand (the vulnerabilty)	implementation of water resource conservation (supply side) • Hard adaptation in the upper region or rural region to upper area or highland area.
IC, Amprong, part of Amprong-Bango (Ambang) sub watershed	Gondanglegi, center to south of Pakis, northern part of Poncokusumo, Tumpang (Malang District); Buring and Kedungkandang (Malang city)	• Dry land are dominant which impacts are increasing runoff & sediment transport • Water sources: PDAM's water in urban area, hand pump or electric pump (groundwater) in north part; and rivers (direct use) or limited springs in south and east part of the zone	- The hazard is increasing one level to high in 2030 - DoWA is relatively unchanged arround 567,153.88 m^3/month. - The vulnerability are very low to high, mostly very low. - The risks are very low to moderate, mostly very low. The causes of the increasing risk are increasing the hazard & water demand (the vulnerabilty)	• Lower region or urban area (west part of the zone or Malang city and its surrounding area) by implementation of water resource conservation. • Hard adaptation in the middle region to upper region or rural region.
IIA, West part of	Dao, Wagir, Pakisaji,	• Recharge area in upper part. Rice	- The hazard is increasing one	• Hard adaptation by implementation of water

ZONE	City / District Area	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK I IN PROJECTION PERIOD	Adaptation Option For Strategy
Metro –Lahor-Lemon sub watershed	Kapanjen, Ngajum, Kromengan, Wonosari(Malang District); Dinoyo, west Lowokwaru, west Klojen, Sukun, west Buring (Malang City)	field and irrigation area in middle to lower part • Water demand is high mainly for irrigation of rice field and domestic use • The irrigation are using only river water (not using water from Soetami dam)	level to high in 2030 - DoWA in 1950 to 2010 reach 3,277,247.63 m^3/month and DoWa 1950 to 2030 reach 2,693,738.53 m^3/month. - The vulnerability becoming very high in lower area, caused by water demand. - The risks is increasing from 2010 to 2030	resource in lower region or urban area (Malang city and capital city of Malang municipal and its surrounding area). • Hard adaptation in the middle to upper region or rural region
IIB, East part of Metro –Lahor-Lemon sub watershed	most part Buring (Malang City), Tajinan, Bululawang, Turen, Pagelaran Selatan, Pagelaran Utara (Malang District)	• Lowland region in greater Malang • Mostly as discharge area. • The main water problem is likely flood • Water resources: PDAM's water, groundwater with electric pump or hand pump, groundwater with dug well and river water or springs	- The hazard is low. - DoWA is relatively unchanged arround 10,424,687.55 m^3/month. - The vulnerability is increasing. - The risks is increasing, still very low. - The causes of the increasing risk are increasing the vulnerability (water demand)	• Collaboration with upper sub watershed in flood adaptation and water shortage adaptation; • Developing agro-forestry as natural recharge for water resource conservation and developing artificial recharges in plantations area (trench or ditch); • Developing artificial recharge by: (a) developing recharge well, especially in north part of the zone; (b) developing retardation basin or polder (*embung* or *urung-urung*); • Drainage and river maintenance.

ZONE	City / District Area	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK I IN PROJECTION PERIOD	Adaptation Option For Strategy
IIC, Lesti	Southern part of Poncokusumo, Wajak, Dampit Northwest Titoyudo (Malang District)	• Recharge area in upper part. Rice field and irrigation area in middle to lower part • Dry land dominated by loosing increase of runoff and sediment transport • Recharge area in upper land & recharge area in low land • Low water demand	- The hazard is high. - DoWA is increasing up to 100,000 m^3/month. - The vulnerability is increasing, mostly high. - The risks are very low-high, mostly moderate. The causes are increasing the vulnerability (water demand) .	• Upper to middle region: (1) forestation/ vegetation of dry-land agriculture or wasteland area, (2) agro-forestry as natural recharge for water resource conservation; (3) artificial recharges by developing trench or ditch in plantations area; (4) developing small dam/ check dam; (5) minimize land erosion; ▪ Lower region / urban area: (1) developing artificial recharge by developing recharge well; (2) drainage maintenance.
III, South part of Metro –Lahor-Lemon sub watershed	Sumberpucung, upper part of Kalipare	• Region is down stream of upper Brantas, Amprong, Bango and Lesti watersheds • Location of Soetami dam • Water demand is high caused by water demand for the dam • Place of high important of water infrastructure	- The hazard is very low. - DoWAis increasing reach 9 million.m^3/month. - The vulnerability is increasing by the condition of water infrastructure. - The risk is very low.	• Collaboration with upper sub watershed in water shortage adaptation as well as flood adaptation; • Upper region : (1) forestation, especially on dry-land agriculture; (2) land erosion prevention ▪ Lower region/dam region: (1) engineering on dam, (2) spillway evaluation, (3) emergency spillway, (4) evaluation of dam ass, etc; (5) preventing water supply for the dam; (3) decreasing sedimentation and dredging sedimentation
IVA,	Kalipare, Pagak,	• Dominated by	- The hazards are	• Agro- forestry as natural

ZONE	City / District Area	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK I IN PROJECTION PERIOD	Adaptation Option For Strategy
Western south coast watershed, outside of Brantas watershed	GedanganBatur, Donomulyo (Malang District)	limestone • Water demand is high caused by high cultivation actvities	increasing one level to very high in western and eastern area. - DoWA is increasing up to 800 thousand m^3/month. - The vulnerability and the risk increasing one level by increasing water demand.	recharge for water resource conservation; and artificial recharges by developing trench or ditch in plantations area; • Developing surface water resource in region that drained abundantly by short rivers; • Developing groundwater or subsurface water resource in karst regions or limestone region ▪ Rain water harvesting in center region which has no potency of both surface water and groundwater.
IVB, Eastern south coast watershed, outside of Brantas watershed	Sumbermanjing, southern part of Tirtoyudo, southern part of AmpelGading (Malang District)	• Dominated by limestone • Water demand is high caused by high cultivation actvities	- The hazard is increasing one level to high in the western part - DoWA is increasing that up to 200 thousand m^3/month. - The vulnerability is increasing to high in the western part. - The risk is increasing one level in the western part to high-very high.	• Agro- forestry as natural recharge for water resource conservation; and artificial recharges by developing trench or ditch in plantations area; • Developing surface water resource in region that drained abundantly by short rivers; • Developing groundwater or subsurface water resource in karst regions or limestone region • Rain water harvesting in center region which has no potency of both surface water or groundwater. ▪ Desalinitation of sea water if necessary

ZONE	**City / District Area**	**Characteristics** **→ MAIN REASONS/ CONDITIONS**	**HAZARD (H), VULNERABILITY (V) & RISK I IN PROJECTION PERIOD**	**Adaptation Option For Strategy**
VA, Konto watershed, outside of Brantas watershed	Pujon, Ngantang and Kasambon (Malang District)	• Region is belong to Konto watershed	- The hazard is moderate. - DoWA is increasing about 500 thousand m3/month. - The vulnerability is low and increasing caused by water demand. - The risks are low and increasing.	• Hard adaptation by implementation of water resource conservation (supply side) and low impact development.
VB, Lawang watershed, outsideBrantas watershed	Northern part of Lawang (Malang District)	• Region in southeast Malang District	- The hazard is high and it is relatively unchange compare to 2010. - DoWAis decreasing about 400 thousand m^3/month. - The vulnerability is very high in northern part of Malang. - The risks are moderate and increasing by the vulnerability (water demand)	• Hard adaptation by implementation of water resource conservation (supply side) and low Developing water piping system by establishing PDAM in Lawang sub-district. Water resource as raw water for this water piping system can be taken from groundwater; ▪ Developing agro forestry as natural recharge for water resource conservation and generating new springs using artificial recharge such as ditch or trench in plantation.
VC, Ampelgading watershed, outside of Brantas watershed	Northern to eastern part of Ampelgading (Malang District)	• Region in eastern Malang District	- The hazard is increasing one level to high. - DoWA is relatively unchanged arround	• Hard adaptation by implementation of water resource conservation (supply side) and low impact development.

ZONE	City / District Area	Characteristics → MAIN REASONS/ CONDITIONS	HAZARD (H), VULNERABILITY (V) & RISK I IN PROJECTION PERIOD	Adaptation Option For Strategy
			900,572.74 m^3/month. - The vulnerability is increasing one level. - The risk is increasing to moderate by the hazard and water demand (the vulnerabilty)	

Based on the description of adaptation option that fit on each zone characteristics above, the implementation criteria is arranged this way (Table 7.4):

Table 7.4 Implementation Rank of Climate Change Adaptation in Malang (Priority scale 1-3)

No	Criteria	Malang City	Malang District	Batu City	Adaptation Strategy Priority
1	Large area factor that has a high risk only	2	1	3	Hard Adaptation + Soft Adaptation
2	Large area factor that has a high to very high risk + water needs factor	1	2	3	Focus on Hard Adaptation,accompanied with Soft Adaptation
3	Large area factor that has a high to very high risk + water supply factor supply factor	3	2	1	Focus on Hard Adaptation,accompanied with Soft Adaptation

7.3. Adaptation for flood risk

The adaptation option for Greater Malang determined base on risk level (Table 7.1).

7.3.1 Reforestation

The process of replacing plants in area that has had them cut down, because of unplanned urban growth, irregular land use occupation or other motives, like economic use of trees, is a very important measure to recover natural flow patterns. Reforestation prevents soil erosion, retains topsoil and favours infiltration. Runoff volumes are reduced and drainage structures keep working efficiently, once a minor quantity of sediments arrives at the system. Renewing a forest cover may be achieved by the artificial planting of seeds or young trees.

Table 7. 5 Reforestation

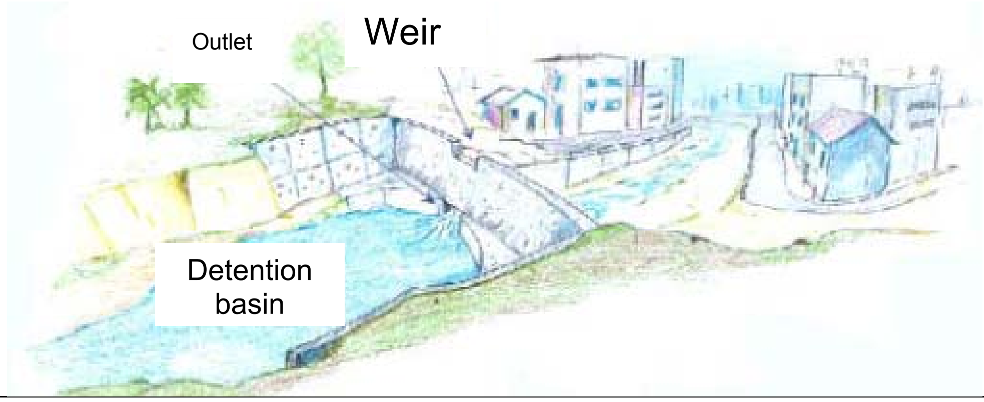
Adaptation Option	Districs	
Reforestation	Pujon Batu BumiAji Jabung Dau Wagir Ngajum Poncokusumo	

7.3.2 Detention Basin

Flood damping is an effective measure to redistribute discharges over time. Increased volumes of runoff, which are resultant from urbanisation, are not diminished, in fact, but flood peaks are reduced. Damping process works storing water and controlling outflow with a limited discharge structure.

There are several possibilities of application of this kind of measure. Detention ponds may be placed in line with rivers, controlling great portions of the basin, upstream the urbanized area, where occupation is lower and there is more free space to set larger reservoirs. Public parks and squares, as well as riverine areas may be used as detention ponds, opening the possibility to construct multifunctional landscapes.

Table 7. 6 Detention Basin

Adaptation Option	Districts	
Detention Basin	Pujon Bumiaji Singosari Gondanglegi Wajak Tumpang	

7.3.3 Ponds (Embung)

The Pond (Embung) provides two primary services. First, the pond has function as a basin that is designed to catch runoff water from higher elevation areas, and retains the runoff before releasing it into streams. Second, the pond will be used as water storage that will have to supply as water source. The pond should be built in near of middle stream area.

Table 7. 7 Ponds

Adaptation Option	Districts	
Ponds (Embung)	Pujon Batu Bumiaji Jabung Dau Wagir Wajak Dampit Turen	

7.3.4 Retention Pond

Retention pond is designed to control storm water runoff on a site—and, in some cases, to remove pollutants from the retained water. Storm water control strategies include ditches, swales, ponds, tanks, and vaults. These generally function by capturing, storing, treating, and slowly releasing storm water downstream or allowing infiltration into the ground. A retention (or infiltration) pond collects water as a final storage destination, where water is held until it either evaporates or infiltrates the soil.

Table 7. 8 Retention Pond

Adaptation Option	Districts	
Retention Pond	Kedung Kandang Pakisaji Kepanjen Tajinan	

7.3.5 Infiltration Measures

Infiltration measures allow to partially recovering the natural catchment hydrologic behaviour. Infiltration measures may be divided into some different categories. There are Infiltration trenches, Vegetated surfaces, Rain gardens, Porous or permeable pavements.

Infiltration trenches, which are very common infiltration devices, are linear excavations backfilled with stones or gravel. The infiltration trench store the diverted runoff for a sufficient period of time, in order to have this volume infiltrated in the soil. Vegetated surfaces are other type of infiltration measure. Two common types of this kind of structure refer to swales and filter strips. Swales are shallow grassed channels used for the conveyance, storage, infiltration and treatment of storm water. The runoff is either stored and infiltrated or filtered and conveyed back to the sewer system. Filter strips are very similar, but with very low slopes and designed to promote sheet flow. Rain gardens are an especial type of garden designed to increase infiltration potential, presenting also a landscape function. Porous or permeable pavements are a type of infiltration measure where superficial flow is derived though a pervious surface inside a ground reservoir, filled with gravel. Porous pavement upper layer consists of a paved area constructed from open structured material such as concrete units filled with gravel, stone or porous asphalt. Another possibility refers on concrete units separated by grass. The depth of the reservoir placed beneath the upper layer determines the capacity of the measure in minimizing runoff. Soil infiltration rates and clogging over time will interfere with the effectiveness of this type of device.

Table 7. 9 Example of Infiltration Measures (Porous or permeable pavement and rain garden)

Adaptation Option	Districts	
Infiltration Measures	Lowokwaru Blimbing Kedung Kandang Dinoyo Sukun BUring Klojen Purwantoro Mulyorejo Oro Oro Dowo Pakisaji Bululawang Kepanjen	

7.4 Adaptation for landslide risk

Landslide risk modelling shows level of landslide risk on Greater Malang, several area show landslide risk with low to high level, while the rest have no risk. The result of landslide risk mapping becomes a based for adaptation strategies option. Acceptable landslide risk area, then implemented the adaptation works by considering the landuse itself. Based on both of landuse and landslide risk, adaptation option are choosen in landslide risk management as an impact of climate change.

Adaptation strategies option are according to Landslide Risk Assessment and Mitigation (LARAM-2000) and Australian Geomechanics Society (AGS) documents. Landslide adaptation strategy are arranged in four practical groups, namely: modification of slope geometry, drainage, retaining structures and internal slope reinforcement which table are attached at appendix I. This chapter brief some adaptation strategy based on landuse area at the risk of landslide using four practical groups that has prepared before.

7.4.1 Landslide adaptation concept on Greater Malang

Adaptation strategy is the last step on landslide risk management research. Method of adaptation strategies that according to Landslide Risk Assessment and Mitigation (LARAM-2000) and Australian Geomechanics Society (AGS), brief the flowchart at appendix H on phases of adaptation strategies, landslide risk evaluation, concept design, construction, monitoring that involved stakeholders as a client and decision-makers. Typical options to identify adaptation strategy include on AGS document:

- *Accept the risk* - this would usually require the risk to be considered to be within the acceptable or tolerable range.
- *Avoid the risk* - this would require abandonment of the project, seeking an alternative site or form of development such that the revised risk would be acceptable or tolerable.
- *Reduce the likelihood* - this would require stabilization measures to control the initiating circumstances, such as reprofiling the surface geometry, groundwater drainage, anchors, stabilizing structures or protective structures etc.
- *Reduce the consequences* - this would require provision of defensive stabilization measures, amelioration of the behavior of the hazard or relocation of the development to a more favorable location to achieve an acceptable or tolerable risk.
- *Monitoring and warning systems* - in some situations monitoring (such as by regular site visits, or by survey), and the establishment of warning systems may be used to manage the risk on an interim or permanent basis. Monitoring and warning systems may be regarded as another means of reducing the consequences.
- *Transfer the risk* - by requiring another authority to accept the risk or to compensate for the risk such as by insurance.
- *Postpone the decision* - if there is sufficient uncertainty, it may not be appropriate to make a decision on the data available. Further investigation or monitoring would be required to provide data for better evaluation of the risk.

Various option offer by landslide risk management expert to stakeholder to get an effective solutions that compatible and acceptable to the needs. Expert and stakeholder works together, in identifying adaptation strategies option, also by using combination between the options or another alternatives that mitigate the landslide risk.

7.4.2 Adaptation for Greater Malang

Based on landslide risk evaluation, several acceptable risk get and then have a further research on it by landslide risk management expert into several priority risk based on greatest loss and greatest occuring. Prioritization risk on Greater Malang are, 779,20 m^2 of building, 15.634,89 m^2 of public facilities, 60,78 m^2 of protected forest, 2.908,91 m^2 of industrial area, 41.603,05 m^2 of tourism area, 70.600,75 m^2 of commercial area, 3.673,96 m^2 of plantation area, 624.679,50 m^2 of settlement area, 19.507,86 m^2 of green open field, 10.552,81 m^2 and 3.101,61 m^2 of watershed. as seen in table below, and adaptation strategies on its own landuse. Adaptation works choosen based on compatible four practical group on every landslide landuse risk. Adaptation works using more than one type of works, or by using several combination of adaptation works.

Table 7. 10 Adaptation strategy on Greater Malang

No	Landuse	Adaptation
1	Building	Combination of slope geometry modification, drainage, retaining structures, and internal slope reinforcement, for some condition
2	Settlement	
3	Public facilities	
4	Industrial	
5	Tourism	
6	Commercial	
7	Plantation	Slope stabilization by cut and fill the slope and proper drainage
8	Green open field	Soft engineering by using combination of forestations with native plants to prevent erotion and shallow landslides and proper drainage
9	Watershed	River bank protection and drainage

Choosen design of every works typology on its group that implemented on the site, by considering engineering dan economic feasibility serta acceptability consistent with the overall needs of the client. Besides, environmental considerations have increasingly become an important factor in choosing strategi adaptasi, as an example combination between slope stability structural works by using retaining wall or anchor and the use of vegetation are more compatible with environment. The more detailed adaptation strategies are brief on every implemented site as seen below.

7.4.3 Adaptation for population vulnerable area

Adaptation strategy to this landuse using combination works of four practical group; modification of slope geometry, drainage, retaining structures and internal slope reinforcement, that implemented to landslide area that has people vulnerable. The implemented works are consider to the site, by using the geological and hydrological knowledge to determined the most compatible stabilizations works, and acceptable to social and environment. Adaptation target strategy, are building, public facilities, Industrial complex, Tourism area, Commercial area, settlement and area with populations. The adaptation strategy on detailed target field are discussed below.

- Area with population

Area with population are settlement, industrial facilities, power plant, petrochemical complex, and refineries. Selective adaptation strategy that most compatible in this area are using combination of structural element to hold the landslide material and drainage to sustain the hydrological factor. Structural element on this purpose are check dam (open type), and soft-engineering that using interaction between biovegetation and hard structural element.

Source : Mihall E. Popescu

Figure 7. 3 Open type check dam (left) and soft-engineering (right)

Open type check dam are considered to capture the material of landslide from its damage to population, the most purpose to check dam are streams catch of debris flow landslide material. Check dam are constructed more than one, with its position to catch as many as possible of landslide material. The open type is the most popular as it open part expected to retrieve the material of sediment or flood material to down stream, on the other hand, landslide material are more effective at the other part. Meanwhile, to prevent the landslide by binding the soil, soft-engineering are used. Interaction between vegetation and hard structural elements in compaction the soil, with the ability of vegetation in anchoring to the soil, and its hydrological benefit in decreasing the ground water table, as hard structural element at lower stabilizing the slope.

- Protection for railroad

Rockfalls are the most common type of landslide that occur on railroad. Falls are abrupt movements of masses of geologic materials, such as rocks and boulders. A fall starts with the detachment of soil or rock from a steep slope along a surface on which little or no shear displacement take place. As public facility, road has a high vulnerability to landslide. There are no reliable methods for calculating the stability of a slope with respect to falls. But, xpert give some advice on adaptation strategies that can be take, by messing or netting the slope and boulder fences, as seen in figure 3 below.

Source : LARAM (Christophe Bonnard, Civ. Eng. EPFL)

Figure 7. 4 Messing (left), rocks blocks (centre) and boulder fence (rights)

Simple prevention option on rockfall are using messing to bind the rocks when it is separated into fracture. Meanwhile, rock blocks that made from metallic material nets, that trusted design to its anchor as a handle of nets, and elongation of nets itself, in catching the fractured rocks before it touch the ground. The last are boulder fences that has the same materials with rocks blocks, but different in construction, it can stand to both of rockfall and debris flow landslide.

- Bridge protection

Considering the space and morfology of bridge construction, the most compatible adaptation works are using anchoring piles, by installing passive or active anchors (bolts or bars set in tension as a consequence of the movements), prestressed anchors, with single or repeated tensioning (in order to compensate the tension losses). The piles or micropiles working in compression may be assimilated to this technique. They can be combined with anchors to avoid the displacement of their head. The piles join two fracture part of the or rocks by anchoring it to the competent sides.

7.4.4 Adaptation for plantation area

Slope modification and drainage are combination type works to most of farming area, the landuse are usually sloping with some vegetation or even bare. The plant is a vulnerability as it is a kind of comodity to protect or prevent from landslide risk. Slope modification by cut and fill are usually used for deep seated landslide. However, the success of slope modification works in landslide stability not depend on size and shape only of cut and fill, but position of cut and fill on the slope also, we need detailed knowledge on geotechnical and landslide translational orientation to determined the geometry and unstable area. This works combined by drainage in sloping area for this purpose, to lower the ground water level in the landslide mass, to reduce the pressure at the level of the slip surface and reducing the flow affecting the landslide mass.

7.4.4.1 Adaptation for open space field

Adaptation strategy for this landuse is a combination between forestation and drainage, as the landusegive so many space for landslide adaptation works, forestation are best-implemented in this landuse area. By using vegetation in that area, some beneficial for slope stabilization are increased in limits infiltration, this is one of efforts to avoid ground water table recharge and soil strength decrease, due to infiltrate of water. Shear strength of soil-root system role in stabilization, but the roots have a limited stabilizing effect to a few meters depth, if the slide is deeper the forest can bear important movements and even survive. The mechanical effect of vegetation planting is not significant for deeper seated landslides, while the hydrological effect is beneficial for both shallow and deep landslides.

In many cases in which the ground water conditions depend on direct infiltration, the interception of surface run-off as well as sub-surface flow may be useful to reduce the ground water level. There are some type of drainage surface drains and ditches shallow or deep trenches, drainage galleries or tunnel, to choose the best type as proper implemented drainage needs more hidrological study based on it water table.

Source : Badan Pengendalian Dampak Lingkungan Propinsi Jawa Timur (2002)

Figure 7. 5 critical land that related to landslide in Greater Malang

Figure 4 shows critical land in Greater Malang that trigger landslide, forestation are able to implemented to this area. The strategy is designing the geometric configurations of forestation and drainage that determines the distribution of pore water pressure. The drainage system usually analyzed in steady-state condition, which is effected in long term, several time after construction. The analysis is carried out by considering continuously present, at the ground surface, infiltrations that able to recharge the water table.

7.4.4.2 River bank stabilisation

Based on Risk map on september 1990, there are indicated landslide activity along the river, where moderate and high level of risk looks dominate along the river bank, some river at Malang District show high and moderate level, it's also looks at some river bank of Malang City. Moreover, fourty seven (47) landslide historical reported occured at Konto Hulu watershed. Risk map on September 1990, one more time seen in figure 7.4, figure show landslide at some watershed

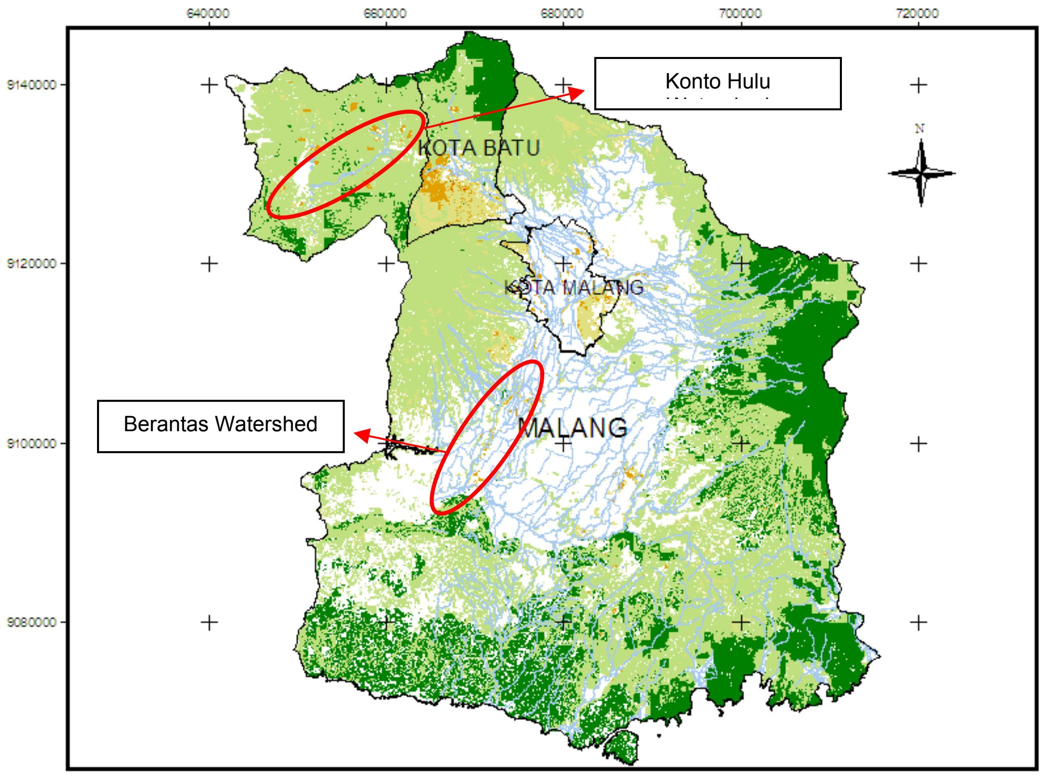


Figure 7. 6 Landslide risk map on september 1990 with landslide indicated at watershed

To prevent the landslide at the river bank, there are needed more detailed study at the site, the scale of landslide, the topography of river bank area that majoring to landslide and etc. Traditionally, riverbanks have been protected using timber or steel piling driven into the riverbed at the bank edge. However, this damages riverbank habitats and can create a very urban feel to an otherwise rural area, and may also encourage boat dry-land agricultureing in inappropriate areas. Many alternative methods of bank protection have been tried, to find new methods which are acceptable visually and in conservation terms. There are some Figure 7.5 below, show an low cost alternative using local sourced natural material and more conservative to the environment in protecting bank habitat.

Source : parsonshurdles.co.uk

Source : Terra Erosion Control Ltd., Nelson, British Columbia, Canada, everesterosioncontrol.com

Figure 7. 7. Left : Local sourced-material fence, right : Riprap vegetation

Stabilizations works above is a elements interaction between vegetation and man-made structural, that integrated working in preventing slide. This concept of slope stabilizations is generally cost effective as compared to hard structural elements. Beside, it is more compatible to the environmental, as it allows the use of local material. The fences bind the compaction of soil, while the riprap vegetation and structural elements, give double beneficial as keeps the stability by roots anchor to the soil and give hydrological effect that caused to slope stabilizations.

7.4.5 Landslide inventory for district scale

Table below shows landslide inventory and adaptation options to be implemented on every district of landslide areas. The adaptation based on Greater Malang strategy above, to implemented into the district that vulnerable by landslide risk.

Table 7. 11 landslide inventory and adaptation options

Adaptation Option	Districts	
Riverbank Protection	Kasembon Ngantang Pujon Pakisaji Kepanjen Sumberpucung	
Forestation	Kasembon, Ngantang, Pujon, Bumiaji, Batu, Jabung, Dau, Wagir, Ngajum, wonosari, Donomulyo, Bantur, Pagak, Gedangan, Sumbermanjing, Dampit Tirtoyudo, Ampel Gading, Poncokusumo, Gondang Legi, Lawang, Singosari, Karang Ploso	
Engineering Works	Kasembon, Pujon, Ngantang, Bumiaji, Batu, Jabung, Kedung Kandang, Buring, Blimbing, Klojen, Sukun, Mulyorejo, Pakisaji, Turen	 

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Appendix

cumulative rainfall departure (CRD) method was used to estimate the net groundwater recharge from rainfall. The data required by the CRD method depends on less uncertain data than other methods are: monthly rainfall records, measurements of groundwater levels, aquifer storativity, abstraction records, and lateral inflow and outflow. The water level series is simulated using a spreadsheet microsoft excel computer program. Simulated water levels are compared with rainfall in figure 1, where dh (crd) refers to water levels calculated by CRD method (Bredenkamp et al. , 1995).

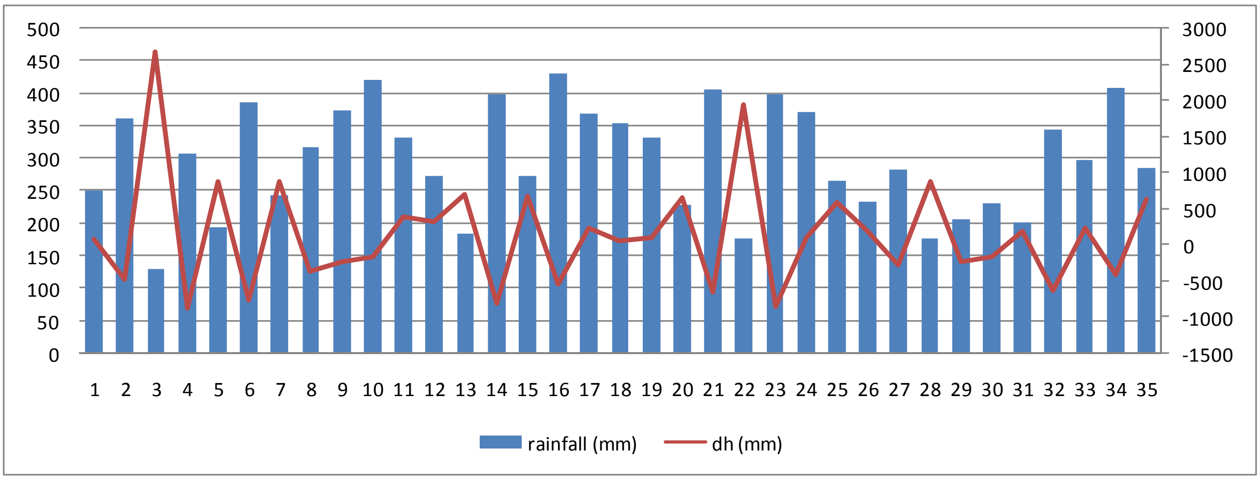

Figure 1. cumulative rainfall departure (CRD) diagram

From the figure above, seen that rainfall on last month will significantly affected to the recharge on next month. The recharge will be higher at dry month as an impact of cumulative rainfall from some rainy months. As seen in figure 1, at 3rd-month the recharge is higher than last month for about 2684mm, due to cumulative rainfall from last rainy months, and at 22th-month the recharge is higher than last month for about 1974mm The fluctuation are varied based on rainfall and geological factor as main components of cumulative rainfall departure (CRD).

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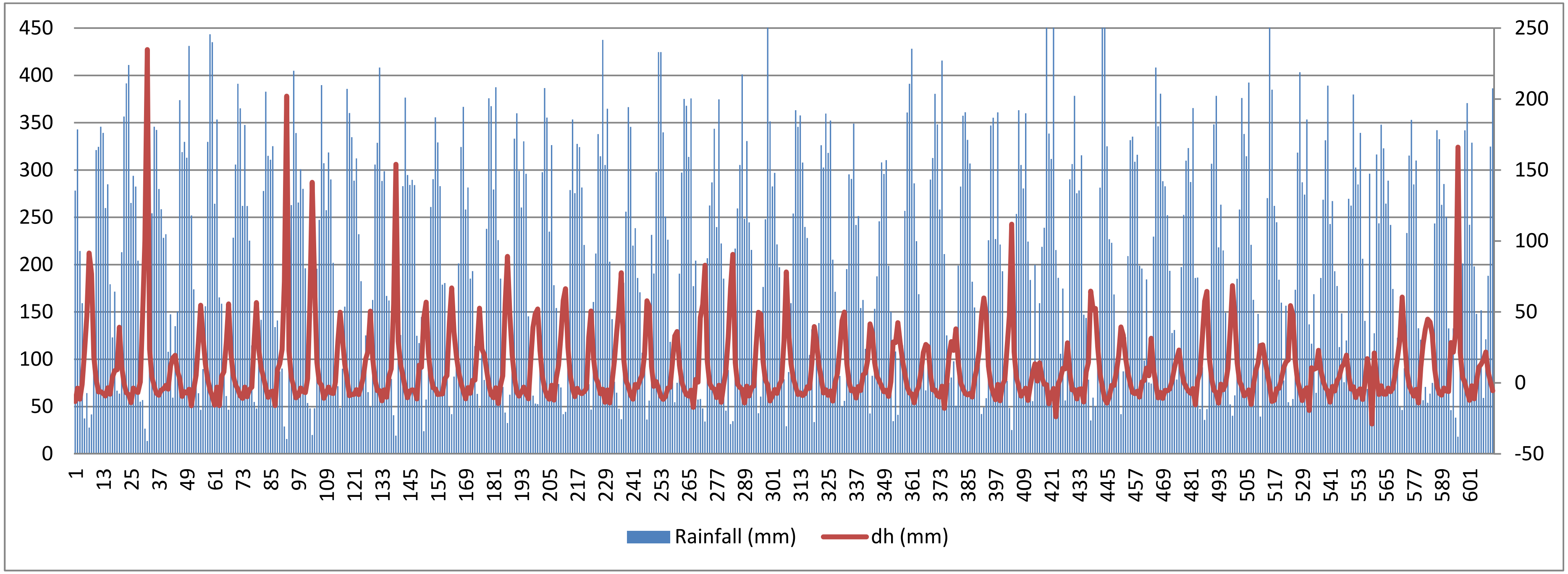
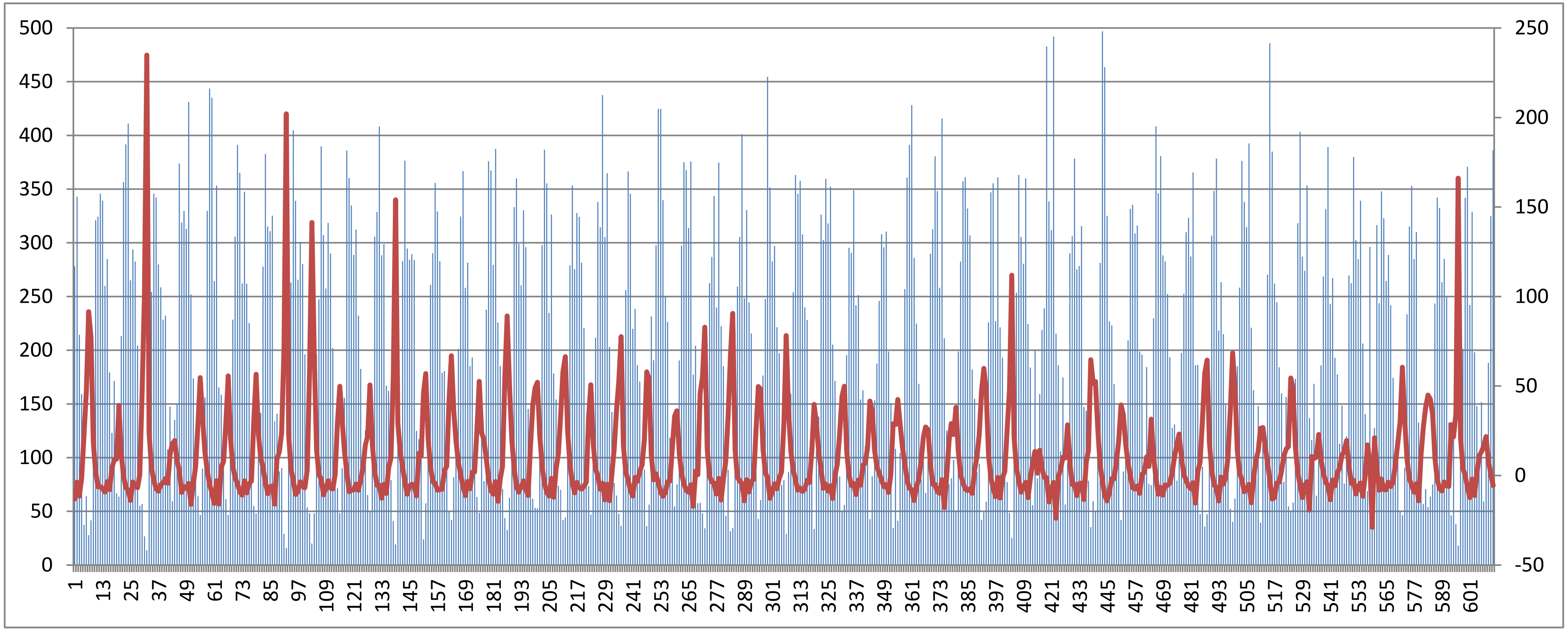
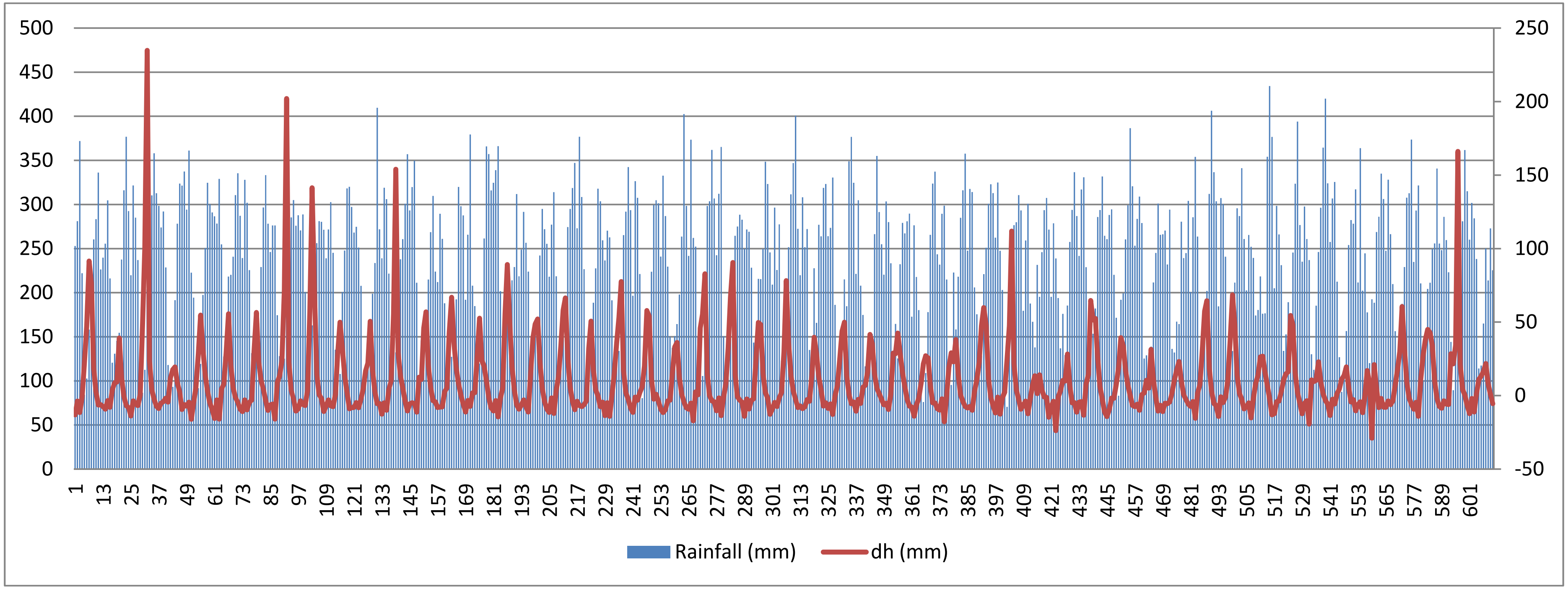


Geology : Endapan lahar



Geology : Batuan gunung api marikeng



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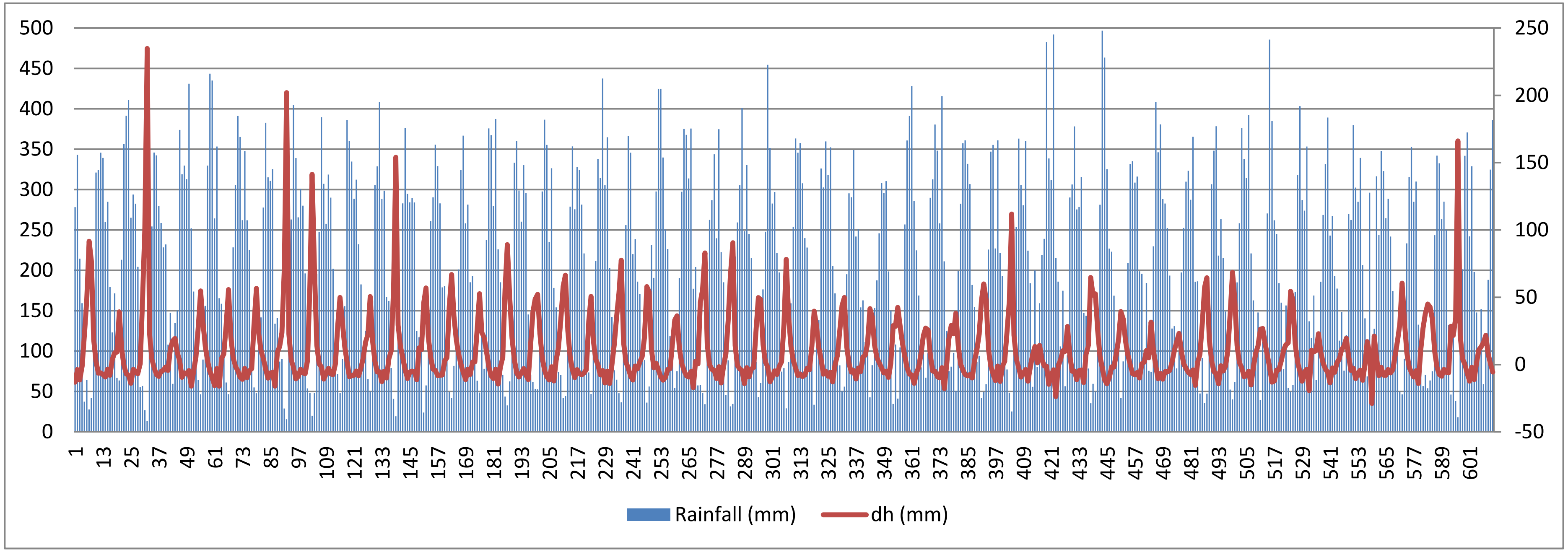

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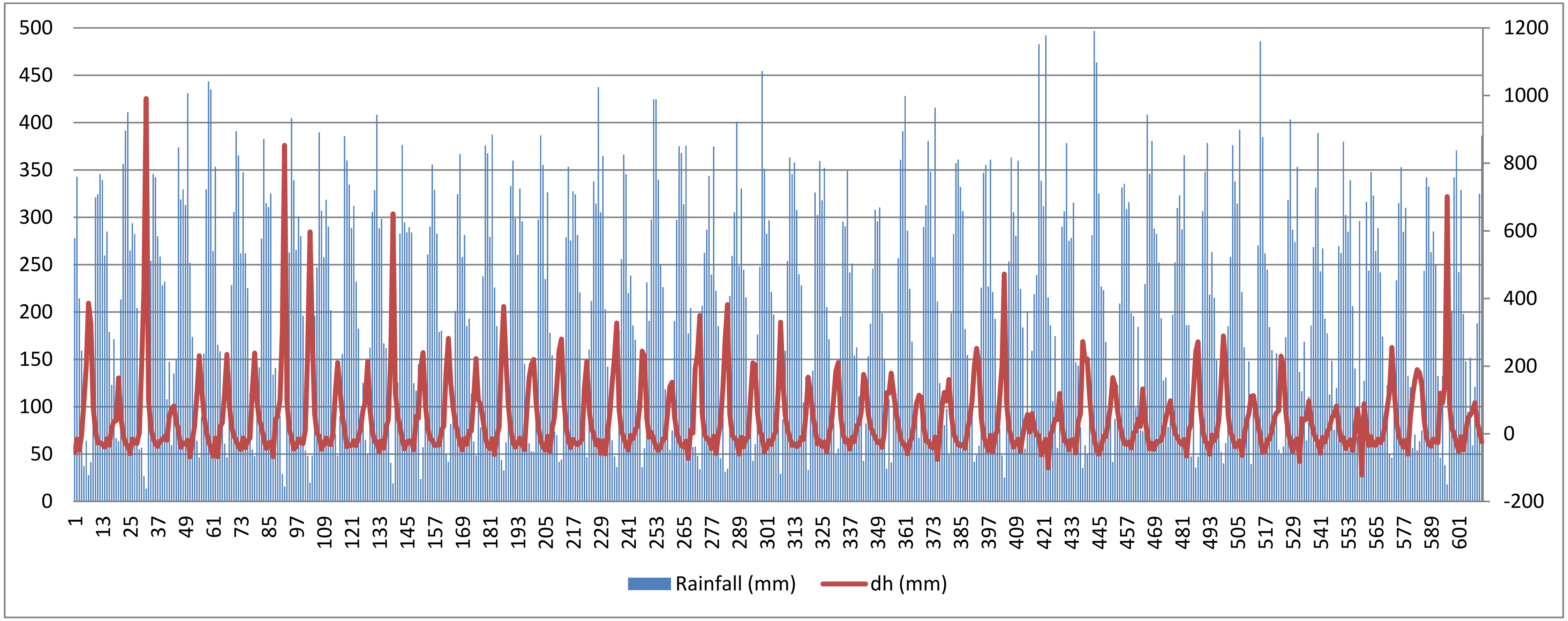

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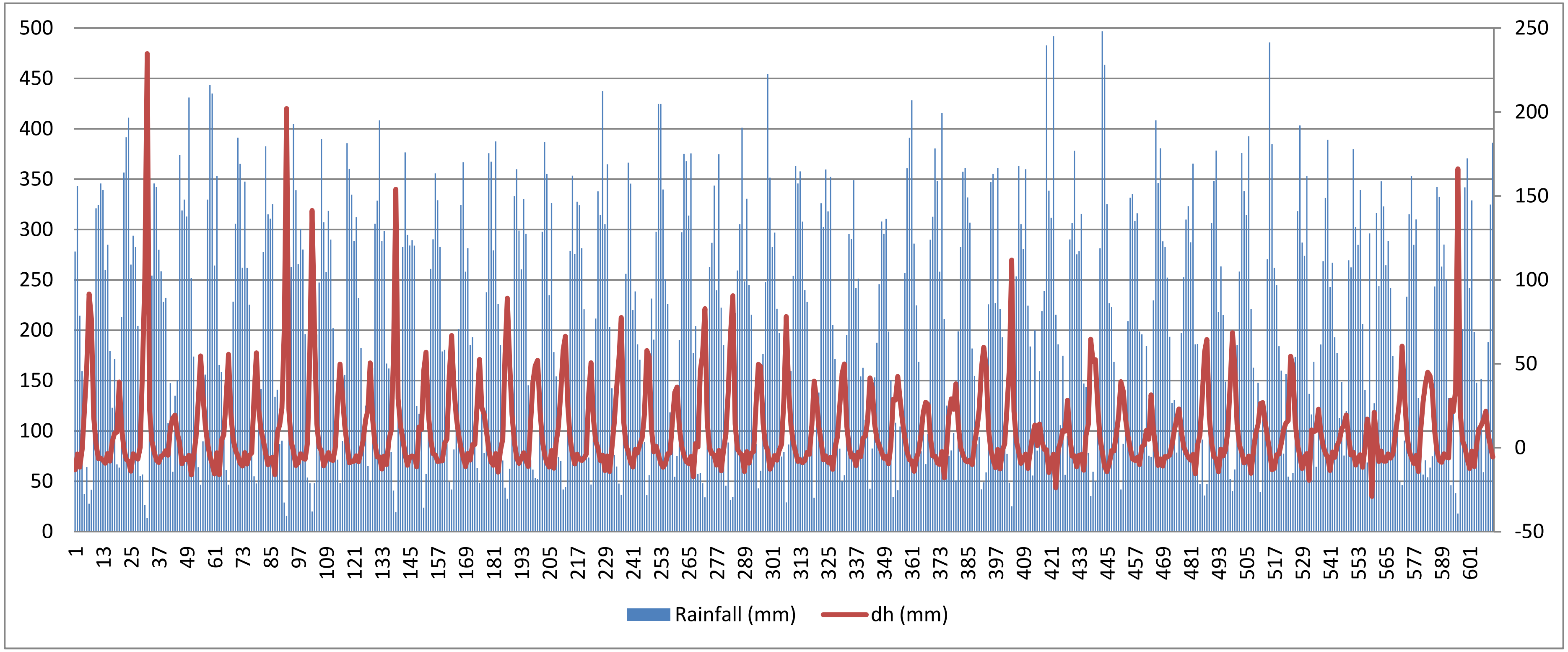

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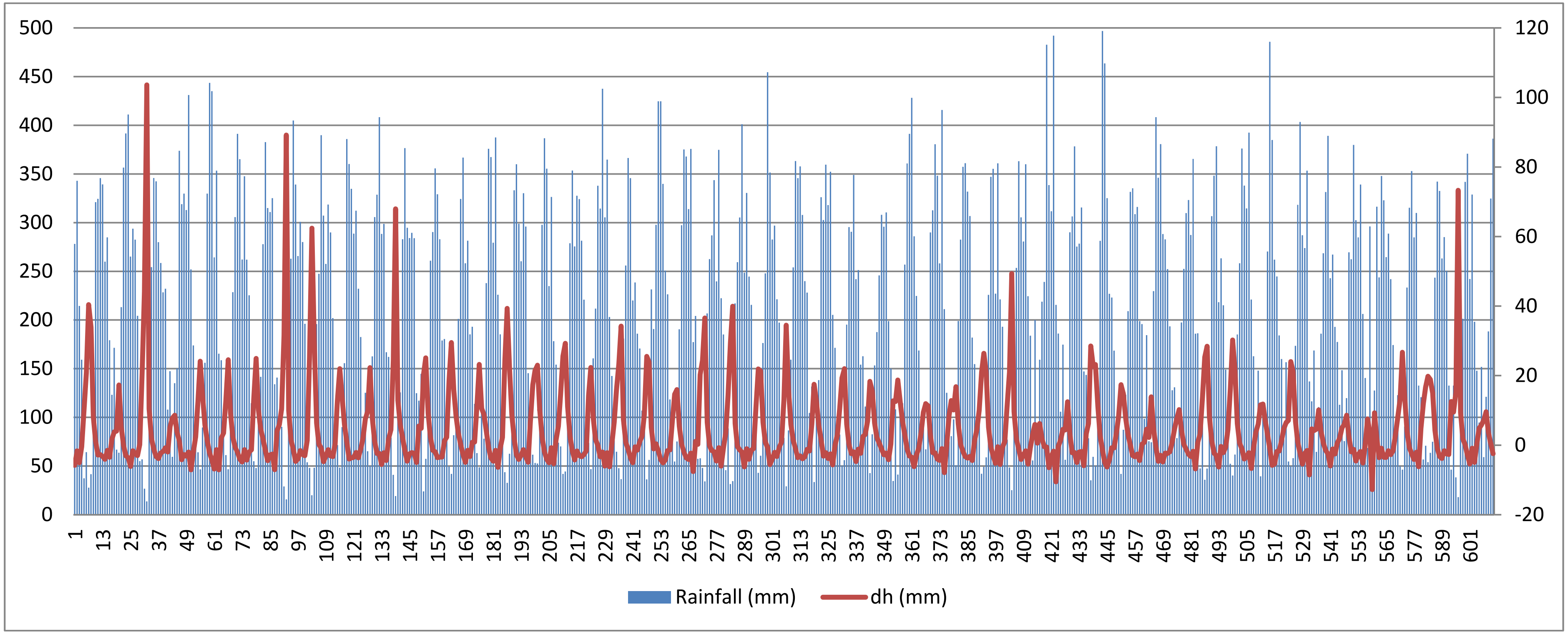

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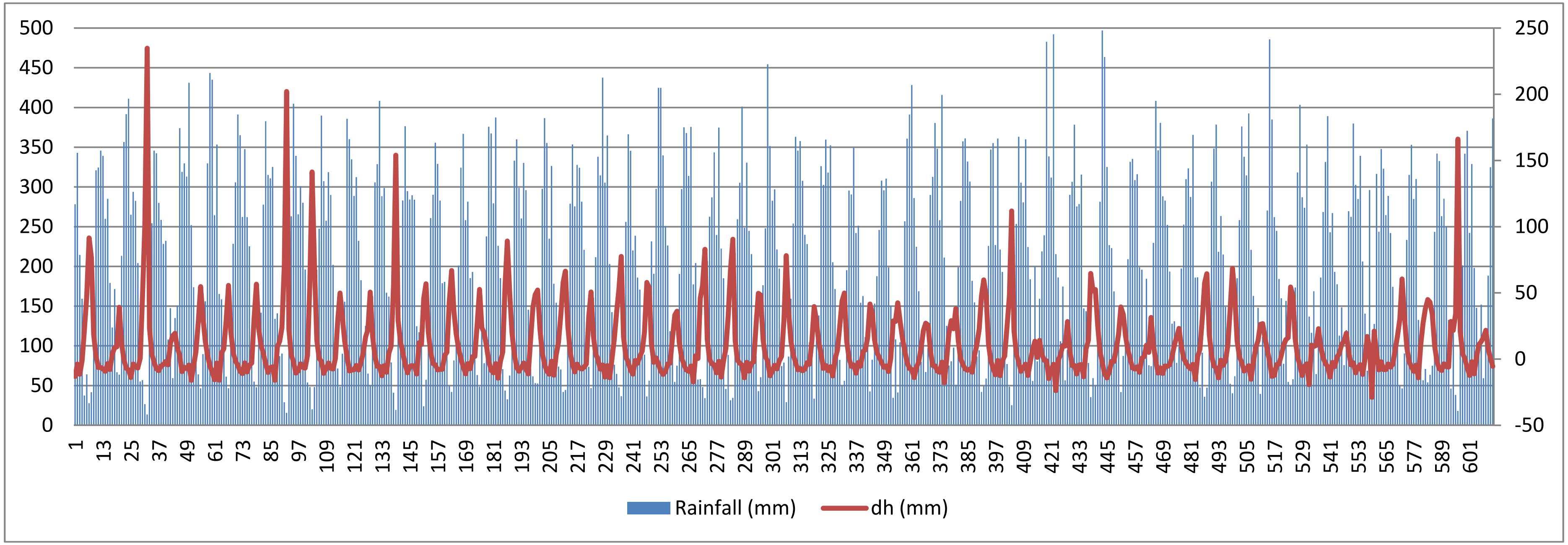

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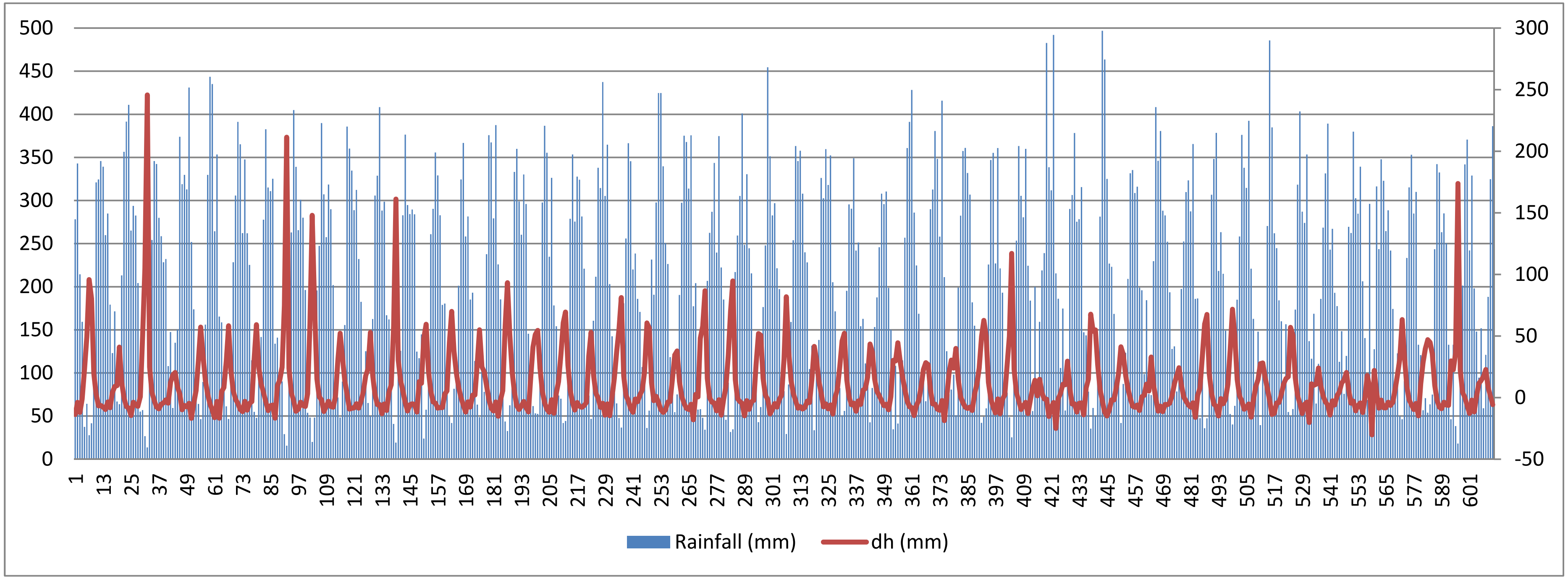

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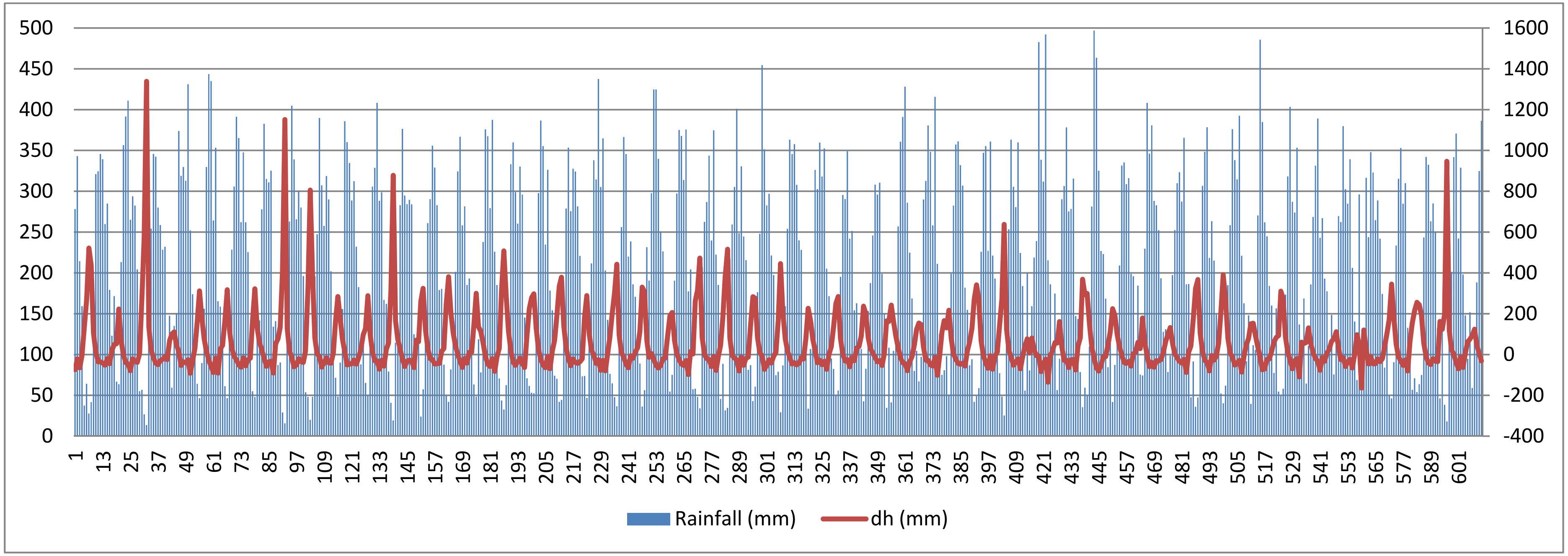

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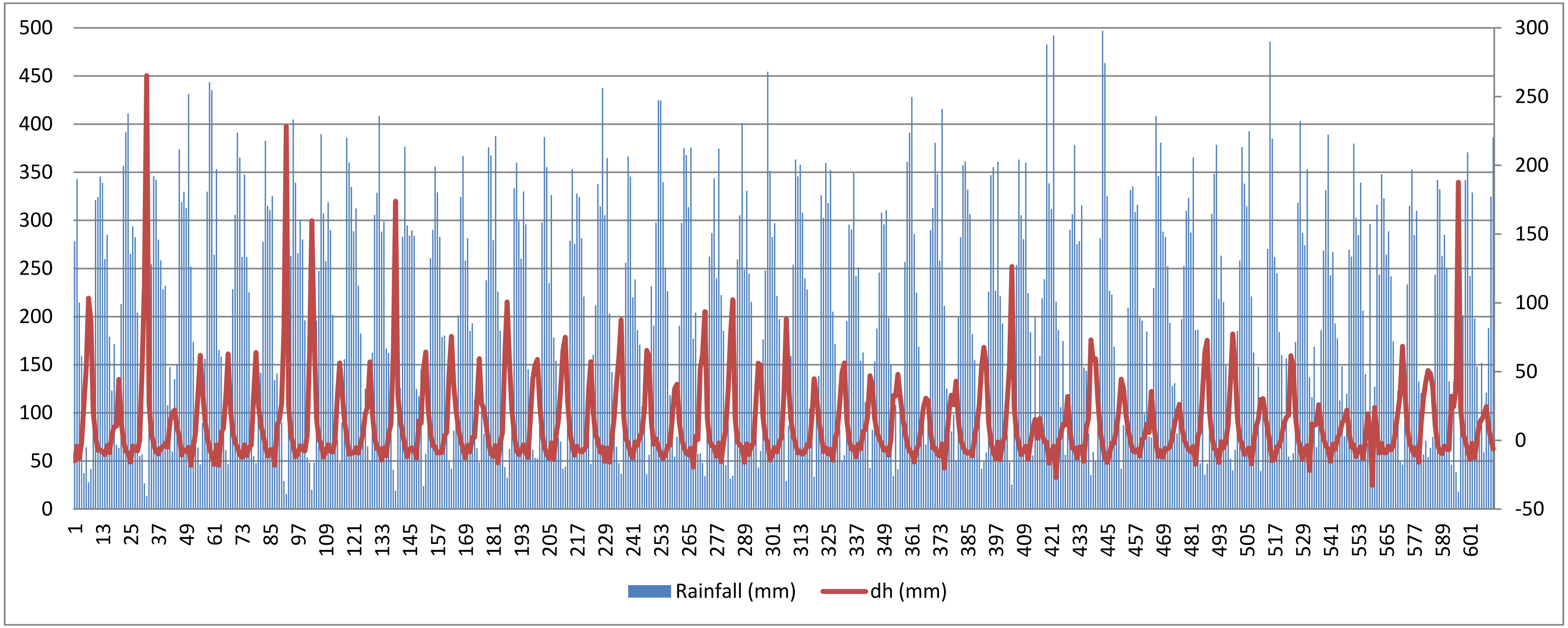

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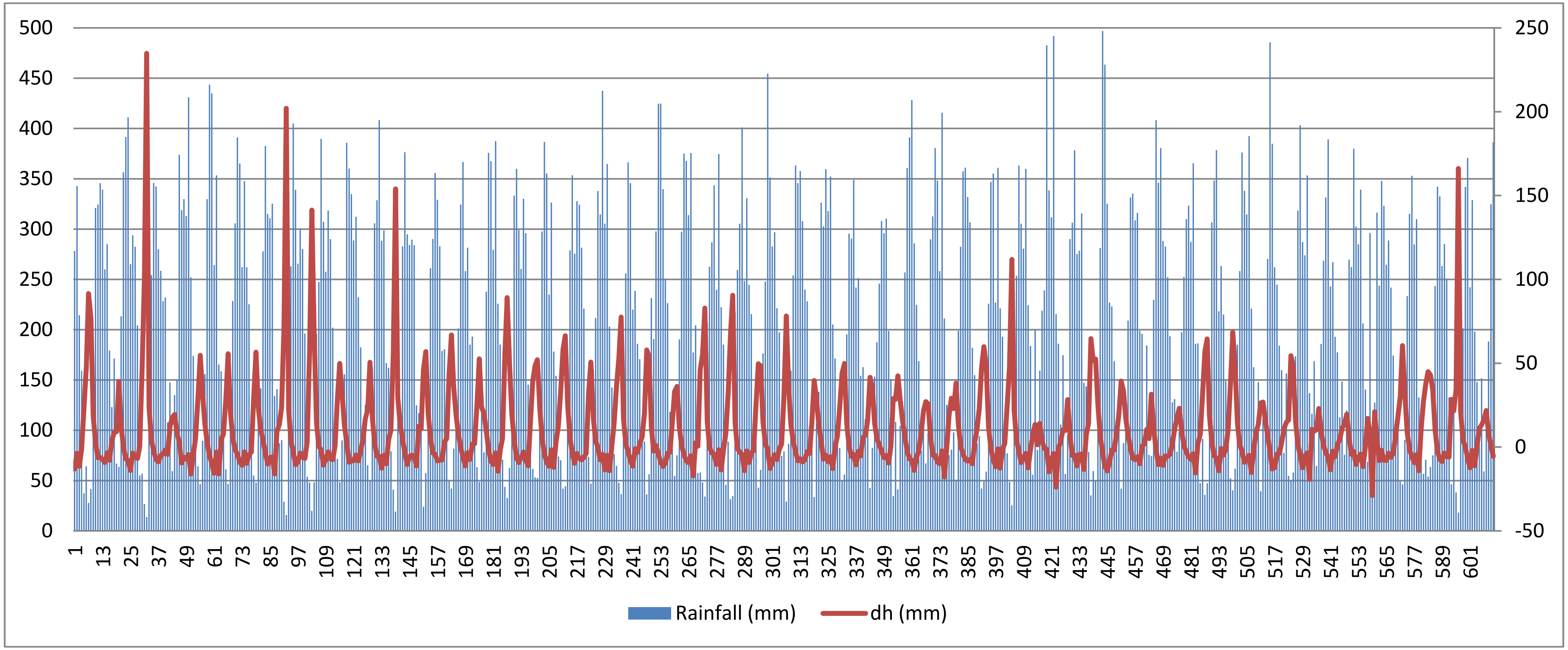

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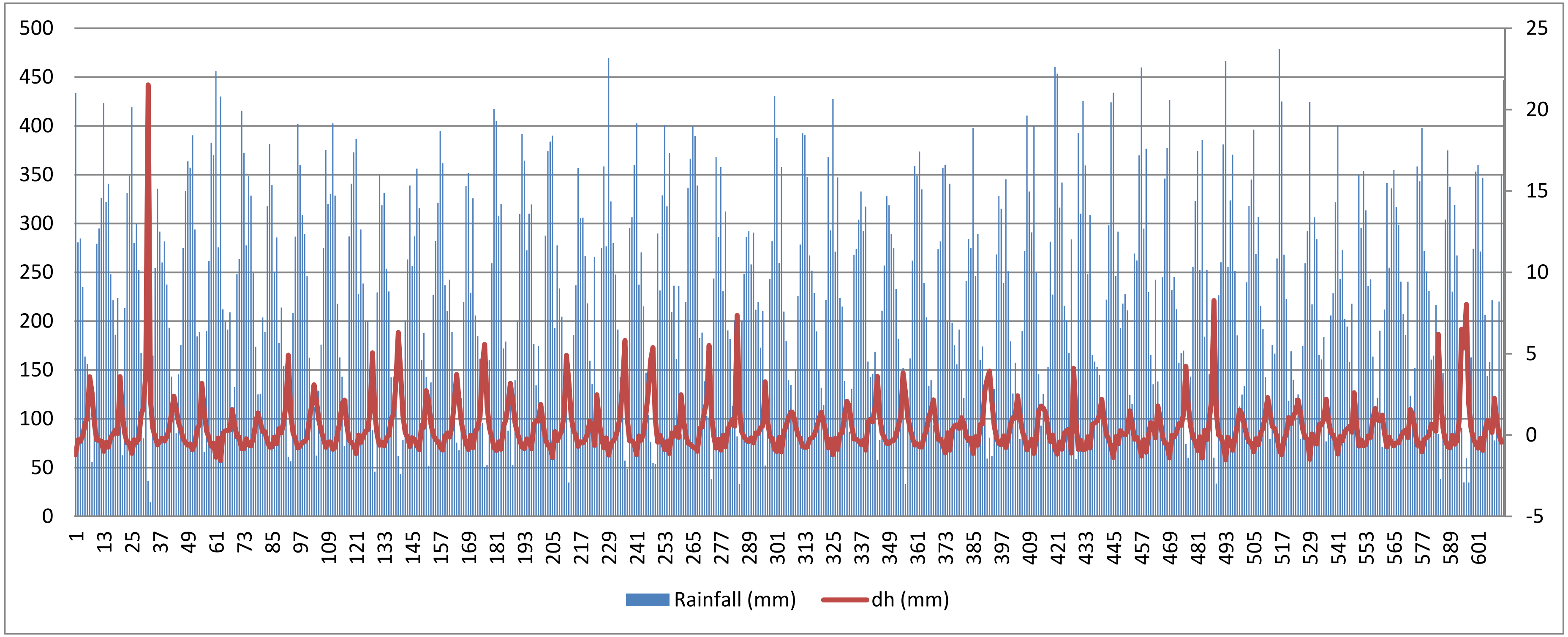

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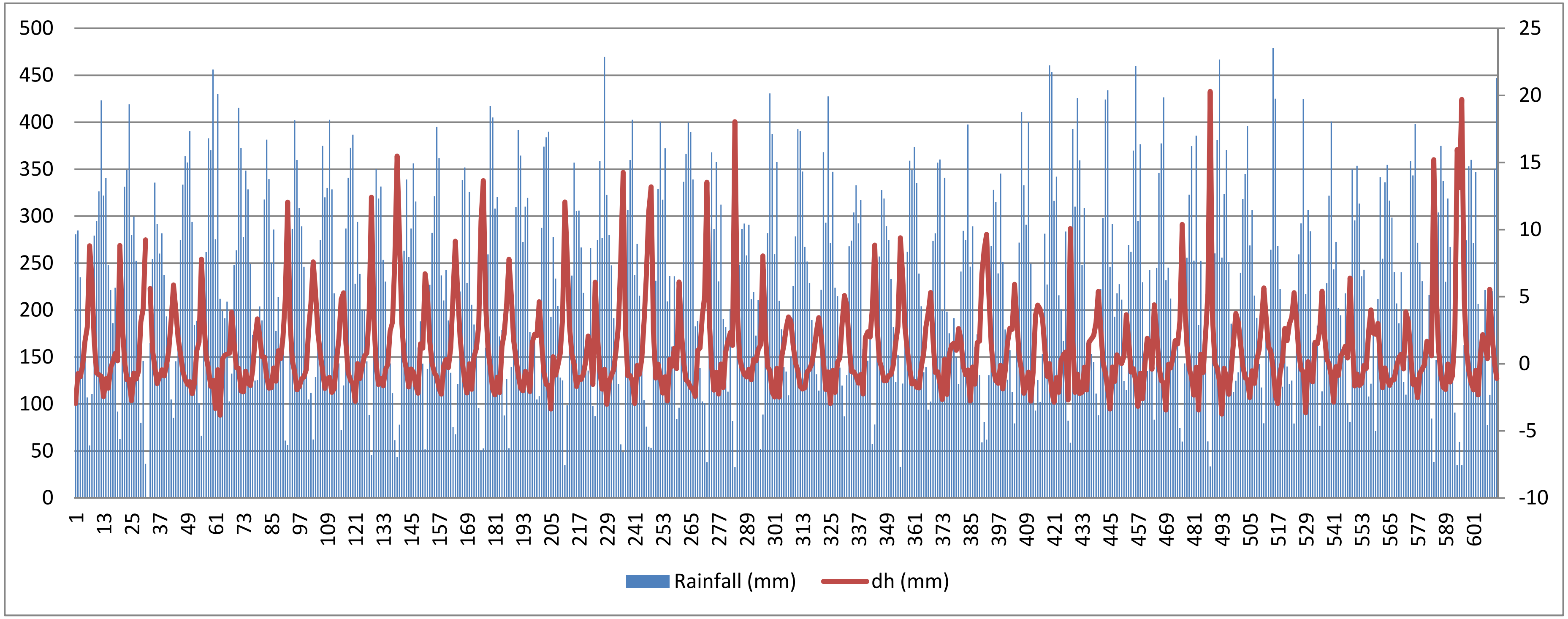

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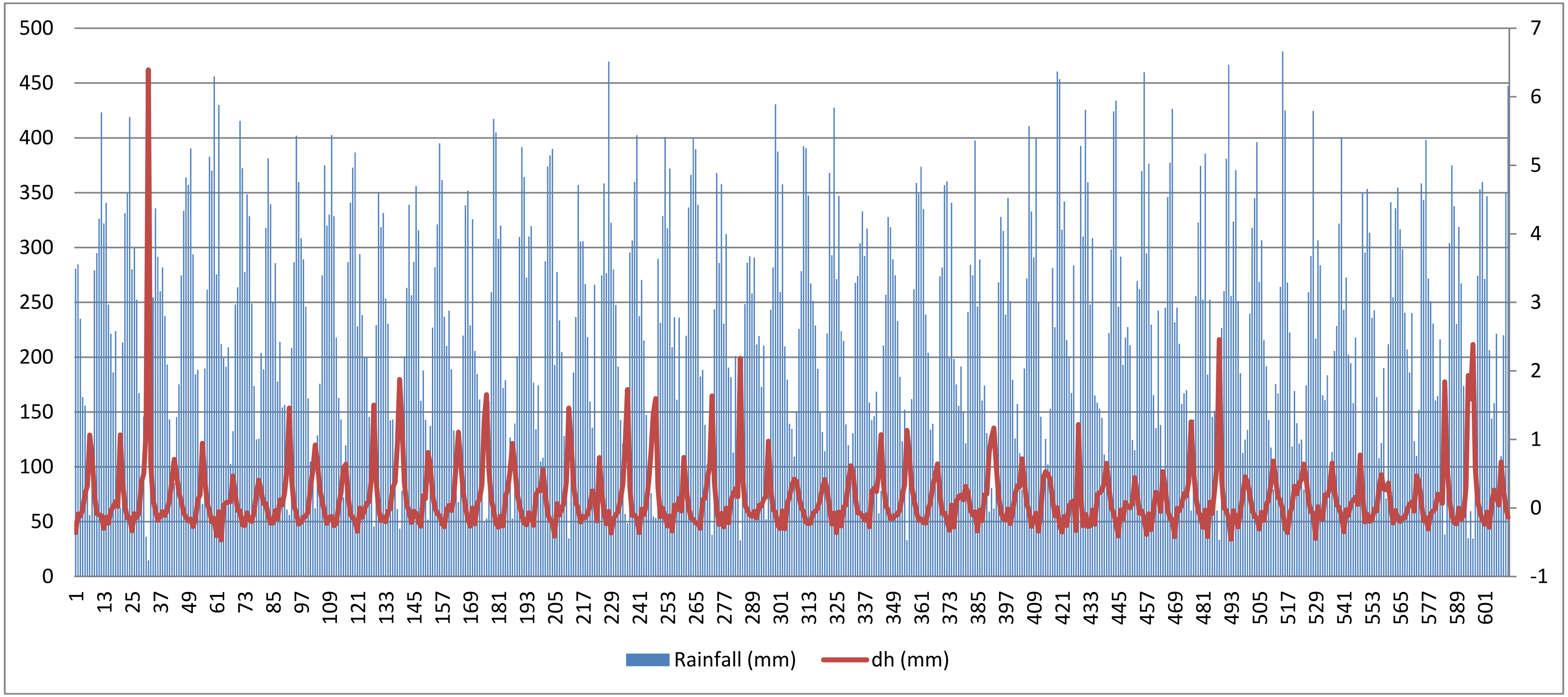

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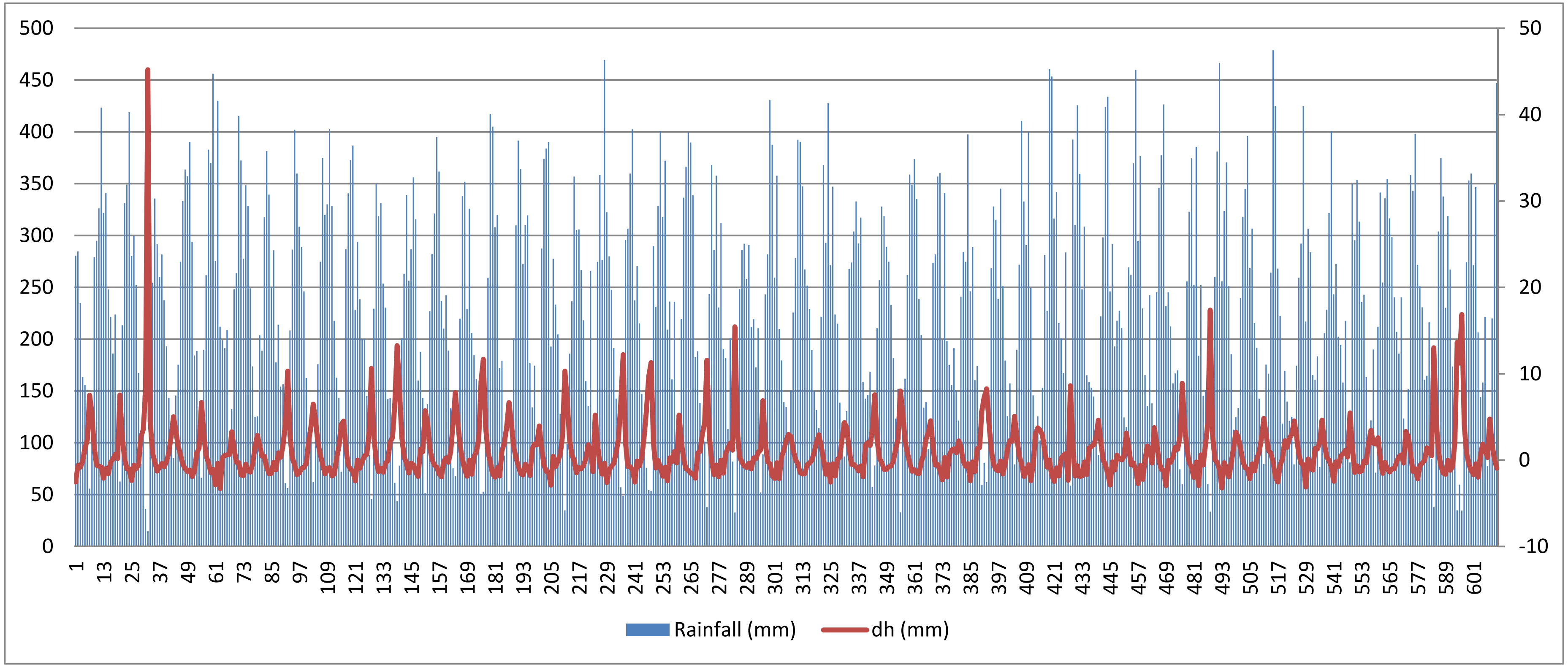

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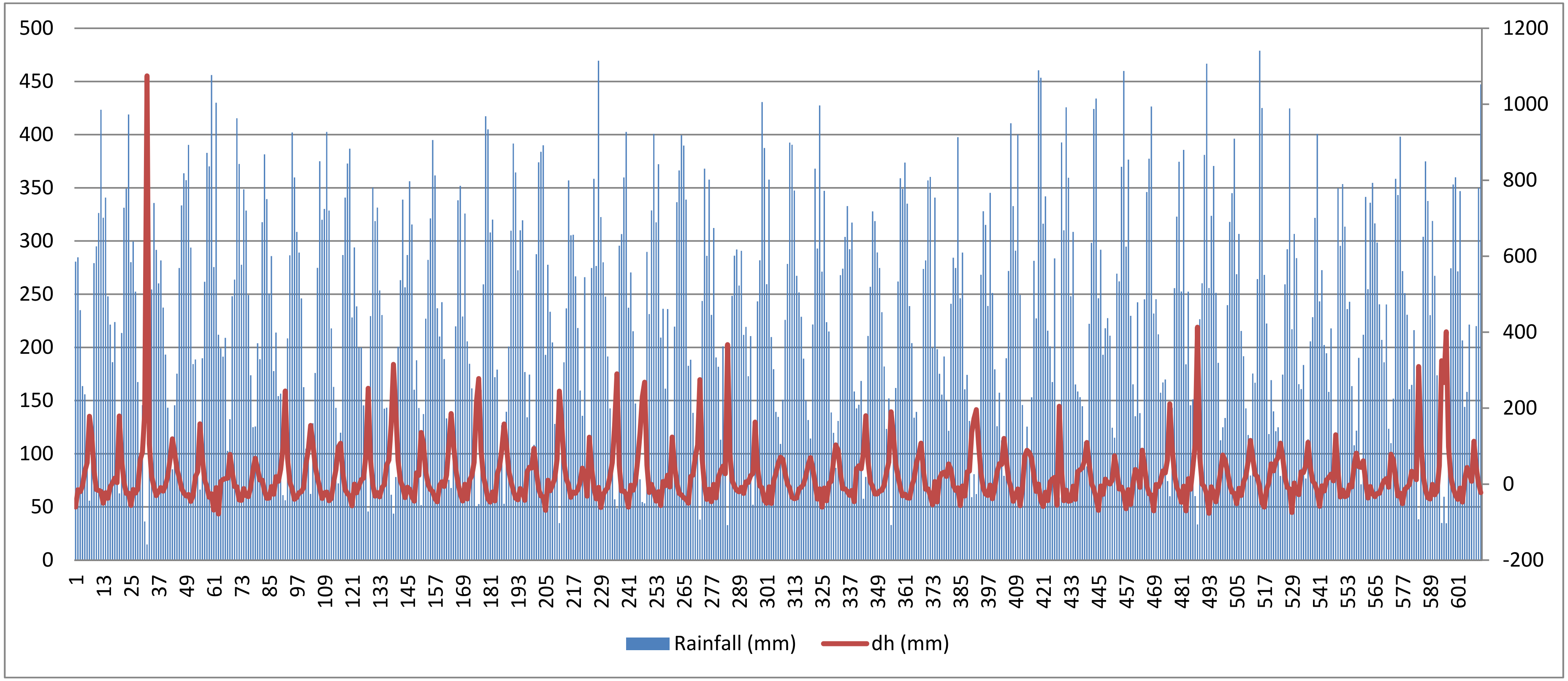

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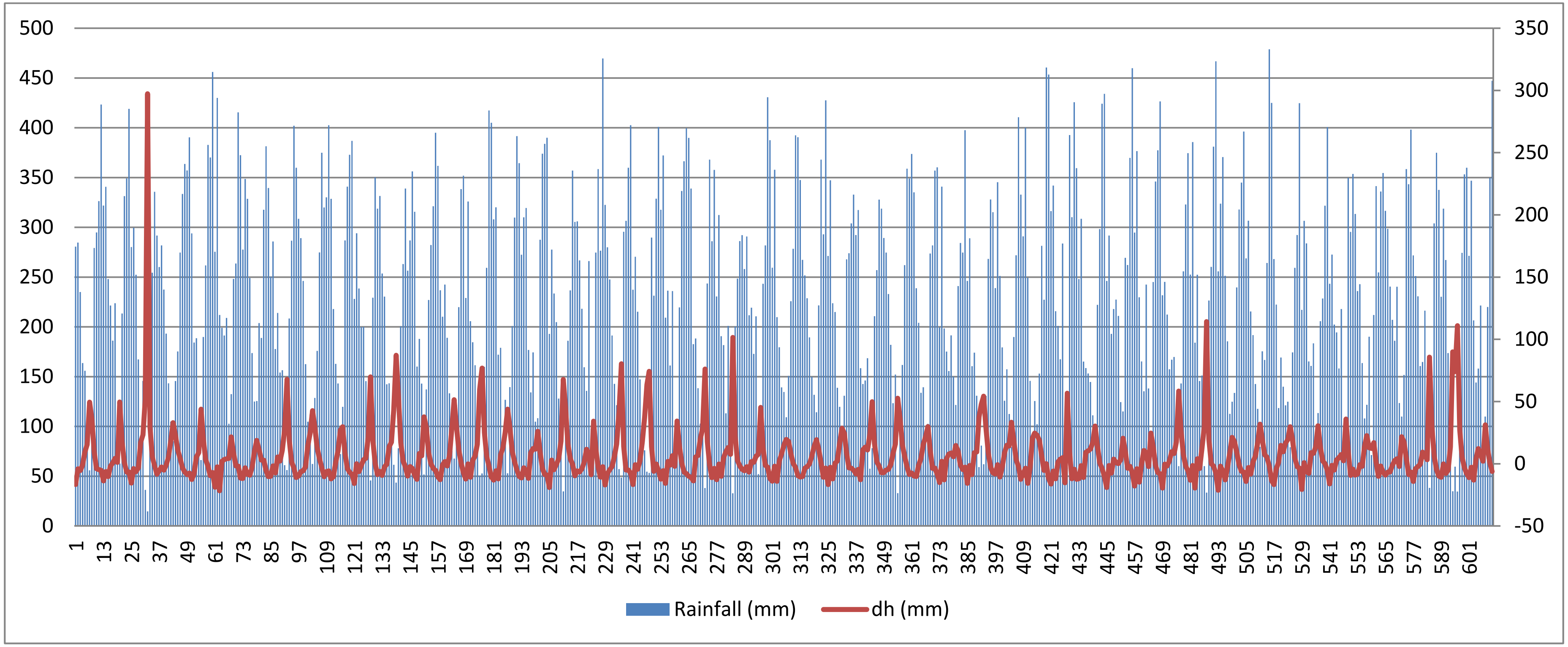
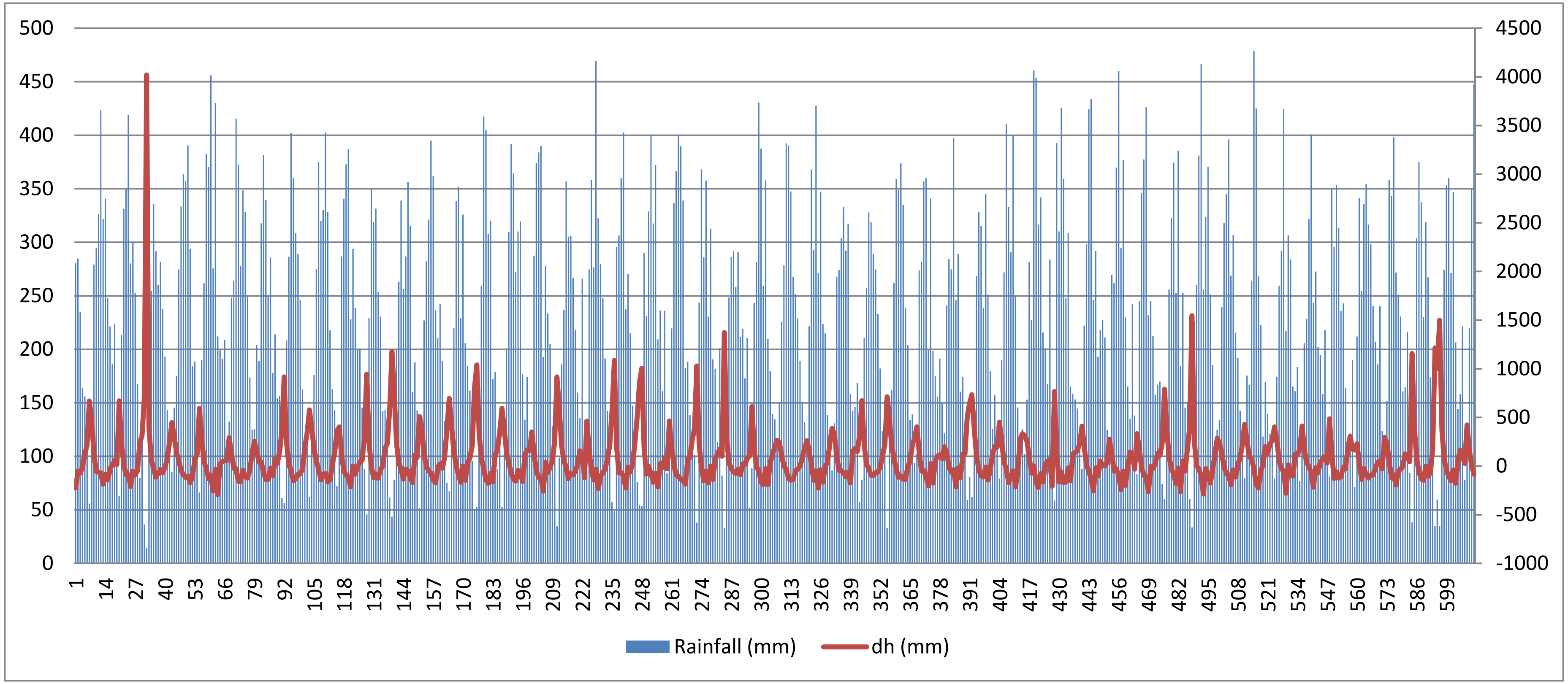


Geology : Swamp and river deposit



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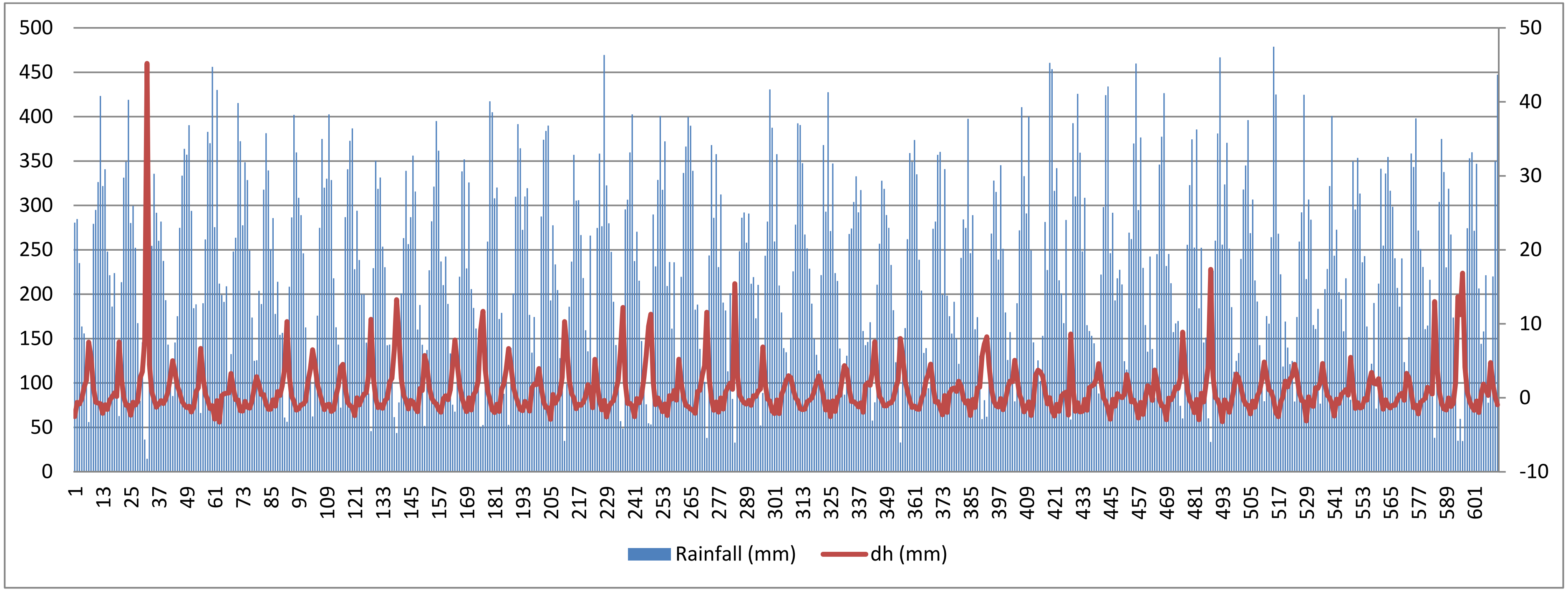

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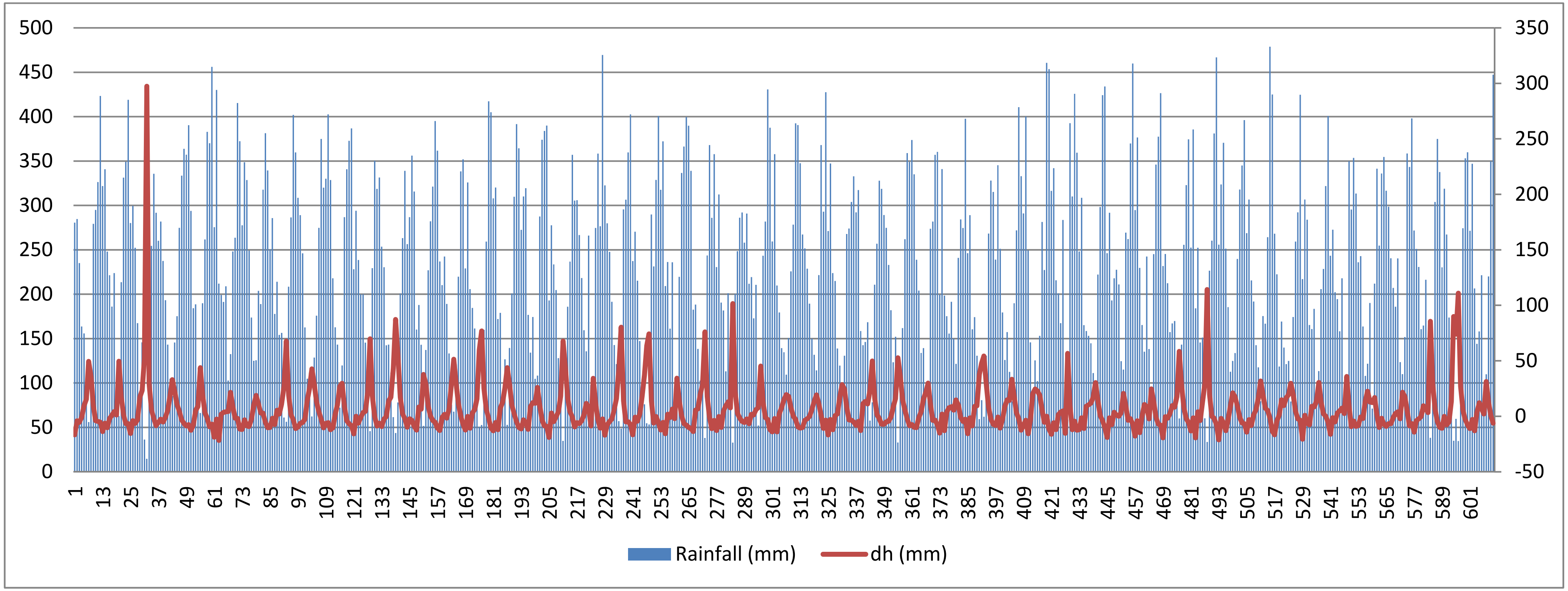

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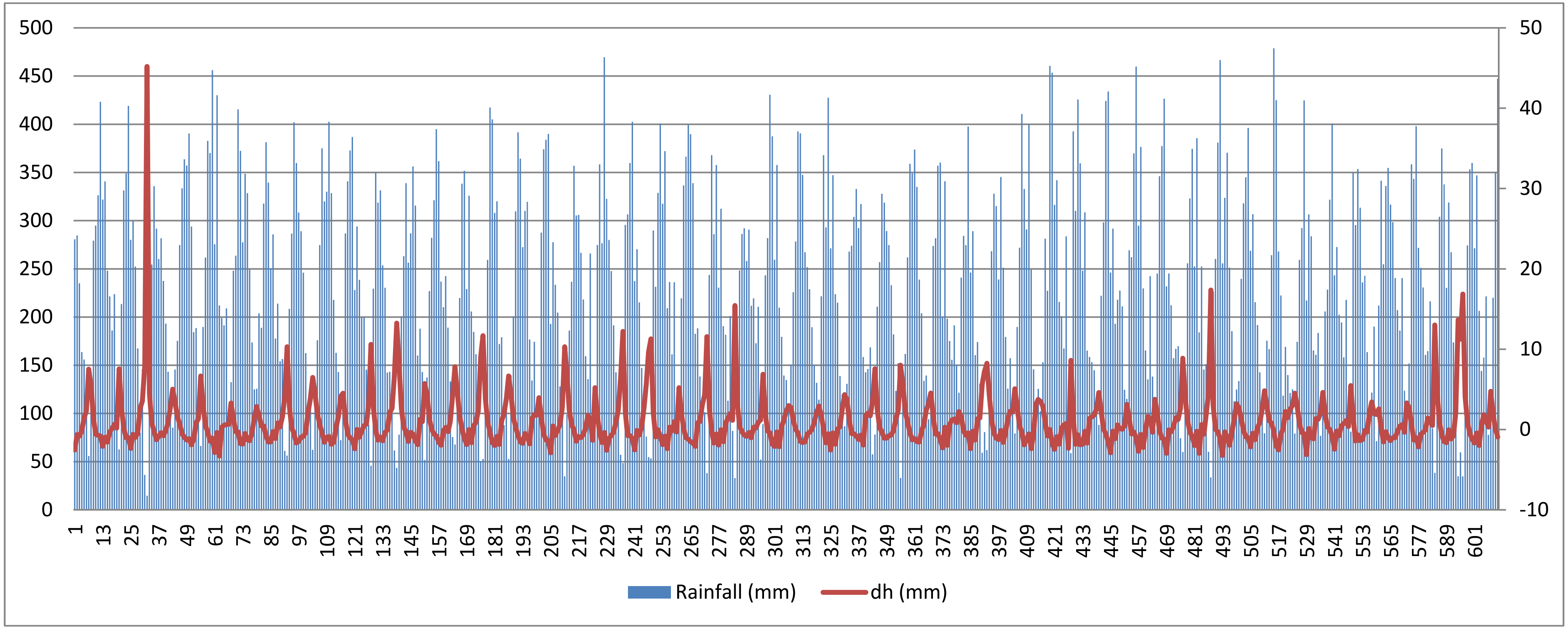
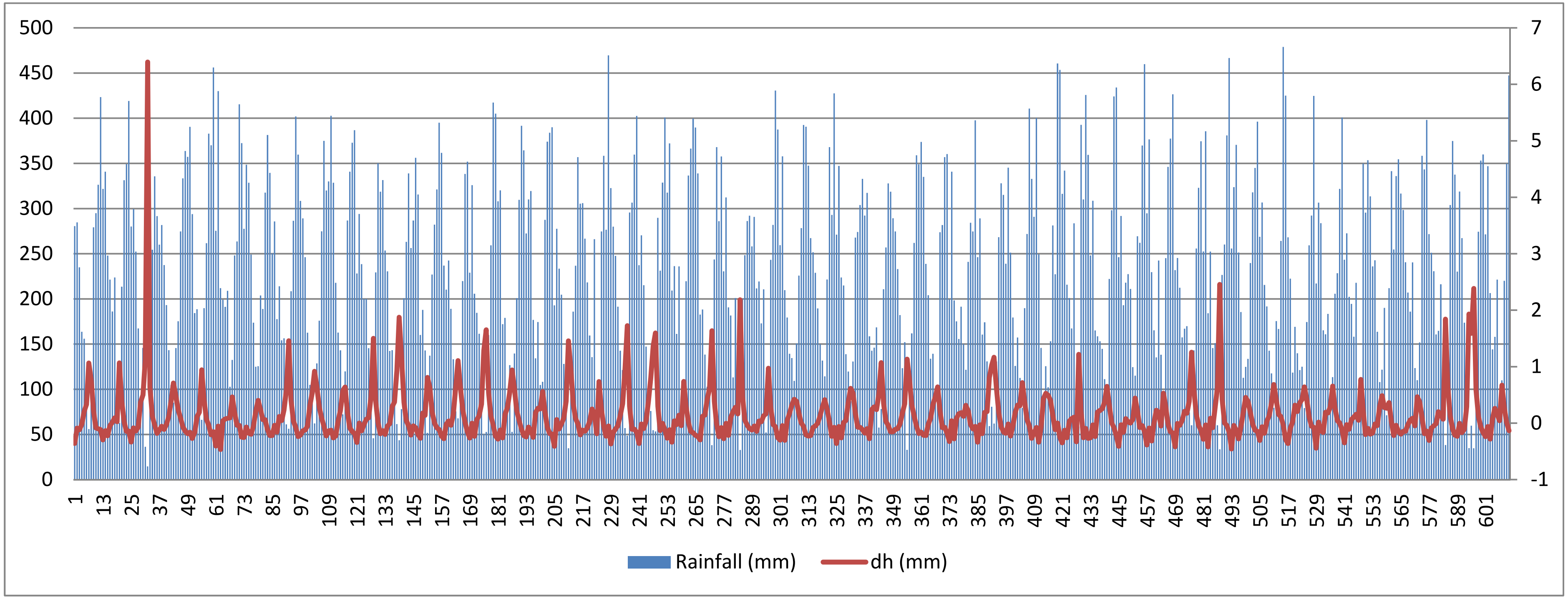
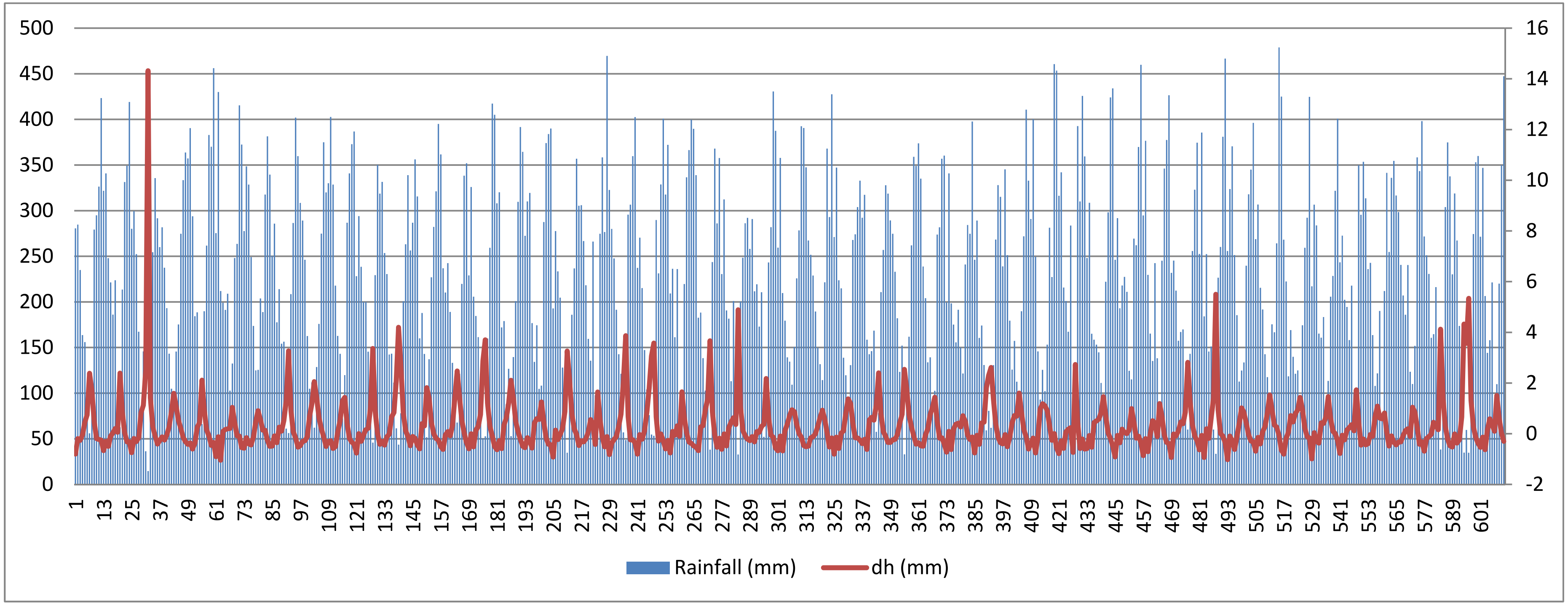


Geology : Batuan gunung api tengger



Geology **: Formasi Jombang**



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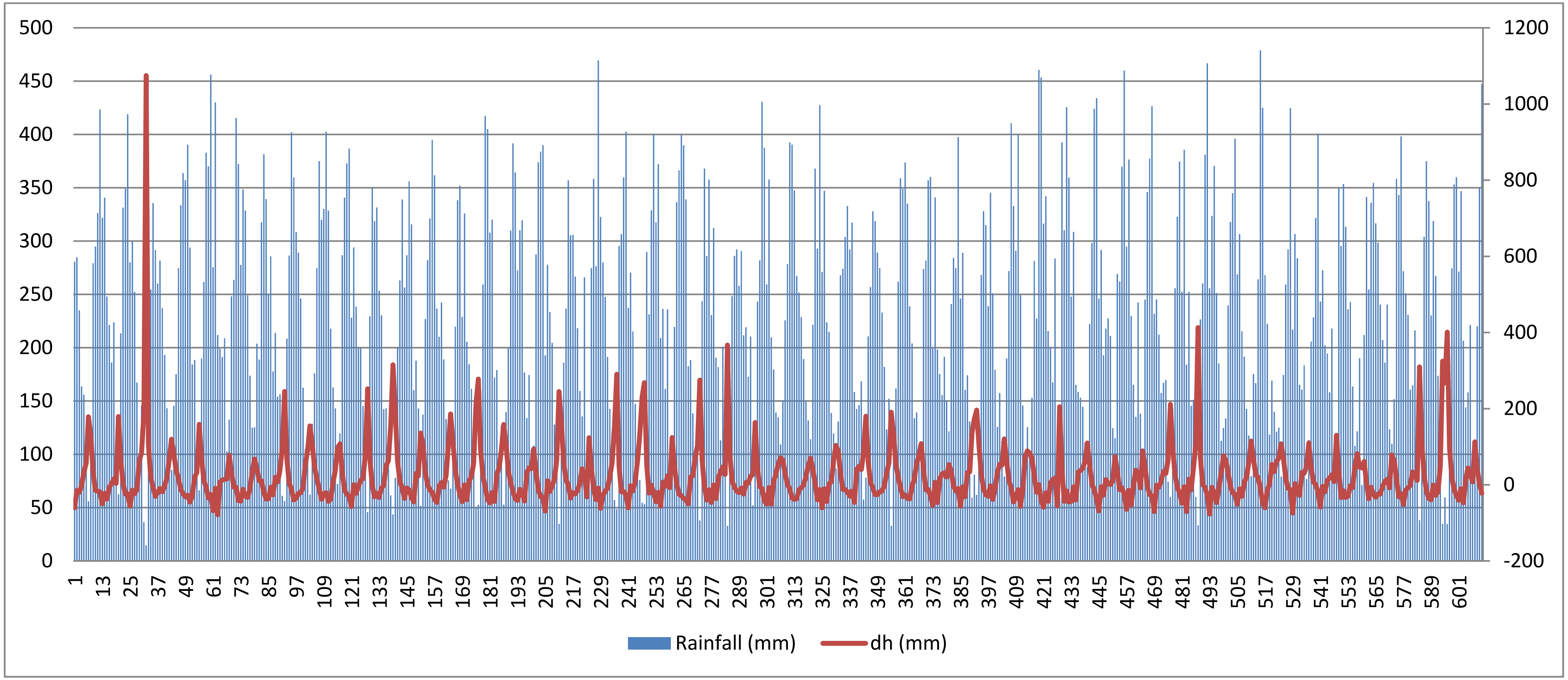
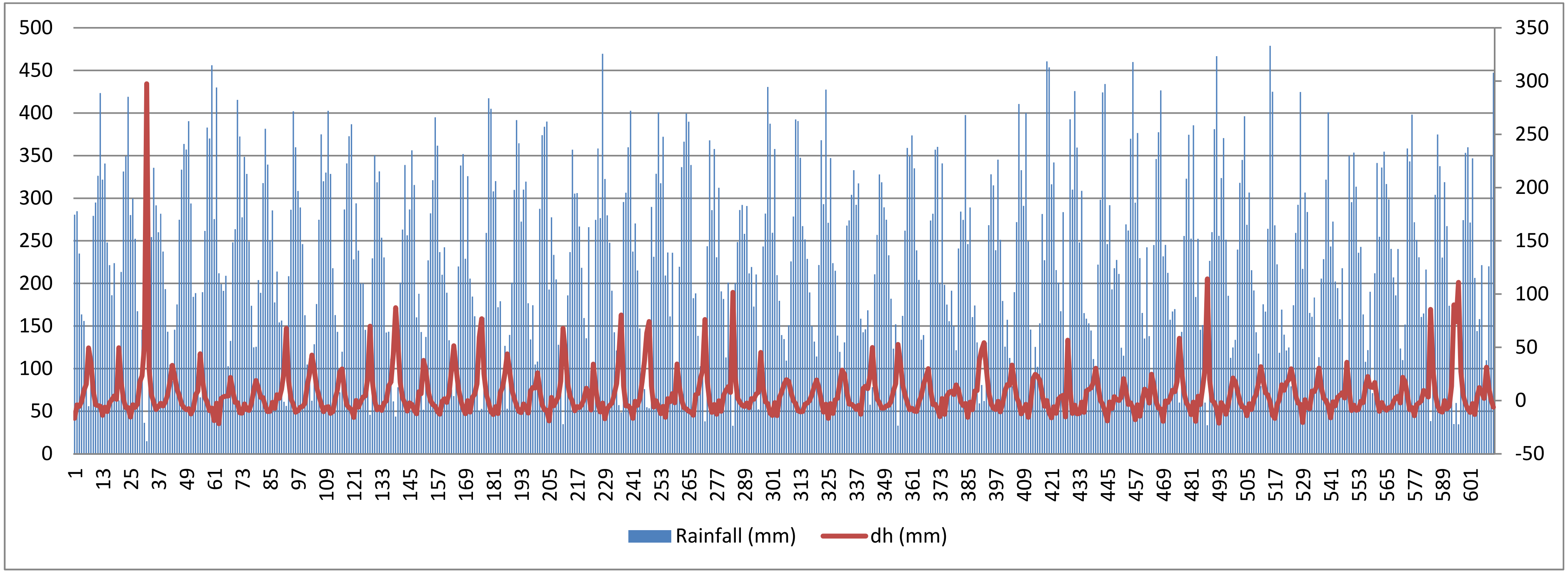
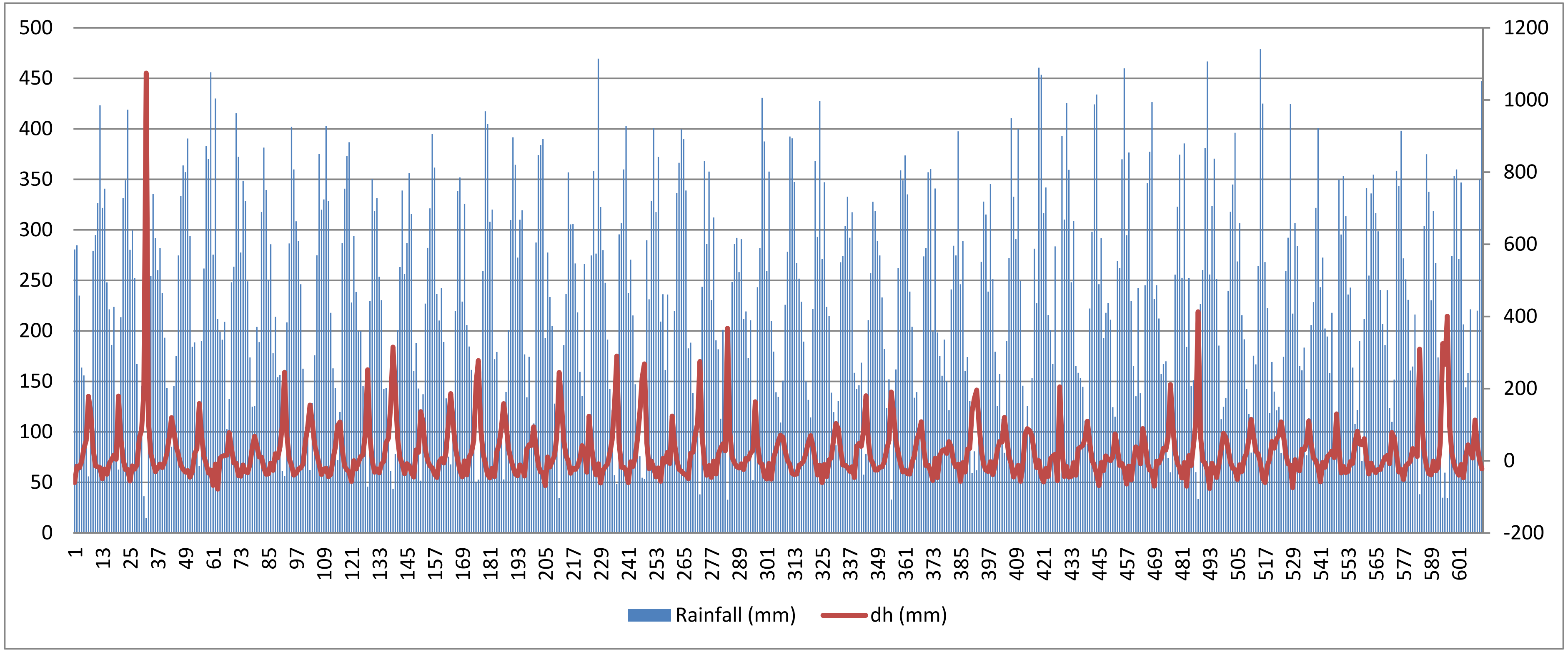


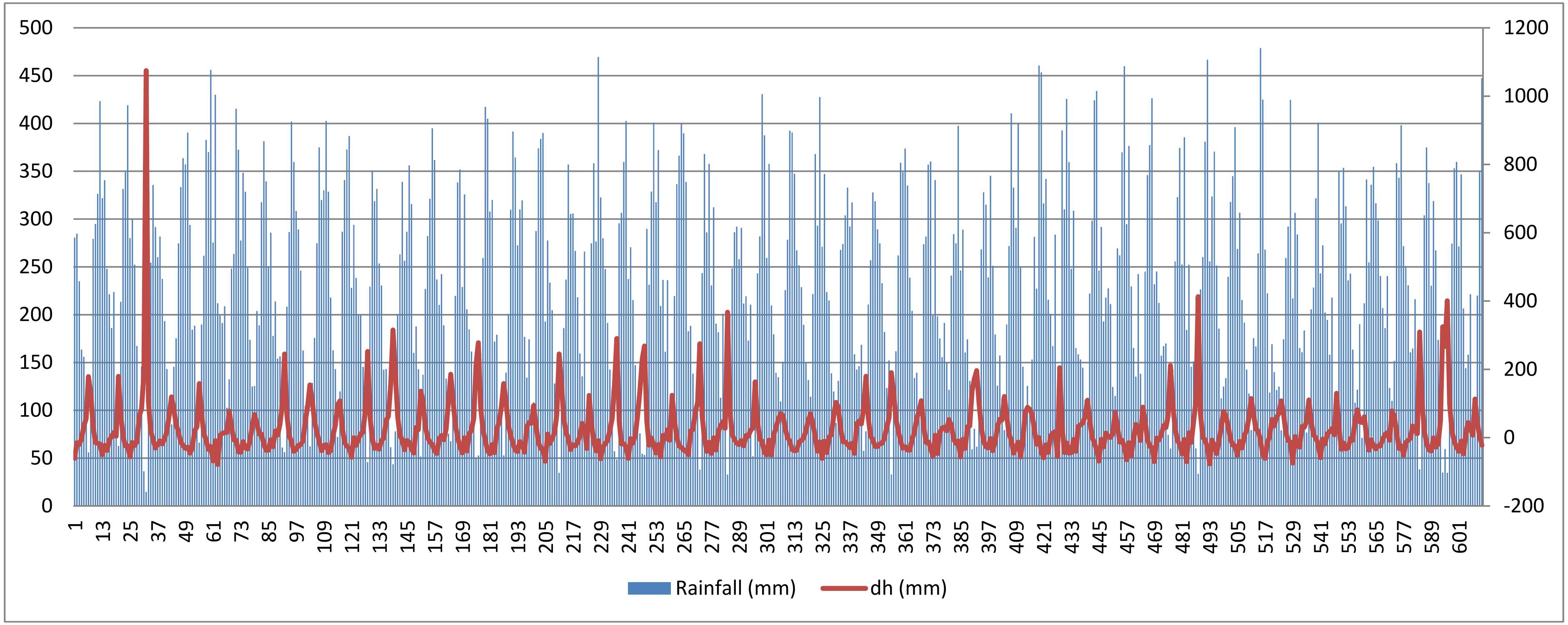
Geology : Aluvial dan endapan koastal



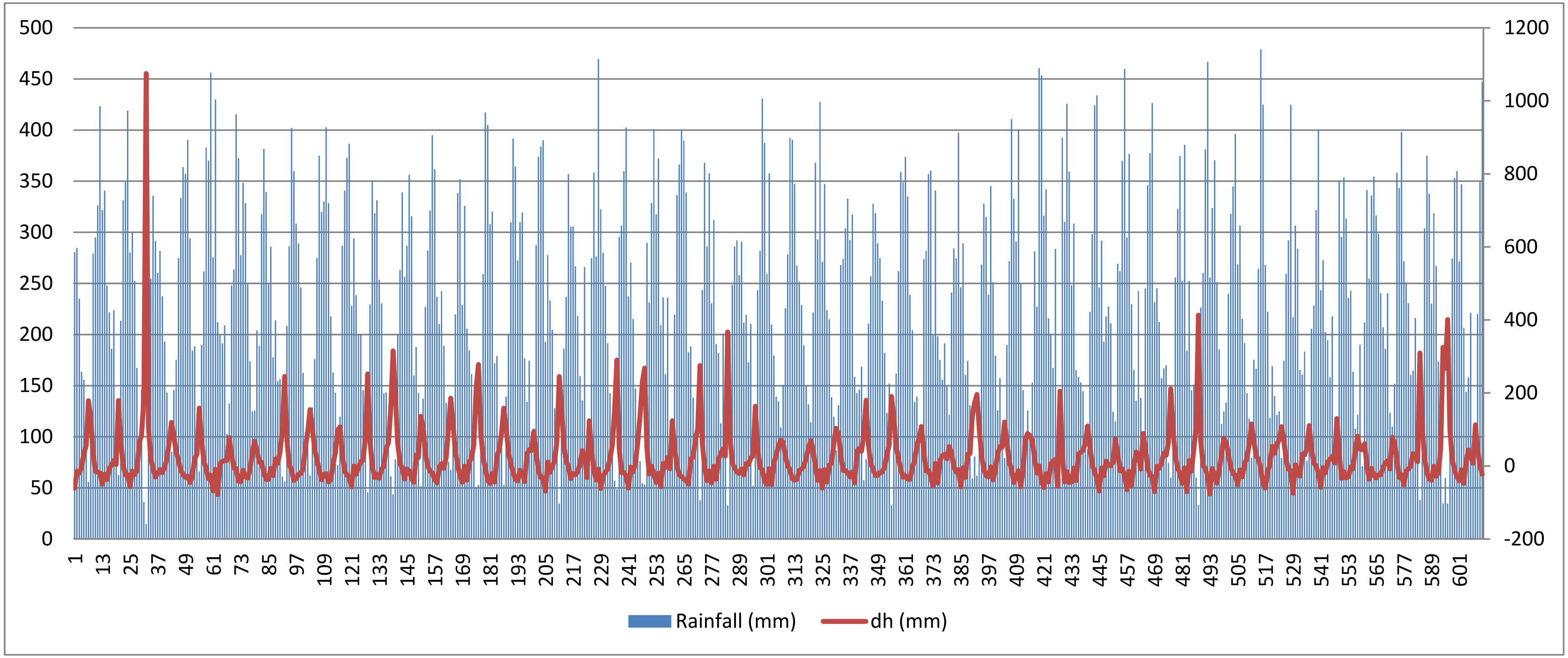
Geology **: Batuan terobosan**



Geology : **Endapan gunung api jembangan**



Geology : Endapan ladu dari rempah gunung api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505
517
529
541
553
565
577
589
601
Rainfall (mm)
dh (mm)