



**WATERSHED CONSERVATION
IN NON-GROUNDWATER BASIN AREA**

Thesis

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ABSTRACT

Water is one of the most important of human needs. Without sufficient water, human life and its activities will have a lot of problems. Therefore, good water management is required in order to provide sufficient water constantly. Hydrological unit for water management is watersheds. In order to maintain water availability in the watershed, it will need watershed conservation. Watershed conservation are the efforts to restore and maintain the existence of water. In general, water storage in a watershed include: surface water, soil moisture and groundwater water. Groundwater is bounded by groundwater basin as a hydrogeological boundary. About 47,8 % of Indonesian region is groundwater basin and the rest as the larger part is non-groundwater basin. In the non-groundwater basin watershed, water is available in the surface and in the thin soil layer, therefore it is very important to maintain water availability on surface water and thin soil layer. The purposes of this study are to reduce soil erosion and to maintain water availability of non-groundwater basin watershed.

Conclusions are given based on the purposes and objectives of the study. Buper Watershed rock layer below the soil layer are mafic and ultramafic layer which is impermeable. Plant can grow according to the thickness of the soil. In savannah area, thin soil layer has a thickness around 3-25 cm, and only in the area where sediments are concentrated, soil layer has a thickness around 40-60 cm. Forest recovery is difficult when the land have been eroded or have been exposed. Exposed surface expansion is occurs go toward upstream because the increasing erosion rate due to the slope of 25-40%. Dependable flow is 0,24 m³/sec for 12.6 km² area of Buper Watershed, estimated water demand in 2011 is 0.28 m³/sec, so it was insufficient for service areas water demand. Buper Watershed have very low erosion rate with a total area of 9,92 km², low erosion rate with a total area of 2,6 km² and moderate erosion rate with a total area of 0,08 km². Management strategies to reduce soil losses are build a medium structure of bench terrace for medium rate erosion and traditional bench terrace for low rate erosion.

The recommendations are expected could be reduce soil erosion and maintain water availability of non-groundwater basin watershed as the purposes of the study. To protect water resources in the non-groundwater basin watershed and to give boundary in land management are required conservation zoning. Forest rehabilitation can be done by planting various kinds of plants in the forest that hasn't been eroded yet, but in areas that have been eroded or have the thickness of the thin soil rehabilitation carried out by planting trees that can survive with limited water and soil. Land cultivation should not be done on the protected forest and upstream areas, cultivation is allowed only on the buffer area with slope of < 15%. Land rehabilitation is planned to recover the impact of soil erosion by develop medium bench terrace on the savannah landcover that has medium erosion rate and develop modification bench terrace called Fanya Juu on the land cover that has medium erosion rate. Sediment and erosion control structure (check dam) are required to reduce soil erosion and create plant growth media. In order to provide adequate water during dry seasons it is necessary to build embung with a discharge of 0,588 m³ /sec throughout the year. Water use controlling is required in order to enlarge the capability to supply water continously by build separated channel for a multipurpose needs and flow control facilities.

Key note : watershed, conservation, groundwater, water balance, soil erosion, USLE, surface water, soil moisture water, watershed delineation

ABSTRAK

Air adalah salah satu kebutuhan paling penting dari manusia. Tanpa air yang cukup, kehidupan manusia dan kegiatannya akan mengalami banyak permasalahan. Oleh karena itu pengelolaan air yang baik sangat diperlukan untuk menyediakan cukup air secara menerus. Unit hidrologi untuk pengelolaan air adalah daerah aliran sungai (DAS). Dalam rangka untuk memelihara ketersediaan air pada DAS akan dibutuhkan konservasi DAS. Konservasi DAS adalah usaha untuk memulihkan dan memelihara keberadaan air. Secara umum, tampungan air pada DAS terdiri dari : air permukaan, kelembaban tanah dan air tanah. Air tanah dibatasi oleh cekungan air tanah sebagai batas hidrologi. Sekitar 47,8 % dari wilayah Indonesia adalah cekungan air tanah dan sisanya yang merupakan bagian terbesar adalah daerah non-cekungan air tanah (Non-CAT). Pada daerah non-CAT, air tersedia pada permukaan dan lapisan tipis tanah. Sehingga sangat penting untuk menjaga ketersediaan air pada permukaan dan lapisan tipis tanah. Maksud dari studi ini adalah mengurangi erosi tanah dan memelihara ketersediaan air pada daerah Non-CAT.

Kesimpulan diberikan berdasarkan maksud dan tujuan dari studi. Lapisan batuan pada DAS Buper yang terletak dibawah lapisan tanah tipis adalah mafic and ultramafic yang merupakan lapisan kedap air. Tanaman dapat tumbuh berdasarkan ketebalan pada tanah, pada daerah savana, ketebalan tanah sekitar 3-25 cm, dan hanya daerah dimana terdapat konsentrasi sedimen ketebalan tanah berkisar 40-60 cm. Pemulihan kembali hutan sangat sulit dilakukan ketika lahan telah tererosi atau telah terbuka. Perluasan permukaan terbuka terjadi mengarah ke hulu karena peningkatan erosi pada kelerengan 25-40%. Debit andalan sebesar 0,24 m³/dtk, kebutuhan air pada tahun 2011 sebesar 0.28 m³/dtk, oleh karena itu masih kurang cukup untuk memenuhi kebutuhan air pada daerah layanan. DAS Buper memiliki tingkat erosi sangat rendah dengan total wilayah 9,92 km², tingkat erosi rendah dengan total wilayah 2,6 km² dan tingkat erosi sedang dengan total wilayah 0,08 km². Strategi pengelolaan untuk mengurangi kehilangan tanah adalah dengan membangun konstruksi sedang teras bangku untuk tingkat erosi sedang dan teras bangku sederhana untuk tingkat erosi rendah.

Rekomendasi yang dihasilkan diharapkan dapat mengurangi erosi tanah dan memelihara ketersediaan air pada daerah Non-CAT sesuai dengan maksud dan tujuan dari studi. Untuk melindungi sumber daya air pada daerah Non-CAT dan memberikan batasan pengelolaan lahan diperlukan konservasi zoning. Rehabilitasi hutan dapat dilakukan dengan menanam beberapa jenis tanaman pada hutan yang belum tererosi, namun pada hutan yang telah tererosi dan mempunyai ketebalan tanah yang tipis rehabilitasi dapat dilakukan dengan menanam jenis tanaman yang dapat bertahan hidup dengan keterbatasan air dan tanah. Pengolahan lahan semestinya tidak boleh dilakukan pada hutan lindung dan daerah hulu, pengolahan lahan diperkenankan pada daerah penyangga dengan kelerengan < 15%. Rehabilitasi lahan direncanakan untuk memulihkan dampak dari erosi tanah dengan membangun teras bangku sedang pada savana yang mempunyai tingkat erosi sedang dan membangun modifikasi teras bangku yang dinamakan Fanya Juu pada tutupan lahan lainnya yang mempunyai tingkat erosi sedang. Bangunan pengendali sedimen dan erosi berupa checkdam diperlukan untuk mengurangi erosi tanah dan menciptakan media tumbuh tanaman. Dalam rangka menyediakan air yang cukup selama musim kemarau maka diperlukan pembangunan embung dengan debit 0,588 m³ /detik sepanjang tahun. Pengendalian penggunaan air diperlukan dalam rangka memperbesar kemampuan untuk menyediakan air secara menerus dengan membangun saluran terpisah untuk multifungsi penggunaan dan fasilitas pengatur debit.

Key note : DAS, konservasi, air tanah, neraca air, erosi tanah, USLE, air permukaan, kelembaban tanah, deliniasi DAS.

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CHAPTER I INTRODUCTION

1.1 Background

Water is the substance of life, there is no single living creature on this planet that do not need water (Suripin, 2002). Water is one of the most important of human needs. The existence of water will allow human to live and perform daily activities. Water become an essential aspect in many areas of life, such as: household, agriculture, plantation, industry, tourism, and so forth. Without sufficient water, human life and its activities will have a lot of problems. Therefore, good water management is required in order to provide sufficient water constantly.

Hydrological unit for water management is watersheds. A watershed is the area of land that drain water into the river, tributaries and main river channel, from the precipitation process draining through the landscape (Smith et al., 2006; Reid, 1993; Shilling et al., 2004; Shamsi, 1997). Watersheds is the most practical ecosystem approach to water resource issues.

In order to maintain water availability in the watershed, it will need watershed conservation. Watershed conservation are the efforts to restore and maintain the chemical, physical, and biological integrity of rivers, streams, and other water bodies in a given watershed. Watershed is a systematic approach to watershed conservation. Watershed boundary determination is needed before the watershed conservation management (Obed Watershed Community Association, 2006).

In general, water storage in a watershed include: surface water, soil moisture and groundwater water. Groundwater is bounded by groundwater basin as a hydrogeological boundary, where all events such as hydrogeological process, drainage, and groundwater discharge take place (PP 43, 2008). In 2003, California Department of Water Resources defines that 'groundwater basin as an area underlain by permeable materials that capable of furnishing a significant supply of groundwater to wells or storing a significant amount of water'. Indonesian Groundwater Basin Map that has been published by Puslitbang Geologi inform that 47,8 % of Indonesia region is groundwater basin and the rest as the larger part is non-groundwater basin. Geologically, the general area of non-groundwater basin is in the form of rock or impermeable layer with a thin soil on top (Kodoatie and Sjarief, 2010). In the non-groundwater basin watershed, water is available in the surface and in the thin soil

layer, therefore it is very important to maintain water availability on surface water and thin soil layer.

Based on the characteristics of non-groundwater basin, there is no water can enter the groundwater system because percolation can not be occurred through the impermeable layer. Water is only stored in the soil-moisture storage and litter storage, while the remaining become into detention storage and depression storage (Chorley, 1978). Surface water, that came resulted from overland flow, is a water that exposed to the atmosphere. It is also said as the result of surface runoff. Soil moisture storage is quantity of water that can be permanently retained in the soil in opposition to the downward pull of gravity (Chorley, 1978). Surface water can be hold longer in the watershed by the forest or vegetation cover, swamps, lakes and other water trap, while the remain of the surface water will run off to the watershed outlet. Surface water decreasing in the forests, vegetation, swamps, lakes, water trap, will bring both soil erosion and flood increasing.

If the watershed can not store sufficient water during rainy season, it may cause water scarcity during dry season. Water scarcity is the result of an imbalance between water supply and water demand (DG Environment, 2007). In the non-groundwater basin, water availability is depend on surface water and soil water, so water imbalance will occur when surface water and soil moisture storage are failed to provide water demand.

Incorrect land use plan will bring land degradation and soil erosion. It will change the balance of the hydrological cycle (Randolph, 2004). Degradation of soil moisture storage can be caused by the soil erosion. Erosion reduces the soil moisture storage, decrease its permeability, increase runoff, and reduce its infiltration rate (Troeh et al., 1991). Soil erosion can be caused by the erosive forces of water (Pimentel, 2000).

Based on the characteristics of non-groundwater basin area, watershed conservation in the non-groundwater basin area is very important to hold water as long as possible in the watershed, decrease the rate of erosion and maintain the water availability. The sustainable water will continuously provide water demand fulfilling over the year. Good water management is necessary in the conservation of non-groundwater basin watershed in order to obtain sustainable of water.

1.2 Scopes of Study

Based on the background description above, some limitation issues need to be examined are:

1. The conservation to be studied here is a conservation in the non-groundwater basin that have been published by the government with watershed as the main boundary.
2. The water that would be conserved are surface water and soil moisture water.

1.3 Purposes and Objectives

The purposes of this study are to reduce soil erosion and to maintain water availability of non-groundwater basin watershed. The objectives of this study are:

- a) To identify the land characteristics of non-groundwater basin at study site.
- b) To analyze the water balances at the study site.
- c) To calculate and reduce the soil erosion at study site.
- d) To formulate conservation planning of non-groundwater basin watershed.

CHAPTER II LITERATURE REVIEW

2.1 River Basin

River basin or river catchment is land area from the source and mouth of a river including all of lands that drain into the river (Ramsar, 2007, pp 9). Unit of Indonesia's water resources management are divided into many river basins. River basin is defined as the territorial integrity of water resources management in single or more of the watershed. It is also included small island that cover the area less than 2,000 km² (UU No. 7, 2004). The Indonesian water resources management are divided into 131 river basin (Kepres RI No. 12, 2012).

2.2 Watershed

Hydrological unit for water management are watersheds. Watershed has become the most practical unit for an ecosystem approach to resource issues. Watershed Conservation is the efforts to restore and maintain the chemical, physical, and biological integrity of rivers, streams, and other waterbodies in a given watershed. Watershed approach is a systematic approach to a conservation plan (Obed Watershed Community Association, 2006). The watershed is the natural planning unit in modeling and monitoring the effect of watershed management policies. Watershed has assumed importance for preserving the ecological balance between natural resource development and conservation, particularly in the fragile and heterogeneous erosion-susceptible hilly ecosystem (Adinarayana, 1995).

A watershed is the area of land that feeds water into river, tributaries and main river channel, through the process of precipitation draining through the landscape. A watershed is a topographical form that concentrates run off (Smith et al., 2008; Reid, 1993; Mazumdar, Azis, 2007; Shilling et al., 2004; Shamsi, 1997; UU No. 7 tahun 2004; Ditjen Tata Ruang dan Pengembangan Wilayah, 2002).

2.3 Groundwater Basin and Non-Groundwater Basin Description

2.3.1 Groundwater Basin

Groundwater basin is an area underlain by permeable materials. The material is capable of furnishing a significant availability of groundwater to wells or storage a significant amount of water (California Department of Water Resources, 2003). Groundwater basin indicates a sedimentary basin. Sedimentary basin is an area

where deposition has occurred continuously for a period of time, and it is formed from the accumulation of thick layers. Alluvial sedimentary basin is the largest source of groundwater (Puslitbang Geologi, 2009; Shibasaki, 1995).

Groundwater basin is defined as an area bounded by the hydrogeological boundary, where all events such as hydrogeological process, drainage, and groundwater discharge takes place. So it can be said that the groundwater basin is the technical boundary of water resources management for groundwater (UU SDA, 2004). Criteria for groundwater basin based on PP 43 of 2008 are :

- It has hydrogeological boundary which is controlled by geological conditions or groundwater hydraulic conditions. Hydrogeological boundary is the physical boundary of the groundwater management area. Hydrogeological boundary can be a boundary between a permeable and impermeable layer, groundwater separator boundary, and boundary formed by the geologic structure. It is included the slope of the rock layers, folds, and sesar.
- It has a recharge and discharge area of groundwater in a single system of groundwater formation. Groundwater recharge area is a groundwater protected area, groundwater in this area is not to be utilized, while the discharge area of groundwater in general can be utilized, it can be said to be the cultivation area of groundwater.
- It has a single aquifer system.

Groundwater basin in Indonesia consists of unconfined aquifer and confined aquifer. Unconfined aquifer is a saturated aquifer. Boundary layer as an aquitard is located only under the unconfined aquifer. Upper boundary of unconfined is a water table. Confined aquifer is a saturated aquifer bounded by impermeable layers in the upper and the bottom (Kodoatie, 1996; Bear, 1979).

The water that occurs beneath the earth's surface is term groundwater. In general, this definition extends to all such water resident within the pore spaces contained in subsurface soil and rock. In this classification, this water can be grouped by depth into the vadose and saturated zones (Freeze and Cherry, 1979).

2.3.2 Non-Groundwater Basin

Geologically, non-groundwater basin is generally in the form of impermeable rock with a layer of thin soil on top (Kodoatie & Sjarief, 2010). Groundwater basin is area underlain by permeable materials. The material is capable of furnishing a significant availability of groundwater to wells or storage a significant amount of water (California Department of Water Resources, 2003), so non-groundwater basin is area which has underlying impermeable material such as impermeable bedrock, clay etc. Referring to the definition of groundwater basin, non-groundwater basin are the area which have no hydrogeological boundaries and it is not a place for hydrological process such as recharge, discharge, drainage and baseflow. Non-groundwater basin (Kodoatie & Sjarief, 2010) are also the region that:

- Does not has a hydrogeological boundary.
- Does not has recharge and discharge area of groundwater in a single groundwater formation system.
- It is not a single aquifer system.

When forest or vegetation covered the area of non-groundwater basin, the forests or vegetation will maintain the soil layer naturally. In non-groundwater basin, the water in the top soil layer as a source of plant life has more volume than in groundwater basin area, so under natural conditions, forests or vegetations in the area of non-groundwater basin are more fertile than in the groundwater basin because in the groundwater basin, water can seep up to hundreds of meters below the soil surface (percolation). This is the way the local natural conditions in non-groundwater basin area is relatively more fertile than in the groundwater basin (Kodoatie & Sjarief, 2010).

2.4 Hillslope Hydrology

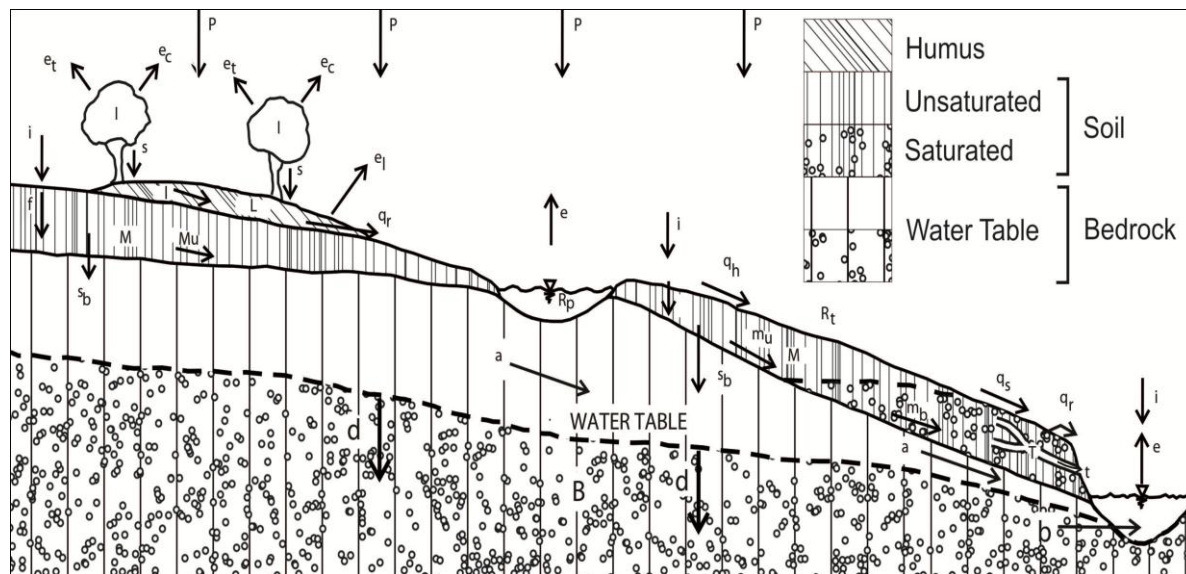
A raindrop falls, but never reaches the earth's land surface because it have been intercepted by a tree leaf or a rooftop. Its moisture is returned to the atmosphere by evaporation, transpiration or evapotranspiration. A second raindrop falls and lands in a natural or artificial depression in the earth's surface. It is termed depression storage and as such, it never enters into the procces of water removal known as runoff. Another raindrop falls, but it penetrates the land surface, or infiltrates into the ground (Chorley, 1978).

The amount of infiltration, or infiltration rate, is variable among different soil even for a given soil it is variable and dependent on the previous dampness, or

antecedent moisture, condition of the soil. Infiltrated water may become part of the soil's field moisture, may continue its percolation through the soil to the water table and become part of the groundwater system, or may respond to gravity and flow down-gradient at shallow soil depths as interflow or throughflow (Chorley, 1978).

Water travelling as stream channel or throughflow may remain at shallow depth until it discharges into stream channel and becomes channel flow, may enter into groundwater system, or return to the land surface and is known as return flow. In the latter instance, it becomes that part of surface runoff which is termed overland flow. Other rain drop fall directly into stream channel and other bodies of water and thus contribute to surface runoff. Such water is termed channel precipitation but it not part of overland flow because, in the strict sense, it does not flow over the land surface en route to the stream channel. Still other raindrop fall on the land surface. Such flow is termed overland flow and occurs when the number of raindrops, or amount of precipitation, exceeds the infiltration capacity of the soil and depression storage capacity of the land surface (Chorley, 1978).

The consumptive utilization of water by evaporation and transpiration must also be included in the total amount of precipitation needed to generate overland flow, but considering the brief time span of overland flow, these effects have much less significance than the infiltration and depression storage capacities. Water en route downslope as overland flow is termed detention storage (Chorley, 1978).



Precipitation (Gross Rainfall)	P	Horton Overland Flow	q_H
Channel Precipitation	P_c	Saturated Overland Flow	q_s
Precipitation Intensity	i	Return Flow	q_r
Evapotranspiration	e_t	Pipe Flow	t
Canopy Interception Loss	e_c	Pipe Storage	T
Interception and Canopy Storage	I	Unsaturated Throughflow	m_u
Steamflow and Drip	s	Saturated Throughflow	m_s
Litter Flow	L	Soil-Moisture Storage	M
Litter Interception Loss	e_l	Seepage into Bedrock	s_b
Litter Storage	L	Interflow in Bedrock	a
Evaporation	e	Aeration Zone Storage	A
Depression Storage	R_p	Deep Seepage	d
Detention Storage	R_T	Baseflow	b
Infiltration	f	Groundwater Storage	B

Figure 2.1 Components of The Hillslope Hydrological Cycle (Chorley, 1978)

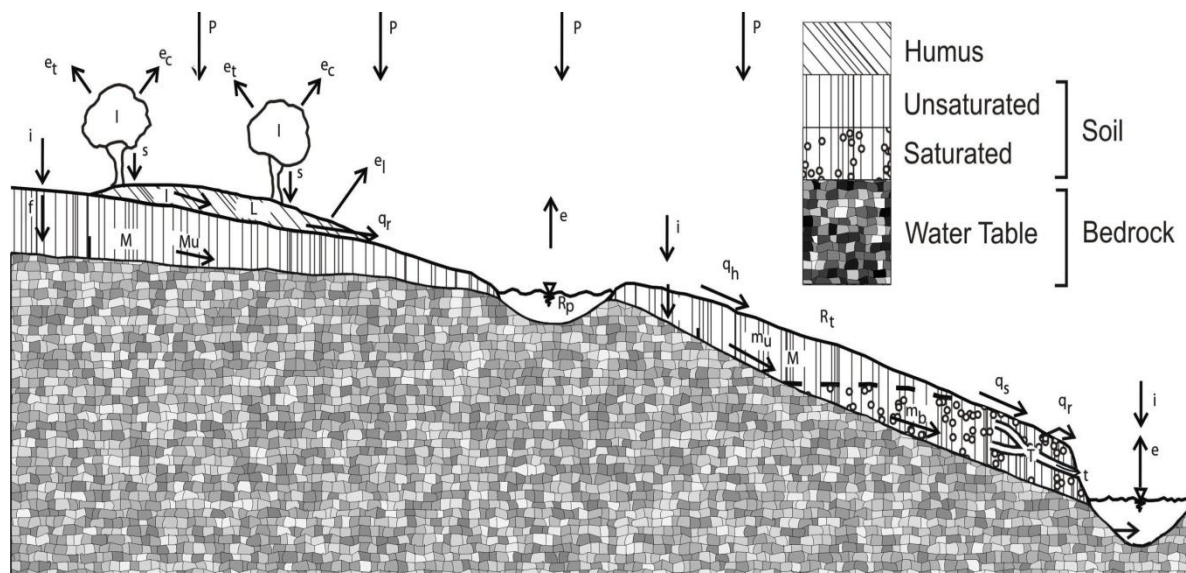
2.5 Hydrological Cycle in the Non-groundwater Basin

The hydrological cycle is a continuous process by which water is purified by evaporation and transported from the earth's surface including the oceans to the atmosphere and back to the land and oceans by precipitation (Shamsi, 1997). Water transform process from liquid state into vapor is called evaporation. Vapor is moving through the atmosphere (air) then because of atmospheric temperature decrease become liquid by condensation process (Chow et al., 1988). Hydrological cycle can be viewed as a mass balance, using the principle of water budget equation the volume of water can be determine (Wanielista et al., 1997; Toth, 1990).

Hydrological cycle in the non-groundwater basin is not much different than the hydrological cycle that generally known, but the geologic structure that contain impermeable layer so water can not seep into the ground. Entire water in the non-

groundwater basin is a surface water. It causes the lack of groundwater flow, the absence of baseflow and only interflow in non-groundwater basin area. It has no percolation process (Kodoatie & Sjarief, 2010). In the area of non-groundwater basin, the water is contained in thin soil layer over an impermeable layer. So the area of non-groundwater basin are only consists of surface water and soil water.

For a general cover of heavy-crowned, open-grown trees, the first mm of rainfall would be intercepted, together with 20 % of the remainder (Horton in Chorley, 1978). Of the latter, some 1-5% would be expected to form stemflow and rest would be evaporated, giving a total throughfall of 75-79% in excess of the first 1 mm (Carson and Kirkby in Chorley, 1978). It can be concluded that surface water and soil water in non-groundwater basin is among of 75-79% because there is no percolation through impermeable layer. Percolation is the passage of water under hydrostatic pressure through the interstices of a soil or rock, excluding the movement through large openings (Horton, 1933).



Precipitation (Gross Rainfall)	P	Horton Overland Flow	q_H
Channel Precipitation	P_c	Saturated Overland Flow	q_s
Precipitation Intensity	i	Return Flow	q_r
Evapotranspiration	e_t	Pipe Flow	t
Canopy Interception Loss	e_c	Pipe Storage	T
Interception and Canopy Storage	I	Unsaturated Throughflow	m_u
Stemflow and Drip	s	Saturated Throughflow	m_s
Litter Flow	L	Soil-Moisture Storage	M
Litter Interception Loss	e_l	Seepage into Bedrock	S_b
Litter Storage	L	Interflow in Bedrock	a
Evaporation	e	Detention Storage	R_T
Depression Storage	R_p	Infiltration	f

Figure 2.2 Components of The Hillslope Hydrological Cycle (Chorley, 1978 with Modification Representing Non-Groundwater Basin)

2.5.1 Surface Water Storage

Surface water storage are surface detention plus depression storage. Surface detention is a portion of rainwater which remains in temporary storage on the land surface as it moves downslope by overland flow and either runs off, evaporated or infiltrated after the rain ends. Surface detention is the storage effect due to the overland flow in transit (Chow, 1988). Depression storage is the volume of water, forming part of surface detention, which is contained in small natural depressions in the land surface during or shortly after rain fall, none of which run off (Tischendorf, 1969).

2.5.2 Soil Water Storage

A part of raindrop falls, penetrates the land surface, or infiltrates into the ground. The amount of infiltration, or infiltration rate, is variable among different soil even for a given soil it is variable and dependent on the previous dampness, or antecedent moisture, condition of the soil. Infiltrated water may become part of the soil's field moisture (Chorley, 1978). Soil moisture is all water which is stored in the weathered soil mantle (Tischendorf, 1969). Soil moisture storage is the quantity of water that can be permanently retain in the soil in opposition to the down ward pull of gravity (Horton, 1933).

2.6 Land Use Suitability

Land evaluation is a process for synchronize the characteristics of land resources for certain uses using a scietifically standardized technique. The result can be used as a guide by land users and planners to identify alternative land uses.

Land Suitability is the degree of appropriateness of land for a certain use. Landsuitability could be assessed for present condition (Actual Land Suitability) or after improvement (Potential Land Suitability).

Actual Land suitability is a land suitability that based on current soil and land conditions, i.e. without applying any input. The information is based on physical environment data generated from soil or land resource surveys. The information is based on soil characteristic and climate data related to growth requirement of crops being evaluated. Potential Land Suitability is the suitability that could be reached after the land is improved.

The land to be evaluated can be natural (conversion) forest, abandoned or unproductive lands, or land that currently used for agriculture, at a sub-optimal level

of management in such a way that the productivity can be improved by changing to more suitable crops (Ritung et al, 2007).

Incorrect land use plan would bring natural degradation and soil erosion. It changes the balance of the hydrological cycle. Incorrect land use plan are also water pollution, habitat destruction, energy use increase, air pollution, and quality of life reduction (Randolph, 2004). The purpose of land use plan is to create harmonious relations between various activities in the territory in order to create its harmonious relation. It will accelerate the process of achieving prosperity and ensuring environmental sustainability (Tarigan, 2004). Environmental sustainability is sustainable environmental protection for next generations. The main goals are both renewable and sustainable water (Albertson, 1999).

2.7 Water Availability

An aspect that should be known before we analyze the water balance for a particular area is the amount of water availability. The water availability is often difficult to estimated accurately. This is because it contains elements of the spatial variability and temporal variability. For the analysis of surface water availability, dependable flow will be used as a reference. Dependable flow is a quantity discharge at a control point in a river where the discharge is a combination of direct runoff and base flow. For limited data, these data can be generated using the rain-flow modeling approach. Rain-flow model used is the Mock. The Mock is more commonly used in Indonesia, it is easy to obtain use and relatively required fewer data (Bappenas, 2006).

The availability of surface water is the result of the hydrological cycle. The availability of surface water is not only in rivers, lakes, reservoirs, swamps, etc, but also in the vadose zone layer that is the area between the surface until the free water table (unconfined aquifer). The process of entry of rainwater into the ground is through a soil-water infiltration in vadoze zone / unsaturated zone (Hunt, 1984; Kodoatie & Sjarief, 2010; USBR, 1979).

The availability of surface water in the area of non-groundwater basin is only found in rivers, lakes, reservoirs, swamps, etc. It also in the lining of the vadose zone which is the area between the surface until the unconfined aquifer (Kodoatie & Sjarief, 2010).

Surface water availability in this study will be analyzed by NRECA, F.J. Mock, and Chorley approaches. We can also compare these result with the previous study

at the study site. The result of surface water availability analysis will be used as an input data of conservation infrastructure.

2.8 Water Demand

Water demand analysis include water demand for irrigation, domestic, non-domestic, industrial, livestock, and fisheries in the recent time and in the future. The population and the land use change will determine the quantity of water demand, for human daily activities, industries, irrigation, fisheries and etc. To project the population and land use changes precisely is very difficult. Many approaches can be done, one of them is an exponential approach. This method uses the assumption of population growth and land use change in the percentage of each year are constant (Direktorat Jenderal SDA, 2001).

2.9 Water Balance

In the hydrological cycle, the relationship between flow inflow and outflow in a watershed is called water balance (Direktorat Pengairan dan Irigasi, 2006). From a hydrological viewpoint, the first step of watershed management is to evaluate past, present, and proposed management practices on a watershed. Watershed water balance refers to the balance between the inflow of water as precipitation and the outflow of water as evapotranspiration, ground water discharge, and surface flow. Basically, watershed water balance is an accounting tool to keep track of the hydrological cycle of a watershed. When the watershed water balance concept is used in conjunction with probability analysis, it can evaluate the hydrological, economic, and ecological feasibility of past, present, and potential activities on a watershed (Tate, 1995).

Watershed water balance is best illustrated as an equation. The water balance equation is the single most recognized equation in hydrology. A basic water balance equation for a watershed is showed with following equation (Tate, 1995) :

$$P = ET + SF + GWD \pm SMC \pm GWS$$

with:

P = Precipitation

ET = Evapotranspiration

SF = Stream flow

GWD = Ground Water Discharge

SMC = Soil moisture Capacity

GWS = Groundwater Storage

The water balance equation should be modified for the condition of non-groundwater basin area. There are no ground water storage and ground water discharge. Water is only stored in a soil layer and in the surface. Those will be replaced with soil water discharge and soil water storage. Water balance equation with modification for a non-groundwater watershed is showed with following equation:

$$P = ET + SF + SWD \pm SMC \pm SS$$

with:

P = Precipitation

ET = Evapotranspiration

SF = Stream flow

SWD = Soil Water Discharge

SMC = Soil Moisture Capacity

SS = Soil Storage

2.10 Soil Erosion

Watershed damage is primarily caused by the erosion process. Soil erosion is caused by the erosive forces of wind or water (Pimentel, 2000). Erosion results in the degradation of a soil's productivity in a number of ways: it reduces the efficiency of plant nutrient use, damages seedlings, decreases plants' rooting depth, reduces the soil water-holding capacity, decreases its permeability, increases runoff, and reduces its infiltration rate (Troeh et al., 1991).

In general, soil erosion composed three-step process. It starts with the detachment of soil particles, continues with the transport of those particles, and ends with the deposition of soil particles in a new location. Bare soils (soils that lack a cover of living or dead plant biomass) are highly susceptible to erosion, even on flat land. There are three main types of water-induced soil erosion: sheet, rill, and gully (O'geen and Schwankl, 2006).

Incorrect land use and processing may accelerate erosion, and will lead reduce soil productivity. Erosion problems related with the planning of water resources. Erosion will increase sediment loads in the river system and changes the hydro-morphological conditions. If the erosion is high, it will change the river hydrology element, such as the increasing of runoff and decreasing base flow (Direktorat Jenderal SDA, 2001).

2.11 Watershed Conservation

2.11.1 The Purposes of Water Resources Conservation

Water conservation is our common problem, therefore the issue of water conservation can be solved if we care about and actively participate on it. Basically, we have the potential to damage as well as potential to improve the water that we have on this earth (Suripin, 2002).

Watershed development refers to conservation, regeneration and judicious utilization of natural resources. It aims to bring about an optimum balance between the demand and use of natural resources. When the optimum balance is reached, it will be sustainable over time (Mazumdar, 2007).

The basic concept of water conservation is not a waste of water. Initially, water conservation are defined to store water and use it for productive purposes in the future. Further, conservation lead to a water use efficiency, known as demand conservation. Good water conservation are combination of two concepts, there are water saving when his excessive and use it as little as possible for specific productive purposes (Suripin, 2002).

2.11.2 Water Resources Conservation Plan

Conservation activities of water resources based on UU no. 7 year 2004 and PP No. 42 year 2008 are defined :

1. Protection of water resources are the effort to secure sources of water from the damage caused by human actions and natural.
2. Preservation of water are the attempt to maintain the existence of water availability or the quantity of water, to be sustainable in accordance with the functions and benefits.
3. Water quality management are the effort to maintain and restore the quality of water that enter and stay in the source of water.

Details of water resources conservation according to PP No. 42 of 2008 are :

1. Protection & Conservation Of Water Resources
 - maintaining the existence of the recharge and catchment areas.
 - controlling of water sources uses
 - water sources recharging
 - sanitation infrastructure settings

- protection of water resources in relation to development activities and land use on the water sources
- soil cultivation controlling in the uplands
- setting border area of water resources
- forest and land rehabilitation
- conservation of protected forests, nature reserves, and nature conservation area.

2. Water Reservation

- a. store the excess water in the rain to be used in time of need. Water storage can be done by developing rain water storage, pool and dam.
- b. effectively and efficiency uses.
- c. groundwater controlling uses.

3. Management of Water Quality and Water Pollution Controlling

- a. improve water quality at water sources and its infrastructure
- b. prevent water pollution at water sources and infrastructure resources

To avoid the effects as mentioned above, a partial of land use is required to provide 30% as forest area. It also classify the arrangement of space to be used as protected areas and cultivation areas. So, the upstream is used as a protected area and the downstream is used as the cultivation area (UU no. 26, 2007).

The conservation planning method occurred in three main phases. The first phase involved ranking lands for protection at the regional scale. Lands identified as high priority formed discrete units called Conservation Focus Areas (CFAs). The second phase consisted of ranking individual land parcels within the larger CFAs. A third phase analysed threats and sources of threats in relationship to CFAs (Kazmierski et al., 2004).

CHAPTER III BUPER WATERSHED DESCRIPTION

3.1 Location

Position of the Buper watershed is between Jayapura City and Jayapura Regency, included in Province of Papua. It is also in the area of Mamberamo-Tami-Apauwer River Basin (DPU, 2010). Mamberamo-Tami-Apauwer River Basin is located between coordinates 136°21'- 140°49' E and 1°27'- 44°32' S, where all the rivers in this river basin flow into the Pacific Ocean except Kampwolker and Buper River which empties into Lake Sentani (Bappeda Papua, 2006). Buper Watershed has an area of 14.335 km² based on the analysis that has been done by DPU in 2010.

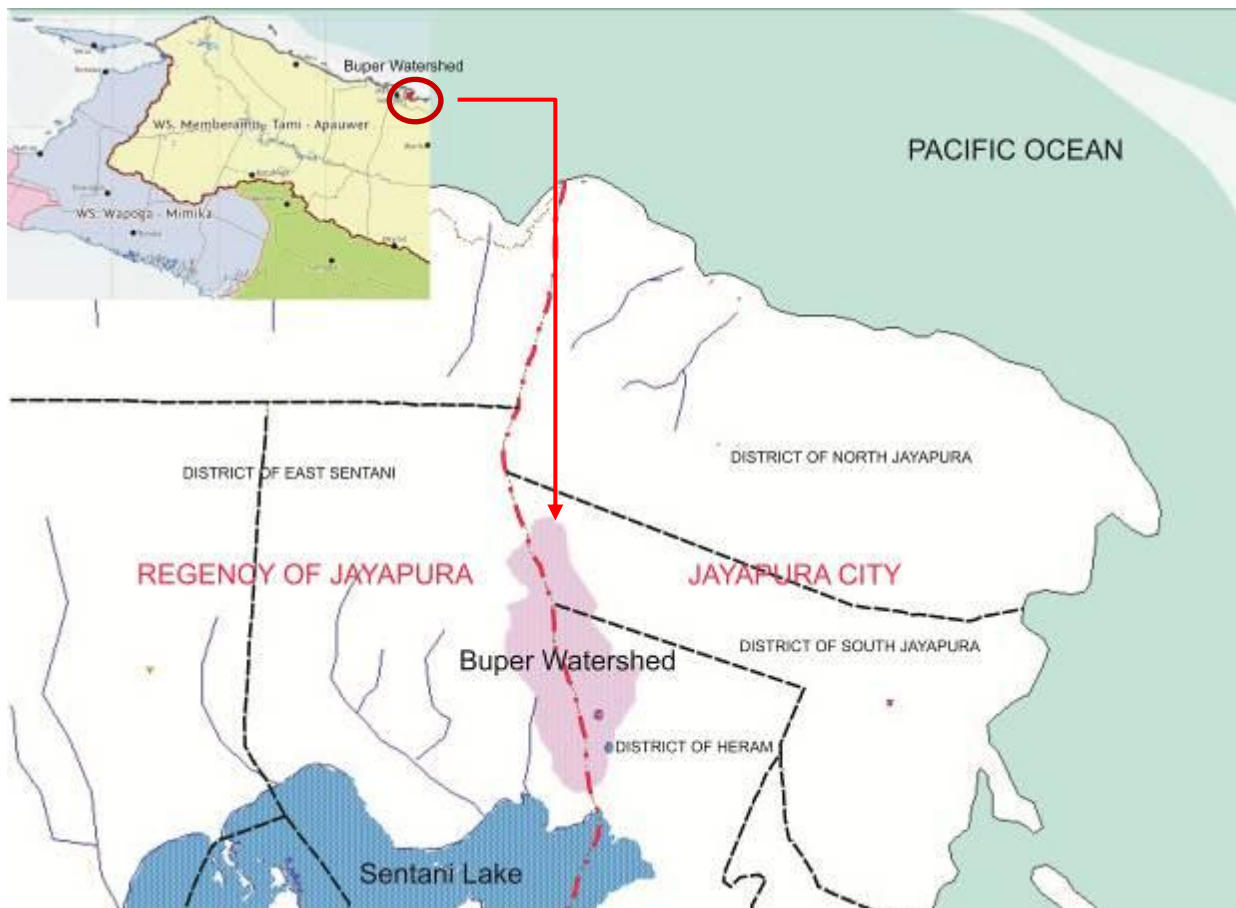


Figure 3.1 Location of Buper Watershed

Jayapura City has an area of 940 km². It is located at 1°27'00"- 3°49'00" South and 137°27'00"- 141°41'00" East. Jayapura city consists of 5 districts namely Abepura District, South Jayapura District, Jayapura District, North Jayapura District and Heram Muara Tami

District. The population of Jayapura in 2008 is 256,705 person. Population density is 254 people / km² Population growth is 14,28 %. Jayapura City is also Capital of Papua Province (BPS Jayapura City, 2011).

Regency of Jayapura has an area of 17.516 km². Regency of Jayapura is located at 129°00'16" – 141°01'47" E dan 2°23'10" N – 9°15'00" S. Regency of Jayapura consists of 19 districts. The population of Jayapura Regency in 2011 is 111.943 person. Population density is 7,05 people / km². Population growth is 10,69 % (BPS Jayapura Regency, 2011).

3.2 Characteristics Climate, Topography and Groundwater Basin

Precipitation around Buper Watershed is 1951 mm/year, with the average of rainy days is 148 days/year. Maximum average of air temperature is 31,7°C and minimum average of air temperature is 23.5°C. Average humidity is 82%, average wind speed is 8,2 knot, and solar shines are 40,5 % (BMKG, 2011).

Buper watershed has a hilly topography with a height of 205 - 1300 MSL. Buper Watershed has an average slope in the upstream of 5% and an average slope in the downstream areas of 20%. In the downstream of the Buper Watershed there is a retention throughout the year.



Figure 3.2 Description of Buper Watershed

Buper watershed is not included in the area of groundwater basin where there is no potential for groundwater that can be utilized. Therefore the characteristics of the non-groundwater will greatly affect Buper Watershed especially in terms of water resources availability (DPU, 2010).

3.3 Landscape and Infrastructure

Until 2011, there is a government office in Buper Watershed located in the downstream area of 0.2 ha. On the Buper river there is a water intake for domestic use

which is constructed by the government with the discharge of 50 liters / sec (PDAM Jayapura, 2008). Most of the Buper watershed land cover are forest and savannah. There are nothing but both infrastructures, a government office and water intake.



Figure 3.3 Intake at Buper Watershed

In the early stages of analysis, it is necessary to analyze previous reports. The purpose of this analysis is to obtain information of study location, condition, and another important factors in the analysis of this study. Previous reports must have approximately the same location with the studies proposed. There was an embung design project at Buper Watershed in 2009. In this Buper embung design project, the volume capacity of embung design is 407,391 m³ with water elevation at +210,50.

In this design project, used dependable flow are dependable flow with 80% reliability. Average dependable flow of Q_{80%} is 0,725 m³/sec (DPU Provinsi Papua , 2010). In order to design this embung, surface water measurement has been done in July and November 2009. Buper watershed outflow as the result of the measurement are 624 lt/sec in July and 654 lt/sec in November 2009. Average of the measurement is 639 lt/sec (DPU Jayapura, 2009).

CHAPTER IV METHODOLOGY

To achieve the objectives of this study, the appropriate methodology will be required. This methodology includes data collection, analysis used and the sequence of processes performed. The methodology of the study can be represented in Figure 4.1 :

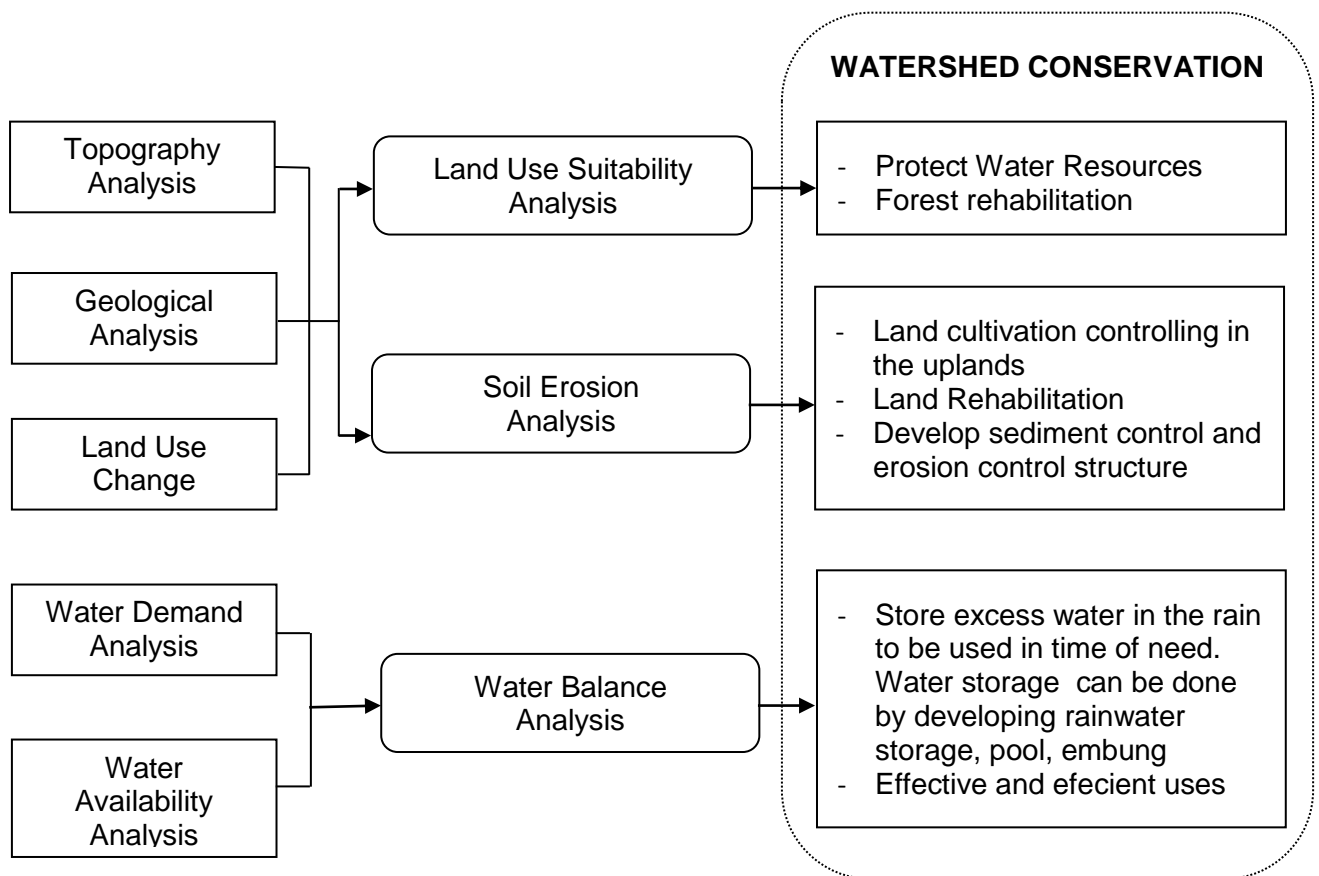


Figure 4.1 Flow Chart of Methodology

4.1 Data Collection

Data collections include secondary data and primary data. Secondary data is collected from various sources especially government institution. Primary data is collected from direct observation and measurement. Both secondary and primary data collection are required to identify the existing water resources condition in study site and support further analysis to achieve the purposes and objectives of the study.

4.1.1 Secondary Data

Secondary data are usually in the form of descriptions, tables, maps, diagram and policy. These data are gathered to support the study analysis. Secondary data collected for this study are :

- previous study reports
- meteorology and climatology data
- supporting data such as social - economic, infrastructures, environment reports and government policies.
- geology, soil type and groundwater basin map
- Digital Elevation Model (DEM)
- land use map

4.1.2 Primary Data

Primary data are focused on study site and it observes existing condition such as topographic and geological, infrastructure, socio – economic and water sources. These data will be collected by field observations, sampling and measurement. These data are gathered to support the analysis.

Field observations are done in order to identify facts and issues related to the study site. These activities may include direct observations in study site by foot or motorcycle, interviews with community or community leaders, and people in charged.

4.2 Analysis

To develop a new concept of watershed conservation in non-groundwater basin area would be required many kind of analysis. Analysis required lead to purposes and objectives of the study. Analysis that would be required are :

1. Previous Studies Review

In the early stages of analysis, there will be reviewed the reports that have been done before. The purposes of this review are to obtain information of study location, specific condition, and another important factor required in this study. Previous studies that would be reviewed are the studies that have approximately the same location with the studies proposed. Data and information would be collected are watershed boundary, embung discharge direct measurement, water demand, water availability, water elevation, etc.

2. Watershed Delineation

Manual delineation of watersheds is done by drawing drainage divides on topographic (contour) maps (Shamsi, 1997; Bertolo, 2000). Automatic delineation of watersheds is done using Digital Elevation Models (DEMs) software (Shamsi, 1997; Xu et al, 2001; Tayler et al, 1999; Wilson et al, 2000; Manual AGWA 2.0; Bertolo, 2000; WCMS , 2004; EPA, 2000; Manual Basin 3,1; Radar Sat International, 2000; ESRI, 2005).

A digital elevation model (DEM) is a 3-dimensional (3-D) representation of the Earth's surface (Radar Sat International, 2000). A DEM is generically described as a spatially geo-referenced dataset that is a popular way of encoding the topography for environmental modelling purposes. DEMs are also directly compatible with remotely sensed data sources and can be used to represent complex terrain units, given an adequate resolution Digital Elevation Models (DEM's) store continuously varying variables such as elevation, groundwater depth or soil thickness. Digital Terrain Models (DTM's) are digital representations of altitude and are frequently used in hydrological, erosion and engineering geological studies (Baxter & Robinson, 2001).

Digital Elevation Models can either be stored in vector or in raster format. DEMs in vector format are often in the form of Triangulated Irregular Networks (TIN), which can be seen as a set of polygons in the form of triangles where the 3 corners of each triangle are known height values. Each triangle has a uniform slope steepness and slope direction. When the terrain is more complex, the number of triangles needed to represent the terrain increases (The Faculty of Geo-Information Science and Earth Observation (ITC), 2001). GIS Watershed delineation is a multi-step process (Forest Hydrology Class, 2011).

Watershed delineation can utilize various kinds of software such as ArcHidro, ArcGIS, Basin, AGWA, WCMS, ILWIS 3.0 and so forth. Software used in this study to delineate watershed using DEM data are Basin and ArcView 3.1.

Watershed delineation products watershed boundary and drainage system at the study site. This product is the first important input for further analysis. It gives area boundary for each analysis that would be done.

3. Topography Analysis

Topography analysis will support watershed conservation plan by providing important data such as contour, elevation, slope. The main products of this analysis are a contour map and slope map. These map are important to support the further analysis. In this topography analysis, contour map, elevation, slope are produced by combination of ArcView 3.3 and Global Mapper 12 which require the DEM data as input of these application.

4. Land Use Suitability Analysis

A geographic information system (GIS) is an efficient tool for organizing, storing, analyzing, displaying and reporting spatial information. GIS capabilities for spatial analysis overcome the drawbacks of the paper map overlay approach. The system enables planners to create and modify a land suitability analysis that makes the best use of available data. Land suitability analysis involves the application of criteria to the landscape to assess where land is most and least suitable for development of structures and infrastructure (NC Division, 2005).

Protected and cultivation areas can be determined by using soil map, precipitation map and topography map (Minister of Agriculture, 1982). Scoring of each map can be shown as Table 4-1:

Table 4-1 Scoring of Soil, Precipitation, Slope (Minister of Agriculture, 1982)

Soil Type	<i>Alluvial</i>	<i>Latosol</i>	<i>Mediterranean</i>	<i>Grumosol</i>	<i>Litosol</i>
Scoring	15	30	45	60	75
Precipitation (mm/year)	<i>750-1250</i>	<i>1250-1750</i>	<i>1750-2250</i>	<i>2250-2750</i>	<i>2750 <</i>
Scoring	10	20	30	40	50
Slope	<i>0 – 8 %</i>	<i>8 – 15 %</i>	<i>15 – 25 %</i>	<i>25 – 40 %</i>	<i>40 % <</i>
Scoring	20	40	60	80	100

Suitability of land use with land-use directives function is determined based on the provisions that already exist. Land suitability recommendation as a result of the analysis consist of protected forest, buffer area, farming / agriculture, settlement (Ditjen RLKT, 1986).

Table 4-2 Land Suitability Recommendation (Ditjen RLKT, 1986)

Land Suitability Recommendation	Scoring and Criteria
Protected Forest (A)	<ul style="list-style-type: none"> • Total scoring > 174, or • Elevation > 2000 MSL, or • Slope > 40 %, or • Slopes > 15% and soil type susceptible to erosion
Buffer Area (B)	<ul style="list-style-type: none"> • Total scoring 125 – 174, or • Nature Preservation Forest and Tourism Forest
Farming / Agriculture (C)	<ul style="list-style-type: none"> • Total scoring < 125, or • Elevation < 1000 MSL, or • Slope < 40%, or • Effective depth of top soil > 30 cm, or • Precipitation between 1500-4000 mm per year, or • Have a system or have a potential for agricultural development
Settlement (D)	<ul style="list-style-type: none"> • Total scoring < 125, or • Do not have a potential for agricultural development

5. Geological Analysis

Geological analysis have purposes to get useful geological information by geological map interpretation and study site observation. Geological analysis that would be done include identification of rock formation, soil type and non-groundwater basin. These identification will need GIS application by ArcView 3.3 to process rocks formation, soil type and groundwater map. Study site observations will be done by documentation collecting and material sampling related to those identifications. Documentation and material sampling are purposed to support the geological information that had reached by GIS application.

Geological information as a result of geological analysis will be used in land use suitability analysis, soil erosion and water availability analysis. Geological information also ensure the existance of groundwater basin and define the geological characteristic at study site.

6. Water Availability Analysis

In principle, The Mock take into account the volume of input, output and soil storage. Input water is precipitation and out water are infiltration, percolation and evapotranspiration. Calculation of evapotranspiration will use Penmann method. Soil storage is the volume of water stored in the soil, until it becomes saturated. Overall calculation of the Mock refers to water balance, where the volume of total water on earth is fixed, only the circulation and distribution is varied. The Mock calculation can be described in general in Figure 4.2 :

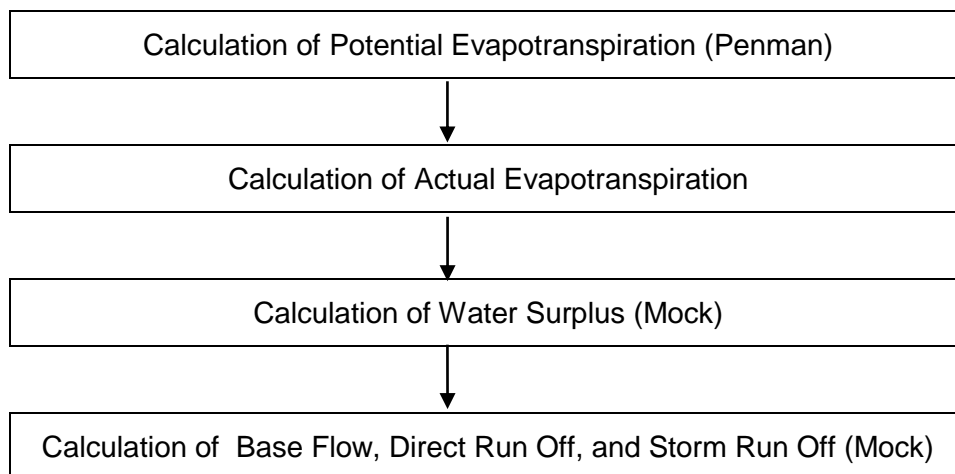


Figure 4.2 Flow Chart of Water Availability (Bappenas, 2006)

A. Evapotranspiration

Evapotranspiration is defined as the loss of water from land and plant from a watershed due to a combination of evaporation and transpiration. More details on potential evapotranspiration and actual evapotranspiration are described below.

1. Potential Evapotranspiration (E)

Potential evapotranspiration is the evapotranspiration that may occur in condition of excess water available. Important factor that affect the potential evapotranspiration is the sufficient availability of water. If the amount of water that available is always excessive , the amount of transpiration is relatively larger than if the water available is limited.

The Mock uses an empirical formula of Penman. Penman empirical formula calculate many climatological data of temperature, solar radiation, humidity, wind speed, thus the results are relatively more accurate. Potential evapotranspiration according to Penman is formulated as follows:

$$E = \frac{(AH + 0,27D)}{A + 0,27}$$

Where :

- H = energy budget,
 $= R (1-r) (0,18 + 0,55 S) - B (0,56 - 0,092 d \sqrt{e_d}) (0,10 + 0,9 S)$
- D = heat for evapotranspiration = $0,35 (e_a - e_d) (k + 0,01w)$
- A = slope vapour pressure curve(mmHg/oF)
- B = black material radiation (mmH₂O/day)
- e_a = saturated vapour pressure(mmHg).
- R = solar radiation (mm/day)
- r = reflection coefficient
- S = monthly solar radiation (%)
- e_d = actual vapour pressure (mmHg) = e_a x h.
- h = monthly relative humidity (%).
- k = evaporating surface coefficient (water surface = 0,5 ; vegetation surface = 1,0)
- w = monthly wind velocity (mile/day)

$$E = F1 \times R(1 - r) - F2 \times (0,1 + 0,9S) + F3 \times (k + 0,01w)$$

when :

$$E1 = F1 \times R(1 - r)$$

$$E2 = F2 \times (0,1 + 0,9S)$$

$$E3 = F3 \times (k + 0,01w)$$

So :

$$E = E1 - E2 + E3$$

The amount of potential evapotranspiration are presented in mm / day. The amount of A, B and e_a depending on average temperatures. The amount of solar radiation depends on the location of latitude. The amount of solar radiation is varies by month. Reflection coefficient is very influential in evapotranspiration.

Table 4-3 Correlation Between Average Temperature vs A, B, & e_a (Bappenas, 2006)

Temp (°C)	8	10	12	14	16	18	20	22	24	26	28
A (mmHg/F)	0.304	0.342	0.385	0.432	0.484	0.541	0.603	0.671	0.746	0.828	0.917
B (mmH ₂ O/hari)	12.6	12.9	13.3	13.7	14.1	14.5	14.9	15.4	15.8	16.2	16.7
e _a (mmHg)	8.05	9.21	10.5	12	13.6	15.5	17.5	19.8	22.4	25.2	28.3

Table 4-4 Solar Radiation Value (mm/day) (Bappenas, 2006)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
5° LU	13.7	14.5	15	15	14.5	14.1	14.2	14.6	14.9	14.6	13.9	13.4
0°	14.5	15	15.2	14.7	13.9	13.4	13.5	14.2	14.9	15	14.6	14.3
5° LS	15.2	15.4	15.2	14.3	13.2	12.5	12.7	13.6	14.7	15.2	15.2	15.1
10° LS	15.8	15.7	15.1	13.8	12.4	11.6	11.9	13	14.4	15.3	15.7	15.8

Table 4-5 Coefficient of Reflection (Bappenas, 2006)

No	Surface Cover	Coefficient of Reflection (r)
1.	Average Earth Surface	40 %
2.	Snow Melt	40 – 85 %
3.	Dry – tall bushes	31 – 33 %
4.	Desert	24 – 28 %
5.	Heavy crown forest	24 – 27 %
6.	Seasonal forest	15 – 20 %
7.	Forest that produce fruits	10 – 15 %
8.	Dry bare soil	12 – 16 %
9.	Humid bare soil	10 – 12 %
10.	Wet bare soil	8 – 10 %
11.	Sand, wet - dry	9 – 18 %
12.	fresh water, solar elevation 450	5 %
13.	fresh water, solar elevation 200	15 %

2. Actual Evapotranspiration

Actual evapotranspiration is the evapotranspiration that occurs in conditions when amount of water available is limited. Actual evapotranspiration is influenced by the proportion of the exposed surface in the dry season. The amount of exposed surface (m) for each region is different.

Table 4-6 Coefficient of Exposed Surface (Bappenas, 2006)

No.	m	Area
1	0 %	Primary and secondary forest
2	10 – 40 %	Eroded area
3	30 – 50 %	Farming / agriculture

In addition to the exposed surface, actual evapotranspiration is also influenced by the number of rainy days (n) in the month.

$$\Delta E = E_P (m/20) \times (18-n)$$

Actual evapotranspiration is the evapotranspiration that actually occurs, it can be calculated as follows:

$$E_{actual} = E_P - \Delta E$$

B. Water Surplus

Water surplus is defined as precipitation which has undergone an evapotranspiration and fill soil storage (SS). Water surplus are directly effect on infiltration / percolation and total run-off which is a component of discharge. Surplus water equations (WS) is as follows :

$$WS = (P - Ea) + SS$$

Water surplus is surface water run-off and infiltrated water. Soil moisture storage (SMS) are composed of soil moisture capacity (SMC), the zone of infiltration, surface runoff and soil storage. The amount of soil moisture capacity (SMC) for each region are depended on crop type, land cover (land cover) and soil type. In the Mock, SMS is calculated as follows :

$$SMS = ISMS + (P - Ea)$$

Where :

ISMS = initial soil moisture storage, is the soil moisture capacity (SMC) in the previous month.

P-Ea = evapotranspiration of precipitation that has undergone.

Assumptions used by Mock is the water will meet the SMC first before the surplus water available for infiltration and deeper percolation or direct run-off. There are two conditions to determine the SMC, namely :

a) $SMC = 200 \text{ mm / month}$, if $P - Ea < 0$.

b) $SMC = SMC \text{ previous month} + (P - Ea)$, if $P - Ea < 0$.

Furthermore, this WS will infiltrate and run off on the surface. The amount of infiltration is depended on the coefficient of the infiltration.

C. Total Runoff

Water of precipitation that have undergone evapotranspiration and stored in the saturated soil, will run-off on the surface and having percolation. Next, according to Mock the amount of infiltration is water surplus (WS) multiplied by the coefficient of infiltration (if), or :

$$\text{Infiltration (i)} = WS \times if$$

Infiltration coefficient are determined by the condition of the porosity and the slope of the drainage area. Land that is porous generally have coefficients that tend to be large. However, if the slope of the land is steep where the water do not get an experience of infiltration and percolation, the infiltration coefficient is small. Infiltration continues until the groundwater storage. Surface runoff water comes from a surplus that has infiltration. So the direct run-off is calculated by the equation :

$$DRO = WS - i$$

After base flow and direct run off, the other components of stream flow is storm run-off. Storm run-off is only a few percent of the precipitation. Storm run-off is only included in the total run-off when precipitation is less than the maximum value of soil moisture capacity. According to the Mock storm run-off is influenced by the percentage factor (PF). Percentage factor is the percent of rainfall becomes runoff. The amount of PF is recommended 5% - 10%, but it have possibility for increasing irregularly until 37.3%.

In the calculation of this discharge, Mock provides that :

- i. If the precipitation (P) > maximum soil moisture capacity then the value of storm run-off = 0.
- ii. If P < maximum soil moisture capacity then the storm run-off is the amount of rainfall in one month in question multiplied by the percentage factor, or:

$$SRO = P \times PF$$

Thus, the total run-off (TRO) which is a component of stream flow are the amount of base flow, direct run-off and storm run-off, or:

$$TRO = BF + DRO + SRO$$

Total run-off are expressed in mm / month. So if the TRO is multiplied by the catchment area in km² with a specific conversion rates obtained in the discharge m³/sec.

7. Water Demand

Water demand can be generally divided into two categories: irrigation purposes and the non-irrigation purposes. For non-irrigation water demand itself are still divided into domestic, non-domestic, industrial, livestock fisheries and flushing / maintenance stream. To estimate the water demands for these purposes, use an approach based on administrative boundaries (Bappenas, 2006).

Household demand or domestic water is the daily water demands of human life. Household water demands include drinking, cooking, bathing, washing, toilet, washing cars, watering the plants and so on (Bappenas, 2006).

To estimate the amount of domestic water demands at recent and in the future can be calculated based on population, the rate of population growth and per capita water demand. Per capita water demands are influenced by physical activity and habits or the level of welfare. Therefore, in estimating of domestic water demand, it is necessary to distinguish between water demand for residents in urban and rural areas (Bappenas, 2006).

Table 4-7 Domestic Water Demand Standard by Type of Urban and Population
(Bappenas, 2006)

Population	Domestic Water Demand (litre/people/day)
> 2.000.000	> 210
1.000.000-2.000.000	150-210
500.000-1.000.000	120-150
100.000-500.000	100-150
20.000-100.000	90-100
3.000-20.000	60-100

Non-domestic water demand, called the municipal water demands, are the water demands for city facilities, such as commercial facilities, tourism facilities, religious facilities, health facilities and other city facilities such as street cleaning, fire fighting, watering crops and urban sanitation . The amount of urban water needs can be determined by the number of urban facilities. This demands are greatly influenced by the urban dynamics and the level of the city. To estimate urban water demands of a city require data about the city's facilities is required. Another way to calculate the amount of urban demands is by using standard urban water demands based on domestic water demands (Bappenas, 2006).

The amount of urban water demands can be obtained by a percentage of total domestic water demand, ranging between 25-40% of domestic water demand. Non - domestic water demandss can be seen in the following table when there are no detailed data of municipal facilities (Bappenas, 2006).

Table 4-8 The Amount of Non Domestic Water Demands According to the Population
(Bappenas, 2006)

Population (people)	Non Domestic Water Demands (% from Domestic Water Demands)
> 500.000	40
100.000-500.000	35
< 100.000	25

Table 4-9 The Amount of Non Domestic Water Demands According to the Density (Bappenas, 2006)

Density (person/km ²)	Non Domestic Water Demands (% from Domestic Water Demands)
> 100	25 - 35
50-100	20 - 30
< 50	15 - 30

8. Water Balance

Water balance analysis is the study of equilibrium between water demand and water availability within a certain time period. The balance between supply and demand for water are determined by supply and demand of water.

Analysis of water balance is strongly associated with the nature of water resources that is always changing with time, space, quantity and quality. Step-by-step analysis of water balance can be explained as follows (Bappenas, 2000) :

- a) calculate the water availability in each watershed that will serve specific administrative areas with its specific water demand.
- b) calculate the water balance.
- c) projection of water demands that can be estimated in the future.

9. Soil Erosion

In this study, soil erosion will be calculated by using USLE (The Universal Soil Loss Equation). USLE predicts the long term average annual rate of erosion on a field slope based on rainfall pattern, soil type, topography, crop system and management practices. USLE only predicts the amount of soil loss as the results from sheet or rill erosion on a single slope and does not account for additional soil losses that might occur from gully, wind or tillage erosion. This erosion model was created for use in selected cropping and management systems, but is also applicable to non agricultural conditions such as construction sites. The USLE can be used to compare soil losses from a particular field with a specific crop and management system to "tolerable soil loss" rates. Alternative management and crop systems may also be evaluated to determine the adequacy of conservation measures in farm planning (Stone and Hilborn, 2000). The result of this analysis are determination of conservation priority area.

Table 4-10 Soil Loss Tolerance Rates (Forest Department, 1988)

Soil Erosion Class	Potential Soil Loss (tons/hectare/year)
Very Low (tolerable)	< 15
Low	15 – 60
Moderate	61 – 180
High	181 – 480
Severe	> 480

a) **USLE Equation**

$$Ea = R \cdot K \cdot LS \cdot C \cdot P$$

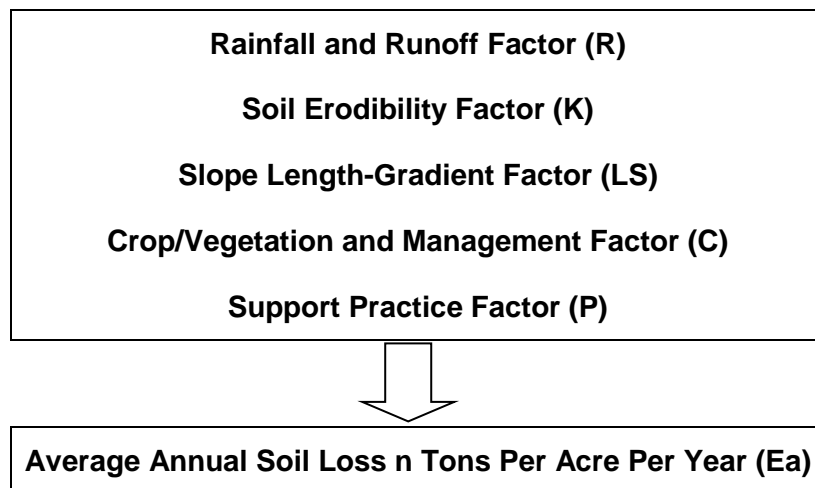


Figure 4.3 USLE Equation (Stone and Hilborn, 2000)

Where :

- **A** represents the potential long term average annual soil loss in tons per acre per year. This is the amount, which is compared to the “tolerable soil loss” limits.
- **R** is the rainfall and runoff factor by geographic location. The greater the intensity and duration of the rain storm, the higher the erosion potential.
- **K** is the soil erodibility factor. It is the average soil loss in tons/acre per unit area for a particular soil in cultivated, continuous fallow with an arbitrarily selected slope length of 72.6 ft. and slope steepness of 9%. **K** is a measure of the susceptibility of soil particles to detachment and

transport by rainfall and runoff. Texture is the principal factor affecting **K**, but structure, organic matter and permeability also contribute.

- **LS** is the slope length-gradient factor. The **LS** factor represents a ratio of soil loss under given conditions to that at a site with the “standard” slope steepness of 9% and slope length of 72.6 feet. The steeper and longer the slope, the higher is the risk for erosion.
- **C** is the crop/vegetation and management factor. It is used to determine the relative effectiveness of soil and crop management systems in terms of preventing soil loss. The **C** factor is a ratio comparing the soil loss from land under a specific crop and management system to the corresponding loss from continuously fallow and tilled land. The **C** Factor can be determined by selecting the crop type and tillage method that corresponds to the field and then multiplying these factors together. The **C** factor resulting from this calculation is a generalized **C** factor value for a specific crop that does not account for crop rotations or climate and annual rainfall distribution for the different agricultural regions of the country. This generalized **C** factor, however, provides relative numbers for the different cropping and tillage systems; thereby helping you weigh the merits of each system.
- **P** is the support practice factor. It reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The **P** factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip cropping.

In this study, each USLE factor that will be used are :

1. Rainfall And Runoff Factor (R)

Rainfall and runoff factor (R) based on RTL-RLKT will use formula :

$$R=2,21 (Rain)_m^{1,36}.$$

(Rain)_m is a monthly precipitation (cm).

2. Soil Erodibility Factor (K)

Erodibilitas soil, or soil erosion sensitivity factor, which is a good soil resistance against release and transport, mainly depending on soil

properties, such as texture, aggregate stability, shear strength, infiltration capacity, organic matter content and chemical.

Table 4-11 **K** Factor Data (Stone and Hilborn, 2000)

Textural Class	Organic Matter Content		
	Average	Less than 2%	More than 2 %
Clay	0.22	0.24	0.21
Clay Loam	0.3	0.33	0.28
Coarse Sandy Loam	0.07	—	0.07
Fine Sand	0.08	0.09	0.06
Fine Sandy Loam	0.18	0.22	0.17
Heavy Clay	0.17	0.19	0.15
Loam	0.3	0.34	0.26
Loamy Fine Sand	0.11	0.15	0.09
Loamy Sand	0.04	0.05	0.04
Loamy Very Fine Sand	0.39	0.44	0.25
Sand	0.02	0.03	0.01
Sandy Clay Loam	0.2	—	0.2
Sandy Loam	0.13	0.14	0.12
Silt Loam	0.38	0.41	0.37
Silty Clay	0.26	0.27	0.26
Silty Clay Loam	0.32	0.35	0.3
Very Fine Sand	0.43	0.46	0.37
Very Fine Sandy Loam	0.35	0.41	0.33

3. Slope Length-Gradient Factor (LS)

LS index by McCool Formula (SWCS 1993)

LS index	Slope
0,40	0-8 %
1,40	8-15 %
3,10	15-25 %
6,80	25-44,5 %

The value of LS for any length and slope can be calculated with the equation given by Wischmeier and Smith (1978).

$$LS = \left(\frac{L}{22} \right)^z (0,006541S^2 + 0,0456S + 0,065)$$

Where:

Slope = slope steepness (%)

Slope length = length of slope (m)

z = an index of S.

S (%)	$S \geq 5$	$5 \geq S \geq 3$	$3 \geq S \geq 1$	$S < 1$
z	0,5	0,4	0,3	0,2

4. Crop/Vegetation And Management Factor (C)

Factor describes the ratio between the magnitude of erosion of land with specific vegetation and with certain management of a amount of soil erosion on non-cultivated land. This factor measures the combination effects of plant and its management.

Table 4-12 Crop/Vegetation and Management Factor (Sarief, 1985; Arsyad, 1989)

No.	Land Use Type	Value (C)
1.	exposed land	1,00
2.	forest or bushes	0,001
3.	good savannah and good prairie	0,01
4.	damaged savannad and prairie	0,10
5.	paddy field	0,01

5. Support Practice Factor (P)

P is the support practice factor. It reflects the effects of practices that will reduce the amount and rate of the water runoff and thus reduce the amount of erosion. The **P** factor represents the ratio of soil loss by a support practice to that of straight-row farming up and down the slope. The most commonly used supporting cropland practices are cross slope cultivation, contour farming and strip cropping.

Table 4-13 **P** Factor Data (Stone and Hilborn, 2000)

Support Practice	P Factor
up & down slope	1
cross slope	0.75
contour farming	0.5
strip cropping, cross slope	0.37
strip cropping, contour	0.25

P is also defined as the constant index of human activities in soil conservation measures. Basic value of **P** is **1,0** given to the land without conservation activities (Suripin, 2002).

Table 4-14 **P** Factor Data (Arsyad,1989 and Seta, 1991)

No.	Support Practice	P value	
1.	no treatment	1,00	
2.	bench terrace	good construction	0,04
		medium construction	0,15
		less construction	0,35
		traditional	0,40
3.	strip vegetation	ahia	0,40
		clotararia	0,64
		contour	0,20
4.	land cultivation with contour	slope 0 – 8%	0,50
		slope 8 – 20%	0,75
		slope > 20%	0,90

b) Management Strategies to Reduce Soil Losses

Based on USLE components calculation, conservation plan can be determined to improve the quality of the land and reduce the soil erosion. USLE calculation components that can be managed is the **LS**, **C** and **P**. The examples of erosion control through the management component of **LS**, **C** and **P** are as follows (Stone and Hilborn, 2000) :

Table 4-15 Management Strategy to Reduce Soil Losses (Stone and Hilborn, 2000)

Factor	Management Strategies	Example
R	The R Factor for a field cannot be altered.	—
K	The K Factor for a field cannot be altered.	—
LS	Terraces may be constructed to reduce the slope length resulting in lower soil losses.	Terracing requires additional investment and will cause some inconvenience in farming. Investigate other soil conservation practices first.
C	The selection of crop types and tillage methods that result in the lowest possible C factor will result in less soil erosion.	Consider cropping systems that will provide maximum protection for the soil. Use minimum tillage systems where possible.
P	The selection of a support practice that has the lowest possible factor associated with it will result in lower soil losses.	Use support practices such as cross slope farming that will cause deposition of sediment to occur close to the source.

Table 4-16 Crop Type Factor (Stone and Hilborn, 2000)

Crop Type	Coefficient Factor (c)
grain corn	0.40
silage corn, beans & canola	0.50
cereals (spring & winter)	0.35
seasonal horticultural crops	0.50
fruit trees	0.10
hay and pasture	0.02

Table 4-17 Tillage Method Factor (Stone and Hilborn, 2000)

Tillage Method	Coefficient Factor (c)
fall plow	1.0
spring plow	0.90
mulch tillage	0.60
Ridge Tillage	0.35
Zone Tillage	0.25
No-Till	0.25

Table 4-18 Support Practise Method Factor (Stone and Hilborn, 2000)

Support Practice	Coefficient Factor (c)
up & down slope	1.0
cross slope	0.75
contour farming	0.50
strip cropping, cross slope	0.37

5.1 Watershed Delineation

Watershed delineation in this study used the combination of Basin 3.1, Global Mapper 12, and Arcview 3.3. Each application has its own advantage in achieving best results. The data used are Digital Elevation Model (DEM) data or Landsat. These data can be downloaded from the internet or others sources. DEM year 2006 is used in this study, and though the study itself has been started since 2010, it could be assumed that there is no major change on Buper watershed elevation as the determining parameter of watershed boundary. This assumption will be evaluated on land use change analysis.

Watershed delineation is focused on the approximation of watershed position according to Google Earth's streaming, previous study report, and field observation. They are all done in 2010 in order to gain fine data according to the similarity of occurring year.

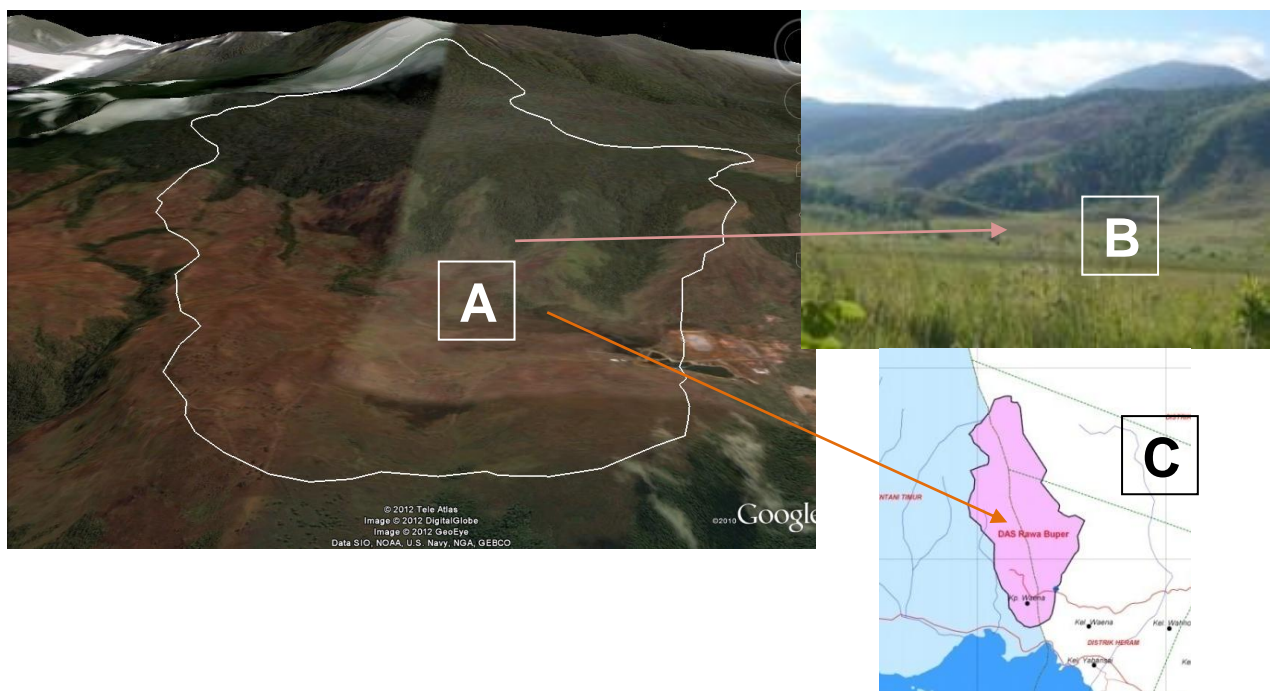


Figure 5.1 Buper Watershed Approximation by Google Earth (A), Field Observation (B) and Previous Study Report Before Watershed Delineation (C)

Primary step of watershed delineation is using Basin 3.1 and produce drainage outlets, streams, sub basin, and basin boundary according to the data from DEM. Basin 3.1 application automatically gives the watershed boundary based on stream and outlet we choose. In this study, the outlet position chosen is similar to the of small dam planning from

DPU. This position is taken because the study site is a watershed that will going to be conserved to give sustainable water supply to the embung will be build by the government.

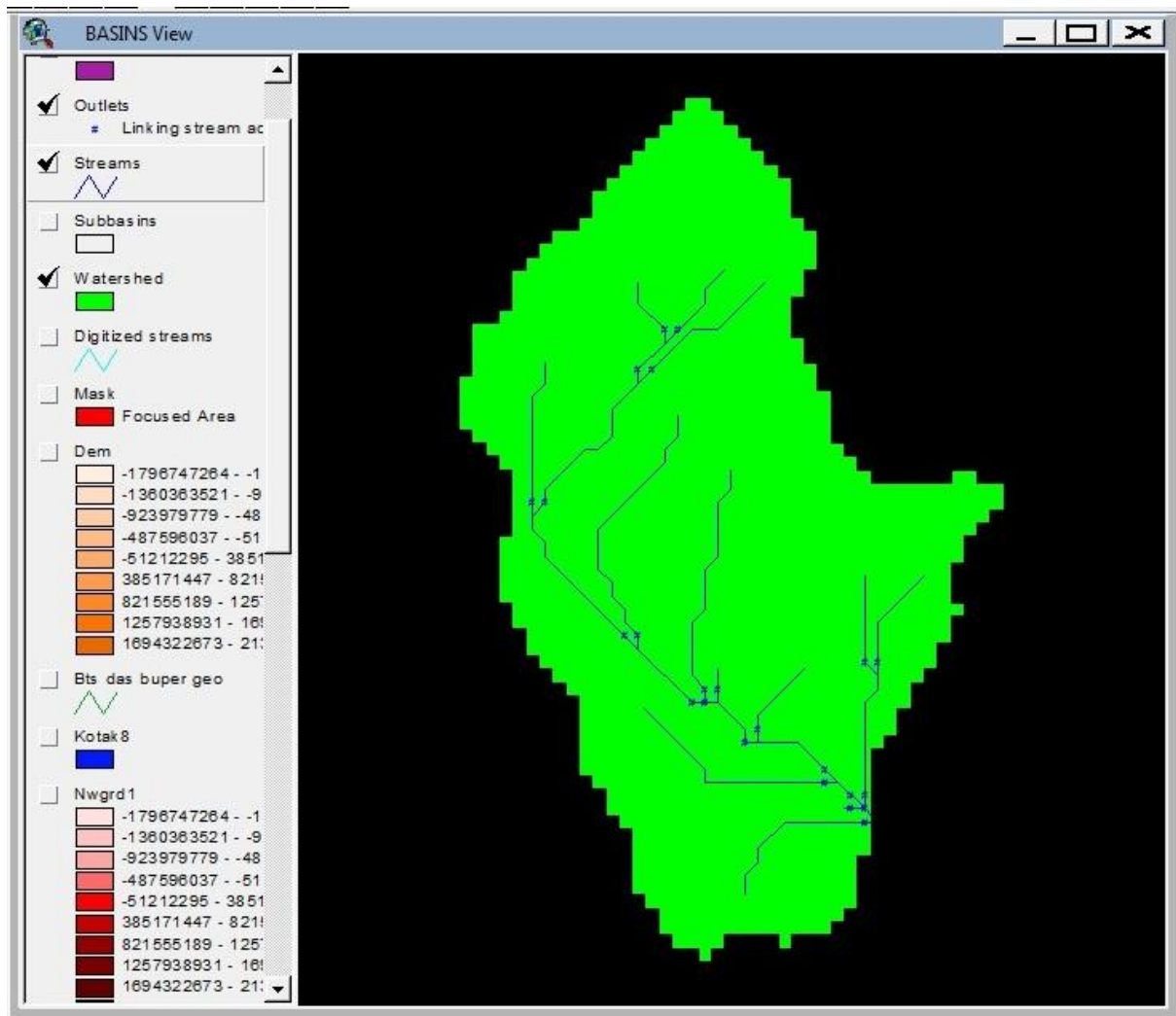


Figure 5.2 Basin 3.1 Operation for Watershed Delineation around Buper

Data and stream overview on Basin 3.1 operation reveal information about surface water flow direction on chosen watershed, and outlets on Basin 3.1 operation gives information about water output on Buper Watershed and each sub basin within. Generally, Basin 3.1 operation will give useful information about Buper Watershed as inputs for next analysis in this study.

Watershed delineation can also be done using Global Mapper 12. This application also provides automatic watershed delineation feature to study site neighborhood. The result is smoother and it's easier to use, but cannot give information about flow location and preferred outlets. Global Mapper cannot make watershed boundary according to the stream we pick. The data needed for Global Mapper 12 is Land Sat data or DEM. The result of this operation can be used as reference to Basin 3.1 operation result.

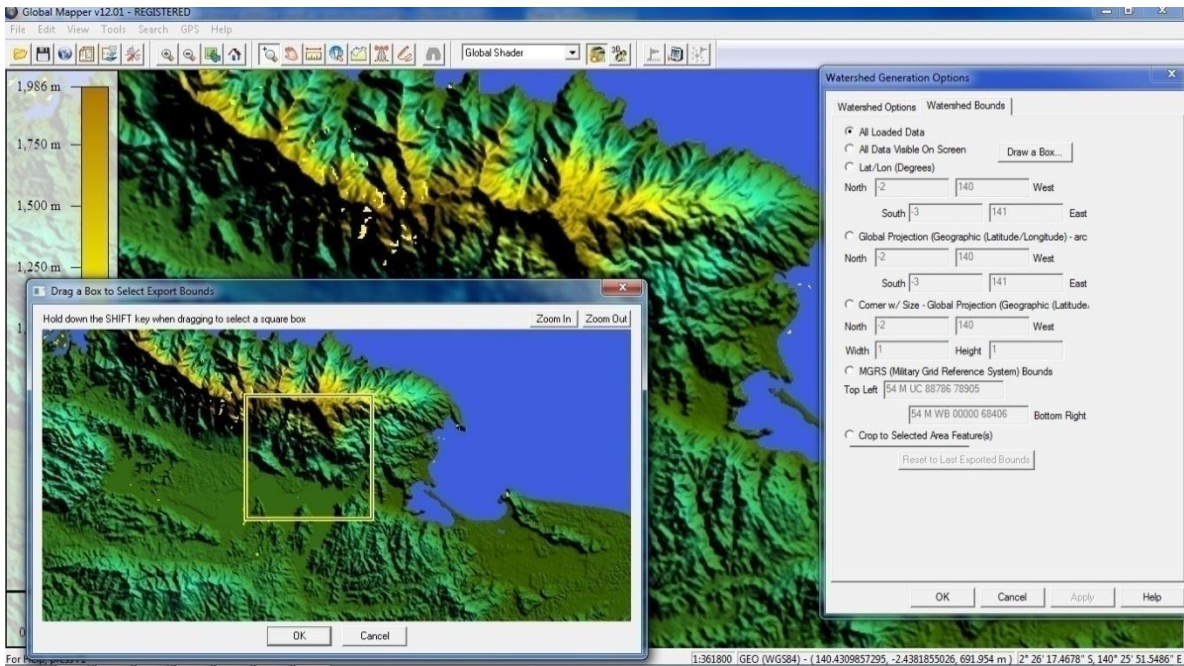


Figure 5.3 Global Mapper 12 Operation Watershed Delineation around Buper

Both through Basin 3.1 and Global Mapper 12, don't have good layout yet, thus that it needs re-digitalization using Arcview 3.3 to repair the results from previous applications and make geographical information system from it. This information system is crucial for the next analysis that need spacial analysis. After the editing using arcView 3.3 we get Buper watershed boundary of 12,6 km² as a result of watershed delineation.

In order to synchronize out the watershed delineation with the actual condition, the watershed boundary is exported to Google Earth and compared with the field observation result within the same coordinates.

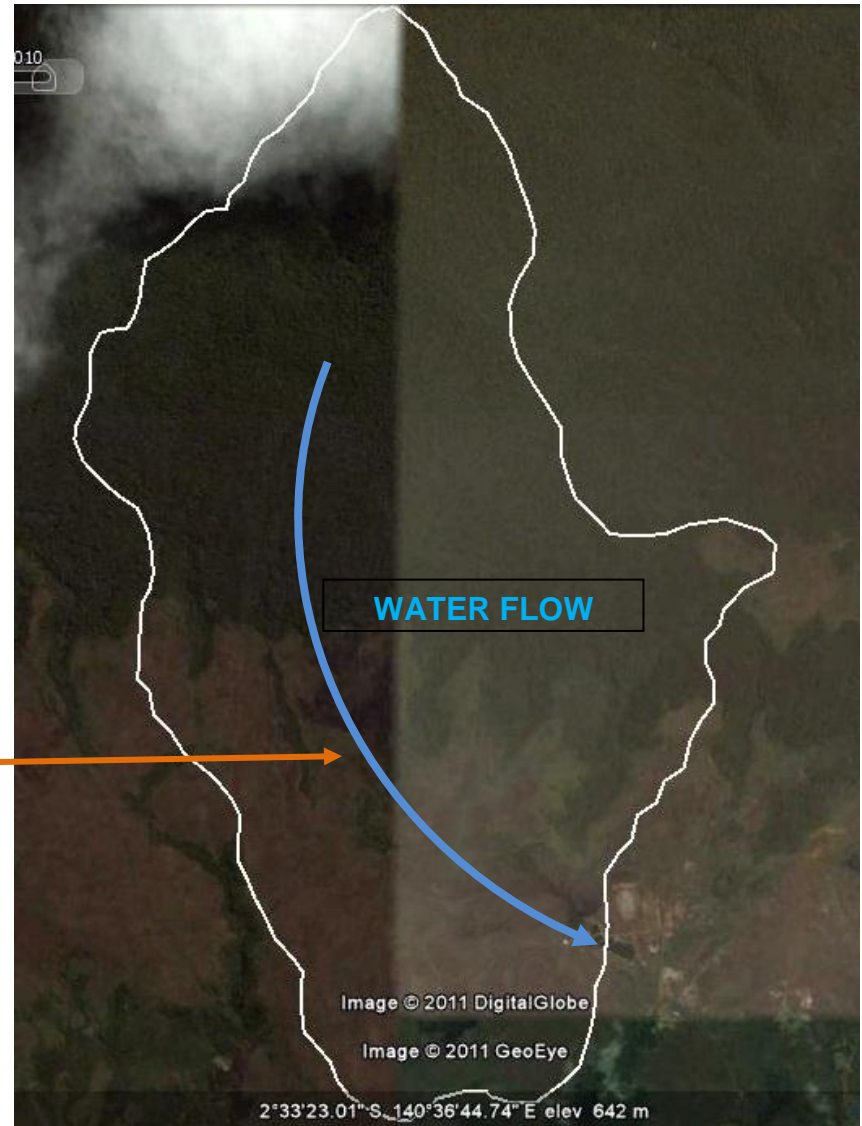
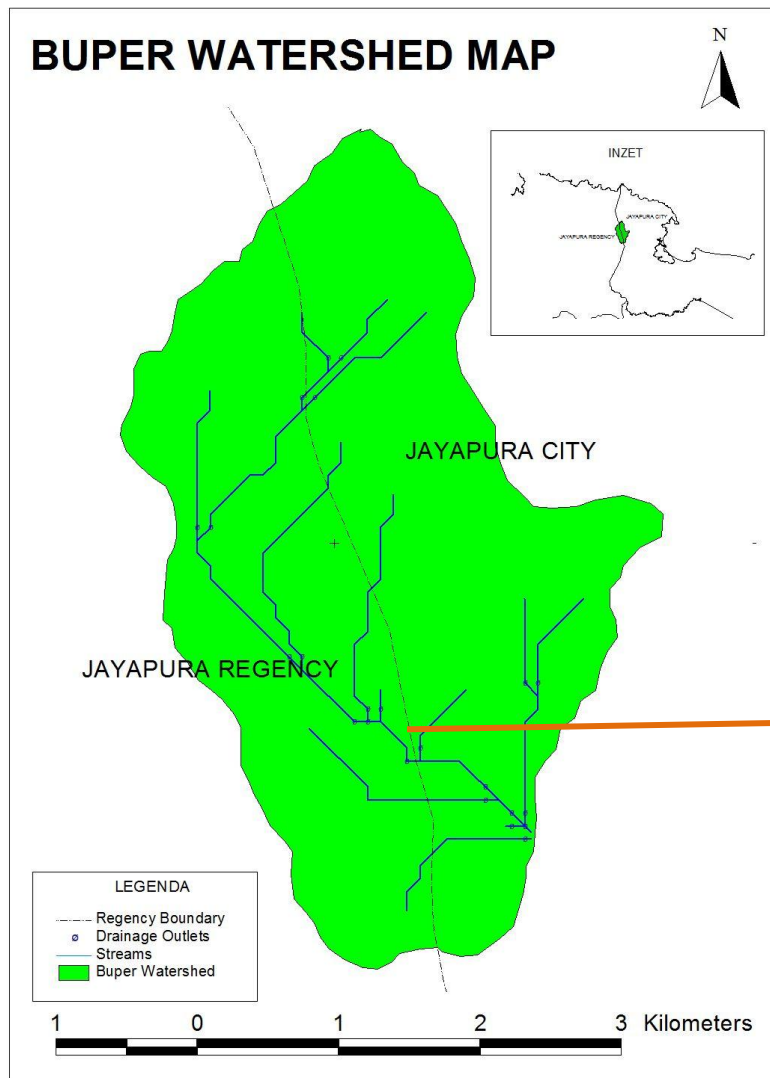


Figure 5.4 Buper Watershed Map and Google Earth Plotting

5.2 Topography Analysis

Topographic analysis is carried out after the watershed delineation, because this analysis will need the perimeter from the object area. The result of this analysis are contour and slope, these are necessary in land suitability analysis and soil erosion. Topographic analysis could help understand the surface condition of Buper watershed.

5.2.1 Contour

The making of contour map requires DEM data as main input for Global Mapper 12, to produce contour vector on the study site. In Global Mapper, the perimeter area is made broader than the existing water boundary because this operation can not give watershed boundary from Arcview 3.3 application.

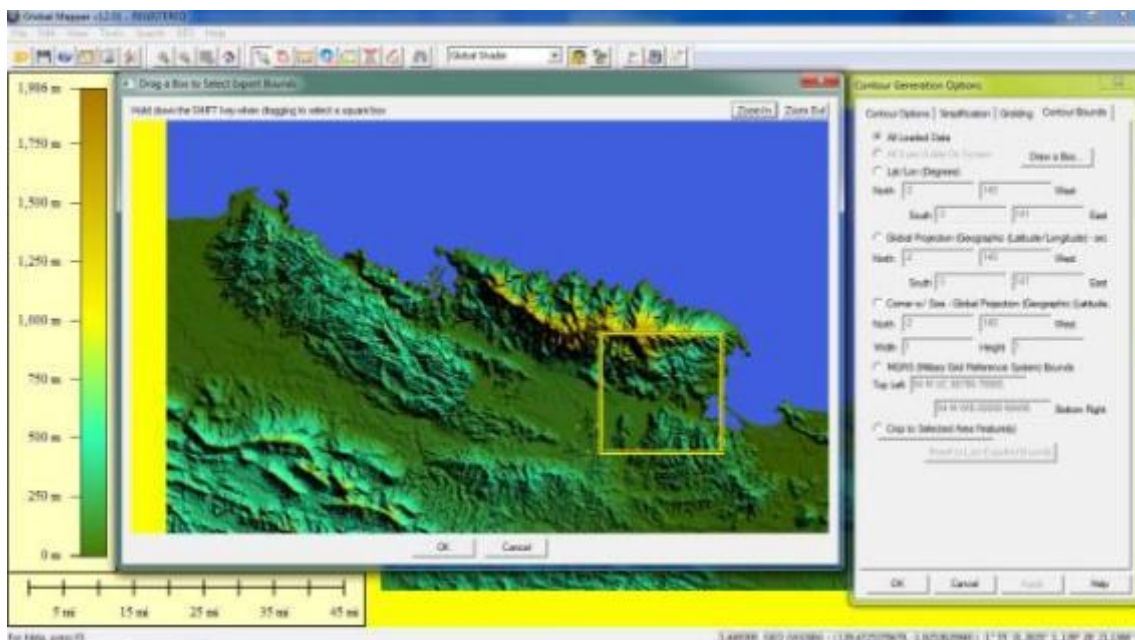


Figure 5.5 Global Mapper 12 Operation for Contour

The result of contour vector in Global Mapper 12 will be treated in Arcview 3.3 by giving existing watershed boundary and adding more information that required. In this process, the contour interval used is 10 meters.

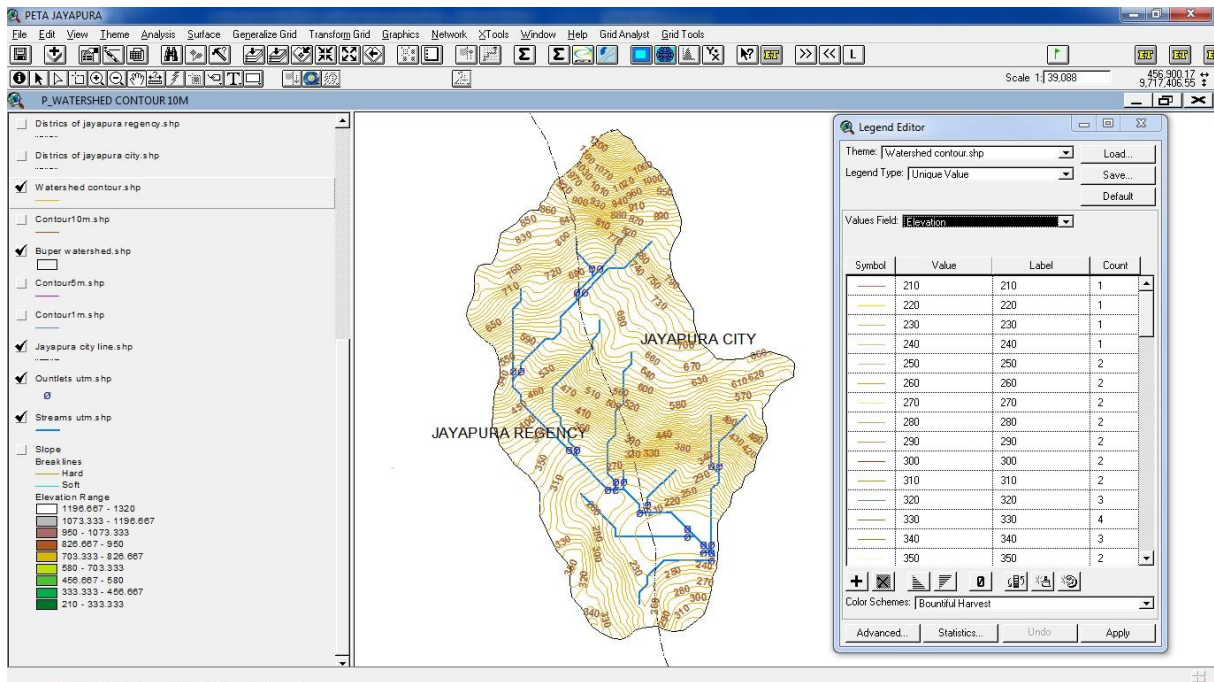


Figure 5.6 ArcView 3.3 Operation for Contour

Topographic of Buper watershed has highest elevation in north and going down to south. The north area has sheer topography with high elevation difference and maximal elevation of 1320 MSL, while in the south the topography is sliding down from the hills to valley where the waters met with lowest elevation of 220 MSL.

BUPER WATERSHED CONTOUR

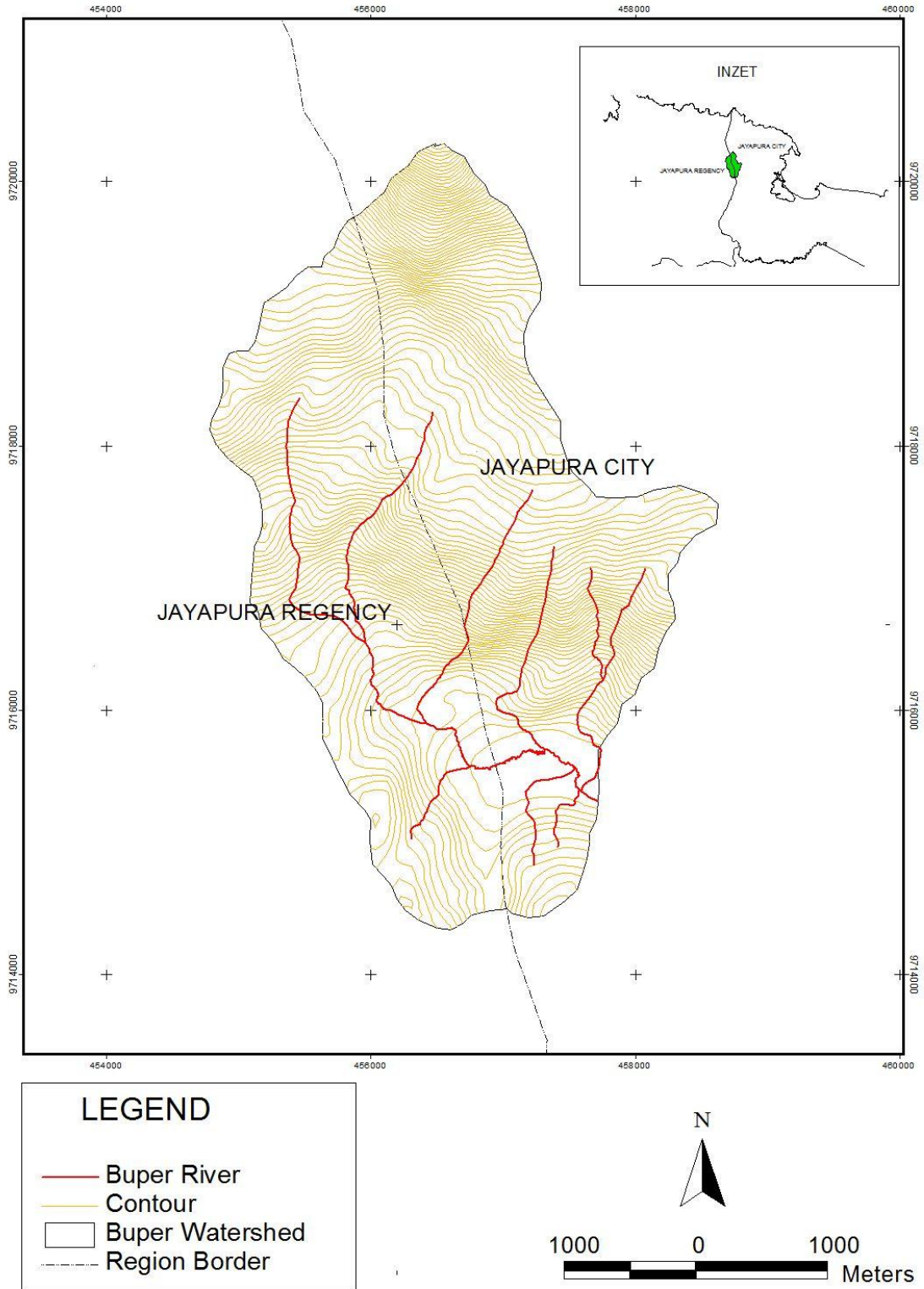


Figure 5.7 Contour of Buper Watershed

5.2.2 Slope

Contour map data base can be used to produce slope map and its data base to help the calculation and further analysis by using ArcView 3.3. Slope classification in this process is made according to slope classification for land use suitability analysis and soil erosion analysis.

The result of ArcView 3.3 process informs that majority of Buper Watershed have slope 8-15% in area of 4,87 km² , and 0-8% in area of 3,72 km² , where most of them located in the downstream of Buper Watershed.

Table 5-1 Slope Classification of Buper Watershed

ID	Gridcode	Slope (%)	Area	
			(Hectares)	(Km ²)
66	1	0-8	372.123	3.72
5	3	15-25	351.963	3.52
3	4	25-40	48.325	0.48
1	2	8-15	486.701	4.87
2	5	> 40	0.203	0.00

The result from ArcView shows that maximum slope of Buper Watershed, reached more than 40%, within a small area of approximately 0,203 Ha. The result of the slope analysis are required to make land suitability scoring and soil erosion analysis according to the slope classification. The result of ArcView 3.3 process to Buper Watershed slope can also be seen from Figure 5.8 :

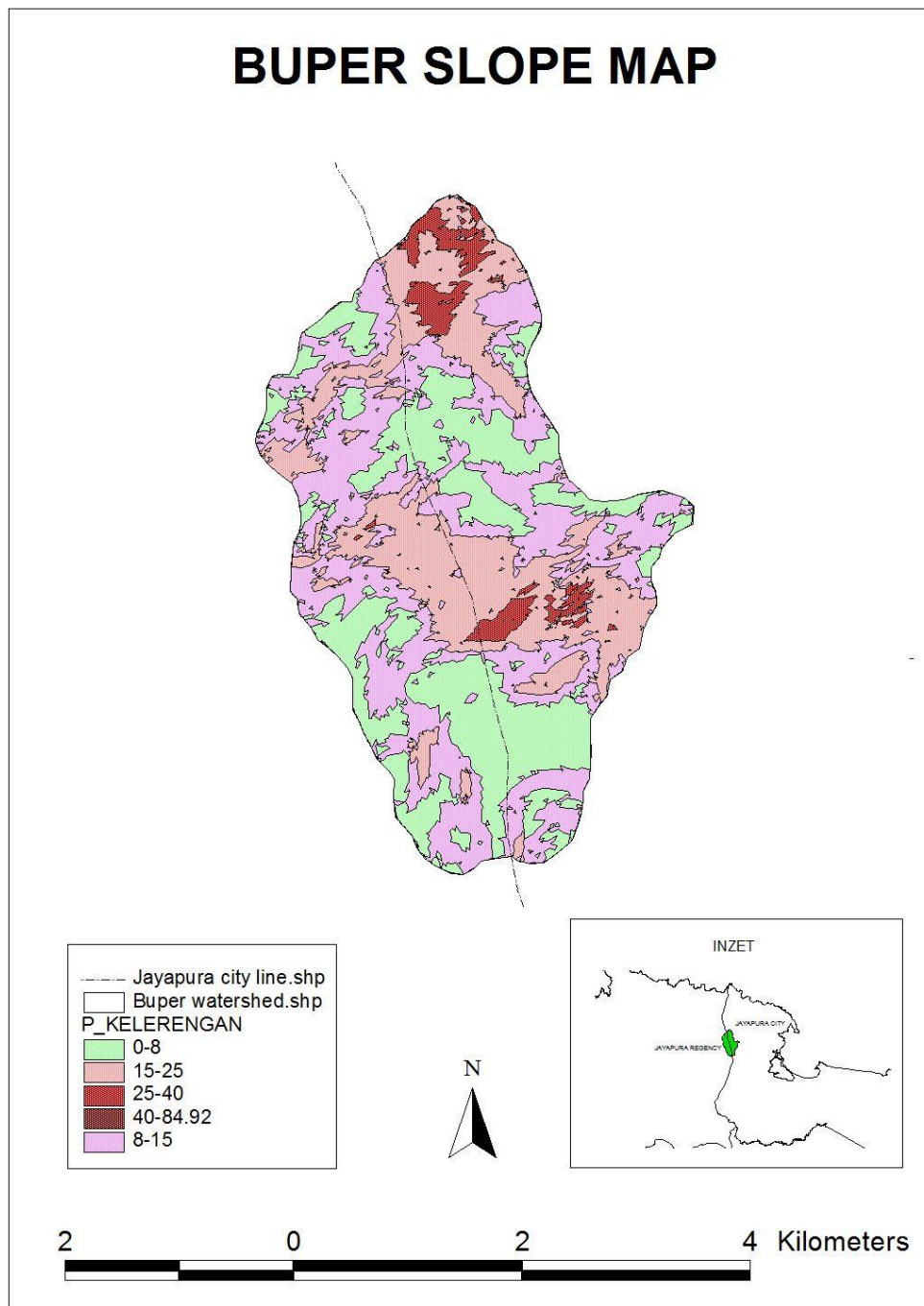


Figure 5.8 Buper Watershed Slope

5.3 Landuse Change Analysis.

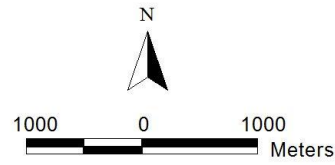
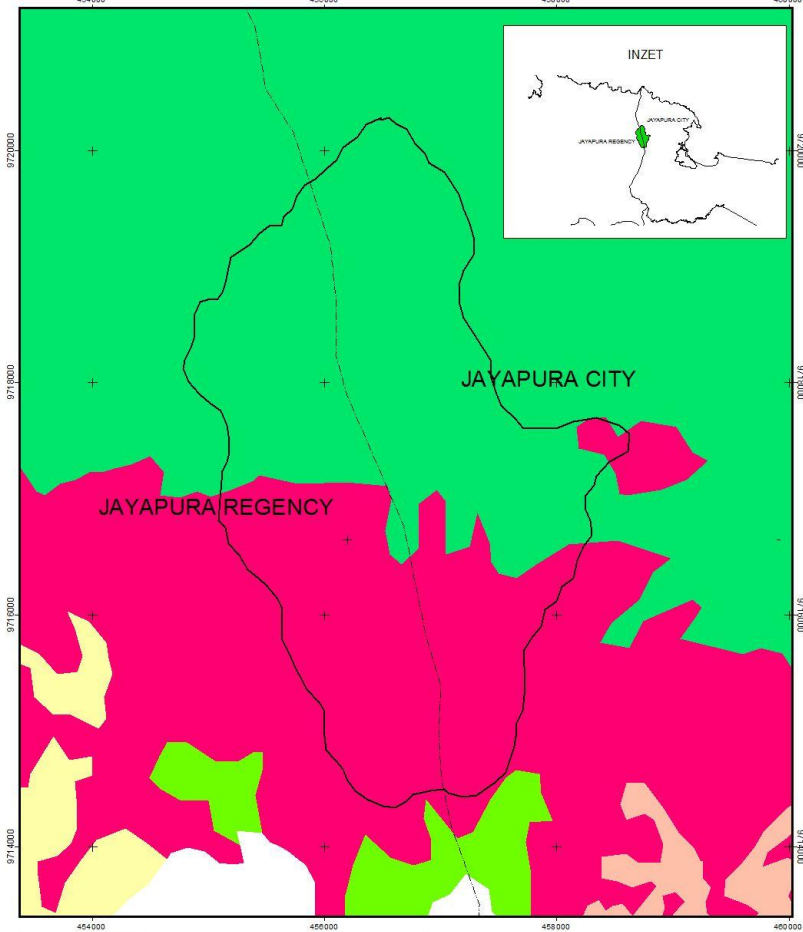
Land use change analysis used to comprehend the area changing trends that occurs in Buper Watershed. Land use change analysis is carried out by identifying area change in study site annually. Data are obtained from land cover map and Google Earth. The land cover map is acquired or downloaded from related agency.

Through Global Mapper 12 operation and ArcView 3.3, land cover map in 2000 and 2005 are obtained for a data input in land use change analysis, land use suitability, and further analysis.

Through ArcView 3.3 operation on the land cover map 2000 and 2005, in general Buper watershed land cover are primary-secondary forest and savannah. In land cover 2000, the primary- secondary forest is 7,39 km² wide, while the savannah area is 5,21 km², which means that 58,7% of Buper Watershed is forest. In 2005 landcover, primary-secondary forest is 7,8 km², while the savannah is 4,8 km², which means that 61,9% of Buper Watershed is forest. Land cover of Buper watershed generally dominated by forest during 2000-2005 and its broadness has been increasing about 3,2 % in five years.

The 2009 and 2010 land cover as one part of land use analysis was obtained from Google Earth combined with ArcView 3.3 to make a land cover map and data base 2010. It was done by exporting watershed boundary from SHP format to kmz format using Global Mapper 12 so that it could be used in Google Earth. To give an accurate result, it was evaluated with study site condition through observatory documentation according to the position or coordinate of Google Earth and field observation. Based on the application, the result emerge on Buper watershed land cover in 2009 and 2010 shows forest 7,78 km² and savannah 4,73 km². Based on the application, a result emerge on Buper watershed land cover in 2009 and 2010 shows forest 7,8 km² and savannah 4,8 km².

BUPER LAND COVER 2000 MAP



BUPER LAND COVER 2005 MAP

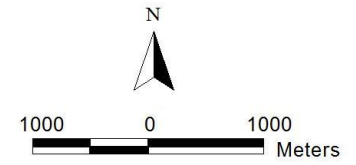
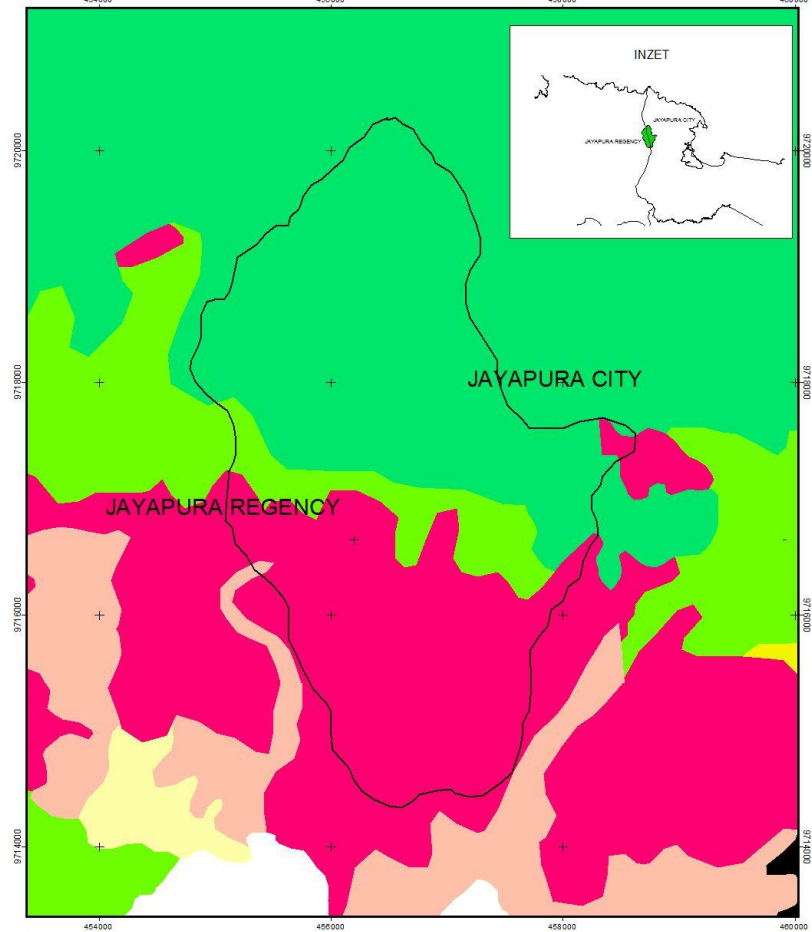


Figure 5.9 Buper Land Cover 2000 and Buper Land Cover 2005

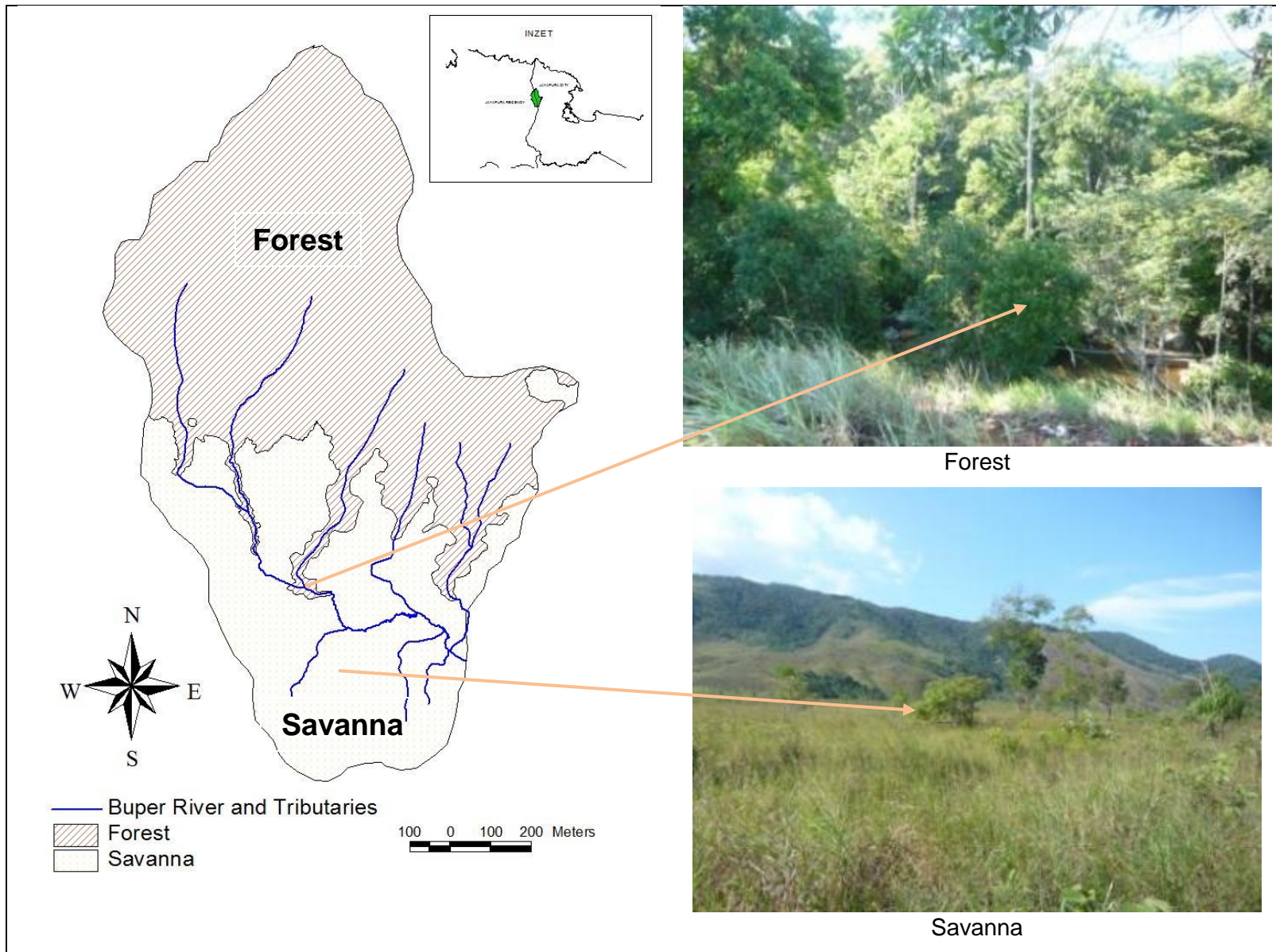


Figure 5.10 Buper Watershed Map and Field Condition 2010 Synchronized

According to land cover maps that has been made, the conclusion that can be taken is land use change in Buper Watershed is slow. In general, land cover can be classified into primary-secondary forest and savannah. Here are the land cover change in year 2000, 2005, 2009, and 2010 :

Table 5-2 Land Use Change

Land Cover	Year			
	2000	2005	2009	2010
Primary and Secondary Forest (km ²)	7,39	7,84	7,78	7,79
Savanah (km ²)	5,21	4,86	4,73	4,82

Average land cover change to Buper Watershed is 0,04 km²/year. Primary and secondary forest has been expanding to 0,04 km²/year, while the savannah has been shrinking to 0,04 km²/year.

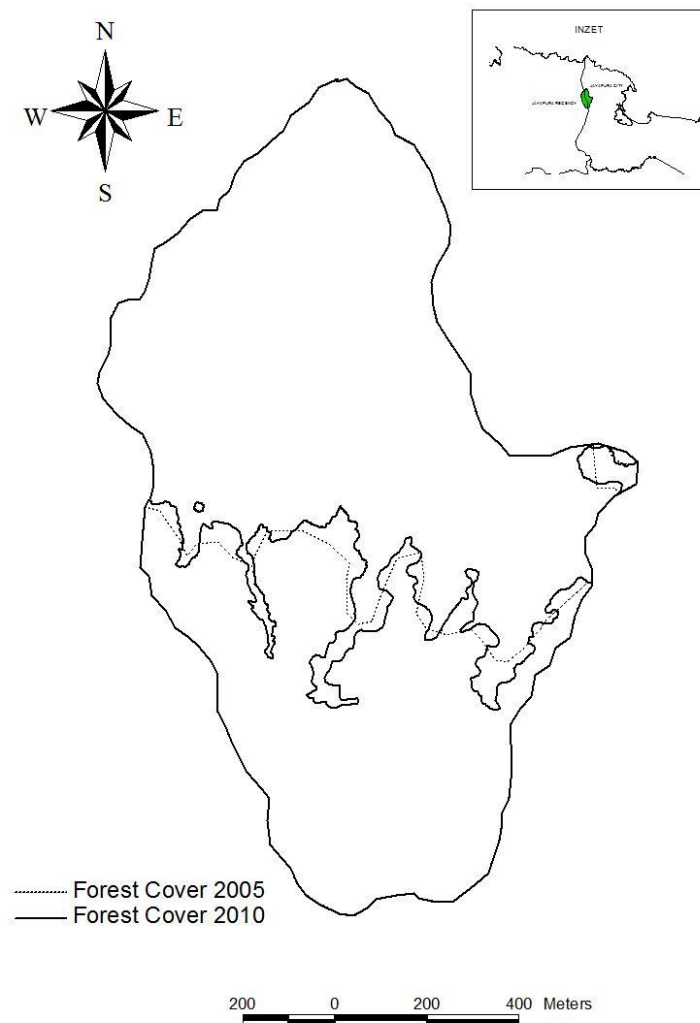


Figure 5.11 Forest Cover 2005-2010

The forest expansion has a pattern following stream where sediments are concentrated. The change to land cover can be seen on Figure 5.15 :

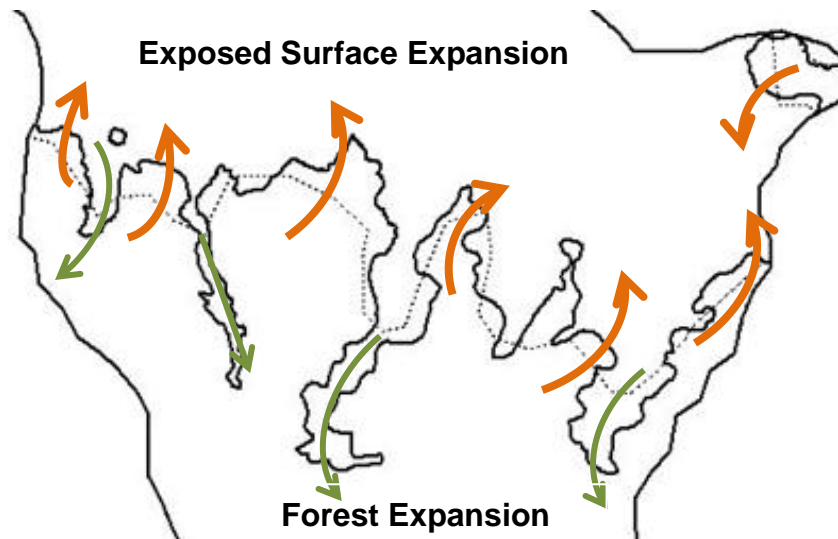


Figure 5.12 Land Cover 2000-2010

The expansion of exposed surface area and the expansion of sedimentation area related closely to erosion rate. The area and the rate of erosion on Buper Watershed will be studied further in soil erosion analysis.

5.4 Geological Analysis

Geological analysis has purpose to get useful geological information by geological map interpretation and study site observation. Geological analysis that would be done include identification of rock formation, identification of soil type and identification of non-groundwater basin.

5.4.1 Identification of Rock Formation

Identification of rock formation is achieved with overlay from watershed boundary with rock formation map. Input data is processed using ArcView 3.3 to get data and layout of rock formation on Buper Watershed.

Geologic formation of Buper watershed consist of ultramafic rock, mafik rock, and makats formation. Figure 5.13 is geological formation map of Buper Watershed as resulted from ArcView 3.3 processing :

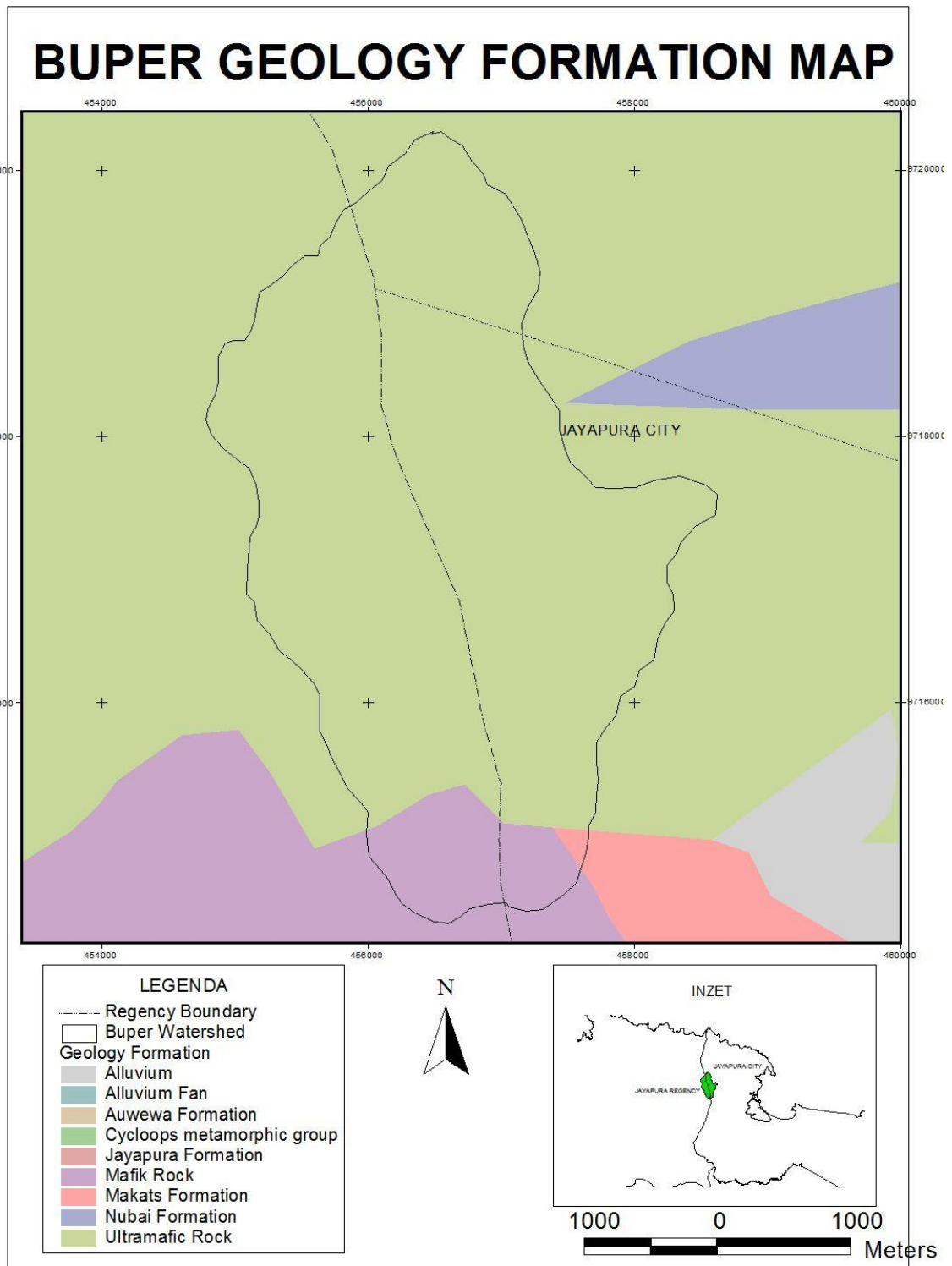


Figure 5.13 Geological Formation Map at Buper Watershed

Igneous rocks form from magmas, and most magmas are associated with plate tectonics. Mafic (basaltic) and ultramafic magmas form along the divergent mid oceanic

ridges and are major components of new oceanic crust. More felsic magmas, such as andesites and rhyolites, are associated with the edges of continental crust at subduction zones along converging plate boundaries. Whether a magma are intermediate or felsic may depend on the relative amounts of oceanic crust and continental crust in the subduction zone that melt to form the magma. The great abundance of granitic intrusions in continental crust is thought to be related to the partial melting of the lower continental crust (Crawford, 1998, p. 21). Mafic rock is an igneous rock containing approximately 50 percent silica and relatively high percentages of iron, magnesium, and calcium. Ultramafic rock consisting almost entirely of ferromagnesian minerals and having no feldspars or quartz (Crawford, 1998).

According to the history and mineral contents, ultramafic and mafic do not contain stable minerals (e.g. quartz and silica) that will affect their corrosion, it will tend to be clay. Clay is an impermeable material that water can not seep through percolation. But clay is a material with high soil moisture, then this layer can be a habitat for some plant species according to the thickness of the soil, while its bedrock is an impermeable rock too (Dirmawan, 2011).



Figure 5.14 Documentation Mafic Rock



Figure 5.15 Mafic Rock Observation Position



Figure 5.16 Documentation Ultra Mafic Rock



Figure 5.17 Ultramafic Observation Position

5.4.2 Identification of Soil Type

This soil type identification is performed by overlay of watershed boundary and soil map acquired from related agency. The input data would be processed using ArcView 3.3 to get data and layout of rock formation on Buper watershed.

Soil type of Buper watershed in accordance to FAO consists of Renzina and Eutric Fluvisol while in accordance to USDA consists of Rendoll and Eutric Entisol/Inceptisol. The broad of each soil type are rendoll of 11,5 km² and inceptisol of 1,1 km². Here is the soil map resulted from analysis:

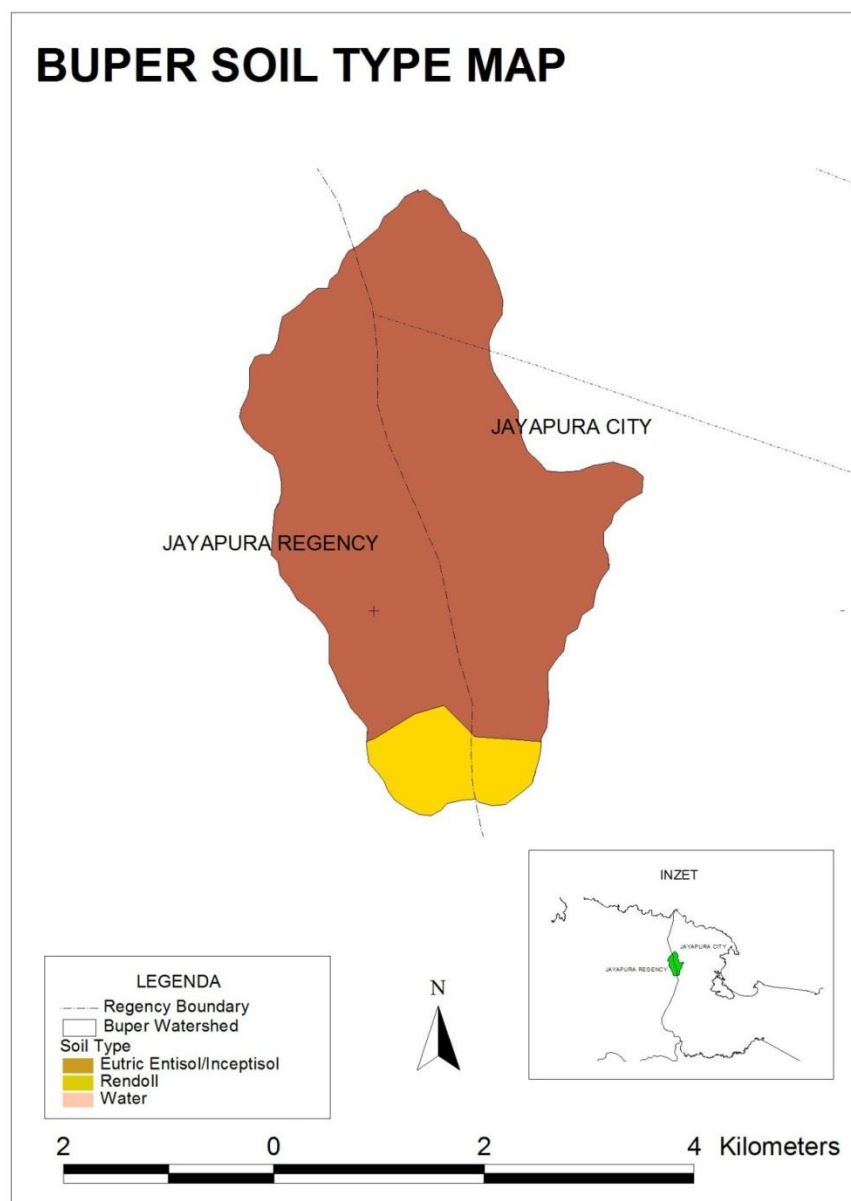


Figure 5.18 Soil Type at Buper Watershed

1. Inceptisol

Inceptisol, one of the 12 soil orders in the U.S. Soil Taxonomy. Inceptisols are soils of relatively new origin and are characterized by having only the weakest appearance of horizons, or layers, produced by soil-forming factors. They are the most abundant on Earth, occupying almost 22 percent of all non polar continental land area. Their geographic settings vary widely, from river deltas to upland forests to tundra environments. For example, they occur in the Mississippi valley, central Europe, the Amazon region, north eastern India, Indonesia, and Alaska. They are usually arable with appropriate control of erosion or drainage (wikimedia, 2011)

Inceptisol soil profiles give some indication of **clay minerals**, metal oxides, or humus accumulating in layers, but such accumulation is not sufficient to classify the soil into an order defined by characteristic surface or subsurface horizons. They commonly are found either with underlying weathering-resistant parent material (for example, quartzite or siliceous sandstone) or in topographic settings conducive to soil erosion or water logging (www.britannica.com, 2011).

The central concept of Entisols is that of soils that have little or no evidence of the development of pedogenichorizons. Most Entisols have no diagnostic horizons other than an ochric epipedon. Entisols may have any mineral parent material, vegetation, age, or moisture regime and any temperature regime, but they do not have permafrost. The only features common to all soils of the order are the virtual absence of diagnostic horizons and the mineral nature of the soils (Soil Survey Staff, 1999).

2. Rendoll

Rendoll composition on Buper Watershed, according to mapping operation result by ArcView 3.3 has the widest, that is, 11,5 km², therefore it can be said that soil type on Buper watershed is dominated by Rendoll.

These are the Mollisols that are of humid regions and that formed in highly calcareous parent materials, such as limestone, chalk, drift composed mainly of limestone, or shellbars. These soils have a mollic epipedon that rests on the calcareous parent materials or on a cambic horizon that is rich in carbonates. A few of the soils are so rich in finely divided lime that the mollic epipedon has a color lighter than normal but is nevertheless rich in dark colored humus and is within the limits of a mollic epipedon. Rendolls have a cryic soil temperature regime or a udic moisture regime, or both. They formed under forest vegetation or under grass and shrubs.

Rendolls are the Mollisols that (Soil Survey Staff, 1999; soils.cals.uidaho.edu, 2011) :

1. Have a mollic epipedon that is less than 50 cm thick;
2. Have a CaCO₃ equivalent of 40 percent or more on the basis of the whole soil, including coarse fragments as much as 7.5 cm in size in or directly below the mollic epipedon;
3. Do not have an argillic or calcic horizon;
4. Have a udic moisture regime or a cryic temperature regime, or both;
5. Do not have both aquic conditions and the colors defined for Aquolls.

To reinforce the soil type information on Buper Watershed, field observation and sampling are executed according to mapping analysis which has been applied through ArcView 3.3 toward soil type map. Observation and sampling are executed on land opening to recognize the soil and rock layers.

According to the history and mineral contents, Rendoll Soil and Inceptisol Soil Type tend to be clay. Clay is an impermeable material that water can not seep through percolation. But clay is a material with high soil moisture, then this layer can be a habitat for some plant species according to the thickness of the soil, while its bedrock is an impermeable rock too (Dirmawan, 2011).

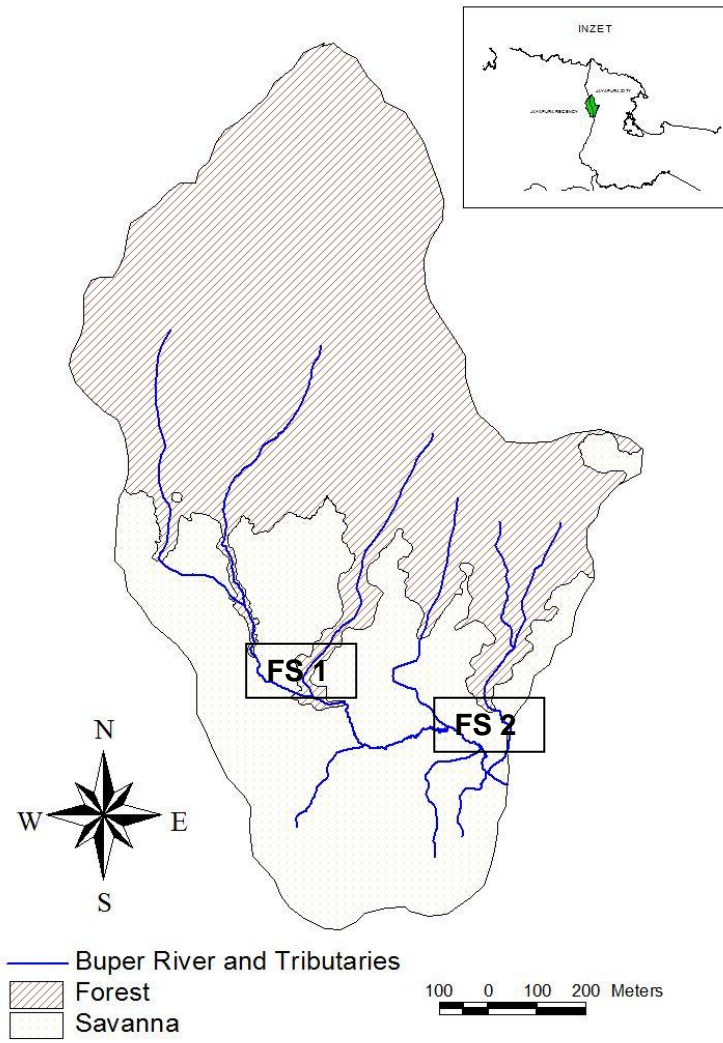


Figure 5.19 Position of Field Observation and Sampling



Figure 5.20 Rendoll Soil Type (FS1)



Figure 5.21 Inceptisol Soil Type (FS2)

5.4.3 Identification of Non-Groundwater Basin

Geologically, non-groundwater basin is generally in the form of impermeable rock with a layer of soil thin on top (Kodoatie & Sjarief, 2010). Groundwater basin is an area underlain by permeable materials. The material is capable of furnishing a significant availability of groundwater to wells or storage a significant amount of water (California Department of Water Resources, 2003), so non-groundwater basin is an area underlain by impermeable material such as impermeable bedrock, clay etc. In observation at study site, there are many identification of non-groundwater basin evidence. Figure below would describe a non-groundwater identification at study site.

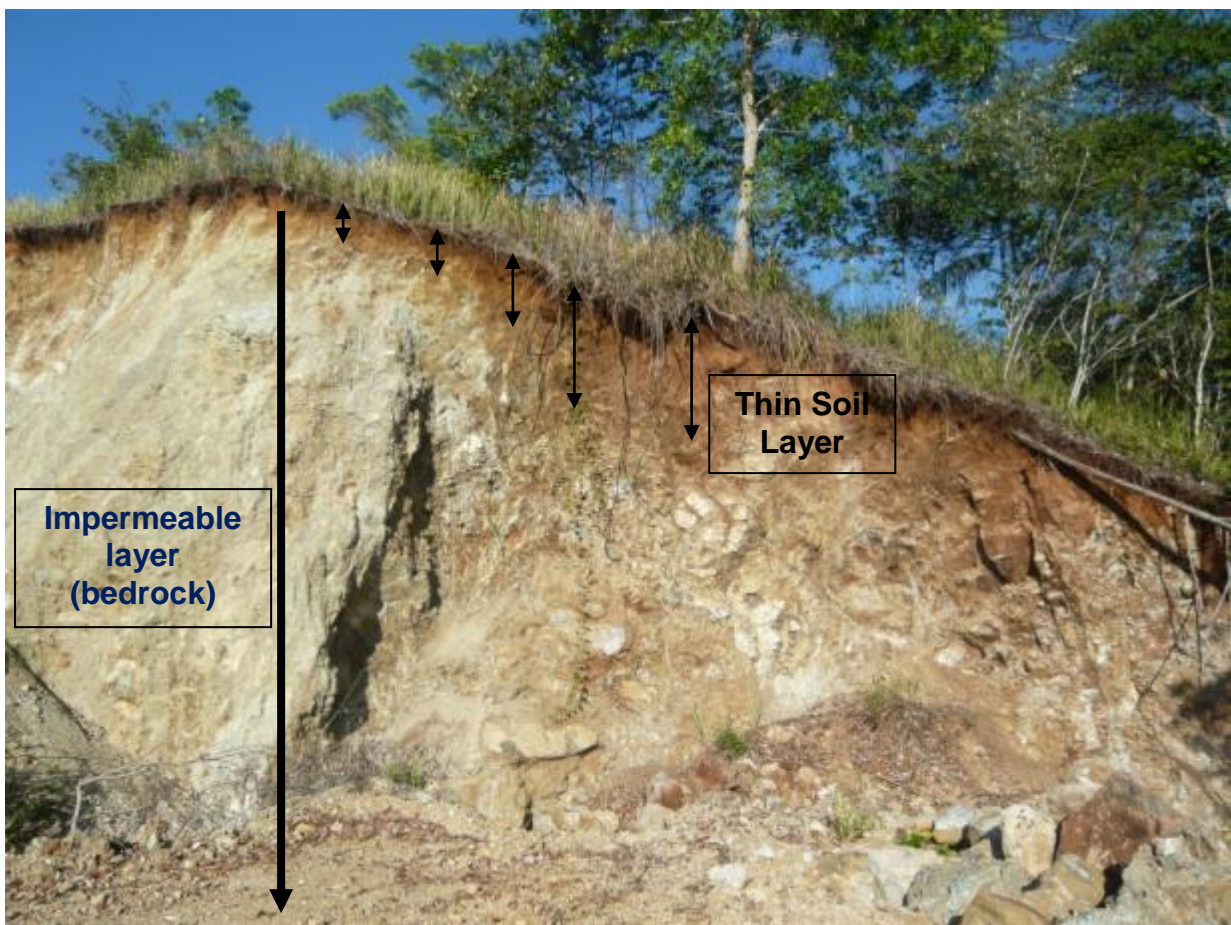


Figure 5.22 Non-Groundwater Basin Layer

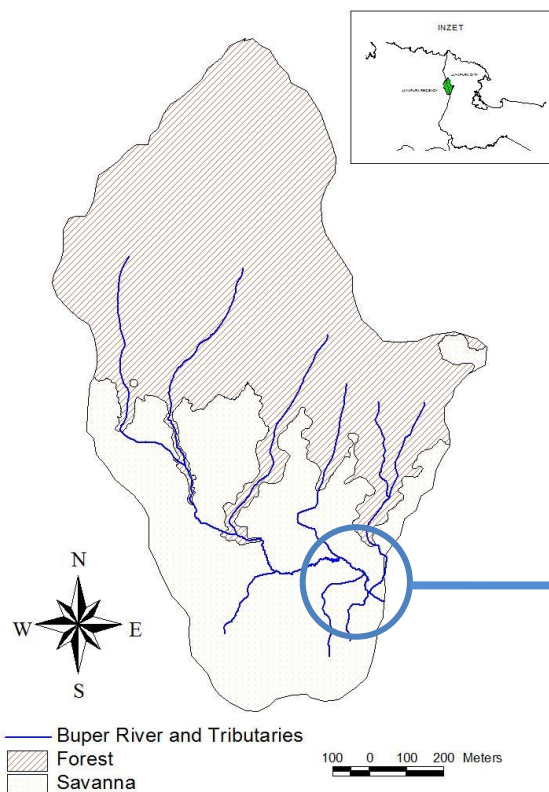


Figure 5.23 Impermeable Layer (Bedrock)



Figure 5.24 Thin Soil Layer

According to field analysis, it can be proved that on Buper Watershed rock layer below the soil layer are mafic and ultramafic layer which are impermeable, so that the water can only infiltrate through the soil layer. On this thin soil layer which has clay, plant can grow according to the thickness of the soil. In savannah area, thin soil layer has a thickness around 3-25 cm, and only in the area where sediments are concentrated, soil layer has a thickness around 30-50 cm.

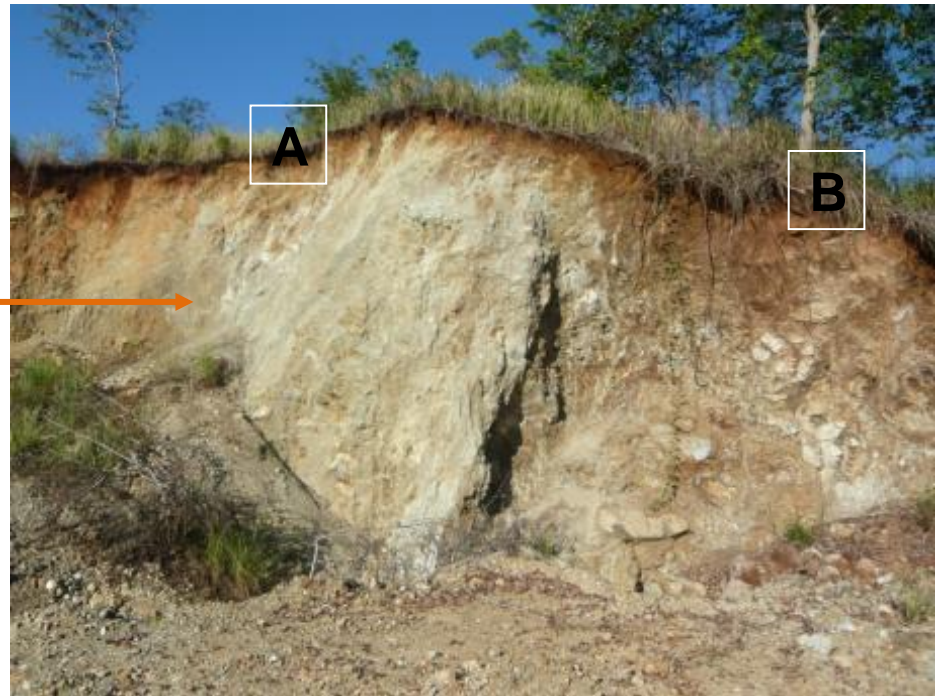


Caption:

- Application Basin 3.1 provides information about the simple direction of stream, but provides sufficient information about the concentration of sediment that affect the thickness of the soil, forming primary and secondary forest.
- At the outlet, there is water retention because no percolation and water run-off out of Buper Watershed through the creek.



Figure 5.25 Correlation between Stream and Non-Groundwater Basin Watershed



Caption:

- A: on the savanna, with the thickness of the thin soil, the plants that can live is grass or shrubs that are able to live with a limited soil. Clay provides water in a limited capacity.
- B: on the savannah, with the thick ness of the soil between 10–25 cm, the plant that can grow is a small plant /root fibers according to the thickness of the existing soil.
- C: on the primary and secondary forest, tall and large plants can grow because the concentration of soil in the area of sedimentation and stream flow.

Figure 5.26 Correlation Between Soil Thickness and Vegetation in Non-Groundwater Basin Watershed

When forest or vegetation covered the area of non-groundwater basin, the forests or vegetation will maintain the soil layer naturally. In case, the top soil absorb thin of water so that the water is stored more and it is more humid than in groundwater basin. In non-groundwater basin, the water in the top soil layer as a source of plant life has more volume than in groundwater basin area, so under natural conditions, forests or vegetations in the area of non-groundwater basin are more fertile than in the groundwater basin because in the groundwater basin, water can seep up to hundreds of meters below the soil surface. It bring percolation into the lower part. This is the way the local natural conditions in non-groundwater basin area will be relatively more fertile than in the groundwater basin (Kodoatie & Sjarief, 2010).



Figure 5.27 Opened Forest 15/8/2006



Figure 5.28 Opened Forest 23/6/2010

Based on observations made by the google earth imagery 2006 until 2010, there were no recovery of forest for 5 years. Existing slope of that area approximately were 8-15%. In other areas that have been opened or eroded, the approximately slope were 25-40%, opened area is the extended go toward the upstream. Exposed surface expansion of the land that had beed eroded could be seen in the following Figure 5.29 :

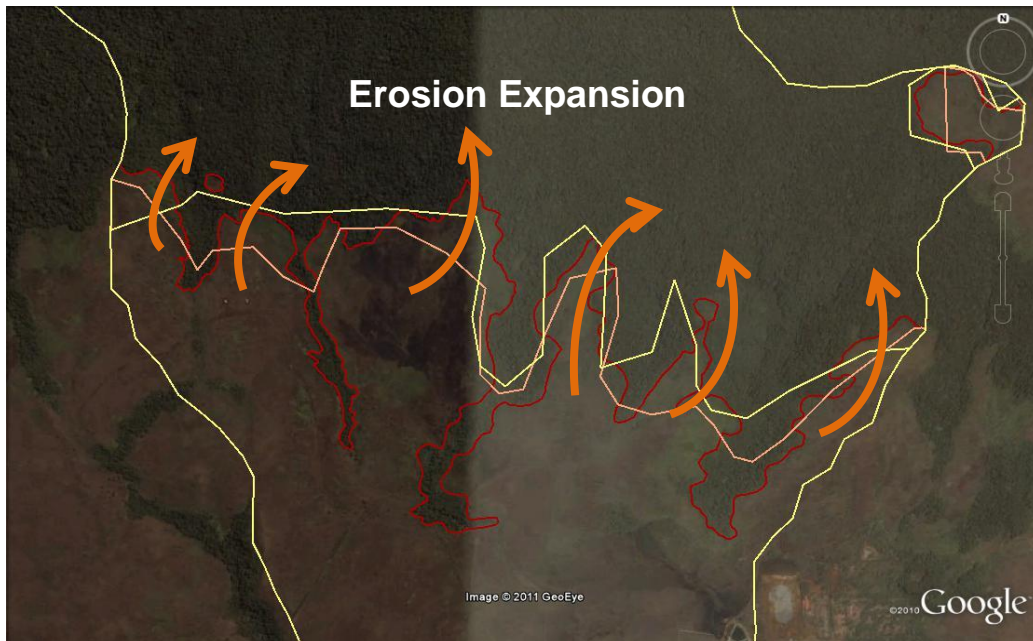


Figure 5.29 Erosion Expansion

Based on the facts and analysis of the condition, it could be concluded that in the area of non- groundwater basin, forest recovery is difficult when the land have been eroded or have been exposed. This condition is occurs because the soil / clay where the plant grew was lost due to erosion. Exposed surface expansion that occur go toward upstream because the increasing of erosion rate due to the slope of land. The erosion rate will be further analyzed using the USLE.

5.5 Landuse Suitability Analysis

Landuse suitability analysis is performed to find the most suitability land use based on the characteristics of the area. This process uses Global Mapper 12 and ArcView 3.3 operation to process the data and maps. Method that will be used is BRKT. This method require several criteria factor to running the analysis, there are soil type, precipitation intensity and slope. Each criteria have a scoring for their specific classification. Total scoring of each criteria will determined the recommendation of Buper Watershed land use. Each of the criteria and their scoring will be discussed in the following section.

5.5.1 Soil Type

Soil type is related to soil erosion. For each type, scoring is given based on the level of soil sensitivity of erosion, soil type and their scoring were as Table 5 3 :

Table 5-3 Soil Type and Scoring (Mentan, 1982)

Class	Soil Type	Scoring
I	Alluvial, Glei, Planosol, Hidromerf	15
II	Latosol	30
III	Brown Forest Soil, Non Calcic Brown Mediteran	45
IV	Andosol, Laterit, Grumosol, Podsol, Podsollic	60
V	Regosol, Litosol, Organosol, Renzina	75

Soil type at the Buper Watershed are Rendoll / Renzina and Inceptisol / Alluvial, for Rendoll scoring is 75 and for Inceptisol scoring is 15. These value will be used as data base of ArcView 3.3 for landuse suitability analysis.

5.5.2 Precipitation Intensity

For an annual precipitation of Buper Watershed is taken by interpolating two closest precipitation stations, namely Dock II station and Sentani station.

Table 5-4 Interpolation Monthly Precipitation Sentani - Dok II Station

Year	Monthly Precipitation (mm)												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Agt	Sep	Oct	Nov	Dec	
2003	167	209	174	71	110	138	172	189	187	120	120	213	1,869
2004	181	151	108	176	129	134	83	59	70	139	217	71	1,518
2005	115	156	365	219	93	63	81	146	160	87	50	228	1,764
2006	262	158	438	313	122	191	191	179	300	129	136	69	2,488
2007	218	334	317	169	218	31	158	172	61	68	161	192	2,100
2008	315	242	101	206	134	232	53	53	128	136	92	162	1,853
2009	123	281	260	112	107	166	148	166	161	157	135	211	2,026
average	188	202	280	190	134	111	137	149	156	109	137	155	2,241

For the annual precipitation, scoring is given between 10 s / d 50. Score 10 to precipitation 750-1250 mm / year, score 20 to precipitation 1250-1750 mm / year, score 30 to precipitation 1750-2250 mm / year, score 40 to precipitation 2250-3250 mm / year, and the score 50 to precipitation 3250 mm / year. Average Annual Precipitation of Buper Watershed is **2241** mm / year, so the scoring for Buper Watershed is **30**.

5.5.3 Slope

Buper Watershed Slope is very diverse, so the assessment should use ArcView 3.3 for providing accurate information after divided into slope range and its scoring. This scoring is required for land suitability analysis.

Table 5-5 Slope, Area and Scoring at Buper Watershed

Slope (%)	Area (km ²)	Scoring
0-8	3.72	20
15-25	3.52	60
25-40	0.48	80
8-15	4.87	40
> 40	0.00	100

5.5.4 Landuse Suitability

Landuse suitability is determined by the sum of the scoring soil type, precipitation scoring and land slope scoring. Scoring and criteria for the results of land suitability recommendation can be seen in the Table 5-6.

Table 5-6 Landuse Suitability Scoring (Ditjen RLKT, 1986)

Land Suitability Recommendation	Scoring and Criteria
Protected Forest (A)	<ul style="list-style-type: none"> • Total scoring > 174, or • Elevation > 2000 m, or • Slope > 40 %, or • Slopes > 15% and soil type susceptible to erosion
Buffer Area (B)	<ul style="list-style-type: none"> • Total scoring 125 – 174, or • Nature Preservation Forest and Tourism Forest
Settlement (D)	<ul style="list-style-type: none"> • Total scoring < 125, or • Do not have a system or having a potential for agricultural development

The result of landuse suitability analysis can be shown as a Figure 5.30 :

LANDUSE SUITABILITY MAP

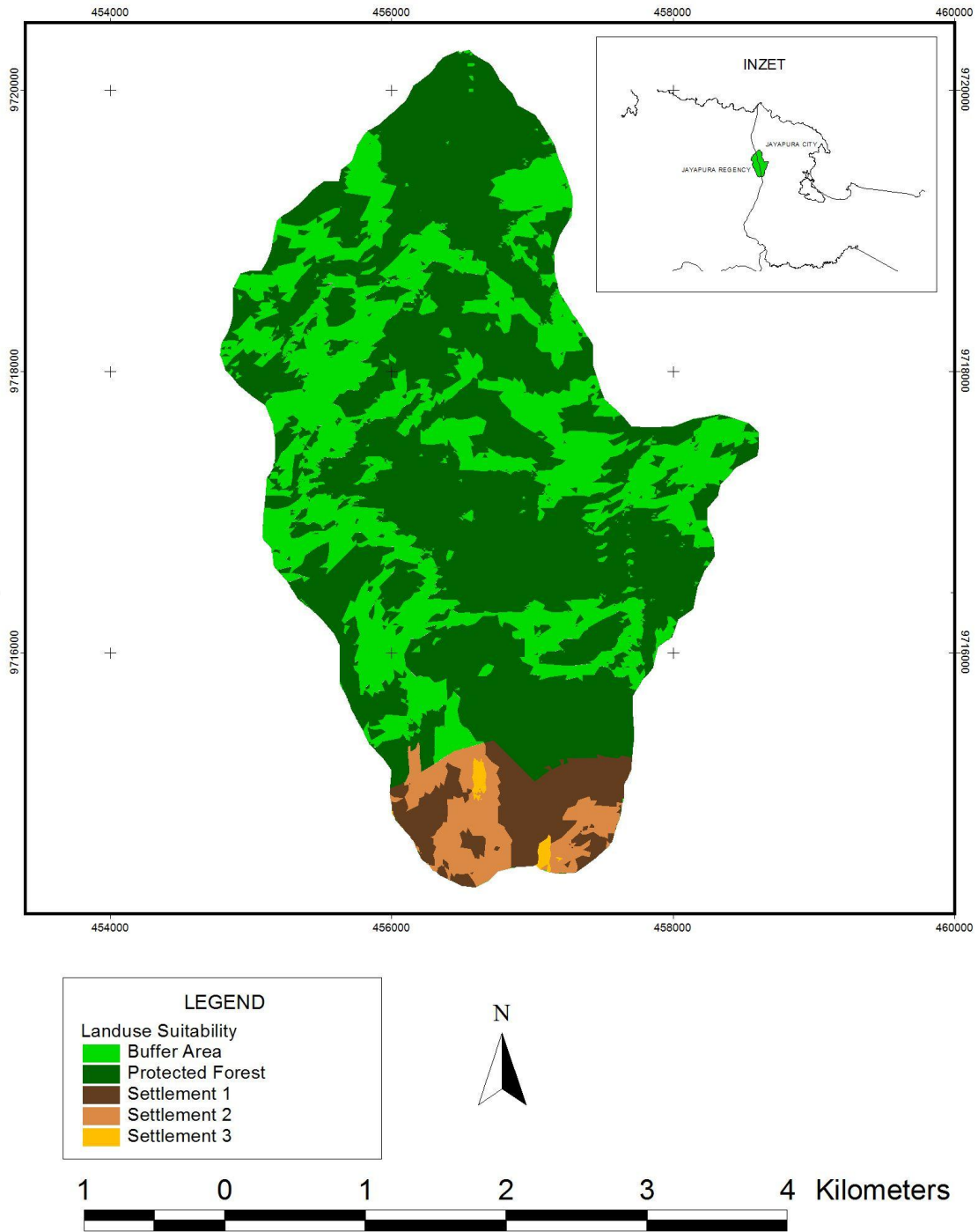


Figure 5.30 Landuse Recommendation

Based on the analysis, it is found that some of the recommendations are buffer area of 4.17 km², protected forest area of 7.35 km² and the rest is recommended as a settlement area in the downstream of Buper Watershed.

Table 5-7 Land Suitability Recommendation of Buper Watershed

No.	Recommendation	Area (km ²)
1.	Buffer Area	4,06
2.	Protected Forest	7,31
3.	Settlement 1	0,67
4.	Settlement 2	0,52
5.	Settlement 3	0,04

Based on the land characteristics of non- groundwater basin, which have a thickness of thin soil, its sensivity to erosion and a few kind of plants that can survive in the savanna area. Plants that survive are the plants that able to live with the condition of the thin soil layer. Here are some plants that can grow and hard to grow areas of savanna Buper Watershed :



Figure 5.31 Vegetation of Buper Watershed

In the buffer area which is located in the savanna, not all plants can grow well. This has been proved by Forest Departement program which has failed in crop planting. The trees were failed to grow properly. But the local native plants such as eucalyptus can grow in Buper Watershed, so that the buffer area in savanna land cover is not appropriate for crop planting.

5.6 Water Availability

5.6.1 Climatology and Hidrology Data

Climatology and hidrology data processing have purpose to provide representative data for surface water analysis. It show the hydrological condition in general at the study site and important input to calculate the water potential at study site.

Table 5-8 Monthly Precipitation at Sentani Station

Year	Monthly Precipitation (mm)												Annual Cumulative
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Oct	Nov	Dec	
2003	151	195	157	75	96	71	114	223	56	90	89	145	1.462
2004	193	128	121	81	108	113	76	87	55	151	152	58	1.323
2005	88	157	316	112	35	31	61	156	164	53	97	181	1.451
2006	220	130	511	217	70	67	251	198	331	129	182	89	2.395
2007	231	344	331	135	240	38	129	148	63	57	149	168	2.033
2008	246	231	91	280	137	248	45	60	134	161	98	179	1.910
2009*	160	91	181	95	114	114	111	163	111	147	131	135	1.553
average	184	182	244	142	114	97	112	148	131	113	128	136	

Source : BMKG Jayapura Regency (* from DPU)

Table 5-9 Monthly Precipitation at Dok II Station

Year	Monthly Precipitation (mm)												Annual Cumulative
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Oct	Nov	Dec	
2000	132	265	343	476	288	214	119	196	77	268	321	208	2.907
2001	152	416	414	201	211	183	92	83	66	376	129	455	2.778
2002	202	296	193	201	346	111	198	177	112	115	240	73	2.264
2003	220	268	232	79	150	252	283	183	395	182	185	343	2.772
2004	202	212	112	335	182	187	109	34	103	151	345	103	2.075
2005	172	187	501	403	186	118	123	163	188	148		335	2.524
2006	368	226	431	500	213	391	150	191	320	156	104	57	3.107
2007	244	389	363	246	234	29	227	238	70	96	210	262	2.608
2008	468	304	133	151	156	258	74	55	145	131	102	172	4.157
2009	100	583	414	156	120	267	225	204	258	201	166	352	5.055
average	241	256	328	313	193	195	178	162	215	147	211	220	

Source: BMKG Jayapura City

Precipitation data used for Buper Watershed are the interpolation precipitation data between Dok II station and Sentani station. Sentani Station position is 02°15' S and 141°15' E; Dok II Station position is 2°31'48" S and 140°43'12." E.

Table 5-10 Interpolation Monthly Precipitation Sentani - Dok II Station

Year	Monthly Precipitation (mm)												Total
	Jan	Feb	Mar	Apr	May	Jun	Jul	Agt	Sep	Oct	Nov	Dec	
2003	167	209	174	71	110	138	172	189	187	120	120	213	1.869
2004	181	151	108	176	129	134	83	59	70	139	217	71	1.518
2005	115	156	365	219	93	63	81	146	160	87	50	228	1.764
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2008	315	242	101	206	134	232	53	53	128	136	92	162	1.853
2009	123	281	260	112	107	166	148	166	161	157	135	211	2.026
average	188	202	280	190	134	111	137	149	156	109	137	155	

5.6.2 Water Availability Calculation

5.6.2.1 Calibration Measurement

Water availability calculation used F. J. Mock method, initially will calculate water availability in 2009, which have direct discharge measurements in July and November at the outlet of Buper Watershed. This is done for the calibration of water availability calculation using F. A Mock method.

In the direct discharge measurements made in 2009 took a position at the outlet Buper Watershed, at the outlet there are retention of water throughout the year. It is informed that there was little different of discharge measurements between July and November 2009. There were 624 l / sec in July and 654 l / sec in November 2009. In the field observation during May to September 2010, there was also no significant water level fluctuation in the retention of Buper Watershed and the main river of Buper Watershed in the down stream has never dry (DPU, 2010).



Figure 5.32 Position of Discharge Measurement 2009



Figure 5.33 Outlet Buper Watershed Documentation

In general, the results of those measurements support the water availability analysis as a calibration components in the calculation of water availability using the F. J Mock method. The calibrated of the F. J. Mock method would be used for the water availability projection.

Input Data for Water Availability 2009 Calculation can be seen in the Table 5-11 and Table 5-12, Water Availability Calculations can be seen in the Table 5-13 :

Table 5-11 Input Data for Water Availability 2009 Calculation Sentani Station

Station : Sentani Jayapura latitude : 02°15' S
 Elevation : 46 m longitude : 141°15' E
 Year 2009

Component	Unit	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
Air Temperature	°C	24,1	25,1	25,2	25,6	25,3	25,3	24,9	25,7	26,2	26,4	26,2	25,8
Wind Velocity	Knots	5,4	5,6	5,5	5,6	5,3	5,5	5,6	5,7	5,4	5,3	5,5	5,7
Relative Humidity	%	84,3	84,1	83,3	83,1	82,6	82,6	83,9	83,9	83,1	84,8	83,0	83,4
Monthly Sun Radiating	%	60,9	61,0	61,8	56,3	55,3	65,8	68,5	66,5	63,5	66,3	61,8	60,6
Number of Rainy Days	day	9,0	16,0	18,0	10,0	8,0	10,0	12,0	8,0	10,0	8,0	9,0	14,0
Monthly Precipitation	mm	120,2	387,6	472,7	268,3	84,0	93,4	145,9	108,5	265,3	93,8	94,0	258,6

Source : Badan Meteorologi dan Geofisika Wilayah V Jayapura

Table 5-12 Input Data for Water Availability 2009 Calculation Dok II Station

Station : DOK II latitude : 2°31'48" S
 Elevation : 3 m longitude : 140°43'12" E
 Year 2009

Component	Unit	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
Air Temperature	°C	28,45	27,75	28	28,8	28,9	27,65	27,95	28,4	28,45	28,7	28,9	28,55
Wind Velocity	Knots	6	5	5	5	5	6	6	6	6	5	5	5
Relative Humidity	%	77	82	80	77	77	80	82	79	77	77	77	80
Monthly Sun Radiating	%	53	35	27	50	59	43	34	57	54	40	47	26
Number of Rainy Days	day	13	16	17	14	17	13	5	10	5	13	17	18
Monthly Precipitation	mm	100,4	583,2	414,2	155,9	120	267	225	203,8	258,4	201,2	165,8	352

Source : Badan Meteorologi dan Geofisika Kota Jayapura

Table 5-13 Water Availability 2009 Calculation

NO	Component of Calculation	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEP	OCT	NOV	DEC
1	Temperature	°C	28,3	27,5	27,4	28,1	28,3	27,9	28,1	28,1	28,1	28,7	28,8	29,0
2	Slope Vapour Pressure Curve (A)	mmHg/F	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	0,9	1,0	1,0	1,0
3	Black Material Radiation (B)	mmH ₂ O/day	16,7	16,5	16,5	16,6	16,7	16,6	16,6	16,6	16,6	16,8	16,8	16,8
4	Saturated Vapour Pressure (ea)	mmHg	28,5	27,2	27,0	28,2	28,5	27,9	28,1	28,2	28,1	29,2	29,4	29,7
5	Monthly Relative Humidity (h)	%	80,6	83,1	81,6	80,1	79,8	81,3	82,9	81,4	80,1	80,9	80,0	81,7
6	Actual Vapour Pressure (ed)	mmHg	23,0	22,6	22,0	22,6	22,7	22,7	23,3	23,0	22,5	23,6	23,5	24,3
7	Reflection Coefficient (r)	%	55	55	55	55	55	55	55	55	55	55	55	55
8	Evaporating Surface Coefficient (k)		0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6
9	Wind Velocity (w)	mile / day	137,2	127,2	126,0	126,7	123,7	137,4	139,3	140,8	136,6	123,7	126,1	127,9
10	Solar Radiation (R) coord. 2° 33' S	mm/day	14,9	15,2	15,2	14,5	13,5	12,9	13,1	13,9	14,8	15,1	14,9	14,7
11	Monthly Solar Radiation (S)	(%)	56,9	48,0	44,4	53,1	57,1	54,4	51,3	61,8	58,8	53,1	54,4	43,3
12	Monthly Precipitation	mm	110,3	485,4	443,5	212,1	102,0	180,2	185,5	156,2	261,9	147,5	129,9	305,3
13	Number of Rainy Days (n)		11	19	22	12	11	14	15	11	14	13	13	19
14	Expose Surface (m)	%	55	55	55	55	55	55	55	55	55	55	55	55
15	Number of Day in The Month		31	28	31	30	31	31	30	31	30	31	30	31
16	Watershed Area	km ²	12,6	12,6	12,6	12,6	12,6	12,6	12,6	12,6	12,6	12,6	12,6	12,6

	Potential Evapotranspiration	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEP	OCT	NOV	DEC
16	$F1 = Ax(0,18+(0,55xS/100))/(A+0,27)$		0,4	0,3	0,3	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,4	0,3
17	$F2=AB(0,56-(0,092(ed^0,5)))/(A+0,27)$		1,5	1,6	1,6	1,6	1,6	1,6	1,5	1,5	1,6	1,5	1,5	1,4
18	$F3 = 0,27 \times 0,35 \times (ea - ed) / (A + 0,27)$		0,4	0,4	0,4	0,4	0,5	0,4	0,4	0,4	0,4	0,4	0,5	0,4
19	$E1 = F1 \times R \times (1-(r/100))$	mm/day	2,6	2,3	2,2	2,4	2,3	2,2	2,1	2,5	2,6	2,5	2,5	2,2
20	$E2 = F2 \times (0,1 + (0,9 \times (S/100)))$	mm/day	0,9	0,8	0,8	0,9	1,0	0,9	0,8	1,0	1,0	0,9	0,9	0,7
21	$E3 = F3 \times (k + (0,01 \times w))$	mm/day	0,9	0,7	0,7	0,8	0,8	0,8	0,8	0,8	0,9	0,8	0,8	0,8
22	$EP = E1 + E2 + E3$	mm/day	4,4	3,9	3,8	4,1	4,1	3,9	3,7	4,4	4,5	4,1	4,2	3,6
		mm/month	135,0	108,1	117,4	123,8	128,0	120,7	110,9	134,9	133,9	128,5	126,8	112,6

	Actual Evapotranspiration	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEP	OCT	NOV	DEC
23	$dE = E_p (m/20) * (18-n)$	mm/day	1,3	0,3	0,0	1,2	1,3	0,9	0,8	1,3	1,0	1,0	1,1	0,3
24	dE compromised	mm/day	1,3	0,3	0,0	1,2	1,3	0,9	0,8	1,3	1,0	1,0	1,1	0,3
25	$E_a = E_p - dE$	mm/day	3,0	3,5	3,8	2,9	2,8	3,0	2,9	3,0	3,4	3,1	3,1	3,3
		mm/month	94,1	99,2	117,4	88,1	87,5	92,5	88,0	94,1	102,6	96,7	93,7	103,3

	Water Balance	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEP T	OCT	NOV	DEC
26	$WS = P - E_a$		16,2	386,2	326,1	124,0	14,5	87,7	97,4	62,1	159,2	50,8	36,2	202,0
27	$SMC = 75$ if $P - E_a > 0$; $SMC_{n-1} + (P - E_a)$ if $P - E_a < 0$	mm/month	75	75	75	75	75	75	75	75	75	75	75	75
28	$SMS = ISMS + (P - E_t)$	mm/month	91,2	461,2	401,1	199,0	89,5	162,7	172,4	137,1	234,2	125,8	111,2	277,0
29	Infiltration = $WS \times i$; if = 0,3	mm/month	4,8	115,9	97,8	37,2	4,3	26,3	29,2	18,6	47,8	15,2	10,9	60,6
30	$SF = WS - \text{Infiltration}$	mm/month	11,3	270,3	228,3	86,8	10,1	61,4	68,2	43,4	111,5	35,5	25,3	141,4
31	$SWD = \text{Infiltration} - SMC$	mm/month	-70,2	40,9	22,8	-37,8	-70,7	-48,7	-45,8	-56,4	-27,2	-59,8	-64,1	-14,4
	$P = E_t + SF + SWD \pm SMC \pm SS$; $SS = 0$		110,3	485,4	443,5	212,1	102,0	180,2	185,5	156,2	261,9	147,5	129,9	305,3

Based on the results of calibration of water availability calculation in 2009, there were obtained discharge surface water availability of 130.8 mm / month or 633 lt / sec. Calibration were performed with adjustments for some coefficients, formula used and assumptions used.

This calibration results also show the same trend fluctuation between the surface water and precipitation in Buper Watershed. Precipitation and surface water fluctuations can be seen the Figure 5.34 :

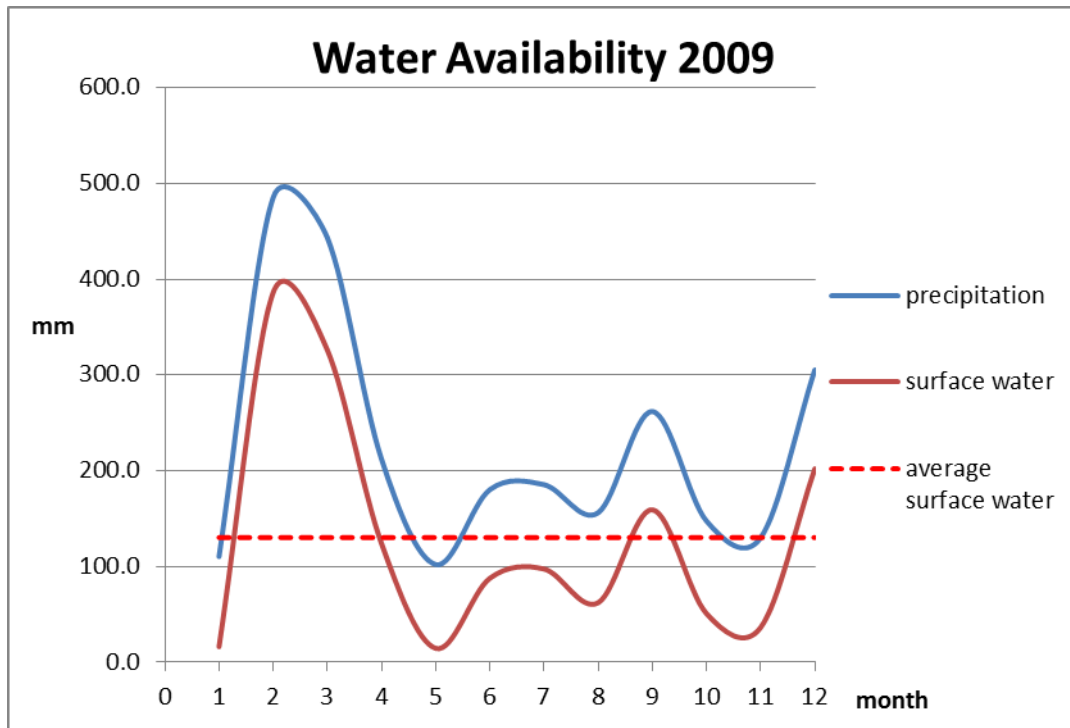


Figure 5.34 Fluctuation of Water Availability 2009

It is possible because at the Buper Watershed there is no percolation and the thickness of thin soil, so most of water storage become a surface water retention. The average surface water availability has a value close to direct measurements of discharge Buper Watershed.

5.6.2.2 Water Availability Projection

Calibrated water availability calibration would be used in the water availability projection for next five years. Types of data, coefficients and assumptions used are the same as the calculation of water availability in 2009 that has been calibrated. Figure 5.35 is the summary of the calculation of water availability a few years :

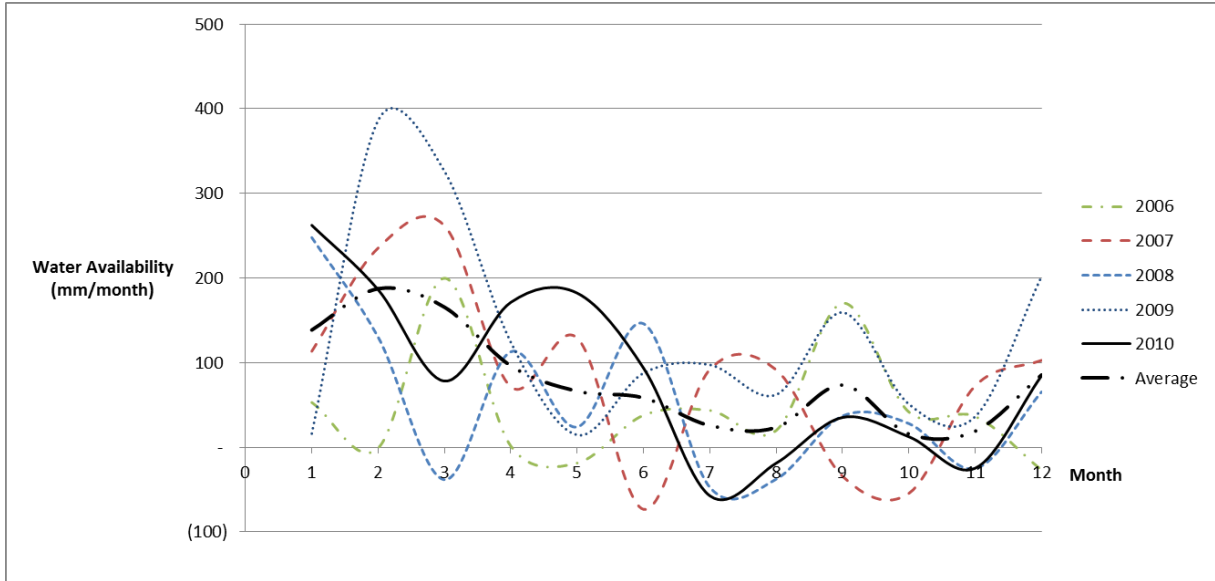


Figure 5.35 Surface Water Availability 2006 - 2010

Table 5-14 Buper Water Availability

Year	Water Availability (mm/month)											
	JAN	FEB	MAR	APR	MAY	JUN	JUL	AGS	SEP	OCT	NOV	DEC
2010	262	186	78	171	182	94	(57)	(19)	35	12	(25)	84
2009	16	386	326	124	14	88	97	62	159	51	36	202
2008	248	130	(38)	113	24	146	(47)	(38)	37	28	(25)	65
2007	113	235	262	71	129	(73)	92	91	(34)	(54)	73	103
2006	53	(1)	200	1	(19)	38	43	20	170	42	36	(27)
2005	47	109	306	168	46	20	40	83	97	39	68	177
Aver	164	210	231	177	102	93	65	54	101	45	64	140

Based on the calculation above, it is obtained that the average water availability is 79,6 mm / month, this result is equivalent to 0.386 m³/sec.

5.7 Water Demand

5.7.1 Services Area by Gravitation

Buper Watershed water uses are based on topographic conditions and the efficiency of implementation. So that the services area are the area with lower topography and distribution easiness. The criteria selection are based on development and controlling capability for water distribution facilities in those region.

Buper Watershed lowest elevation is 220 MSL, so services area by gravitation based on topographic analysis for the Buper Watershed are District of Heram and District of South Jayapura. Both area are the District of Jayapura City. In 2010, public activity center and settlement areas in District of Heram have elevation of 75-110 m above MSL, while public activity center and settlement areas in South Jayapura have elevation of 10-45 m above MSL.

5.7.2 Water Demand Projection

Water demands of both areas are generally to provide daily household and urban activities. Both of area don't have area of irrigation. Services area based on topographic analysis results for the Buper Watershed are District of Heram and District of South Jayapura. Both area have a domestic water demands standard of 100-150 ltr / day and has a non-domestic water demand standard of 35 % from domestic water demands.

Table 5-15 Service Area by Gravitation of Buper Watershed

No	District	Area (km ²)	Population 2008
1	South Jayapura	626.7	69,336
2	Heram	51	38,251

Table 5-16 Population Projection

No	District	Area (km ²)	Population Growth (%)	Population Projection	
				2011	2016
1	South Jayapura	626.7	3.3	76,429	89,900
3	Heram	51.0	3.3	42,164	49,596

Table 5-17 Daily Water Demand Projection (m³/day)

District	Water Demand (m ³ /day)	
	2011	2016
South Jayapura	0.18	0.21
Heram	0.10	0.12
Total	0.28	0.32

5.8 Water Balance

Water balance analysis is the study of equilibrium between water demand and water availability within a certain time period. The balance between supply and demand for water are determined by the supply and demand of water.

Dependable flow used for the domestic and non-domestic demand are 80 % (Bapenas, 2006). The calculation of water availability informed that average annual water availability in 2006 – 2010 are :

Table 5-18 Weibull Formula for Buper Watershed

Water Availability (m ³ /sec)	Rank	Possibility
0.63	1	0,14
0.41	2	0,29
0.41	3	0,43
0.39	4	0,57
0.26	5	0,71
0.23	6	0,86

Because of the highest dependable flow based on Weibul formula is 86%, it is lower than Buper Watershed dependable. Dependable flow is 0,24 m³/sec for 12.6 km² area of Buper Watershed. Estimated water demand in 2011 is 0.28 m³/sec, so it was insufficient for water demand.

5.9 Soil Erosion

5.9.1 USLE Equation

In this study, soil erosion will be calculated by USLE (The Universal Soil Loss Equation). USLE predicts the long term average of long term annual erosion rate on a field slope based on runoff, soil type, topography, crop system and management practices.

1. Runoff Factor (R)

Rainfall and runoff factor (R) based on RTL-RLKT will use formula :

$$R=2,21 (Rain)_m^{1,36}.$$

(Rain)_m is a monthly precipitation (cm). Monthly precipitation used here are monthly precipitation as a interpolation results between two stations, they are

Doc II station and Sentani station. Monthly precipitation data used here are average monthly precipitation from in 2003 until 2009.

Table 5-19 Interpolation Monthly Precipitation Sentani - Dok II Station

Tahun	Monthly Precipitation (mm)												Total
	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Ot	Nov	Dec	
2003	167	209	174	71	110	138	172	189	187	120	120	213	1,869
2004	181	151	108	176	129	134	83	59	70	139	217	71	1,518
2005	115	156	365	219	93	63	81	146	160	87	50	228	1,764
2006	262	158	438	313	122	191	191	179	300	129	136	69	2,488
2007	218	334	317	169	218	31	158	172	61	68	161	192	2,100
2008	315	242	101	206	134	232	53	53	128	136	92	162	1,853
2009	123	281	260	112	107	166	148	166	161	157	135	211	2,026
average	188	202	280	190	134	111	137	149	156	109	137	155	2,241

Based on the interpolation of precipitation data processing Sentani station and Dock II station of the in 2003-2009 is obtained average monthly precipitation is over 7 of 162 mm / month.

For the rain erosivity (R) in the calculation of USLE, the monthly precipitation would be inserted in the formula $R=2,21 (Rain)_m^{1,36}$:

$$R = 2,21 \times (162)^{1,36}$$

$$R = 2235.284 \text{ mm/month}$$

So the rain erosivity (R) of Buper Watershed which is used for USLE calculating is **2235,284 mm / month**.

2. Soil Erodibility (K)

Soil Erodibility, or soil erosion sensitivity factor, which is a index of soil resistance to the release and transport, mainly depends on soil characteristics such as texture, aggregate stability, shear, infiltration capacity, organic and chemical content. Based on the geological analysis and soil type, can be concluded that Buper Watershed soil is clay. **K** values that are used in the calculation of USLE is 0.22 according to soil type.

3. Slope-Length Factor (LS)

LS is the slope-length factor. The LS factor represents a ratio of soil loss under given conditions to the site with the "standard" slope steepness of 9% and slope length of 72.6 feet. The steeper and longer the slope, the higher is the risk for erosion. Buper Watershed slope is very diverse, so the assessment should use ArcView 3.3 for providing an accurate information. Scoring is based on the

classification of the LS slope index by McCool Formula (SWCS 1993 in RTL-RLKT) :

Table 5-20 Slope Index (SWCS 1993 in RTL-RLKT)

LS index	Slope
0,40	0-8 %
1,40	8-15 %
3,10	15-25 %
6,80	25-44,5 %

This slope information and its scoring will then be inserted into ArcView 3.3 to determined land suitability analysis.

4. Land Cover Factor (C)

This factor measures the effect of the plant and its management. Based on the results of previous analysis, Buper Watershed land cover are generally classified into forest and savannah. Based on the Table of Land Cover Factor, the value of C to be used in the calculation of the USLE to forest to savannah are 0.001 and 0.01.

5. Support Practice Factor (P)

P is the support practice factor. It reflects the effects of practices hat will reduced the amount and rate of the water runoff and the amount of erosion (Stone and Hilborn, 2000). The base rate of P is one (1) is given to the land without conservation treatment (Suripin, 2002). Based on field observations, it has been found that the land cover on Buper Watershed has no practical conservation treatment, then P will be used in calculating the USLE to forest is 1.

After all necessary USLE data have been prepared and processed, then the soil erosion calculation can be processed using ArcView 3.3. Annual soil erosion map can be seen in the Figure 5.36.

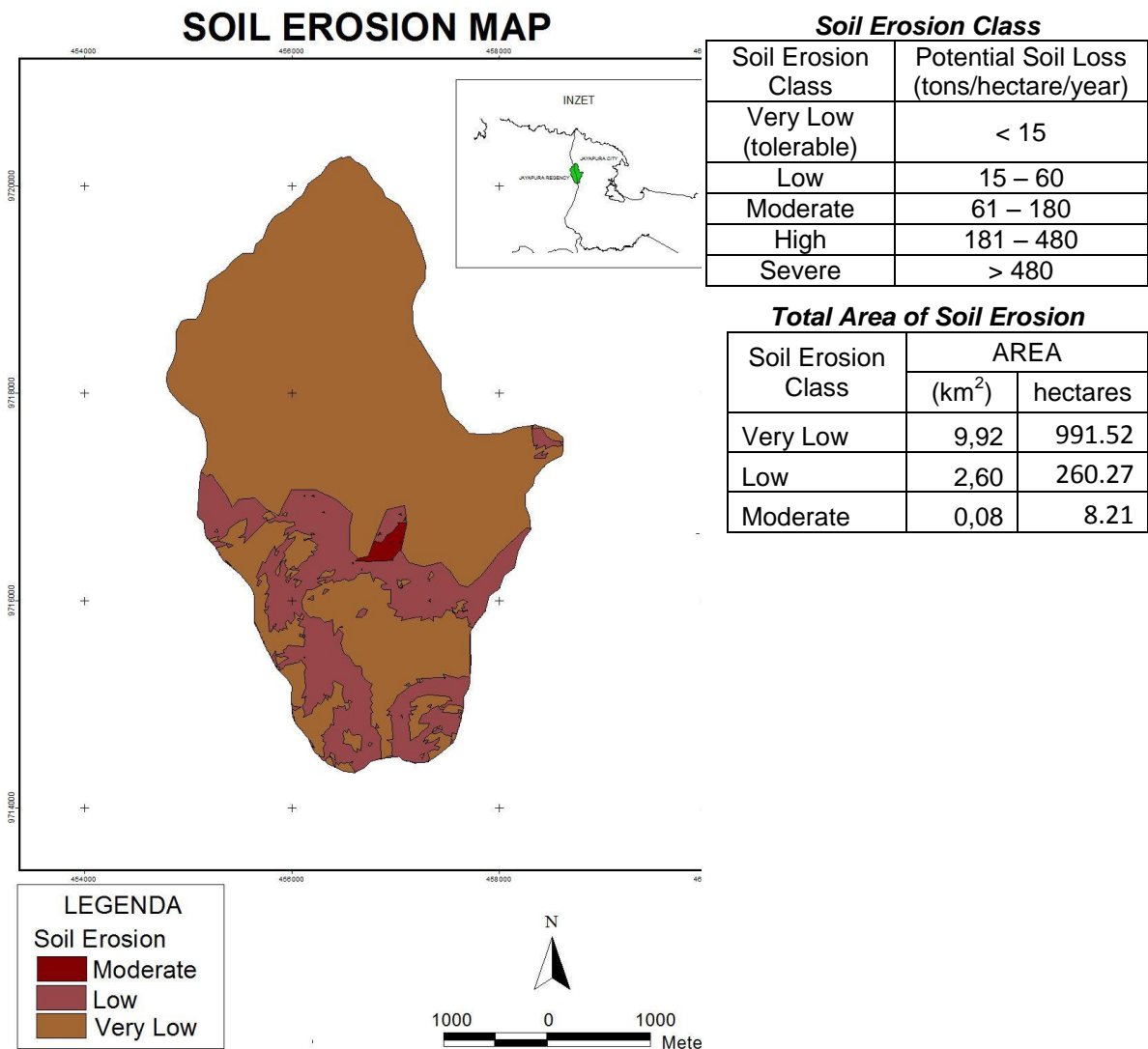


Figure 5.36 Annual Soil Erosion Map

The results of USLE through ArcView 3.3 showed that most of the Buper Watershed have very low erosion rate with a total area of 9,92 km², low erosion area of 2,6 km² and moderate erosion area of 0,08 km². The highest erosion in Buper Watershed is 82,63 ton/hectare/year and the lowest erosion in Buper Watershed is 1,71 ton/hectare/year.

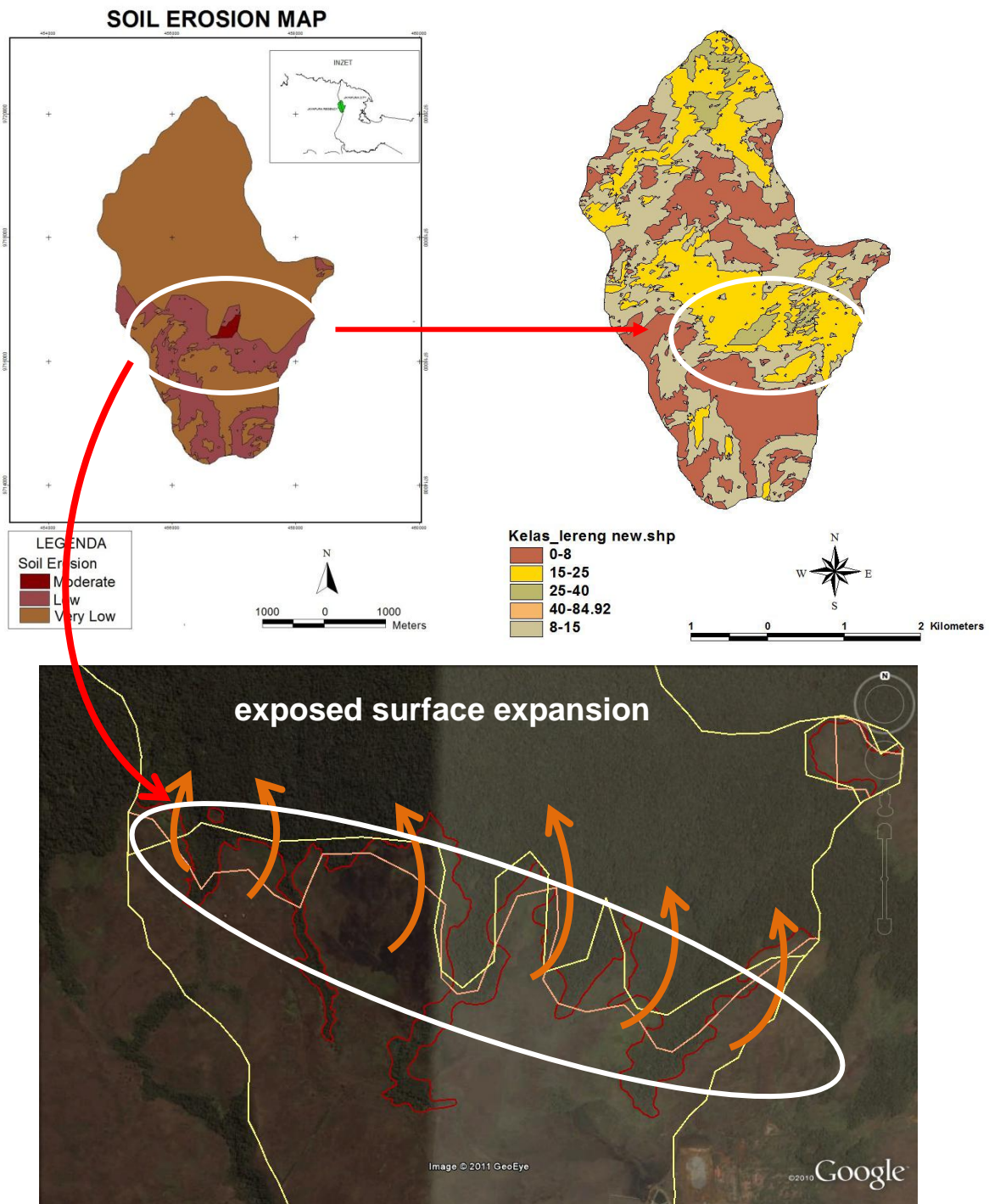


Figure 5.37 Correlation of Soil Erosion, Slope and Exposer Surface Expansion

Areas with medium erosion is savanna areas with slopes 15-45%, so it can be concluded that the effect of slope in the savanna is very significant. In contrast to the savanna, primary-secondary forest has a low erosion rate although some have a high slope, so it can be concluded that in areas which did not covered by forest, slope had a huge influence on the erosion rate in the Buper Watershed. Forest can control the erosion rate.

At the forest areas were also found moderate rate of erosion, based on field observations and other data sources, this area is an opened forest that had beed logged.

Analysis of land use change on the landcover map 2000, 2005 and 2010 showed that the forest ability to recover which have had eroded and logged aren't significant. This is proves that maintain forest conditions in the area of non-groundwater basin is an effective way to control the rate of erosion.

In the areas with a high slope and have been eroded, exposed surface expansion will occur. The exposed surface expansion is moved to the top of a slope. This is because the very sensitivity of the soil in the non-groundwater basin area so that it is necessary for practical conservation to reduce erosion and the movement of exposed surface expansion in the area with a high slope. Soil erosion in a year can be calculated by multiplying each classification of soil erosion.

Table 5-21 Soil Erosion in Buper Watershed

Soil Erosion Classification	Annual Soil Erosion (ton/hectares/year)	Area (Hectares)	Soil Erosion (ton/year)
Very Low	4,87	2,961	14,4
Very Low	4,87	159,731	777,9
Very Low	4,87	1,401	6,8
Very Low	0,49	167,176	81,9
Very Low	4,87	43,173	210,3
Low	37,66	0,111	4,2
Low	37,66	69,629	2.622,2
Very Low	3,76	278,224	1.046,1
Low	37,66	3,234	121,8
Moderate	82,63	8,138	672,4
Very Low	8,25	48,046	396,4
Moderate	82,63	0,042	3,5
Moderate	82,63	0,027	2,2
Very Low	8,25	0,074	0,6
Low	17,00	3,520	59,8
Low	17,00	122,964	2.090,4
Low	17,00	0,036	0,6
Very Low	1,71	290,738	497,2
Low	17,00	60,776	1.033,2
<i>Total Soil Erosion</i>			9.639,92

Approximate amount of soil erosion in Buper Watershed is 9.639,9 tons/year. This amount represents the amount of soil that has been eroded in Buper Watershed. Eroded soil has been accumulated into local sedimentary basin where the plants is growth.

5.9.2 Management Strategies to Reduce Soil Losses

The quality of the land related to soil erosion can be improved with the corrective measures based on the USLE calculation components, USLE calculation components that can be managed is the **LS**, **C** and **P** (Stone and Hilborn, 2000). Based on geology and land use suitability analysis, it is not recommended to cultivate land in Buper Watershed as a farming.

Management Strategies to Reduce Soil Losses are :

- Terraces may be constructed to reduce the slope length resulting in lower soil losses.
- The selection of a support practice that has the lowest possible factor associated with it will result in lower soil losses.

Table 5-22 Management Strategies to Reduce Soil Losses (m³/day)

Land Cover	Soil Erosion Classification	Recommendation
forest	very low	no treatment
savannah	very low	no treatment
savannah	very low	no treatment
forest	very low	no treatment
savannah	very low	no treatment
forest	low	traditional cons
savannah	low	traditional cons
forest	very low	no treatment
savannah	low	traditional cons
savannah	moderate	medium construct
forest	very low	no treatment
savannah	moderate	medium construct
savannah	moderate	medium construct
forest	very low	no treatment
forest	low	Fanya Juu
savannah	low	traditional cons
forest	low	traditional cons
forest	very low	no treatment
savannah	low	traditional cons

EROSION CONTROL

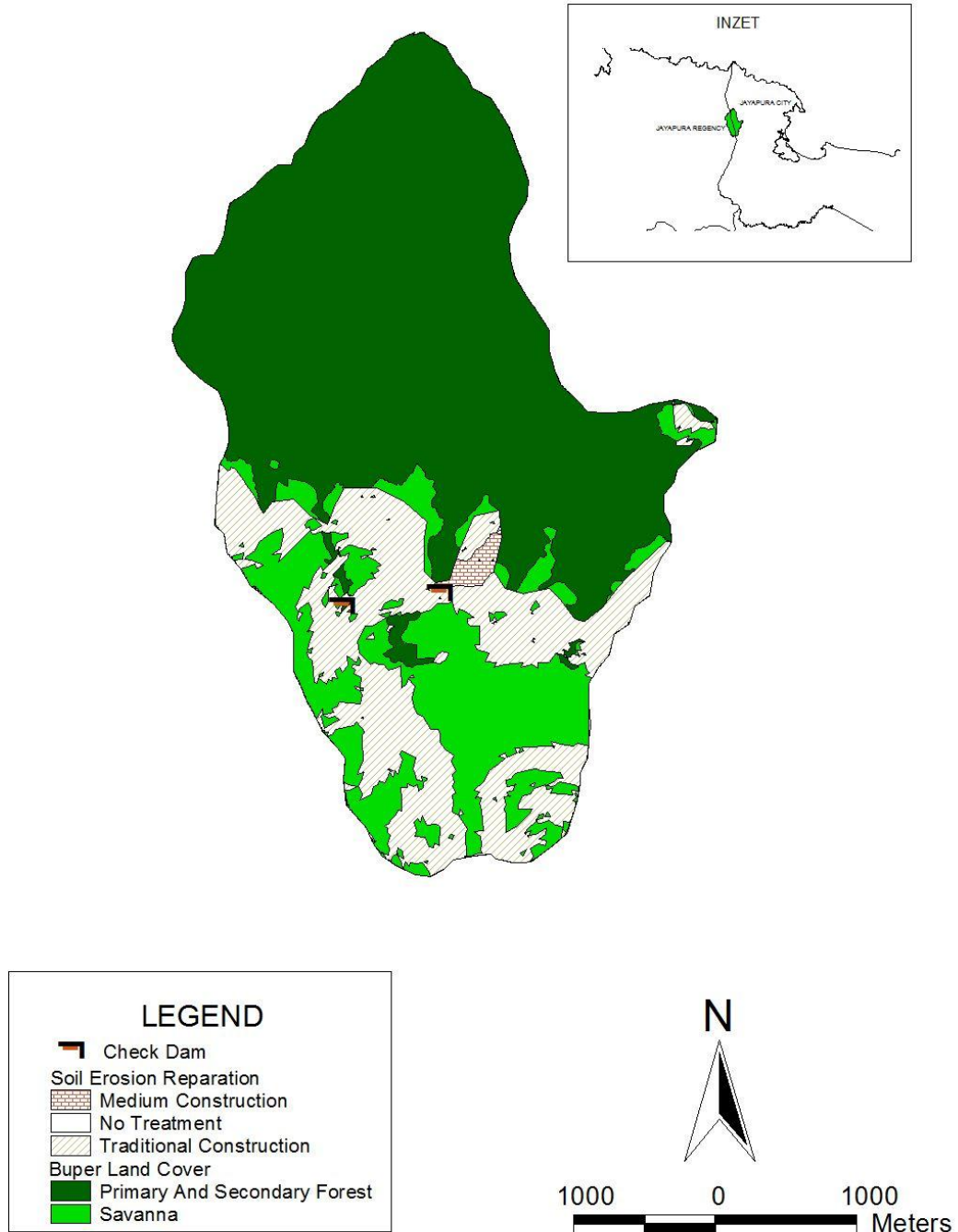


Figure 5.38 Erosion Control

CHAPTER VI

CONCLUSION AND RECOMMENDATION

6.1 Conclusion

Conclusion are given based on the purposes and objectives of the study. The purposes of this study are to reduce soil erosion and to maintain water availability of non-groundwater basin watershed. The conclusion for the objectives of this study are :

6.1.1 Land Characteristics of Non-Groundwater Basin in Buper Watershed

1. Buper Watershed rock layer below the soil layer are mafic and ultramafic layer which are impermeable, so that the water can only infiltrate through the soil layer. On this thin soil (clay), plant can grow according to the thickness of the soil. In savannah area, thin soil layer has a thickness around 3-25 cm, and only in the area where sediments are concentrated, soil layer has a thickness around 40-60 cm.
2. In the area of non- groundwater basin, forest recovery is difficult when the land have been eroded or have been exposed. This condition occurs because the soil / clay where the plant grew was lost due to erosion.
3. Exposed surface expansion is occurs go toward upstream because the increasing erosion rate due to the slope of 25-40%.

6.1.2 Water Balance in Buper Watershed

1. Dependable flow is 0,24 m³/sec for 12.6 km² area of Buper Watershed. Estimated water demand in 2011 is 0.28 m³/sec, so it was insufficient for water demand..
2. The service areas are area with lower topography and distribution easiness. These criterias selection are based on development and controlling capability for water distribution facilities.
3. The service area are District of Heram and District of South Jayapura, which have population projection until 2016 of 139,496 people.

6.1.3 Erosion in Buper Watershed

1. The results of USLE showed that most of the Buper Watershed have very low erosion rate with a total area of 9,92 km², low erosion area of 2,6 km² and moderate erosion area of 0,08 km². The highest erosion in Buper Watersehed is 82,63 ton/hectare/year and the lowest erosion in Buper Watershed is 1,71 ton/hectare/year.

2. Management strategies to reduce soil loss are to build a medium structure of bench terrace for medium rate erosion and traditional bench terrace for low rate erosion.

6.1.4 Conservation Planning Of Non-Groundwater Basin Watershed

Recommendation for conservation planning in Buper Watershed are based on the results of the analysis made before. The recommendation is also the objective of the study. That recommendation are expected could be reduce soil erosion and maintain water availability of non-groundwater basin watershed as the purposes of the study. The recommendation made for Buper Watershed as a non-groundwater basin area are :

6.1.4.1 Protect Water Resource

To protect water resources in the non-groundwater basin watershed and to give boundary in land management for water and soil protection are required conservation zoning. Conservation zoning includes the protected forest, buffer area and settlement. Full protection was given to protected forest while the limited cultivation is allowed on the buffer area. Infrastructure developments and residence can be carried out on the settlement area.

6.1.4.2 Forest Rehabilitation

Forests provide excellent protection to the top soil against erosion. They maintain high rates of evapotranspiration, interception and infiltration and therefore generate only small quantities of runoff (Morgan, 2005). Forest rehabilitation can be done by planting various kinds of plants in the forest that hasn't been eroded yet, but in areas that have been eroded or have the thickness of the thin soil rehabilitation carried out by planting trees that can survive with limited water and soil like eucalyptus.

6.1.4.3 Land Cultivation Controlling In The Uplands

Cultivation should not be done on the protected forest or upstream areas. Cultivation is allowed only on the buffer area with slope of < 15%. This is should be done to avoid increasing of erosion and rehabilitation ineffectiveness due to the land utilization.

6.1.4.4 Land Rehabilitation

Land rehabilitation is planned to recover the impact of soil erosion. On the savannah landcover that has medium erosion rate is required to build medium bench terrace, but on the land cover that has medium erosion rate is required to build modification bench terrace called Fanya Juu. On land that have low erosion rate is only required cultivation control.

6.1.4.5 Develop Sediment And Erosion Control Structure

A amount of eroded soil need to be reduced and accumulation of sediment is expected for plant growth media, so on the slopes where there is transport and accumulation of sediment that it is necessary to develop sediment and erosion control structure (check dam).

6.1.4.6 Store Excess Water In The Rain To Be Used In Time Of Need By Developing Embung

In order to provide adequate water during dry seasons it is necessary to build embung with a discharge of $0,588 \text{ m}^3 / \text{sec}$ throughout the year according to the average water availability. The discharge would be required to fulfill water demand of services area. Services area are South Jayapura District and Heram District. Both services area are expected to supply water by gravitation according the development and controlling capability for water distribution facilities in those region.

6.1.4.7 Effective And Efecient Uses

Water use controlling is required in order to enlarge the capability to supply water continuously. It could be performed by divide the demand for fishery and other demands in the outlet of Buper Watershed. Water should not fully utilized for fishery by taking water from Buper Watershed outlet as a fishing pool inlet. It are needed to build separated channel for a multipurpose needs and flow control facilities.

6.2 Recommendation

1. Further analysis is required about the types of plants that can grow in areas that have been eroded and have a thickness of the thin soil in the non-groundwater basin as part of the forest and land rehabilitation.
2. Dependable flow of Buper Watershed is 1167 mm / year or 0.47 m³/sec for 12.6 km² area of Buper Watershed. Estimated water demand in 2016 is 0.32 m³/sec. It is a surplus of up to 5 years for its serviced area, so it is advisable for the enlargement of the service area through the development of distribution methods in addition to gravity.
3. Reduced soil management strategies to build a medium are loss structure of bench terrace erosion rate for medium and traditional bench terrace for low erosion rate. So that further analysis is required about the specific dimensions and design of medium and traditional bench terrace.
4. Conservation Planning in Buper Watershed need to be specified such as : forest area that needs to be rehabilitated, kinds of activities allowed in the upstream, the dimension and design of sediment and erosion control structure, dimension and design of embung, application of effective and efecient uses.

CHAPTER VII REFERENCES

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ATTACHMENTS

Stasiun : DOK II

latitude 2°31'48.00"S

Elevasi : 3 m

longitude 140°43'12.00"E

Monthly Precipitation													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	2010	478	233,6	257,4	224,8	360,1	243	70,9	134,1	44,9	222,6	109,4	261,4
2	2009	100,4	583,2	414,2	155,9	120	267	225	203,8	258,4	201,2	165,8	352
3	2008	467,5	303,7	133,3	150,7	156	258,3	74,2	55,3	144,5	131,2	101,7	172
4	2007	243	387	456	248	228	24	230	245	72	55	212	333,7
5	2006	210	144	325	115	208	308	142	190	399	258	165	70

Stasiun : DOK II

latitude 2°31'48.00"S

Elevasi : 3 m

longitude 140°43'12.00"E

Number of Rainy Days													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	day	day	day	day	day	day	day	day	day	day	day	day
1	2010	9	14	21	22	15	16	19	19	21	18	20	17
2	2009	13	22	26	13	13	17	17	14	17	18	16	24
3	2008	23	21	21	21	20	19	12	12	12	14	24	18
4	2007	26	22	21	18	15	10	13	13	9	12	22	25
5	2006	14	14	17	14	19	23	17	13	19	14	5	9

Stasiun : DOK II

latitude 2°31'48.00"S

Elevasi : 3 m

longitude 140°43'12.00"E

Air Temperature													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C	°C
1	2010	28,4	27,4	27,2	28,0	28,8	29,2	30,0	29,5	29,2	29,6	29,8	29,9
2	2009	28,45	27,75	28	28,8	28,9	27,65	27,95	28,4	28,45	28,7	28,9	28,55
3	2008	27,95	28,15	28,5	28,2	28,15	28	28,25	28,45	28,65	28,65	28,8	28,5
4	2007	28,15	27,85	28,2	28,3	28,4	29,15	28,1	28,1	28,35	28,8	27,9	28,7
5	2006	27,7	26,9	26,7	26,7	26,95	20,9	21,9	21,4	27,7	28,2	28,3	29,15

Stasiun : DOK II

latitude 2°31'48.00"S

Elevasi : 3 m

longitude 140°43'12.00"E

Wind Velocity													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	knot	knot	knot	knot	knot	knot	knot	knot	knot	knot	knot	knot
1	2010	8	6	6	6	6	11	9	5	5	4	5	4
2	2009	6	5	5	5	5	6	6	6	6	5	5	5
3	2008	6	7	7	7	7	7	7	7	7	8	8	7
4	2007	6	6	6	6	7	6	6	7	7	6	6	6
5	2006	4	4	4	4	4	5	3	4	4	4	4	3

Station : Sentani Jayapura

Elevation : 46 m

latitude : 02°15' S

longitude : 141°15' E

Monthly Precipitation													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	2010	268,6	356,7	131,5	362,6	207,1	167	30,5	46	273,1	40,8	77,6	118,4
2	2009	120,2	387,6	472,7	268,3	84	93,4	145,9	108,5	265,3	93,8	94	258,6
3	2008	246	231	91	280	137	248	45	60	134	161	98	179
4	2007	231	344	331	135	240	38	129	148	63	57	149	168
5	2006	220	130	511	217	70	67	251	198	331	129	182	89

Station : Sentani Jayapura

Elevation : 46 m

latitude : 02°15' S

longitude : 141°15' E

Number of Rainy Days													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	day	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	2010	17	20	13	19	17	14	8	5	11	5	10	6
2	2009	9	16	18	10	8	10	12	8	10	8	9	14
3	2008	18	19	19	8	17	15	21	7	10	14	10	13
4	2007	9	21	18	17	12	17	7	13	13	14	7	18
5	2006	14	8	30	14	4	4	16	13	21	8	12	6

Station : Sentani Jayapura
 Elevation : 46 m

latitude : 02°15' S
 longitude : 141°15' E

Air Temperature													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	°C	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm	mm
1	2010	28,16	27,25	26,82	27,46	27,63	28,20	28,19	27,81	27,66	28,65	28,68	29,37
2	2009	24,1	25,1	25,21	25,58	25,31	25,31	24,94	25,7	26,21	26,36	26,16	25,79
3	2008	28,68	27,64	27,97	28,07	27,77	27,41	26,69	27,40	27,67	28,34	28,28	28,46
4	2007	29,04	27,70	27,64	27,95	28,24	28,14	29,00	27,39	27,36	28,17	29,19	28,63
5	2006	28,60	28,08	27,50	27,42	28,23	27,75	27,65	27,07	27,51	26,20	28,90	29,58

Station : Sentani Jayapura
 Elevation : 46 m

latitude : 02°15' S
 longitude : 141°15' E

Wind Velocity													
No.	Month	Jan	Feb	Mar	Apr	Mei	Jun	Jul	Agt	Sep	Okt	Nov	Dec
	Year	knot	knot	knot	knot	knot	knot	knot	knot	knot	knot	knot	knot
1	2010	8	9	5	7	4	5	5	7	6	9	6	5
2	2009	5	6	6	6	5	5	6	6	5	5	6	6
3	2008	5	16	9	6	11	7	6	8	8	8	9	7
4	2007	5	7	8	8	6	5	5	5	9	5	5	6
5	2006	4	6	6	6	7	3	3	12	4	4	7	7

Tahun 2009														
NO.	Component of Calculation	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
1	Temperature	°C	28.3	27.5	27.4	28.1	28.3	27.9	28.1	28.1	28.1	28.7	28.8	29.0
2	Slope Vapour Pressure Curve (A)	mmHg/F	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0
3	Black Material Radiation (B)	mmH ₂ O/day	16.7	16.5	16.5	16.6	16.7	16.6	16.6	16.6	16.6	16.8	16.8	16.8
4	Saturated Vapour Pressure (ea)	mmHg	28.5	27.2	27.0	28.2	28.5	27.9	28.1	28.2	28.1	29.2	29.4	29.7
5	Monthly Relative Humidity (h)	%	80.6	83.1	81.6	80.1	79.8	81.3	82.9	81.4	80.1	80.9	80.0	81.7
6	Actual Vapour Pressure (ed)	mmHg	23.0	22.6	22.0	22.6	22.7	22.7	23.3	23.0	22.5	23.6	23.5	24.3
7	Reflection Coefficient (r)	%	55	55	55	55	55	55	55	55	55	55	55	55
8	Evaporating Surface Coefficient (k)		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
9	Wind Velocity (w)	mile / day	137.2	127.2	126.0	126.7	123.7	137.4	139.3	140.8	136.6	123.7	126.1	127.9
10	Solar Radiation (R) coord. 2° 33' S	mm/day	14.9	15.2	15.2	14.5	13.5	12.9	13.1	13.9	14.8	15.1	14.9	14.7
11	Monthly Solar Radiation (S)	(%)	56.9	48.0	44.4	53.1	57.1	54.4	51.3	61.8	58.8	53.1	54.4	43.3
12	Monthly Precipitation	mm	110.3	485.4	443.5	212.1	102.0	180.2	185.5	156.2	261.9	147.5	129.9	305.3
13	Number of Rainy Days (n)		11	19	22	12	11	14	15	11	14	13	13	19
14	Expose Surface (m)	%	55	55	55	55	55	55	55	55	55	55	55	55
15	Number of Day in The Month		31	28	31	30	31	31	30	31	30	31	30	31
16	Watershed Area	km ²	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Potential Evapotranspiration		UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
16	$F1 = A \times (0,18 + (0,55 \times S / 100)) / (A + 0,27)$		0.4	0.3	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
17	$F2 = A \times B \times (0,56 - (0,092 \times (ed^{0,5}))) / (A + 0,27)$		1.5	1.6	1.6	1.6	1.6	1.6	1.5	1.5	1.6	1.5	1.5	1.4
18	$F3 = 0,27 \times 0,35 \times (ea - ed) / (A + 0,27)$		0.4	0.4	0.4	0.4	0.5	0.4	0.4	0.4	0.4	0.4	0.5	0.4
19	$E1 = F1 \times R \times (1 - (r/100))$	mm/day	2.6	2.3	2.2	2.4	2.3	2.2	2.1	2.5	2.6	2.5	2.5	2.2
20	$E2 = F2 \times (0,1 + (0,9 \times (S/100)))$	mm/day	0.9	0.8	0.8	0.9	1.0	0.9	0.8	1.0	1.0	0.9	0.9	0.7
21	$E3 = F3 \times (k + (0,01 \times w))$	mm/day	0.9	0.7	0.7	0.8	0.8	0.8	0.8	0.8	0.9	0.8	0.8	0.8
22	$EP = E1 + E2 + E3$	mm/day	4.4	3.9	3.8	4.1	4.1	3.9	3.7	4.4	4.5	4.1	4.2	3.6
		mm/month	135.0	108.1	117.4	123.8	128.0	120.7	110.9	134.9	133.9	128.5	126.8	112.6
Actual Evapotranspiration		UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
23	$dE = Ep \times (m/20)^{18-n}$	mm/day	1.3	0.3	0.0	1.2	1.3	0.9	0.8	1.3	1.0	1.0	1.1	0.3
24	dE compromised	mm/day	1.3	0.3	0.0	1.2	1.3	0.9	0.8	1.3	1.0	1.0	1.1	0.3
25	$Ea = Ep - dE$	mm/day	3.0	3.5	3.8	2.9	2.8	3.0	2.9	3.0	3.4	3.1	3.1	3.3
		mm/month	94.1	99.2	117.4	88.1	87.5	92.5	88.0	94.1	102.6	96.7	93.7	103.3
Water Balance		UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
26	$WS = P - Ea$		16.2	386.2	326.1	124.0	14.5	87.7	97.4	62.1	159.2	50.8	36.2	202.0
27	$SMC = 75$ if $P - Ea > 0$; $SMC_{n-1} + (P - Ea)$ if $P - Ea < 0$	mm/month	75	75	75	75	75	75	75	75	75	75	75	75
28	$SMS = ISMS + (P - Et)$	mm/month	91.2	461.2	401.1	199.0	89.5	162.7	172.4	137.1	234.2	125.8	111.2	277.0
29	Infiltration = WS x if ; if = 0,3	mm/month	4.8	115.9	97.8	37.2	4.3	26.3	29.2	18.6	47.8	15.2	10.9	60.6
30	$SF = WS - Infiltration$	mm/month	11.3	270.3	228.3	86.8	10.1	61.4	68.2	43.4	111.5	35.5	25.3	141.4
31	$SWD = Infiltration - SMC$	mm/month	-70.2	40.9	22.8	-37.8	-70.7	-48.7	-45.8	-56.4	-27.2	-59.8	-64.1	-14.4
	$P = Et + SF + SWD \pm SMC \pm SS ; SS = 0$		110.3	485.4	443.5	212.1	102.0	180.2	185.5	156.2	261.9	147.5	129.9	305.3

Tahun 2010														
NO.	Component of Calculation	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
1	Temperature	°C	28.3	27.3	27.0	27.7	28.2	28.7	29.1	28.6	28.4	29.1	29.2	29.6
2	Slope Vapour Pressure Curve (A)	mmHg/F	0.9	0.9	0.9	0.9	0.9	1.0	1.0	1.0	0.9	1.0	1.0	1.0
3	Black Material Radiation (B)	mmH ₂ O/day	16.7	16.4	16.4	16.5	16.6	16.8	16.9	16.8	16.7	16.9	16.9	17.0
4	Saturated Vapour Pressure (ea)	mmHg	28.5	26.8	26.3	27.5	28.4	29.3	30.0	29.1	28.7	30.0	30.2	31.0
5	Monthly Relative Humidity (h)	%	80.1	84.2	85.4	82.7	81.5	82.3	79.0	77.0	75.7	73.8	75.0	73.8
6	Actual Vapour Pressure (ed)	mmHg	22.8	22.6	22.5	22.8	23.1	24.1	23.7	22.4	21.8	22.1	22.7	22.9
7	Reflection Coefficient (r)	%	55	55	55	55	55	55	55	55	55	55	55	55
8	Evaporating Surface Coefficient (k)		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
9	Wind Velocity (w)	mile / day	182.9	171.8	135.4	164.5	116.2	192.3	163.9	142.9	134.9	165.4	130.1	117.2
10	Solar Radiation (R) coord. 2° 33' S	mm/day	14.9	15.2	15.2	14.5	13.5	12.9	13.1	13.9	14.8	15.1	14.9	14.7
11	Monthly Solar Radiation (S)	(%)	60.9	61.0	61.8	56.3	55.3	65.8	68.5	66.5	63.5	66.3	61.8	60.6
12	Monthly Precipitation	mm	373.3	295.2	194.5	293.7	283.6	205.0	50.7	90.1	159.0	131.7	93.5	189.9
13	Number of Rainy Days (n)		13	17	17	21	16	15	14	12	16	12	15	12
14	Expose Surface (m)	%	55	55	55	55	55	55	55	55	55	55	55	55
15	Number of Day in The Month		31	28	31	30	31	31	30	31	30	31	30	31
16	Watershed Area	km ²	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Potential Evapotranspiration														
16	F1 = $A \times (0,18 + (0,55 \times S / 100)) / (A + 0,27)$		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
17	F2 = $A \times B \times (0,56 - (0,092 \times (ed^{0,5}))) / (A + 0,27)$		1.6	1.5	1.5	1.5	1.5	1.4	1.5	1.6	1.7	1.7	1.6	1.6
18	F3 = $0,27 \times 0,35 \times (ea - ed) / (A + 0,27)$		0.4	0.3	0.3	0.4	0.4	0.4	0.5	0.5	0.5	0.6	0.6	0.6
19	E1 = F1 x R x (1-(r/100))	mm/day	2.7	2.7	2.7	2.5	2.3	2.5	2.6	2.7	2.7	2.9	2.7	2.7
20	E2 = F2x (0,1 + (0,9 x (S/100)))	mm/day	1.0	1.0	1.0	0.9	0.9	1.0	1.1	1.1	1.1	1.2	1.1	1.0
21	E3 = F3 x (k + (0,01 x w))	mm/day	1.1	0.8	0.6	0.9	0.7	1.0	1.1	1.0	1.1	1.3	1.1	1.1
22	EP = E1 + E2 + E3	mm/day	4.8	4.5	4.3	4.3	3.9	4.5	4.7	4.8	4.9	5.4	4.9	4.8
		mm/month	147.5	126.3	134.8	127.7	121.5	138.0	141.1	150.1	148.3	167.8	146.4	148.2
Actual Evapotranspiration														
23	dE = Ep (m/20)*(18-n)	mm/day	1.2	0.6	0.6	0.2	0.6	0.9	1.1	1.3	0.8	1.6	0.9	1.4
24	dE compromised	mm/day	1.2	0.6	0.6	0.2	0.6	0.9	1.1	1.3	0.8	1.6	0.9	1.4
25	Ea = Ep - dE	mm/day	3.6	3.9	3.8	4.1	3.3	3.6	3.6	3.5	4.1	3.8	3.9	3.4
		mm/month	111.0	109.0	116.3	122.4	101.5	111.4	108.1	108.9	123.8	119.3	118.2	105.4
Water Balance														
26	WS = P - Ea		262.3	186.2	78.2	171.3	182.1	93.6	-57.4	-18.8	35.2	12.4	-24.7	84.5
27	SMC = 75 if P-Ea > 0; SMC _{n-1} + (P-Ea) if P-Ea < 0	mm/month	75	75	75	75	75	75	17.6	-1.2	75	75	50.3	75
28	SMS = ISMS + (P - EtI)	mm/month	337.3	261.2	153.2	246.3	257.1	168.6	-39.9	-20.0	110.2	87.4	25.5	159.5
29	Infiltration = WS x if ; if = 0,3	mm/month	78.7	55.9	23.4	51.4	54.6	28.1	-17.2	-5.6	10.6	3.7	-7.4	25.3
30	SF = WS - Infiltration	mm/month	183.6	130.3	54.7	119.9	127.5	65.5	-40.2	-13.2	24.6	8.7	-17.3	59.1
31	SWD = Infiltration - SMC	mm/month	3.7	-19.1	-51.6	-23.6	-20.4	-46.9	-34.8	-4.4	-64.4	-71.3	-57.7	-49.7
	P = Et + SF + SWD ± SMC ± SS ; SS = 0		373.3	295.2	194.5	293.7	283.6	205.0	50.7	90.1	159.0	131.7	93.5	189.9

Tahun 2008														
NO.	Component of Calculation	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
1	Temperature	°C	28.3	27.9	28.2	28.1	28.0	27.7	27.5	27.9	28.2	28.5	28.5	28.5
2	Slope Vapour Pressure Curve (A)	mmHg/F	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	1.0	0.9
3	Black Material Radiation (B)	mmH ₂ O/day	16.7	16.6	16.7	16.6	16.6	16.5	16.5	16.6	16.6	16.7	16.7	16.7
4	Saturated Vapour Pressure (ea)	mmHg	28.6	27.8	28.4	28.3	27.9	27.5	27.1	27.9	28.3	28.9	29.0	28.9
5	Monthly Relative Humidity (h)	%	79.3	76.7	77.8	79.0	79.1	81.1	81.4	77.7	76.9	75.7	76.6	78.5
6	Actual Vapour Pressure (ed)	mmHg	22.7	21.3	22.1	22.3	22.1	22.3	22.1	21.7	21.8	21.9	22.2	22.7
7	Reflection Coefficient (r)	%	55	55	55	55	55	55	55	55	55	55	55	55
8	Evaporating Surface Coefficient (k)		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
9	Wind Velocity (w)	mile / day	131.2	281.1	195.3	156.7	218.7	171.0	158.9	183.9	185.6	192.2	202.3	173.5
10	Solar Radiation (R) coord. 2° 33' S	mm/day	14.9	15.2	15.2	14.5	13.5	12.9	13.1	13.9	14.8	15.1	14.9	14.7
11	Monthly Solar Radiation (S)	(%)	39.5	51.5	62.5	52.5	51.0	53.0	59.0	58.5	58.0	54.0	54.0	49.5
12	Monthly Precipitation	mm	356.8	267.4	112.2	215.4	146.5	253.2	59.6	57.7	139.3	146.1	99.9	175.5
13	Number of Rainy Days (n)		21	20	20	15	19	17	17	10	11	14	17	16
14	Expose Surface (m)	%	55	55	55	55	55	55	55	55	55	55	55	55
15	Number of Day in The Month		31	28	31	30	31	31	30	31	30	31	30	31
16	Watershed Area	km ²	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Potential Evapotranspiration														
	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC	
16	$F1 = A \times (0,18 + (0,55 \times S / 100)) / (A + 0,27)$	0.3	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
17	$F2 = A \times B \times (0,56 - (0,092 \times (ed^{0,5}))) / (A + 0,27)$	1.6	1.7	1.6	1.6	1.6	1.6	1.6	1.7	1.7	1.7	1.6	1.6	1.6
18	$F3 = 0,27 \times 0,35 \times (ea - ed) / (A + 0,27)$	0.5	0.5	0.5	0.5	0.5	0.4	0.4	0.5	0.5	0.5	0.5	0.5	0.5
19	$E1 = F1 \times R \times (1 - (r/100))$	mm/day	2.1	2.4	2.8	2.4	2.2	2.1	2.3	2.4	2.6	2.5	2.5	2.3
20	$E2 = F2 \times (0,1 + (0,9 \times (S/100)))$	mm/day	0.7	1.0	1.1	0.9	0.9	0.9	1.0	1.1	1.1	1.0	1.0	0.9
21	$E3 = F3 \times (k + (0,01 \times w))$	mm/day	0.9	1.8	1.3	1.0	1.3	1.0	0.9	1.2	1.3	1.4	1.4	1.1
22	$EP = E1 + E2 + E3$	mm/day	3.7	5.2	5.1	4.3	4.4	4.0	4.2	4.7	4.9	4.9	4.8	4.3
	mm/month	113.6	145.2	159.3	129.2	135.6	124.2	126.1	145.3	146.6	151.5	145.0	134.0	
Actual Evapotranspiration														
	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC	
23	$dE = Ep \times (m/20) \times (18 - n)$	mm/day	0.2	0.3	0.3	0.9	0.4	0.6	0.6	1.6	1.5	1.1	0.7	0.8
24	dE compromised	mm/day	0.2	0.3	0.3	0.9	0.4	0.6	0.6	1.6	1.5	1.1	0.7	0.8
25	$Ea = Ep - dE$	mm/day	3.5	4.9	4.9	3.4	4.0	3.5	3.6	3.1	3.4	3.8	4.2	3.5
	mm/month	108.9	137.2	150.5	102.5	122.5	107.1	107.0	95.3	102.3	118.2	125.1	110.0	
Water Balance														
	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC	
26	$WS = P - Ea$	247.8	130.1	-38.4	112.8	24.0	146.0	-47.4	-37.7	37.0	27.9	-25.2	65.5	
27	$SMC = 75$ if $P - Ea > 0$; $SMC_{n-1} + (P - Ea)$ if $P - Ea < 0$	75	75	75	75	75	75	27.6	-10.1	75	75	49.8	75	
28	$SMS = ISMS + (P - Et)$	322.8	205.1	36.6	187.8	99.0	221.0	-19.9	-47.8	112.0	102.9	24.5	140.5	
29	Infiltration = WS x if ; if = 0,3	74.3	39.0	-11.5	33.9	7.2	43.8	-14.2	-11.3	11.1	8.4	-7.6	19.6	
30	$SF = WS - \text{Infiltration}$	173.5	91.1	-26.9	79.0	16.8	102.2	-33.2	-26.4	25.9	19.6	-17.7	45.8	
31	$SWD = \text{Infiltration} - SMC$	-0.7	-36.0	-86.5	-41.1	-67.8	-31.2	-41.8	-1.2	-63.9	-66.6	-57.3	-55.4	
	$P = Et + SF + SWD \pm SMC \pm SS ; SS = 0$	356.8	267.4	112.2	215.4	146.5	253.2	59.6	57.7	139.3	146.1	99.9	175.5	

Tahun 2007														
NO.	Component of Calculation	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
1	Temperature	°C	28.6	27.8	27.9	28.1	28.3	28.6	28.6	27.7	27.9	28.5	28.5	28.7
2	Slope Vapour Pressure Curve (A)	mmHg/F	1.0	0.9	0.9	0.9	0.9	1.0	1.0	0.9	0.9	0.9	1.0	1.0
3	Black Material Radiation (B)	mmH ₂ O/day	16.7	16.6	16.6	16.6	16.7	16.8	16.7	16.5	16.6	16.7	16.7	16.8
4	Saturated Vapour Pressure (ea)	mmHg	29.1	27.6	27.9	28.2	28.6	29.2	29.0	27.6	27.8	28.9	29.0	29.2
5	Monthly Relative Humidity (h)	%	78.8	78.8	78.1	79.0	78.6	79.6	76.7	78.5	78.6	77.6	75.5	76.9
6	Actual Vapour Pressure (ed)	mmHg	22.9	21.8	21.8	22.3	22.5	23.2	22.2	21.6	21.8	22.4	21.9	22.4
7	Reflection Coefficient (r)	%	55	55	55	55	55	55	55	55	55	55	55	55
8	Evaporating Surface Coefficient (k)		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
9	Wind Velocity (w)	mile / day	136.9	152.3	171.5	162.4	151.7	134.6	132.9	147.8	192.9	126.6	130.5	141.2
10	Solar Radiation (R) coord. 2° 33' S	mm/day	14.9	15.2	15.2	14.5	13.5	12.9	13.1	13.9	14.8	15.1	14.9	14.7
11	Monthly Solar Radiation (S)	(%)	59.0	59.0	52.5	58.0	59.0	65.5	59.0	59.5	59.5	61.5	54.0	63.0
12	Monthly Precipitation	mm	237.0	365.5	393.5	191.5	234.0	31.0	179.5	196.5	67.5	56.0	180.5	250.9
13	Number of Rainy Days (n)		18	22	20	18	14	14	10	13	11	13	15	22
14	Expose Surface (m)	%	55	55	55	55	55	55	55	55	55	55	55	55
15	Number of Day in The Month		31	28	31	30	31	31	30	31	30	31	30	31
16	Watershed Area	km ²	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Potential Evapotranspiration														
16	F1 = $A \times (0,18 + (0,55 \times S / 100)) / (A + 0,27)$		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
17	F2 = $A \times B \times (0,56 - (0,092 \times (ed^{0,5}))) / (A + 0,27)$		1.6	1.7	1.7	1.6	1.6	1.5	1.6	1.7	1.7	1.6	1.7	1.6
18	F3 = $0,27 \times 0,35 \times (ea - ed) / (A + 0,27)$		0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
19	E1 = F1 x R x (1-(r/100))	mm/day	2.6	2.7	2.5	2.5	2.4	2.5	2.3	2.4	2.6	2.7	2.5	2.7
20	E2 = F2x (0,1 + (0,9 x (S/100)))	mm/day	1.0	1.1	1.0	1.0	1.0	1.1	1.0	1.1	1.1	1.1	1.0	1.1
21	E3 = F3 x (k + (0,01 x w))	mm/day	0.9	1.0	1.1	1.0	1.0	0.9	1.0	1.0	1.2	0.9	1.0	1.0
22	EP = E1 + E2 + E3	mm/day	4.5	4.7	4.6	4.6	4.4	4.4	4.4	4.5	4.9	4.7	4.5	4.8
		mm/month	141.0	131.9	141.5	137.0	136.9	136.3	130.8	139.6	146.1	146.8	135.9	150.2
Actual Evapotranspiration														
23	dE = Ep (m/20)*(18-n)	mm/day	0.6	0.1	0.3	0.6	1.0	1.0	1.4	1.1	1.5	1.2	0.9	0.1
24	dE compromised	mm/day	0.6	0.1	0.3	0.6	1.0	1.0	1.4	1.1	1.5	1.2	0.9	0.1
25	Ea = Ep - dE	mm/day	4.0	4.6	4.2	4.0	3.4	3.4	2.9	3.4	3.4	3.6	3.6	4.8
		mm/month	123.6	130.1	131.7	120.0	104.9	104.4	87.6	105.1	101.9	110.4	107.9	148.2
Water Balance														
26	WS = P - Ea		113.4	235.4	261.8	71.5	129.1	-73.4	91.9	91.4	-34.4	-54.4	72.6	102.7
27	SMC = 75 if P-Ea > 0; SMC _{n-1} + (P-Ea) if P-Ea < 0	mm/month	75	75	75	75	75	1.6	75	75	40.6	-13.8	75	75
28	SMS = ISMS + (P - Et)	mm/month	188.4	310.4	336.8	146.5	204.1	-71.8	166.9	166.4	6.2	-68.3	147.6	177.7
29	Infiltration = WS x if ; if = 0,3	mm/month	34.0	70.6	78.5	21.4	38.7	-22.0	27.6	27.4	-10.3	-16.3	21.8	30.8
30	SF = WS - Infiltration	mm/month	79.4	164.8	183.2	50.0	90.4	-51.4	64.3	64.0	-24.1	-38.1	50.8	71.9
31	SWD = Infiltration - SMC	mm/month	-41.0	-4.4	3.5	-53.6	-36.3	-23.6	-47.4	-47.6	-50.9	-2.5	-53.2	-44.2
	P = Et + SF + SWD ± SMC ± SS ; SS = 0		237.0	365.5	393.5	191.5	234.0	31.0	179.5	196.5	67.5	56.0	180.5	250.9

Tahun 2006														
NO.	Component of Calculation	UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
1	Temperature	°C	28.2	27.5	27.1	27.1	27.6	24.3	24.8	24.2	27.6	27.2	28.6	29.4
2	Slope Vapour Pressure Curve (A)	mmHg/F	0.9	0.9	0.9	0.9	0.9	0.8	0.8	0.8	0.9	0.9	1.0	1.0
3	Black Material Radiation (B)	mmH ₂ O/day	16.6	16.5	16.4	16.4	16.5	15.8	15.9	15.8	16.5	16.4	16.7	16.9
4	Saturated Vapour Pressure (ea)	mmHg	28.3	27.1	26.5	26.4	27.3	22.3	22.9	22.2	27.3	26.7	29.1	30.5
5	Monthly Relative Humidity (h)	%	41.5	41.5	40.5	40.5	39.5	39.5	40.0	40.5	39.5	37.5	39.5	39.5
6	Actual Vapour Pressure (ed)	mmHg	11.7	11.3	10.7	10.7	10.8	8.8	9.2	9.0	10.8	10.0	11.5	12.0
7	Reflection Coefficient (r)	%	55	55	55	55	55	55	55	55	55	55	55	55
8	Evaporating Surface Coefficient (k)		0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
9	Wind Velocity (w)	mile / day	88.5	111.1	108.0	120.5	127.2	88.3	65.8	182.8	93.7	91.3	123.5	122.6
10	Solar Radiation (R) coord. 2° 33' S	mm/day	14.9	15.2	15.2	14.5	13.5	12.9	13.1	13.9	14.8	15.1	14.9	14.7
11	Monthly Solar Radiation (S)	(%)	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	62.0	34.7
12	Monthly Precipitation	mm	215.0	137.0	418.0	166.0	139.0	187.5	196.5	194.0	365.0	193.5	173.5	79.5
13	Number of Rainy Days (n)		14	11	24	14	12	14	16	13	20	11	8	7
14	Expose Surface (m)	%	55	55	55	55	55	55	55	55	55	55	55	55
15	Number of Day in The Month		31	28	31	30	31	31	30	31	30	31	30	31
16	Watershed Area	km ²	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6	12.6
Potential Evapotranspiration		UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
16	$F1 = A \times (0,18 + (0,55 \times S / 100)) / (A + 0,27)$		0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.3
17	$F2 = A \times B \times (0,56 - (0,092 \times (ed^{0,5}))) / (A + 0,27)$		3.2	3.2	3.2	3.2	3.3	3.3	3.3	3.3	3.3	3.4	3.2	3.2
18	$F3 = 0,27 \times 0,35 \times (ea - ed) / (A + 0,27)$		1.3	1.3	1.3	1.3	1.3	1.2	1.2	1.2	1.3	1.4	1.4	1.4
19	$E1 = F1 \times R \times (1 - (r/100))$	mm/day	2.7	2.7	2.7	2.6	2.4	2.2	2.3	2.4	2.7	2.7	2.7	1.9
20	$E2 = F2 \times (0,1 + (0,9 \times (S/100)))$	mm/day	2.1	2.1	2.1	2.1	2.2	2.2	2.2	2.2	2.2	2.2	2.1	1.3
21	$E3 = F3 \times (k + (0,01 \times w))$	mm/day	1.9	2.2	2.2	2.3	2.5	1.8	1.6	3.0	2.0	2.1	2.5	2.5
22	$EP = E1 + E2 + E3$	mm/day	6.7	7.0	7.0	7.1	7.1	6.3	6.0	7.5	6.9	7.0	7.3	5.8
		mm/month	208.1	196.9	218.2	212.2	219.9	194.5	180.6	233.4	206.2	217.1	220.4	178.7
Actual Evapotranspiration		UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
23	$dE = Ep \times (m/20) \times (18 - n)$	mm/day	1.5	2.1	-0.3	1.6	2.0	1.4	0.9	1.9	0.4	2.1	2.8	2.3
24	dE compromised	mm/day	1.5	2.1	0.0	1.6	2.0	1.4	0.9	1.9	0.4	2.1	2.8	2.3
25	$Ea = Ep - dE$	mm/day	5.2	4.9	7.0	5.5	5.1	4.8	5.1	5.6	6.5	4.9	4.6	3.4
		mm/month	162.1	138.0	218.2	164.7	157.7	149.7	153.0	174.1	194.7	151.9	137.1	106.5
Water Balance		UNIT	JAN	FEB	MAR	APR	MAY	JUNI	JUL	AGS	SEPT	OCT	NOV	DEC
26	$WS = P - Ea$		52.9	-1.0	199.8	1.3	-18.7	37.8	43.5	19.9	170.3	41.6	36.4	-27.0
27	$SMC = 75$ if $P - Ea > 0$; $SMC_{n-1} + (P - Ea)$ if $P - Ea < 0$	mm/month	75	74.0	75	75	56.3	75	75	75	75	75	75	48.0
28	$SMS = ISMS + (P - Et)$	mm/month	127.9	73.0	274.8	76.3	37.6	112.8	118.5	94.9	245.3	116.6	111.4	20.9
29	Infiltration = WS x if ; if = 0,3	mm/month	15.9	-0.3	59.9	0.4	-5.6	11.4	13.0	6.0	51.1	12.5	10.9	-8.1
30	$SF = WS - Infiltration$	mm/month	37.1	-0.7	139.8	0.9	-13.1	26.5	30.4	13.9	119.2	29.1	25.5	-18.9
31	$SWD = Infiltration - SMC$	mm/month	-59.1	-74.3	-15.1	-74.6	-61.9	-63.6	-62.0	-69.0	-23.9	-62.5	-64.1	-56.1
	$P = Et + SF + SWD \pm SMC \pm SS ; SS = 0$		215.0	137.0	418.0	166.0	139.0	187.5	196.5	194.0	365.0	193.5	173.5	79.5