MODELING OF FLOOD FOR LAND USE MANAGEMENT

(Case Study of Ciliwung Watershed)

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GRADUATE SCHOOL
BOGOR AGRICULTURAL UNIVERSITY
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MODELING OF FLOOD FOR LAND USE MANAGEMENT

(Case Study of Ciliwung Watershed)

I PUTU SANTIKAYASA

A Thesis submitted for the degree of Master of Science
of Bogor Agricultural University

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY
FOR NATURAL RESOURCES MANAGEMENT
GRADUATE SCHOOL
BOGOR AGRICULTURAL UNIVERSITY
August 2006
STATEMENT

I, I Putu Santikayasa, here by stated that this thesis entitled

**Modeling of Flood for Land Use Management**

*(Case Study of Ciliwung Watershed)*

are result of my own work during the period February 2005 until April 2006 and that it has not been published before. The content of the thesis has been examined by the advising committee and the external examiner.

Bogor, August 2006

I Putu Santikayasa
ACKNOWLEDGMENT

All the praises and thanks be to Hyang Widhi, The Lord of Heaven. The title of the research, which was held in January to September 2005 is “Modeling of Flood for Land Use Management (Case Study of Ciliwung Watershed)”.

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Hopefully, this hardwork can be usefull.
CURRICULUM VITAE

I Putu Santikayasa was born in Pohsanten, Jembrana - Bali at February 24, 1979. He received his undergraduate from Bogor Agricultural University in 2002 in the field of Agrometeorology. Since 2005 until now, He works as lecturer in Department of Geophysics and Meteorology, Faculty of Mathematics and Natural Sciences, Bogor Agricultural University.

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ABSTRACT


Floods are one of the major disasters affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems. It causes damage to lives, natural resources and environment as well as the loss of economy and health. Floods represent complex problems because of its variety. Therefore, this variety cannot be studied or controlled only by one or two specific methods.

The objectives of this research are to understand the process of flood events and its interaction with hydrometeorological components, to develop flood model for watershed management and to determine the effect of land use change to watershed discharge which indicates flood event.

The research consists of four processes those are 1) Data Preparation, 2) Model Development, 3) Model Simulation and 4) Model Calibration and Validation. Data preparation was conducted for two kinds of data namely spatial data and tabular data. Model developed as numerical model of the hydrology of a river basin system. This model includes the response of watershed to precipitation, the actions of the river network as water flows through the river, the effect of land use changes, and the effect of engineering structures to the watershed. Model simulated by change land use as an input. Model calibrated by using water level data of field measurement in year 1996 and model validated by using water level data of field measurement in year 2000.

The result of this research showed how the process based modeling is useful to model hidrological processes over the watershed. Precipitation is the main input for hidrology simulation and land use change gives the effect of water level in the watershed. The model which is built in this research can be used to evaluate runoff from different land use areas. For assessing the hydrological effects of land use changes on floods, three hypothetical scenarios, namely urbanization, deforestation and afforestation scenario, were considered made. It was found from the model simulation that the urbanization scenario has the highest negative impact on increasing water level. Deforestation has the second largest negative impact, while afforestation causes positive impact shown by decreasing water level. The result indicated that the urbanization produce the highest peak flow, followed by the deforestation and afforestation scenario. The simulated water level for the present land use is 84 cm, for the urbanization scenario 135 cm, deforestation scenario 92 cm, and afforestation scenario 59 cm. Accordingly, the urbanization scenario increases the peak discharge by 61%, the deforestation scenario increase 15%, and afforestation decrease by 19%.
Research Title : Modeling of Flood for Land Use Management (Case Study of Ciliwung Watershed)

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I. INTRODUCTION

1.1 Background

Floods are one of the major disasters affecting many countries in the world year after year. It is an inevitable natural phenomenon occurring from time to time in all rivers and natural drainage systems. It causes damage to lives, natural resources and environment as well as the loss of economy and health.

According to Islam (2002), in recent decades, floods losses have increased worldwide. This can be linked to socio-economic, hydrological and climatic factors. An increase of flood risk is also foreseen for the future. Several landuse changes, such as deforestation and urbanization, reduce the available water storage capacity and increase the flood hazard.

Flood is becoming an increasing major contributor to personal and to property damage worldwide and in many places strikes without warning. Increasing population pressure and economic activities has led to the development of extensive infrastructures near the rivers. These economic activities and land use changed increase the risk of future inundations.

Floods represent complex problems because of its variety. Therefore, this variety cannot be studied or controlled only by one or two specific methods. In this case, flood has been viewed as a system that integrates any discipline by including social discipline.

In Indonesia, climate change especially of extreme rainfall, caused by La Nina effect contributes extensively to flooding process. Problems related to flood
have greatly increased and there is a need for effective modeling and understanding of the problem to help mitigate the worst effects of flood disasters and the need for developing a system to understand the threatened areas. The understanding of process will help in flood hazard assessment and in giving insights to various ways of dealing with the hazard and disaster problems.

Ciliwung River is one of the biggest rivers which passes Jakarta and eventually causes flood in Jakarta. In the first year of 1996, Ciliwung River causes flood in Jakarta and damage. In year 2002 the flood event was bigger than previously and causing damage about 40% of Jakarta area (BPS Jakarta).

The land use of Ciliwung watershed has been changed in the last 25 years. This change increases runoff of about 54%. This runoff change has high correlation with the land use change in the Ciliwung watershed (Fakhrudin, 2003).

Land use change affects hydrological characteristics such as infiltration, surface storage, and evapotranspiration. The decrease of infiltration will increase runoff. This condition is potential to cause flood in the wet season while causes drought in the dry seasons. Surface storage has a correlation with time lag of runoff. The decrease of surface storage will increase runoff flow which means the water has no time to infiltrate but directly flows to the river and causes flood in low places.

Flood is a dynamic system because flood process is time dependent. Dynamic system is described by time-differential equations; therefore, the future response of the system is determined by the present state of the system
(the initial conditions) and the present input. Thus, a dynamic system may continue to have a time-varying response after the inputs are held constant.

As a dynamic process flood event can be forecasted. One method to forecast flood events is by considering flood process as a system. As a system, flood process has component such as input, process, output, feedback process, environment, and boundary. The important factor from system is its behavior. The behavior will provide the explanation of flood event and bring it to the solution. By changing the value of variables during simulation it also gives the effect degree of each component. This is very important to make decision related to the action in the field.

Geographic information system (GIS) provides a broad range of tools for determining area affected by floods and for forecasting areas that are likely to be flooded due to high water level in a river. Prahasta (2001) also mentioned that GIS is the nucleus of the environmental information system. Most of the information needed to operate an urban is geo-referenced, i.e. it is referenced to specific geographic location. Information about zoning, properties, roads, rivers, administration boundary are connected to geographic locations.

Based on the explanation above, this research will study hydrology response to land use change and modeling flood event by using system dynamic approach. The benefit of this model is that the model can explain flood process and its behavior and can be used to evaluate watershed system. This model will be used as a tool to evaluate the effect of land use change to the water level in the watergate station which are indicated flood.
1.2 **Objectives**

The objectives of this research are:

- To understand the process of flood events and its interaction with hydrometeorological components.
- To develop flood model for watershed management
- To determine the effect of land use change to watershed discharge which indicates flood event.

1.3 **Hypothesis**

- Land use change influence discharge in the outlet.

1.4 **Thesis Structure**

The thesis consists of six consecutive chapters. The contents of each chapter are described below:

- Chapter I introduces the research by focusing on the background such as introduction, objectives, hypothesis, and thesis organization.
- Chapter II provides comprehensive summary of related work ranging from watershed, process-based hydrological modeling, flood, and landuse management.
- Chapter III introduces the study area, materials and methods.
- Chapter IV focuses on the results and discussion. This chapter includes an overview of characteristics of study area, model structure, discussion
of study area characteristics and model structure, model calibration, and model profile.

- Chapter V consists of Conclusion and Recommendation.
II. LITERATURE REVIEW

2.1 Watershed

2.1.1 Watershed definition

The term watershed describes an area of land that drains downslope to the lowest point. The water moves through a network of drainage pathways, both underground and on the surface. Generally, these pathways converge into streams and rivers, which become progressively larger as the water moves on downstream, eventually reaching an estuary and the ocean. Other terms used interchangeably with watershed include drainage basin or catchments basin.

Watersheds can be large or small. Every stream, tributary, or river has an associated watershed, and small watersheds join to become larger watersheds. It is relatively easy to delineate watersheds using a topographic map that shows stream channels. Watershed boundaries follow major ridgelines around channels and meet at the bottom, where water flows out of the watershed, a point commonly referred to as a stream or river.

The connectivity of the stream system is the primary reason for doing aquatic assessments at the watershed level. Connectivity refers to the physical connection between tributaries and the river, between surface water and groundwater, and between wetlands and water. Because water moves downstream, any activity that affects the water quality, quantity, or rate of movement at one location can affect locations downstream. For this reason,
everyone living or working within a watershed needs to cooperate to ensure good watershed conditions.

2.1.2 Watershed as a System

Watershed as a system consider the form and appearance of a typical watershed, illustrated in the Figure 1. Included in this Figure are some of the physical characteristics of a typical watershed.

![Flow of Water in a Watershed](http://www.sbg.ac.at/geo/idrisi/gis_environmental_modeling/sf_papers/collins_fred/collins.html)

**Figure 1. Physical Characteristics Of Watershed**

Source: http://www.sbg.ac.at/geo/idrisi/gis_environmental_modeling/sf_papers/collins_fred/collins.html

From the Figure above, the amount of water in a river depends on the inputs and the outputs. The inputs are water flowing over the surface water seeping in through the bed of the stream from the soil and/or groundwater (although in arid regions, this second inflow is actually an outflow; the stream lies above the water Table and loses water to the soil and ground water). The flow of water from soil and ground water sources constitutes the base flow of a stream.
and most streams are maintained by this ground water and soil water contribution. Water leaves the river by flowing down the channel; this rate is controlled by stream parameters like the gradient of the stream, the roughness of the stream bed, and the shape of the channel. The shape of the channel is important since it determines what portion of the flowing water is in contact with the stream bed and can thus be slowed by friction associated with the rough surface of the stream bed.

2.1.3 Watershed Modeling

Watershed modeling encompasses processes that make up the land portion of the hydrologic cycle. Such models track the flow of water from rainfall inputs to infiltration, seepage to groundwater, overland flow, channel flow, subsurface stormflow, and evapotranspiration. Models that simulate a single precipitation/runoff event are called event based models, while models that can simulate processes occurring between Precipitation events are called continuous simulation models. If watershed models only have one parameter value for a given watershed or sub watershed, the model is referred to as a lumped-parameter model. If the model allows for multiple location values for a given parameter within a watershed or sub watershed, the model is referred to as a distributed model.

Watershed models can be further categorized as either conceptual models or physics-based models. Conceptual models make use of idealizations of processes in the simulation of watershed phenomena. For example, a conceptual model may simulate the watershed as a collection of reservoirs connected in series or parallel with rules for moving water from one reservoir to another to simulate
watershed processes. In such model, there may be a reservoir for groundwater, a reservoir for infiltrated water, a reservoir for water in channels, and a reservoir for overland flow water. Water is moved from one reservoir to another to simulate the precipitation-runoff process. The rules for transferring water from one reservoir to another are based on a parameterization of the particular process (e.g. infiltration moving precipitation to sub-surface storage or groundwater). Such models are useful for viewing at total watershed response (runoff at the outlet of the watershed). These models rely on observed data for calibration of the parameters that govern the movement of water between the different components. Parameters are changed until the modeled runoff at the outlet of the watershed matches the observed runoff. In some conceptual models there are possibilities of matching modeled to observed data in the interior of the watershed as well.

An alternative to conceptual models are physics-based watershed models. In general, these are the most complex of watershed models as they utilize conservation equations (conservation of mass, momentum, or energy) to simulate watershed processes. As an example, physics based models may use versions of the shallow water equations (conservation of mass and momentum) like the diffusion wave to simulate channel flow or overland flow. Movement of water through each part of the land portion of the hydrologic cycle is governed by a conservation equation in one, two or three dimensions. Initial and boundary conditions are required to solve the equations and provide linkages between the different processes. The parameters of physics-based models are either measurable field quantities or they can be derived from land features such as soils, vegetation, topographic, and geologic maps. As such, the parameters of physics-
based models can be estimated directly from field data and land features, negating the requirement of historical concurrent precipitation-runoff data for their calibration.

2.1.4 Watershed and Drainage Basin

Streams and rivers convey both surface runoff and ground water flow away from high water areas, preventing surface flooding and rising groundwater problem. A watershed area supplies surface runoff to a river stream, whereas a drainage basin for a given stream is the fact of land drained of both surface runoff and groundwater discharge.

Surface runoff from a watershed flows downhill until reaching a tributary or stream. The lines separating the land surface into watershed are called divides. These normally follows ridges and mounds and can be delineated using contour maps, fields surveys, or stereograph pairs of areal photographs to identify gradient directions.

2.1.5 Basin Characteristics Affecting Runoff

The nature of stream flow in a region is a function of hydrologic input to the region and the physical, vegetative, and climatic characteristic. As indicated by the hydrologic equation, all the water that occurs in an area as a result of precipitation does not appear as stream flow. Fractions of the gross precipitation are diverted into paths that do not terminate in the regional surface transport system. Precipitation striking the ground can go into storage on the surface or in the soil and into groundwater reservoir beneath the surface. Some basin character
that influences runoff are: 1) geologic consideration, 2) stream pattern, and 3) geomorphology of drainage basin.

2.2 Process-Based Hydrology Modeling

2.2.1 Hydrology Cycle

The hydrology cycle is a continuous process by which water is transported from the oceans to the atmosphere then to the land and back to the sea. Many sub-cycles exist inside. The driving force for the global water transport system is provided by the sun, which furnishes the energy required by evaporation.

Because the total quantity of water available to the earth is finite and indestructible, the global hydrologic system may be looked upon as closed system. Open hydrologic sub systems are abundant, however and these are usually the type analyzed. For any system a water budget can be developed to account for the hydrologic component. The process of hydrologic cycle describe as Figure below:

![Figure 2. Conceptual of Hydrologic Cycle Diagram](http://www.sbg.ac.at/geo/idrisi/gis_environmental_modeling/sf_papers/collins_fred/collins.html)
2.2.2 Physically Based Hydrological Models

The physically based models are based on our understanding of the physics of the hydrological processes which control the catchments response and use physically based equations to describe these processes. A discretization of spatial and temporal coordinates is made and the solution is obtain hydrological applications has broadened dramatically over the past four decades. Although the problems of flood protection and water resources management continue to be of importance and relevance for the security of communities and for human, social and economic development, many applied problems relating to the wider role of hydrology have come into focus.

Physically based distributed models of the hydrological cycle can in principle be applied to almost any kind of hydrological problem. These models are based on our understanding of the physics of the hydrological processes which control catchments response and use physically based equations to describe these processes. Some typical examples of field applications include study of effect of catchments changes, prediction of behavior of ungauged catchments, of spatial variability in catchments inputs and outputs, movement of pollutants and sediment.

Hydrological modeling is a powerful technique of hydrologic system investigation for both the research hydrologists and the practicing water resources engineers involved in the planning and development of integrated approach for management of water resources. Physically based distributed models do not consider the transfer of water in a catchments to take place in a few defined storage as in case of lumped conceptual models. From their physical basis such
models can simulate the complete runoff regime, providing multiple outputs (e.g. river discharge, phreatic surface level and evaporation loss) while black box models can offer only one output. In these models transfer of mass, momentum and energy are calculated directly from the governing partial differential equations which are solved using numerical methods. As the input data and computational requirements are enormous, the use of these models for real-time forecasting has not reached the ‘production stage’ so far.

Physically-based distributed models can in principle be applied to almost any kind of hydrological problem. Some examples of typical fields of application are catchments changes, ungaged catchments and spatial variability.

2.2.3 Hydrometeorology Component

Precipitation

Precipitation is the primary input vector of the hydrologic cycle and the most important input into a simulation model of the land phase of hydrological model. Precipitation is derived from atmospheric water, its form and quantity thus being influenced by the action of the climatic factor such as wind, temperature and atmospheric pressure.

Interception

Interception is defined as the process whereby precipitation is retained on the leaves, branches, and steams of vegetation and on the litter covering the ground.
Some observed percentages of interception by various crops and grasses shown as Table 1.

Table 1. Percentages of Interception by Various Crops and Grass

<table>
<thead>
<tr>
<th>Vegetation</th>
<th>Vegetation Type</th>
<th>Intercepted (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Crops</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Alfalfa</td>
<td>36</td>
</tr>
<tr>
<td></td>
<td>Corn</td>
<td>16</td>
</tr>
<tr>
<td></td>
<td>Soybeans</td>
<td>15</td>
</tr>
<tr>
<td></td>
<td>Oats</td>
<td>7</td>
</tr>
<tr>
<td><strong>Grasses</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Little Bluestem</td>
<td>50-60</td>
</tr>
<tr>
<td></td>
<td>Big Bluestem</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Tall panic grass</td>
<td>57</td>
</tr>
<tr>
<td></td>
<td>Bindweed</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Buffalo grass</td>
<td>31</td>
</tr>
<tr>
<td></td>
<td>Blue grass</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Mixed species</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>Natural grasses</td>
<td>14-19</td>
</tr>
</tbody>
</table>

*source: O. R. Clark (1937)*

**Evaporation and Transpiration**

Evaporation is the transfer of water mass from the liquid to the vapor state. Transpiration is a plant metabolism process where water is received from the soil and released as vapor to the atmosphere. Evapotranspiration take place from water, snow, land, and vegetation surface. The volume of water which leaves the land phase of the hydrologic cycle by actual evaporation and transpiration in the most cases exceeds that which flows to the oceans by runoff.

**Radiation**

The processes by which the sun’s energy reaches the surface of the earth are complex. Radiation is one form of energy transfer. From a hydrologic viewpoint, the important forms of solar energy reaching the surface of the earth are: shortwave solar radiation consisting of direct solar radiation, scattered sky
radiation, and long-wave atmospheric radiation, all in downward direction; and reflected components of short-wave radiation and the long-wave terrestrial radiation emitted by the surface of the earth.

*Wind speed and direction*

Both wind speed and direction are important for calculating another atmosphere processes. Wind speed is important for calculating evaporation, snow melt, or rain gauge loses. Wind direction can be used to estimate flow of water vapor.

*Cloud cover*

Cloud cover affects the transfer of energy to the land surface by intercepting part of the direct sort-wave radiation. Cloud cover observations are important in situations where no observations exist on incoming radiation. In such cases, estimated values of clear sky radiation are used with adjustments for affect of cloud cover.

*Stream flow*

Stream flow records provide a measure of the response of a catchments to the time variable input and internal hydrologic processes. These records are used in simulation techniques during model calibration to assess the dominant processes contributing to the response of base flow and overland flow. Figure below describe the relationship of each hydrologic component.
2.2.4 Classification of Hydrology Modeling

Watershed models are developed for different purposes. Nevertheless many of those models share structural similarities, because their underlying assumptions are the same, and some of the models are distinctly different. The watershed models can be classified according to different criteria that encompass process description, scale, and technique of solutions.

The watershed model can be classified based on the time scale of models. One of the time intervals is used for input and internal computations. The second is the time-interval used for the output and calibration of the model. Based on these description, the models can be classified as 1) continuous-time or event based, 2) daily, 3) monthly, and 4) yearly models (Sigh, 1995).
The watershed can also be classified depend on the space of watershed. These criteria is use to classify into small watershed, medium size watershed, and large watershed. For consideration of runoff generation on these watersheds, two phases can be considered: 1) land phase and 2) channel phase. Large watersheds have well developed channel network and channel phase, and thus, channel storage is dominant. The other hand, small watershed have dominant land phase and overland flow, have relatively less conspicuous channel phase, and are highly sensitive to high-intensity, short-duration rainfalls.

Watershed can be classified base on land use. Watershed can be classified into agriculture, urban, forest and range land, desert, mountain, coastal, wetlands and mixed area. In many case, large or even medium size of watersheds have mixed land use. These watersheds behave hierologically differently, indeed so differently that they have given rise to different branches of hydrology.

And frequently watershed model classified on the basis of their intended use. Model are classify into: 1) planning models, 2) management models, and 3) prediction models. A comprehensive watershed model can be employed to accomplish a considerable array of analytical tasks for planning and management of water resources (Viesman, 1989).

2.3 **Flood**

2.3.1 **Flood Definition**

Flood is defined as any relatively high flows that overtop the natural or artificial banks in any reach of a stream. When the banks are overtopped, water spreads over the flood-plain and generally comes into conflict with man.
Flood may be measurable as to height, area inundated, peak discharge, and volume of flow. The height of a flood is of interest to those planning of build structure along or across streams; the area inundated is of interest to those planning to occupying in any manner the floodplains adjacent to a streams; the peak discharge is of interest to those designing spillways, bridges, culverts, and flood channel; and the volume of flow is interest to those designing storage works for irrigation, water supply, and flood control.

Floodplains are areas with ecologically important wetlands, and mainly exhibit competitive advantages for human urban. Resolving the potential conflict between ecological value and human use is consequently a major issue in determining the most appropriate flood hazard management strategy.

2.3.2 Flood Routing

Flood routing defined as the procedure whereby the time and magnitude of a flood wave at a point on a stream is determined from the known or assumed data at one or more points upstream.

The movement of a flood wave down a channel or through a reservoir and the associated change in timing or attenuation of the wave constitute an important topic in floodplain hydrology. It is essential to understand the theoretical and practical aspects of flood routing to predict the temporal and spatial variations of a flood wave through a river reach or reservoir. Flood routing methods can also be used to predict the outflow hydrograph from watershed subjected to a known amount of precipitation.
Routing technique may be classified into two major categories: simple hydrologic routing and more complex hydraulic routing. Hydrologic routing involves the balancing of inflow, outflow and the volume of storage through use of the continuity equation. Hydrologic routing can be used in flood prediction, flood control measures, reservoir design and operation, watershed simulation, and urban design. Whereas hydraulic routing method is based on the solution of the continuity equation and the momentum equation for unsteady flow in open channel. Hydraulic routing method is used in case: upstream movement of tides and storm surge, backwater effect from downstream reservoir and tributary inflows, flood waves in channels of very flat slope, and abrupt wave caused by sudden releases from reservoir or dam failure.

Figure 4. Flood in Jakarta
2.3.3 Flood Modeling

The first step in risk management for floods is the flood hazard mapping. For planning and evacuation procedures, the demand for flood information and digital maps of predicted extent and risk of flooding has been increased. To produce these maps Geographical Information System (GIS), Remote Sensing (RS) and flood modeling is very useful.

Simulation and modeling of flood are a rapidly developing field in hydrology. The flood simulation and model results are a good way of providing relevant information on how the flood is going to behave at the location where people live and how the flood will affect them.

There are many types of flood models, 1-dimensional (1D) floods models such as manning equation, HEC-2, and dynamic one-dimensional model such as SOBEK, MIKE-11 have been used to estimate the possible flood using time series of river discharge. 1-D model has some limitation on include all details in modeling and it is very difficult to simulate local conditions on a small scale accurately (Singh, 1995)

Two dimensional (2D) modeling based on the raster grids for terrain description, surface roughness coefficients and hydrological data (water level, discharge and cross section) provide information to generate flood hazard maps.

Over the past ten years significant advances have been made in integrating 1D and 2D models resulting in hydrodynamic model of floodplains and integrated 1D (channel flow) and 2D (overland flow). The idea of integrating 1D hydrodynamic modeling technologies, Digital Elevation Model (DEM) and GIS system is to take advantage of the best combination of 1D and 2D and presenting
them in the GIS as maps. Benefit of the integration of GIS, RS, 2D flood modeling is to provide information for users such as land use planning, evacuation planning and environmental impact assessment.

2.3.4 Step in Hydrology Modeling Development

A simulation model is a set of equations and algorithm that describe the real system and imitate the behavior of the system. A fundamental first step in organizing a simulation model involves a detailed analysis of all existing and proposed components of the system and the collections of relevant data. This step is called the system identification or inventory phase. Included items of interest are site locations reservoir characteristics, precipitation and stream flow histories, water and power demands, and so forth.

The second phase is model conceptualization, which often provides feedback to the first phase by defining actual data requirements for the planner and identifying system components that are important to the behavior of the system. This step involves 1) selecting a technique that are to be used to represent the system elements, 2) formulating the comprehensive mathematics of the techniques, and 3) translating the proposed formulation into a working computer program that interconnects all the subsystems and algorithm.

Following the system identification and conceptualization phases are several steps of the implementation phase. These include 1) validating the model, 2) modifying the algorithms as necessary to improve the accuracy of the model, and 3) putting the model to work by carrying out the simulation experiments.
2.4 Landuse Effects on Runoff

Watershed is the hydrology system which include the component of input, processes, and output. The primary input is precipitation and by the process in the watershed, excess water from precipitation will become channel outflow in the outlet. If process in the watershed “normal”, the fluctuation of channel flow will not be significant.

Hydrology process in the watershed influence by geomorphology, geology, topography, climate, soil, and landuse factor. Those factor relate each other and land use is the factor which change faster compare with the other factor. Landuse changed caused by the increasing of population and socio-economic.

Runoff processes if amount of precipitation larger than rate of infiltration, interception and soil water storage. Increasing rate of infiltration will decreasing runoff. The rate of infiltration influenced by such factor as the type and extent of vegetation cover, the condition of surface layer, temperature, rainfall intensity, physical properties of the soil, and water quality. The water at which water is transmitted through the surface layer is highly dependent on the condition of the surface. The volume of storage available below the ground is also a factor affecting infiltration rates.

Modification of the land surface have varying effects on the runoff characteristics. For example if a heavily forested area with its thick layer of mulch is converted to cropland or pasture, the soil is disturbed and the overlying absorptive cover is changed. The result is increased runoff volume and a change in timing of flows. When lowlands or marshes are surface drained, the flooding characteristics of these areas are modified. Change in the vegetal cover affect the
infiltration capacities of soils and landuse changes that modify the nature of vegetation can have significant impact on the timing and volume of flows.

The principle effects of landuse change have been classified by Leopold (1968) as follows: 1) changes in peak flow characteristics, 2) changes of total runoff, 3) changes of water quality, and 4) changes in hydrologic amenities (the appearance or impression a watercourse)

Land use change can increase or decrease the volume of runoff and the maximal rate and timing of flow from a given area. The most influential factors affecting flow volume are the infiltration and surface storage. If the landuse change decrease flow volume also decrease the peak rate of flow and vice versa. Some effect of landuse treatment on the direct runoff are shown in the Table below:

Table 2. Effect Of Some Landuse Treatment And Treatment Measure On The Direct Runoff

<table>
<thead>
<tr>
<th>Measure</th>
<th>Reduction in direct runoff volume Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Increasing infiltration rate</td>
</tr>
<tr>
<td>Landuse change that increases plant or root density</td>
<td>√</td>
</tr>
<tr>
<td>Increasing mulch of litter</td>
<td>√</td>
</tr>
<tr>
<td>Contouring</td>
<td></td>
</tr>
<tr>
<td>Contouring furrowing</td>
<td></td>
</tr>
<tr>
<td>Level terracing</td>
<td></td>
</tr>
<tr>
<td>Graded terracing</td>
<td></td>
</tr>
</tbody>
</table>

Source: Bras (1990)

2.5 The Influenced of Land Use Management on Flood Risk

Catchments landscapes are complex mosaics of land use and land management activities, each of which will have an influence on hydrological
functioning and flood responses, but the way in which these diverse influences combine to generate the flood hydrograph and flood frequency curve at increasing catchments scales is not well understood. Typical influences which can impact local scale flood responses include soil compaction in fields, resulting in reduced porosity and infiltration, the acceleration of sub-surface runoff through field drains, enhanced flow connectivity pathways through ploughing ditches etc. While various measures might be taken to counteract these effects, their potential impact on large scale flood responses needs to be investigated through a combination of field experiments and modeling.

Bad land use management practices are thought to be the cause of increased flooding. This result when land use decisions not taking into account the effect of development on the water resources of the basin are implemented.

Since there are economic consequences involved in flooding issues it becomes important to assess the flood risks in a basin and where possible to minimize those risks in order to reduce costs. This is a concern for individuals, private enterprises and governments who bears the cost of floods when they occur.

It is also true that damages to flooding tend to be inequitable affecting those who likely have no control of the situation and even without any compensation. When bad land use practices occur upstream they affect homeowners, farmers and communities downstream with increased flooding potential, more sedimentation, polluted water and reduced water availability. It is therefore important to understand the role of land use changes on flooding risks at local scale such that political and technical measures can be taken to reduce the negative developments on the environment and society.
III. RESEARCH METHODOLOGY

3.1 Time and Location of Research

This research was conducted in Bogor from September 2004 until October 2005. Location of the research is Ciliwung watershed. That is located between 06° 05’ S – 06° 55’ S and 106° 40’ E – 107° 00’ S. Location of the study is shown in Figure 5.

Figure 5. Map of Study Area
3.2 Data Collection

Three types of data will be needed in this research, *i.e.* Ciliwung watershed spatial data, water level data, and statistical data of climate. Those data are listed as follows:

Table 3. List of data Required in developing Flood Model

<table>
<thead>
<tr>
<th>No</th>
<th>Data</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>The spatial data of Ciliwung watershed in ESRI format.</td>
<td>Digital (*.shp)</td>
</tr>
<tr>
<td></td>
<td>• Landuse/Landcover</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Soil Type</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Contour</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• River</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>Water level data of watergate station</td>
<td>Hardcopy/printed</td>
</tr>
<tr>
<td>3.</td>
<td>Climate data</td>
<td>Digital (*.csv)</td>
</tr>
</tbody>
</table>

3.3 Required Tools

3.3.1 Software

In this research, some supporting tools of software and hardware were used:

- ESRI ArcView version 3.x plus extension
- Microsoft Visual Basic 6
- ESRI Map Object 2.x
- Microsoft Access
- Microsoft Visio
- Microsoft Excel

3.3.2 Hardware

- PC (Pentium III) with minimum 450 MHz and 64 MB RAM
3.4 Method

The research consists of four processes those are 1) Data Preparation, 2) Model Development, 3) Model Simulation and 4) Model Calibration and Validation.

3.4.1 Data Preparation

Data preparation was conducted for two kinds of data namely spatial data and tabular data. Preparation of spatial data converts vector data format to raster data format with size 30 m x 30 m. Process of converting data from vector to raster uses spatial analysis and 3D analysis of ArcView extension. Raster format is needed by each process of hydrology calculation because each calculation should be conducted in each cell.

Preparation of tabular format was made to the attribute of shape file. The process divides each theme into one Table. This format is called “one cell many table”. Converting process was done by using Microsoft Excel and Microsoft Access.

3.4.2 Model Development

3.4.2.1 Model Description

This model is a numerical model of the hydrology of a river basin system. This model includes the response of watershed to precipitation, the actions of the river network as water flows through the river, the effect of land use changes, and the effect of engineering structures to the watershed. The computation center for the program is in two main modules, the watershed module and the river system module. Both of them influence each other. Computation result from watershed
submodel will become input for the river system submodel and also computation result from the river system submodel become input for watershed submodel. These are interfaced by numerous utility programs and several databases, providing the user with a variety optional configurations and applications in setting up the programs.

A. Watershed submodel

Watershed module simulates precipitations, interceptions, and the state of soil system as it affects runoff, the effect of land use changes, and the translation of runoff in several components to the stream system. Evapotranspiration and long-term soil moisture routing was accounted for making it possible to simulate continuously throughout several year period in low as well as high flow conditions.

B. River submodel

River module simulates the routing of streamflow through a river. Several variations in specifying channel routing methodology are available, including the provision to account for backwater effects from independent downstream sources. This module also contains the algorithms for simulating reservoir operations, and a variety of operational specifications are permitted.
3.4.2.2 Model Construction

The model constructed by following the processes of water cycle. The boundary of the model is the watershed boundary. The source is precipitation (P) over the watershed. The mass flow is water, and the sinks are atmosphere for evapotranspiration and the next channel for channel outflow.

The processes in the model shown as forester diagram in Figure 6.

![Forester Diagram of Flood Modeling](image)
Some of the precipitation (P) are intercepted by trees, grass, other vegetation, and structural objects. Precipitation (P) data are generated from point precipitation depth in the precipitation gauge as a point data. Spatial precipitation is generated by interpolating point precipitation data from each precipitation gauge by using isohyets method.

Area precipitation is calculated by using the following equation:

\[ P = \sum A_i P_i \]

Where \( A_i \) is the area of each isohyet and \( P_i \) is the precipitation of the isohyets.

Interception (Ic) is influenced by vegetation parameter that is Leaf Area Index (LAI) and Precipitation. The value of Ic is determined by Zinke (1967) as the following equation:

\[
Ic = \begin{cases} 
\left( \frac{1.2}{3} \right) LAI & \quad 0 < LAI < 3 \\
1.2 & \quad LAI \geq 3 \\
P & \quad P < Ic 
\end{cases}
\]

Precipitation occurring over the watershed falls on two types of surfaces which are a portion of the upper zone. These are, 1) a permeable portion of soil mantle, and 2) a portion of soil mantle covered by stream, lake surfaces, marshes, rock, pavement, or other impervious material which is or becomes linked to the stream as soil moisture increases. Both of them produce runoff (Ro). Ro of the first area will be produced when precipitation is heavy, while the second area produces Ro from the portion of the watershed which is actively impervious. Ro is influenced by slope, precipitation netto, extractable water (EW), field capacity (\( Fc_{(b)} \)) and wilting point (\( \theta_{wp} \)). Ro is calculated following the equation:
The remaining P will be infiltrated before filling the ground. The infiltration rate (mm d-1) equals to precipitation minus interception and runoff. Infiltration (Is) is calculated by the difference between precipitation and canopy interception (Penning de Vries F.W.T. et al. 1989; Handoko, 1994)

\[ Is = Stft - Ro \]  .................................................................(4)

Not all water that reaches the surface infiltrates the soil surface, especially during heavy rain. Runoff from a field can be 0-20 % of precipitation, and even more on unfavorable surfaces (Penning de Vries F.W.T. et al. 1989). Runoff occurs when the rate of water supply at the soil surface exceeds the maximum infiltration rate.

Infiltration process change surface soil water content or Soil Water Content Layer 1 (SWC₁). SWC₁ represents the balance input from precipitation and losses of water including interflow (If₁) and surface percolation (Pc₁).

The water balance equations which represent soil water content for upper and lower layer on day t are:

\[ \theta(t) = \theta(t-1) + Is(t) - Pc₁(t) - Tr₁(t) - Ea₁ \]

\[ \theta(2) = \theta(t-1) + Pc₁(1) - Pc₂(2) - Tr₁(2) \]  ......................................................(5)
Interflow ($F_{l1}$) is water which moves laterally through the upper soil layers to the stream channel. The amount of interflow is defined as:

$$F_{l1} = RCF_1 \times FW_1$$  \hspace{1cm} (6)

Where $F_{l1}$ is Interflow, $RCF_1$ is the upper zone free water storage depletion coefficient, and $FW_1$ is the residual volume of free water stored in the upper zone after immediate percolation requirements have been met. In this study, we assumed that soil is divided into two layers.

Percolation will take place from each soil layer when soil water content of each layer $\theta_m$ is higher than its field capacity ($F_{cm}$). Percolation is shown by the following equation (Handoko, 1994):

$$P_{cm} = (\theta_m - F_{cm}) \quad \theta_m > F_{cm} \hspace{1cm} (7)$$

$$P_{cm} = 0 \quad \theta_m \leq F_{cm}$$

Some water vapor will become the actual evapotranspiration (Eta) to the atmosphere. Eta influenced by maximum evapotranspiration (Etm). Etm influenced by meteorology parameter such as Radiation (Q), Relative Humidity (RH), Wind speed (Wind), and Temperature (T). When the Field capacity ($F_{c1}$) of surface area has been met, excess water will become $P_{c1}$. The $F_{l1}$ and $R_0$ accumulated to become surface flow accumulation ($A_{f1}$).

Maximum evapotranspiration (Etm) is assumed to be 80% of potential evapotranspiration (ETp) which is calculated by using Penman method (1948):

$$ETm = 0.8ETp$$  \hspace{1cm} (8)

$$ETp = \frac{\Delta Q + \gamma f(u)(e_s - e_a)}{\langle \Delta(\Delta + \gamma) \rangle}$$  \hspace{1cm} (9)
where $\Delta$ is the gradient of saturation vapour pressure against air temperature (Pa K$^{-1}$), $Q$ is net radiation (MJ m$^{-2}$), $\gamma$ is psychometric constant (66.1 Pa K$^{-1}$), $f(u)$ is aerodynamic function (MJ m$^{-2}$ Pa$^{-1}$), $(ea-es)$ is vapour pressure deficit (Pa), and $\lambda$ is specific heat of vaporization (2.454 MJ kg$^{-1}$).

The value of $\Delta$ and $f(u)$ are calculated using the equation from Meyer et al. (1987) in Impron & Handoko (1993):

$$f(u) = (4.84 + 0.0472 \times u \times 24)/1000 \quad \text{………………………………………(10)}$$

$$\Delta = 47.139 e^{(0.0551297)}$$

where $u$ is wind velocity (km h$^{-1}$).

Saturated vapour pressure ($es$) is calculated by using equation from Tatens (1930) in Javanovic (1999) as:

$$es = 0.611 e^{17.27T/ (T+237.3)} \quad \text{………………………………………………..(11)}$$

and actual vapour pressure ($ea$) is calculated by:

$$ea = es \times \frac{RH}{100} \quad \text{………………………………………………..(12)}$$

The soil evaporation and the maximum transpiration are estimated from maximum evapotranspiration and leaf area index (LAI) assumed that proportion of radiation interception by canopy equals $Tm/ETm$ (Handoko, 1992):

$$Em = ETm(e^{-kLAI}) \quad \text{………………………………………………..(13)}$$

$$Tm = ETm – Em \quad \text{………………………………………………..(14)}$$

The actual evaporation ($Ea$) is calculated using a two-stage soil evaporation of Ritchie (1972). The first stage occurs as maximum soil evaporation ($Em$) until a characteristic cumulative evaporation ($U$) is reached. During the second stage, evaporation decreases exponentially with time.
where \( t_2 \) is time during stage-2 drying (days), \( \theta_{wpl} \) is wilting point of surface layer and \( \alpha \) is a constant. The value of \( \alpha \) is taken from experiment by Ritchie & Johnson (1990) which the value equals to 3.5 mm d\(^{-0.5}\).

Actual transpiration is calculated by assuming that roots of vegetation will absorb the water firstly from the most upper layer, than continue to the next layer until \( T_a = T_m \) (Handoko, 1992). Soil water limits were uptake if soil water content \( (\theta_m) \) falls below 40\% of extractable water (Turner, 1991 in Handoko, 1992). The root water uptake is calculated by the following equations:

\[
T_r_m = T_m \left[ \frac{\theta_m - \theta_{wpm}}{0.4 \times (\theta_{fcm} - \theta_{wpm})} \right] \quad \theta_{fcm} \geq \theta_m \geq \theta_{wpm}
\]

\[
T_a = \sum T_r
\]

\[
T_a = T_m \quad \theta_m > \theta_{fcm}
\]

\[
T_a = 0 \quad \theta_m < \theta_{wpm} \quad \cdots\cdots\cdots(16)
\]

Where \( T_r_m \) is the root water uptake in layer \( m \) (mm), \( \theta_m \) soil water content in layer \( m \) (mm), \( \theta_{wpm} \) is permanent wilting point of layer \( m \) (mm) and \( \theta_{fcm} \) is field capacity of layer \( m \) (mm).

Temperature data is used to calculate evapotranspiration. Measurements of maximum and minimum daily air temperature are adjusted using lapse rate and
the elevation which generates Digital Elevation Model (DEM). The following equation is used:

\[ T(z_i) = T(zo) + TLR \cdot (z_i - zo) \]  

where \( T(z_i) \) is temperature in the point with height \( z_i \) (m), \( T(zo) \) is measured temperature in weather station in height \( zo \) (m), \( TLR \) is averaged lapse rate of the watershed area (K/m), \( z_i \) is height of the point and \( zo \) is the height of point at which the temperature is measured.

Radiation is used to calculate evapotranspiration. The amounts of radiation can be estimated by using Brunt equation (1932), which is generated from Stefan-Boltzman Rule, humidity, and cloud cover:

\[ Q_1 = \delta T^4 (0.56 - 0.079e^a)^{0.5}(0.1 + 0.9 \frac{n}{N}) \]  

where \( Q_1 \) is long wave radiation (Wm-2), \( T \) is temperature (Kelvin), \( e_a \) is air pressure (mb), and \( n/N \) is cloud cover. In this model, cloud cover is assumed to be constant at 0.2. By inputting this value, the equation can be written as:

\[ Q_1 = 0.28 \delta T^4 (0.56 - 0.079e^a)^{0.5} \]  

The Evaporation from lower zone will take place immediately after the water fills soil water content (SWC2) of the sub surface. After the SWC2 reaches its Field Capacity (FC2), the excess water will generate sub surface flow (If2). This If2 will be accumulated as sub surface flow accumulation (Af2). Af1 and Af2 will be accumulated to become channel flow (CF). The flow of water to the next outlet is defined as flow discharge (Q) which is influenced by river parameter such as river coefficient (Cr) and river longitudinal section area (A).
The subsurface reservoir simulates the relatively rapid component of flow that may occur in the saturated, unsaturated and ground water zones during period of rainfall. The subsurface reservoir can be defined as being linear.

\[ FL_2 = RCF_2 \times FW_2 \]………………………………………………….………… (20)

Where \( FL_2 \) is Subsurface Flow, \( RCF_2 \) is routing coefficient, and \( RES \) is the storage volume in the subsurface reservoir.

Channel flow (ChF) is the accumulation of interflow (Fl1) and subsurface flow (Fl2). Channel flow is calculated using the following equation:

\[ ChF = FL_1 + FL_2 \]………………………………………………….………… (21)

The water in the channel flow (CF) will evaporate (Ea) to the atmosphere, and flows to the next inlet. The information of flood can be generated from channel flow information.

Flood is calculated by taking the information from channel flow. If channel flow is more than flood limit defined as the lower limit of water level before flood warning, flood is calculated from the different between water level (CF) and flood limit (CF\(_{\text{limit}}\)). The following equations show these calculations.

\[ Flood = CF - CF_{\text{limit}} \quad CF \geq CF_{\text{limit}} \]
\[ Flood = 0 \quad CF < CF_{\text{limit}} \]………………..(22)
3.4.3 Model Calibration and Validation

Model calibration is the activity of parameterization and adjusting the model until most of the model outputs are not significantly different to field measured data. Calibration process are using data in year 1996 on three location.

Model validation is the activity of applying model by using real data. Data are used for model validation is data in year 2000 on three location.
IV. RESULT AND DISCUSSION

4.1 Result

4.1.1 Physical and Environmental Condition

Ciliwung watershed is located between 06°05’ S – 06°55’S and 106°40’ E – 107°00’ S. Upper plain of Ciliwung watershed is located at Telaga Mandalawangi mountain (Bogor) and lower plain is at Jakarta bay. Ciliwung watershed which flows from south to north has length about 76 km and covers the area of 322 km². The upper plain pattern of Ciliwung watershed is radial and dendritic in the lower area.

Ciliwung watershed covers the wide area at Bogor regency (Cisarua, Ciawi, Kedunghalang, Cibinong, Cimanggis), Depok regency and Jakarta. Ciliwung watershed confine by Cisadane watershed in the west and Citarum watershed in the east.

A topography map which is generated from elevation contour map shown as Figure 7. Based on the elevation and topography map, Ciliwung watershed can be grouped into three areas, as:

1) Upper Plain Area. The upper plain area is mountainous area with elevation ranges from 300 - 3000 m. This area covers 146 km² or 45% of the total area.

2) Middle Plain area. The middle part of Ciliwung watershed is hilly with elevation ranges from 100 - 300 m and covers area 94 km² or 29 % of the total area.
3) Lower Plain area. The lower plain area has elevation from 0 to 100 m. This area cover about 82 km² or 25% of the total area.

![Topography of Ciliwung Watershed](image)

Figure 7. Topography map of Ciliwung Watershed

4.1.2 Climate

Indonesia lies in the equator where the area of Indonesia is divided into three pattern of precipitation; those are monsoon, equatorial and local. Monsoon has the characteristics of unimodal (one peak rains that is around December). Equatorial is characterized by rain pattern with form of bimodal, that is two rain top which usually happened around March or April and October or November. Local has characteristics where the precipitation is opponent of Monsoon.
Daily and monthly precipitation of Ciliwung watershed is shown in Figure 8. The pattern of Ciliwung precipitation is monsoon. The peak occurs in January with averaged precipitation of 525 mm. The minimum precipitation occurs in July with the precipitation of 158 mm. The relative dry period starts from June to August and wet season commences in October until April.

![Figure 8. Daily (left) and Monthly (right) Precipitation of Ciliwung Watershed](image)

Monthly average temperature and humidity is shown in Figure 9. Monthly temperature recorded in Ciliwung site shows a small range of monthly temperature, that is 25° C – 28° C. March is the month with maximum temperature, meanwhile the month with minimum temperature is August. Monthly average of relative humidity (RH) is relatively constant throughout the range from 74% to 88%. Minimum RH is in July which is the peak of dry season.
Figure 9. Monthly average temperature (left) and relative humidity (right)

4.1.3 Soil

Soil type of Ciliwung watershed is shown in Figure 10. Classification was done by using soil map of Ciliwung with the scale 1:50.000 obtained from National Soil Agency. Classification result shows in Table 4.

Figure 10. Soil Map of Ciliwung watershed
Table 4. Soil Type of Ciliwung Watershed

<table>
<thead>
<tr>
<th>Id</th>
<th>Soil Type</th>
<th>Area (ha)</th>
<th>Area (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>Typic hapludants typic troposament</em></td>
<td>3376</td>
<td>22.5</td>
</tr>
<tr>
<td>2</td>
<td><em>Typic humitripepts</em></td>
<td>72</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td><em>Andic humitropepts</em></td>
<td>2709</td>
<td>18.0</td>
</tr>
<tr>
<td>4</td>
<td><em>Complex alluvial</em></td>
<td>32</td>
<td>0.2</td>
</tr>
<tr>
<td>5</td>
<td><em>Complex typic troporthent typic fluvaquent</em></td>
<td>304</td>
<td>2.0</td>
</tr>
<tr>
<td>6</td>
<td><em>Typic distropepts</em></td>
<td>1864</td>
<td>12.4</td>
</tr>
<tr>
<td>7</td>
<td><em>Typic eutropepts</em></td>
<td>2390</td>
<td>15.9</td>
</tr>
<tr>
<td>8</td>
<td><em>Typic hapludant</em></td>
<td>2409</td>
<td>16.0</td>
</tr>
<tr>
<td>9</td>
<td><em>Konsosiasi typic hapludent</em></td>
<td>1806</td>
<td>12.0</td>
</tr>
<tr>
<td>10</td>
<td><em>Latosol</em></td>
<td>49</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Ade Suryana (1989) mentioned that there is no horizon O soil type. Horizon A is neither found although horizon C has layer more than one meter. The high activity of soil treatment and high of erosibility cause this condition.

4.1.4 Land Use change

Land use change of Ciliwung watershed is shown in Figure 11. The map is generated from spatial data year 1996 and 2000. Land use classification is done using image processing.
Figure 11. Land Use Map of Ciliwung Watershed in year 1996 and 2000
From Figure 11, forested area in 1996 is covering 5.044 km² or about 15% from the whole area. In year 2000, forest area is decrease about 2%. Cultivated area which are consist of plantation, commercial plantation, non irrigated field, rice field and rain field, covers 43% from the total area. In year 2000 decrease about 5%. Urban area which are consist of building and settlement covering about 37% from the total area. In year 2000 increase about 8%. The remaining is about 5% identified as “other” classification. In year 2000 the decrease was about 1%. Land use changes over year 1996 to 2000 are shown in Figure 12.

Figure 12. Land Use Change of Ciliwung Watershed in year 1996 and 2000
4.1.5 Water level

Water level compared and precipitation data are shown in Figure 12. From the Figure12, it can be indicated that there are high correlation between water level and precipitation.

![Graph showing water level and precipitation correlation](image)

Figure 13. Water Level in Manggarai and Area Precipitation in Ciliwung Watershed

Water level in three location named Katulampa, Depok and Manggarai in year 1996 and 2000 are shown in Figure14.
From Figure 14, water level in each location have changed over the years 1996 to 2000.
4.1.6 Model Calibration

The model was tested by comparing the model outputs with the measurement data in year 1996. Model calibration result can be seen as Figure 14.

Figure 15 The simulated and observed water level in location, year: (A) Katulampa, 1996; (B) Depok, 1996; (C) Manggarai, 1996.
Validation process is done by comparing calibrated model outputs with field data. Field data used for model validation are water level in three location (Katulampa, Depok and Manggarai) in year 2000. The result of model validation shown in Figure 16.

Figure 16 The simulated water level in location: (A) Katulampa (B) Depok (C) Manggarai
4.1.7 Model Structure

This flood model provides the user about information of hydrological factor and their interaction of the river basin system. This model include the response of watershed to precipitation, river networks, and the effect land use change to the watershed.

This flood model based on GIS calculation for each grid cell of the study area. Interfacing was created to assist in processing data, initiating model simulation and analyzing model result. Graphical interfaces were created to allow interaction with the model by intercepting input and output and interconnect them with database in the system.

The input data and output result of model have been organized in Table 5 and Table 6.

<table>
<thead>
<tr>
<th>Input</th>
<th>Table</th>
<th>Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Topography</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>• Land use</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>• Climate data</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Input Data of Flood Model

<table>
<thead>
<tr>
<th>Output</th>
<th>Table</th>
<th>Chart</th>
<th>Map</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Spatial Interpolation of Climatic Data</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Water Flow</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Water Level</td>
<td>√</td>
<td>√</td>
<td></td>
</tr>
<tr>
<td>• Watershed delineation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 6. Output of Flood Model

In order to create such interfaces, interactive programs were written to assist in processing data, initiating model simulations and analyzing model result. The design of the interface consist of a main window that controls the access to
the different available toolbars. The toolbars grouped on different task or procedures to perform in order to collect/edit required data, run model and display result. The interaction between the interfaces and the programs are done through interchange of data via ASCII files and executable files.

Main window is showed in the Figure 16. Each button access a different toolbar. The same toolbars can be selected from the tool menu. Toolbar beneath the buttons is the status bar that gives a short description of what each tool will active.

![Figure 17. Main Window of Flood Model](image)

When a main button selected, the specific toolbar is displayed and the different option for the active procedure are enable. The sequence of the procedures and tools are arranged to provide a proper order in the creation of a specific scenario. Function of each toolbars explained in table 7.
Table 7. Toolbar of the Interface

<table>
<thead>
<tr>
<th>Toolbar</th>
<th>Tool/procedure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Print</td>
<td>Print</td>
<td>Print map</td>
</tr>
<tr>
<td>Data Properties</td>
<td>Show</td>
<td>Show data properties window</td>
</tr>
<tr>
<td>Query</td>
<td>Show</td>
<td>Show Query window</td>
</tr>
<tr>
<td>Full extent</td>
<td>Show</td>
<td>Show map into full extent</td>
</tr>
<tr>
<td>Full extent for active layer</td>
<td>Extent</td>
<td>Extent to active layer only</td>
</tr>
<tr>
<td>Zoom in</td>
<td>Zoom</td>
<td>Zoom in the map</td>
</tr>
<tr>
<td>Zoom out</td>
<td>Zoom</td>
<td>Zoom out the map</td>
</tr>
<tr>
<td>Pan</td>
<td>Pan</td>
<td>Pan the map</td>
</tr>
<tr>
<td>Identify</td>
<td>Identify</td>
<td>Show the identify window</td>
</tr>
<tr>
<td>Spatial select</td>
<td>Show</td>
<td>Show the spatial model window</td>
</tr>
<tr>
<td>Graphic</td>
<td>Show</td>
<td>Show graphic toolbar</td>
</tr>
</tbody>
</table>

While the main window is active, there are six menus displayed. Those menus are shown in Table 8.

Table 8. Menu on the Interface

<table>
<thead>
<tr>
<th>No</th>
<th>Menu</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>File</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Refresh</td>
<td>Start the model from the first procedure</td>
</tr>
<tr>
<td></td>
<td>• Save to Jpeg</td>
<td>Save map result simulation/action to jpeg file format</td>
</tr>
<tr>
<td></td>
<td>• Print</td>
<td>Print Map result which displayed in the main window</td>
</tr>
<tr>
<td></td>
<td>• Exit</td>
<td>Exit the Program</td>
</tr>
<tr>
<td>2.</td>
<td>View</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Map properties</td>
<td>Display window to review and change the properties of view</td>
</tr>
<tr>
<td></td>
<td>• Full extent</td>
<td>Zoom display to full extent</td>
</tr>
<tr>
<td></td>
<td>• Zoom in</td>
<td>Zoom display to the area define in the layout</td>
</tr>
<tr>
<td></td>
<td>• Zoom out</td>
<td>Zoom out from the center of display</td>
</tr>
<tr>
<td></td>
<td>• Pan</td>
<td>Pan the layout to any direction define in the view</td>
</tr>
<tr>
<td></td>
<td>• Identify</td>
<td>Display the attribute of theme in the view</td>
</tr>
<tr>
<td></td>
<td>• Graphic</td>
<td>Show graphic toolbar in the main view</td>
</tr>
<tr>
<td></td>
<td>• Clear Graphic</td>
<td>Clear all drawn graphic from view</td>
</tr>
<tr>
<td></td>
<td>• Spatial Select</td>
<td>Show window of spatial simulation</td>
</tr>
<tr>
<td>3.</td>
<td>Layer</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Add layer</td>
<td>Add layer to the view</td>
</tr>
<tr>
<td></td>
<td>• Remove layer</td>
<td>Remove the active layer</td>
</tr>
<tr>
<td></td>
<td>• Remove all layers</td>
<td>Remove all layers from the view</td>
</tr>
<tr>
<td></td>
<td>• Legend editor</td>
<td>Edit legend by rendering field of attribute of map</td>
</tr>
<tr>
<td>4.</td>
<td>Simulation</td>
<td>Simulate area precipitation from point</td>
</tr>
</tbody>
</table>
### 5. Hydrology

- **Data Initialization**
- **Digital Elevation Model**
- **Hydrometeorology**
  - Precipitation
  - Temperature
  - Humidity
  - Pressure
  - Wind
- **Land Surface Process**
  - Interception
  - Infiltration
  - Evapotranspiration
  - Runoff
- **Channel Network Delineation**
- **Watershed Delineation**
- **Channel Process**
  - Flow Direction
  - Flow Accumulation
  - Contributing Area
  - Time Concentration
- **Flood**
  - Water Level
  - Flood Extent

**Initialization database**
- Display DEM on the view
- Display Precipitation on the view
- Display Temperature on the view
- Display Humidity on the view
- Display Pressure on the view
- Display Wind on the view
- Display Interception on the view
- Display Infiltration on the view
- Display Evapotranspiration on the view
- Display Runoff on the view
- Create Channel Network Delineation
- Create Watershed Delineation
- Display Flow Direction
- Display Flow Accumulation
- Display Contributing Area
- Display Time Concentration
- Display Water Level
- Display Flood Extent

### 6. Help

Display Help to assist user using application

### 4.2 Discussion

#### 4.2.1 Physical and Environment Condition

Dendritic and radial pattern of Ciliwung watershed increase streamflow in downstream of watershed. This pattern generally transporting large amounts of sediment, but often less than the amount supplies. The accumulation of sediment shallowed the river of watershed.
Topographic map of Ciliwung as shown in Figure 7, slope is high in upstream and decrease in middle part followed by downstream. This condition indicates flow rate of water is faster in the upstream and decrease in the middle and downstream. Decreasing of flow rate in downstream, will cause the amount of inflow more than outflow, causing flood in downstream.

4.2.2 Climate

Interpolating precipitation data from point data has disadvantages because of the topographic of ciliwung watershed is not uniform. But interpolation should be done to generate spatial data of precipitation. Insufficiency of interpolation output overcome by including topographic factor in process of interpolating calculation.

Temperature and humidity are used to calculate evapotranspiration in the model. Temperature and humidity are also interpolated by including topographic factor.

4.2.3 Soil

Soil is one factor influencing infiltration. Based on soil type especially the physic, soil was classified by Holtan (1961) as:

1. Soils having high infiltration rates even if thoroughly wetted and consisting chiefly of deep well to excessively drained sand and gravels. They have a high rate of water transmission

2. Soil having moderate infiltration rates if thoroughly wetted and consisting chiefly of moderately deep to deep, moderately well to well-drained soils with moderately fine to moderately coarse textures
3. soils having slow infiltration rates if thoroughly wetted and consisting chiefly of soils with a layer that impedes the downward movement of water, or soils with moderately fine to fine texture.

4. soils having very slow infiltration rates if thoroughly wetted and consisting chiefly of clay soils with high swelling potential, soil with a permanent high water Table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material.

Based on soil map in Figure 10, soil of Ciliwung watershed dominated by moderate texture and clay texture. This texture causes slow infiltration in which causes high runoff.

4.2.4 Land use change

As shown in Figure 11, land use of Ciliwung dominated change from forest and cultivated to urban area. This modification of land use surface have varying effects on the runoff characteristics on a given drainage area. Forest and cultivated area converted to urban areas, the soil disturbed and the overlying absorptive cover is changed and increasing runoff. Changes in the vegetation cover affect the infiltration capacities of soils and land use changes that modify the nature of vegetation can be significant impact on the volume flows. In the urban area, most of infiltration is eliminated and most of precipitation water become runoff.
The peak of runoff increase more rapidly than the volume of runoff and urban area occurs. This is because of the increase in the water of overland flow to stream channels and the resultant decrease in concentration time of the basin.

4.2.5 Water level

Water level has high correlation with the precipitation. From Figure 13, indicated that high water level fall when high precipitation. High precipitation falls into the ground increase soil water balance. When soil water balance reach field capacity, means soil cannot accommodating water and increase runoff. Increasing runoff means increase of water flows to the water channel and increase water level.

4.2.6 Model calibration and validation

Calibration results as shown in Figure 15, show that the model can predict water level in three location of the outlet. As can be seen from Figure 15, the model also can predict water level in different year.

From Figure 14, some result of model is overestimate. This is indicates that model can be used to predict the high water level of the watershed as indicates flood. However, the model is inaccurate if used to predict low water level.

Validation result shown in Figure 15. This show that model gives result closely with real data of Ciliwung watershed on year 2000. It can be conclude model can be used to simulate water level by use land use and precipitation as input.
The resolution of model is daily, means that the model can cover the change in daily step such as the change of precipitation. But the model cannot be used as flood warning system which are need time resolution less than daily.

4.2.7 Model Structure

Spatial input is needed to complete the input of database. The model originally runs daily but the time set can be adjusting according to the objective and the available of data such as spatial and tabular data. In this study the time resolution of model is daily.

As describe in Chapter 3, data needed for this model are classified in two categories: spatial data (watershed) and tabular data for each cells. Spatial data includes information of the entire watershed such as watershed boundary and number of cell. Tabular data which are interconnected with spatial data includes information of parameters based of topography (DEM), soil type and land use.

The output of model can be show as chart, map and Table. The output is also can be printed.

4.3 Model Simulation using Scenario

Model was applied for simulating the effects of land use change to runoff by using scenario. Changes in land use gives significant effects on infiltration rates, water balance and thus on the runoff production.

In general, the flood potential of the watershed significantly increases by land use change from forest and cultivated to urban area. This model accounts for
spatially distributed hydrologic characteristics of the watershed, it is suitable for assessing the impact of land use changes on hydrologic behaviors by using land use change scenario.

Three scenario was done by using this model. Those scenario was chosen to cover particular future land use policies. Three distinct scenario are consider where urban area are increased at the expense of cultivated and forest. This scenario is named urbanization. All forest are converted into urban and cultivated area. This scenario is named deforestation. Last scenario is increased of forest area at the expense of urban and cultivated which is named afforestation. The urbanization scenario was elaborated on the basis of information regarding the changes of land use planned by the government. The afforestation scenario was meant to recreate the condition of Ciliwung watershed in many years ago when most of Ciliwung watersheds are covered by forests. Those scenario was compared with the present condition that is Ciliwung watershed in year 2000.

Afforestation scenario reduces cultivated area about 30% and urban area reduces about 45%. The deforestation scenario was more and less chosen to evaluate what the behavior of the watershed would be without forest cover. Deforestation scenario reduces forested area about 100%, and increase cultivated areas about 12% and urban area increase about 27% from the origin. Urbanization scenario is decrease forest area about 20%, decrease cultivated area about 21% and increase urban area about 32%. Each scenario would be change the partition of each land use in the watershed which shows in the Table 9.
Table 9. Listed of the percentages area on each scenario

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Forest (%)</th>
<th>Cultivated (%)</th>
<th>Urban (%)</th>
<th>Other (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Urbanization</td>
<td>12</td>
<td>34</td>
<td>49</td>
<td>5</td>
</tr>
<tr>
<td>Deforestation</td>
<td>0</td>
<td>48</td>
<td>47</td>
<td>5</td>
</tr>
<tr>
<td>Afforestation</td>
<td>71</td>
<td>7</td>
<td>17</td>
<td>5</td>
</tr>
<tr>
<td>Present</td>
<td>15</td>
<td>43</td>
<td>37</td>
<td>5</td>
</tr>
</tbody>
</table>

Map of each scenario is shows as Figure 18.

Figure 18. Land Use Map Of Ciliwung Watershed For Each Scenario; (A) Urbanization, (B) Deforestation, (C) Afforestation, (D) Present
Based on these land use change scenarios, model parameters were recalculated and model was run in Manggarai to deliver the modified flows. Figure 19 shows water level of simulation result for the present and three scenarios.

The result indicated that the urbanization produce the highest peak flow, followed by the deforestation and afforestation scenario. The simulated water level for the present land use is 83.88 cm, for the urbanization scenario 135.05 cm, deforestation scenario 92.46 cm, and afforestation scenario 58.71 cm. Accordingly, the urbanization scenario increases the peak discharge by 61%, the deforestation scenario increase 15%, and afforestation decrease by 19%.

![Figure 19. Simulated Hydrograph For Each Scenario in Manggarai](image)

Some result value of each scenario was selected and compared with present value. The result show in Figure 19.
Figure 20. Comparison of water level of each Scenario

Figure 20 shows the afforestation has positive effect in reducing discharge in comparison to the present situation. On the contrary, urbanization and deforestation lead to an increase the simulated discharge.

In this simulation, precipitation is not simulated but constant for each scenario. The different of water level is caused by different of land use. Considering the result of each scenario, the model can be applied to simulate the effect of land use change. However, the model needs to be further validated to make it more precise.
V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The widespread availability of modeling technique, digital geographic data and GIS techniques open new opportunities for using integrated simulation model in assessing land use impact on flood processes. In this paper, a flood modeling running on daily time scale and compatible with GIS and remote sensed information, was presented. The model uses elevation, soil and land use data in a simple way to predict water level, water flow direction and the spatial distribution of hydrologic characteristics over the watershed. GIS provides a powerful platform for developing the model, calibrating parameters, and displaying model results in a spatial way, so that it becomes possible to capture local complexities of a watershed and compare model results to field measurements.

Referring to the result of this research, there are several important conclusion related with the modeling of flooding for land use management as follows:

1. The process based modeling is useful to model hydrological processes over the watershed.
2. Precipitation is the main input for hydrology simulation and land use change gives the effect of water level in the watershed.
3. The model which is built in this research can be used to evaluate runoff from different land use areas
4. For assessing the hydrological effects of land use changes on floods, three hypothetical scenarios, namely urbanization, deforestation and afforestation scenario, were considered made. It was found from the model simulation that the urbanization scenario has the highest negative impact on increasing water level. Deforestation has the second largest negative impact, while afforestation causes positive impact shown by decreasing water level.

As discussed in the paper, the model uses the remote sensed data and calculations are for the most part performed by standard GIS tools. The model is especially useful for flood management on complex terrain and analyzing the effects of land use or soil cover on the flood characteristics.

5.2 Recommendation

The present elementary research that has been done could be improved by using a finer resolution of data (spatial and temporal resolutions).

It is recommended that hydrometeorological measurement is further needed in order to derived model parameter to increase the accuracy of model.
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