DISSERTATION

DEVELOPMENT OF A WATERSHED MODELING SELECTION PROGRAM AND SIMPLE EQUATIONS AS AN ALTERNATIVE TO COMPLEX WATERSHED MODELING

Submitted by

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ABSTRACT

DEVELOPMENT OF A WATERSEHD MODELING SELECTION PROGRAM AND SIMPLE EQUATIONS AS AN ALTERNATIVE TO COMPLEX WATERSHED MODELING

Population pressures, land-use conversion and its resulting pollution consequences appear to be the major diffuse pollution problems of today. Research also indicates that the increase in imperviousness of land due to urbanization increases the volume, rate of stormwater runoff causing increased channel erosion and flooding downstream, water quality contamination, aquatic biota, and drinking water supplies. In the past, negative impacts were never seriously considered as urbanization increased, but the attitude of citizens and governments are changing and people now want to retain, restore or rehabilitate existing waterways, and manage future urban and rural development in order to improve environmental conditions.

Water quality management in the contributing watersheds is vital to the management of water quality in the main stem rivers. Hence, policy makers should decide which places should be considered for restoration projects based on priority analyses. To carry out these evaluations in Korea, mathematical models are needed to forecast the environmental results after applying watershed restoration measures. However, the scope of sophisticated watershed modeling is very complicated, expensive and time consuming, and not really required for planning level decision making. Therefore, simpler evaluation methods should be applied, that can adequately discern for planning purposes the changes in aquatic environmental quality that can be expected in different watersheds after adapting restoration or protective measures.

Thus, this research proposed to create a simple equation specifically for watershed planning. To create such a simple equation, three main tasks were undertaken. The tasks are as follows: (1) the creation of a selection program for available watershed models, (2) establish simple equations to be used instead of watershed models, and (3) verify the simple equations by comparing them with a physically based model (HSPF).

In regards to the first task mentioned above, this dissertation presents a review of thirty three watershed models available for watershed planning and shows that these watershed models can not easily be applied to large-scale planning projects that are being undertaken by South Korea like the Four River Restoration Project. One of the main reasons for their inapplicability is that they require vast amounts of data and significant application effort to be used in a prioritization project involving many watersheds (Roesner, personal commucation). In addition, it is vital to select an appropriate watershed model that are realistically models a watershed's conditions and more specifically, to match users' needs. However a selection program has not yet developed, as well. Therefore, eight factors were selected for task 1 to examine the specific characteristics of each of the 33 watershed models in great detail. Based on the results of the 8 factors proposed, the selection program was developed to screen which will be most useful to a project.

Based on these literature reviews of the 33 available watershed models but unrealistically complex models, it was determined that a simpler model utilizing accessible base data, such as land use type, is needed to evaluate and prioritize watersheds in the feasibility stage of a spatially large projectstudies for national based projects (i.e. National level). A correlation study between land use types and water quality parameters has been published (Tu, 2011, Mehaffey et al., 2005, Schoonover et al., 2005, etc.), however, the research examined the correlation between land usage and water quality in great detail, but did not address any correlations to implement real-based watersheds.

Therefore, Task 2 is the development of simple equstions, for this task, two important sub-tasks were undertaken 1) Hydrology (rainfall), geology (slope), and land usage data were analyzed to verify their relationships with the water quality (BOD, COD, T-N, T-P) in the watershed, and 2) Simple Equations were constructed based on Statistical Methods (Excel Solver, Statistical Analysis Systems) and Data Mining (Model Tree, Artificial Neural Network, and Radial Based Function) in order to prove their accuracy. Thus, if the equations are accurate, they can be used to prioritize basins within a watershed with respect to their impact on water quality in the mainstem river.

For the final task, task 3, Simple Equations were verified by comparing them with a physically based model, HSPF, based upon the real-based watersheds which are located in South Korea in order to prove the Simple Equations are capable of being a reliable alternative to physically based models. These simple equations could be used to allow management to identify and prioritize restoration and rehabilitation areas in a watershed even though sufficient data had yet been collected to satisfy the requirements of a physically based model.

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CHAPTER 1. INTRODUCTION

1.1. BACKGROUND INFORMATION

It is well established that population pressures, land-use conversion and its resulting pollution consequences appear to be the major diffuse pollution problem today (Novotny, 2003). Research also indicates (Roesner, et. al., 2001) that the increase in imperviousness of land due to urbanization increases the volume and rate of stormwater runoff causing increased channel erosion and flooding downstream. Contaminates in the runoff have adverse impacts on receiving water quality affecting aquatic biota and drinking water supplies. In the past, negative impacts were never seriously considered as urbanization increased, but the attitude of citizens and governments are changing and people now want to retain, restore or rehabilitate existing waterways, and manage future urban and rural development in order to improve environmental conditions.

The importance of water quality and water quantity management were highlighted in South Korean President Lee Myung-bak's strategy for stimulating economic growth, entitled the "Green New Deal". The 4 year plan, which was announced in January 2009, will focus on energy conservation, carbon reductions, recycling, flood prevention and the development of the country's four main rivers with a total budget of 20 billion U.S$. (reference: http://english.kwater.or.kr/)

As part of the "New Green Deal", a massive project entitled the "Four Major River Project" was initiated. This project focused on three specific areas: the revitalization of the four rivers, projects on their 14 tributaries and the refurbishment of other smaller-sized streams. The project had five key objectives as well: securing abundant water resources to combat water scarcity, implementing comprehensive flood control measures, improving water quality and restoring river ecosystems, creating multipurpose spaces for local residents, and regional development centered on the rivers. More than 929 km of streams in Korea will be restored as part of the project, with a follow-up operation planned to restore more than 10,000 km of local streams. More than 35 riparian wetlands will also be reconstructed.

While this project will improve water resources and quality situation of the major rivers, much work remains to be done to insure that the numerous tributaries to the main rivers are protected and that mainstem river improvements are not reduced in the future as the South Korean population continues to migrate to urban areas. In order for this project to succeed, water quality management in the contributing watersheds is vital to the management of water quality in the mainstem rivers. Therefore, there is a great demand for schematic watershed water quality management skills.

1.2. PROBLEM STATEMENT

For the Four River Restoration project to be successful, many urban areas contributing to the deteriorated condition of receiving water need to be compared with respect to their individual impacts on receiving water quality and then prioritized for remediation because the amount of funds needed to conduct a nationwide restoration project would be insurmountable for the government to bear. Hence, policy makers should decide which places should be considered for restoration projects based on priority analyses. This prioritization has to include the evaluation of economic, social, technological, and environmental factors. To carry out these evaluations in Korea, mathematical models are needed to forecast the environmental results after applying watershed restoration measures. However, the scope of sophisticated watershed modeling is very complicated, expensive, time consuming, and not definitively required for planning-level decision making. Given time, resource, and data constraints, simpler evaluation methods capable of adequately discerning the impacts of restoration and protective measures on the aquatic environmental quality of different watersheds at the planning level should be applied.

A major problem that needs to be addressed is how simple can the watershed model be and still produce sufficiently accurate results and sufficient detail to enable planners to prioritize watersheds and projects for implementation in a planning area that covers about 17 km^2 to about 1,574 km^2.

1.3. HYPOTHESIS OF THIS RESEARCH

This dissertation presents a review of thirty three watershed models available for watershed planning and shows that these watershed models can not easily be applied to large-scale planning projects like the Four Rivers Restoration Project in order to be used to prioritize watershed, because these watershed models require too much data and significant application effort (Roesner, personal commucation). In addition, it is so crucial to select appropriate watershed models that are applicable to unique watershed conditions and more specifically, to match users' needs and a selection program has not yet developed, as well. Therefore, a selection program was developed based on thirty three watershed models reviews to screen which will be most useful to a project in Chapter II.

The conclusion is that a simpler model is required to implement evaluate and prioritize watershed in the feasibility phase of spatially large national projects. A correlation study between land use types and water quality parameters has been published (Tu, 2011, Mehaffey et al., 2005, Schoonover et al., 2005, etc.). However, this study's objective was to determine a correlation between land usage and water quality, not apply the correlation to a real-world watershed to obtain unknown data, as is the objective of the study in this dissertation.

My hypotheses in this research are the following:

1. Hydrology, geology, and land usage have great relationships with water quality (BOD, COD, T-N, T-P) in the watershed.

2. Simple equations constructed based on Statistical Methods (i.e. Excel Solver and Statistical Analysis Systems) and Data Mining (i.e. Model Tree, Artificial Neural Network, and Radial Based Function) are sufficiently accurate to allow user to prioritize basins within a watershed with respect to their impact on water quality in a mainstem river which is covered in Chapter III.

3. Results from these simple equations can be verified by comparing their results with those of a physically-based HSPF model of real watershed in South Korea in order to prove that the Simple Equations are capable of being a reliable alternative the physically based model analyzed in Chpater IV.

CHAPTER 2. SELECTION PROGRAM FOR AVAILABLE WATERSHED MODELING

2.1. WATERSHED MODEL'S PRESENT CONDITION

Watershed modeling is a combination of hydrogeographical and biochemical mathematical models that simulate the movement of water and the relevant biogeochemical process in order to reflect the change of water quality and quantity as affected by watershed management plans (Novotny, 2008, Singh, 2004). These components include: areal precipitation, watershed representation, surface runoff, infiltration, subsurface flow and interflow, groundwater flow and base flow, evaporation and evapotranspiration, interception, depression storage, detention storage, rainfall-excess/soil moisture accounting, snowmelt runoff, stream-aquifer interaction, reservoir flow routing, channel flow routing, and water quality (Singh, 2004). Watershed models provide the methods of approach for estimating loads, source loads, and evaluating various management alternatives, including sets of equations which take into consideration natural or man-made processes such as runoff or stream transport in a watershed system, and forecasting or estimating future condition based on various conditions in order to comparing pre- and post-development (EPA, 2008).

The development of watershed models began in the 1970s to estimate non-point sources of pollution in the United States and their impacts on receiving water quality (Leon et al., 2000). From the middle of the 1980s, a variety of models were developed due to advancements in computers and science. Many watershed models have been developed for specific pollutants based on each watershed conditions (EPA, 2008).

2.2. MODEL FUNCTION AND PROCESS

Models are a description of an environmental system based on a set of equations or algorithms that are used to simulate a physical system and offers a reliable method for estimating loads, provide source load estimates, and evaluate various management alternatives. In addition, models are used to forecast natural or man-made process in an environmental system such as runoff or stream transport (Leslie et al., 2005, EPA 2008).

Flooding, upland soil, stream erosion, sedimentation, and contamination of water from agricultural chemicals are serious environmental, social, and economical problems all over the world (Borah, 2003). Hence, various kinds of models have been developed that present specific characteristics depending on the applicant's needs. If a user needs to find a resolution very quickly, simplified techniques such as USLE (Universal Soil Loss Equations) could be used but is limited in applicability to the various pollutants and water bodies by TMDLs. On the other hand, physical based models, known as the state of art models, include various mechanisms associated with water, sediment, pollutant, movement, transport, transformation, and delivery. Both simplified models and physical based models have advantages and disadvantages, and if there is enough data to represent the watersheds, such as areal precipitation, watershed representation (geometry characteristics), surface runoff, infiltration, subsurface flow and interflow, groundwater flow and baseflow, evapotranspiration, interception, depression storage, detention storage, snowmelt runoff, stream-aquifer interaction, reservoir flow routing, channel flow routing, water quality, etc., it is easy to access a physical based model. However, if there is not enough data for a physical based model, a simplified model could be applied to start with and then the database can accumulate data continuously to achieve the next steps.

A watershed model is a tool for analyzing watershed characteristics based on the pollutant loads. In order to enhance a watershed model's ability, users have to understand the processes of the watershed model. The process applied for watershed is shown below in Figure 2-1.

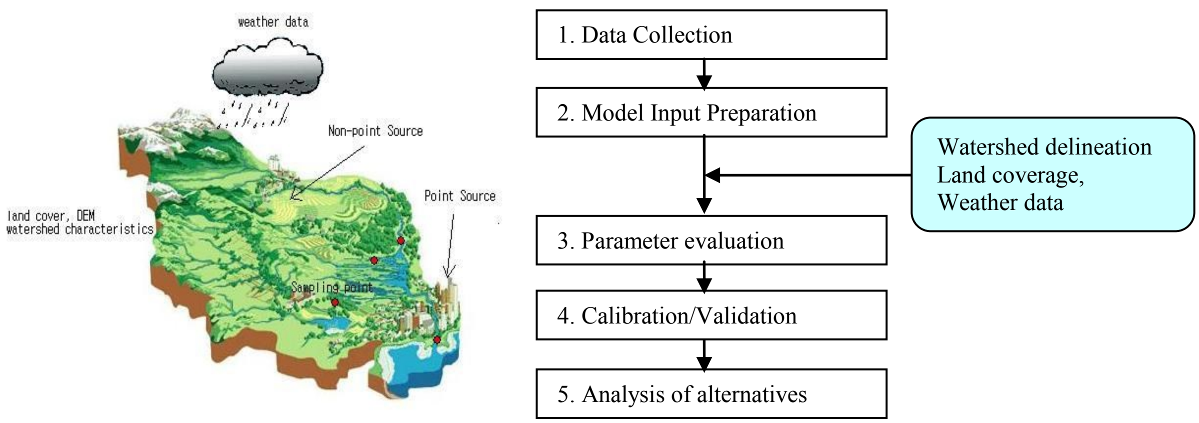

Figure 2- 1: The process of application for watershed model.
(Sources: http://www.watershedactivities.com/projects/fall/h2omodel.html)

A. Data Collection

Data collection is the first process required for watershed modeling application. Required data could vary depend on each watershed's characteristics. Basically weather data, point source data, land coverage, and geological characteristic data would be required. In addition, weather data should be determined based on certain times or daily data according to the watershed model.

B. Model input Preparations

After the input data has been collected for the watershed model, the data should be reorganized by using an input form for each watershed model because various watershed models have used respective computer programming languages. At this point, input data has to be built accurately, if not, the model will not perform well because of language problems. In addition, sub-watershed (separate) and land coverage classifications should be implemented by using the available data and their applied purposes appropriately when making the input data.

C. Parameter Evaluation

The third step of a watershed model is the process of deciding parameters. In order to reflect the watershed characteristics, the process to decide parameters needs to predict the current situation, such as soil maps, land coverage, and the buildup and wash off of polluted matter. During this process, each predicted item and parameter should be analyzed and evaluated carefully to determine how much the differenes were from before and after as well as any kinds of interaction among the reactions.

D. Calibration & Validation

After evaluating the predicted items and parameters, calibrations need to be implemented to decide the parameters when comparing the estimated and observed data. The next step, validation, is to confirm whether the parameters satisfy the other conditions which could represent watershed characteristics. At this time, the best method for deciding the appropriate parameters is to conduct field experiments of watersheds, however, experiments do take up a significant amount of time, they are costly and require labor force, etc. Hence, a trial and error method was used to compare the measured field and estimated data based on the suggestion value through watershed model.

E. Analysis Alternatives

In the last step, users can analyze pollution characteristics and loading from a targeted watershed through the use of the constructed watershed model which was calibrated and validated. Loading could be analyzed by numerous conditions. The effects of sub-watershed management alternatives could be evaluated by the contributing factors of pollutants from the sub-watershed to the reservoir through the process of calibration and validation.

2.3. REVIEW OF WATERSHED MODELING

As part of the background research for this thesis proposal, thirty three currently most popular watershed models were reviewed. From the models reviewed, the U.S. Environmental Protection Agency (U.S. EPA.) developed twelve of the watershed models; The United States Department of Agriculture – Agricultural Research Service (USDA-ARS) developed five of the watershed models which are AGNPS, AnnAGNPS, KINEROS2, SWAT, and WEPP. The United States Army Corps of Engineers (USACE) developed three of the watershed models (GSSHA, HEC-HMS, STORM). As well, the U.S. Geological Survey developed one of the watershed models; SPARROW. In addition, various universities and research agencies developed several of the models such as Colorado State University (CASC2D), Argonne National Laboratory (DIAS/IDLAMS), North Carolina State University (DRAINMOD), Illinois State Water Survey (DWSM), Texas A & M (EPIC), College of Charleston (GISPLM), DHI Water and Environment (MIKE SHE), Prince George's County, MD (PGC-BMP), University of Newcastle upon Tyne (SHETRAN), Lancaster University (TOPMODEL), Systech Engineering, Inc. (WARMF), and Scientific Software Group (WMS). These models are listed below in Table 2-1 with abbreviated descriptions of their capabilities.

Table 2-1: Description of Watershed Models Reviewed.

MODEL	Full-name	Description	Literature
AGNPS	Agricultural Nonpoint Source Pollution	An event-based model simulating water runoff, sediment, COD, N, P, and pesticides	Borah, 2003b; Deva, 2002.
AnnAGNPS	Annualized Agricultural Nonpoint Source Pollution Model	Annualized of AGNPS; continuous simulation watershed scale program developed based on the AGNPS	A. Shamshad et al., 2008; Polyakov, 2007; Shrestha, 2005.
ANSWERS	Area Nonpoint Source Watershed Environment Response Simulation	Developed for agricultural watersheds and construction sites for surface water hydrology and erosion/sediment transport	Huggins et al., 1966; Beasley et al., 1980; Ramadhar et al., 2005.
BASINS	Better Assessment Science Integrating point and Nonpoint Sources	A decision support system for multipurpose environmental analysis by regional, state, and local agencies performing watershed and water-quality based studies	EPA, 2000; Imhoff, et al., 2007.
CASC2D	-	The runoff and soil erosion modeling and a state-of-art hydrologic model based on GIS (Geographic Information Systems) and remote sensing	Julien, 1998
DIAS/IDLAMS	Dynamic Information Architecture System/ Integrated Dynamic Landscape Modeling and Analysis System	An object-based software framework for modeling and simulation application and allows many disparate simulation models and other applications to interpolate to address a complex problem based on the context of the specific problem	Leslie et al, 2005; Hummel et al, 2002 ; Sydelko et al., 2000
DRAINMOD	A Hydrological Model for Poorly Drained Soils	Used to simulate the performance of drainage and related water management system on a field scale.	Sinai, 2006; Leslie et al., 2005; Helwig et al., 2002; Wang et al., 2006; Gupta et al, 1993
DWSM	Dynamic Watershed Simulation Model	Simulates surface and subsurface storm water runoff, flood waves, soil erosion, entrainment and transport of sediment, and agricultural chemicals in agricultural watersheds.	Borah, et al, 2001A; Borah et al., 2001B; Kim et al.,2003; Ashraf, et al., 1992
EPIC	Erosion Productivity Impact Calculator	A tool used for determining the effects of soil erosion on crop production including erosion, plant growth, related processes, and economic components for assessing the cost of erosion and components for determining optimal management strategies.	Williams, 1990; Williams et al., 1983; Martin et al., 1993; Gassman et al, 2004, Leslie et al., 2005; Warner et al., 1997; Chung et al., 2002; Guerra et al., 2002
GISPLM	GIS-Based Phosphorus Loading Model	A tool used for developing cost-effective strategies to reduce phosphorus loads from watersheds	GeoEngineers 2010; Leslie et al. 2005; William W. W. 1997; Walker, W. W. 1987.
GLEAMS	Groundwater Loading Effects of Agricultural Management Systems	A mathematical model for field-size areas to evaluate the effects of agricultural management system and could predict the movement of agricultural chemicals within and through the plant root zone.	Leonard et al., 1987, 1989 ; Foster et al., 1981, 1985; Knisel et al, 1980, 1993, 1999; Jensen et al., 1990; Monteith, 1965; Onstad et al., 1975; Leone et al, 2007
GSSHA	Gridded Surface Subsurface Hydrologic Analysis	A reformulation and enhancement of the two-dimensional physically based model CASC2D, sediment and water quality transport and coupled to one-dimensional stream flow	Ogden et al., 2008; Sharif et al., 2010; Niedzialek et al., 2003; Downer et al., 2004.
GWLF	Generalized Watershed Loading Functions	A middle ground between the empiricism of export coefficients and the complexity of chemical simulation models	Medina, 2005; Haith, 1992; Chikondi, 2010; Limbrunner, 2005; Ning, 2005.
HSPF	Hydrologic Simulation Program FORTRAN	A comprehensive model for simulating the quantity and quality of streamflow, reservoir system operations, ground water development and protection	Said et al., 2007; Ryu, 2009; Lohani et al., 2000; Bicknell et al., 2001; Bai, 2010; Yanqing, 2007; Jeon, 2007; Mishra, 2009; Ribarova, 2008; Hayashi ,2004; Albek, 2003.
HEC-HMS	Hydraulic Engineering Center Hydrologic Modeling System	Simulating the rainfall-runoff processes of networked watershed systems as a successor to HEC-1 and includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff	Scharffenberg et al., 2008; HEC-HMS user's manual, 2009; Chu, 2009; Anderson et al.,2002; Goodell, 2005.

Table 2-1: Description of Watershed Models Reviewed (Continued).

MODEL	Full-name	Description	Literature
KINEROS2	Kinematic Runoff and Erosion Model v2	A physically based, distributed, rainfall-runoff model describing the processes of interception, infiltration, surface runoff and erosion from small agricultural and urban watersheds in arid and semi-arid zone catchment	Aisha et al., 2008; Woolhiser et al., 1990,2000; Duru, 1993; Canfield et al., 2005; Smith et al., 1999; Martinez-Carreras et al., 2006.
LSPC	Loading Simulation Program in C++	A comprehensive data management and watershed modeling system which includes HSPF algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model	LSPC Users' Manual; Lu et al., 2005; Shen et al., 2004, 2005; Henry et al., 2002; Wang, T. et al., 2005; Zou et al., 2007; Steg et al., 2008.
Mercury Loading Model	Watershed Characterization System—Mercury Loading Model	A distributed grid-based watershed mercury loading model which represents the spatial and temporal dynamics of mercury from both point and nonpoint sources with long-term average hydrology and sediment yield and mercury transport.	Dai et al., 2005; Ambrose, 2005; U.S. EPA, 2001, 2004.
MIKE SHE	-	A physically based, spatially distributed hydrological model and combining four components such as overland flow (two-dimensional saint-venant equation), river flow (one-dimensional saint-venant equation), soil profile (one-dimensional Richards' equation), and ground water flow (three-dimensional Boussinesq equation)	Christiaens et al., 2001, 2002; Copp, 2004, 2007; CUI, 2005; DHI, 2007; Im et al., 2008; Cui, 2005; Demetriou et al.,1998; Gupta, 2008
MUSIC	Model for Urban Stormwater Improvement Conceptualization	A decision support system to improve and integrate the urban stormwater management measures	Wong et al., 2002; MUSIC brochure version 4; Persson et al., 1999; Chiew et al.,1997;
P8-UCM	Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds—Urban Catchment Model	A hydrologic and BMP model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds	Tetra Tech, Inc., 2005, 2005b, 2007; William, 1990;
PCSWMM	Storm Water Management Model	Simulate runoff and hydraulics in pipe networks having the capacity to create a storm sewer network and massive database management with relative ease	Sands et al., 2004; nhc, 2010; PCSWMM Brochure; James, 2002, 2003; Heier et al., 2003; Hong, 2008.
PGC-BMP	Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds—Urban Catchment Model	BMP ToolBox model, in order to evaluate BMP applications before and after the development and effectiveness of structural BMP	Tetra Tech, 2003; Cheng et al., 2004, 2009; Riverson, 2004; Chen et al., 2010; Zhen et al., 2010.
SHETRAN	Système Hydrologique Europeén TRANsport	A 3D coupled surface/subsurface Physically Based Spatially Distributed finite-difference model for coupled water flow, multi fraction sediment transport, and multiple, reactive solute transport in river basins.	Ewen et al., 2000; Lukey et al., 2000; Dunn et al., 1995, 1996; Adams et al., 2002, Bathurst et al ., 2004; Birkinshaw et al., 2000, 2010; Burton et al., 1998.
SLAMM	Source Loading and Management Model	Developed to enhance the understanding of the relationship between sources of urban runoff pollutants and runoff quality in an urban area.	Pitt et al., 2000, 2002, 2007; Kabbes et al, 2008; Neilson et al., 2010;
SPARROW	SPAtially Referenced Regression on Watershed Attributes	SPARROW is a statistically calibrated regression model composed of both mechanistic components and mass-balance constraints used to set up mathematical relationships between water quality measurements and the attributes of watersheds.	Schwarz et al., 2006; Alexander et al., 2000, 2002a,2004, 2006, 2008; Goodall et al., 2010; Robert et al., 2010; Smith et al., 1997, 2003; Brakebill et al., 2003
STORM	Storage, Treatment, Overflow, Runoff Model	Provides predictions of wet-weather pollutographs (Mass Loading curves for use in a receiving water assessment model) and preliminary sizing of storage and treatment facilities to satisfy the desired criteria for control of stormwater runoff.	Deliman, 1999; Abbott, 1997; U.S. ACE, 1997; Heineman, 2005; Baerenklaus et al., 2008; Najjar et al., 1995; Warwick et al., 1990;

Table 2-1: Description of Watershed Models Reviewed (Continued).

MODEL	Full-name	Description	Literature
SWAT	Soil and Water Assessment Tool	A multidiscipline model and includes following models: GLEAMS for pesticide components, GREAMS for daily rainfall hydrology components, EPIC for crop growth components, SWRRB for multiple subbasins and other components, Qual2E for instream kinetics, and ROTO for routing structures.	Gassman et al., 2007; Neitsch et al., 2005; Heathman et al., 2008; Fitz Hugh et al., 2001; Gong et al., 2010; Ghebremichael et al., 2008; Ullrich et al., 2009;
SWMM	Storm Water Management Model	A dynamic rainfall-runoff simulation model for water quality and quantity and is used primarily for urban areas. The purposes of this model are for planning, analysis and design of urban watersheds, including rainfall-runoff, flow routing, water quality, storage/treatment, and sewer-systems	Rossman, 2010; Huber, 2003, 2010; Jawdy et al., 2010; Alfredo et al., 2010; Roehr et al., 2010; Lucas, 2010; McCutcheon et al., 2010; Magill et al., 2010
TOPMODEL	-	A semi-distributed variable contributing area hydrological model (rainfall-runoff model) which provides distributed predictions of catchment response to rainfall based on the a simple theory of hydrological similarities of points in a catchment	Wu et al., 2007; Gallart et al., 2007; Candela et al., 2005; Xiong et al., 2004; Holko et al., 1997; Brasington et al., 1998; Cameron et al. 1999; Xiong et al., 2004; Candela et al., 2005; Engman, 1986; Beven, 1997
WAMVIEW	Watershed Assessment Model with an Arc View Interface	A process-based model with GIS (Geographic Information System) interface to simulate watershed hydrologic and pollutant transport.	Bottcher and Hiscock, Bottcher, 2003; Zhang et al., 2005, 2006;
WARMF	Watershed Analysis Risk Management Framework	A watershed model and analysis tool with short and long term predictions capabilities and has a variety of functions such as the ability to calculate TMDL, evaluate water quality management for a river basin, simulating flow, water quality constituents	Keller, 2007; Chen et al., 2005, 2004, 2000 A, B; Geza et al., 2009, 2010; Rich et al., 2005; Weintraub et al., 2004;
WEPP	Water Erosion Prediction Project	A process-based distributed parameter model and a continuous simulation computer program used to predict soil loss (erosion) and sediment deposition (delivery) based on the overland flow on hillslopes, the concentrated flow in small channels, and the sediment deposition in compounds.	Flanagan et al., 1995; Abaci et al., 2007, 2008; Baigorria et al., 2006.

2.4. COMPARING WATERSHED MODELS BASED ON THEIR CHARACTERISTICS

Each of the watershed models were developed based on the needs of unique environmental situations. Therefore watershed models could be classified into several groups such as field scales[1], physically based models[2], lumped models[3], mechanistic models[4], numerical

[1] *Field scale: some applications are focused on small areas at the subbasin or smaller level. Field-scale modeling usually refers to geographic areas composed of one land use (e.g., a cornfield) (Leslie et al, 2005)*

models[5], steady state models[6], dynamic models[7]. Selection of a watershed model is so important to accomplish the most accurate and efficient solution because watershed models have various complexities, strengths, and weakness. To begin with, general characteristics of a watershed such as the developer, programming language, temporal scale etc. are going to explain and then specify characteristics of a watershed like runoff, subsurface, sediment, etc.

2.4.1 GENERAL CHARACTERISTICS OF WATERSHED MODELS

The general characteristics of a watershed model are the developer, programming language, temporal scale, level of complexity, lumped or distributed model, and spatial scale which are shown in Table 2-2.

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[2] *Physically based models: A physically based model includes a more detailed representation of fundamental processes such as filtration. Applying physically based models requires extensive data and experience to set up and test model (U.S. EPA, 2005).*

[3] *Lumped model: A model in which the physical characteristics for land units within a subwatershed unit are assumed to be homogeneous is referred to as a "lumped" model. Discrete land use areas within a subwatershed area are lumped into one group (Leslie et al, 2005).*

[4] *Mechanical model: A mechanistic model attempts to quantitatively describe a phenomenon by its underlying casual mechanisms*

[5] *Numerical model: A numerical model approximates a solution of governing partial equations that describe a natural process. The approximation uses a numerical discretization of the space and time components of the system or process(Leslie et al, 2005)*

[6] *Steady state model: A steady state model is a mathematical model of fate and transport that uses constant values of input variables to protect constant values of receiving water quality concentrations. Steady state models are typically used to evaluate low-flow conditions(Leslie et al, 2005).*

[7] *Dynamic model: A dynamic model is a mathematical formulation describing the physical behavior of a system or a process and its temporal variability(Leslie et al, 2005).*

Table 2-2: General characteristics of watershed models.

MODEL	Developer	Program Language	Lumped or distributed	Level of complexity
AGNPS	USDA -ARS	Borland C	distributed	Physically based[8]
AnnAGNPS	USDA-ARS /National Sediment Laboratory	ANSI FORTRAN 95	distributed	Physically based
ANSWERS	USEPA		distributed	Physically based
BASINS	USEPA	•BASINS system & PLOAD : ArcView 3.X. •Models(HSPF, SWAT and KINEROS) : FORTRAN	lumped	export coefficients[9], loading functions[10], physically based
CASC2D	Prof. Pierre Y. Julien at Colorado State University -> USEPA	Fortran version was reformulated, -> C programming language	distributed	physically based
DIAS/IDLAMS	Argonne National Laboratory	SmallTalk, C, Java, and FORTRAN	distributed	-
DRAINMOD	North Carolina State University	Visual Basic and FORTRAN	lumped	physically based
DWSM	Illinois State Water Survey	FORTRAN	distributed	physically based
EPIC	Texas A&M University–Texas Agricultural Experiment Station	FORTRAN version 5125	lumped	-
GISPLM	College of Charleston, Stone Environmental, and Dr. William Walker	Quattro Pro Macros and FORTRAN	-	Loading functions
GLEAMS	U.S EPA	FORTRAN	lumped	-
GSSHA	U.S. ACE	C Language	distributed	Physically based
GWLF	U.S. EPA	BASIC, Visual BASIC	distributed	Loading functions
HSPF	U.S. EPA	FORTRAN (model)	Semi-distributed	physically based
HEC-HMS	HEC US Army Corps of Engineers	C, C++, and FORTRAN	lumped	physically based
KINEROS2	USDA-ARS	FORTRAN 77/90	distributed	physically based
LSPC	EPA and Tetra Tech, Inc.	C++	lumped	physically based
Mercury Loading Model	U.S. EPA	ArcView 3.x and Avenue script	distributed	physically based
MIKE SHE	DHI Water and Environment. (MIKE SHE 2003)	-	distributed	physically based
MUSIC	Monash University,Cooperative Research Center for Catchment Hydrology	Unknown	distributed	physically based
P8-UCM	U.S. EPA	FORTRAN	lumped	export coefficients, physically based
PCSWMM	U.S. EPA	FORTRAN (model) Visual Basic (interface)	lumped	loading functions, physically based
PGC-BMP	Prince George's County, MD	Module interface: C++, Analysis Tool: Visual Basic Applications in Microsoft Excel	distributed	loading functions

[8] *Physically based models include more physically based representations of runoff, pollutant accumulation and washoff, and sediment detachment and transport. Most detailed models use a mixture of empirical and physically based algorithms (Leslie et al., 2005)*

[9] *Export functions are simplified rates that estimate loading based on a very limited set of factors (e.g., Land use)*

[10] *Loading Functions are empirically based estimates of load based on generalized meteorological factors (e.g. precipitation, temperature)*

Table 2-2: General characteristics of watershed models (Continued).

MODEL	Developer	Program Language	Lumped or distributed	Level of complexity
SHETRAN	Origins SHE : A consortium of the Danish Hydraulic Institute, the British Institute of Hydrology and SOGREAH, France SHETRAN (SHE-TRANsport) : the Water Resource Systems Research Laboratory, School of Civil Engineering and Geosciences, University of Newcastle upon Tyne	No information	distributed	physically based
SLAMM	U.S EPA	Visual Basic	distributed	-
SPARROW	USGS, NAWQA Hydrologic Systems Team	SAS Macro Language, SAS IML	Stochastic/ probabilistic	Between empirically and physically based
STORM	USACE (mainframe version), Dodson & Associates, Inc. (PC version)	FORTRAN	lumped	export coefficients, physically based
SWAT	USDA Agricultural Research Service	FORTRAN (model) and ArcView Avenue (interface)	distributed	physically based
SWMM	U.S. EPA	FORTRAN (v4.4 and previous ver.) C (v5)	Semi-distributed	physically based
TOPMODEL	Lancaster University(UK), Institute of Environmental and Natural Sciences	FORTRAN, Visual Basic	Semi-distributed	physically based
WAMVIEW	Soil and Water Engineering Technology (SWET) and U.S. EPA	•FORTRAN for BUCSHELL and BLASROUTE •AVENUE for pre- and post-processor in a customized ArcView	-	physically based
WARMF	Systech Engineering,Inc	Computational code: FORTRAN	lumped	physically based
WEPP	USDA ARS	FORTRAN 77	distributed	physically based

Various program languages have been used to build these watershed models, for example, FORTRAN, C programming language, Arcview series, Visual Basic, SAS, etc. FORTRAN has been used the most, followed by C programming language, Visual Basic, Arcview series, and SAS (Statistical Analysis Software).

2.4.2 SPECIFIC CHARACTERISTICS OF WATERSHED MODELS

Each watershed model has different characteristics based on various fields such as land usage (urban, rural, agricultural, etc.), temporal scale (event or continuous), type of model (grid-based, stream routing included, dynamic), watershed representation, rainfall on overland, subsurface flow, overland sediment, BMP evaluation, and so on. Major specific characteristics are shown in Table 2-3. There are several land usages of watershed models such as urban, rural, agriculture, forest, river, lake, and reservoir/impoundment. BASINS, GWLF, HSPF, HEC-HMS, LSPC, MIKE SHE, MUSIC, P8-UCM, PCSWMM, PGC-BMP, SHETRAN, SPARROW, STORM, SWAT, and SWMM models are typically applied to simulate urban areas. AGNPS, AnnAGNPS, BASINS, CASC2D, DIAS/IDLAMS, DIAMOND, DWSM, EPIC, GISPLM, GSSHA, GWLF, HSPF, HEC-HMS, KINEROS2, LSPC, Mercury Loading Model, MIKE SHE, PCSWMM, PGC-BMP, SHETRAN, SPARROW, SWAT, SWMM, TOPMODEL, WAMVIEW, WARMF, and WEPP models are applied to rural areas. AGNPS, AnnACNPS, ANSWERS, BASINS, CASC2D, DIAS/IDLAMS, DIAMOND, DWSM, EPIC, GISPLM, GLEAMS, GSSHA, GWLF, HSPF, HEC-HMS, KINEROS2, LSPC, Mercury Loading Model, MIKE SHE, PGC-BMP, SPARROW, SWAT, TOPMODEL, WAM*view*, WARMF, and WEPP models are used for predicting agriculture areas. BASINS, CASC2D, DIAS/IDLAMS, DIAMOND, DWSM, EPIC, GISPLM, GSSHA, GWLF, HSPF, HEC-HMS, KINEROS2, LSPC, Mercury Loading Model, MIKE SHE, PGC-BMP, SPARROW, SWAT, TOPMODEL, WARview, WARMF, WEPP models are usually applied to forested areas.

The temporal scale could be classified into two cases, events and continuous. As well, continuous also classifies several time steps: seconds, minutes, hours, days, months, and years. Event based models are as follows; AGNPS, ANSWERS, CASC2D, and DWSM (interval ranging from a few minutes to a few hours). GSSHA is capable of using time steps in seconds. KINEROS2, SWMM, and MUSIC are capable of using time steps in minutes. Watershed models that use hourly time steps are as follows: DRAINMOD, HSPF, LSPC, P8-UCM, PGC-BMP, SLAMM, STORM, SWAT, PCSWMM, and TOPMODEL. AnnAGNPS, EPIC, GISPLM, GLEAMS, GWLF (input data), HEC-HMS, MISE SHE, SHETRAN, WAM*view*, WARMF, and WEPP models use daily time steps. Only GWLF (output) uses monthly time steps. DIAS/IDLAMS, Mercury Loading Model, and SPARROW models use annual time steps.

In order to represent a watershed, each watershed model has different characteristics; one dimensional-grid-channel network and overland elements, two dimensional square overland grids, three dimensional finite-difference mesh, and so on.

Rainfall excess on overland could be estimated using a variety of methods depending on each watershed model. Generally, runoff curve number and water balance methods (surface detention, interception and ET loss, and infiltration) were used. Some watershed models use WDM file, USLE and MUSLE, which can profile soils, in order to estimate effective rooting depths for water, precipitation distribution, generic balance, and empirical regression approach based on the mass balance.

In order to simulate runoff, various methods were used such as the runoff curve number method, coefficient method, flow peak, SCS (TR-55 method), Manning's equation, continuity equations, explicit finite-difference, explicit or implicit numerical scheme, flow routing equation, unidirectional flow, dynamic wave routing, kinematic wave, steady-state routing, diffusive wave equation, overland flow routing, unit hydrograph, GIUH method, empirical equations, time delay histogram, grid-based runoff, approximate method, etc. Among these methods, runoff curve number (AGNPS, AnnAGNPS, GISPLM, GLEAMS, GWLF, Mercury Loading Model, STORM) was used at first and then SCS (TR-55) was used (AGNPS, AnnAGNPS, EPIC, P8-UCM, SWAT, SWMM), followed by flow peak (AGNPS, AnnAGNPS, EPIC, SWAT, SWMM), then Manning's equation (ANSWERS, HSPF, WAMVIEW, WARMF) and finally overland flow routing (CASC2D, GLEAMS, GSSHA, LSPC).

There are several methods that are suitable for simulating overland sediments such as USLE, RUSLE, MUSLE, HUSLE, steady-state continuity, Bagnold stream power equation, Manning's equation, Horton's equation, runoff curve number, SCS TR-55, Yalin's equation, explicit numerical solution, sediment module equations (accumulation/attachment, detachment, transport, and scour of soil matrix), Kilinc-Richardson equation, conservation of mass, water balance, sediment transport capacity, the order kinetics model, empirical equation, advection equation advection-dispersion equation, etc. USLE had the highest number when used for predicting overland sediment and sediment transport capacity and MUSL was used for several watershed models. The remaining methods have only been used on one or two watershed models.

In addition, watershed models have various Best Management Practices (BMP) based on their field scales. The types of BMPs vary and listed are as follows: agricultural practices, forest, wetlands, ponds, grass water ways, tile drainage, vegetative field strips, vegetated swales, riparian buffer, irrigation, filter strips, bioretention system, infiltration practices, land use planning, sediment and pollutant load reductions, nutrient and pesticide management, subsurface drainage system, detention basins, septic systems, CSOs, SSOs, LIDs and so on. Watershed models have different BMPs based on a model's characteristics therefore when we choose a watershed model, BMP has to be considered.

Table 2-3: Specific characteristics of watershed models.

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff & subsurface	Overland sediment	BMP evaluation
AGNPS	Rural, Agricultural	Event	Grid-based, stream routing included	Uniform square areas (cells), some containing channels (1-D overland and channel network)	Runoff curve number method.	Runoff volume using runoff curve number, and flow peak using an empirical relation similar to Rational formula or SCS TR-55 method./ Subsurface not simulated	Soil erosion using USLE and routing of clay, silt, sand, and small and large aggregates through cells based on steady-state continuity, effective transport capacity from a modification of the Bagnold stream power equation, fall velocity, and Manning's equation.	Agricultural practices, ponds, grassed waterways, tile drainage, vegetative filter strips, riparian buffers
AnnAGNPS	Rural, Agricultural	Daily	Stream routing included	Homogeneous land areas (cells), reaches, and impoundments.	GEM and Complete-Climate used for generating climate data and simple water balance approach	Runoff curve number generating daily runoff following SWRRB and EPIC procedures and SCS TR-55 method for peak flow/ Lateral subsurface flow using Darcy's equation or tile drain flow using Hooghoudt's equation and parallel drain approximation	Runoff curve number generating daily runoff following SWRRB and EPIC procedures and SCS TR-55 method for peak flow	Agricultural practices, ponds, grassed waterways, tile drainage, vegetative filter strips, riparian buffers
ANSWERS	Agricultural	Storm event; variable constant step depending numerical stability.	Grid-based	Square grids with uniform hydrologic characteristics, channel elements (1-D simulations)	Surface detention (empirical relations), Infiltration (modified Holton-Overton relation)	Manning and continuity equations (temporarily variable and spatially uniform) solved using an explicit numerical scheme/ Water moving from a control zone to tile drainage and groundwater release or interflow depending on infiltration rate, total porosity, and field capacity.	Raindrop detachment using USLE factors and flow erosion and transport of four sizes (0.01 to 0.30 mm) using modified Yalin's equation and an explicit numerical solution of the steady-state continuity equation	Agricultural management, ponds, grassed waterways, tile drainage

Table 2-3: Specific characteristics of watershed models (Continued).

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff/subsurface	Overland sediment	BMP evaluation
BASINS	Urban, Rural, Agriculture, Forest, River, Lake, Reservoir	BASINS consists of four models having different temporal scales[11]	Dynamic, stream routing included	Automatic watershed delineation tools based on DEM GRID (1-D waterbody)	Using WDM file (Watershed Data Management)	Flow routing equation (continuity) based on completely mixed reach (single layer), unidirectional flow, kinematic wave or storage-routing method (conservation of momentum is not considered)/ Simulates watershed processes using SWM and 1-D transport in stream channels. Includes agricultural components for nutrient and pesticide processes. (HSPF)	Sediment module equations for accumulation/ attachment, detachment, transport, and scour of soil matrix depending on the pervious (applied all cases) and impervious land (applied accumulation and transport cases).	Changes in land use acreage's due to land use planning/ management, wet detention pond, dry detention pond, vegetated swale, stream buffers, sediment and pollutant load reductions
CASC2D	Rural, Agriculture, Forest, River, Lake, Reservoir/ impoundment	Long term & storm event; variable steps depending numerical stability.	two-dimensional overland flow routing algorithm	2-D square overland grids and 1-D channels.	Interception and ET loss, infiltration using Green-Ampt method, and overland flow retention.	2-D diffusive wave equations solved by explicit finite-difference scheme The two-dimensional overland flow routing/ Not simulated	Soil erosion and sediment deposition are computed using modified Kilinc-Richardson equation with USLE factors and conservation of mass.	No information
DIAS/IDLAMS	Rural, Agriculture, forest	Annual step Depends on models integrated in the system	Dynamic	1-D grid and subwatershed overland	-	-	The Revised Universal Soil Loss Equation (RUSLE) to generate an erosion status map for each current condition or simulated vegetation/land cover map input by the user.	-
DRAINMOD	Rural Agriculture Forest Reservoir/ Impoundment	Sub-daily step : Hourly and daily	one-dimensional water balance	1-D water balance	DRAINMOD is based on water balances in the soil and at the soil surface	-/ Subsurface drainage is computed using the Hooghoudt's equation	$P = F + \Delta S + RO$ Where P is the precipitation (cm), F is infiltration (cm), ΔS is the change in volume of water stored on the surface(cm), and RO is runoff during time interval Δt. (water balance)	Design subsurface drainage system

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[11] **HSPF** (user-defined time step, typically hourly, continuous simulation from days to years), **SWAT** (daily time step, continuous simulation for months to years), **PLOAD** (Export coefficient model, annual), and **KINEROS** (single-storm event, part of AGWA, variable time step typically in minutes)

Table 2-3: Specific characteristics of watershed models (Continued).

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff/subsurface	Overland sediment	BMP evaluation
DWSM	Rural, Agriculture, Forest, River (Reservoir/ impoundment)	Several days of storm events divided into constant time intervals ranging from few minutes to few hours	Dynamic, stream routing included	1-D overland elements, channel segments, and reservoir units. Distributed, single event model	Curve number method. Smith-Parlange infiltration model.	Kinematic Wave equations The overland elements are the primary sources of runoff in which rainfall turns into surface runoff after losing first to interception at canopies and ground covers. / A portion of the infiltrated water flows laterally towards downstream as subsurface flow sometimes in accelerated mode in the presence of tile drains using an effective lateral saturated hydraulic conductivity concept	Raindrop detachment and sediment transport, scour, and deposition of user specified particle size groups based on sediment transport capacity and approximate analytical solution of temporarily and spatially varying continuity equation.	Detention basins, alternative ground covers, tile drains
EPIC	Rural, Agriculture, Forest	Daily time step, long-term simulations (1–4,000 years)	-	One-dimensional, agricultural field/farm scale, Field-scale, erosion based	equations—the USLE, the Onstad-Foster modification of the USLE, the MUSLE, variations of MUSLE	the SCS curve number method and the peak runoff rate/ Lateral subsurface flow is computed for each soil layer using a kinematic storage model starting at the top layer and progressing downward	The variation between these models is the energy factor used to drive erosion, where USLE uses rainfall only, MUSLE uses runoff only, and Onstad-Foster uses a combination of rainfall and runoff.	Agricultural practices
GISPLM	Rural, Forest Agriculture, (Urban, Lake, Reservoir/impoundment)	Daily time step	Dynamic, stream routing included	A number of subwatersheds or segments linked in a branched network: One-dimensional	Summarizes downstream flow and loads simply by adding the outputs from the upstream subwatersheds	HYDRO generates a table relating unit area surface runoff from pervious areas to SCS Runoff Curve Number./ Highly simplifies groundwater inflow	Does not simulate sediment and sediment phosphorus	-
GLEAMS	Agriculture	Daily	Continuous simulation	One-dimensional field-scale	Soil profile and crop data were used to estimate the effective rooting depth for water. Priestley-Taylor (PM) equation and Modified Penman-Monteith equations for evaportranspiration.	Physically based, daily simulation interface Flow is determined by SCS curve number method One and two-dimensional diffusive wave flow routing at channels and overland planes/ water losses below root zone	Erosion in overland flow areas is estimated using modified USLE	Agricultural practices, ponds, irrigation

Table 2-3: Specific characteristics of watershed models (Continued).

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff/subsurface	Overland sediment	BMP evaluation
GSSHA	Rural, Agriculture, Forest, River, Lake, (Urban, Reservoir/impoundment)	Sub-daily step Variable time step (seconds to minutes)	Dynamic, Grid-based, stream routing included	square-grid-based Two-dimensional grid overland	the equations of conservation of mass and energy to determine the timing for precipitation distribution	an explicit finite-difference, two-dimensional, diffusive-wave method for overland flow routing/ Darcy's Law for stream/groundwater interaction and exfiltration	The empirical Kilinc and Richardson soil erosion model, as modified by Julien (1995), is applied in GSSHA to determine the sediment transport from one overland flow grid cell to the next.	Agricultural practices
GWLF	Urban, Rural, Agriculture, Forest, (River)	Input: daily Output: monthly	stream routing included	One-dimensional, subwatershed overland	Generic / Water balance is performed daily using supplied or computed precipitation, snowmelt, initial unsaturated zone storage, maximum available zone storage, and evapotranspiration values	Surface runoff using the SCS-CN approach with daily weather (temperature and precipitation) inputs/ Implicit – recharge movement of water	Erosion and sediment yield are estimated using monthly erosion calculations based on the USLE algorithm (with monthly rainfall-runoff coefficients) and a monthly composite of KLSCP values for each source area (i.e., land cover/soil type combination).	Agricultural practices, septic systems, manured areas
HSPF	Urban, Rural, Agriculture, Forest, River, Lake, Reservoir/impoundment	User-defined time step, typically hourly	Dynamic, stream routing included	Plane / Channel Pervious and impervious land areas, stream channels, and mixed reservoirs; 1-D simulation	Water budget considering, interception, ET, and infiltration with empirically based areal distribution.	Non-linear reservoir Empirical outflow depth to detention storage relation and flow using Chezy-Manning equation/ Interflow outflow, percolation, and groundwater outflow using empirical relations.	Rainfall splash detachment and wash off of the detached sediment based on transport capacity as function of water storage and outflow plus scour from flow using power relation with water storage and flow.	Nutrient and pesticide management, ponds, urbanization
HEC-HMS	Urban, Rural, Agriculture, Forest, River, Reservoir/impoundment	Sub-daily step User-defined	stream routing included	Plane / Channel The GUI has the capability to create schematic representations of a network of hydrologic elements (1-D simulation)	The SCS curve number method, and the Green-Ampt method. Runoff transform methods include the Clark, Snyder, and SCS unit hydrograph techniques.	Unit hydrograph, GIUH Method/ The constant monthly method, linear reservoir method, and non-linear Boussinesq methods	No information	No information

Table 2-3: Specific characteristics of watershed models (Continued).

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff/subsurface	Overland sediment	BMP evaluation
KINEROS 2	Rural, Agriculture, Forest, (Urban, River, Reservoir/impoundment)	Sub-daily step Variable time step (normally in minutes)	stream routing included	Plane / Channel Runoff surfaces or planes, channels or conduits, and ponds or detention storage; 1-D simulations	Interception loss and extensive infiltration procedure by Smith and Parlange.	Non-linear reservoir Kinematic wave equations solved by an implicit numerical scheme/ Not simulated.	Raindrop detachment and sediment transport, scour, and deposition of one particle size based on sediment transport capacity and explicit numerical solution of temporarily and spatially varying continuity equation	Agricultural practices, detention basins, culverts
LSPC	Urban, Rural, Agriculture, Forest, River, Lake, Reservoir/impoundment	Sub-daily step User-defined time step, typically hourly	Dynamic, stream routing included	One-dimensional in-stream fate and transport	Water balance of soil (or storage) in different layers as described by the Stanford Watershed Model (SWM) methodology.	For overland flow, model assumes one-directional kinematic-wave flow/ considering infiltration, interflow, subsurface storage, groundwater flow and loss (a grid-based watershed simulation model)	Using PQUAL and IQUAL modules in HSPF model. -Land process: wash off of loose sediment, scouring soil matrix -Stream channel process: transport, deposition, and scouring of sediments	Support TMDL study and loads allocation
Mercury Loading Model	Rural, Agriculture, Forest, (Urban River, Lake, Reservoir/impoundment)	Annual and long-term average	spatial and temporal dynamic	ArcView 3.x based, calculates soil mercury concentrations and loading potential grid-by-grid (1-D sub-watershed, grid)	Rainfall/event is used to calculate the runoff using the curve number method developed by USDA-NRCS	Water balances including evaportranspiration and infiltration is used to calculate the mercury load from surface runoff through curve numbers and monthly rainfall/ -	Using WCS Mercury Loading Model through USLE, hydrologic algorithm, mercury chemistry algorithm	Mercury simulation and reduction for watershed
MIKE SHE	Urban, Rural, Agriculture, Forest, River, Reservoir/impoundment	Sub-daily step User-defined, variable time step.	stream routing included	2-D rectangular /square overland grids,1-D channels, 1-D unsaturated and 3-D saturated flow layers.	Interception and ET loss and vertical flow solving Richard's equation using implicit numerical method.	Interception and ET loss and vertical flow solving Richards equation using implicit numerical method/ 3-D groundwater flow equations solved using a numerical finite-difference scheme and simulated river-groundwater exchange.	No information	Agricultural and forest practices, wetlands, nutrient and pesticide management, irrigation, drainage
MUSIC	Urban	Sub-daily step 6 minutes to 24 hours	-	A catchment (the entire catchment being simulated) is made up of a number of nodes, joined together by drainage links. (the 1st order kinetic model)	Involves potential ET, impervious storage, soil moisture storage, and a groundwater component.	generally represented by empirical equations/ generally represented by empirical equations	Physical process (sedimentation) is the predominant pollutant removal mechanism during the event and is described by the order kinetics (k-C*) model	Retarding basin, wetlands, bioretention systems, and vegetated swales etc.

Table 2-3: Specific characteristics of watershed models (Continued).

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff/subsurface	Overland sediment	BMP evaluation
P8-UCM	Urban, Reservoir/impoundment, (Rural, Agriculture, Forest, River)	Hourly	Continuous water & mass balance	-	Generic, Storm - mass balance	Runoff from pervious areas is computed using the Soil Conservation Service's (SCS) curve number technique/ Linear reservoir ground water model, shallow saturated zone (simple linear reservoir)	Empirical equation for pervious land and differential equation for impervious land.	Detention basin, infiltration practices, swale/buffer strip, Manhole/splitter, street sweeping
PCSWMM	Urban, Rural, River, Reservoir/impoundment, (Agriculture, Forest, Lake)	User-defined time step, typically hourly	Dynamic	Subwatershed. Flexible size One-dimensional channel/pipe system	One-dimensional mass balance flow and pollutant routing	Three routing runoff methods: dynamic wave routing, kinematic wave routing, steady-state routing./ Unsaturated soil layers (Horton, Green-Ampt, and SCS curve number), percolation of infiltrated water into groundwater layers, interflow between groundwater and the drainage system	Subcatchments were divided based on soil type, slope, and land use through GIS. Manning's N, Horton's equation, and USLE used to simulate sediment.	Design and sizing of drainage system, detention facilities, CSOs, and SSOs, BMP, LIDs.
PGC-BMP	Urban, Rural, Agriculture, Forest, (Reservoir/impoundment)	Hourly input and output time series	-	Site-level or small watershed-scale analysis	One-dimensional mass balance flow and pollutant routing (land-to-BMP or BMP-to-BMP)	Class A: the storage/Infiltration BMPs and includes physical storage volume exists, storage routing techniques need to be applied, and outflow can be controlled by weir, orifice, pump, etc. Class B: the channelized BMP included no physical storage volume exists, friction flow routing technique needs to be applied and outflow can be estimated by a frictional flow formula		detention basins, infiltration trenches, dry wells, porous pavement, wetlands, swale filter strips, bioretention, etc.
SHETRAN	Urban, Rural, Agriculture, Forest, River	Daily, Sub-daily step User-defined, variable time step.	Dynamic, stream routing included	Three-dimensional finite-difference mesh.(Physically based, spatially distributed)	Actual evaporation Ea (Penman-Monteith) Canopy interception storage (Rutter) and snowmelt model	Overland & channel flow model including water depth, surface area, lateral influxes, and vertical influxes (Saint-Venant equations, diffusion approximation(2D))/ The subsurface is treated as a variably-saturated heterogeneous porous medium and fully three-dimensional flow including unsaturated and saturated flow (Variably saturated flow equation (3D))	Advection-dispersion equation (2D) with terms for deposition and erosion by raindrop and leaf drip impact and overland flow (Ewen et al., 2000)	Land erosion, pollution, and the effects of changes in land use and climate. A decision-support system for env. impact management
SLAMM	Urban, Rural, (Forest)	Sub-daily step Variable time step (hourly or sub-hourly)	-	Physically based, spatially distributed, Statistical approach	Generic - mass balance for particulate and dissolved pollutant and runoff volume	computes runoff volume for each source area using empirical non-linear equations Runoff is based on rainfall minus initial abstraction. Triangular runoff hydrograph/ Implicit – recharge Does not simulate base flow	Not simulated	Infiltration practices, wet detention ponds, porous pavement, street & catchment cleaning, grass swales, etc.

Table 2-3: Specific characteristics of watershed models (Continued).

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff/subsurface	Overland sediment	BMP evaluation
SPARROW	Urban, Rural, Agriculture, Forest, River	Annual step User-defined modeling period	spatially calibrated regression model	Empirical, regression-based Uses national datasets, wide applicability	The model is based on an empirical regression approach using mass balance calculations	First step is pre-processing steps for obtaining reach-level information: diffuse source, industrial/municipal point source, landscape transport, and aquatic transport. Second step is the monitoring of station flux estimations for estimating the long-term flux: water-quality & flow data, rating curve model of pollutant flux, mean-annual pollutant flux estimation Calibration minimize differences between predicted (by first step) and calculated mean-annual loads (by second step)/ no simulation of subsurface		The probability of exceeding Water-quality criteria. Total nitrogen and phosphorus estimation
STORM	Urban	Sub-daily step Hourly	Quasi-dynamic,	Urban watershed model Watershed scale	Pollutants accumulated over the land between the consecutive rainfall events will be washed off during a rainfall event	methods—coefficient method, the SCS Curve Number technique, or a combination of the two/ Not simulated	Erosion is simulated using USLE, and water quality is simulated by linear buildup and wash off coefficients.	pollutants accumulation and wash off, land surface erosion, treatment rates, and detention reservoir storage
SWAT	Urban, Rural, Agriculture, Forest, (River, Lake Reservoir/impoundment)	Long term / a daily time step/an hourly time step	Quasi-dynamic, stream routing included	Sub-basins group based on climate Hydrologic response units Ponds, Groundwater, Main channel (1-D simulation)	Daily water budget; precipitation, runoff, ET, percolation, and return flow from subsurface and groundwater flow.	Runoff volume using curve number and flow peak using modified Rational formula or SCS TR-55 method. / Lateral subsurface flow using kinematic storage model (Sloan et al., 1983), and groundwater flow using empirical relations.	Sediment yield based on Modified Universal Soil Loss Equation (MUSLE) expressed in terms of runoff volume, peak flow, and USLE factors.	Agricultural management: irrigation, fertilization, pesticide applications, and grazing
SWMM	Urban, Rural, Reservoir/impoundment, (Agriculture, Forest, River, Lake)	User-defined time step, typically minutes to hourly	Dynamic, stream routing included	Homogeneous land areas (cells), reaches, and impoundments. (1-D simulation, subwatershed of flexible size)	Water balance for constant sub-daily time steps and two soil layers (8-in. tillage depth and user supplied second layer).	a non-linear reservoir model to compute overland flow, Runoff curve number generating daily runoff following SWRRB and EPIC procedures and SCS TR-55 method for peak flow/ Lateral subsurface flow using Darcy's equation or tile drain flow using Hooghoudt's equation and parallel drain approximation.	Uses RUSLE to generate sheet and rill erosion daily or user-defined runoff event, HUSLE for delivery ratio and sediment deposition based on size distribution and particle fall velocity.	Agricultural management, Detention basins, street cleaning
TOPMODEL	Rural, Agriculture, Forest, (River)	Variable, from 1 to 24 hours	Dynamic	A regular raster grid of elevations for any watershed or subwatershed	Grid, catchment response to rainfall based on the topographic index ln (α/tanβ)	Overland flow is routed using a time delay histogram computed from pixel slope, distance from the stream, and a velocity parameter/ Subwatershed discharges are routed to the watershed outlet using a linear routing algorithm with constant velocity both in the main channel and in the internal subwatershed. Soil hydraulic conductivity	Only simulates watershed hydrology	-

Table 2-3: Specific characteristics of watershed models (Continued).

MODEL	Model Usage	Temporal scale	Type of model	Watershed representation	Rainfall excess on overland	Runoff/subsurface	Overland sediment	BMP evaluation
WAM*view*	Urban, Rural, Agriculture, Forest, River, Lake, Reservoir/impoundment	User-defined time step: typically, a day	Dynamic, Grid-based, stream routing included	One-dimensional stream routing. Grid-based watershed; typical grid size 100m x 100m. Typical reach/stream length 1000m to 10000m.	climate data input to the unique cells for load estimation by BUCSHELL	BUCSHELL generate grid-based runoff and BLASROUTE simulate the routing and attenuation of loads and flow generated on each source cell. BLASROUTE is developed based on Manning's equation without a momentum component./ Simulate groundwater based on land use, soil and weather empirically without fully integrated into the system	Including Total Suspended Solids, Soluble (nitrate, ammonia, organic nitrogen, phosphorous), Sediment (Ammonia, Organic Nitrogen, Phosphorous)	Overland, wetland, and stream load attenuation. TMDL and stormwater treatment.
WARMF	Urban, Rural, Agriculture, Forest, Lake, Reservoir/impoundment, (River)	Daily step	Dynamic, stream routing included	Watershed One-dimensional stream Lake layers	Precipitation based on temp., canopy by the leaf area index (LAI), ET by a function of latitude according to Hargreave[12]	The total surface runoff from catchment is the sum of water on impervious surfaces plus runoff from pervious surfaces calculated using Manning's equation/ Each of the five soil layers has their own characteristics. Infiltration used modified-Raphson method. Lateral flow used Darcy's law	The transport of clay, silt, and sand simulate separately. Along with the results are combined for total suspended solids. Algorithms for sediment erosion and pollutant transport from farm lands and other land uses were adapted from ANSWERS and the Universal Soil Loss Equation (USLE).	Management Alternative, TMDL, Cost and benefit
WEPP	Rural, Agriculture, Forest	Daily, monthly or annual	continuous simulation	Single watershed composed of a network of hillslopes and channels	The two-state Markov chain model was used. Precipitation occurs based on the previous day's wet and dry conditions; A random number (0-1) is generated and compared with the appropriate wet-dry probability.	Surface runoff is relevant to infiltration, rainfall excess, depression storage and peak discharge; infiltration is computed using the Green-Ampt Mein-Larson model and rainfall excess and peak discharge are calculated by the kinematic wave model or approximate method/ No simulation	A steady-state sediment continuity equation, hydrologic inputs, flow shear stress, sediment transport capacity	terraces, farm ponds, and check dams

[12] Hargreaves, 1974.

2.5. CRITERIA FOR SELECTING APPROPRIATE APPLICATIONS

The models reviewed and shown in Table 2-3 vary greatly in terms of their complexity; some are very simple, whereas others are extremely complex; and the complex models can only be run by modeling experts. Some of the models target urban runoff and others target agricultural runoff, but none of the models do a good job at both. Furthermore, the focus of the models is different, some are watershed based focusing on watershed loading to receiving waters while others focus on receiving water impacts. Finally, most of the models are not well documented and some models are no longer available, and the others are used as non-commercial or commercial models (Borah et al., 2009). The selection process for determining which models are appropriate can be an extremely difficult exercise because there is no guidance available for model selection. Leslie et al. (2005) suggests that five factors be taken into account in reviewing a model: type, complexity, time-step, hydrology and water quality. The factors are shown below in Table 2-4.

Table 2-4: The five separate factors for watershed model evaluations.

Separate factor	Detail explain	
Type	Land-based	Simulate only land-based process
	Comprehensive	Including land and rivers, pipes (conveyance systems)
Complexity	Export coefficient	Loading based on limited factors such as land use etc.
	Loading functions	Empirically load based on generalized meteorological factors such as temperature, precipitation etc.
	Physically based	Physically based representations of runoff, pollutant accumulate and wash off, and sediment detachment and transport.
Time steps	Single-event	Limited to simulation of individual events
	Continuous	Second, minute, Hour, day, month, year
Hydrology	Includes surface runoff only	
	Includes surface and groundwater inputs	
Water quality	Based on the pollutants or parameters simulated by the model complexity	

2.5.1 EXPLANATION OF THE FACTORS USED FOR DEVELOPEING A SELECTION PROGRAM

Thirty three available watershed models were selected and reviewed for this research (see Table 2-3). When taking into consideration the five factors from Leslie et al. (2005) (see Table 2-4) and the reviewed literature, it was assumed that eight factors would provide more vital descriptions and represent the watershed models more accurately. The eight factors are land usage, lumped/distributed, event/continuous, time steps, overland sediment transport, subsurface, water quality, and BMP. Each of the factors will be used as follows and can be compared like in Figure 2-2 between five factors and eight factors. In addition, a selection program will be developed based on the process of Figure 2-3.

- **Land use (1)** can be segregated into urban, rural, agriculture, forest, river, and lake/reservoir
- **Complexity** will be changed to **lumped and distributed (2).**
- **Temporal scale** will be divided into **single-event model and continuous simulation model (3)**. The period of steps include seconds, minutes, hours, days, months, and years **(Time steps (4))**.
- **Hydrology** will be divided into **overland sediment transport (5)** and **subsurface flow (6)** For overland sediment transport, there are many equations that have been put into practice such as USLE, RUSLE, MUSLE, manning's equations, etc. In the case of subsurface flow, some watershed models were applicable while others were not.
- **Water quality (7)** Will be used based upon available water quality parameters
- **BMPs (8)** were carried out based upon land type/use characteristics like agricultural, forest, wetlands, etc.

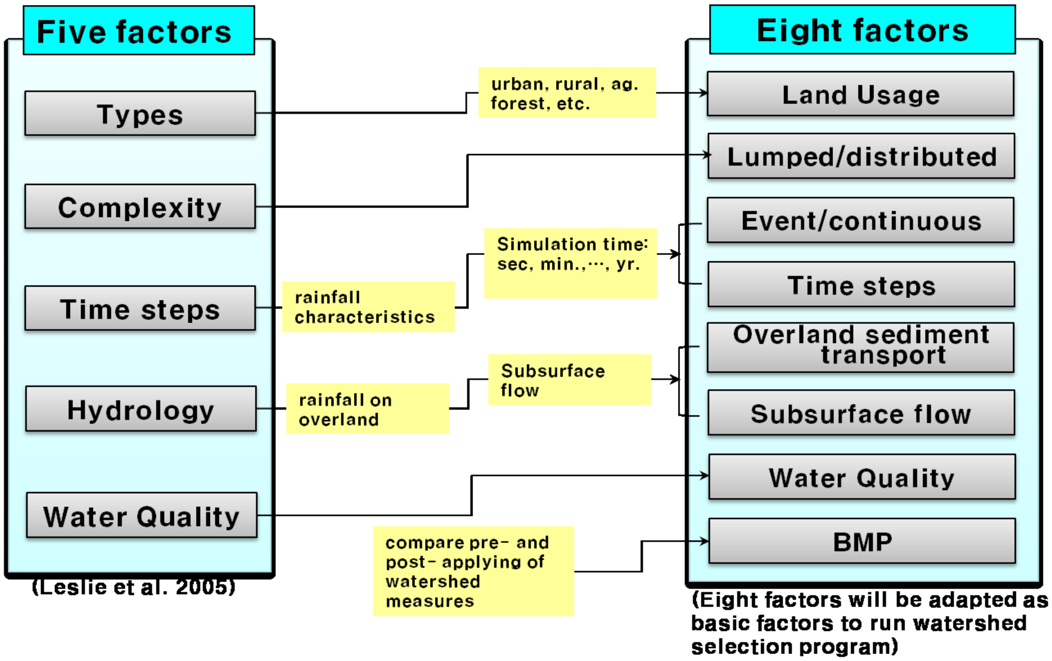


Figure 2-2: New factors to develop the selection program.

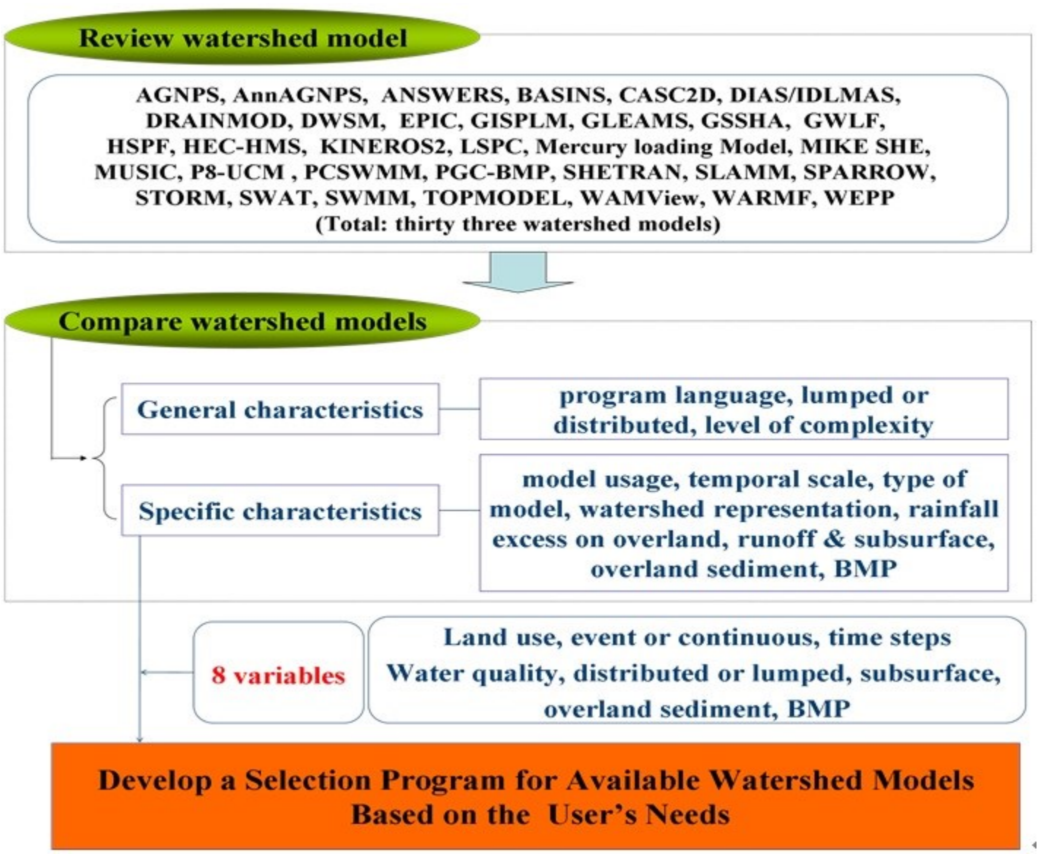


Figure 2-3: The Schematic for researching existing watershed models and developing a selection program.

2.6. SELECTION PROGRAM FOR AVAILABLE WATERSHED MODELS

As was mentioned above, each watershed model has its own unique characteristics which are shown in Tables 2-2 and 2-3. When approaching the models for predicting of watersheds, in order to save time and effort, a program and methods for choosing available watershed models needed to be developed. In this chapter, a Selection Program for Available Watershed Models (Version 1) was developed using Excel Visual Basic, as shown in Figure 2-4.

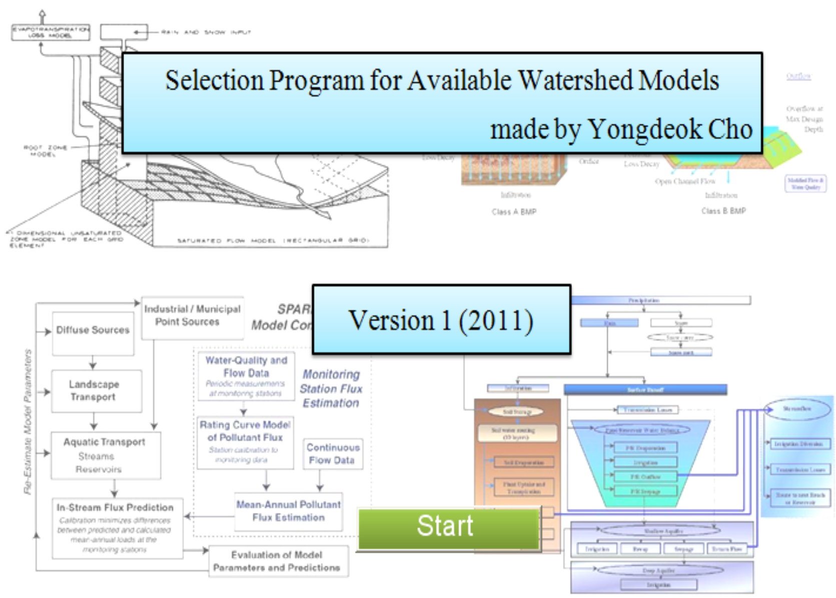


Figure 2-4: The cover page of the Selection Program for Available Watershed models.

2.6.1 SELECTION ITEMS OF 8 VARIABLES

If you were to click the start button like in Figure 2-4, you can see a more detailed expression window (Figure 2-5). In order to simplify the selection process of watershed models for each watershed area, eight variables were chosen, which are as follows; (1) Land Use, (2) Event or Continuous, (3) Time Steps, (4) Water Quality, (5) Distributed or Lumped, (6) Subsurface, (7) Overland Sediment, and (8) BMP. Variables can be chosen separately or they can overlap. Then the items of 8 variables could be selected based on the user's need, as shown in Figure 2-5. When you select the desirable items of each variable, the selected watershed models change to a yellow color in the model window.

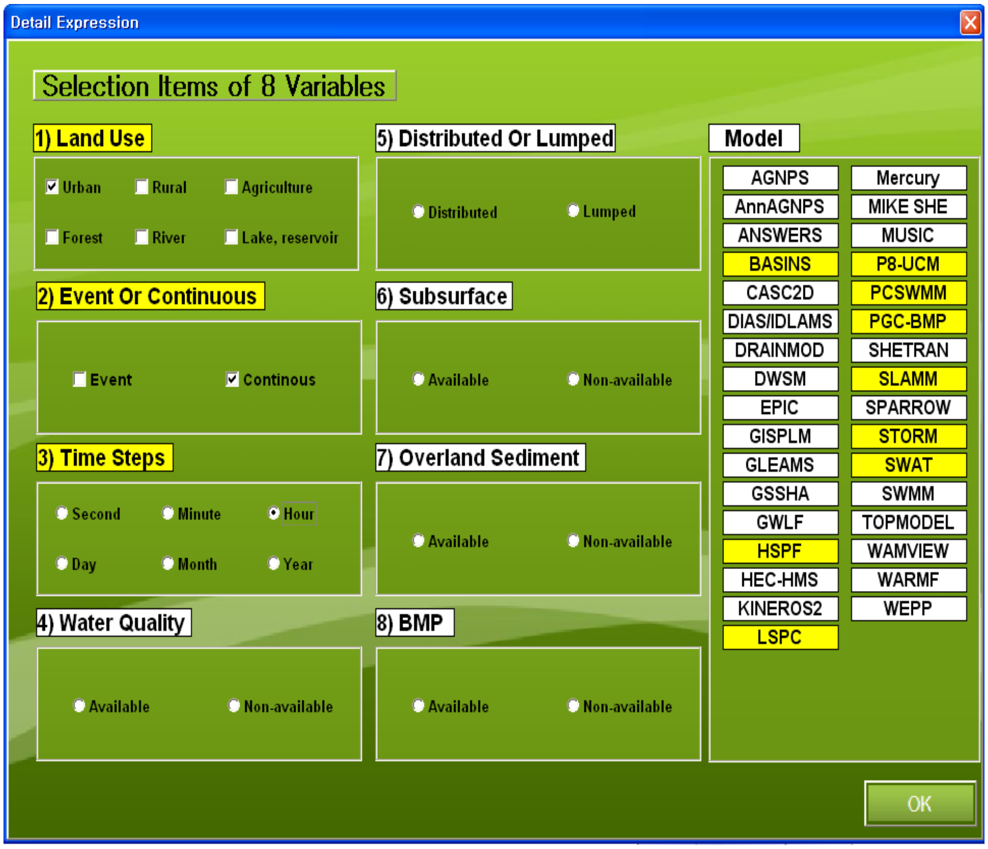


Figure 2-5: Detailed expression Window for selecting items of the 8 variables.

Land use includes urban, rural, agriculture, forests, rivers, and lakes or reservoirs. Event or Continuous could be selected separately or they can overlap. Time steps can be chosen separately and can overlap as well among seconds, minutes, hours, days, months, and years. Distributed or lumped, Subsurface, Overland Sediment, and BMP could be selected depending on the user's needs.

2.6.2 MODEL DESCRIPTIONS OF SELECTED WATERSHED MODELS

After choosing the desirable items of the 8 variables, push the ok button. You will see the model description in the results window which includes input data, the developer, programming language, level of complexity, rainfall excess on overland/water balance, runoff on overland, subsurface flow, overland sediment, water quality simulation, BMP evaluation, Model limitation, and References which are connected to an excel file sheet.

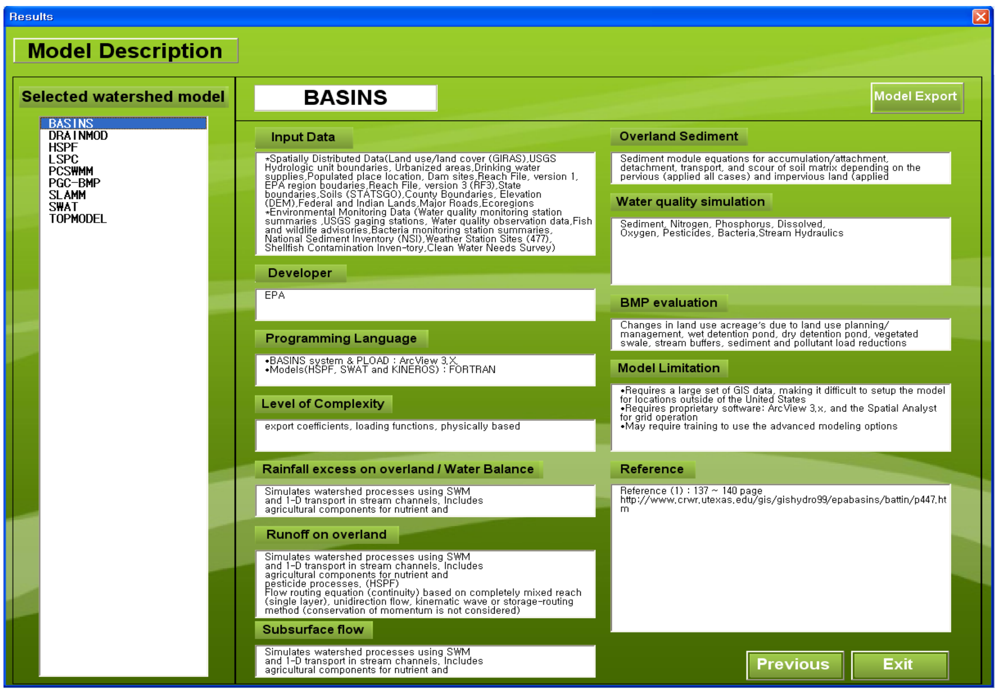


Figure 2-6: Selected Model Description in result window.

If you select a desirable watershed model, you can see the detailed model description. Furthermore, results could be shown as a text file by pushing the model export button. To go back to the previous page, click the previous button.

2.7. SUMMARY AND CONCLUSION

In this chapter, numerous watersheds models, which have their own unique characteristics, were reviewed to determine each model's mechanisms and functions. Furthermore, about 217 references examples, which have been applied to the watershed models, were reviewed and analyzed with a focus on their applicability. Hence, in this paper, thirty three different watershed models were reviewed to show how they can be applied to different situations and watershed characteristics. These models included AGNPS, AnnAGNPS, ANSWERS, BASINS, CASC2D, IAS/IDLMAS, DRAINMOD, DWSM, GISPLM, GLEAMS, GSSHA, GWLF, HSPF, HEC-HMS, KINEROS2, LSPC, Mercury Loading Model, MIKE SHE, MUSIC, P8-UCM, PGC-BMP, SHETRAN, SLAMM, SPARROW, STORM, SWAT, SWMM, TOPMODEL, WAMView, WARMF, and WEPP.

In addition, the watershed models were classified based on several characteristics which were program language, lumped or distributed, level of complexity, model usage (Land use), temporal scale, type of model, watershed representation, rainfall excess on overland, runoff and subsurface, overland sediment, and BMP evaluation. According to these classifications, the characteristics of watershed models could be explained in detail and the key points of each model are highlighted.

Based on this study's literature review, currently available watershed models designed for the purpose of developing flow and water quality management plans at a watershed scale—such as Nakdong River watershed (23,860 km^2) in South Korea—require too much data and application effort to be used to prioritize watersheds with respect to their relative contribution to environmental degradation within a multiwatershed basin. Therefore, as was hypothesized in Chapter 1, simple equations relating easily obtained data to watershed water quality impacts need to be developed to sufficiently prioritize target restoration areas in the feasibility phase of spatially large projects (i.e. national scale).

In addition, a model selection program is needed to aid the engineer in the selection of the best watershed model to use in future complex modeling following the feasibility phase. Eight variables were chosen considering five factors from Leslie et al. (2005) and the reviewed literature such as land use, event or continuous, time steps, water quality, distributed or lumped, subsurface, overland sediment, and BMP. Using these eight variables as input, the selection program developed in this dissertation screens available watershed models for the best model for the user's needs.

After the selection program uses the modeler's needs to screen available watershed models and makes a selection, information related to the data of the selected model—such as input data, the developer, programming language, level of complexity, rainfall excess on overland / water balance, runoff on overland, subsurface flow, overland sediment, water quality simulation, BMP evaluation, model limitation, and references—are shown and can be printed out if 'sheet export' is selected.

The watershed selection program described in this dissertation could be highly useful to many watershed modelers. In addition, this program could be upgraded by anyone who knows how to apply state-of-art data that has been collected from a watershed model. This program is still not perfect because we could not obtain the entire data for each watershed model. Finally this program is going to be upgraded continuously to fulfill the needs of users of watershed models.

CHAPTER 3. DEVELOPING SIMPLE EQUATIONS FOR WATER QUALITY IN SOUTH KOREA

3.1. INTRODUCTION

Population pressures and mitigation, land-use conversion and its pollution consequences appear to be the major diffuse pollution problem today (Novotny, 2003). Many people have moved to the countryside and have transformed rural areas into suburban areas. Due to the recent trends of land use, imperviousness has abruptly increased. This increase in impervious land has resulted in the increase in the ease of pollutant conveyance from the watershed to river channels downstream. Watershed changes to impervious cover have resulted in the shifting of stream and watershed environmental conditions that are entirely different from their historic forms. In addition, such changes have affected urban stream hydrographic conditions and have resulted in significantly higher and earlier peak discharge rate than is seen in rural or undeveloped streams (CWP, 2005).

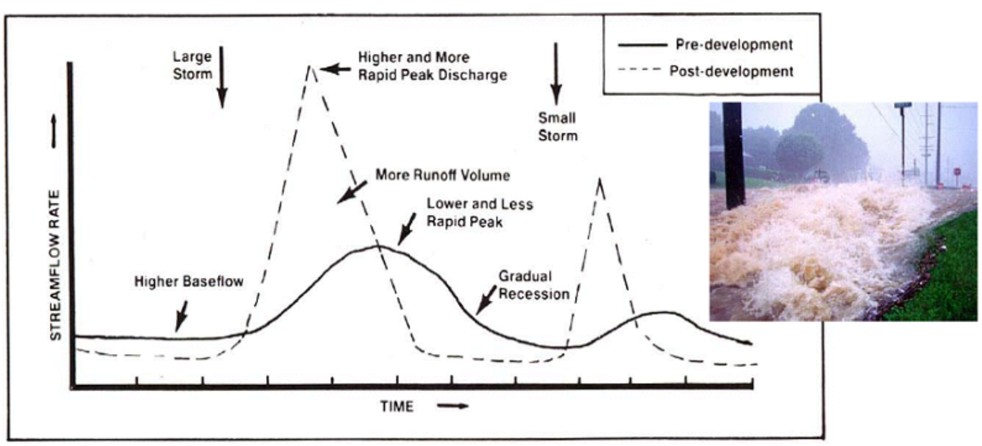


Figure 3-1: Comparison of pre and post development (Source: Schueler, 1987).

Urbanization has spread widely all over the world. However, people want to restore or rehabilitate urban and rural areas for better environmental conditions. In order to do this, we need to compare urban areas and then try to find the best areas through priority comparison, because the amount of funds needed to conduct a nationwide project would be insurmountable for the government to bear. Hence, policy makers should decide which places have the highest priority for restoration. This has to include the evaluation of economic, social, technological, and environmental factors. To carry out these evaluations, we need to adapt nationwide watershed modeling for forecasting after applying watershed restoration measures. However, sophisticated watershed modeling is extremely broad, complicated, and time-consuming work. Therefore, simplified evaluation methods of watershed environmental conditions should be applied, such as pre- and post-water quality measures, to quantify the effects of restoration methods.

Watershed modeling is a hydrological and geographical model that simulates the movement of water and relevant processes in order to reflect the change of water quality and quantity (Novotny, 2008, Singh, 2004). A plethora of watershed models exist, all of which combining and integrating together physically and empirically relationships and parameters to approximate the behavior of the natural systems. A few of these watershed modeling parameters, characteristics and processes include: areal precipitation, watershed representation, surface runoff, infiltration, subsurface flow and interflow, groundwater flow and base flow, evaporation and evapotranspiration, interception, depression storage, detention storage, rainfall-excess/soil moisture accounting, snowmelt runoff, stream-aquifer interaction, reservoir flow routing, channel flow routing, water quality, model calibration and model testing (Singh, 2004). However, these methods are difficult to follow and only modeling experts deal with them. In addition, it takes a lot of time to collect data from an area.

In order to perform water quality modeling for one watershed and carry out data collection, a significant amount of time and money must be devoted. This process will require a period of more than two years just to collect data and at least two to three additional years to analyze it (Roesner, personal communication). Along with the time needed, a large amount of money will be required for data gathering, and model application. The Water Quality Modeling Process is shown in Figure 3-2 (by Chapra, 2003). In the case of the Four River Restoration project in South Korea, this is neither a practical or affordable approach due to the scale of work being done.

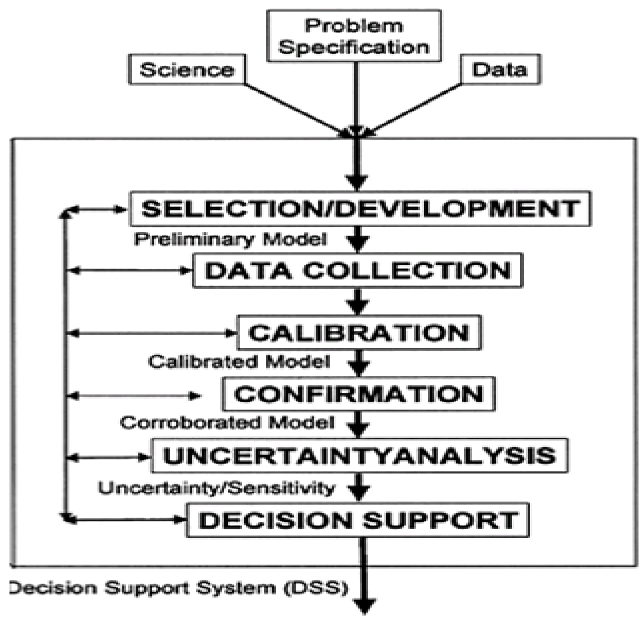


Figure 3-2: Water Quality Modeling Process.

The objective of this research is to streamline the process outlined in Figure 3-3 and develop a sophisticated yet simple decision-making system that utilizes existing data such as land coverage and watershed area. Water quality could change due to the watershed conditions, especially land coverage. Therefore, if a relationship is found between land coverage and water quality, it can be used to prioritize watersheds for restoration. Therefore, a simple method is to be developed to prove the relationship between land coverage and water quality and this methodology will then be verified using an existing watershed model in this research.

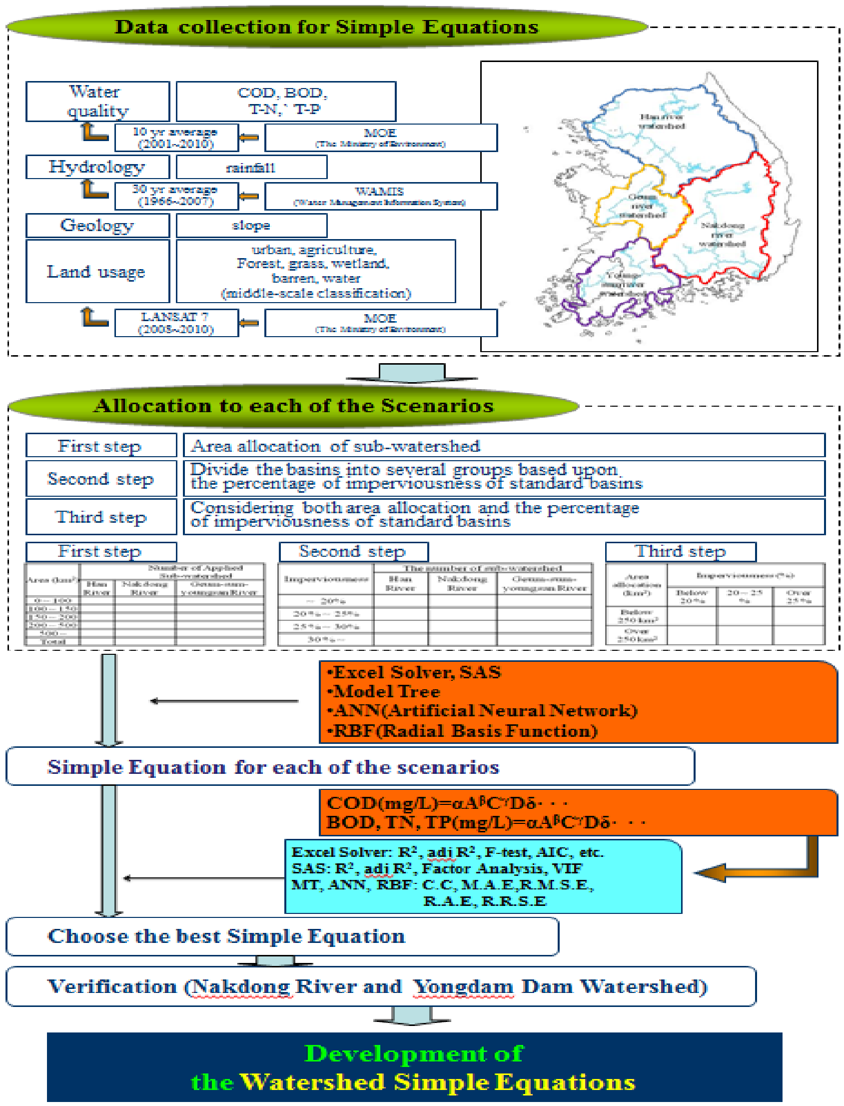


Figure 3-3: Research schematic for developing simple methods.

3.2. DATA COLLECTION FOR SIMPLE EQUATIONS

Many research studies have been published globally reporting impact correlation between land use types and water quality parameters (Tu, 2011. Mehaffey et al., 2005. Schoonover et al., 2005, Sliva et al., 2001, Stutter et al., 2007, Woli et al., 2004)

Tu (2011) researched the relationship between six land usages (agricultural, forest, commercial, industrial, residential, and recreation land) and fourteen water quality indicators in

Eastern Massachusetts. Most of the water quality indicators have been significantly associated with most of the land use indicators. Randhir (2001) studied a watershed-based land prioritization model for water supply protection based on the integration of three types of information: geographic information, relationships between land criteria and effects, and travel-time of runoff. In the case of land use modeling studies, geographic information systems (GIS) have been used for assembling data and defining decision zones (Wang, 2004).

Lately, there has been a dramatic increase in watershed surveys. Therefore, data on water quality and land coverage could be obtainable for all over the world, including South Korea. In order to determine a relationship among water quality, hydrology, geology, and land usage, the data shown in Table 3-1 were collected.

Table 3-1: The collection data to make simple methods.

Division	Parameter	
Water Quality	COD, BOD, T-N, and T-P	
Hydrology	Rainfall	
Geology	Slope	
Land Usage	Pervious and impervious,	
	Middle-scale (23 items)	residential areas, industry areas, business areas, recreational facilities areas, traffic areas, public facilities areas, rice paddies, fields, greenhouse areas, orchards, cultivation areas, broad-leaved forests, coniferous forests, mixed stand forests, natural grasslands, golf courses, grasslands, inland wetlands, coastal wetlands, mining areas, bare land, inland water, and sea water
	Large-scale (7 items)	urban, agriculture, forest, grass, wetland, barren, and water

Water quality data were obtained from the Ministry of Environment (MOE) from 2001 to 2010. For rainfall, the 30 years average rainfall was used per standard basin from 1966 to 2007, which was obtained from the WAMIS (Water Management Information System). Land Usage is gained from land cover maps (scale of 1:50,000) which was photographed by LANSAT 7 from

2008 to 2010. It was published by MOE, Republic of Korea, in 2010. The characteristics of the present land usage survey are displayed in Table 3-2.

Table 3-2: The present situation for survey of the large, middle, and small-scale classification (http://egis.me.go.kr/egis/home/Info/m02_DB_a3.asp).

	Classification				
	Large-scale	Middle-scale			Small-scale
Production years (photographs years)	1998(1987~1989) 2000(1997~1999) 2010(2008~2010)	2000~2004 (1999, 2000, 2002)	2007 (2006)	2009 ~04 (2002)	2010 Demonstration
Area	The whole nation	Seoul, Gyunggi, Inchun, Hangang Geumgang Nakdong Youngsangang	The whole nation	Seoul, Inchun, Daegeon, Gyunggi, Chungnam, and Chungbuk	A few areas
Primitive images	Lansat TM (30m)	IRS-1C(5m), Lansat ETM+(30m), IKONOS(1m), IRS-1D(5m), SPOT5(5.2m)	SPOT5(5.2m)	KOMPSAT-2(1m)	KOMPSAT-2(1m)
Scale	1:50,000	1:50,000	1:25,000	1:25,000	1:5,000
Format	GeoTiff	GeoTiff	shp	shp	shp

Land use classification at both large and middle scales are listed in Table 3-3. Large-scale land use classifications include seven categories and middle-scale land use classifications include 23 categories.

Table 3-3: The items of large-scale and middle-scale classification.

Large-scale classification(7 items)	Middle-scale classification (23 items)
Urban	residential areas
	industry areas
	business areas
	recreational facilities areas
	traffic areas
	public facilities areas
Agriculture	rice paddies
	Fields
	greenhouse areas
	Orchards
	cultivation areas
Forest	broad-leaved forests
	coniferous forests
	mixed stand forests
Grass	natural grasslands
	golf courses
	Grasslands
Wetland	inland wetland
	coastal wetland
Barren	mining areas
	bare land
Water	inland water
	sea water

The areas associated with the large-scale land use classifications in table 3-3 were calculated for each standard basin (Figure 3-4) using the land cover classification map and the standard basin shapefile (Figure 3-5). ArcView GIS version 3.2 was used for this processing. South Korea was delineated into 840 standard basins (Figure 3-6). Classified standard basins were then used to clip the land use classification map to each basin using the Geo Processing CLIP function (Figure 3-4). After being divided, the clipped land-cover map was merged with standard basins through the GeoProcessing UNION tool, as shown in Figure 3-5. Finally, the area of the merged shapefile was calculated.

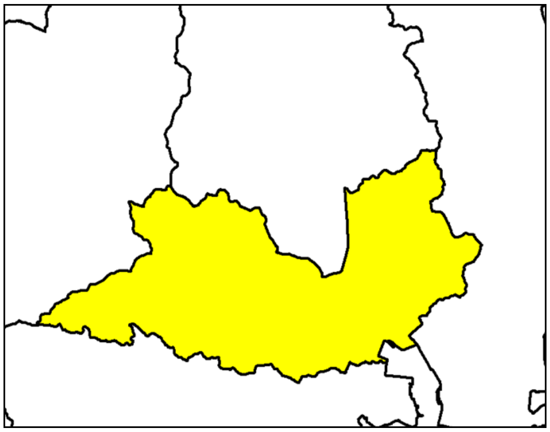


Figure 3-4: Seperated classified standard basin through the CLIP function of Geo Processing.

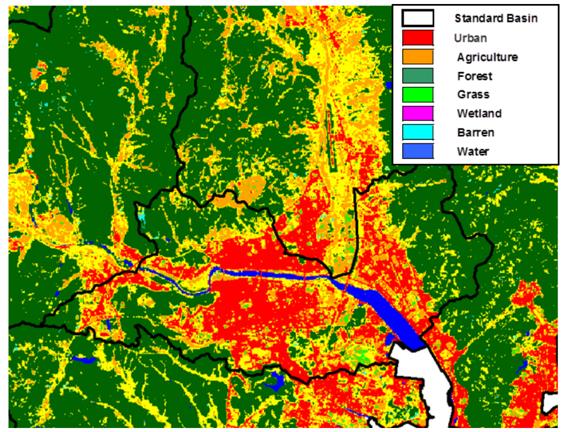


Figure 3-5: Merged clipped land-cover map and the standard basin.

Figure 3-6: Classified standard basin in South Korea.

3.3. ALLOCATION TO EACH SCENARIO

The sub-watersheds of South Korea consist of about 840 sub-watersheds which are called standard basins. The five rivers considered in this research flow through 522 of these standard basins. Table 3-4 shows the present situation of the five rivers' watersheds and the number of standard basins.

Table 3-4: The present situation of five rivers' watersheds (MOCT, 2006, MOE).

Watershed	watershed area (km^2)	Annual rainfall (mm/year)	river length (km)	Number of standard basins	Number of water quality monitoring points	Adaptable water quality monitoring point and sub-watersheds
Han River	25,954	1,208	494	195	236	64
Nakdong River	23,384	1,178	506	191	191	69
Geum River	9,912	1,227	398	79	78	56
Sumjin River	3,468	1,433	224	46	46	17
Youngsan River	3,468	1,336	32	11	32	11
Total	-	-	-	522	583	217

Water quality points were chosen based on the available sites for representation of watersheds' land use. Therefore, at first, standard basins and water quality points were compared and then water quality, which stand for standard basins, were chosen. If there were no water quality points for standard basins, upstream and downstream standard basins were combined. Through this process, adaptable water quality monitoring points and sub-watersheds were chosen at 217 points and are shown in Table 3-4.

In addition, in order to build simple methods for watershed water quality forecasting, the interrelationship between water quality and land usage, including pervious or impervious, has to be considered. Therefore the allocation of land usage should be divided into 3 steps. The first step takes into consideration the area of sub-watersheds, while the second step is imperviousness, and last step is the combination of the area and imperviousness.

3.3.1 FIRST STEP: AREA ALLOCATION OF SUB-WATERSHEDS

Sub-watersheds were divided into 5 cases, as shown in Table 3-5. However, areas were separated based upon the area distribution of each watershed which is shown in Table 3-6. The reason for this is because the co-relationships between land use and water quality are not constant in different regions because the characteristics and pollution sources of watersheds are not the same in different places (Tu, 2011). Hence, five rivers' watersheds were divided into three groups of watersheds, the Han River, Nakdong River, and Geun-Sum-Youngsan River, which are located on the upper side, east side, and west side of South Korea, respectively as shown in Figure 3-7. The difference in the total numbers between Table 3-5 and Table 3-6 is due to the lack of data like water quality, land use, etc.

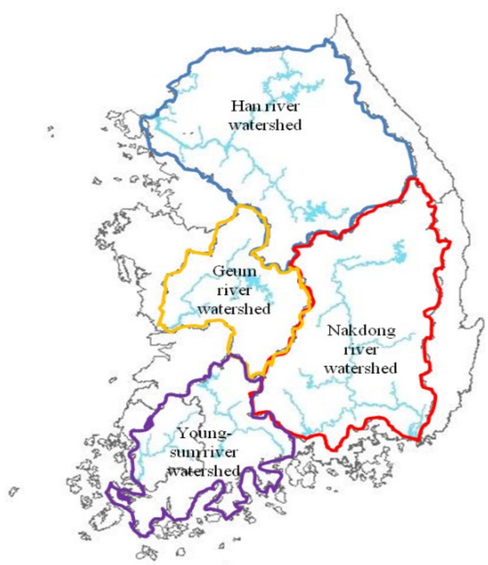


Figure 3-7: Watershed map of South Korea.

Table 3-5: The number of applied sub-watersheds in South Korea.

Area (km^2)	Number of Applied Sub-watershed
0 ~ 100	30
100 ~ 150	36
150 ~ 200	25
200 ~ 500	82
500 ~	44
Total	217

Table 3-6: The number of applied sub-watershed of each river watershed.

Area (km^2)	Number of Applied Sub-watershed		
	Han River	Nakdong River	Geum-sum-youngsan River
0 ~ 100	8	4	14
100 ~ 150	7	9	17
150 ~ 200	7	4	13
200 ~ 500	23	28	38
500 ~	16	19	-
Total (207)	61	64	82

3.3.2 SECOND STEP: DIVIDE THE BASINS INTO SEVERAL GROUPS BASED UPON THE PERCENTAGE OF IMPERVIOUSNESS

In order to find the imperviousness of each standard basin, land-cover maps were used to characterize the pervious and impervious surface in each basin. Land-cover maps have several scales—large-scale, middle-scale, and small scale—which vary in their amount of detail. Large-scale and middle-scale, but not small-scale could be used right now in South Korea. In this research, large-scale and middle-scale maps were considered to find the percentage of imperviousness for seven land-cover and twenty three land-cover items using the runoff C-coefficients (Michael, 2003) of the rational method, which is shown in Table 3-7.

The runoff C-coefficients of the rational method for seven & twenty three land-covers do not exactly correspond. Hence, to match the coefficient value, the average value of the runoff C-coefficient of the rational method was used. In addition, it was assumed that runoff coefficients are the same as imperviousness; for example, if the runoff coefficient for a watershed is 0.7, it is the same as saying the watershed has an imperviousness of 70%, because the C value is the amount of rainfall that transforms into runoff. Additionally, there is no exact standard to allocate between pervious and impervious at present in South Korea.

Table 3-7: Converted runoff coefficients from runoff C-coefficient of rational method.

Large and middle scale classification			
Land usage	runoff coefficient	Land usage	runoff coefficient
Urban	0.530	residential areas	0.500
		industry areas	0.700
		business areas	0.713
		recreational facilities areas	0.275
		traffic areas	0.819
		public facilities areas	0.175
Agriculture	0.319	rice paddies	0.319
		Fields	0.319
		greenhouse areas	0.319
		orchards	0.319
		cultivation areas	0.319
Forest	0.150	broad-leaved forests	0.150
		coniferous forests	0.150
		mixed stand forests	0.150
Grass	0.207	natural grasslands	0.225
		golf courses	0.171
		grasslands	0.225
Wetland	0.000	inland wetland	0.000
		coastal wetland	0.000
Barren	0.450	mining areas	0.500
		bare land	0.400
Water	0.000	inland water	0.000
		sea water	0.000

In conclusion, the imperviousness of the standard basins ranges from 9.8 % to 42 %, while the average imperviousness is 22.27 %, as shown in Figure 3-8.

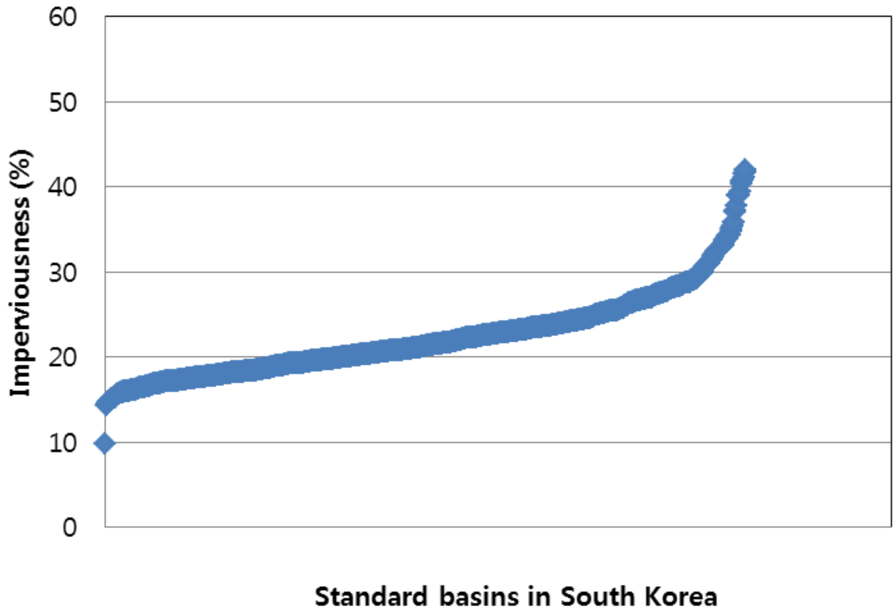


Figure 3-8: The imperviousness of the standard basins in South Korea.

Based upon the imperviousness of the standard basins, several previously grouped watersheds had to be divided in order to match the watershed land-usage characteristics. The Center for Watershed Protection shows recent research on the impact of urbanization on stream quality for subwatersheds with more than 10% impervious cover. Impervious cover (IC) of watersheds could impact the following: stream hydrology, physical alteration of the stream corridor, stream habitat degradation, declining water quality, and loss of aquatic diversity. Therefore IC is divided into 4 cases according to Figure 3-9. Below 10% is sensitive, 10 to 25% is impacted, 25 to 60% is non-supporting and over 60% is urban drainage.

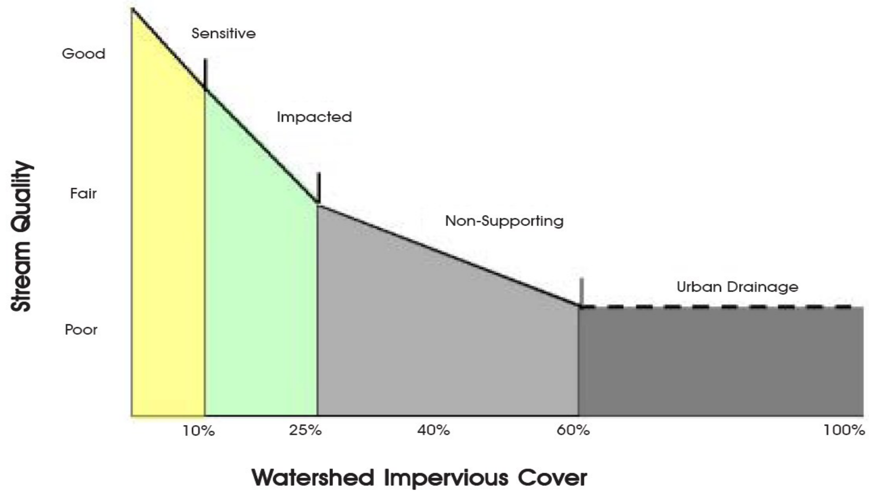


Figure 3-9: Representation of the impervious cover (IC) (CWP, 2005).

However, it was not possible to find a standard basin with an impervious cover over 60 % because the maximum basin imperviousness is 42 % for South Korea. Therefore in order to divide the standard basin effectively and considering CWP reporting, 25 % imperviousness was set as the mid-point. This point was chosen because it borders both impacted and non-supporting streams which are shown in Figure 3-9. Twenty percent and 30 %, which have a ±5 % different from 25%, were then set as additional dividing points. When IC is used to divide sub-watersheds into categories, 84 sub-watersheds fall below 20% imperviousness, 94 sub-watersheds fall between 20 % ~ 25 %, 29 sub-watersheds fall between 25 % ~ 30 %, and 10 sub-watersheds fall over 30 %. The breakdown of sub-watersheds is shown in Table 3-8.

Table 3-8: The number of sub-watersheds used to analyze the impact of imperviousness.

Imperviousness	The number of sub-watersheds			
	Total	Han River	Nakdong River	Geum-Sum-Youngsan River
~ 20%	84	34	25	25
20 % ~ 25%	91	19	36	39
25 % ~ 30%	29	5	7	17
30 % ~	10	6	1	3

3.3.3 THIRD STEP: COMBINE STEPS ONE (AREAS) AND TWO (IMPERVIOUS COVER)

In order to achieve optimized results, the first and second steps should be merged, the area allocation and the percentage of imperviousness of standard basin. Actually, the first step was modified from 50 km^2 intervals for each step to below and over 250 km^2 in regards to considering the balance of the number of allocated sub-watersheds which are shown in Table 3-9.

Table 3-9: The number of standard basins for both area allocation and the percentage of imperviousness of standard basins.

Area allocation (km^2)	Imperviousness (%)		
	Below 20 %	20 ~ 25 %	Over 25 %
Below 250 km^2	23	53	24
Over 250 km^2	53	41	13

3.4. DATA SOURCES FOR ANALYSIS

This study was based on four types of data — water quality, hydrology, geology, and land usage — which are shown in Table 3-10. Large and middle scale land use maps were considered to help correlate land use to other watershed parameters like perviousness, imperviousness, slope, etc. When the middle-scale land use classifications were used, it was found that land usage was too detailed. Hence, it is hard to get the multi-lateral relationship among parameters. On the other hand, out of the seven items of large scale classifications, almost all includes data, except for a few cases. Therefore, in order to maintain the clarity of the study, obtain data readily, and determine correlations clearly, large-class land use classification (i.e. urban, agriculture, forest, grass, wetland, barren, and water) and perviousness/ imperviousness were used.

Table 3-10: The data source and period in order to compare land usage and water quality.

Division	Parameter	Source	Period
Water Quality	COD, BOD, T-N, T-P	Ministry of Environment	10 years (2001-2010)
Hydrology	Rainfall	Water Management Information System (WAMIS)	30 years (1966~2007)
Geology	Slope		
Land Usage	Pervious & impervious, urban, agriculture, forest, grass, wetland, barren, water	Remote sensing. Landsat TM data was collected between 2008 and 2010 at a 30*30m spatial resolution, and were processed in order to reveal the LUCC features. The data geometrical corrections, classification and accuracy assessment were carried out with the support of the digital image processing software PCI. Topographical maps (1:50, 000) were used as the reference for the geometric corrections. According to the geographical names, the maps were re-drawn on the digitized topographical map base using ArcView GIS 3.2 ver. software to complete editing, labeling, projection, transformation, edge matching and overlaying processes.	2008~2010

3.4.1 FIRST STEP

The first step in correlating water quality, hydrology, geology, and land usage was to sort the sub-watersheds into bins according to area—0 ~ 100 km^2, 100 ~ 150 km^2, 150 ~ 200 km^2, 200 ~ 500 km^2, and over 500 km^2 like in Table 3-11. However the number of data collected was slightly small to represent the characteristics of sub-watersheds. According to Hyudman (2007), it is always necessary to have more observations than parameters in terms of a purely statistical point of view. Due to this observation, the number of intervals used to divide the sub-watersheds into bins was increased as shown in Table 3-11. The observation data (pervious/impervious, rainfall, slope, land use, water quality) of each sub-watershed like the Han, Nakdong, and Geum-Sum-Youngsan River are attached in Appendix B.

Table 3-11: The number of applied sub-watersheds for each river watershed (step one).

Area (km^2)	Number of Applied Sub-watershed		
	Han River	Nakdong River	Geum-sum-youngsan River
0 ~ 100	-	-	14
100 ~ 150	-	-	17
150 ~ 200	-	-	13
200 ~	-	-	38
0 ~ 200	22	17	-
200 ~ 500	23	28	-
500 ~	16	19	-
Total (207)	61	64	82

3.4.2 SECOND STEP

Imperviousness has a strong relationship with water-quality impacts (Conway, 2006). Therefore, in the second step, imperviousness is the standard to allocate watershed data. In this step, imperviousness is divided into four intervals—below 20 %, 20 % ~ 25 %, 25 % ~ 30 %, and over 30%. However, when applied to each watershed, over 30 % is included in the 25 % ~ 30 % interval because the number of watersheds over 30 % is so small. The number of sub-watersheds falling within each range of impervious cover for each watershed is shown in Table 3-12. The observation data (pervious/impervious, rainfall, slope, land use, water quality) of each sub-watershed for step two are attached in Appendix B.

Table 3-12: The number of applied sub-watersheds for each river watershed (step two).

Imperviousness	The number of sub-watersheds			
	Total	Han River	Nakdong River	Geum-Sum-Youngsan River
~ 20%	75	33	21	21
20 % ~ 25%	88	19	35	34
25 % ~	36	9	8	19

3.4.3 THIRD STEP

In order to consider both sub-watershed areas and the percentage of imperviousness among sub-watershed characteristics, sub-watershed areas were divided below and above 250 km^2 and their imperviousness cover was broken up into categories of 0 ~ 20 %, 20 ~ 25 %, and over 25 % which is same as the guideline already displayed in Table 3-9. The total observation data of each sub-watershed for step three is shown in Appendix B.

3.4.4 ESTABLISH SIMPLE EQUATIONS

Figure 3-10 shows the process that is used to determine simple equations for the final analysis. After completing the three cases and ten scenarios, Excel solver, Model Tree, ANN (Artificial Neural Network), RBF (Radial Basis Function), and SAS (Statistical Analysis System) were used based on these same scenarios to conduct the data analysis.

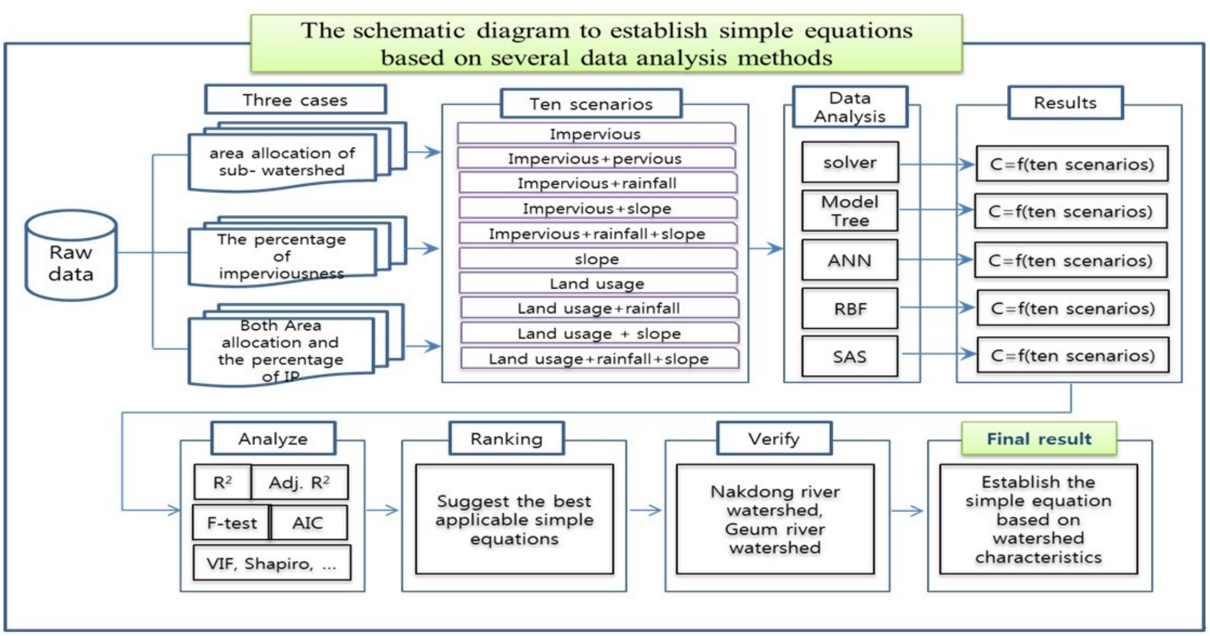


Figure 3-10: The schematic diagram to establish simple equations based on several data analysis methods.

3.5. BUILDING SIMPLE EQUATIONS

In order to build the best implemented simple equations, two processes were reviewed such as; model selection process and evaluation/validation model with parameter estimation (Kutner et al., 2004). Which are calculated and evaluated using following methods (chapter 3.5.1 through 3.5.2).

3.5.1 MODEL SELECTION PROCESS

There are many criteria for model selection. In this research, five "good" subsets according to the criteria specified were used to select the best applicability model to represent watershed characteristics in relevant with water quality (Kutner et al., 2004, Pruden et al., 2012). Which are including such as; coefficient of multiple determination (R^2), adjusted coefficient of multiple determination (Adj R^2), F-test, Akaike Information Criteria (AIC), and factor analysis.

① Coefficient of multiple determination (R^2)

R^2 is the coefficient of determination which could apply to finding a quantitative relation between the predicted and observed values. The range of this coefficient is zero to 1, where zero means no correlation and 1 means a perfect correlation.

$$R^2 = 1 - \frac{SSE}{SSTO} \qquad \text{Equation 1}$$

Where, SSE = the sum of squares of residuals

$= \sum_i (f_i - y_i)^2$

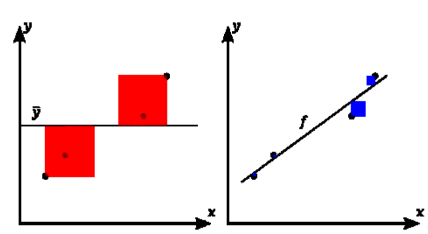
SSTO = the total sum of squares

$= \sum_i (y_i - \bar{y}_i)^2$

f_i = the modeled (predicted) values

y_i = the observed values

$\bar{y}_i$ = the mean of the observed values



② **Adjusted R^2**

Since R^2 does not take account of the number of parameters in the regression model and since max can never decrease as p increases, the adjust coefficient of multiple determination R^2 has been suggested as an alternative criterion (Kutner et al., 2004)

$$Adj.R^2 = 1 - (1 - R^2)\frac{n-1}{n-p-1} = R^2 - (1 - R^2)\frac{p}{n-p-1} \qquad \text{Equation 2}$$

Where, n = the total number of data sample size

p = the total number of regressors in the linear model

③ **EF**

EF is the Nash-Sutcliffe efficiency or coefficient of efficiency which compares the predicted values to the mean of the observed values. The range of this measure is -∞ to 1, where 1 represents the best model performance. A value near one indicates a close match between observations and model predictions. A value of zero indicates that the model predicts individual observations no better than the mean of the observations. Values less than zero indicate that the observation mean would be a better predictor than the model results (Stow et al, 2002). The equations of three statistical methods are as follow;

$$EF = \frac{\sum_{i=1}^{n}(O_i - \bar{O})^2 - \sum_{i=1}^{n}(P_i - O_i)^2}{\sum_{i=1}^{n}(O_i - \bar{O})^2} \qquad \text{Equation 3}$$

④ **CC, MAE, RAE, RMSE, and RRSE**

Correlation coefficient (CC) measures the statistical correlation between observed (a) and predicted (p) values. The correlation coefficient ranges from 1 for perfectly correlated results, through to o when there is no correlation, to -1 when the results are perfectly negative, which could be calculated by equation 5 (Witten et al., 2011).

$$CC = \frac{S_{PA}}{\sqrt{S_p S_A}}$$ Equation 4

Where, $S_{PA} = \frac{\sum_i (P_i - \overline{P})(a_i - \overline{a})}{n-1}$, $S_P = \frac{\sum_i (P_i - \overline{P})^2}{n-1}$, $S_A = \frac{\sum_i (a_i - \overline{a})^2}{n-1}$

p = predicted value, a = actual value, n = the number of data

$\overline{P}$ = the mean value of predicted data, $\overline{a}$ = the mean value of the test data.

Mean absolute error (MAE) is the average magnitude of the individual errors without taking account of their signs. Mean-squared error tends to exaggerate the effect of outliers-instances when the prediction errors are larger than the others-but an absolute error does not have this effect. Therefore all sizes of errors are treated evenly according to their magnitude based upon MAE and could be calculated by equation 6 (Witten et al., 2011)..

$$MAE = \frac{|p_1 - a_1| + \ldots + |p_n - a_n|}{n}$$ Equation 5

In some cases, the Relative absolute error (RAE) is more important than MAE, for example, when we consider the errors in both cases 50 to 500 and 0.2 to 2, the absolute error will be meaningless. Therefore, relative errors are appropriate in this case. It could be calculated using Equation 7 (Witten et al., 2011).

$$RAE = \frac{|p_1 - a_1| + \ldots + |p_n - a_n|}{|a_1 - \overline{a}| + \ldots + |a_n - \overline{a}|}$$ Equation 6

RMSE is the root mean squared error and measures the size of the discrepancies between predicted and observed values. The range of this measure is zero to ∞ and the smaller a value is, the better the model's performance will be (i.e. zero indicates a close match). It could be calculated by Equation 7.

$$RMSE = \sqrt{\frac{(p_1 - a_1)^2 + \ldots + (p_n - a_n)^2}{n}}$$ Equation 7

Root relative squared error (RRSE) is calculated from relative square error which takes the total squared error and normalizes it by dividing it by the total squared error of the default preditor. And the root relative squred error could be obtained by Equation 8.

$$RRSE = \sqrt{\frac{(p_1 - a_1)^2 + \ldots + (p_n - a_n)^2}{(a_1 - \bar{a})^2 + \ldots + (a_n - \bar{a})^2}} \qquad \text{Equation 7}$$

⑤ **F-test**

An *F*-test is the analysis of variance approach to provide us useful tests for regression models. For the simple linear regression case considered here, the analysis of variance provides us with a test for:

$$H_o : \beta_1 = 0 , \qquad H_a : \beta_1 \neq 0 \qquad \text{Equation 8}$$

The test statistic for the analysis of variance approach is denoted by F, it compared MSR and MSE in the following equation:

$$F^* = \frac{MSR}{MSE} \qquad \text{Equation 9}$$

In addition, MSR and MSE could be calculated following.

Table 3-13: ANOVA table for Simple Linear Equation for calculation F-test

Source of variance	SS (sum of square)	df (degree of freedom)	MS (mean square)	F
regression (Between groups)	SSR $=\sum_i (f_i - \bar{y})^2$ (regression sum of square)	1	$\text{MSR} = \frac{SSR}{1}$	$F^* = \frac{MSR}{MSE}$
error (within groups)	SSE $=\sum_i (f_i - y_i)^2$ (sum of squares of residuals)	n-2 (n=the number of data)	$\text{MSE} = \frac{SSE}{n-2}$	
total	SSTO $=\sum_i (y_i - \bar{y}_i)^2$ the total sum of squares			

According F-test (upper-tail), the results could be decided following procedures:

F^* is distributed as F (1, n-2) when Ho holds, the decision rule is as follows when the risk of error is to be controlled at α:

$$\text{If } F^* \leq F(1-\alpha: 1, n-2), \text{ conclude } H_o$$
$$\text{If } F^* \geq F(1-\alpha: 1, n-2), \text{ conclude } H_a \qquad \text{Equation 10}$$

Therefore, F^* is larger than F (1- α: 1, n-2), there is some difference between their different groups and if p-value is less than 0.05, we would conclude H_a , as well.

⑥ Akaike Information Criterion(AIC)

The Akaike information criterion (AIC) is a measure of the relative quality of a statistical model, for a given set of data. And also AIC could provide a means for model selection which could be calculated by following equation:

$$AIC = n \times \ln(SSE) - n \times \ln(n) + 2p \qquad \text{Equation 11}$$

Where, n= a number of sample size, p=the number of parameters

On the other hand, AIC does not provide a test of a model in the sense of testing a null hypothesis.

Therefore, in order to select the best applicable simple equations, using coefficient of multiple determination (R^2), adjusted coefficient of multiple determination (Adj R^2), and F-test, each simple equations could be qualified whether it is applicable or not. And the best simple equation could be selected by using Akaike Information Criteria (AIC).

⑦ Factor Analysis

Factor analysis is a statistical method for investigating whether response variable, Y, is linearly related to exploratory variables, $X_1, X_2, \cdots, X_n$ which is shown as follows;

- determining the factor extraction model

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n \qquad \text{Equation 12}$$

- extracting and determining the number of factors

① eigenvalue

The "eigenvalues greater than one" rule has been most commonly used due to its simple nature and availability in various computer packages. It states that the number of factors to be extracted should be equal to the number factors having an eigenvalue greater than 1.0 (Source: SAS library)

The FACTOR Procedure
Initial Factor Method: Principal Components

Prior Communality Estimates: ONE

Eigenvalues of the Correlation Matrix: Total = 16 Average = 1

	Eigenvalue	Difference	Proportion	Cumulative
1	8.91956968	6.56112672	0.5575	0.5575
2	2.35844295	0.46717955	0.1474	0.7049
3	1.89126340	0.88745854	0.1182	0.8231
4	1.00380486	0.21804293	0.0627	0.8858
5	0.78576193	0.25082795	0.0491	0.9349
6	0.53493398	0.28594115	0.0334	0.9684
7	0.24899283	0.13785883	0.0156	0.9839
8	0.11113400	0.01948090	0.0069	0.9909
9	0.09165310	0.06441688	0.0057	0.9966
10	0.02723623	0.01023089	0.0017	0.9983
11	0.01700533	0.00727659	0.0011	0.9994
12	0.00972874	0.00925577	0.0006	1.0000
13	0.00047297	0.00047297	0.0000	1.0000
14	0.00000000	0.00000000	0.0000	1.0000
15	0.00000000	0.00000000	0.0000	1.0000
16	0.00000000		0.0000	1.0000

4 factors will be retained by the MINEIGEN criterion.

Figure 3-11 Eigenvalues of the correlation matrix

② scree test

Plotting the eigenvalues against the corresponding factor numbers gives insight into the maximum number of factors to extract. The Scree plot illustrates the rate of change in the magnitude of the eigenvalues for the factors. The rate of decline tends to be

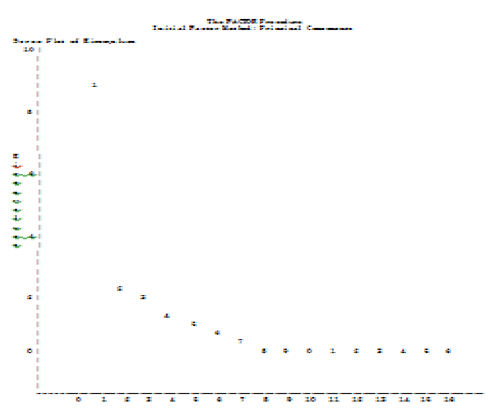


Figure 3-12 Scree plot of eigenvalues

fast for the first few factors but then level off. The “elbow”, or the point at which the curve bends, is considered to indicate the number of factors to extract. The figure 3-12 illustrates an example of scree plot, where a elbow occurred at the fourth factor, which has an eigenvalue right around 1 (Source: SAS library).

- Calculate factor loading using correlation between response variable, Y, and exploratory variable, X_1, X_2,⋯,X_n.

  Below 0.3 → low significance level

  Below 0.4 → medium of significance level

  Over 0.5 → high significance level

- Selecting final simple equations using variables having high significance level.

$$Y = \beta_0 + \beta_1 X_1(over\ 0.5) + \cdots + \beta_n X_n(over\ 0.5) \qquad \text{Equation 13}$$

3.5.2 EVALUATION MODEL WITH PARAMETER ESTIMATION

To examine the normality of the error terms of simple equation, the Shapiro-Wilk test could be used. In addition, to identify multicollinearity in the matrix of predictor variables for each general linear regression model, the variance inflation factor (VIF) could be used (Amy Pruden et al., 2012).

① **Shapiro-Wilk test**

The Shapiro-Wilk test, proposed in 1965 (Shapiro and Wilk, 1965), calculates a W statistic that tests whether a random sample comes from normal distribution. Pearson and Hartley (1972) reproduced the way of obtaining the W statistic using Monte Carlo simulations. This test could be used for normality among elements which has a limitation of samples between 3 and 50 elements. And this test could be calculated as follows *(NIST/SEMATECH e-Handbook of Statistical Methods)* :

- Rearrange the data in ascending order so that $x_1 \leq \ldots \leq x_n$.
- Calculate SS as follows

$$SS = \sum_{i=1}^{n}(x_i - \bar{x})^2 \qquad \text{Equation 14}$$

Where, SS = the sum of squares of deviations of data points from their sample mean

$\bar{x}$= the average of data

n = the number of data

- If n is even, let $m = n/2$, while if n is odd let $m = (n-1)/2$
- Calculate b as follows, taking the a_i weights from the Shapiro-Wilk Table (based on the value of n). Note that if n is odd, the median data value is not used in the calculation of b.

$$b = \sum_{i=1}^{n} a_i(x_{n+1-i} - x_i) \qquad \text{Equation 15}$$

- Calculate the test statistics $W = b^2 / SS$
- p-value could be calculated using the Shapiro-Wilk Table (probability) based upon the n and W, and it could be proved whether the data are normally distributed or not.

② Variance Inflation Factor

Variance Inflation Factor (VIF) is widely accepted a formal method of detecting the presence of multicollinearity (Kutner, 2004, O'Brien, 2007, Amy Pruden et al., 2012). Collinearity can increase estimates of parameter variance; even though R^2 is large, if there is no statistically significant variable, the results of parameter estimations could be the "incorrect sign". Therefore VIF value in excess of 10 is frequently taken as an indication that multicollinearity may be unduly influencing the least squares estimates. VIF is able to be calculated as follows:

$$VIF = \frac{S_x^2(n-1)SE_b^2}{S^2} \qquad \text{Equation 16}$$

Where, S_x^2 = the square of standard deviation of the variable

n = the number of data (observation)

SE_b^2 = the square of standard error of the parameter

S^2 = the mean square of residual

3.5.3 MODEL SELECTION PROCESS FOR EACH DATA ANALYSIS METHODS

As abovementioned in Chapter 3.4.4, five data analysis methods were used to establish Simple Equations, such as Excel Solver, SAS, Model Tree, ANN, and RBF. In addition, model selection process and model evaluation with parameter analysis were implemented for each data analysis methods based on table 3-14.

Table 3-14: Model selection process and evaluation methods for each data analysis method.

<table>
<tr><th>Methods</th><th>Type of Simple Equation</th><th>Model Selection Process</th><th>Evaluation Model</th></tr>
<tr><td>Excel Solver</td><td>Non-linear Eq.</td><td>R^2, Adj R^2, F-test, and AIC</td><td>Shapiro-Wilk test</td></tr>
<tr><td>SAS</td><td>Linear Eq.</td><td>R^2, Adj R^2, Factor Analysis</td><td>Variance Inflation Factor (VIF)</td></tr>
<tr><td>Model Tree</td><td>Linear Eq. for each divided section</td><td colspan="2" rowspan="3">C.C (correlation coefficient), M.A.E.(mean absolute error), R.M.S.E (root mean squred error), R.A.E (relative absolute error), R.R.S.E (root relative squred error)</td></tr>
<tr><td>ANN</td><td>Neural Network using sigmoid funtion</td></tr>
<tr><td>RBF</td><td>Neural Network using Gaussian function</td></tr>
</table>

For Excel Solver, R^2, Adj R^2, F-test, and AIC to select the best Simple Equation among the bunch of Simple Equations and Shapiro-Wilk test were implemented for model evaluation with parameter analysis. The Simple Equations using Model Tree, ANN, and RBF were evaluated and selected by computing C.C (correlation coefficient), M.A.E.(mean absolute error), R.M.S.E (root mean squred error), R.A.E (relative absolute error), and R.R.S.E (root relative squred error). In case of SAS, R^2, Adj R^2, Factor Analysis were applied to select the best Simple Equation, and Variance Inflation Factor were used for model evaluation with parameter analysis.

3.6. TOOLS FOR DATA ANALYSIS

3.6.1 EXCEL SOLVER

The Excel Solver (Microsoft Excel 2007 for Windows) is a tool for solving linear and nonlinear optimization problems, as well as integer programs. The Solver is easy to use, powerful, fast, can handle constraints, and can maximize and minimize. Solver performs three main functions: 1) optimization through maximum or minimum with constraints on values, 2) nonlinear regression which is an optimization problem that seeks to minimize the sum of the squared error, SSE, between dependent values predicted by a regression model (y_p) and those from the data set (y) (equations 1), and 3) linear programming (Larsen, 2005).

$$SSE = \left[\sum_{i=1}^{n}(y_i - y_{pi})^2\right] \qquad \text{Equation 17}$$

Where, yp = the value predicted by the regression model

y = the data set.

Solver has been evaluated and tested in its abilities to solve both linear and non-linear equations by Walsh et al. (1994) and found to be successful in modeling data obtained in many analytical situations. Manoj et al. (2010) used Solver to determine critical and normal depths based on geometric parameters for complex compound sections and suggested that Solver is an easy and efficient method to calculate critical and normal depths. Nilsson et al. (2010) used Solver to minimize the root-mean-squared error (RMSE) between the actual pool volumes and the V-h (Volume/depth) model generated volumes by adjusting the respective wetland shape parameter. Solver was used to optimize linear programs in order to maximize the net benefit of watershed management including the specified constraints such as human demand, management limits on human demand reduction, in-stream flow standards, land-use restrictions, the capacity or volume of facilities, and surface water and groundwater flow out of a watershed (Zoltay et al., 2010). In Helbling et al., (2009) Solver was used to minimize the sum of the squares of the residuals between the observed and predicted chlorine concentrations for modeling residual chlorine response to a microbial contamination event in drinking water distribution systems using nonlinear regression.

In this research, whose purpose is to determine relationships and derive a simple equation between water quality and other watershed parameters—hydrology, geology, and land usage, the multi-lateral connection should be discovered using various methods. Solver is one of the best and easiest tools available to determine these final results.

3.6.2 DATA MINING

While the availability of data has increased due to the technical development and globalization of information networks, the reliable data is, contradictorily, still difficult to find. In order to overcome this limitation, many researches have been implemented in finding and organizing data and data mining is one of these efforts. Data mining is applicable to many applications such as decision supporting, predicting and forecasting. Data mining began to make its mark in the early 2000s with the development of Data Warehouses (Hadzilacos et al., 2000, Saegrove et al., 1999).

Data mining can be classified according to various criteria, as shown in Table 3-15. Data-driven data mining is used to discover the relationships between attributes in unknown data, with or without known data with which to compare the outcome. There may or may not be a specific scenario. Clustering and association, for example, are primarily data-driven data mining techniques. In data-driven data mining, the data itself drives the data mining process. This approach is best employed in situations in which true data discovery is needed to uncover rules and patterns in unknown data. This tends to be the "I don't know what I don't know" approach: you can discover significant attributes and patterns in a diverse set of data without using training data or a predefined scenario. Data-driven data mining is treated as a "white box" operation, in which the user is concerned about both the process used by the data mining algorithm to create the model and the results generated by viewing data through the model.

Table 3-15: General classification of data mining algorithms.

Types	Rules	Algorithms
Data mining-oriented (Data-driven data mining)	**Association**: any association between features is sought, not just ones y\that predict a particular class value	Apriori/AprioriTid, DHP etc.
	Clustering: groups of examples that belong together are sought	PAM, CLARA etc.
Machine learning-oriented (Model-driven data mining)	**Clustering/Classification**: examining the features of a newly presented object and assigning it to one of a predefined set of classes (**Unsupervised learning**: detects & categorizes persistent features without any feedback from the environment)	Bayesian Network, GA, ANN(SOM, ART)
	Classification (**Supervised learning**: operates under supervision by being provided with the actual outcome for each of the training examples.)	ANN (MLP, RBF), Decision Tree

Machine learning known as model-driven data mining provides the technical basis of data mining. Classifications and estimations are typically categorized as model-driven data mining techniques. This approach is best employed when a clear scenario can be employed against a large body of known historical data to construct a predictive data mining model. This tends to be the "I know what I don't know" approach: you have a good idea of the specific scenarios to be modeled, and have solid data illustrating such scenarios, but are not sure about the outcome itself or the relationships that lead to this outcome. Model-driven data mining is treated as a "black box" operation, in which the user cares less about the model and more about the predictive results that can be obtained by viewing data through the model.

Data mining depends on both data-driven and model-driven data mining techniques to be truly effective, depending on what questions are asked and what data is analyzed. Data-driven and model-driven data mining can be employed separately or together, in varying amounts, depending on specific business requirements. There is no set formula for mining data; each data set has its own patterns and rules. Generally speaking, the data mining model drives the process in model-driven data mining in environmental research fields because of its predictive results.

The basic ideas underlying data mining in recent studies are linked between many artificial intelligence algorithms, for examples, neural network (NN), fuzzy logic (FL), genetic algorithm (GA), probabilistic reasoning (PR) and model tree (MT). The combination of these algorithms is generally called soft computing (SC). The inclusion of neural network theory in soft computing came at a later point. At this juncture, the principal constituents of soft computing (SC) are fuzzy logic (FL), neural network theory (NN) and probabilistic reasoning (PR), with the latter subsuming belief networks, genetic algorithms, chaos theory and parts of learning theory. What is important to note is that SC is not a melange of FL, NN and PR. Rather, it is a partnership in which each of the partners contributes a distinct methodology for addressing problems in its domain. In this perspective, the principal contributions of FL, NN and PR are complementary rather than competitive.

3.6.3 M5P MODEL TREE

Many problems have been encountered during the process of predicting a “class” that takes on a continuous numeric value rather than a discrete category into which an example falls.

However, decision-tree and decision-rule learners are not commonly extended to situations where the class value itself is numeric.

There are, of course, several learning techniques that do predict numeric values. These techniques include standard regression, neural nets, regression trees, and prediction by pre discretization. But all of these have weaknesses. Standard regression is not a very potent way of representing and inducing functions because it imposes a linear relationship on the data having special and temporal variations rather non-linear. Neural nets are more powerful but suffer from opacity: the model does not reveal anything about the structure of the function that it represents.

MTs are not yet as popular as ANNs. For example, their use started only recently (Kompare, 1997; Solomatine and Dulal, 2003) in the water sector, and they are unknown to water quality related research. Solomatine (2002) demonstrated the use of MTs in hydrological and other problems, along with other data-driven models. The predictive accuracy of the simplest MT model was observed to be very high and on par with that of an ANNs model built with the same data. The advantages of model trees (M5) (Solomatine & Dulal, 2003) are that they are more accurate than regression trees, more understandable than ANNs, easy to train, and robust when dealing with missing data.

Model trees are tree-structured regression models that associate leaves with multiple linear regression functions calculating numeric values. A regression tree is a machine learning concept, which takes input data, and tries to learn the characteristics of the data. It looks like a decision tree with each of the intermediate nodes as routing nodes with a 'split' value to decide the destination data and the terminal nodes which have the function to compute the estimates.

Internal nodes are typically splitting tests that partition the space spanned by m independent (or predictor) random variables x_i (both numerical and categorical). Regression models at the leaves capture the linear dependency between one or more independent variables and the continuous dependent (or response) variable *y*, locally to a partition of the sample space. Therefore, MTs differ from the better-known classification or decision trees only in that they have a numeric value rather than a class label associated with the leaves. Statistics and machine learning have settled the problem of inducing MTs from a training set. Several methods have been proposed for the construction of the tree and for the estimation of the linear dependence at the leaves on the basis of a training sample. They have been implemented in some well-known model tree induction systems such as SMOTI (Stepwise Model Tree Induction, Orkin, Drogin, 1990), MARS (Multiple Adaptive Regression Splines, Friedman,1991), M5 (machine learning method, Quinlan, 1992), RETIS (Karalic, 1992), TSIR (Lubinsky, 1996), M5' (Wang, Witten, 1997), RegTree (Lanubile, Malerba, 1997), and HTL (Torgo, 1997). All these systems perform a top-down induction of model trees (TDIMT). However, the SMOTI and TSIR are characterized by two types of internal nodes: regression nodes, which perform only straight line regressions, and splitting nodes, which partition the sample space. The regression model at a leaf is obtained by combining the straight-line regression functions associated to the regression nodes along the path from the root to the leaf.

The new technique for machine learning algorithms is called "M5 model tree" for dealing with continuous-class learning problems and was developed by Quinlan (1992). An implementation called M5P was described by Wang and Witten (1997) as performing somewhat better than the original algorithm M5P. M5P allows the tree size to be reduced dramatically with only a small penalty in prediction performance leading to much more comprehensible models. Finally, the results which test the method used for dealing with missing values are presented.

[Building the Tree]

The basic tree has been formed by splitting criteria. The splitting criterion is based on treating the standard deviation of the class values that reach a node as a measure of the error at that node and calculating the expected reduction in error as a result of testing each attribute at that node. The attribute which maximizes the expected error reduction is chosen. The standard deviation reduction (SDR) for M5 is calculated by the Equation 18.

$$SDR = sd(T) - \sum_i \frac{|T_i|}{|T|} \times sd(T_i) \qquad \text{Equation 18}$$

Where, SDR = the standard deviation reduction

T = the set of examples that reach the node

T_1, T_2, ⋯⋯ are the sets that result from splitting the node according to the chosen attribute. The splitting process ceases when the class values of all the instances that reach a node vary very slightly, that is, just less than 5% of the standard deviation of the original instance set or only a few instances remain.

[Pruning the Tree]

The pruning procedure makes use of an estimate of the expected error that will be experienced at each node for test data. First, the absolute difference between the predicted value and the actual class value is averaged for each of the training examples that reach that node. This average will underestimate the expected error for unseen cases, of course, and to compensate, it is multiplied by factor *(n+v)/ (n-v)*, where *n* is the number of training examples that reach the node and *v* is the number of parameters in the model that represents the class value at that node.

M5 computes a linear model for each interior node of the unpruned tree. The model is calculated using standard regression, using only the attributes that are tested in the subtree below this node. The resulting linear model is simplified by dropping terms to minimize the estimated error calculated using the above multiplication. By factor-dropping a term, it decreases the multiplication factor, which may be enough to offset the inevitable increase in average error over the training examples as terms are dropped one by one, greedily, so long as the error estimate decreases. Finally, once a linear model is in place for each interior node, the tree is pruned back from the leaves, so long as the expected estimated error decreases.

[Smoothing]

The final stage is to use a smoothing process to compensate for sharp discontinuities that will inevitably occur between adjacent linear models at the leaves of the pruned tree, particularly for some models constructed from a small number of training instances. The smoothing procedure described by Quinlan (1992) first uses the leaf model to compute the predicted value, and then filters that value along the path back to the root, smoothing it at each node by combining it with the value predicted by the linear model for that node. The calculation is

$$p' = \frac{np+kq}{n+k} \qquad \text{Equation 19}$$

Where, *p'* = the prediction passed up to the next higher node, *p* = the prediction passed to this node from below, q = the value predicted by the model at this node, *n* = the number of training instances that reach the node below, and *k* = a constant. In general, smoothing substantially increases the accuracy of predictions.

[Modification of SDR]

M5P does not clearly know how enumerated attributes and missing values should be handled. These features are of vital importance for real-world data sets that have been encountered in our practical working cases. To take account for the enumerated attributes and the missing values the SDR is further modified to

$$SDR = \frac{\mathrm{m}}{|\mathrm{T}|} \times \beta(\mathrm{i}) \times \left[sd(T) - \sum_{j\in\{\mathrm{L,R}\}} \frac{|T_i|}{|T|} \times sd(T_i)\right] \qquad \text{Equation 20}$$

Where, m = the number of examples without missing values for that attribute, T = is the set of examples that reach this node, $\beta(i)$ = the correction factor calculated for the original attribute to which this synthetic attribute corresponds, T_L, and T_R = sets that result from splitting on this attribute for all attributes are now binary.

3.6.4 ARTIFICIAL NEURAL NETWORK (ANN)

An artificial neural network (ANN) is an information processing system that replicates the rudimentary behaviors of a human brain by emulating the operations and connectivity of biological neurons. It consists of an often large number of neurons, i.e. simple linear on nonlinear computing elements, interconnected in often complex ways and often organized into layers. ANN is used in three main ways:

- as models of biological nervous systems and intelligence
- as real-time adaptive signal processors or controllers implemented in hardware for applications such as robots
- as data analytic methods

In this study, ANN was used in data analysis. ANN, like many statistical methods, is capable of processing vast amounts of data and making predictions that are sometimes surprisingly accurate. This, however, does not make it "intelligent" in the useful sense of the word. ANN learns in much the same way statistical algorithms arrive at optimization estimations, but usually much more slowly than statistical algorithms.

ANNs and statistics are not competing methodologies for data analysis. There is considerable overlap between the two fields. ANNs include several models, such as Multi-Layer Perception (MLPs), that are useful for statistical applications. Statistical methodology is directly applicable to neural networks in a variety of ways, including the estimation of criteria, optimization algorithms, confidence intervals, diagnostics, and graphical methods. Better communication between the fields of statistics and neural networks would benefit both.

From a mathematical point of view, an ANN is a complex non-linear function with many parameters that are adjusted (calibrated, or trained) in such a way that the ANN output becomes similar to the measured output of a known data set.

The true power and advantage of neural networks lie in their ability to represent both linear and non-linear relationships and in their ability to learn these relationships directly from the data being modeled. Traditional linear models are simply inadequate when it comes to modeling data that contains non-linear characteristics.

MLP ANN (Multi-Layer Perceptron Artificial Neural Network)

The most common neural network model is the multi-layer perceptron (MLP). This type of neural network is known as a supervised network because it requires a desired output in order to learn. The goal of this type of network is to create a model that correctly maps the input to the output using historical data so that the model can then be used to produce the output when the desired output is unknown.

[Network Diagrams]

Various models can be displayed as network diagrams such as the one shown in Figure 3-13, which illustrates ANN and the statistical terminology for a simple linear regression model. Neurons are represented by circles and boxes, while the connections between neurons are shown as arrows:

- Circles represent observed variables, with the name shown inside the circle.

- Boxes represent values computed as a function of one or more arguments. The symbol inside the box indicates the type of function. Most boxes also have a corresponding parameter called a bias.

- Arrows indicate that the source of the arrow is an argument of the function computed at the destination of the arrow. Each arrow usually has a corresponding weight or parameter to be estimated.

- Two long parallel lines indicate that the values at each end are to be fitted by the least squares, maximum likelihood, or some other estimation criterion.

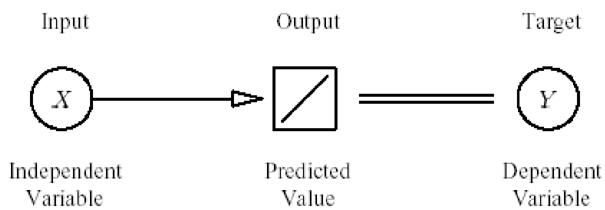


Figure 3-13: Simple linear regression

[Perceptrons]

A perceptron computes a small linear combination of the inputs called the net input. A possible nonlinear activation function is then applied to the net input to produce the output. An activation function maps any real input into a usually bounded range, often 0 to 1 or -1 to 1. Some common activation functions are:

- linear or identity: act(x) = x
- hyperbolic tangent: act(x) = tanh(x)
- logistic: act(x): = $(1 + e^{-x})^{-1}$ = (tanh(x/2) + 1)/2
- threshold: act(x) = 0 if $x < 0$, 1 otherwise
- Gaussian: act(x) = $e^{-x^2/2}$

The symbols used in the network diagrams for various types of neurons and activation functions are shown in Figure 3-14. A perceptron can have one or more outputs. Each output has a separate bias and set of weights. Usually the same activation function is used for each output, although it is possible to use different activation functions.

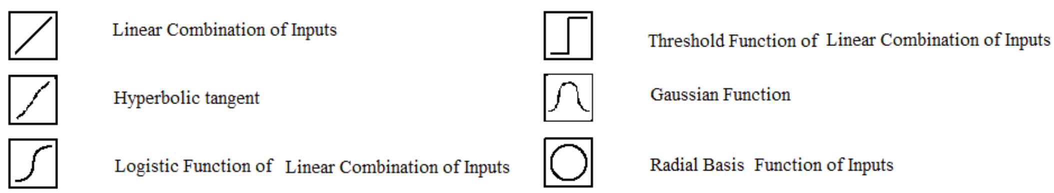


Figure 3-14: Commonly used activation functions

[Multilayer Perceptrons (MLPs)]

A Functional link network introduces an extra hidden layer of neurons, but there is still only one layer of weights to be estimated. If the model includes estimated weights between the inputs and the hidden layer, and the hidden layer uses nonlinear activation functions such as a logistic function, the model becomes genuinely nonlinear, i.e., nonlinear in the parameters. The resulting model is called a multilayer perceptron or MLP. An MLP can have multiple inputs and outputs, as shown in Figure 3-15, and this is what makes the methodology non-linear.

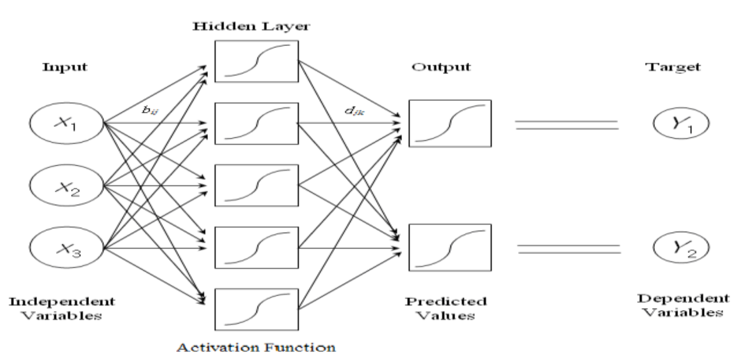


Figure 3-15: Multilayer perceptron ANN.

3.6.5 RADIAL BASIS FUNCTION (RBF)

A Radial Basis Function (RBF) is another type of feed-forward ANN. Typically in an RBF network, there are three layers: one input, one hidden layer and one output layer which are shown in Figure 3-16. The number of hidden layers cannot be more than one. The hidden layer uses a radial basis (Gaussian) function instead of the sigmoid or other function used in the MLP ANN. A sigmoid function is a mathematical function having an "S" shape (sigmoid curve). In RBF networks, one major advantage is that if the number of input variables is not too high, then learning is much faster than other types of networks. However, the required number of hidden units increases geometrically with the number of the input variables. It becomes practically impossible to use this network for a large number of input variables.

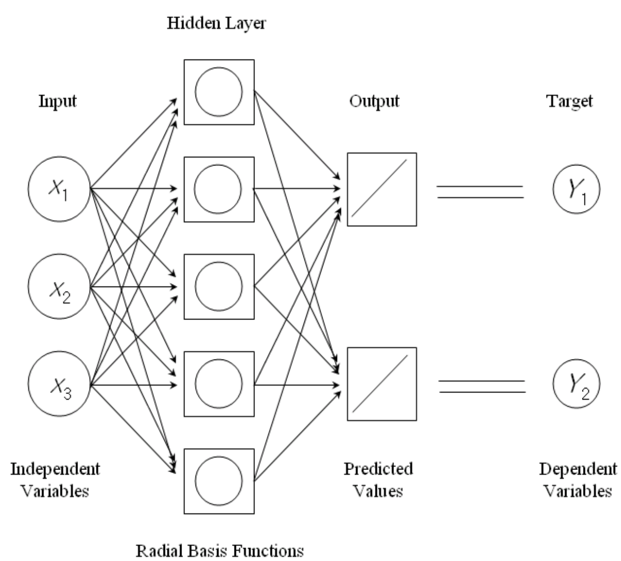


Figure 3-16: Radial Basis Function ANN.

The net input to the hidden layer is the distance from the input vector to the weight vector called a 'radial centre' vector (Schalkoff, 1997). There is usually a bandwidth s_j associated with each hidden node, often called sigma. The activation function can be any of a variety of functions on the non-negative real numbers with a maximum at zero, approaching zero at infinity, such as $e^{-x^2/2}$. The outputs are computed as linear combinations of the hidden values with an identity activation function.

For comparison, typical formulas for an MLP hidden neuron and an RBF neuron are as follows:

$$\text{MLP:} \quad g_j = a_j + \sum_{i=1}^{n_x} b_{ij} x_i, \qquad h_j = (1 + e^{g_j})^{-1} \qquad \text{Equation 21}$$

$$\text{RBF:} \quad g_j = \left[\sum_{i=1}^{n_x} \frac{(b_{ij} - x_i)^2}{2s_j} \right]^{1/2}, \qquad h_j = e^{-g_j^2/2} \qquad \text{Equation 22}$$

Where, g_j = net input to hidden layer, a_j = bias for hidden layer, n_x = number of independent variables (inputs), b_{ij} = weight from input to hidden layer.

Since an RBF network can be viewed as a nonlinear regression model, the weights can be estimated by any of the usual methods for nonlinear least squares or maximum likelihood, although this would yield a vastly overparameterized model if every observation were used as an RBF centre. Usually, however, RBF networks are treated as hybrid networks. The inputs are clustered, and the RBF centres are set equal to the cluster means. The bandwidths are often set to the nearest-neighbor distance from the centre (Moody and Darken 1988), although this is not a good idea because nearest-neighbor distances are excessively variable; it works better to determine the bandwidths from the cluster variances. Once the centres and bandwidths are determined, the weights from the hidden layer to the outputs reduce to an estimate derived from linear least squares.

3.6.6 STATISTICAL ANALYSIS SYSTEMS

SAS (Statistical Analysis Systems) – The SAS$^{@}$ system is an integrated system of software for data management, analysis, and presentation (Littell, 2006). Using the SAS$^{@}$ system, the linear simple equation is established as shown in the following procedures:

- UNIVARIATE: The univariate procedure compliments the central tendency of the input data and involves the study of the data's statistical dispersion. The SAS code use in this analysis is shown below.

```
PROC UNIVARIATE <OPTION>;
   VAR variables ;
   FREQ variable ;
   ID variables ;
RUN;
```

- Factor Analysis: Factor analysis involves trying to describe the variability of the observed data and determining the parameter priorities impacted by water quality. The SAS code used in this procedure is shown in the box below.

```
PROC FACTOR DATA=       OUT;
   NFACTORS=            ROTATE=VARIMAX   SCORE;
RUN;
```

- Linear regression or non-linear regression: Linear or non-linear regression uses the results of the factor analysis to determing simple equations characterizing the pattern of the data. The SAS code used in this portion of the analysis is shown in the box below.

```
PROC REG DATA=       OUT ;
   MODEL               ;
RUN;
```

3.7. THE PROCESS AND RESULTS OF DATA ANALYSIS

The full data analysis used to link pervious/impervious, slope, rainfall, land use, and water quality was implemented using Excel Solver, MT, ANN, RBF, and SAS.

3.7.1 THE PROCESS OF DATA ANALYSIS

Through the Data Analysis method illustrated in chapters 3.6.1 to 3.6.6 (Excel Solver, Model tree, ANN, RBF, SAS), several simple equations were determined using the ten scenarios developed in chapters 3.7.2 to 3.7.4 which linked each watershed parameter－hydrology, geology, land usage－, and water quality. Five parameters－impervious, pervious, rainfall, slope, and land usage－were combined with impervious and land usage as shown in Table 3-16. The equations representing the basin water-quality measures COD, BOD, T-N, and T-P (mg/L) of the ten scenarios were determined through an analysis of observed (10 year average) and predicted water quality values. The overall relationship determined from this analysis is shown in Equation 23. Coefficients were used as variables in order to minimize the difference between observed and predicted water quality. Once the difference between observed and model-predicted value was minimized, the most representative simple equation relating to the watershed parameters was selected based upon the model selection process which was shown in chapter 3.5.

In order to select the best Simple Equation, R^2, Adjusted R^2, F-test, and Akaike's information criterion (AIC), Factor Analysis, Variance Inflation Factor (VIF), Shapiro-wilk test were implemented depending upon the analysis method as shown in Table 3-16.

Table 3-16: Ten scenarios for making a simple equation based upon the parameters.

Scenarios	Parameters			Equation	Statistical Methods for selection model
1	Impervious			COD, BOD, T-N, T-P	R^2, Adj. R^2, F-test, AIC, Shapiro-wilk test, , Factor Analysis, VIF (Variance Inflation Factor)
2	Impervious	Pervious			
3	Impervious	Rainfall			
4	Impervious	Slope			
5	Impervious	Rainfall	Slope		
6	Slope				
7	Land Usage				
8	Land Usage	Rainfall			
9	Land Usage	Slope			
10	Land Usage	Rainfall	Slope		

$$\text{COD, BOD, TN, TP(mg/L)} = \alpha P1^{\beta} P2^{\gamma} P3^{\delta} P4^{\varepsilon} \cdots\cdots\cdots \qquad \text{Equation 23}$$

Where, COD, BOD, TN, TP are predicted water quality concentrations (mg/L) based on the coefficients and parameters, α, β, γ, δ, ε, ⋯. α, β, γ, δ, ε, ⋯ are the optimizing coefficients for developing a simple equation based upon minimizing the difference between observed and predicted water quality values, P1, P2, P3, P4, ⋯. P1, P2, P3, P4, ⋯ are the standard watershed parameters (p= pervious, ip= impervious, Ra= rainfall, Sl= slope, Ur= urban, Ag=agriculture, Fo=forest, Gr=grass, Wet=wetland, Ba= barren, and Wa= water)

3.7.2 EXCEL SOLVER

The best appropriate Simple Equations were selected like in Figure 3-17 based upon Excel Solver. There are five steps including developing simple equation (1st step), trying to minimize observed water quality data and predicted water quality data using solver (2nd step), calculating R^2, adj. R^2, F-test, Shapiro-wilk test, and AIC (3rd step). Then the simple equations for each of the 10 scenarios (table 3-16) were established and the best appropriate Simple Equation was selected based on the model which has the small value of AIC (4th and 5th step).

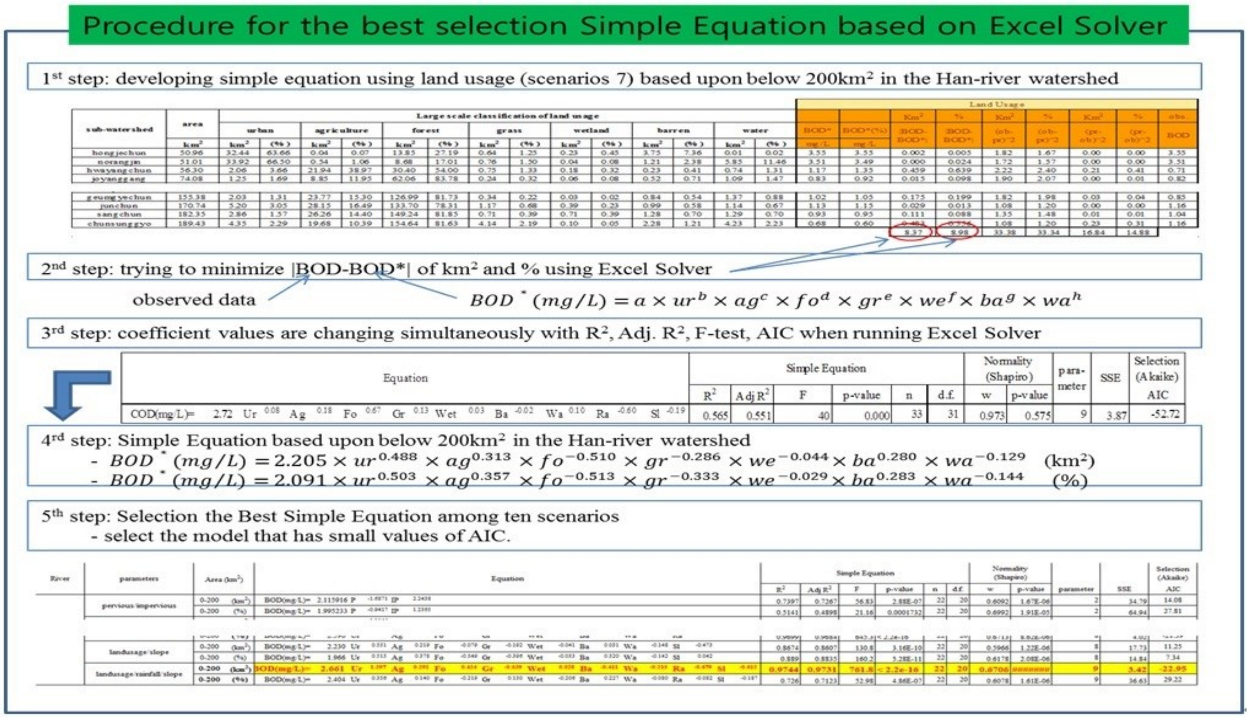


Figure 3-17: Procedure to select the best Simple Equations based on Excel Solver.

[The results of the first step simple equations]

Tables 3-17 to 3-20 show the best simple equations derived from the first step of the analysis described in chapter 3.4.1. These equations relate the standard watershed parameter (i.e. watershed land use, imperviousness, rainfall, slope, etc.) to the watershed's water quality as represented through COD, BOD, TN, and TP

Table 3-17: The best simple equations for COD (mg/L) based on parameters and the area of three watersheds for the first step.

River	parameters	Area (km^2)	Equation	Simple Equation						Normality (Shapiro)		parameter	SSE	Selection (Akaike)	Arttribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Hanriver	landusage/rainfall	0-200	COD(mg/L)= 3.45 $Ur^{0.69}$ $Ag^{0.29}$ $Fo^{-0.18}$ $Gr^{-0.35}$ $Wet^{-0.01}$ $Ba^{0.01}$ $Wa^{-0.11}$ $Ra^{-0.28}$	0.937	0.934	299	0.000	22	20	0.72	0.00	8	9.85	-1.68	km2
	land usage/rainfall/slope	200-500	COD(mg/L)= 4.81 $Ur^{-0.07}$ $Ag^{-0.45}$ $Fo^{-0.29}$ $Gr^{0.00}$ $Wet^{0.06}$ $Ba^{0.40}$ $Wa^{-0.18}$ $Ra^{1.43}$ $Sl^{-1.08}$	0.963	0.961	549	< 2.2e-16	23	21	0.71	0.00	9	8.75	-4.23	km2
	land usage/rainfall/slope	500-	COD(mg/L)= 3.59 $Ur^{0.09}$ $Ag^{0.00}$ $Fo^{1.25}$ $Gr^{0.23}$ $Wet^{-0.32}$ $Ba^{0.35}$ $Wa^{0.00}$ $Ra^{-0.25}$ $Sl^{-1.39}$	0.990	0.989	1242	0.000	15	13	0.73	0.73	9	0.25	-43.24	%
Nakdong river	impervious	0-200	COD(mg/L)= 5.50 $IP^{0.02}$	0.471	0.442	16	0.001	20	18	0.96	0.63	1	34.09	12.67	%
	land usage/rainfall	200-500	COD(mg/L)= 5.08 $Ur^{0.46}$ $Ag^{0.02}$ $Fo^{0.31}$ $Gr^{0.08}$ $Wet^{0.17}$ $Ba^{-0.17}$ $Wa^{0.15}$ $Ra^{-0.48}$	0.621	0.609	51	0.000	33	31	0.86	0.00	8	35.81	18.70	%
	landusage/rainfall	500-	COD(mg/L)= 4.06 $Ur^{0.47}$ $Ag^{-0.09}$ $Fo^{-0.11}$ $Gr^{0.57}$ $Wet^{-0.48}$ $Ba^{-0.53}$ $Wa^{0.29}$ $Ra^{-0.06}$	0.995	0.994	1682	0.000	11	9	0.83	0.02	8	0.13	-32.90	km2
Geun -Sum -Youngsan river	land usage/slope	0-100	COD(mg/L)= 5.54 $Ur^{0.32}$ $Ag^{-0.51}$ $Fo^{0.97}$ $Gr^{-0.47}$ $Wet^{0.16}$ $Ba^{-0.12}$ $Wa^{0.33}$ $Sl^{-0.93}$	0.919	0.913	137	0.000	14	12	0.92	0.19	8	2.61	-7.53	km2
	slope	100-150	COD(mg/L)= 155.40 $Sl^{-1.09}$	0.780	0.763	46	0.000	15	13	0.78	0.00	1	18.62	5.24	km2
	landusage/rainfall/slope	150-200	COD(mg/L)= 5.93 $Ur^{0.44}$ $Ag^{-0.19}$ $Fo^{0.48}$ $Gr^{-0.15}$ $Wet^{-0.21}$ $Ba^{-0.15}$ $Wa^{0.88}$ $Ra^{-0.77}$ $Sl^{0.13}$	0.962	0.958	228	0.000	11	9	0.89	0.14	9	0.78	-11.11	km2
	land usage	200 -	COD(mg/L)= 5.21 $Ur^{-0.02}$ $Ag^{0.33}$ $Fo^{-0.33}$ $Gr^{-0.01}$ $Wet^{0.00}$ $Ba^{0.17}$ $Wa^{0.13}$	0.771	0.764	114	0.000	36	34	0.90	0.00	7	20.21	-6.78	%

*km^2: Impervious, pervious, and land usage were calculated by area (km^2)

*%: Impervious, pervious, and land usage were calculated by percentage (%) of area

For COD simulation, the Han River and Geum-sum-youngsan River watersheds have a strong and significant relationship between water quality and watershed parameters compared with the Nakdong River watershed. The statistical values of Han River are as follows: 0 ~ 200 km^2 ($F = 299$, $P < 0.001$, df =20, $R^2 = 0.937$), 200 ~ 500 km^2 ($F = 549$, $P < 0.001$, df =21, $R^2 = 0.963$), over 500km^2 ($F = 1242$, $P < 0.001$, df =13, $R^2 = 0.990$). Geum-sum-youngsan River's statistical values are as follows: 0 ~ 100 km^2 ($F = 137$, $P < 0.001$, df =12, $R^2 = 0.919$), 100 ~ 150 km^2 ($F = 46$, $P < 0.001$, df =13, $R^2 = 0.780$), 150 ~ 200 km^2 ($F = 228$, $P < 0.001$, df =9, $R^2 = 0.962$), over 200km^2 ($F = 114$, $P < 0.001$, df =34, $R^2 = 0.771$). The Nakdong River watershed has a weak relationship between water quality and watershed parameters as follows: 0 ~ 200 km^2 ($F = 16$, $P < 0.001$, df =18, $R^2 = 0.471$), 200 ~ 500 km^2 ($F = 51$, $P < 0.001$, df =31, $R^2 = 0.621$), over 500km^2 ($F = 1682$, $P < 0.001$, df =9, $R^2 = 0.995$). Otherwise, based upon the F-test results, all of the p-values are less than 0.05, hence, these Simple Equations were fitted to a data set well. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected (p value < 0.05) such as; 0 ~ 200 km^2 and 200 ~ 500 km^2 of the Han River watersheds, 200 ~ 500 km^2 and over 500 km^2 of Nakdong River watershed, and 100 ~ 150 km^2 and over 200 km^2 of the Geum-sum-youngsan River watershed. As for the rest of the watersheds, the null hypothesis is not rejected (p-value > 0.05).

Table 3-18: The best simple equations for BOD (mg/L) based on parameters and the area of three watersheds for the first step.

River	parameters	Area (km^2)	Equation	Simple Equation						Normality (Shapiro)				Selection (Akaike)	Arttribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value	parameter	SSE	AIC	
Hanriver	landusage/rainfall/slope	0-200	$BOD(mg/L)= 2.66\ Ur^{1.30}\ Ag^{0.29}\ Fo^{0.42}\ Gr^{-0.54}\ Wet^{0.03}\ Ba^{-0.41}\ Wa^{-0.22}\ Ra^{-0.68}\ Sl^{-0.61}$	0.974	0.973	762	< 2.2e-16	22	20	0.671	0.000	9	3.42	-22.95	km2
	land usage/rainfall	200-500	$BOD(mg/L)= 2.33\ Ur^{0.47}\ Ag^{-0.51}\ Fo^{-0.64}\ Gr^{0.20}\ Wet^{0.26}\ Ba^{0.35}\ Wa^{-0.64}\ Ra^{0.90}$	0.988	0.988	1788	< 2.2e-16	23	21	0.604	0.000	8	5.10	-18.64	AREA
	land usage/slope	500-	$BOD(mg/L)= 1.53\ Ur^{0.12}\ Ag^{-0.13}\ Fo^{1.83}\ Gr^{0.27}\ Wet^{-0.47}\ Ba^{0.54}\ Wa^{-0.04}\ Sl^{-2.40}$	0.962	0.959	324	0.000	15	13	0.676	0.000	8	0.44	-37.04	%
Nakdong river	impervious	0-200	$BOD(mg/L)= 0.01\ IP^{1.97}$	0.319	0.284	9	0.008	21	19	0.888	0.021	1	13.03	-8.03	%
	impervious	200-500	$BOD(mg/L)= 0.00\ IP^{2.16}$	0.335	0.313	15	0.001	32	30	0.893	0.004	1	13.98	-24.50	%
	landusage/rainfall	500-	$BOD(mg/L)= 1.91\ Ur^{0.39}\ Ag^{-0.06}\ Fo^{-0.65}\ Gr^{0.45}\ Wet^{-0.07}\ Ba^{-0.61}\ Wa^{0.28}\ Ra^{0.47}$	0.985	0.983	573	0.000	11	9	0.775	0.004	8	0.09	-36.50	%
Geun -Sum -Youngsan river	land usage/rainfall/slope	0-100	$BOD(mg/L)= 3.32\ Ur^{0.48}\ Ag^{-0.98}\ Fo^{2.04}\ Gr^{-0.69}\ Wet^{0.22}\ Ba^{-0.40}\ Wa^{0.09}\ Ra^{0.27}\ Sl^{-2.24}$	0.863	0.851	75	0.000	14	12	0.856	0.027	9	1.26	-15.70	km2
	land usage/slope	100-150	$BOD(mg/L)= 1.95\ Ur^{0.00}\ Ag^{0.33}\ Fo^{2.62}\ Gr^{0.21}\ Wet^{-0.51}\ Ba^{0.00}\ Wa^{-0.28}\ Sl^{-3.63}$	0.919	0.912	136	0.000	14	12	0.886	0.071	8	2.61	-7.51	%
	landusage/rainfall	150-200	$BOD(mg/L)= 2.85\ Ur^{1.16}\ Ag^{-0.40}\ Fo^{1.54}\ Gr^{0.10}\ Wet^{-0.55}\ Ba^{-0.71}\ Wa^{1.63}\ Ra^{-1.99}$	0.998	0.998	4296	0.000	11	9	0.882	0.111	8	0.02	-52.36	km2
	pervious/impervious	200 -	$BOD(mg/L)= 3.45\ P^{-1.98}\ IP^{2.38}$	0.643	0.632	61	0.000	36	34	0.832	0.000	2	21.16	-15.13	km2

For BOD simulation, the Han River and Geum-sum-youngsan River watersheds have a strong and significant relationship between water quality and watershed parameters compared with the Nakdong River watershed like the results of COD simulation. The statistical values of Han River are as follows: 0 ~ 200 km^2 ($F = 762$, $P < 0.001$, df =20, $R^2 = 0.974$), 200 ~ 500 km^2 ($F = 1788$, $P < 0.001$, df =21, $R^2 = 0.988$), over 500km^2 ($F = 324$, $P < 0.001$, df =15, $R^2 = 0.962$). Geum-sum-youngsan River's statistical values are as follows: 0 ~ 100 km^2 ($F = 75$, $P < 0.001$, df =12, $R^2 = 0.863$), 100 ~ 150 km^2 ($F = 136$, $P < 0.001$, df =12, $R^2 = 0.919$), 150 ~ 200 km^2 ($F = 4296$, $P < 0.001$, df =9, $R^2 = 0.998$), over 200km^2 ($F = 61$, $P < 0.001$, df =34, $R^2 = 0.643$). The Nakdong Rver watershed has a weak relationship between water quality and watershed parameters as follows: 0 ~ 200 km^2 ($F = 9$, $P = 0.008$, df =19, $R^2 = 0.319$), 200 ~ 500 km^2 ($F = 15$, $P = 0.001$, df =30, $R^2 = 0.335$), over 500km^2 ($F = 573$, $P < 0.001$, df =9, $R^2 = 0.985$). Otherwise, based upon the F-test results, all of the p-values are less than 0.05, hence, these Simple Equations were fitted to a data set well. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected such as; the total Han River watersheds, 200 ~ 500 km^2 and over 500 km^2 of Nakdong River watershed, and 0 ~ 100 km^2 and over 200 km^2 of the Geum-sum-youngsan River watershed. And for the rest of the watersheds, the null hypothesis that the predicted data are normally distributed is not rejected.

Table 3-19: The best simple equations for TN (mg/L) based on parameters and the area of three watersheds for the first step.

River	parameters	Area (km^2)	Equation	Simple Equation						Normality (Shapiro)				Selection (Akaike)	Arttribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value	parameter	SSE	AIC	
Hanriver	landusage/rainfall	0-200	$TN(mg/L) = 4.59\ Ur^{0.44}\ Ag^{0.15}\ Fo^{-0.30}\ Gr^{-0.04}\ Wet^{0.00}\ Ba^{0.34}\ Wa^{-0.01}\ Ra^{-0.14}$	0.937	0.934	298.900	0.000	22	20	0.720	0.000	8	9.850	-1.68	km2
	land usage/rainfall/slope	200-500	$TN(mg/L) = 4.97\ Ur^{-0.01}\ Ag^{-0.68}\ Fo^{0.62}\ Gr^{-0.21}\ Wet^{0.03}\ Ba^{0.41}\ Wa^{-0.48}\ Ra^{1.66}$	0.963	0.961	548.800	<2.2e-16	23	21	0.707	0.000	9	8.750	-4.23	km2
	land usage/slope	500-	$TN(mg/L) = 2.84\ Ur^{-0.08}\ Ag^{-0.27}\ Fo^{1.83}\ Gr^{0.03}\ Wet^{-0.27}\ Ba^{0.70}\ Wa^{-0.10}\ Sl^{-2.11}$	0.912	0.905	134.300	0.000	15	13	0.885	0.056	8	1.161	-22.38	%
Nakdong river	impervious	0-200	$TN(mg/L) = 0.52\ IP^{0.56}$	0.251	0.210	6.039	0.024	20	18	0.953	0.421	1	12.490	-7.42	%
	land usage/rainfall	200-500	$TN(mg/L) = 3.35\ Ur^{0.65}\ Ag^{0.23}\ Fo^{0.61}\ Gr^{-0.05}\ Wet^{0.11}\ Ba^{-0.04}\ Wa^{-0.13}\ Ra^{-0.91}$	0.602	0.589	46.860	0.000	33	31	0.856	0.000	8	23.830	5.26	%
	landusage/rainfall/slope	500-	$TN(mg/L) = 4.14\ Ur^{-0.75}\ Ag^{-0.07}\ Fo^{-1.00}\ Gr^{-0.31}\ Wet^{-1.91}\ Ba^{0.08}\ Wa^{1.65}\ Ra^{1.52}\ Sl^{-1.05}$	0.979	0.977	421.100	0.000	11	9	0.961	0.784	9	0.327	-20.67	%
Geun -Sum -Youngsan river	impervious/slope	0-100	$TN(mg/L) = 2.23\ IP^{0.32}\ Sl^{-0.23}$	0.362	0.309	6.814	0.023	14	12	0.944	0.477	2	12.652	2.58	km2
	land usage/rainfall/slope	100-150	$TN(mg/L) = 4.79\ Ur^{-0.02}\ Ag^{-0.14}\ Fo^{2.48}\ Gr^{0.03}\ Wet^{-0.04}\ Ba^{0.82}\ Wa^{-0.17}\ Ra^{-0.46}\ Sl^{-2.67}$	0.983	0.982	744.000	0.000	15	13	0.800	0.004	9	1.890	-13.07	km2
	slope	150-200	$TN(mg/L) = 10.45\ Sl^{-0.40}$	0.276	0.196	3.435	0.097	11	9	0.935	0.464	1	5.026	-6.62	%
	pervious/impervious	200 -	$TN(mg/L) = 8.87\ P^{-1.97}\ IP^{2.26}$	0.677	0.668	71.360	0.000	36	34	0.832	0.000	2	27.800	-5.31	km2

For TN simulation, the Han River watershed has a strong and significant relationship between water quality and watershed parameters compared with the Nakdong River and Geum-sum-youngsan River watersheds. The statistical values of Han River are as follows: 0 ~ 200 km^2 ($F = 299$, $P < 0.001$, df =20, $R^2 = 0.937$), 200 ~ 500 km^2 ($F = 549$, $P < 0.001$, df =21, $R^2 = 0.963$), over 500km^2 ($F = 134$, $P < 0.001$, df =13, $R^2 = 0.912$). The Nakdong River and Geum-sum-youngsan River watersheds have a weak relationship between water quality and watershed parameters. The statistical values of Nakdong River are as follows: 0 ~ 200 km^2 ($F = 6$, $P = 0.02$, df =18, $R^2 = 0.251$), 200 ~ 500 km^2 ($F = 47$, $P < 0.001$, df =31, $R^2 = 0.602$), over 500km^2 ($F = 421$, $P < 0.001$, df =9, $R^2 = 0.979$). Geum-sum-youngsan River's statistical values are as follows: 0 ~ 100 km^2 ($F = 7$, $P = 0.02$, df =12, $R^2 = 0.362$), 100 ~ 150 km^2 ($F = 744$, $P < 0.001$, df =13, $R^2 = 0.983$), 150 ~ 200 km^2 ($F = 3$, $P = 0.09$, df =9, $R^2 = 0.276$), over 200km^2 ($F = 71$, $P < 0.001$, df =34, $R^2 = 0.677$). Otherwise, based upon the F-test results, all of the p-values are less than 0.05, hence, these Simple Equations were fitted to a data set well except 150 ~ 200 km^2 of the Geum-sum-youngsan River watershed. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected such as; 0 ~ 200 km^2 and 200 ~ 500 km^2 of the Han River watersheds, 200 ~ 500 km^2 of Nakdong River watershed, and 100 ~ 150 km^2 and over 200 km^2 of the Geum-sum-youngsan River watershed. As for the rest of the watersheds, the null hypothesis that the predicted data are normally distributed is not rejected.

Table 3-20: The best simple equations for TP (mg/L) based on parameters and the area of three watersheds for the first step.

River	parameters	Area (km^2)	Equation	Simple Equation						Normality (Shapiro)		parameter	SSE	Selection (Akaike)	Arttribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Hanriver	landusage/rainfall/slope	0-200	TP(mg/L)= 0.13 $Ur^{1.58}$ $Ag^{0.75}$ $Fo^{-0.72}$ $Gr^{-1.07}$ $Wet^{\#\#\#\#}$ $Ba^{0.39}$ $Wa^{-0.20}$ $Ra^{-0.97}$ $Sl^{0.58}$	0.998	0.998	10410	< 2.2e-16	22	20	0.475	0.000	9	0.006	-162.55	km2
	landusage/slope	200-500	TP(mg/L)= 0.12 $Ur^{1.13}$ $Ag^{0.60}$ $Fo^{-0.05}$ $Gr^{-1.04}$ $Wet^{0.31}$ $Ba^{0.91}$ $Wa^{-0.47}$ $Sl^{-1.11}$	0.990	0.990	2137	< 2.2e-16	23	21	0.551	0.000	8	0.032	-135.28	%
	land usage/rainfall	500-	TP(mg/L)= 0.05 $Ur^{-0.05}$ $Ag^{0.85}$ $Fo^{1.78}$ $Gr^{0.95}$ $Wet^{\#\#\#\#}$ $Ba^{0.96}$ $Wa^{-0.09}$ $Ra^{-2.34}$	0.962	0.960	332	0.000	15	13	0.760	0.001	8	0.001	-129.99	%
Nakdong river	impervious	0-200	TP(mg/L)= 0.12 $IP^{0.02}$	0.192	0.148	4	0.053	20	18	0.964	0.633	1	0.098	-104.37	%
	land usage	200-500	TP(mg/L)= 0.10 $Ur^{1.08}$ $Ag^{-0.27}$ $Fo^{-0.23}$ $Gr^{0.26}$ $Wet^{\#\#\#\#}$ $Ba^{-0.30}$ $Wa^{-0.25}$	0.654	0.642	58	0.000	33	31	0.648	0.000	7	0.127	-169.51	%
	landusage/rainfall	500-	TP(mg/L)= 0.11 $Ur^{0.19}$ $Ag^{1.81}$ $Fo^{-0.54}$ $Gr^{-0.15}$ $Wet^{\#\#\#\#}$ $Ba^{-0.52}$ $Wa^{0.87}$ $Ra^{-1.64}$	0.989	0.987	779	0.000	11	9	0.851	0.044	8	0.001	-91.10	km2
Geun -Sum -Youngsan river	land usage/slope	0-100	TP(mg/L)= 0.15 $Ur^{0.71}$ $Ag^{-0.92}$ $Fo^{2.62}$ $Gr^{-0.70}$ $Wet^{0.34}$ $Ba^{-0.51}$ $Wa^{0.25}$ $Sl^{-2.68}$	0.964	0.961	317	0.000	14	12	0.917	0.198	8	0.002	-108.74	km2
	land usage/rainfall/slope	100-150	TP(mg/L)= 0.08 $Ur^{-0.13}$ $Ag^{-0.33}$ $Fo^{9.73}$ $Gr^{0.35}$ $Wet^{\#\#\#\#}$ $Ba^{0.47}$ $Wa^{-0.71}$ $Ra^{-1.82}$ $Sl^{\#\#\#\#}$	0.996	0.995	2851	< 2.2e-16	15	13	0.747	0.001	9	0.002	-120.16	%
	land usage/rainfall/slope	150-200	TP(mg/L)= 0.14 $Ur^{0.08}$ $Ag^{0.51}$ $Fo^{8.61}$ $Gr^{-0.53}$ $Wet^{\#\#\#\#}$ $Ba^{0.46}$ $Wa^{0.27}$ $Ra^{-5.56}$ $Sl^{\#\#\#\#}$	0.999	0.999	7368	0.000	11	9	0.677	0.000	9	0.000	-102.07	%
	pervious/impervious	200 -	TP(mg/L)= 0.68 $P^{-3.25}$ $IP^{3.63}$	0.659	0.649	66	0.000	36	34	0.744	0.000	2	0.126	-199.69	km2

For TP simulation, the Han River and Geum-sum-youngsan River watershed have a strong and significant relationship between water quality and watershed parameters compared with Nakdong River watershed like the results of COD and BOD simulation. The statistical values of Han River are as follows: 0 ~ 200 km^2 ($F = 10410$, $P < 0.001$, df =20, $R^2 = 0.998$), 200 ~ 500 km^2 ($F = 2137$, $P < 0.001$, df =21, $R^2 = 0.990$), over 500km^2 ($F = 332$, $P < 0.001$, df =13, $R^2 = 0.962$). Geum-sum-youngsan River's statistical values are as follows: 0 ~ 100 km^2 ($F = 317$, $P < 0.001$, df =12, $R^2 = 0.964$), 100 ~ 150 km^2 ($F = 2851$, $P < 0.001$, df =13, $R^2 = 0.996$), 150 ~ 200 km^2 ($F = 7368$, $P < 0.001$, df =9, $R^2 = 0.999$), over 200km^2 ($F = 66$, $P < 0.001$, df = 34, $R^2 = 0.659$). The Nakdong River watershed has a weak relationship between water quality and watershed parameters as follows: 0 ~ 200 km^2 ($F = 4$, $P = 0.05$, df =18, $R^2 = 0.192$), 200 ~ 500 km^2 ($F = 58$, $P = 0.001$, df =31, $R^2 = 0.654$), over 500km^2 ($F = 779$, $P < 0.001$, df = 9, $R^2 = 0.989$). Otherwise, based upon the F-test results, all of the p-values are less than 0.05, hence, these Simple Equations were fitted to a data set well except 0 ~ 200 km^2 of the Nakdong River watershed. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected such as; the total Han River watersheds, 200 ~ 500 km^2 and over 500 km^2 of Nakdong River watershed, and 100 ~ 150 km^2, 100 ~ 150 km^2, and over 200 km^2 of the Geum-sum-youngsan River watershed. As for the rest of the watersheds, the null hypothesis that the predicted data are normally distributed is not rejected.

The number of equations relating land usage and watershed characteristics (i.e. rainfall, slope, imperviousness, etc.) determined in the first step of the analysis process are shown in Table 3-21. Land usage is the best important factors to display the watershed characteristics compared to imperviousness. The combination of land usage/rainfall/slope is the best resuts in the first step. The relationships between land usage and rainfall and land usage and slope have the same number of best simple equations.

Table 3-21: The number of best simple equations of each scenario for the first step.

Scenarios	Parameters			COD	BOD	T-N	T-P
1	Impervious			1	2	1	1
2	Impervious	Pervious			1	1	1
3	Impervious	Rainfall					
4	Impervious	Slope				1	
5	Impervious	Rainfall	Slope				
6	Slope			1		1	
7	Land Usage			1			1
8	Land Usage	Rainfall		3	3	2	2
9	Land Usage	Slope		1	2	1	2
10	Land Usage	Rainfall	Slope	3	2	3	3

[The results of the second step simple equations]

Tables 3-22 to 3-25 show the best simple equations derived from the second step of the anlaysis decribed in chapter 3.4.2. These equations relate the standard watershed parameters (i.e. watershed land use, imperviousness, rainfall, slope, etc.) to the watershed's water quality as represented through COD, BOD, TN, and TP.

Table 3-22: The best simple equations for COD (mg/L) based on parameters and the area of three watersheds for the Second step.

River	parameters	Area	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Arttribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Hanriver	landusage/rainfall/slope	0~20%	COD(mg/L)= $2.72\ Ur^{0.08}\ Ag^{0.18}\ Fo^{0.67}\ Gr^{0.13}\ Wet^{0.03}\ Ba^{-0.02}\ Wa^{0.10}\ Ra^{-0.60}\ Sl^{-0.19}$	0.565	0.551	40	0.000	33	31	0.973	0.575	9	3.87	-52.72	%
	land usage/slope	20~25%	COD(mg/L)= $5.01\ Ur^{0.52}\ Ag^{-0.04}\ Fo^{0.10}\ Gr^{0.09}\ Wet^{0.13}\ Ba^{-0.01}\ Wa^{-0.58}\ Sl^{-0.38}$	0.895	0.889	145	0.000	19	17	0.907	0.064	8	4.58	-11.03	km2
	landusage/rainfall/slope	25%~	COD(mg/L)= $12.87\ Ur^{0.45}\ Ag^{-0.64}\ Fo^{0.64}\ Gr^{1.23}\ Wet^{-0.15}\ Ba^{-0.07}\ Wa^{0.13}\ Ra^{-0.35}\ Sl^{-1.24}$	1.000	1.000	1005000	< 2.2e-16	9	7	0.880	0.156	9	0.00	-	%
Nakdong river	land usage/rainfall/slope	0~20%	COD(mg/L)= $4.77\ Ur^{0.23}\ Ag^{-0.22}\ Fo^{0.66}\ Gr^{0.03}\ Wet^{0.15}\ Ba^{0.13}\ Wa^{0.01}\ Ra^{-0.12}\ Sl^{-0.56}$	0.601	0.580	29	0.000	21	19	0.941	0.231	9	7.64	-3.23	%
	land usage/slope	20~25%	COD(mg/L)= $5.54\ Ur^{0.11}\ Ag^{0.34}\ Fo^{0.24}\ Gr^{-0.03}\ Wet^{0.03}\ Ba^{0.24}\ Wa^{-0.12}\ Sl^{-0.77}$	0.445	0.428	26	0.000	35	33	0.958	0.199	8	48.15	27.16	%
	landusage	25%~	COD(mg/L)= $7.41\ Ur^{-0.21}\ Ag^{0.34}\ Fo^{-0.41}\ Gr^{0.47}\ Wet^{0.01}\ Ba^{0.12}\ Wa^{0.16}$	1.000	1.000	33250	0.000	8	6	0.955	0.763	7	0.00	-49.11	%
Geun -Sum -Youngsan river	land usage/rainfall/slope	0~25%	COD(mg/L)= $4.77\ Ur^{0.23}\ Ag^{-0.22}\ Fo^{0.66}\ Gr^{0.03}\ Wet^{0.15}\ Ba^{0.13}\ Wa^{0.01}\ Ra^{-0.12}\ Sl^{-0.56}$	0.638	0.620	35	0.000	22	20	0.897	0.026	9	4.77	-15.63	km2
	land usage/slope	20~25%	COD(mg/L)= $5.54\ Ur^{0.11}\ Ag^{0.34}\ Fo^{0.24}\ Gr^{-0.03}\ Wet^{0.03}\ Ba^{0.24}\ Wa^{-0.12}\ Sl^{-0.77}$	0.483	0.467	31	0.000	35	33	0.906	0.006	8	50.29	28.69	km2
	landusage	25%~	COD(mg/L)= $7.41\ Ur^{-0.21}\ Ag^{0.34}\ Fo^{-0.41}\ Gr^{0.47}\ Wet^{0.01}\ Ba^{0.12}\ Wa^{0.16}$	0.648	0.627	31	0.000	19	17	0.944	0.310	7	24.32	18.69	km2

For COD simulation, the results of the second step have weak relationships between water quality and watershed parameters. And the reasons for having high R^2 valules of over 25%

in the Han River watershed and over 25% in the Nakdong River watershed are because they have a very small degree of freedom compared to the number of parameters. Based upon the F-test results, all of the p-value are less than 0.05, hence, these Simple Equations were fitted to a data set well. However the R^2 of this step's results are lower than first step's results. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected such as; 0 ~ 20 % and 20 ~ 25 % of the Geum-sum-youngsan River watershed. As for the rest of the watersheds, the null hypothesis that the predicted data are normally distributed is not rejected.

Table 3-23: The best simple equations for BOD (mg/L) based on parameters and the area of three watersheds for the Second step.

River	parameters	Area	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Arttribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Hanriver	landusage/rainfall	0~20%	$BOD(mg/L) = 1.09\ Ur^{0.10}\ Ag^{-0.09}\ Fo^{-0.36}\ Gr^{0.03}\ Wet^{0.07}\ Ba^{0.08}\ Wa^{0.02}\ Ra^{0.43}$	0.429	0.410	23	0.000	33	31	0.934	0.045	8	0.98	-99.991	km2
	landusage/rainfall	20~25%	$BOD(mg/L) = 2.38\ Ur^{0.41}\ Ag^{-0.90}\ Fo^{-3.01}\ Gr^{0.51}\ Wet^{0.06}\ Ba^{0.65}\ Wa^{-1.47}\ Ra^{3.15}$	0.954	0.951	349	0.000	19	17	0.741	0.000	8	1.90	-27.749	%
	land usage/rainfall/slope	25%~	$BOD(mg/L) = 12.53\ Ur^{1.59}\ Ag^{-1.05}\ Fo^{0.28}\ Gr^{2.75}\ Wet^{0.08}\ Ba^{-1.18}\ Wa^{0.16}\ Ra^{-1.47}\ Sl^{-0.09}$	1.000	1.000	813800000	< 2.2e-16	9	7	0.877	0.147	9	0.00	-	km2
Nakdong river	land usage/rainfall/slope	0~20%	$BOD(mg/L) = 1.47\ Ur^{0.51}\ Ag^{0.69}\ Fo^{-1.45}\ Gr^{-0.05}\ Wet^{-0.03}\ Ba^{0.03}\ Wa^{0.18}\ Ra^{-0.80}\ Sl^{2.11}$	0.674	0.657	39	0.000	21	19	0.943	0.248	9	1.60	-36.131	km2
	land usage/rainfall	20~25%	$BOD(mg/L) = 2.00\ Ur^{0.66}\ Ag^{0.27}\ Fo^{-1.03}\ Gr^{0.22}\ Wet^{0.21}\ Ba^{-0.24}\ Wa^{-0.13}\ Ra^{0.55}$	0.543	0.529	39	0.000	35	33	0.960	0.231	8	12.05	-21.320	km2
	land usage/rainfall/slope	25%~	$BOD(mg/L) = 3.92\ Ur^{-0.35}\ Ag^{-0.28}\ Fo^{-0.03}\ Gr^{0.64}\ Wet^{0.09}\ Ba^{-0.49}\ Wa^{0.01}\ Ra^{0.10}\ Sl^{0.39}$	1.000	1.000	2506000	< 2.2e-16	8	6	0.943	0.637	9	0.00	-	%
Geun -Sum -Youngsan river	land usage/slope	0~25%	$BOD(mg/L) = 1.15\ Ur^{0.28}\ Ag^{-0.23}\ Fo^{1.79}\ Gr^{0.09}\ Wet^{0.02}\ Ba^{0.03}\ Wa^{-0.09}\ Sl^{-2.03}$	0.541	0.518	24	0.000	22	20	0.938	0.177	8	0.81	-56.525	%
	land usage/rainfall/slope	20~25%	$BOD(mg/L) = 3.71\ Ur^{0.77}\ Ag^{-0.38}\ Fo^{0.00}\ Gr^{-0.28}\ Wet^{0.13}\ Ba^{0.11}\ Wa^{-0.07}\ Ra^{0.35}\ Sl^{-0.66}$	0.477	0.461	30	0.000	35	33	0.928	0.024	9	17.82	-5.626	km2
	landusage/rainfall	25%~	$BOD(mg/L) = 3.31\ Ur^{0.06}\ Ag^{0.35}\ Fo^{-0.84}\ Gr^{0.49}\ Wet^{-0.07}\ Ba^{-0.01}\ Wa^{0.04}\ Ra^{0.26}$	0.535	0.508	20	0.000	19	17	0.924	0.137	8	18.99	15.990	km2

For BOD simulation, the results of the second step have weak relationships between water quality and watershed parameters. And the reasons for having high R^2 valules over 25% in the Han River watershed and over 25% in the Nakdong River watershed are because they have a very small degree of freedom compared to the number of parameters. Based upon the F-test results, all of the p-values are less than 0.05, hence, these Simple Equations were fitted to a data set well. However the R^2 of this step's results are lower than first step's results. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected such as; 20 ~ 25 % of the Han River watershed and the Geum-sum-youngsan River watershed. As for the rest of the watersheds, the null hypothesis that the predicted data are normally distributed is not rejected.

Table 3-24: The best simple equations for T-N (mg/L) based on parameters and the area of three watersheds for the Second step.

River	parameters	Area	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Attribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Hanriver	impervious/slope	0~20%	$TN(mg/L)= 0.02\ IP^{1.44}\ Sl^{0.12}$	0.184	0.157	7	0.013	33	31	0.891	0.003	2	15.92	-20.07	%
	land usage/rainfall/slope	20~25%	$TN(mg/L)= 4.79\ Ur^{-0.01}\ Ag^{-0.98}\ Fo^{-1.64}\ Gr^{0.11}\ Wet^{0.14}\ Ba^{0.31}\ Wa^{-0.90}\ Ra^{2.17}\ Sl^{0.00}$	0.897	0.891	148	0.000	19	17	0.784	0.001	9	7.42	0.14	%
	land usage/slope	25%~	$TN(mg/L)= 12.04\ Ur^{0.34}\ Ag^{-0.17}\ Fo^{0.55}\ Gr^{-0.04}\ Wet^{-0.12}\ Ba^{0.53}\ Wa^{0.00}\ Sl^{-1.60}$	0.990	0.989	718	0.000	9	7	0.809	0.026	8	2.54	4.61	km2
Nakdong river	land usage/rainfall/slope	0~20%	$TN(mg/L)= 2.62\ Ur^{1.14}\ Ag^{-0.20}\ Fo^{0.91}\ Gr^{-0.20}\ Wet^{0.17}\ Ba^{-0.09}\ Wa^{-0.08}\ Ra^{-1.83}\ Sl^{1.13}$	0.570	0.547	25	0.000	21	19	0.944	0.257	9	4.97	-12.25	%
	land usage/rainfall	20~25%	$TN(mg/L)= 3.46\ Ur^{0.09}\ Ag^{0.09}\ Fo^{-1.00}\ Gr^{0.13}\ Wet^{-0.03}\ Ba^{0.05}\ Wa^{-0.18}\ Ra^{0.78}$	0.193	0.169	8	0.008	35	33	0.850	0.000	8	33.44	14.40	%
	land usage/rainfall/slope	25%~	$TN(mg/L)= 3.87\ Ur^{0.00}\ Ag^{-0.15}\ Fo^{0.55}\ Gr^{0.49}\ Wet^{-0.32}\ Ba^{-0.54}\ Wa^{0.29}\ Ra^{-0.78}\ Sl^{0.63}$	0.961	0.955	150	0.000	8	6	0.615	0.000	9	0.53	-3.67	%
Geun -Sum -Youngsan river	land usage/rainfall/slope	0~25%	$TN(mg/L)= 2.76\ Ur^{0.92}\ Ag^{-0.30}\ Fo^{0.15}\ Gr^{-0.21}\ Wet^{-0.37}\ Ba^{-0.20}\ Wa^{-0.11}\ Ra^{0.39}\ Sl^{-0.81}$	0.781	0.770	71	0.000	22	20	0.846	0.003	9	3.58	-21.92	km2
	land usage/rainfall/slope	20~25%	$TN(mg/L)= 3.72\ Ur^{0.57}\ Ag^{-0.09}\ Fo^{1.13}\ Gr^{-0.09}\ Wet^{-0.09}\ Ba^{0.18}\ Wa^{-0.14}\ Ra^{-0.45}\ Sl^{-1.03}$	0.488	0.473	31	0.000	35	33	0.930	0.027	9	27.75	9.88	%
	landusage/slope	25%~	$TN(mg/L)= 4.87\ Ur^{-0.21}\ Ag^{0.44}\ Fo^{-0.34}\ Gr^{0.58}\ Wet^{0.10}\ Ba^{0.39}\ Wa^{0.12}\ Sl^{-0.23}$	0.683	0.665	37	0.000	19	17	0.824	0.003	8	35.69	27.98	%

For TN simulation, the results of the second step have weak relationships between water quality and watershed parameters. Based upon the F-test results, all of the p-value are less than 0.05, hence, these Simple Equations were fitted to a data set well. However the R^2 of this step's results are lower than first step's results. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected such as; total of Han River watershed, 20 ~ 25 % and over 25 % of the Nakdong River watershed and 0 ~ 25 % and over 25 % the Geum-sum-youngsan River watershed. As for the rest of the watersheds, the null hypothesis that the predicted data are normally distributed is not rejected.

Table 3-25: The best simple equations for T-P (mg/L) based on parameters and the area of three watersheds for the Second step.

River	parameters	Area	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Arttribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Hanriver	landusage/slope	0~20%	$TP(mg/L)= 0.04\ Ur^{-0.19}\ Ag^{0.28}\ Fo^{-0.65}\ Gr^{0.22}\ Wet^{0.07}\ Ba^{0.15}\ Wa^{0.00}\ Sl^{0.50}$	0.237	0.213	10	0.004	33	31	0.961	0.267	8	0.027	-218.24	km2
	land usage	20~25%	$TP(mg/L)= 0.09\ Ur^{0.72}\ Ag^{-0.04}\ Fo^{-0.10}\ Gr^{-0.10}\ Wet^{0.33}\ Ba^{0.85}\ Wa^{-1.48}$	0.991	0.991	1893	< 2.2e-16	19	17	0.540	0.000	7	0.005	-144.61	km2
	land usage/rainfall/slope	25%~	$TP(mg/L)= 0.75\ Ur^{1.25}\ Ag^{-0.10}\ Fo^{-0.25}\ Gr^{0.12}\ Wet^{0.19}\ Ba^{0.43}\ Wa^{0.09}\ Ra^{-0.35}\ Sl^{-1.25}$	1.000	1.000	1286000000	< 2.2e-16	9	7	0.841	0.060	9	0.000	-	km2
Nakdong river	land usage/slope	0~20%	$TP(mg/L)= 0.03\ Ur^{1.60}\ Ag^{0.80}\ Fo^{-6.42}\ Gr^{-0.17}\ Wet^{-0.16}\ Ba^{-0.08}\ Wa^{-0.09}\ Sl^{6.79}$	0.801	0.791	76	0.000	21	19	0.861	0.007	8	0.004	-166.48	%
	land usage/rainfall	20~25%	$TP(mg/L)= 0.14\ Ur^{0.69}\ Ag^{0.22}\ Fo^{-1.36}\ Gr^{0.75}\ Wet^{0.04}\ Ba^{0.01}\ Wa^{-0.36}\ Ra^{0.81}$	0.362	0.343	19	0.000	35	33	0.905	0.005	8	0.149	-175.01	%
	landusage/rainfall	25%~	$TP(mg/L)= 0.20\ Ur^{-0.75}\ Ag^{-0.86}\ Fo^{1.47}\ Gr^{1.25}\ Wet^{-0.08}\ Ba^{-1.15}\ Wa^{0.45}\ Ra^{-0.29}$	1.000	1.000	2450000000	< 2.2e-16	8	6	0.715	0.003	8	0.000	-	km2
Geun -Sum -Youngsan river	land usage/rainfall/slope	0~25%	$TP(mg/L)= 0.05\ Ur^{1.22}\ Ag^{-0.72}\ Fo^{4.08}\ Gr^{0.02}\ Wet^{0.02}\ Ba^{0.04}\ Wa^{-0.31}\ Ra^{-0.02}\ Sl^{-4.68}$	0.645	0.628	36	0.000	22	20	0.632	0.000	9	0.005	-166.01	%
	land usage/rainfall/slope	20~25%	$TP(mg/L)= 0.12\ Ur^{0.85}\ Ag^{0.00}\ Fo^{4.15}\ Gr^{-0.37}\ Wet^{0.42}\ Ba^{0.47}\ Wa^{-0.24}\ Ra^{-1.77}\ Sl^{-3.06}$	0.576	0.563	45	0.000	35	33	0.841	0.000	9	0.078	-195.62	%
	landusage/slope	25%~	$TP(mg/L)= 0.20\ Ur^{-0.69}\ Ag^{0.34}\ Fo^{1.91}\ Gr^{0.76}\ Wet^{-0.13}\ Ba^{0.59}\ Wa^{0.24}\ Sl^{-2.90}$	0.639	0.618	30	0.000	19	17	0.792	0.001	8	0.185	-71.99	%

For TP simulation, the results of the second step have weak relationships between water quality and watershed parameters. And the reasons for having high R^2 valules over 25% in the Han River watershed and over 25% in the Nakdong River watershed are because they have a very small degree of freedom compared to the number of parameters. Based upon the F-test results, all of the p-values are less than 0.05, hence, these Simple Equations were fitted to a data set well. However, the R^2 of this step's results are lower than first step's results. According to the Shapiro-wilk test, the null hypothesis that the predicted data are normally distributed is rejected such as; 20 ~ 25 % for the Han River watershed and total of Nakdong River and Geum-sum-youngsan River watershed. As for the rest of watersheds, the null hypothesis that the predicted data are normally distributed is not rejected.

As in the results of the second step, land usage and not imperviousness resulted in the large number of simple equations generated. The combination of land usage/rainfall/slope resulted in the largest number of equations relating water quality and watershed parameters, land usage and slope resulted in the second largest number of equations, and land usage alone resulted in the third largest number of eqautions. The correlations between imperviousness and water quality were the poorest and, in most cased did not result in any equations relating the parameters. These results are shown in Table 3-26.

Table 3-26: The number of best simple equations of each scenario for the second step.

Scenarios	Parameters			COD	BOD	T-N	T-P
1	Impervious						
2	Impervious	Pervious					
3	Impervious	Rainfall					
4	Impervious	Slope				1	
5	Impervious	Rainfall	Slope				
6	Slope						
7	Land Usage			2	2		2
8	Land Usage	Rainfall				1	1
9	Land Usage	Slope		3	4	2	3
10	Land Usage	Rainfall	Slope	4	3	5	3

[The results of the third step simple equations]

Tables 3-27 through 3-30 show the best simple equations derived from the third step of the analysis in chapter 3.4.3. These equations relate the standard watershed parameters (i.e. watershed land use, imperviousness, rainfall, slope, etc.) to the watershed's water quality as represented through COD, BOD, TN, and TP.

Table 3-27: The best simple equations for COD (mg/L) based on parameters and the area of three watersheds for the Third step.

Area	parameters	impervious	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Attribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Below 250km	land usage/slope	0~20%	$COD(mg/L)= 3.76\ Ur^{0.06}\ Ag^{0.25}\ Fo^{-0.40}\ Gr^{0.05}\ Wet^{0.07}\ Ba^{0.06}\ Wa^{0.06}\ Sl^{0.23}$	0.4192	0.4134	72.2	0.000	102	100	0.9742	0.0428	8	39.77	-80.07	%
	land usage/slope	20~25%	$COD(mg/L)= 8.17\ Ur^{0.30}\ Ag^{0.05}\ Fo^{0.00}\ Gr^{-0.24}\ Wet^{0.08}\ Ba^{-0.01}\ Wa^{-0.01}\ Sl^{-0.37}$	0.2524	0.2385	18.2	0.000	56	54	0.9765	0.3428	8	128.83	62.66	km2
	land usage/rainfall/slope	25%~	$COD(mg/L)= 7.43\ Ur^{-0.23}\ Ag^{0.05}\ Fo^{-1.00}\ Gr^{0.38}\ Wet^{0.04}\ Ba^{0.11}\ Wa^{-0.04}\ Ra^{0.65}\ Sl^{0.17}$	0.7719	0.7599	64.3	0.000	21	19	0.7954	0.0006	9	28.73	24.58	%
Above 250km	land usage	0~20%	$COD(mg/L)= 3.51\ Ur^{0.05}\ Ag^{0.19}\ Fo^{-0.16}\ Gr^{0.08}\ Wet^{0.05}\ Ba^{0.06}\ Wa^{0.07}$	0.481	0.4697	42.6	0.000	48	46	0.9788	0.5291	7	15.05	-41.67	%
	land usage/rainfall	20~25%	$COD(mg/L)= 6.86\ Ur^{0.40}\ Ag^{0.25}\ Fo^{-0.49}\ Gr^{-0.13}\ Wet^{0.09}\ Ba^{-0.08}\ Wa^{0.01}\ Ra^{0.01}$	0.3641	0.3442	18.3	0.000	35	33	0.9667	0.3767	8	42.15	22.51	%
	landusage/slope	25%~	$COD(mg/L)= 7.53\ Ur^{0.05}\ Ag^{-0.14}\ Fo^{0.36}\ Gr^{0.09}\ Wet^{-0.04}\ Ba^{0.20}\ Wa^{-0.18}\ Sl^{-0.52}$	0.0287	-0.06	0.3	0.580	8	6	0.9319	0.3606	8	76.93	34.11	%

Table 3-28: The best simple equations for BOD (mg/L) based on parameters and the area of three watersheds for the Third step.

Area	parameters	impervious	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Attribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Below $250km^2$	land usage/rainfall/slope	0~20%	$BOD(mg/L)= 3.60\ Ur^{0.17}\ Ag^{0.16}\ Fo^{0.26}\ Gr^{-0.03}\ Wet^{0.07}\ Ba^{0.02}\ Wa^{0.01}\ Ra^{-0.30}\ Sl^{-0.38}$	0.284	0.277	39.64	0.000	102	100	0.968	0.013	9	9.48	-224.35	%
	land usage/slope	20~25%	$BOD(mg/L)= 8.99\ Ur^{0.60}\ Ag^{0.01}\ Fo^{0.14}\ Gr^{-0.27}\ Wet^{0.07}\ Ba^{-0.01}\ Wa^{-0.32}\ Sl^{-0.86}$	0.379	0.368	32.98	0.000	56	54	0.938	0.007	8	43.83	2.28	km2
	land usage/rainfall	25%~	$BOD(mg/L)= 6.78\ Ur^{-0.07}\ Ag^{0.08}\ Fo^{-0.83}\ Gr^{0.40}\ Wet^{-0.06}\ Ba^{0.06}\ Wa^{-0.11}\ Ra^{0.41}$	0.846	0.838	104.20	0.000	21	19	0.675	0.000	8	14.09	7.62	%
Above $250km^2$	land usage/rainfall/slope	0~20%	$BOD(mg/L)= 4.21\ Ur^{0.17}\ Ag^{0.12}\ Fo^{-0.70}\ Gr^{-0.03}\ Wet^{0.06}\ Ba^{0.07}\ Wa^{0.03}\ Ra^{0.01}\ Sl^{0.47}$	0.465	0.453	39.96	0.000	48	46	0.979	0.525	9	3.29	-110.73	km2
	land usage/rainfall/slope	20~25%	$BOD(mg/L)= 5.10\ Ur^{0.82}\ Ag^{-0.12}\ Fo^{-0.26}\ Gr^{-0.01}\ Wet^{0.05}\ Ba^{-0.01}\ Wa^{-0.21}\ Ra^{0.39}\ Sl^{-0.88}$	0.606	0.594	49.29	0.000	35	33	0.873	0.001	9	11.91	-19.73	km2
	landusage/rainfall/slope	25%~	$BOD(mg/L)= 7.73\ Ur^{-2.41}\ Ag^{-3.16}\ Fo^{0.29}\ Gr^{-0.39}\ Wet^{-0.01}\ Ba^{0.66}\ Wa^{-0.73}\ Ra^{4.94}\ Sl^{-2.58}$	0.973	0.970	393.30	0.000	8	6	0.835	0.018	9	7.65	17.64	%

Table 3-29: The best simple equations for T-N (mg/L) based on parameters and the area of three watersheds for the Third step.

Area	parameters	impervious	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Attribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Below 250km	land usage/rainfall	0~20%	$TN(mg/L)= 6.87\ Ur^{0.40}\ Ag^{-0.08}\ Fo^{-0.03}\ Gr^{-0.16}\ Wet^{-0.01}\ Ba^{-0.02}\ Wa^{-0.13}\ Ra^{-0.23}$	0.255	0.247	34.1	0.000	102	100	0.931	0.000	8	50.23	-56.25	km2
	land usage/rainfall	20~25%	$TN(mg/L)= 5.45\ Ur^{0.56}\ Ag^{-0.17}\ Fo^{0.12}\ Gr^{-0.15}\ Wet^{0.01}\ Ba^{0.14}\ Wa^{-0.19}\ Ra^{-0.29}$	0.265	0.251	19.4	0.000	56	54	0.846	0.000	8	87.34	40.89	%
	land usage/rainfall	25%~	$TN(mg/L)= 6.97\ Ur^{-0.22}\ Ag^{-0.01}\ Fo^{-1.16}\ Gr^{0.53}\ Wet^{0.04}\ Ba^{0.31}\ Wa^{-0.05}\ Ra^{0.80}$	0.802	0.792	77.1	0.000	21	19	0.766	0.000	8	57.83	37.27	%
Above 250km	land usage/rainfall/slope	0~20%	$TN(mg/L)= 2.62\ Ur^{0.09}\ Ag^{0.26}\ Fo^{-0.04}\ Gr^{-0.09}\ Wet^{-0.17}\ Ba^{0.17}\ Wa^{-0.20}\ Ra^{-0.41}\ Sl^{0.28}$	0.227	0.210	13.5	0.001	48	46	0.986	0.812	9	22.427	-18.52	km2
	land usage/slope	20~25%	$TN(mg/L)= 5.41\ Ur^{0.35}\ Ag^{0.51}\ Fo^{-0.44}\ Gr^{-0.37}\ Wet^{0.03}\ Ba^{0.40}\ Wa^{-0.37}\ Sl^{-0.29}$	0.480	0.464	29.5	0.000	34	32	0.946	0.093	8	28.37	9.85	km2
	landusage/rainfall/slope	25%~	$TN(mg/L)= 7.62\ Ur^{0.70}\ Ag^{-0.34}\ Fo^{0.25}\ Gr^{0.53}\ Wet^{0.01}\ Ba^{-0.02}\ Wa^{-0.19}\ Ra^{0.26}\ Sl^{-1.51}$	0.939	0.934	170.2	0.000	13	11	0.803	0.007	9	22.4	25.07	km2

Table 3-30: The best simple equations for T-P (mg/L) based on parameters and the area of three watersheds for the Third step.

Area	parameters	impervious	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Attribute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Below 250km	impervious/rainfall/slope	0~20%	$TP(mg/L) = 19.54\ IP^{-0.14}\ Ra^{-0.19}\ Sl^{-1.38}$	0.077	0.068	8.4	0.005	102	100	0.974	0.038	8	0.09	-703.45	km2
	slope	20~25%	$TP(mg/L) = 11.81\ Sl^{-1.65}$	0.000	-0.019	0.0	0.984	56	54	0.690	0.000	8	0.73	-226.75	km2
	pervious/impervious	25%~	$TP(mg/L) = 6.30\ P^{-1.86}\ IP^{1.25}$	0.322	0.286	9.0	0.007	21	19	0.780	0.000	9	1.85	-33.03	%
Above 250km	pervious/impervious	0~20%	$TP(mg/L) = 76.42\ P^{-4.06}\ IP^{3.68}$	0.122	0.103	6.4	0.015	48	46	0.964	0.146	7	0.04	-328.53	km2
	land usage/rainfall/slope	20~25%	$TP(mg/L) = 5.55\ Ur^{0.78}\ Ag^{0.47}\ Fo^{-2.26}\ Gr^{-0.51}\ Wet^{0.08}\ Ba^{0.50}\ Wa^{-0.96}\ Ra^{0.73}\ Sl^{-0.19}$	0.698	0.689	74.0	0.000	35	33	0.835	0.000	8	0.06	-209.64	%
	landusage/slope	25%~	$TP(mg/L) = 8.88\ Ur^{1.33}\ Ag^{-0.55}\ Fo^{0.23}\ Gr^{-0.86}\ Wet^{0.59}\ Ba^{-0.21}\ Wa^{-0.18}\ Sl^{-1.68}$	0.937	0.932	164.4	0.000	8	6	0.743	0.002	8	0.14	-16.13	%

The results of the third step resulted in poor values of R^2, thus the simple equations derived from the third step's methodology should not be used to relate watershed characteristics to water quality parameters because the correlations between the parameters are poor and the relationships are not suitable.

An overall comparison of the statistical results of the equations generated through the methodologies in analysis steps first, second, and third, show that the strongest equations are those derived in step first. Therefore, the first step's simple equations are the best of the simple equations and should be used for predicting the future water quality in South Korea for each standard sub-watershed according to analyses undertaken using the Excel Solver tool.

3.7.3 STATISTICAL ANALYSIS SYSTEM (SAS)

An additional analysis was undertaken using SAS to correlate water quality parameters to watershed parameters. The "SAS 8.02" software was used to perform regression analysis between watershed parameters and water quality. Factor analysis was implemented to describe the variability among observed data and determinded the parameter priorities as they relate to impacts on water quality. The code shown in Figure 3-18 below was used.

```
DATA thesis1.First_han_200below ;
 SET thesis1.First_han_200below ;
 LABEL ID='water quality survey point' a1='urban'
            a2='agriculture' a3='forest' a4='grass' a5='wetland'
            a6='barren' a7='water' ;
RUN;
PROC FACTOR DATA=First_han_200below OUTSTAT=thesis1.First_han_200belowout
SIMPLE1) CORR2) SCREE3)
        MINEIGEN=1 4)  ;
    VAR area pervious impervious rainfall slope a1-a7 BOD COD TN TP;
 RUN:
PROC PRINT DATA=First_han_200belowout label ;
RUN ;
```

1) SIMPLE: command to print out mean and standard deviation

2) CORR: for multivariate data, the sample correlations are provided as well as sample means and standard deviation of each variable.

3) SCREE: print out scree picture for each factor's eigenvalue

4) MINEIGEN=1: set the minimum eigenvalue as one

Figure 3-18: Factor analysis examples for first step, below 200km^2 in the Han-river watershed.

Based upon correlations results for BOD, COD, TN, and TP, the resulting parameter combinations with correlations over 0.5 were chosen (bold values were selected in Figure 3-19). If there were no results with correlations over 0.5, the two or three parameters with the strongest correlations were choosen.

Means and Standard Deviations from 22 Observations

Variable	Mean	Std Dev
area	118.63038	42.014756
pervious	91.47630	35.617895
impervious	27.15174	9.784867
rainfall	103.30151	6.367717
slope	27.69864	11.374213
a1	12.70232	16.370477
a2	25.90418	13.552582
a3	72.15588	42.289050
a4	2.17758	1.907685
a5	0.66380	0.837642
a6	1.87833	1.470666
a7	3.14595	3.046465
BOD	2.40182	2.522827
COD	3.97000	2.735072
TN	4.18977	3.884045
TP	0.19215	0.387311

Figure 3-19: Mean and standard deviation for first step, below 200km^2 in the Han-river watershed.

Correlations					
		BOD	COD	TN	TP
area	area	0.05467	0.04801	-0.03589	0.07954
pervious	pervious	-0.11685	-0.12572	-0.20416	-0.09007
impervious	impervious	**0.65959**	**0.66323**	**0.58850**	**0.66884**
rainfall	rainfall	0.23548	0.22133	0.19241	0.09040
slope	slope	-0.54583	-0.59897	-0.50919	-0.47123
a1	urban	**0.88137**	**0.90186**	**0.89691**	**0.84966**
a2	agriculture	0.05197	0.05239	-0.05055	0.06670
a3	forest	-0.34486	-0.37039	-0.40169	-0.30967
a4	grass	0.43312	0.47729	0.38747	0.45946
a5	wetland	-0.12422	-0.04831	-0.17653	-0.14145
a6	barren	**0.78164**	**0.80128**	**0.77551**	**0.73040**
a7	water	-0.04219	0.05017	-0.08394	-0.07012
BOD	BOD	1.00000	0.98573	0.97697	0.97065
COD	COD	0.98573	1.00000	0.96866	0.96471
TN	TN	0.97697	0.96866	1.00000	0.97406
TP	TP	0.97065	0.96471	0.97406	1.00000

Figure 3-20: Correlations between parameters and water quality for first step, below 200km^2 in the Han-river watershed.

Using the selected parameters, statistical multiple regression was performed using the following SAS code.

```
PROC REG DATA=thesis1.First_200below ;
    model BOD = impervious a1 a6 /collin vif tol ;
    RUN;
PROC REG DATA=thesis1.First_200below ;
    model COD = impervious a1 a6 /collin vif tol ;
    RUN;
PROC REG DATA=thesis1.third_per_250o_25over ;
    model TN = impervious a1 a6 /collin vif tol ;
    RUN;
PROC REG DATA=thesis1.third_per_250o_25over ;
    model TP = impervious a1 a6 /collin vif tol ;
    RUN;
```

PROC REG: Estimates the coefficients of a multiple regression and their standard errors are provided
Collin: prints multicollinearity
vif: prints the variance inflation factor for each parameter estimate
tol: prints the tolerance

Figure 3-21: Regression analysis code for first step, below 200km^2 in the Han-river watershed.

After implementing the regression analysis procedure, the results shown in Figure 3-22 were obtained.

The REG Procedure
Model: MODEL1
Dependent Variable: BOD BOD
Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Pr > F
Model	3	109.90871	36.63624	27.77	<.0001
Error	18	23.74902	1.31939		
Corrected Total	21	133.65773			

Root MSE	1.14865	R-Square	0.8223
Dependent Mean	2.40182	Adj R-Sq	0.7927
Coeff Var	47.82406		

Parameter Estimates

Label	DF	Parameter Estimate	Standard Error	t Value	Pr > |t|	Tolerance	Variance Inflation
Intercept	1	-0.82862	0.77558	-1.07	0.2995	.	0
impervious	1	0.07385	0.03572	2.07	0.0534	0.51432	1.94430
urban	1	0.12744	0.02947	4.33	0.0004	0.27002	3.70346
barren	1	-0.20956	0.37897	-0.55	0.5871	0.20226	4.94402

Figure 3-22: Regression analysis code for first step, below $200km^2$ in the Han-river watershed.

The models for BOD, COD, TN, and TP in relation with available parameters could be calculated by following the procedures mentioned above. For instance, the following function shown in equation 11 gave the BOD model in the Han-river of $200km^2$ below watershed. Based on Figure 3-22, p-value (Pr) is less than 0.05, and multicollinearity doesn't need to be considered because the tolerance is over 0.1 and Variance Inflation is less than 10 based upon the Kim (2011).

$$BOD\ (mg/L) = -0.82862 + 0.07385 * impervious + 0.12744 * urban - 0.20956 * barren$$

Equation 24

Based upon the abovementioned procedures, a variety of regression functions were examined and evaluated. Among them, the best simple equations (regression analysis) are shown in Tables 3-31 to 3-34. These tables include the statistical coefficients of each statistical model used. The first case of the analysis in chapter 3.4.1, which is the area allocation of a sub-watershed, could acquire the best coefficient when compared with the second and third step, which were the percentage of imperviousness in chapter 3.4.2, both area allocations and the percentage of imperviousness in chapter 3.4.3, respectively. These results show the same tendencies in the results as were determined using EXCEL SOLVER. Thus, these equations could also be used to predict the concentrations (mg/L) of BOD, COD, TN, and TP depending on the areas of standard sub-watersheds. For instance, the equations can be used for standard sub-watershed within the Geum-Sum-Youngsan River watershed with the following areas: below 100 km^2, 100 to 150 km^2, 150 to 200 km^2, and over 200 km^2. They can also be used for the Han River and Nakdong River watersheds for the following areas: below 200 km^2, 200 to 500 km^2, and over 500 km^2.

According to the statistical analysis of the simple equations for BOD (mg/L), the range of RMSE was 0.392 to 1.908, R^2 was 0.427 to 0.854, adjusted R^2 was 0.267 to 0.801, and the p-value is almost lower than 0.05 except in the case of the Geum-Sum-Youngsan River's sub-watershed below 100 km^2. Most of the simple equations were within the criteria in which multicollinearity did not occur, except the Geum-Sum-Youngsan River, which was over the 200km^2 scenario based on the criteria of the tolerance (tol) and variance inflation factor (vif), which were below 0.1 and over 10, respectively.

Table 3-31: The simple equations (BOD) based upon regression analysis using SAS.

Watershed	Cases	Scenarios	Equations	RMSE	R^2	Adj R^2	coeff var	p-value	tol	vif
Geum-Sum-Youngsan-river	first(km)	100 below	BOD= 0.218 + 0.080 imp + 0.017 ag + 0.215 we	0.720	0.436	0.267	32.318	0.1121	0.75598 0.65237 0.54489	1.32278 1.53287 1.83523
	first(%)	100-150	BOD= -7.682 + 0.458 imp - 0.054 ur + 0.006 gr + 0.099 ba	0.905	0.770	0.667	41.572	0.006	0.13947 0.06820 0.34954 0.15016	7.17009 14.66381 2.86088 6.65934
		150-200	BOD= 0.116 + 0.026 imp + 0.036 ag + 0.415 wa	0.744	0.651	0.476	31.397	0.08	0.16515 0.14073 0.62690	7.10573 1.59514
		200 over	BOD= 1.041 - 0.090 imp + 0.164 ur + 0.058 ag + 0.469 ba	0.700	0.744	0.711	34.177	<.0001	0.00927 0.03920 0.02271 0.43282	107.88533 25.50841 44.03676 2.31044
Han-river	first(km)	200 below	BOD= -0.829 + 0.074 imp + 0.127 ur - 0.210 ba	1.149	0.822	0.793	47.824	<.0001	0.51432 0.27002 0.20226	1.94430 3.70346 4.94402
	first(%)	200~500	BOD= 4.322 - 0.296 imp + 0.298 ur + 1.867 ba	1.908	0.842	0.818	61.424	<.0002	0.10321 0.12300 0.39578	9.68944 8.13036 2.52663
		500 over	BOD= 0.030 + 0.003 imp + 0.187 ur + 0.262 gr + 0.242 ba	0.392	0.854	0.801	30.596	0.0001	0.34282 0.30225 0.43529 0.52463	2.91701 3.30850 2.29732 1.90612
Nak-river	first(per)	200 below	BOD= -2.742 + 0.217 imp	0.760	0.427	0.397	34.475	0.0013	1.000	1.000
		200~500	BOD= 1.799 - 0.056 imp + 0.061 ur + 0.664 gr	0.700	0.471	0.414	42.663	0.0004	0.31338 0.23590 0.26163	3.19099 4.23917 3.82220
	first(km)	500 over	BOD= -0.020 - 0.004 ur - 0.026 gr + 0.108 we + 0.115 wa	0.534	0.777	0.628	38.427	0.0372	0.18933 0.13205 0.08443 0.08840	5.28167 7.57290 11.84382 11.31225

Table 3-32: The simple equations (COD) based upon regression analysis using SAS.

watershed	Cases	Scenarios	Equations	RMSE	R^2	Adj R^2	coeff var	p-value	tol	vif
Geum-Sum-Youngsan-river	first(km)	100 below	COD= 2.231 + 0.023 ag + 0.945 we + 0.562 wa	0.985	0.700	0.609	21.527	0.0057	0.55441 0.64430 0.83002	1.80373 1.55206 1.20479
	first(%)	100-150	COD= -14.540 + 0.924 imp - 0.363 ur + 0.078 ga + 0.664 ba	1.363	0.800	0.711	28.941	0.0033	0.13947 0.06820 0.34954 0.15016	7.17009 14.66381 2.86088 6.65934
	first(km)	150-200	COD= 1.870 + 0.017 ag + 0.850 wa	0.774	0.770	0.705	15.676	0.08	0.47767 0.41484 0.79793	2.09351 2.41056 1.25325
	first(%)	200 over	COD= 13.917 - 0.880 imp + 0.376 ur + 0.221 ag + 1.443 ba	0.701	0.827	0.805	15.950	<.0001	0.00927 0.03920 0.02271 0.43282	107.88533 25.50841 44.03676 2.31044
Han-river	first(km)	200 below	COD= 0.504 + 0.075 imp + 0.140 ur - 0.185 ba	1.128	0.854	0.830	28.423	<.0001	0.51432 0.27002 0.20226	1.94430 3.70346 4.94402
	first(%)	200~500	COD= -0.160 + 0.089 imp + 0.123 ur + 1.164 ba	1.007	0.919	0.906	23.674	<.0001	0.10321 0.12300 0.39578	9.68944 8.13036 2.52663
		500 over	COD= -1.649 + 0.205 imp + 0.169 ag - 0.039 ag + 0.638 gr	0.466	0.904	0.869	16.241	0.0001	0.34282 0.30225 0.43529 0.52463	2.91701 3.30850 2.29732 1.90612
Nak-river	first(per)	200 below	COD= -4.009 + 0.404 imp	1.396	0.433	0.403	26.886	0.0013	1.000	1.000
		200~500	COD= 3.042 - 0.062 imp + 0.130 ur + 1.373 gr	1.406	0.538	0.489	36.242	0.0004	0.31338 0.23590 0.26163	3.19099 4.23917 3.82220
		500 over	COD= -1.758 + 0.003 ar + 0.658 gr + 0.916 we + 1.266 wa	1.071	0.799	0.664	29.701	0.0441	0.46770 0.21932 0.19118 0.21798	2.13811 4.55945 5.23075 4.58750

According to the statistical analysis of the simple equations for COD (mg/L), the range of RMSE was 0.466 to 1.406, R^2 was 0.433 to 0.854, adjusted R^2 was 0.403 to 0.906, p-value was almost lower than 0.05, except in the case of the Geum-Sum-Youngsan River's 150 to 200 km^2 area and Nakdong River's over 500 km^2 scenarios. The multicollinary value is almost satisfied within the criteria except Geum-Sum-Youngsan River's over 200km^2 scenarios as was found with the BOD simple equations.

Table 3-33: The simple equations (TN) based upon regression analysis using SAS.

watershed	Cases	Scenarios	Equations	RMSE	R^2	Adj R^2	coeff var	p-value	tol	vif
Geum-Sum-Youngsan-river	first(km)	100 below	TN= 0.690 + 0.098 imp + 0.922 we	1.000	0.445	0.345	32.203	0.039	0.75639 0.75639	1.32206 1.32206
		100-150	TN= -6.839 + 0.299 imp + 0.038 ur + 1.129 ba	0.839	0.933	0.913	21.325	<.0001	0.28627 0.08394 0.14761	3.49317 11.91298 6.77456
		150-200	TN= 2.063 + 0.011 ag + 0.250 wa	0.762	0.335	0.145	23.468	0.240	0.86407 0.86407	1.15731 1.15731
	first(%)	200 over	TN= 5.393 - 0.363 imp + 0.285 ur + 0.110 ag + 0.760 ba	0.913	0.700	0.662	32.903	<.0001	0.00927 0.03920 0.02271 0.43282	107.88533 25.50841 44.03676 2.31044
Han-river	first(km)	200 below	TN= 0.232 + 0.064 imp + 0.210 ur + -0.244 ba	1.788	0.818	0.788	42.673	<.0001	0.51432 0.27002 0.20226	1.94430 3.70346 4.94402
		200~500	TN= 2.563 - 0.018 imp + 0.136 ur + 0.049 ba	1.783	0.895	0.879	36.164	<.0001	0.36232 0.34358 0.38673	2.76002 2.91049 2.58581
	first(%)	500 over	TN= -0.082 + 0.103 imp + 0.124 ur - 0.039 gr + 0.308 ba	0.676	0.618	0.480	26.326	0.022	0.34282 0.30225 0.43529 0.52463	2.91701 3.30850 2.29732 1.90612
Nak-river	first(%)	200 below	TN= -0.221 + 0.142 imp	0.841	0.206	0.164	27.952	0.039	1.000	1.000
	first(km)	200~500	TN= 2.352 - 0.009 imp + 0.079 ur - 0.079 gr	1.183	0.445	0.385	43.977	0.001	0.77809 0.43720 0.38797	1.28520 2.28729 2.57754
	first(%)	500 over	TN= -1.310 + 0.002 ar + 0.107 ag	0.945	0.638	0.548	32.565	0.017	0.99925 0.99925	1.00075 1.00075

The statistical analysis of the simple equations for TN (mg/L) acquired the following results: RMSE ranged from 0.676 to 1.788, R^2 ranged from 0.206 to 0.933, adjust R^2 ranged from 0.164 ~ 0.933, the p-value of Geum-Sum-Youngsan river's 150 to 200 km^2 was over 0.05 and the others were less than 0.05. The multicollinary value is almost satisfied within the criteria except Geum-Sum-Youngsan river's over $200km^2$ scenarios as was found for the BOD simple equations.

The statistical analysis of the simple equations for TP (mg/L) acquired the following results, RMSE ranged from 0.025 to 0.189, R^2 ranged from 0.151 to 0.960, adjust R^2 ranged from 0.106 ~ 0.899, and the p-value was over 0.05 with Geum-Sum-Youngsan River's over 200 km^2 and Nakdong river's below 200 km^2 scenarios. Multicollinary value is almost satisfied within the criteria except in the case of the Geum-Sum-Youngsan River's over $200km^2$ and Nakdonf river's over 500 km^2 scenarios.

Table 3-34: The simple equations (TP) based upon regression analysis using SAS.

watershed	Cases	Scenarios	Equations	RMSE	R^2	Adj R^2	coeff var	p-value	tol	vif
Geum-Sum-Youngsan-river	first(km)	100 below	TP= 0.018 + 0.000 ag + 0.067 we + 0.01468 wa	0.041	0.666	0.565	40.012	0.010	0.55441 0.64430 0.83002	1.80373 1.55206 1.20479
		100-150	TP= -0.230 + 0.008 imp + 0.015 ur + 0.000734 gr + 0.027 ba	0.057	0.908	0.868	40.677	0.000	0.28302 0.08389 0.53288 0.13644	3.53336 11.92074 1.87659 7.32915
	first(%)	150-200	TP= 0.184 - 0.011 imp + 0.007 ag	0.119	0.383	0.207	82.968	0.080	0.16515 0.14073 0.62690	6.05514 7.10573 1.59514
		200 over	TP= 0.105 - 0.012 imp + 0.018 ur + 0.00405 ag + 0.038 ba	0.058	0.719	0.682	62.076	<.0001	0.00927 0.03920 0.02271 0.43282	107.88533 25.50841 44.03676 2.31044
Han-river	first(km)	200 below	TP= -0.338 + 0.015 imp + 0.021 ur + -0.0748 ba	0.189	0.795	0.761	98.568	<.0001	0.51432 0.27002 0.20226	1.94430 3.70346 4.94402
		200~500	TP= 0.072 - 0.002 imp + 0.010 ur + 0.01011 ba	0.152	0.868	0.847	71.221	<.0001	0.36232 0.34358 0.38673	2.76002 2.91049 2.58581
	first(%)	500 over	TP= -0.007 + 0.00004 imp + 0.007 ur + 0.01583 gr + 0.007 ba	0.021	0.800	0.727	46.578	0.001	0.34282 0.30225 0.43529 0.52463	2.91701 3.30850 2.29732 1.90612
Nak-river	first(km)	200 below	TP= -0.111 + 0.010 imp	0.074	0.151	0.106	59.354	0.451	0.82642 0.82642	1.21004 1.21004
		200~500	TP= 0.090 - 0.001 imp + 0.006 ur + 0.003 gr	0.074	0.587	0.543	74.154	0.001	0.77809 0.43720 0.38797	1.28520 2.28729 2.57754
		500 over	TP= -0.052 + 0.001 imp - 0.001 ur - 0.00010 ag - 0.002 gr - 0.020 we + 0.015 wa	0.025	0.960	0.899	28.410	0.009	0.04364 0.15002 0.10024 0.04770 0.07979 0.06523	22.91369 6.66583 9.97600 20.96563 12.53244 15.32989

In conclusion, it is determined using the methodology carried out by the SAS program as the R^2 values obtained for the data correlations were smaller than those obtained through other methods like the Excel Solver method.

3.7.4 MODEL TREE 5, ANN (ARTIFICIAL NEURAL NETWORK), RBF

Three methods used to generate equations relating watershed parameters to water quality parameters utilized the Weka Software. The Weka Software was used for building the Model Tree, the ANN, and the RBF. Version 3.4.4 (Figure 3-23) was used in the analysis. In this research, the input files were constructed based upon three steps which were already mentioned in chapter 3.3 (Table 3-35).

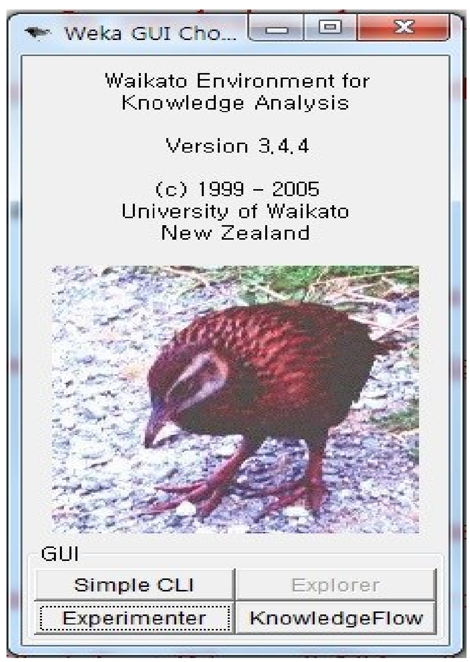


Figure 3-23: Weka Software (Verson 3.4.4).

Table 3-35: Data classification and scenarios for Model Tree, ANN, RBF.

step	Watershed	range	km, percent of land use	scenarios	total Scenarios
First (area)	Han river watershed	Below 200 km^2	(01) Km (land use), (02)Percent (land use)	(01) imp (02) imp, per (03) imp, ra (04) imp, ra, sl (05) imp, sl (06) sl (07) land (08) land, ra (09) land, sl (10) land, ra, sl	60 (han) 60(Nak) 80(GSY) Total:200
		200 ~ 500 km^2			
		Over 500 km^2			
	Nakdong river watershed	Below 200 km^2			
		200 ~ 500 km^2			
		Over 500 km^2			
	Geum-sum-youngsum river watershed	Below 100 km^2			
		100 ~ 150 km^2			
		150 ~ 200 km^2			
		Over 200 km^2			
Second (impervious)	Han river watershed	Below 20 %	(01) Km (land use), (02)Percent (land use)	(01) imp (02) imp, per (03) imp, ra (04) imp, ra, sl (05) imp, sl (06) sl (07) land (08) land, ra (09) land, sl (10) land, ra, sl	60 (han) 60(Nak) 60(GSY) Total:180
		20 ~ 25 %			
		Over 25%			
	Nakdong river watershed	Below 20 %			
		20 ~ 25 %			
		Over 25%			
	Geum-sum-youngsum river watershed	Below 20 %			
		20 ~ 25 %			
		Over 25%			
Third (area+impervious)	Below 250Km^2	Below 20 %	(01) Km (land use), (02)Percent (land use)	(01) imp (02) imp, per (03) imp, ra (04) imp, ra, sl (05) imp, sl (06) sl (07) land (08) land, ra (09) land, sl (10) land, ra, sl	60 (be250) 60(ov250) Total:120
		20 ~ 25 %			
		Over 25%			
	Over 250Km^2	Below 20 %			
		20 ~ 25 %			
		Over 25%			

*imp: impervious, per: pervious, ra: rain, sl: slope, land: land usage,
Land usage: urban, agriculture, forest, grass, wetland, barren, water (7 items)

The data file was opened in the preprocess board. This is shown in Figure 3-24. Statistical values such as minimum, maximum, mean, and standard deviation of the data were confirmed in the preprocessing stage. Weka Explorer was also displayed for each parameter.

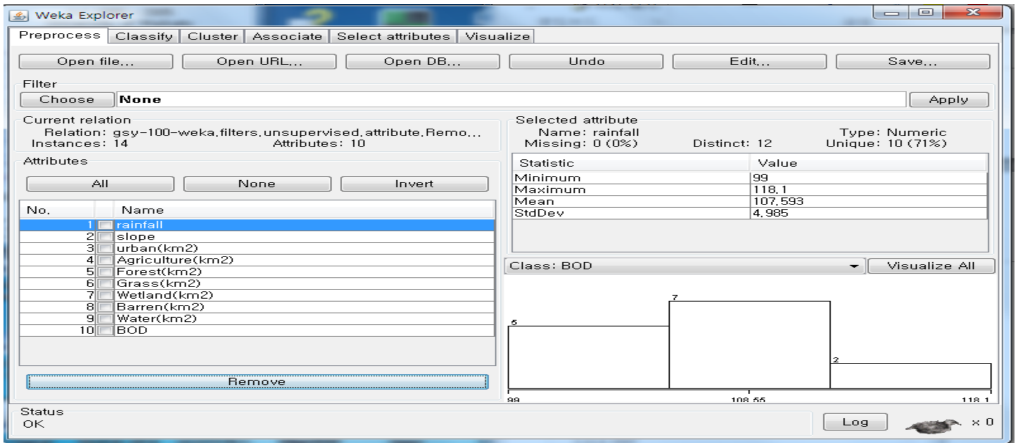


Figure 3-24: The preprocess to open the input file for Model Tree 5, ANN, RBF.

After selecting the data file, the Model Tree 5, ANN, and RBF model options were chosen in Weka Classify. This is shown in Figure 3-25.

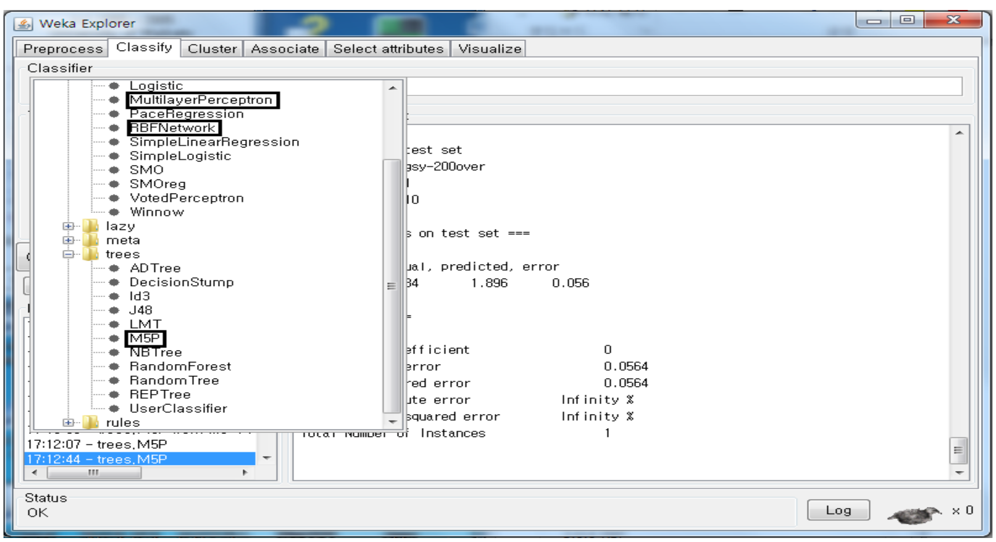
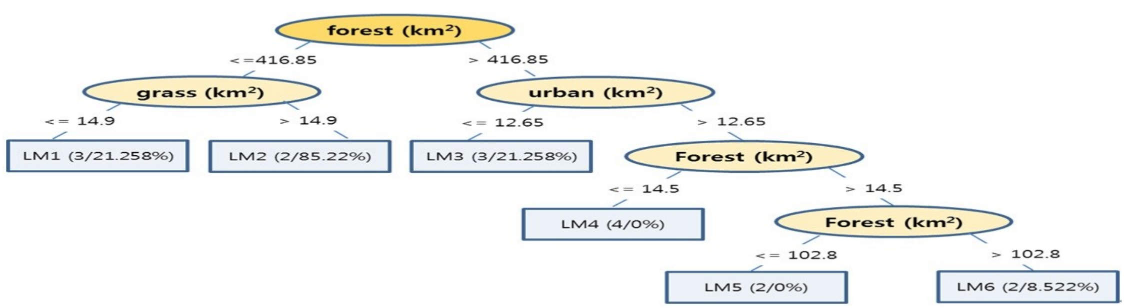


Figure 3-25: The classification scene to choose Model Tree 5, ANN, and RBF model.

There are four kinds of test options; use training set, used supplied test set, cross-validation, and percentage split. In this research, percentage split was chosen. Two thirds of the data (66%) were selected for calibration and the rest (34%) were used for verification. In order to compare the three models, Model Tree 5, ANN, and RBF model, for example, first step (area) – Han River watershed – km of land usage – 10 scenarios (see the Table 3-36) was applied.

In the case of Model Tree 5, the regression trees were tried not pruned and pruned to find optimization results. The minimum number of instances was set to 4 instances. The results of Model Tree 5 are shown at Figure 3-26. Verification could then be assured using the correlation coefficient, mean absolute error, root mean squared error, etc. as illustrated in Table 3-36. According to the statistical evaluation value, the correlation coefficient was 0.9872 and the mean absolute error was 0.3897. These measures indicate the equation is a reasonably applicable equation.



LM1	BOD(mg/L) = 0.0228 × urban(km^2) - 0.0011 × Forest(km^2) + 0.0532 × Grass(km^2) + 1.0866
LM2	BOD(mg/L) = 0.0228 × urban(km^2) - 0.0011 × Forest(km^2) + 0.0549 × Grass(km^2) + 1.1347
LM3	BOD(mg/L) = 0.0176 × urban(km^2)- 0.0009 × Forest(km^2)+ 0.0199 × Grass(km^2)+ 1.0422
LM4	BOD(mg/L) = 0.0006 × rainfall+ 0.0176 × urban(km^2) - 0.0009 × Forest(km^2) + 0.0199 × Grass(km^2)- 0.0003 × Water(km^2)+ 0.9968
LM5	BOD(mg/L) = 0.001 x rainfall+ 0.0176 × urban(km^2)- 0.0009 × Forest(km^2) + 0.0199 × Grass(km^2)- 0.0003 × Water(km^2)+ 0.9563
LM6	BOD(mg/L) = 0.001 × rainfall+ 0.0176 × urban(km^2) - 0.0009 × Forest(km^2) + 0.0199 × Grass(km^2)- 0.0003 × Water(km^2)+ 0.9568

Figure 3-26: Structure and linear models of Model Tree for Han River Watershed.

Table 3-36: The BOD result of verification using Model Tree .

Han River Watershed (over 500km^2)			
Number of Model	6		
Time taken to build model		0.02 seconds	
Predictions on test split			
Instance number	actual	predicted	Error
1	0.8	0.574	-0.226
2	1.4	1.843	0.443
3	1	0.902	-0.098
4	1.6	2.642	1.042
5	0.9	0.578	-0.322
6	0.8	0.592	-0.208
Correlation coefficient		0.9872	
Mean absolute error		0.3897	
Root mean squared error		0.4982	
Relative absolute error		101.6737 %	
Root relative squared error		112.8298 %	

The ANN model was built with MultilayerPerceptron. In order to make a condition for MultilayerPerceptron, training time, validation threshold were set to 700 iterations and 20, respectively. Learning rate and momentum were installed at 0.3 and 0.2. In order to optimize the results, several hidden layer values were input into the model. This neural network uses back-propagation to train the model. Figure 3-27 shows the model training process to try to determine the best value of each sigmoid Node.

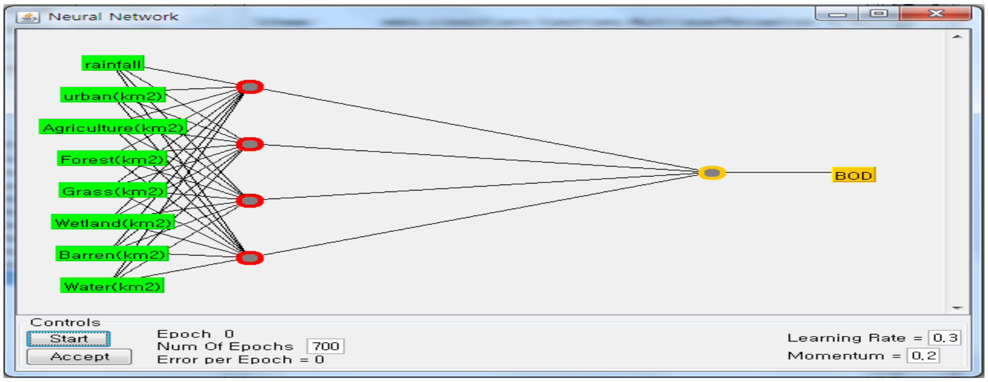


Figure 3-27: Structure of ANN with four hidden layers.

As in the case of the ANN scenario, two thirds of the data were used for training and calibration in the ANN training and the remaining data were used for calculated for verification same as Model Tree 5. The results of ANN processing are shown at Figure 3-28. These resulting data could be saved and applied to another supplied data set using "the Re-evaluate model on current test set" menu. In addition, verification could be assured using correlation coefficient, mean absolute error, root-mean squared error, etc. as shown in Table 3-37. According to the statistical evaluation, correlation coefficient was 0.7528 and the mean absolute error was 1.0297. These correlations indicate the resulting equation could be used to correlate watershed parameters and water quality. However, the equations determined using the Model Tree 5 methodology are stronger than those determined by ANN, and are therefore preferred.

```
=== Classifier model (full training set) ===

Linear Node 0
    Inputs    Weights
    Threshold    1.8622749989837082
    Node 1    -0.21940230009537384
    Node 2    -2.23255189052738
    Node 3    -0.6202904016938504
    Node 4    -0.34135450095104486
Sigmoid Node 1
    Inputs    Weights
    Threshold    -0.7360270615068755
    Attrib rainfall    -0.1139465968588408
    Attrib urban(km2)    0.33303280195517315
    Attrib Agriculture(km2)    -0.019795138003605314
    Attrib Forest(km2)    0.367797710083048
    Attrib Grass(km2)    0.15898404232619276
    Attrib Wetland(km2)    -0.36669851485770805
    Attrib Barren(km2)    -0.585618850560819
    Attrib Water(km2)    0.49681931588765066
Sigmoid Node 2
    Inputs    Weights
    Threshold    2.02543079184067
    Attrib rainfall    0.5705568302691448
    Attrib urban(km2)    -2.0320851218826936
    Attrib Agriculture(km2)    -0.5917153760451686
    Attrib Forest(km2)    1.0859168414123292
    Attrib Grass(km2)    -2.003568605239934
    Attrib Wetland(km2)    0.3636330381036232
    Attrib Barren(km2)    -0.9768696531212865
    Attrib Water(km2)    -0.6129437639777807
Sigmoid Node 3
    Inputs    Weights
    Threshold    0.07364216566072915
    Attrib rainfall    0.1694010483610415
    Attrib urban(km2)    0.10275601786731599
    Attrib Agriculture(km2)    0.4954698730996255
    Attrib Forest(km2)    0.257984550987477
    Attrib Grass(km2)    -0.1504141015367104
    Attrib Wetland(km2)    -0.780562333070119
    Attrib Barren(km2)    -0.06056344738700687
    Attrib Water(km2)    0.013978311691206292
Sigmoid Node 4
    Inputs    Weights
    Threshold    -0.9198120364007478
    Attrib rainfall    -0.09708242430119039
    Attrib urban(km2)    0.2771978368085623
    Attrib Agriculture(km2)    -0.10026262070524744
    Attrib Forest(km2)    0.4377005493812114
    Attrib Grass(km2)    0.35058832662335515
    Attrib Wetland(km2)    -0.38816459718986707
    Attrib Barren(km2)    -0.6408645248822346
    Attrib Water(km2)    0.42204597926064963
Class
    Input
    Node 0


Time taken to build model: 0.03 seconds
```

Figure 3-28: Classifier model using MultilayerPerceptron (ANN).

Table 3-37: The BOD result of verification using ANN.

Han River Watershed (over 500km^2)			
Number of Model	6		
Time taken to build model		0.03 seconds	
Predictions on test split			
Instance number	actual	predicted	Error
1	0.8	2.443	1.633
2	1.4	3.288	1.888
3	1	1.600	0.600
4	1.6	3.104	1.504
5	0.9	0.392	-0.508
6	0.8	0.754	-0.046
Correlation coefficient		0.7528	
Mean absolute error		1.0297	
Root mean squared error		1.2323	
Relative absolute error		268.6217 %	
Root relative squared error		279.0523 %	

The RBF model was built with the RBFNetwork which implements a normalized Gaussian radial basics function network. It uses the k-means clustering algorithm to provide the basics functions and learns either a logistic regression or linear regression. Clustering Seed, minimum standard deviation, and number of clusters were set to 1, 0.1 and 4, respectively. In order to optimize the results, the number of cluster values was input from 2 to 5 or 6.

For RBF training, two third of the data were used for calibration and the remaining data were used for verification as with Model Tree 5 and ANN processing. The results of RBF are shown in Figure 3-29 which could be saved and applied to another supplied data set using "the Re-evaluate model on current test set" menu. In addition, verification could be assured using the correlation coefficient, mean absolute error, roots mean squared error, etc. as shown in Table 3-38. According to the statistical evaluation, the correlation coefficient was 0.4521 and mean absolute error was 0.5387. The correlation coefficient for the RBF process is less than both those for the Model Tree 5 and ANN.

```
=== Classifier model (full training set) ===
Radial basis function network
(Linear regression applied to K-means clusters as basis functions):
Linear Regression Model
BOD =  -0.0459 * pCluster_0_0 +  0.0459 * pCluster_0_1 + 1.2872
Time taken to build model: 0.02 seconds
```

Figure 3-29: Classifier model using RBFNetwork.

Table 3-38: The BOD result of verification using RBF.

Han River Watershed (over 500km^2)			
Number of Model	6		
Time taken to build model		0.02 seconds	
Predictions on test split			
Instance number	actual	predicted	Error
1	0.8	1.952	1.152
2	1.4	1.960	0.560
3	1	0.840	-0.16
4	1.6	1.960	0.360
5	0.9	1.860	0.960
6	0.8	0.840	0.04
Correlation coefficient		0.4521	
Mean absolute error		0.5387	
Root mean squared error		0.6733	
Relative absolute error		140.5353 %	
Root relative squared error		152.4698 %	

A comparison of the three models used in the Weka software package (Model Tree 5, ANN, and RBF) shows that Model Tree 5 is the best model to relate BOD to watershed parameters of standard subwatershed areas 500km^2 in the Han River watershed.

Following the above-mentioned procedure, the best applicable simple equations of each watershed are shown in Tables 3-39 to 3-41.

Table 3-39: The evaluation results of First step's M5P, ANN, RBF (BOD, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden /cluster	Evaluation on test split						km^2/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(M5P)_100	9	14	2	0.9943	0.2044	0.2401	40.52%	42.45%	5	km
gsy(ANN)_150	2	14	6	0.959	1.1982	1.4216	67.07%	63.91%	5	km
gsy(ANN)_200	5	10	6	0.9374	0.3663	0.4321	38.89%	34.00%	4	km
gsy(RBF)_200over	7	36	6	0.9192	0.2501	0.3272	28.52%	35.09%	13	%
han(M5P)_200	2	22	1	0.9408	0.7205	1.0108	61.13%	79.48%	8	%
han(ANN)_500	5	23	7	0.9949	2.5715	4.3443	101.91%	146.32%	8	km
han(RBF)_500over	5	16	3	0.9682	0.2217	0.2957	57.84%	66.96%	6	km
nakdong(M5P)_200	3	21	2	0.7428	0.6569	0.6923	79.62%	77.21%	8	%
nakdong(ANN)_500	8	32	6	0.7651	0.5259	0.5861	68.98%	66.82%	11	km
nakdong(RBF)_500over	9	11	3	0.8828	0.3331	0.404	49.88%	49.07%	4	%

*C.C: Correlation coefficient, M.A.E: Mean absolute error, R.M.S.E: Root mean squared error,
R.A.E: Relative absolute error, R.R.S.E: Root relative squared error,
Total NO. of Instances: Total number of instances.

* Scenario 1: impervious, Scenario 2: Impervious + pervious
Scenario 3: Impervious + rainfall, Scenario 4: Impervious + rainfall + slope
Scenario 5: Impervious + slope Scenario 6: slope
Scenario 7: Land use Scenario 8: Land use + rainfall
Scenario 9: Land use + slope Scenario 10: Land use + rainfall + slope

Table 3-40: The evaluation results of Second step's M5P, ANN, RBF (BOD, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden/ cluster	Evaluation on test split						km^2/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(RBF)_20	8	22	3	0.8006	0.0769	0.0952	60.68%	64.86%	8	km
gsy(M5P)_25	4	35	16	0.7918	0.5101	0.5812	63.76%	63.57%	12	km
gsy(M5P)_25over	8	17	7	0.8349	1.368	1.7094	104.99%	122.68%	6	%
han(RBF)_20	8	22	3	0.7967	0.1335	0.1619	65.58%	70.65%	8	%
han(ANN)_25	9	19	7	0.8791	0.8319	1.0882	105.40%	123.76%	7	km
han(ANN)_25over	6	9	4	0.9734	2.1819	2.9446	35.28%	46.20%	4	%
nakdong(ANN)_20	3	21	2	0.7842	0.3947	0.5347	107.73%	118.51%	6	%
nakdong(ANN)_25	5	35	6	0.6889	0.7105	0.8348	101.13%	108.22%	12	%
nakdong(M5P)_25over	5	8	1	0.9991	0.2502	0.2997	43.63%	45.40%	3	%

Table 3-41: The evaluation results of Third step's M5P, ANN, RBF (BOD, mg/L).

Model	Scenario	No.of Instances	No.of Rules	Evaluation on test split						km^2/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
250km(RBF)_20per	5	23	5	0.7115	0.1341	0.1916	69.67%	65.40%	8	%
250km(RBF)_25per	6	53	4	0.7731	1.0049	1.1041	77.52%	70.24%	19	km
250km(ANN)_25over	3	13	4	0.8315	2.7585	3.5475	55.67%	54.34%	5	%
250over(ANN)_20per	8	53	4	0.5242	0.4451	0.5893	177.03%	189.75%	19	%
250over(RBF)_25per	3	41	4	0.8375	0.5184	0.6751	65.39%	70.55%	14	%
250over(ANN)_25over	9	13	6	0.941	2.5878	3.4387	52.23%	52.68%	5	km

When it comes to the BOD simple equations, the R value obtained using the first method was much higher than those obtained using the second and third methods except in the case of the second method's Nakdong River watershed for sub-watershed with over 25 % imperviousness. Therefore, as was the case with the Excel Solver results, the first method results can be applied to the Han River, Nakdong River, and Geum-Sum-Youngsan River watersheds. Additionally, the second methodology can be applied to the abovementiond specific condition which is shown in Figure 3-30.

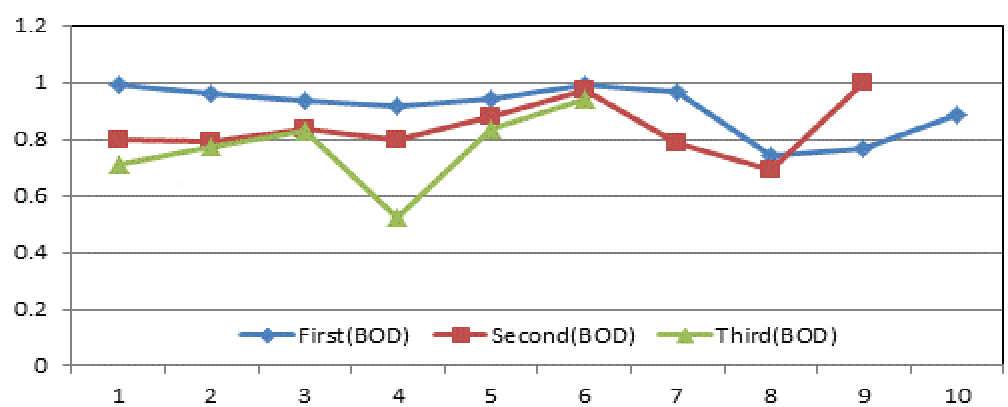


Figure 3-30: R value (BOD) of first, second, third scenarios using M5P, ANN, RBF.

Table 3-42: The evaluation results of First step's M5P, ANN, RBF (COD, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden /cluster	Evaluation on test split						km²/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(ANN)_100	7	14	7	0.9797	0.3207	0.437	20.30%	26.83%	5	km
gsy(ANN)_150	5	14	6	0.9486	0.8815	1.1354	26.62%	30.10%	5	km
gsy(ANN)_200	5	10	6	0.9787	0.4142	0.4792	33.14%	36.43%	4	km
gsy(ANN)_200over	6	36	6	0.9612	0.5482	0.6887	44.50%	50.16%	13	%
han(M5P)_200	4	22	1	0.9116	0.8383	0.9723	64.75%	65.25%	8	%
han(RBF)_500	1	23	3	0.983	1.5737	2.2918	76.80%	83.10%	8	km
han(M5P)_500over	3	16	2	0.9591	0.3172	0.3503	55.98%	55.46%	8	km
nakdong(M5P)_200	3	21	2	0.9591	0.3172	0.3503	55.98%	55.46%	6	km
nakdong(M5P)_500	6	23	2	0.7361	2.046	2.6269	99.84%	95.25%	8	km
nakdong(ANN)_500over	2	11	5	0.9471	0.5433	0.7336	41.91%	44.44%	4	%

Table 3-43: The evaluation results of Second step's M5P, ANN, RBF (COD, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden/ cluster	Evaluation on test split						km²/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(ANN)_20	9	22	5	0.7519	0.4453	0.5087	78.4%	74.4%	8	%
gsy(ANN)_25	4	35	2	0.7943	0.7779	1.014	54.3%	63.8%	12	%
gsy(RBF)_25over	5	17	4	0.6196	1.4373	1.7643	65.56%	73.23%	6	km
han(RBF)_20	8	33	5	0.8208	0.4132	0.453	85.48%	78.66%	12	%
han(RBF)_25	7	23	2	0.7997	0.956	1.198	91.88%	93.27%	7	%
han(ANN)_25over	9	9	6	0.995	2.1461	3.0918	55.7%	72.9%	4	km
nakdong(ANN)_20	4	21	6	0.7272	0.9333	1.2449	141.1%	156.1%	8	%
nakdong(RBF)_25	9	35	3	0.5036	1.2243	1.3252	90.44%	87.06%	12	km
nakdong(ANN)_25over	5	8	6	0.9826	1.0467	1.3161	71.7%	73.1%	3	km

Table 3-44: The evaluation results of Third step's M5P, ANN, RBF (COD, mg/L).

Model	Scenario	No.of Instances	No.of Rules	Evaluation on test split						km²/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
250km(RBF)_20per	8	23	2	0.8049	0.8907	1.0529	97.70%	98.17%	8	%
250km(ANN)_25per	4	53	2	0.9123	2.3575	2.7006	88.96%	86.05%	19	%
250km(RBF)_25over	7	13	2	0.976	0.7985	0.9599	30.13%	30.58%	5	%
250over(M5P)_20per	1	53	23	0.3957	0.481	0.6694	100.67%	104.31%	19	%
250over(RBF)_25per	1	41	2	0.7511	2.2422	2.5397	84.61%	80.92%	14	%
250over(RBF)_25over	7	13	2	0.976	0.7985	0.9599	30.13%	30.58%	5	%

In case of the developed COD simple equations, the R value trend is similar to the trend of the BOD simple equations. The first methodology produces much higher correlations than the second and third methods except in the case of the second methodology's Nakdong River watershed for sub-watershed with imperviousness over 25 %. The first methodology for COD simulation can be applied to the Han River, Nakdong River, and Geum-Sum-Youngsan River watersheds. Additionally, the results from the second scenarios can be applied to the abovementioned specific condition which is shown in Figure 3-31.

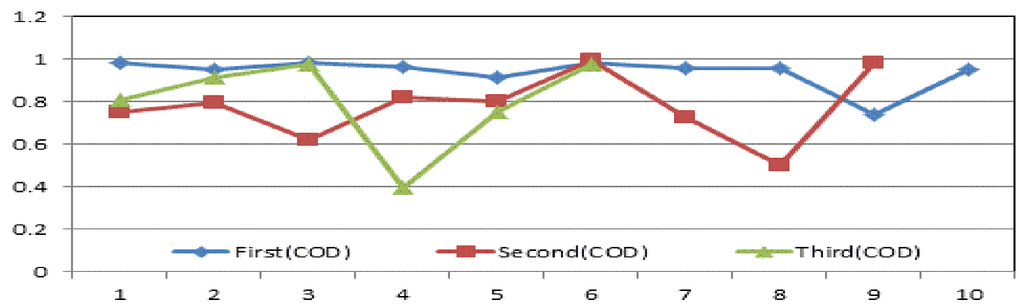


Figure 3-31: R value (COD) of first, second, third scenarios using M5P, ANN, RBF.

The average R values were 0.820, 0.819, and 0.818 with the first, second, and third methodologies as shown in Figure 3-32. Based on these strong correlations, the equations derived using these three methods can be applied to simulate TN concentration of the watershed and depend on the watershed's case.

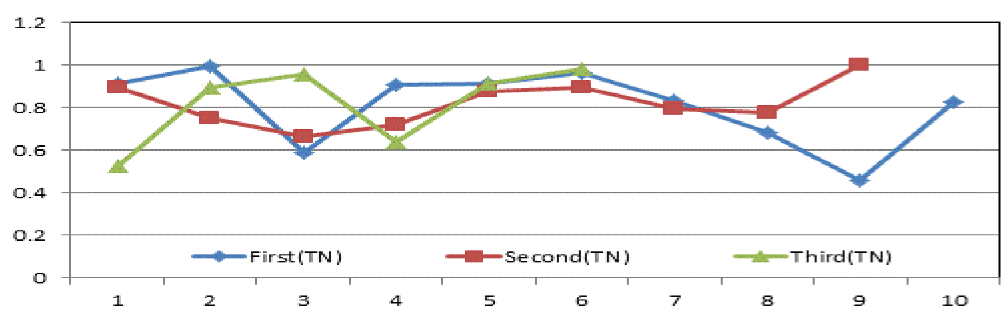


Figure 3-32: R value (TN) of first, second, third scenarios using M5P, ANN, RBF.

Table 3-45: The evaluation results of First step's M5P, ANN, RBF (TN, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden /cluster	Evaluation on test split						km²/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(ANN)_100	9	14	7	0.9138	0.754	0.9051	53.44%	58.59%	5	km
gsy(ANN)_150	1	14	7	0.9955	1.5211	1.9738	45.81%	43.62%	5	%
gsy(RBF)_200	8	10	2	0.5868	0.3753	0.4215	94.12%	87.23%	4	km
gsy(M5P)_200over	10	36	15	0.9092	0.5854	0.6454	50.50%	52.78%	13	km
han(RBF)_200	2	22	2	0.9099	1.2393	1.9347	64.26%	95.81%	8	%
han(M5P)_500	10	23	2	0.9598	1.3066	1.7262	35.71%	32.92%	8	km
han(RBF)_500over	7	16	6	0.8338	0.4062	0.6188	85.64%	84.98%	6	km
nakdong(RBF)_200	5	21	5	0.6812	0.6489	0.7179	90.58%	90.35%	8	km
nakdong(RBF)_500	7	32	2	0.4579	1.0166	1.1383	92.86%	88.67%	11	%
nakdong(ANN)_500over	9	11	6	0.8285	0.7515	0.8961	48.21%	47.84%	4	%

Table 3-46: The evaluation results of Second step's M5P, ANN, RBF (TN, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden/ cluster	Evaluation on test split						km²/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(ANN)_20	7	22	4	0.8942	0.5527	0.7501	126.43%	119.92%	8	%
gsy(RBF)_25	8	35	4	0.7486	0.7202	0.8525	61.10%	61.56%	12	%
gsy(RBF)_25over	4	17	4	0.664	1.6691	2.9519	78.55%	91.11%	4	%
han(RBF)_20	3	33	2	0.7221	0.4084	0.5836	72.21%	83.97%	12	%
han(RBF)_25	9	23	4	0.8748	0.432	0.492	40.13%	40.79%	8	km
han(ANN)_25over	9	9	6	0.8916	8.437	8.7956	99.34%	102.88%	4	km
nakdong(RBF)_20	7	21	4	0.7955	0.3386	0.4633	59.88%	72.03%	8	km
nakdong(RBF)_25	2	35	4	0.7777	0.6232	0.7031	77.23%	78.96%	12	%
nakdong(ANN)_25over	4	8	3	1	0.8764	1.2363	58.59%	58.30%	4	%

Table 3-47: The evaluation results of Third step's M5P, ANN, RBF (TN, mg/L).

Model	Scenario	No.of Instances	No.of Rules	Evaluation on test split						km²/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
250km(RBF)_20per	3	23	4	0.5258	0.4649	0.6059	75.18%	78.15%	8	km
250km(RBF)_25per	6	53	4	0.8968	1.3994	1.4847	62.48%	58.47%	19	km
250km(M5P)_25over	10	13	6	0.9569	1.5245	2.1475	25.50%	31.22%	5	%
250over(RBF)_20per	10	53	2	0.6396	0.6283	0.7472	93.94%	91.54%	12	%
250over(ANN)_25per	9	41	7	0.9108	2.2629	2.9337	37.85%	42.65%	14	km
250over(ANN)_25over	7	13	7	0.9786	1.3111	1.5207	21.93%	22.11%	5	km

TP simple equations displayed different results for BOD, COD, and TN as shown in Figure 3-33. First step's R value was higher for the Han River and Geum-Sum-Youngsum River watersheds and lower for the Nakdong river watershed than the second step's R. Therefore for TP simulation, the first and second methods results can be applied to Han River, Geum-Sum-Youngsan River, and Nakdong river watershed, respectively. Third step's results are not applicable as they lack consistency.

Table 3-48: The evaluation results of First step's M5P, ANN, RBF (TP, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden /cluster	Evaluation on test split						km^2/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(RBF)_100	8	14	2	0.9245	0.0377	0.0439	72.48%	70.32%	5	km
gsy(M5P)_150	9	14	5	0.9922	0.0318	0.0393	17.79%	16.61%	5	%
gsy(RBF)_200	8	10	2	0.9382	0.1176	0.1901	92.75%	93.70%	4	km
gsy(M5P)_200over	10	36	13	0.9697	0.0315	0.0521	48.55%	75.31%	13	km
han(RBF)_200	2	22	3	0.913	0.1151	0.1907	70.82%	108.95%	8	%
han(RBF)_500	9	23	4	0.9605	0.0639	0.0943	29.10%	30.85%	8	%
han(RBF)_500over	10	16	3	0.8286	0.0121	0.0136	72.86%	79.26%	6	%
nakdong(ANN)_200	3	21	5	0.7478	0.0718	0.0836	124.69%	136.00%	8	km
nakdong(RBF)_500	7	32	2	0.6127	0.0507	0.0606	88.35%	90.07%	11	%
nakdong(RBF)_500over	3	11	3	0.7268	0.0485	0.0578	64.12%	73.60%	4	%

Table 3-49: The evaluation results of Second step's M5P, ANN, RBF (TP, mg/L).

Model	Scenario	No.of Instances	No.of Rules/hidden/ cluster	Evaluation on test split						km^2/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
gsy(M5P)_20	6	22	9	0.7404	0.009	0.0127	66.64%	78.59%	8	km
gsy(RBF)_25	4	14	2	0.7235	0.0599	0.0675	76.28%	76.32%	5	km
gsy(RBF)_25over	10	10	4	0.6014	0.085	0.1434	52.15%	78.34%	4	km
han(ANN)_20	7	19	5	0.6784	0.0394	0.0529	54.71%	64.01%	7	km
han(RBF)_25	3	19	4	0.7345	0.0262	0.0298	36.35%	36.10%	7	km
han(RBF)_25over	10	9	4	0.8738	1.1019	1.1118	137.13%	138.09%	6	%
nakdong(RBF)_20	6	21	4	0.9116	0.0132	0.0152	63.54%	49.30%	8	km
nakdong(RBF)_25	1	35	5	0.7619	0.0442	0.0536	82.95%	88.60%	12	%
nakdong(RBF)_25over	7	8	3	0.9994	0.1304	0.2016	88.98%	92.33%	4	%

Table 3-50: The evaluation results of Third step's M5P, ANN, RBF (TP, mg/L).

Model	Scenario	No.of Instances	No.of Rules	Evaluation on test split						km^2/%
				C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
250km(M5P)_20per	7	23	10	0.472	0.0402	0.0473	171.87%	190.63%	8	%
250km(RBF)_25per	6	53	4	0.8657	0.1217	0.1569	69.54%	79.39%	19	km
250km(RBF)_25over	9	13	3	0.9977	0.045	0.0499	11.41%	11.50%	5	%
250over(RBF)_20per	8	53	6	0.513	0.0121	0.0147	88.18%	91.24%	12	km
250over(ANN)_25per	9	41	6	0.8809	0.2941	0.3835	74.54%	88.41%	14	km
250over(RBF)_25over	9	13	3	0.9977	0.045	0.0499	11.41%	11.50%	5	%

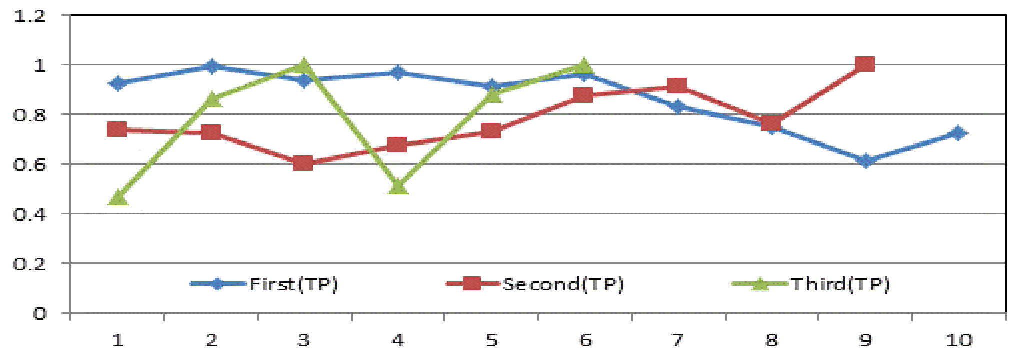


Figure 3-33: R value (TP) of first, second, third scenarios using M5P, ANN, RBF.

3.8. SUMMARY AND CONCLUSIONS

Data collection, the development of a simple equation for each scenario, and the selection of the best simple equations were implemented in this chapter to establish simple equations most applicable to water quality forecasting.

Water quality (BOD, COD, T-N, and T-P, 10 year average from 2001 to 2010), Hydrology (rainfall, 30 year average from 1966 to 2007), Geology (slope of sub-watershed), and Land Usage (Large-scale classification: urban, agriculture, forest, grass, wetland, barren, and water) were accumulated from MOE (The Ministry of Environment) and WAMIS (Water Management Information Systems).

217 standard basins of the 522 within the five watersheds were selected because they contain available water quality monitoring points. The five rivers' watersheds were divided into three groups of watersheds and then the allocation of land usage was divided into three cases: 1) the area allocation of sub-watersheds (Han River and Nakdong River are 0 km^2 ~ 200 km^2, 200 km^2 ~ 500 km^2, and 500 km^2 ~ and Geum-Sum-Young River is 0 km^2 ~ 100 km^2, 100 km^2 ~ 150 km^2, and 150 km^2 ~). 2) the watershed imperviousness (below 20 %, 20 % ~ 25 %, and over

25 %), and 3) the combination of the area (below and above 250 km^2) and imperviousness (below 20 %, 20 % ~ 25 %, and over 25 %).

To find out the co-relationship between water quality and watershed parameters, parameters were separated into ten scenarios: 1) impervious, 2) impervious+pervious, 3) impervious+rainfall, 4) impervious+slope, 5) impervious+rainfall+slope, 6) slope, 7) land usage, 8) lang usage+rainfall, 9) land usage+slope, 10) land usage+rainfall+slope.

The Simple equations were established through the application of the three cases and ten scenarios in Excel Solver, SAS (Statistical Analysis System), Model Tree, ANN (Artificial Neural Network), and RBF (Radial Basis Function). The best simple equations were then identified from the generated equations using statistical methods (Excel Solver: R^2, Adj. R^2, F-test AIC and Shpari-Wilk test, SAS: R^2, Adj. R^2, Factor Analysis, and VIF, and Model Tree, ANN, RBF: CC, MAE, RMSE, and RRSE).

When Excel Solver was used, the first step's R^2 for COD was 0.96 (Han River), 0.70 (Nakdong River), and 0.86 (GSY River), the second step's R^2 for COD was 0.78 (Han River), 0.61 (Nakdong River), and 0.54 (GSY River), and the last step's R^2 for COD was 0.48 (below 250 km^2) and 0.52 (over 250 km^2). The results for BOD, T-N, and T-P have a similar trend to those for COD. The simple equations determined using Eexcel Solver can be used for water quality simulation of three watersheds as shown in Table 3-51. Based upon the F-test results of first step, most of the p-values are is less than 0.05, hence, these Simple Equations were fitted to a data set well.

When the SAS was used, R^2 ranged from 0.43 to 0.85 for BOD, 0.43 to 0.85 for COD, 0.21 to 0.93 for T-N, and 0.15 to 0.96 for T-P, A comparison of these results with those generated from Excel Solver, show that the SAS results have smaller R^2 values.

When Data Mining (Model Tree, ANN, and RBF) is used, the first step's R (correlation coefficient) for COD ranged from 0.91 to 0.98 (Han River), 0.73 to 0.96 (Nakdong River), and 0.95 to 0.98 (GSY River), the second step's R for COD ranged from 0.79 to 0.99 (Han River), 0.50 to 0.98 (Nakdong River), and 0.61 to 0.79 (GSY river), and the last step's R for COD ranged from 0.80 to 0.98 (below 250 km^2) and 0.40 to 0.98 (over 250 km^2). The results for BOD, T-N, and T-P have the same trend as the results presented for COD.

Based on the collected results from Excel Solver, the SAS, and Data Mining, the first steps' results are much better than the second and third step's results. Therefore, these simple equations generated from the first step are the best to apply to real-based watersheds. This chapter proved the hypothesis that simple equations can be determined correlating water quality and phycial watershed parameters.

Table 3-51: The Simple Equations for water quality simulation based upon Excel Solver

Water Quality	River	parameters	Area (km^2)	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike) AIC	Attri-bute
					R^2	Adj R^2	F	p-value	n	d.f.	w	p-value				
BOD	Hanriver	landusage/rainfall/slope	0-200	$BOD(mg/L)= 2.66\ Ur^{1.30}\ Ag^{0.29}\ Fo^{0.42}\ Gr^{-0.54}\ Wet^{0.03}\ Ba^{-0.41}\ Wa^{-0.22}\ Ra^{-0.68}\ Sl^{-0.61}$	0.974	0.973	762	< 2.2e-16	22	20	0.671	0.000	9	3.42	-22.95	km2
		land usage/rainfall	200-500	$BOD(mg/L)= 2.33\ Ur^{0.47}\ Ag^{-0.51}\ Fo^{-0.64}\ Gr^{0.20}\ Wet^{0.26}\ Ba^{0.35}\ Wa^{-0.64}\ Ra^{0.90}$	0.988	0.988	1788	< 2.2e-16	23	21	0.604	0.000	8	5.10	-18.64	km2
		land usage/slope	500-	$BOD(mg/L)= 1.53\ Ur^{0.12}\ Ag^{-0.13}\ Fo^{1.83}\ Gr^{0.27}\ Wet^{-0.47}\ Ba^{0.54}\ Wa^{-0.04}\ Sl^{-2.40}$	0.962	0.959	324	0.000	15	13	0.676	0.000	8	0.44	-37.04	%
	Nakdong river	impervious	0-200	$BOD(mg/L)= 0.01\ IP^{1.97}$	0.319	0.284	9	0.008	21	19	0.888	0.021	1	13.03	-8.03	%
		impervious	200-500	$BOD(mg/L)= 0.00\ IP^{2.16}$	0.335	0.313	15	0.001	32	30	0.893	0.004	1	13.98	-24.50	%
		landusage/rainfall	500-	$BOD(mg/L)= 1.91\ Ur^{0.39}\ Ag^{-0.06}\ Fo^{-0.65}\ Gr^{0.45}\ Wet^{-0.07}\ Ba^{-0.61}\ Wa^{0.28}\ Ra^{0.47}$	0.985	0.983	573	0.000	11	9	0.775	0.004	8	0.09	-36.50	%
	Geun -Sum -Youngsan river	land usage/rainfall/slope	0-100	$BOD(mg/L)= 3.32\ Ur^{0.48}\ Ag^{-0.98}\ Fo^{2.04}\ Gr^{-0.69}\ Wet^{0.22}\ Ba^{-0.40}\ Wa^{0.09}\ Ra^{0.27}\ Sl^{-2.24}$	0.863	0.851	75	0.000	14	12	0.856	0.027	9	1.26	-15.70	km2
		land usage/slope	100-150	$BOD(mg/L)= 1.95\ Ur^{0.00}\ Ag^{0.33}\ Fo^{2.62}\ Gr^{0.21}\ Wet^{-0.51}\ Ba^{0.00}\ Wa^{-0.28}\ Sl^{-3.63}$	0.919	0.912	136	0.000	14	12	0.886	0.071	8	2.61	-7.51	%
		landusage/rainfall	150-200	$BOD(mg/L)= 2.85\ Ur^{1.16}\ Ag^{-0.40}\ Fo^{1.54}\ Gr^{0.10}\ Wet^{-0.55}\ Ba^{-0.71}\ Wa^{1.63}\ Ra^{-1.99}$	0.998	0.998	4296	0.000	11	9	0.882	0.111	8	0.02	-52.36	km2
		pervious/impervious	200 -	$BOD(mg/L)= 3.45\ P^{-1.98}\ IP^{2.38}$	0.643	0.632	61	0.000	36	34	0.832	0.000	2	21.16	-15.13	km2
COD	Hanriver	landusage/rainfall	0-200	$COD(mg/L)= 3.45\ Ur^{0.69}\ Ag^{0.29}\ Fo^{-0.18}\ Gr^{-0.35}\ Wet^{-0.01}\ Ba^{0.01}\ Wa^{-0.11}\ Ra^{-0.28}$	0.937	0.934	299	0.000	22	20	0.72	0.00	8	9.85	-1.68	km2
		land usage/rainfall/slope	200-500	$COD(mg/L)= 4.81\ Ur^{-0.07}\ Ag^{-0.45}\ Fo^{-0.29}\ Gr^{0.00}\ Wet^{0.06}\ Ba^{0.40}\ Wa^{-0.18}\ Ra^{1.43}\ Sl^{-1.08}$	0.963	0.961	549	< 2.2e-16	23	21	0.71	0.00	9	8.75	-4.23	km2
		land usage/rainfall/slope	500-	$COD(mg/L)= 3.59\ Ur^{0.09}\ Ag^{0.00}\ Fo^{1.25}\ Gr^{0.23}\ Wet^{-0.32}\ Ba^{0.35}\ Wa^{0.00}\ Ra^{-0.25}\ Sl^{-1.39}$	0.990	0.989	1242	0.000	15	13	0.73	0.73	9	0.25	-43.24	%
	Nakdong river	impervious	0-200	$COD(mg/L)= 5.50\ IP^{0.02}$	0.471	0.442	16	0.001	20	18	0.96	0.63	1	34.09	12.67	%
		land usage/rainfall	200-500	$COD(mg/L)= 5.08\ Ur^{0.46}\ Ag^{0.02}\ Fo^{0.31}\ Gr^{0.08}\ Wet^{0.17}\ Ba^{-0.17}\ Wa^{0.15}\ Ra^{-0.48}$	0.621	0.609	51	0.000	33	31	0.86	0.00	8	35.81	18.70	%
		landusage/rainfall	500-	$COD(mg/L)= 4.06\ Ur^{0.47}\ Ag^{-0.09}\ Fo^{-0.11}\ Gr^{0.57}\ Wet^{-0.48}\ Ba^{-0.53}\ Wa^{0.29}\ Ra^{-0.06}$	0.995	0.994	1682	0.000	11	9	0.83	0.02	8	0.13	-32.90	km2
	Geun -Sum -Youngsan river	land usage/slope	0-100	$COD(mg/L)= 5.54\ Ur^{0.32}\ Ag^{-0.51}\ Fo^{0.97}\ Gr^{-0.47}\ Wet^{0.16}\ Ba^{-0.12}\ Wa^{0.33}\ Sl^{-0.93}$	0.919	0.913	137	0.000	14	12	0.92	0.19	8	2.61	-7.53	km2
		slope	100-150	$COD(mg/L)= 155.40\ Sl^{-1.09}$	0.780	0.763	46	0.000	15	13	0.78	0.00	1	18.62	5.24	km2
		landusage/rainfall/slope	150-200	$COD(mg/L)= 5.93\ Ur^{0.44}\ Ag^{-0.19}\ Fo^{0.48}\ Gr^{-0.15}\ Wet^{-0.21}\ Ba^{-0.15}\ Wa^{0.88}\ Ra^{-0.77}\ Sl^{0.13}$	0.962	0.958	228	0.000	11	9	0.89	0.14	9	0.78	-11.11	km2
		land usage	200 -	$COD(mg/L)= 5.21\ Ur^{-0.02}\ Ag^{0.33}\ Fo^{-0.33}\ Gr^{-0.01}\ Wet^{0.00}\ Ba^{0.17}\ Wa^{0.13}$	0.771	0.764	114	0.000	36	34	0.90	0.00	7	20.21	-6.78	%
TN	Hanriver	landusage/rainfall	0-200	$TN(mg/L)= 4.59\ Ur^{0.44}\ Ag^{0.15}\ Fo^{-0.30}\ Gr^{-0.04}\ Wet^{0.00}\ Ba^{0.34}\ Wa^{-0.01}\ Ra^{-0.14}$	0.937	0.934	298.900	0.000	22	20	0.720	0.000	8	9.850	-1.68	km2
		land usage/rainfall/slope	200-500	$TN(mg/L)= 4.97\ Ur^{-0.01}\ Ag^{-0.68}\ Fo^{0.62}\ Gr^{-0.21}\ Wet^{0.03}\ Ba^{0.41}\ Wa^{-0.48}\ Ra^{1.66}$	0.963	0.961	548.800	< 2.2e-16	23	21	0.707	0.000	9	8.750	-4.23	km2
		land usage/slope	500-	$TN(mg/L)= 2.84\ Ur^{-0.08}\ Ag^{-0.27}\ Fo^{1.83}\ Gr^{0.03}\ Wet^{-0.27}\ Ba^{0.70}\ Wa^{-0.10}\ Sl^{-2.11}$	0.912	0.905	134.300	0.000	15	13	0.885	0.056	8	1.161	-22.38	%
	Nakdong river	impervious	0-200	$TN(mg/L)= 0.52\ IP^{0.56}$	0.251	0.210	6.039	0.024	20	18	0.953	0.421	1	12.490	-7.42	%
		land usage/rainfall	200-500	$TN(mg/L)= 3.35\ Ur^{0.65}\ Ag^{0.23}\ Fo^{0.61}\ Gr^{-0.05}\ Wet^{0.11}\ Ba^{-0.04}\ Wa^{-0.13}\ Ra^{-0.91}$	0.602	0.589	46.860	0.000	33	31	0.856	0.000	8	23.830	5.26	%
		landusage/rainfall/slope	500-	$TN(mg/L)= 4.14\ Ur^{-0.75}\ Ag^{-0.07}\ Fo^{-1.00}\ Gr^{-0.31}\ Wet^{-1.91}\ Ba^{0.08}\ Wa^{1.65}\ Ra^{1.52}\ Sl^{-1.05}$	0.979	0.977	421.100	0.000	11	9	0.961	0.784	9	0.327	-20.67	%
	Geun -Sum -Youngsan river	impervious/slope	0-100	$TN(mg/L)= 2.23\ IP^{0.32}\ Sl^{-0.23}$	0.362	0.309	6.814	0.023	14	12	0.944	0.477	2	12.652	2.58	km2
		land usage/rainfall/slope	100-150	$TN(mg/L)= 4.79\ Ur^{-0.02}\ Ag^{-0.14}\ Fo^{2.48}\ Gr^{0.03}\ Wet^{-0.04}\ Ba^{0.82}\ Wa^{-0.17}\ Ra^{-0.46}\ Sl^{-2.67}$	0.983	0.982	744.000	0.000	15	13	0.800	0.004	9	1.890	-13.07	km2
		slope	150-200	$TN(mg/L)= 10.45\ Sl^{-0.40}$	0.276	0.196	3.435	0.097	11	9	0.935	0.464	1	5.026	-6.62	%
		pervious/impervious	200 -	$TN(mg/L)= 8.87\ P^{-1.97}\ IP^{2.26}$	0.677	0.668	71.360	0.000	36	34	0.832	0.000	2	27.800	-5.31	km2
TP	Hanriver	landusage/rainfall/slope	0-200	$TP(mg/L)= 0.13\ Ur^{1.58}\ Ag^{0.75}\ Fo^{-0.72}\ Gr^{-1.07}\ Wet^{-0.12}\ Ba^{0.39}\ Wa^{-0.20}\ Ra^{-0.97}\ Sl^{0.58}$	0.998	0.998	10410	< 2.2e-16	22	20	0.475	0.000	9	0.006	-162.55	km2
		landusage/slope	200-500	$TP(mg/L)= 0.12\ Ur^{1.13}\ Ag^{0.60}\ Fo^{-0.05}\ Gr^{-1.04}\ Wet^{0.31}\ Ba^{0.91}\ Wa^{-0.47}\ Sl^{-1.11}$	0.990	0.990	2137	< 2.2e-16	23	21	0.551	0.000	8	0.032	-135.28	%
		land usage/rainfall	500-	$TP(mg/L)= 0.05\ Ur^{-0.05}\ Ag^{0.85}\ Fo^{1.78}\ Gr^{0.95}\ Wet^{-0.62}\ Ba^{0.96}\ Wa^{-0.09}\ Ra^{-2.34}$	0.962	0.960	332	0.000	15	13	0.760	0.001	8	0.001	-129.99	%
	Nakdong river	impervious	0-200	$TP(mg/L)= 0.12\ IP^{0.02}$	0.192	0.148	4	0.053	20	18	0.964	0.633	1	0.098	-104.37	%
		land usage	200-500	$TP(mg/L)= 0.10\ Ur^{1.08}\ Ag^{-0.27}\ Fo^{-0.23}\ Gr^{0.26}\ Wet^{-0.23}\ Ba^{-0.30}\ Wa^{-0.25}$	0.654	0.642	58	0.000	33	31	0.648	0.000	7	0.127	-169.51	%
		landusage/rainfall	500-	$TP(mg/L)= 0.11\ Ur^{0.19}\ Ag^{1.81}\ Fo^{-0.54}\ Gr^{-0.15}\ Wet^{-0.19}\ Ba^{-0.52}\ Wa^{0.87}\ Ra^{-1.64}$	0.989	0.987	779	0.000	11	9	0.851	0.044	8	0.001	-91.10	km2
	Geun -Sum -Youngsan river	land usage/slope	0-100	$TP(mg/L)= 0.15\ Ur^{0.71}\ Ag^{-0.92}\ Fo^{2.62}\ Gr^{-0.70}\ Wet^{0.34}\ Ba^{-0.51}\ Wa^{0.25}\ Sl^{-2.68}$	0.964	0.961	317	0.000	14	12	0.917	0.198	8	0.002	-108.74	km2
		land usage/rainfall/slope	100-150	$TP(mg/L)= 0.08\ Ur^{-0.13}\ Ag^{-0.33}\ Fo^{9.73}\ Gr^{0.35}\ Wet^{-0.25}\ Ba^{0.47}\ Wa^{-0.71}\ Ra^{-1.82}\ Sl^{-9.11}$	0.996	0.995	2851	< 2.2e-16	15	13	0.747	0.001	9	0.002	-120.16	%
		land usage/rainfall/slope	150-200	$TP(mg/L)= 0.14\ Ur^{0.08}\ Ag^{0.51}\ Fo^{8.61}\ Gr^{-0.53}\ Wet^{-0.85}\ Ba^{0.46}\ Wa^{0.27}\ Ra^{-5.56}\ Sl^{-3.56}$	0.999	0.999	7368	0.000	11	9	0.677	0.000	9	0.000	-102.07	%
		pervious/impervious	200 -	$TP(mg/L)= 0.68\ P^{-3.25}\ IP^{3.63}$	0.659	0.649	66	0.000	36	34	0.744	0.000	2	0.126	-199.69	km2

CHAPTER 4. VERIFICATION SIMPLE EQUATIONS COMPARING PHYSICALLY BASED MODEL, HSPF

4.1. INTRODUCTION

Urbanization has accelerated land cover and usage changes. The increase in impervious surface has lead to the following water quality problems: sedimentation, turbidity, eutrophication, hypoxia, reducing submerged aquatic vegetation (SAV), and affecting many other aquatic ecosystems (Brietbure, 1992, Hasset et al., 2005, Roberts et al., 2009). Non-Point Source pollution is the main pollutant of the watersheds and is transported either in a solution with runoff water, suspended in water, or absorbed by eroded soil particles. A variety of watershed models could be used to evaluate the relationship between land use/cover and water quality processing within a watershed (Im et al., 2003).

Watershed models can be classified into comprehensive models (physical based models) and empirical based models. The established simple equations determined in this study were generated from empirical based models in chapter 3. In order to verify these simple equations applicability to real-world conditions, a comparative study was implemented with the physical based model and is presented in this chapter.

There are many physically based models, however, starting in the 2000s, South Korea has started to use models such as HSPF and SWAT for watershed management. HSPF needs an enormous amount of data including hourly temperature, rainfall, evaporation, etc. which are possible to access in the United States of America because of institutions like USEPA, USGS, and others that collect and provide the data for research and analysis purposes. On the other hand, South Korea has not yet collected enough data base to simulate conditions using HSPF and

SWAT, hence the data base has to be updated continuously (K-water, 2005). K-water (Korea Water Resources Corporation) researched the applicability of HSPF using data from 2005 to 2006 at the Yongdam Dam's watershed. These data included field survey estimates of the watershed's water quality changes at pre- and post- watershed management and restoration. There are also several additional available watersheds that can be used in the HSPF model within the Nakdong River area. In this research, the HSPF was used to compare physically based model results with those determined from the simple equations. HSPF is a physical based model and relies on criteria to provide predictions at fine spatial and temporal resolution, however the cost of parameterizing and calibrating the model are excessive.

4.2. MODEL DESCRIPTIONS

4.2.1 HSPF MODEL

HSPF (Hydrologic Simulation Program Fortran) is a comprehensive model for simulating the quantity and quality of streamflow, reservoir system operations, ground water development and protection, surface water and ground water conjunctive use management, water distribution systems, water use, and a range of water resources management activities on pervious and impervious land segments and river channels (Leslie et al., 2005, Said et al., 2007, Ryu, 2009). Table 4-1 shows the characteristics of the HSPF model.

Table 4-1: The characteristics of the HSPF models.

Reference	HSPF Hydrologic Simulation Program-FORTRAN
Developer	USEPA
Program Language	FORTRAN (model)
Model usage	Urban, Rural, Agriculture, Forest, River, Lake, Reservoir/impoundment
Temporal scale	User-defined time step, typically hourly
Type of model	Dynamic, stream routing included
Watershed representation	Plane / Channel Pervious and impervious land areas, stream channels, and mixed reservoirs; 1-D simulation
Rainfall excess on overland	Water budget considering, interception, ET, and infiltration with empirically based areal distribution.
Runoff	Non-linear reservoir Empirical outflow depth to detention storage relation and flow using Chezy-Manning equation
Overland sediment	Rainfall splash detachment and wash off of the detached sediment based on transport capacity as a function of water storage and outflow plus scour from flow using power relation with water storage and flow.
Subsurface	Interflow outflow, percolation, and groundwater outflow using empirical relations.
BMP	Nutrient and pesticide management, ponds, urbanization

The HSPF model was composed of the following models: Stanford Watershed Model (SWM), advanced process conceptual models, and several water quality models (Lohani et al., 2000). Especially SWM is used to determine the water balance of soil or storage from different layers of hydrology. The advantages of the HSPF model are its cell-based representation of land segments and drainage channels, subdivided storage columns to denote the water available for infiltration, runoff, and groundwater recharge, and automatic calibration tools to optimize model performance by adjusting hydrologic parameters (Ryu, 2009). Subwatersheds were classified into various groups depending on their land uses (forest, agricultural and urban built-up), impervious land segment (urban built-up), and stream or mixed reservoir segment which are all routed to a representative stream segment (Leslie et al., 2005, Ryu, 2009). Interception, infiltration, evapotranspiration, interflow, groundwater loss, and overland flow processes are calculated based on the empirical equations. The primary parameter modules are composed of three representative modules called PERLND, IMPLND, and RCHRES (Bicknell et al., 2001). The main functions of PERLND are the simulation of snow accumulation and melt (SNOW), the water budget (PWATER), sediment produced by land surface erosion (SEDMNT), and water quality constituents by various methods (PQUAL). IMPLND has the following functions: simulating retention, routing, and evaporation of water from impervious land water without infiltration and subsurface processes (IWATER), simulating the accumulation and removal of solids by runoff and other means from the impervious land segment (SOLIDS), estimating the water temperature and concentrations of dissolved oxygen and carbon dioxide in the outflow from the impervious land segment (IWYGAS), and simulating water quality constituents or pollutants in the outflows from an impervious land segment using simple relationships with water yield and/or solids (IQUAL). The RCHRES module simulates the flow of water in a single reach of open or closed channel or a completely mixed lake which is a one-dimensional fluid dynamic model (Ryu, 2009, Bicknell et al., 2001).

The HSPF model has been used frequently for research and engineering practice, therefore there is an abundance of literature available on simulated data and resolution: sediment transport modeling in the watershed, sediment yield simulation by typhoon events, stream water temperature modeling, herbicide transport simulation, and nutrient simulation (Bai, 2010). The North Creek watershed is located in Knox County, Illinois and has experienced problems like flooding, excessive stream bank erosion, and agricultural pollution. In this watershed, the HSPF and SWAT models were applied based on the same topographic, hydrographic, land use, soil type data, and hydrologic data. The HSPF model outperformed the SWAT model for daily and monthly flow (the r^2 of HSPF was 0.83, 0.87, 0.93 and the r^2 of SWAT was 0.67, 0.76, 0.95, for daily, monthly, and annual temporal resolutions, respectively). In the case of the suspended sediment load, the HSPF model also performed better than the SWAT model as well (Yanqing, 2007). The HSPF-Paddy model, a modified version of HSPF (Jeon, 2007), simulates rice paddy fields and the watershed reasonably well. Mishra (2009) successfully applied the HSPF model to decide the most appropriate management option for protecting the water resources from NPS pollution and minimizing nutrient losses from the agricultural fields. Furthermore, nitrogen and phosphorus were simulated in the Iskar River case study, Bulgaria. The simulation provided a better understanding and was able to forecast nutrient concentrations during first flood events. Percent differences between observed and simulated values for nitrogen and phosphorus were 13.1% (hourly) and 18% (daily simulations), 16.6% (hourly) and 34.4 (daily simulations), respectively (Ribarova, 2008).

Hayashi (2004) used HSPF in order to simulate runoff and sediment loads in the upper region of the Changjiang (Yangtze River) basin, China. For water runoff, the Nash-Sutcliffe coefficient (R^2) was 0.94 for calibration and 0.95 for verification when the simulated and observed 5-day average streamflows were compared. Peak flows in the case of this model were underestimated. For sediment runoff, R^2 was 0.31 to 0.65 which performed fairly well in the headwaters, but it is underestimated during the flood season. In conclusion, HSPF is suitable for simulating runoff and sediment load over short time intervals in this research area, but the model did not perform well in all regions at all times especially during flooding situations (underestimated) because ISLSCP (International Satellite Land Surface Climatology Project) precipitation was more frequent and less intense than observed.(Hayashi, 2004).

The HSPF model was applied to find out how watershed outflow is impacted by climate change (air temperature increases) in the Seydi suyu stream in Turkey. There are three kinds of scenarios: first is just increasing annual mean temperature by 3℃ with no other meteorological time series being changed, second is the existence of deep root vegetation covering the whole of the watershed, and third is no deep root vegetation. The result of the first scenarios was that watershed outflow decreased by 21%, which means that there will be a serious water shortage problem in the future. The second scenario showed a 37% decrease due to the increase of evapotranspiration, and the third scenario experienced a 40% increase due to the decrease of evapotranspiration. Therefore, in order to cope with the climate change, we need to consider the relationship among vegetation, evapotranspiration, stream flow et al. through the HSPF and other models (Albek, 2003).

4.2.2 SIMPLE EQUATIONS

Simple equations relating water quality to watershed parameters were established using Excel SOLVER, the Statistical Analysis Systems (SAS), M5P, ANN, and RBF. An assumption was made that adjacent watershed do not have similar physical characteristics. This assumption is based on the fact that the co-relationships between land use and water quality are not constant in different regions because the characteristics and pollution sources of watersheds are not the same in different places (Tu, 2011). For this research, South Korea was delineated into four large watersheds: 1) the Han River watershed, 2) the Nakdong River watershed, 3) the Geum River watershed, and 4) the Sumjin/Youngsan River watershed shown in Figure 3-7. To reflect watershed characteristics and determine the best parameters requires two steps. The first step is to subdivide each watershed based on the watershed's area and imperviousness. The second step, as shown in Table 4-2, is to create scenarios which use various parameters and equations in order to determine which parameters have the strongest relationships with water quality.

In order to access the data in detail, the first step will be divided into three cases. The first case is the area allocation of sub-watersheds. The second case is the division of basins into several groups based upon the percentage of imperviousness of standard basins, and the third case takes into consideration both area allocation and the percentage of imperviousness of standard basins, which is shown in Tables 4-3, 4-4, and 4-5.

Table 4-2: Ten scenarios used for finding out the parameters which have the best relationship with water quality.

Scenarios	Parameters			Equation
1	Impervious			COD, BOD, T-N, T-P
2	Impervious	Pervious		
3	Impervious	Rainfall		
4	Impervious	Slope		
5	Impervious	Rainfall	Slope	
6	Slope			
7	Land Usage			
8	Land Usage	Rainfall		
9	Land Usage	Slope		
10	Land Usage	Rainfall	Slope	

Land usage will be divided into urban, agriculture, forest, grass, wetland, barren, and water (7 items)

Table 4-3: Examples of area allocation of sub-watershed (The First case).

Area (km^2)	The number of Applied Sub-watersheds		
	Han River	Nakdong River	Geum River Sum-youngsan River
0 ~ 100			
100 ~ 150			
150 ~ 200			
200 ~ 500			
500 ~			
Total			

Table 4-4: Examples of the division of basins into several groups based upon the percentage of imperviousness (The Second case).

Imperviousness	The number of sub-watersheds			
	Han River	Nakdong River	Geum River	Sum-youngsan River
~ 20%				
20 % ~ 25%				
25 % ~ 30%				
30 % ~				

Table 4-5: The number of standard basins based on both area allocation and the percentage of imperviousness of standard basins (The Third case).

Area allocation (km^2)	Imperviousness (%)		
	Below 20 %	20 ~ 25 %	Over 25 %
Below 250 km^2			
Over 250 km^2			

Using the process shown in Figure 4-1, the simple equations were established using Excel SOLVER, Model Tree, ANN (Artificial Neural Network), RBF (Radial Basis Function), and SAS (Statistical Analysis System) based on the same three methodologies/steps used to conduct data analysis.

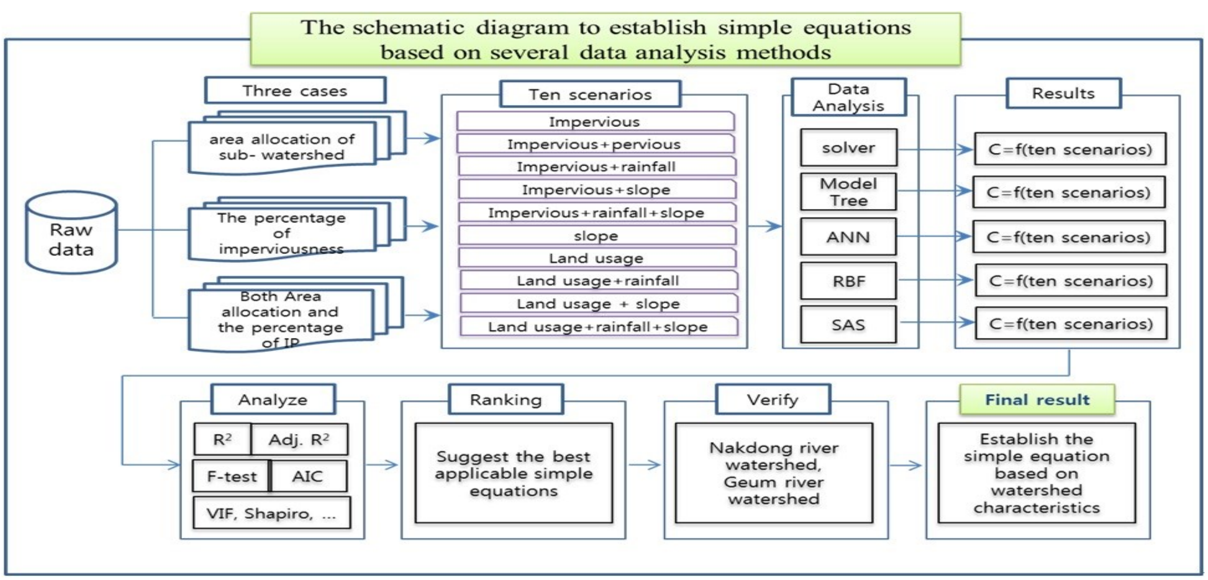


Figure 4-1: The Schematic diagram to establish simple equations based on several data analysis methods.

4.3. APPLY HSPF AND SIMPLE EQUATIONS

4.3.1 YONGDAM DAM'S WATERSHED

The Present Situation

Yongdam Dam's watershed is located at 127˚18′49″ ~ 127˚44′47″ east longitude and 35˚34′50″ ~ 36˚1′37″ north latitude. Jinan Gun, Muju Gun, and Jangsu Gun, Jeunbuk provinces are included in Yongdam Dam watershed. The area of the Yongdam Dam watershed is 930.43 km^2. The circumference, average width, average elevation, and average slope of the watershed are 188.69 km, 14.87 km, EL. 510.22 m and 37.52%, respectively. The river length is about 60km. Total population is 42,360 and the density is 46 persons/km^2. There is a forested area which is 743.57 km^2 and covers 79.92 % of the total watershed area. The agricultural area is 130.13 km^2 (13.99 %), the urban area is 29.44 km^2 (3.16 %), and grassland/water makes up 27.29 km^2 (2.93 %) of the watershed.

The Yongdam Dam's watershed is surrounded by several mountains; Deokyou Mt. (EL. 1,614 m) is at the eastern end of the watershed and Jangan Mt (EL. 1,236.9 m), Sinmu Mt. (EL. 896.8 m), Palgong Mt. (EL. 1,151 m), Sungsu Mt. (EL. 1,059.2 m), and Mai Mt. (EL. 678 m) are at the southern end of the watershed. Jangsu Mt. (EL. 1,125.9 m) is at the eastern end of the watershed. The watershed of Juja-Cheon, the first tributary to the Yongdam Dam's watershed, is mainly composed of granite and porphyry and has a steep slope. On the other hand, the watershed of Jeongja-Cheon consists of Granite Gneiss and has a slow gradient. Relatively broad farmland exists in the upper zone of the watershed, with stone and gravel the main composition of the river bed. The Yongdam Multi-purpose Dam is located at the outlet of the watershed. The usable capacity and flood control storage of Yongdam Dam is 672 million m^3 and 137 million m^3. There are two kinds of water supply systems, agricultural water (492.7 million m^3/year) and river maintenance water (157.7 million m^3/year). The yearly electric generation capacity is 198,553,000GWh. Figure 4-2 shows a map of the Yongdam watershed and Figure 4-3 shows the schematic of the watershed streams.

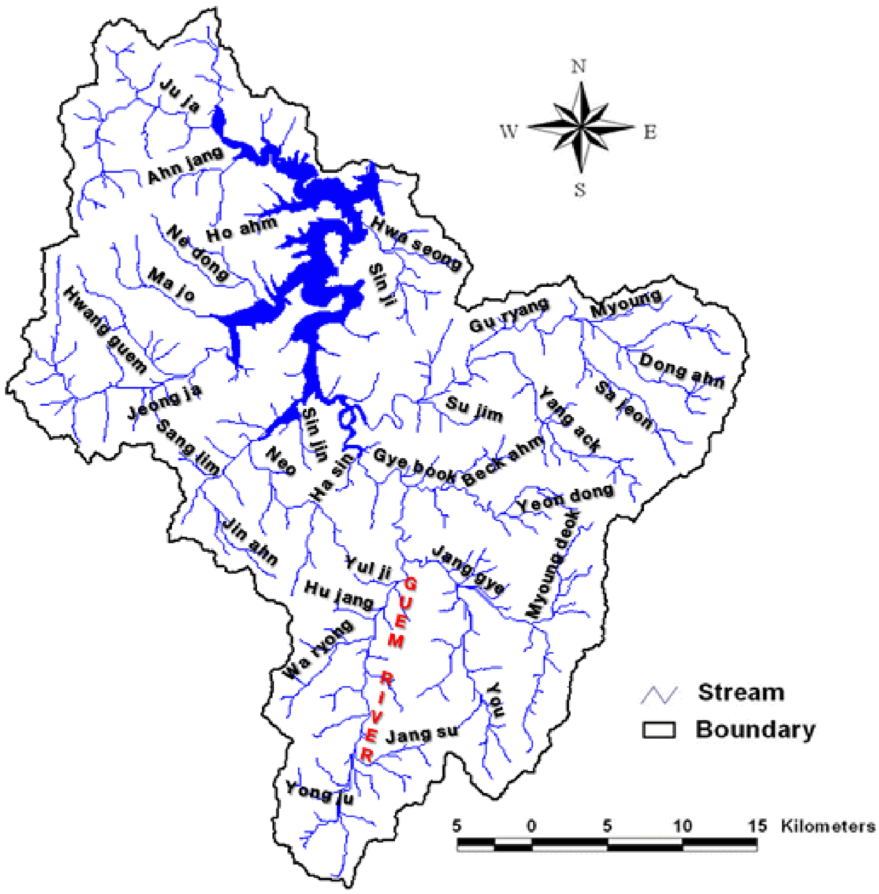


Figure 4-2: Yongdam Dam's watershed.

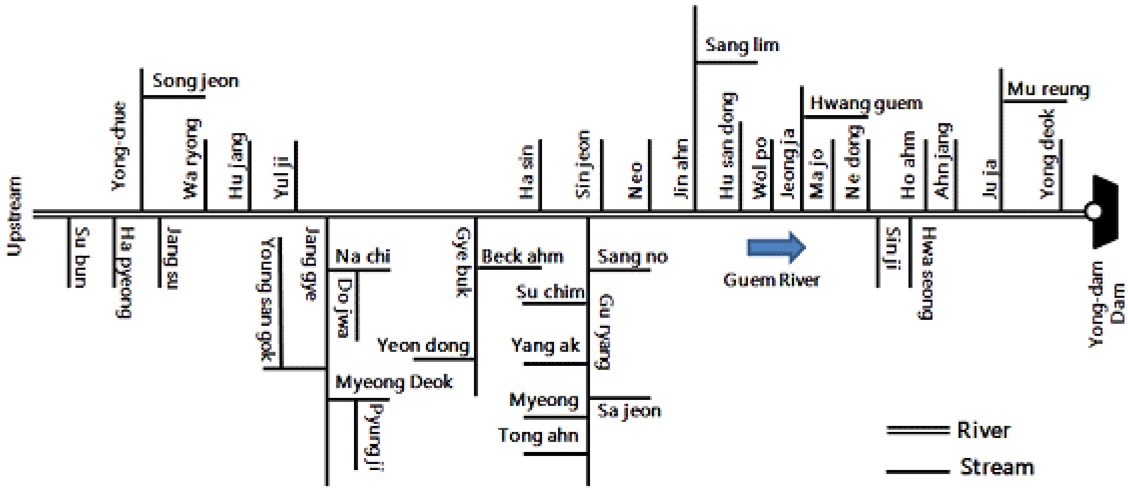


Figure 4-3: Schematic of the watershed streams.

Land Coverage and Land Usage (LC/LU)

As of 2000, the urban area of the Yongdam watershed is 3.2% of the total area, while agricultural land, forest, grass land, marshy land, bare land, and waters are 14.0 %, 79.9%, 2.4%, 0.0%, 0.3%, and 0.3%, respectively. This watershed is mainly composed of forests. The trend in watershed urbanization has experienced a 4.5 times increase from 4.5 km^2 (0.5 %) as of 1975 to above 29.44 km^2 (3.2 %) by 2000. Urban areas have been developed at the junction of the Gu ryang and Tong ahn streams. Agricultural land has increased by 8.26 km^2, 0.9% (121.87 km^2, 13.1% → 130.13 km^2, 14.0%) from 1975 to 2000, and is adjacent to the Gumgang river. There was almost no exchanged agricultural land in the upstream of the Gumgang River as it is mostly composed of forests. According to the image of Landsat MultiSpectral Scanner (MSS) image shown in Figure 4-4, agricultural land rapidly reduced from 1980. Forestry was continuously reduced from 778.84 km^2 (83.7%) in 1975 to 743.57 km^2 (79.9%) in 2000. It has been estimated that the reduced forestry was changed to urban and dry land. Five years of land cover change in the Yongdam watershed is shown in Figure 4-4.

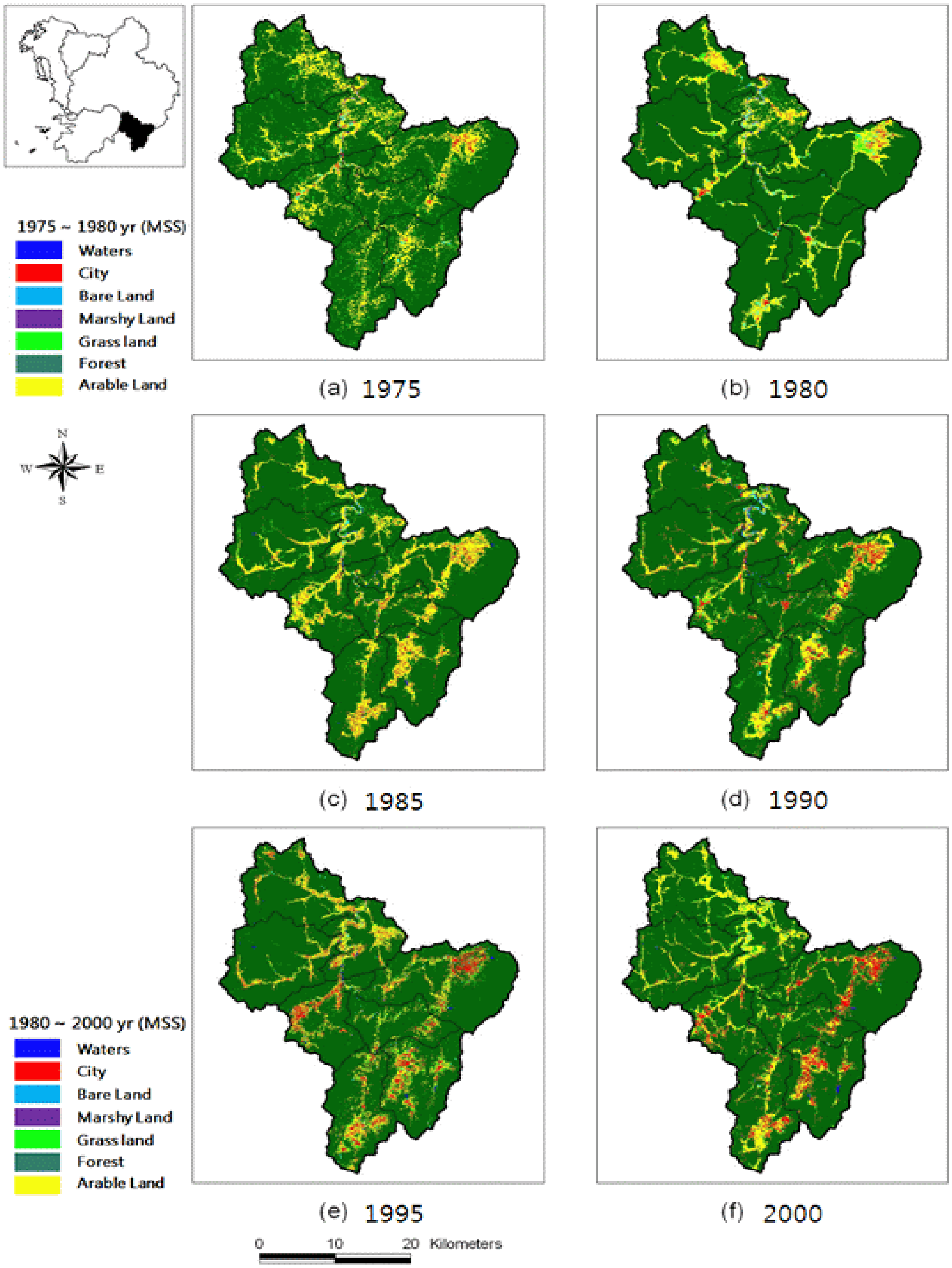


Figure 4-4: The land cover map of Yongdam watershed.

Water Quality

The water quality and quantity data were obtained from the Yongdam Dam Management office of Korea Water Resources Corporation for a period of two years from 2005 to 2006. They measured two sites at inflow tributaries and four sites in the reservoir once a month. In order to analyze more specifically the water quality, the sampling station and times were added. The data is shown in Table 4-6 and Figure 4-5. There were ten sites at three differnet layers in the reservoir, five sites at inflow tributaries and an Automatic Weather Station (AWS) installed in the reservoir.

Table 4-6: The interval and number of samples at Yongdam watershed.

Month	Interval (times/month)	Number of samples	Remarks
Jan. ~ Mar.	One	159	Sampling site (35 sites) = inflow tributary (5 sites) + reservoir (10sites, 3 layer)
April	Two	106	
May ~ Oct.	Four	1,272	
Nov. ~ Dec.	Two	212	
Total	33	1,749	

The sampling interval was set at about 30 times per year in order to obtain reliable data. In detail, the interval of spring/fall, summer, and winter were decided twice a month, once a week, and once a month, respectively. In brief, the detailed parameters of the water quality, meteorological data, hydraulic and hydrologic data are as follows

- Water quality: Dissolved Oxygen, pH, Electrical conductivity, Transparency, Turbidity, BOD, SS, Chlorophyll-a, Phosphorous (Total Phosphorous, Inorganic Phosphorous), Nitrogen (Ammoniac Nitrogen, Nitrate/Nitrite Nitrogen), Dissolved Oxygen Carbon (DOC), Particle Oxygen Carbon (POC), COD_{Mn}, COD_{Cr}, etc.
- Meteorological data: Water temperature, Wind direction and speed, etc.

● Hydraulic and hydrologic data: Precipitation, Evaporation, water quantity (inflow and outflow), and water level.

✓ Interval of measure: week to month in general, increasing the interval during the initial steps of when rainfall occurred depending on the situation.

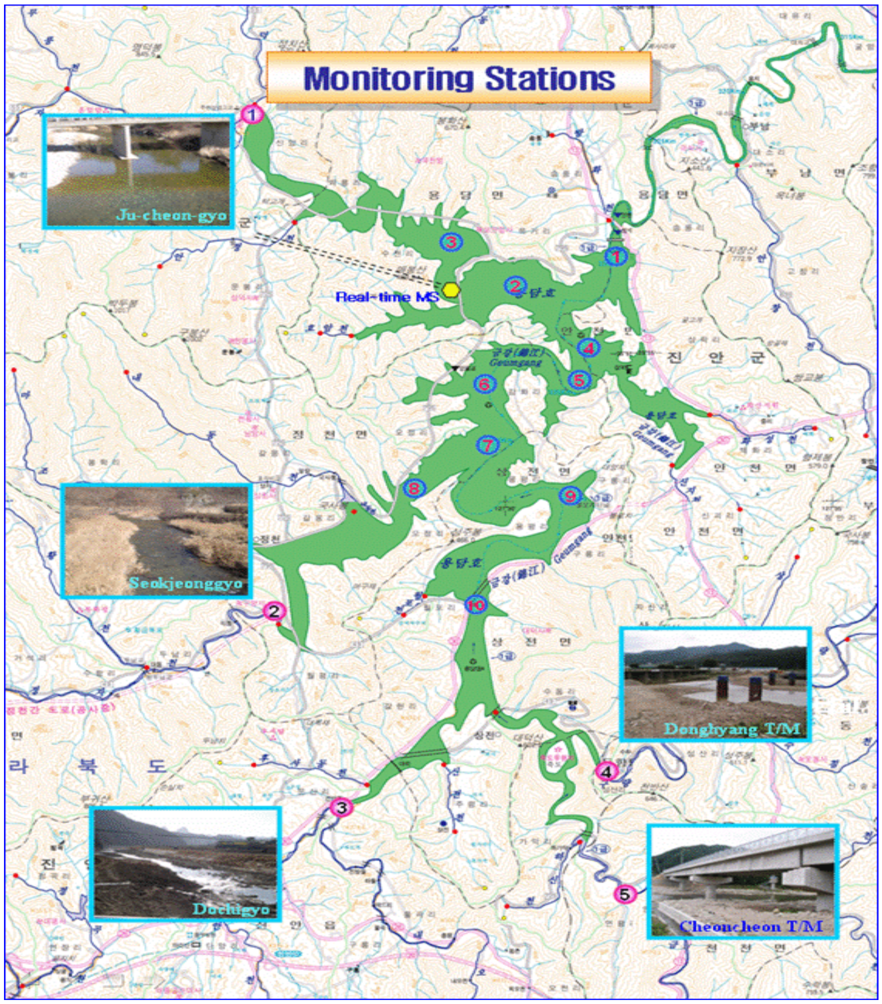


Figure 4-5: The sampling station for water quality, quantity, and meteorological data of Yongdam watershed.

More information pertaining to Yongdam Dam's Watershed characteristics, topography characteristics, hydrology, river characteristics, and geographic characteristics are shown in Appendix C.

4.3.2 NAKDONG RIVER'S WATERSHED

General Condition of Watershed

Nakdong river's watershed is located at 127°29′~129°18′ east longitude and 35°03′~37°13′ north latitude. The watershed area is 23,702 ㎢ which is one fourth the size of South Korea. The average watershed elevation and slope are EL. 291.2 m and 32.3%, respectively. Nakdong River begins in Taebaek which is located in the Gangwon-do sub-watershed. The northern side of the river is adjacent to the Han-river watershed, the western side is close to the Geum and Sumjin river watersheds, the eastern side is close to the coastal area, and the southern side is the main stream of the Nakdong River which is 521.5 km length. The Nakdong river watershed includes the Busan, Daegu, Woolsan, Gyeongsangnam-do, Gyeongsanbuk-do, and Gangwon-do administrative districts.

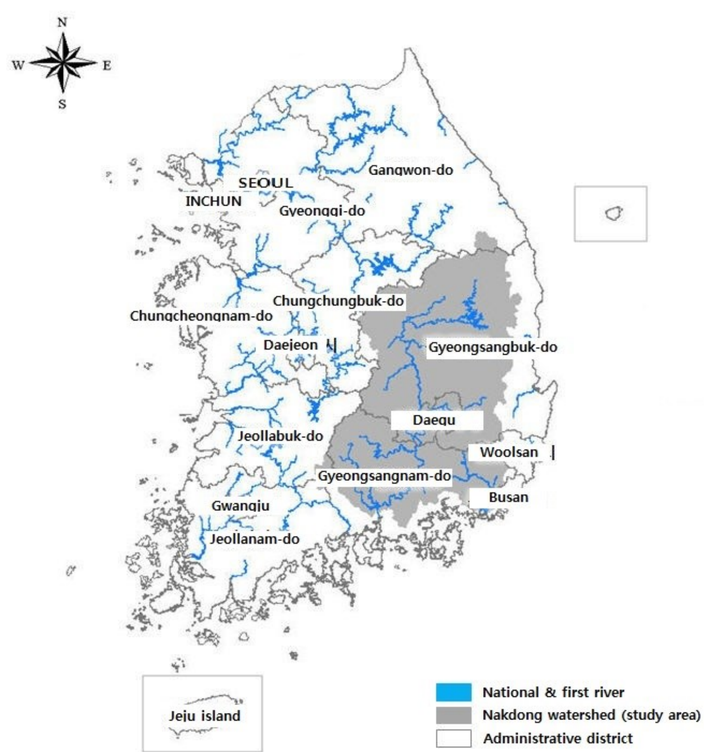


Figure 4-6: River Map of South Korea.

The Status of Water Quality Monitoring

The Nakdong River watershed has a total of 424 water quality monitoring sites. 198 of these sites are in the river, 23 sites are at the reservoir and 174 sites are on agriculture land. The six watersheds for this research are circled in Figure 4-7.

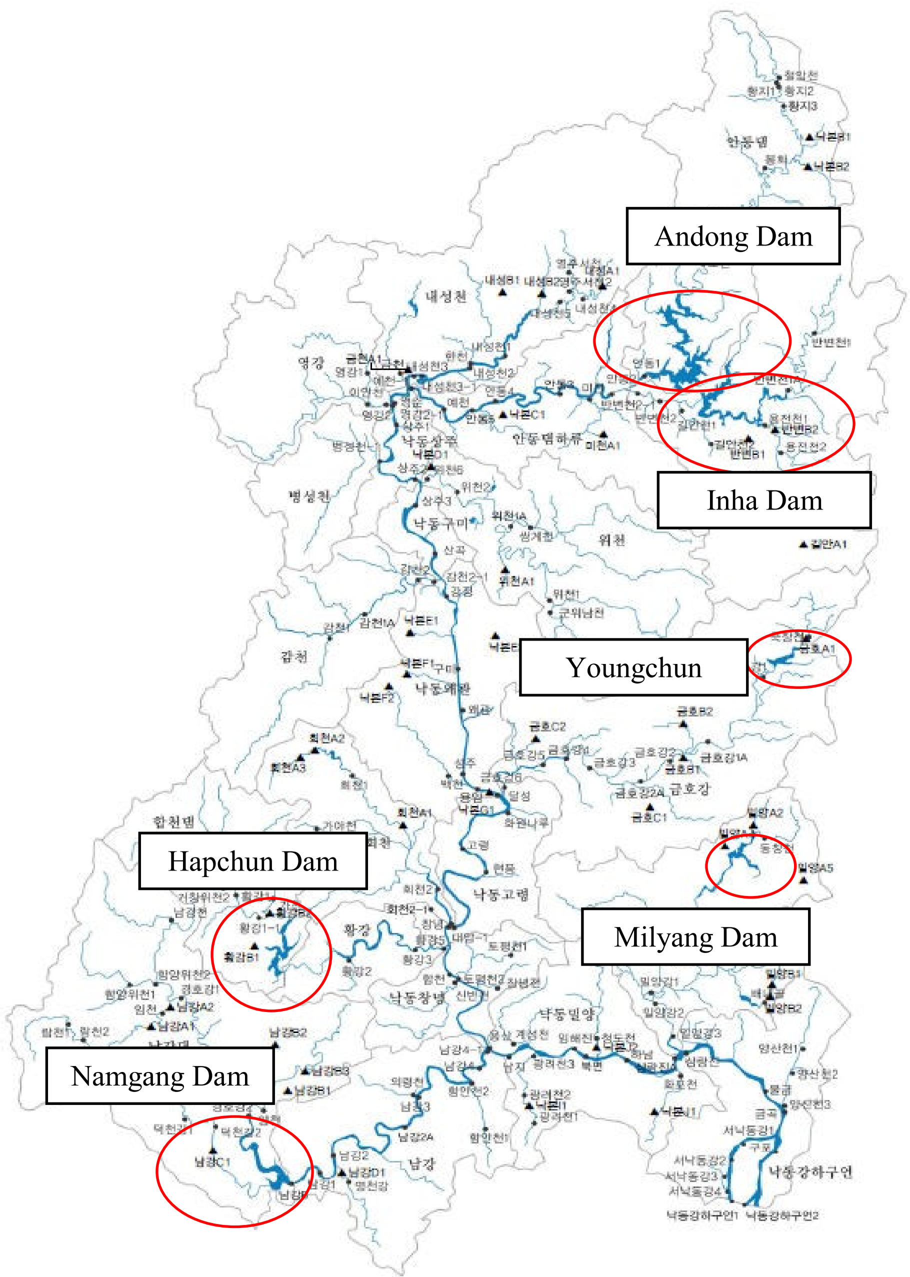


Figure 4-7: Nakdong river watershed's water quality monitoring map.

The Status of Land Cover & Land Use

Land-usage analysis indicates that 16,107.43 km^2 of the Nakdong River watershed, about 68.0% of total area is forest. Agriculture is 24.4%, 5,772.78 km^2 and urban area is 5.6%, 1,324.39 km^2. The land cover and land usage of the six dam's watersheds are displayed in Table 4-7. Forest is the largest land use area among the six watersheds and ranges from 70.9 % ~ 89.4 % of the watershed area. The second most abundant land use type is agriculture which ranges from 4.5 % to 22.3 % of the total watershed areas. Other land cover types are distributed equally within the watersheds.

Table 4-7: The status of land cover and land use in researched site.

Watershed	Divide	Area	Urban	Agriculture	Forest	Grass	Wetland	Barren	Water
Andong Dam	Area(km^2)	1,590.7	22.5	189.1	138.5	6.4	9.8	15.7	38.6
	Percent(%)	100	1.4	11.9	82.3	0.4	0.6	1.0	2.4
Imha Dam	Area(km^2)	1367.7	18.8	204.6	1,091.6	5.5	6.2	8.1	32.9
	Percent(%)	100	1.4	15.0	79.8	0.4	0.5	0.6	2.4
Younchun Dam	Area(km^2)	234.5	2.3	22.1	201.6	0.3	1.5	1.3	5.4
	Percent(%)	100	1.0	9.4	86.0	0.1	0.7	0.6	2.3
Hapchun Dam	Area(km^2)	928.9	23.8	207.3	658.9	4.4	3.8	12.0	18.9
	Percent(%)	100	2.56	22.31	70.93	0.47	0.41	1.29	2.03
Milyang Dam	Area(km^2)	103.5	1.0	4.6	92.5	2.0	0.2	1.3	1.9
	Percent(%)	100	1.0	4.5	89.4	1.9	0.1	1.3	1.9
Namgang Dam	Area(km^2)	2,293.1	54.4	452.8	4,685.5	23.6	20.0	23.0	33.7
	Percent(%)	100	2.4	19.7	73.5	1.0	0.9	1.0	1.5

General conditions of rivers, the status of main dams, and the status of weather conditions for the Nakdong River watershed are shown in Appendix D. Nakdong River watershed survey data was based upon quotes from "K-water Report (2013)".

4.3.3 HSPF APPLICATION FOR NAKDONG RIVER WATERSHED AND YOUNGDAM DAM'S WATERSHED

Delineate Watershed & Stream Network

Six sub-watersheds within the Nakdong River watershed−andong dam, imha dam, youngchun dam, hapchun dam, namgang dam, and milyangdam−and Yongdam Dam's watershed were used and modeled in this research These sub-watershed are shown in Figure 4-8.

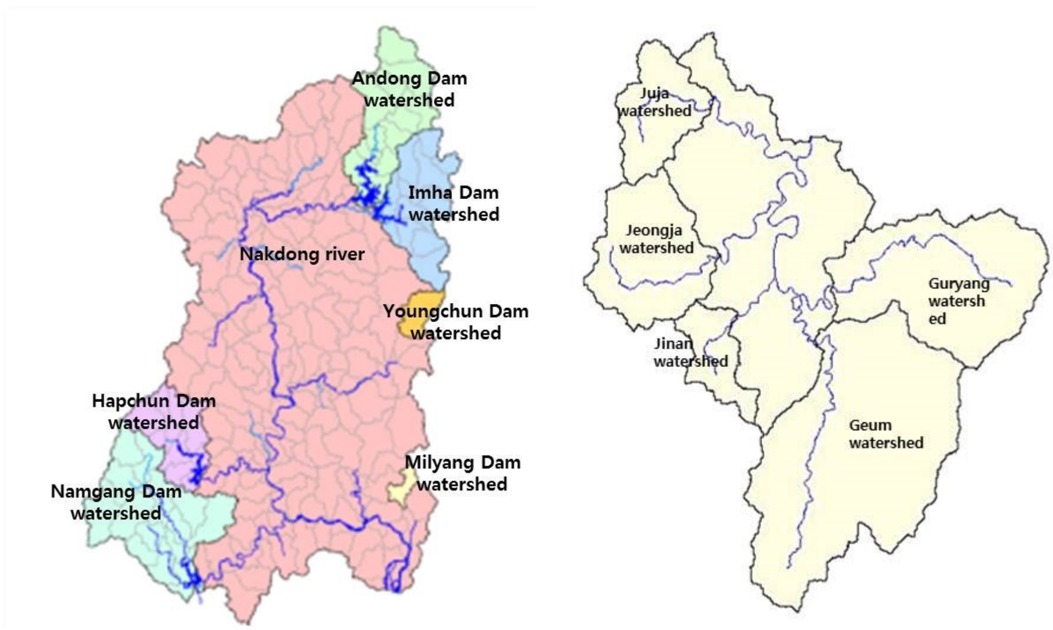


Figure 4-8: The map of Nakdong river (left) and Yongdam dam's (right) watershed.

BASINS was used to delineate the study watershed by calculating the flow direction and flow accumulation using an automatic procedure operating on the watershed's DEM (Digital Elevation Model). In addition, a national standard watershed map was used to delineate watersheds as well. The initial stream networks of the watersheds and their outlets were defined using a threshod area for which to define a stream. The threshold area used was determined by comparing stream networks generated through BASINS to the existing stream networks shown on maps. This ensured the generated stream networks being reliable.

The determined threshold area for stream delineation differed for each watershed, on the other hand, when this number was close to minimum values, it has a tendency to be similar between generated stream network and existing stream network.

The threshold areas for the Nakdong River watershed were 158, 136, 23, 92, 226, and 10 km for the Andong-dam, Imha-dam, Youngchun-dam, Hapchun-dam, Namgang-dam, and Milyang-dam. The threshold area used for the Yongdam dam stream delineation was 1,800km.

Figure 4-9 ~ 4-15 show the outlet locations, watershed delineations, and stream networks determined through threshold processing for the sites of this study.

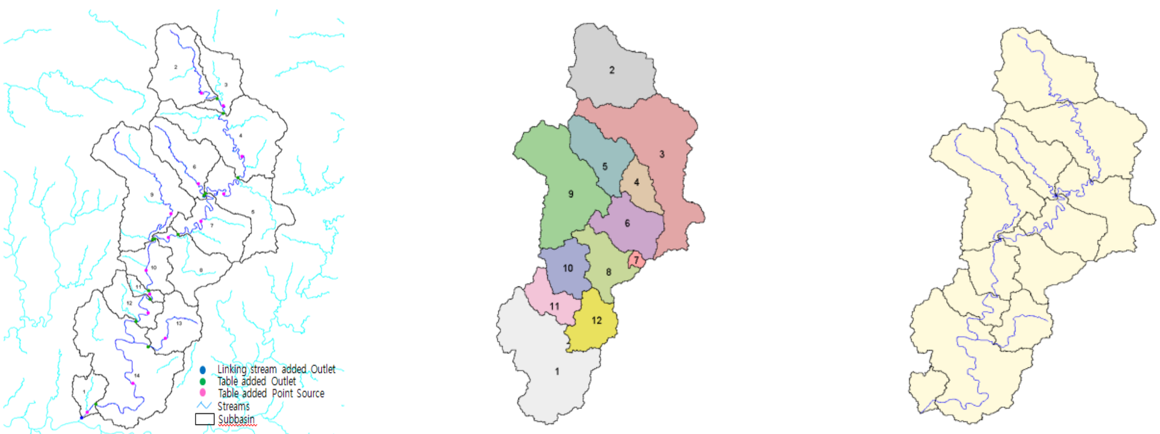


Figure 4-9: Outlet location, watershed delineation, and generated stream network at Andong Dam Watershed.

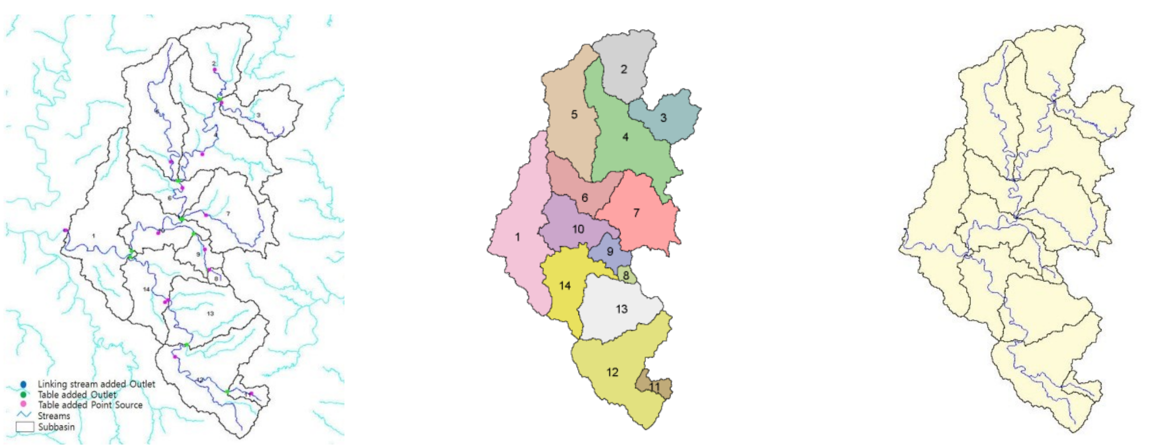


Figure 4-10: Outlet location, watershed delineation, and generated stream network at Imha Dam Watershed.

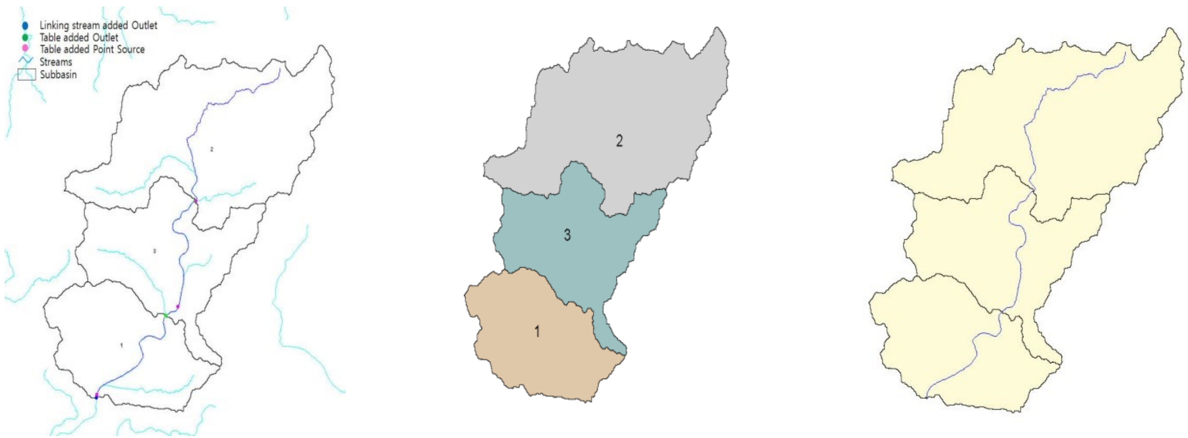


Figure 4-11: Outlet location, watershed delineation, and generated stream network at Youngchun Dam Watershed.

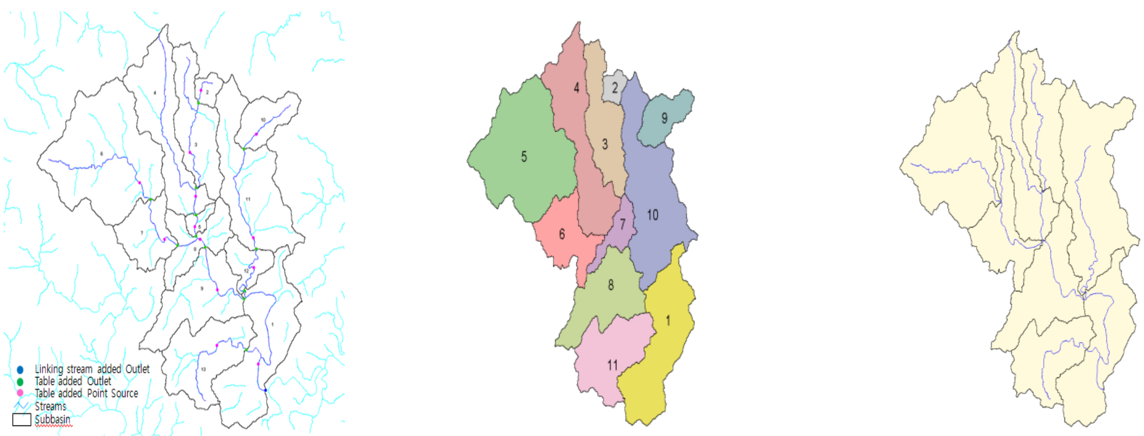


Figure 4-12: Outlet location, watershed delineation, and generated stream network at Hapchun Dam Watershed.

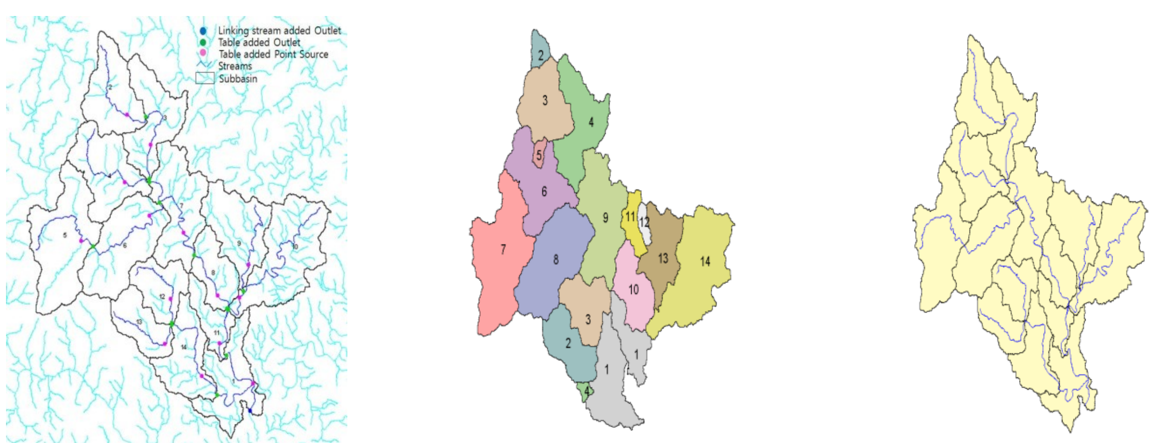


Figure 4-13: Outlet location, watershed delineation, and generated stream network at Namgang Dam Watershed.

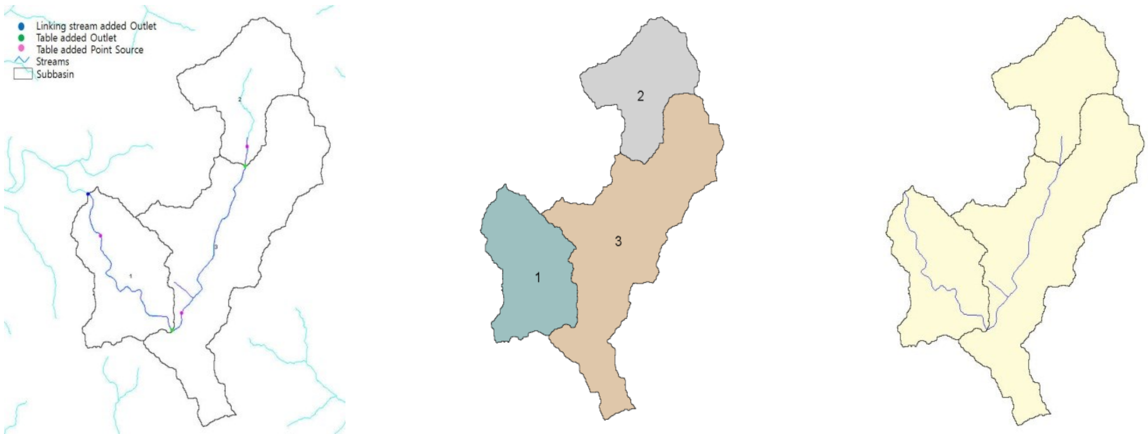


Figure 4-14: Outlet location, watershed delineation, and generated stream network at Milyang Dam Watershed.

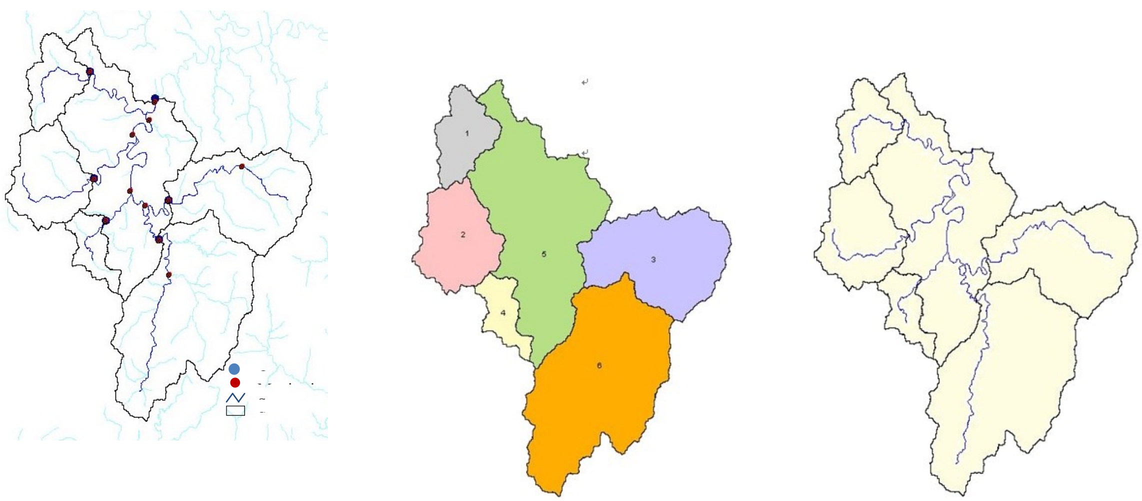


Figure 4-15: Outlet location, watershed delineation, and generated stream network at Yongdam Dam Watershed.

DEM (Digital Elevation Model)

A DEM (Digital elevation model) is a digital model representing elevation as a constant grid of earth's surface. DEM files are provided as 30 m grids by US Geological Survey (USGS). In order to implement the HSPF model, a DEM was downloaded and processed for six sites−Andong dam, Imha dam, Youngchun dam, Hapchun dam, Namgang dam, and Milyang dam watersheds which are shown in Figures 4-16 to 4-22.

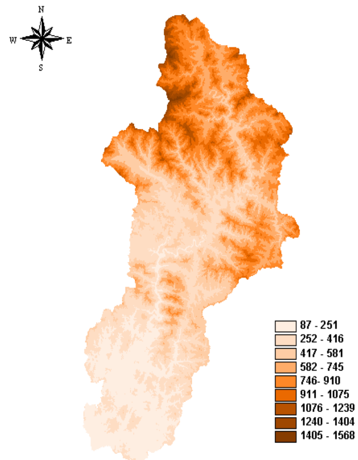


Figure 4-16: DEM for Andong Dam.

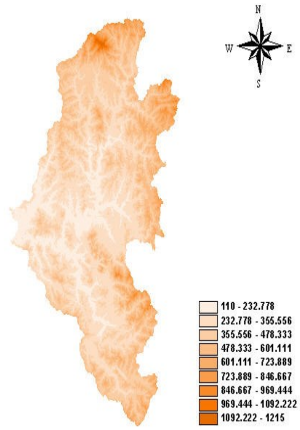


Figure 4-17: DEM for Imha Dam.

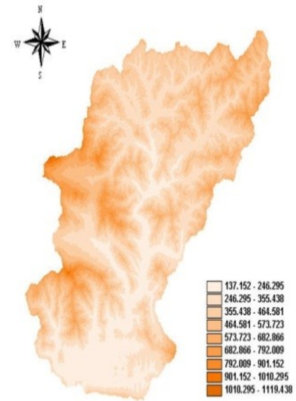


Figure 4-18: DEM for Youngchun Dam.

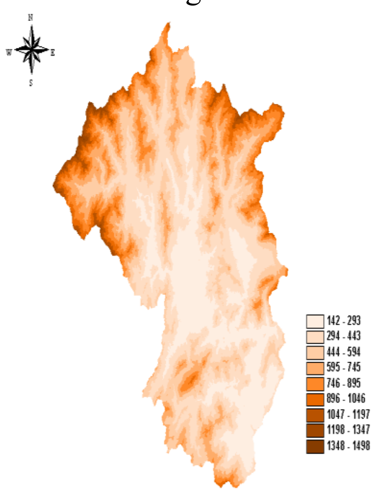


Figure 4-19: DEM for Hapchun Dam.

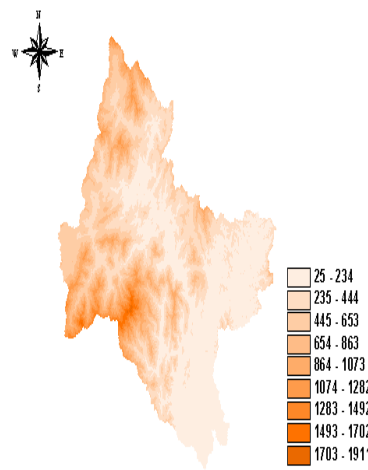


Figure 4-20: DEM for Namgang Dam.

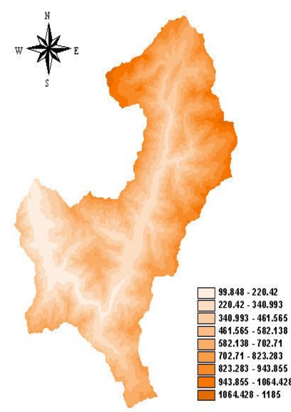


Figure 4-21: DEM for Milyang Dam.

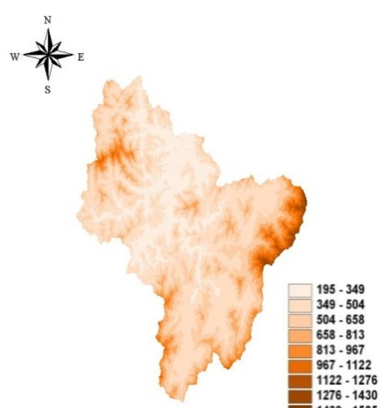


Figure 4-22: DEM for Yongdam Dam.

Land use

Land use was used for extracting land usage information of the delineated sub basins using "Land use and Soil Definition Utility" based on over layer land use map. In this research, land use was downloaded from the Environmental Geographic Information System (EGIS) at the Ministry of Environmental in South Korea. Large scale classification land use among three scale classification (large, medium, and small scale classification) were used. Data for the HSPF model were constructed by overlapping both land use data and a database input file. Each dam's land use map is shown in Figures 4-23 through ~ 4-29.

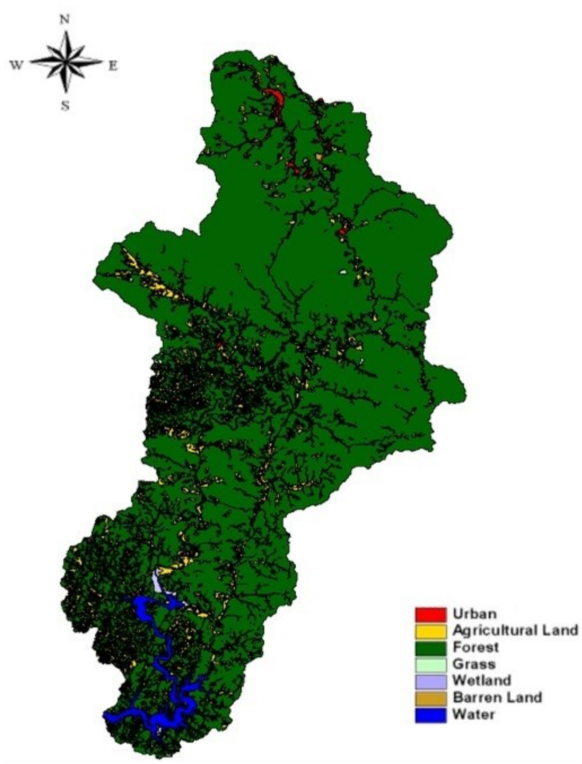


Figure 4-23: Land use of Andong Dam.

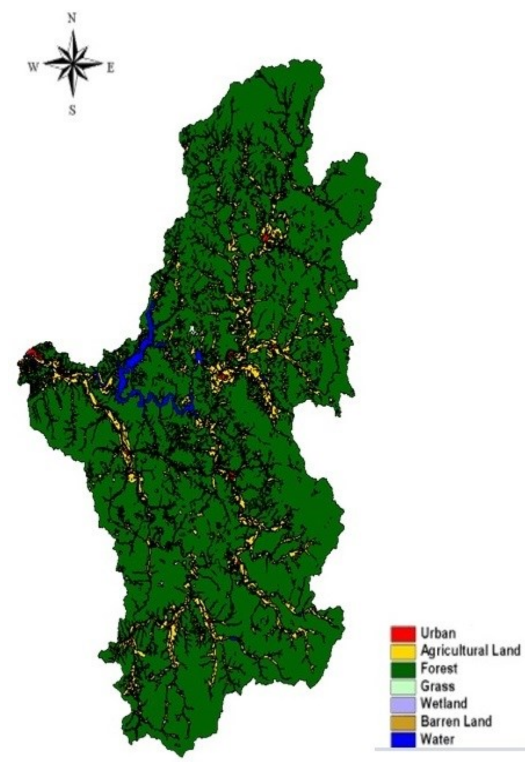


Figure 4-24: Land use of Imha Dam.

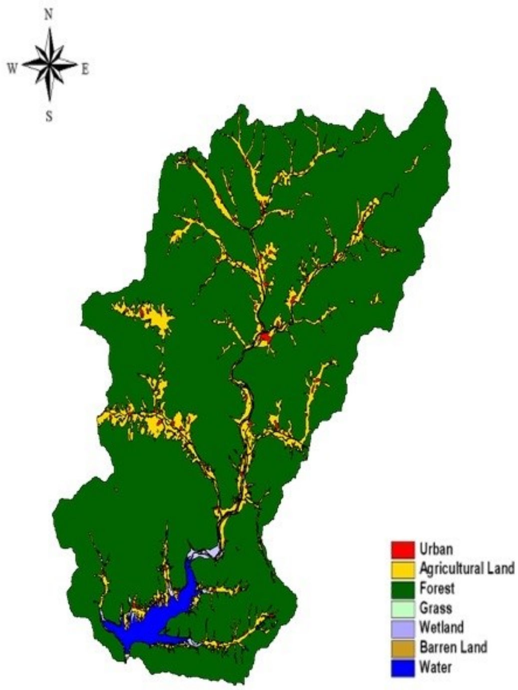


Figure 4-25: Land use of Youngchun Dam.

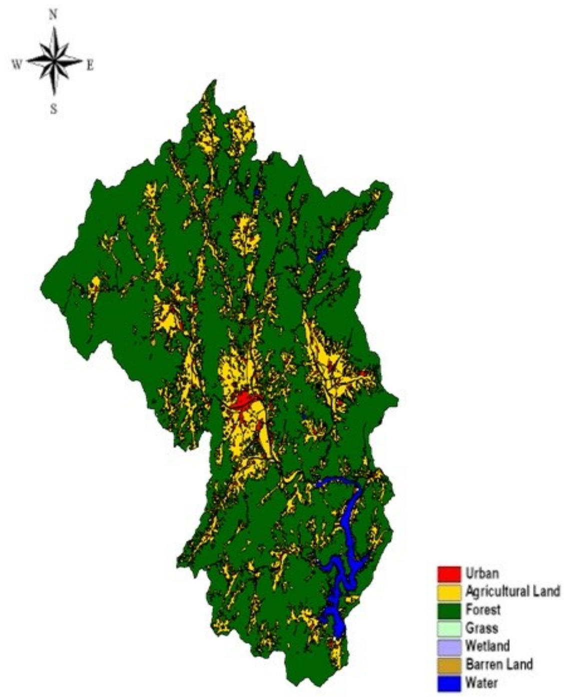


Figure 4-26: Land use of Hapchun Dam

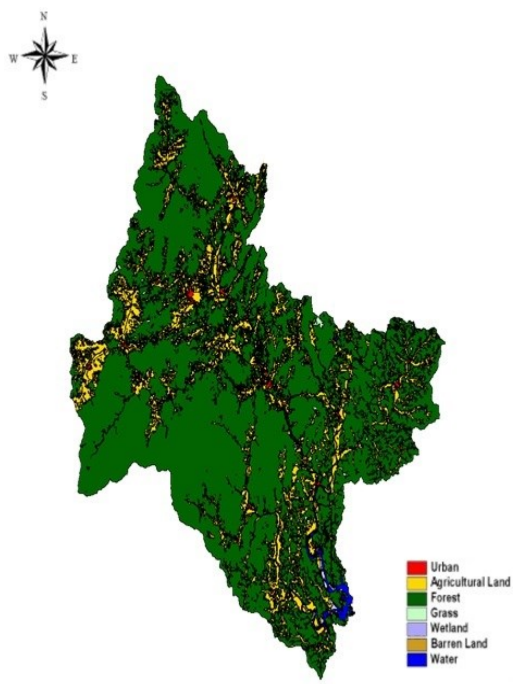


Figure 4-27: Land use of Namgang Dam.

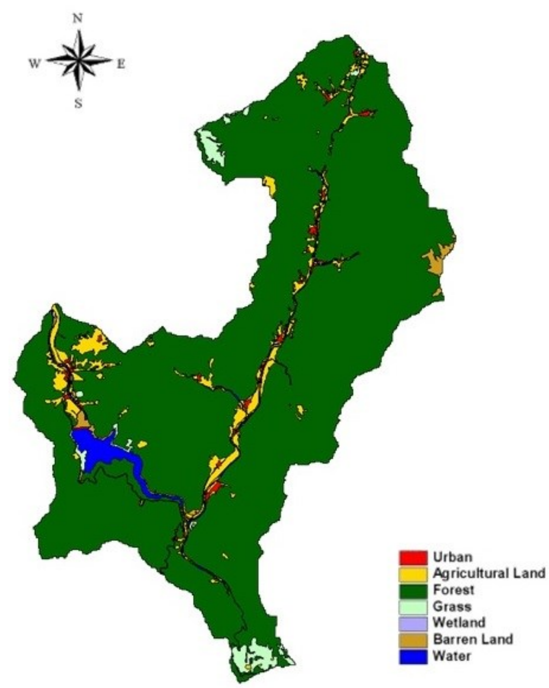


Figure 4-28: Land use of Milyang Dam.

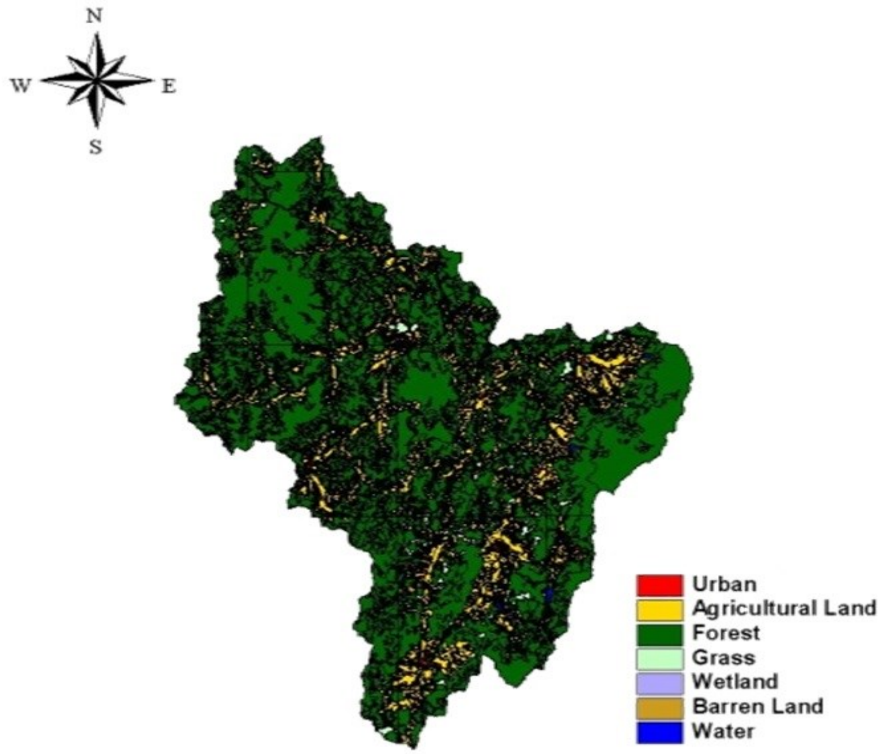


Figure 4-29: Land use of Yongdam Dam.

Weather Data

Seven types of weather input data are required for watershed modeling: hourly rainfall, temperature, dew point temperature, clouds, solar radiation, wind, and evapotranspiration data which are shown in Table 4-8. Six of the seven variables' hourly data were saved in the WDMUtil file and used to generate a *.wdm file. Hourly evapotranspiration is generated first using, daily evapotranspiration calculated using the Jensen equation and the Penman Pan equation in WDMUtil based upon daily maximum and minimum temperature, dew point temperature, the amount of clouds, and solar radiation data from WDMUtil. Secondly, hourly evapotranspiration is developed by using "Evapotranspiration" among Disaggregate Functions in WDMUtil.

Table 4-8: Weather input data in WDMUtil.

Parameter Name	Parameter	Time step	Unit	Name in UCI file
ATEM	Air Temperature	Hourly	℃	GATMP
PREC	Precipitation	Hourly	Mm/hr	PREC
DEWP	Dewpoint Temperature	Hourly	℃	DEWTMP
WIND	Wind movement	Hourly	km/hr	WIND
SOLR	Solar radiation	Hourly	Ly/hr	SOLRAD
CLOU	Cloud cover	Hourly	1/10	CLOUD
PEVT	Potential Evapotranspiration	Hourly	mm/hr	PETINP

For this research, each watershed's weather data was acquired from six weather stations for the Nakdong River watershed and two weather stations for Yongdam Dam's watershed. These are shown in Table 4-9.

Table 4-9: The location of weather stations for HSPF model.

Watershed	Weather station	Longitude (TM)	Latitude (TM)	Height (EL. m)
Andong Dam	Andong	128.70732	36.572930	140.700
Imha Dam	Youngdeok	129.40936	36.533310	41.200
Youngchun Dam	Youngchun	128.95141	35.977430	93.300
Hapchun Dam	Gyuchang	127.91102	35.671210	221.400
Namgang Dam	Sanchung	127.87910	35.412990	138.700
Milyang Dam	Milyang	128.74410	35.491480	10.700
Yongdam Dam	Jangsu	127.52029	35.656950	407.000
	Jeonju	127.09	35.49	54.200

Pollution Loads

Pollution loads were computed from pollution sources data collected from 2004 to 2010 from the National Institute of Environmental Research (NIER) for Nakdong River watershed and Yongdam Dam watershed pollution sources were collected from the Annual Report of Dam Reservoir Water Quality (K-water) generated from 2005 to 2006. Point source loads included sewage effluent. Land usage and stock loads were excluded from the considered discharge loads. In case of sewage and wastewater treatment plants with flow over 500 m^3, daily effluent flow and water quality were collected and input into the model as a point source load. The status of sewage and waste water treatment plants are shown in Table 4-10.

Table 4-10: The status of sewage and waste water treatment plant for HSPF.

Watershed		Treatment plant	Location	Capacity (ton/d)	Effluent River	Sort of facility
Nakdong river watershed	Andong Dam	Taebaek	Dongjeom-dong, Taebaek-si, Gangwon-do	30,000	Hwangji stream	Sewage water treatment plant
	Imha Dam	Cheongsong	Pacheon-myeon, Cheongsong-gun, Gyeongsangbuk-do	20	-	Human waste treatment plant
		yeongyang	Yeongyang-eup, yeongyang-gun, Gyeongsangbuk-do	30	-	Human waste treatment plant
	Youngchun Dam	-	-	–	-	-
	Hapchun Dam	Geochang	Yangpyeong-ri, Geochang-eup, Geochang-gun, Gyeongsangnam-do	10,500	Nakdong river	Sewage water treatment plant
		Gajo	Daecho-ri, Gajo-myeon, Geochang-gun, Gyeongsangnam-do	5,500	Nakdong river	Sewage water treatment plant
	Namgang Dam	Hamyang	Yongpyeong-ri, Hamyang-eup, Hamyang-gun, Gyeongsangnam-do	7,000	Nam river	Sewage water treatment plant
		Sancheong	Oksan-ri, Sancheong-eup, Sancheong-gun, Gyeongsangnam-do	2,800	Nam river	Sewage water treatment plant
	Milyang Dam	-				
Yongdam river watershed	Yongdam Dam	Jinan	Gunsnag-ri, Jian-eup, Jian-gun, Jeollabuk-do	3,000	Jinan Stream	Sewage water treatment plant
		Jangsu	Seonchang-ri, Jangsu-eup, jangsu-gun, Jeollabuk-do	2,000	Geum river	Sewage water treatment plant
		Janggye	Munong-ri, Janggye-myeon, jangsu-gun, Jeollabuk-do	2,000	Geum river	Sewage water treatment plant

Hydrology Data

Hourly effluent flow data from 2006 to 2010 were accumulated and input into WDMutil in order to run HSPF model for Andong dam, Imha dam, Youngchun dam, Hapchun dam, Namgang dam, and Milyang dam. The Dam status is displayed in Table 4-11.

Table 4-11: The present situation of Dam's hydrology in Nakdong river watershed.

Division	Dam	Watershed Area (km^2)	Total Capacity (million m^3)	Effective capacity (million m^3)	river
Multipurpose Dam	Andong Dam	1,584	1,248	1,000	Nakdong river
	Imha Dam	1,361	595	424	Banbyun stream
	Hapchun Dam	925	790	560	Hwang river
	Namgang Dam	2,285	309.2	299.7	Nam river
	Milyang Dam	95.4	73.6	69.8	Danjang stream
Domestic & industry purpose Dam	Youngchun Dam	235	96.4	81.4	Jaho stream

For acquiring Yongdam dam watershed's hydrology data, hourly effluent flow data from 2005 to 2006 was calculated from a rating curve of water elevation and flow for 5 monitoring stations. This is shown in Table 4-12.

Table 4-12: The monitoring situations of hourly flow in Yongdam dam watershed.

Watershed	Station name	Stream	Area (km^2)
Yongdam dam	Jucheon	Juja	57
	Seokjeong	Jeongja	97
	Dochi	Jinan	34
	Donghyang	Guryang	163
	Cheoncheon	Geum river	282

PERFORM HSPF

HSPF pre-process includes generating the river network, watershed delineation, and land use overlay, after the pre-processing is finished, a BASINS *wsd file is produced through the following: BASINS > DATA folder.

First of all, create a new project in the initial image and then input *.wsd file to BASINS Watershed File, second of all, select *.wdm file including weather data, point pollution loads, the amount of dam effluent to the Met WDM Files, lastly, in Project WDM File, select the new *.wdm file for accumulating HSPF results (Figure 4-30).

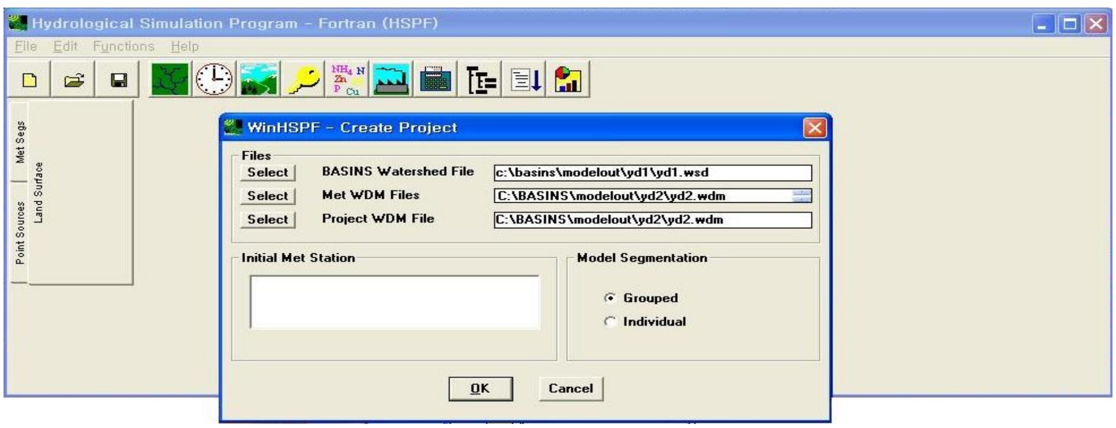


Figure 4-30: The new project generating picture for HSPF model.

Following Figure 4-30 processes and if there is no error, Figure 4-31 will be generated.

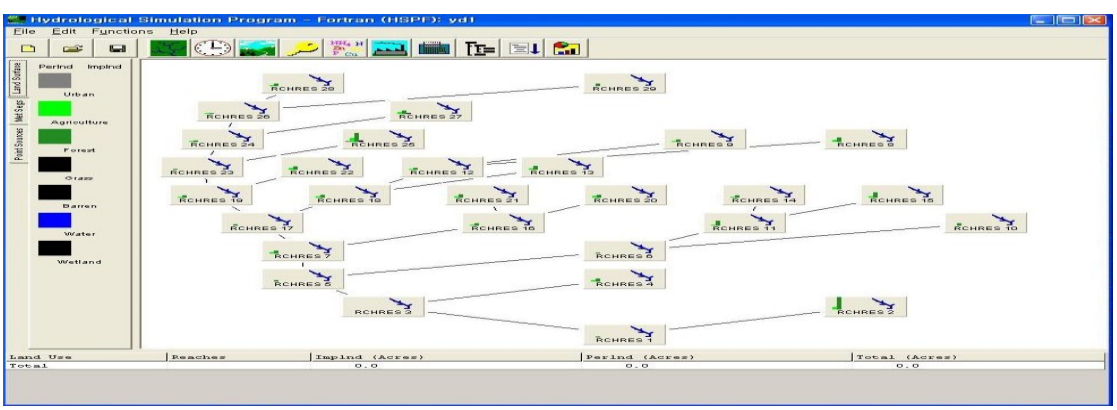


Figure 4-31: The picture of HSPF running.

4.3.4 CALIBRATION AND VALIDATION

Discharge Calibration & Validation

Model calibration and validation are important steps in ensuring the realism of a model. Calibration is an iterative procedure of parameter evaluation and refinement to compare simulated and observed values of interest based upon changing the model parameters. Validation is an extension of the calibration process. The purpose of validation is to assure that the calibrated models evaluated the variables and condition which can affect results (Donigian, 2002).

In order to calibrate and validate for Nakdong river watershed, observed data from the Dosan water level station was adopted for Andong dam watershed, and inflow data of Dam's upstream is chosen for the other dams' watersheds which are shown at Figure 4-32.

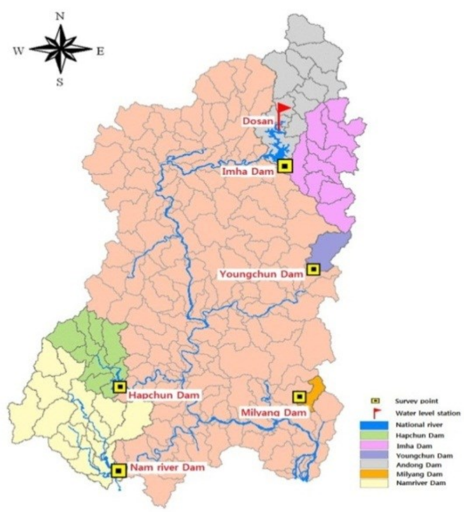


Figure 4-32: The calibration and validation point for Nakdong river watershed.

For Yongdam Dam's Discharge calibration and validation, the end points of subwatersheds; Juja, Jeongja, Jinan, Guryang, and Geum river subwatersheds were used which are shown in Figure 4-33.

Figure 4-33: The calibration and validation point for Nakdong river waterhed.

Three goodness-of-fit statistical measures were used to evaluate the model results in calibration and validation results: the Coefficient of Determination (R^2), EF (NSE), and % difference. R^2 ranges from 0.0 to 1.0 and a value of 1.0 indicates a perfect correlation between observed and simulated data. However R^2 only evaluates the random error, therefore, in order to consider fluctuation between simulation and observation, NSE and percent difference (Equation 25 and 26) were used as additional measures of fit. If the simulation value is perfect, the value is close to one, if not, the value is close to zero. percent difference used to confirm the credibility of repeated survey values which are predicting same results comparing between observed and simulated data. Donigan (2000) suggested the confidence range of R^2, NSE, and percent difference for HSPF calibration and validation which are shown in Table 4-13.

$$\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{n}(O_i - P_i)^2}{\sum_{i=1}^{n}(O_i - \overline{O_i})^2} \qquad \text{Equation 25}$$

$$\%\ \mathrm{difference} = \frac{\left|\sum_{i=0}^{n} O_i - \sum_{i=0}^{n} P_i\right|}{\sum_{i=0}^{n} O_i} \times 100 \qquad \text{Equation 26}$$

Where, P_i: simulation value, O_i: observation value, n: the number of data,

$\overline{O_i}$: average of observation value

Table 4-13: Confidence range and effective range of HSPF calibration and validation (Donigan, 2000).

Criteria	Very good	Good	Fair	Poor
R^2	> 0.80	0.80 ~ 0.70	0.70 ~ 0.60	< 0.60
NSE	0.90 ~ 0.8	0.80 ~ 0.70	0.70 ~ 0.60	0.60 ~ 0.50
% difference	< 10	10 ~ 15	15 ~ 25	-

The largest impact parameters of HSPF discharging calibration and validation were LZSN, INFILT, AGWRC, UZSN, DEEPER, INTEW, IRC, and so on. Table 4-14 shows the parameter values of preceding research.

Table 4-14: The parameter values of preceding research for HSPF model.

Para-meter	Definition	unit	Typicalrange	Laroche et al. (1996)	Engelmann et al. (2002)	Minealbdk et al. (2003)	Jaswinder at al. (2005)	Ribarovaatal. (2008)	A-Hyun, Shin (2008)	Jae-Ho Jang (2010)
LZSN	Lower zone nominal soil moisture storage	in	3.0~8.0	14.2	5	3.1	5.00	15	4~6.5	6.0 ~6.5
UZSN	Upper zone nominal soil moisture storage	in	0.05 ~2.0	0.76	0.7	0.6	0.2~1.4	2	0.128~1.128	0.55
		mm	1.27 ~50.8							
INFILT	The infiltration capacity of the soil	in/hr	0.01 ~0.25	0.23	0.04	0.0	0.20	0.05 ~0.16	0.16 ~0.96	
		mm/hr	0.25 ~25.0							0.46 ~9.96
AGWRC	The basic groundwater recession rate	1/day	0.92 ~0.99	0.99	0.99	0.99	0.98	0.994	0.90 ~0.98	0.95
DEEPER	Fraction of groundwater inflow which will enter deep groundwater	-	0.0~2.0	-	0.18	0.35	0.05	0.15	0.55 ~0.90	0.5
LZETP	Lower zone ET parameter	-	0.1~0.9			0.1		0.2~0.7		0.1
INTFW	Interflow inflow parameter	-	1.0 ~10.0	9.83	0.5	2.0	1.2~1.8	1.25	8.0 ~30.0	6.2
IRC	The interflow recession parameter	1/day	0.30 ~0.85	0	0.5	0.65	0.6~0.8	0.3	0.50 ~0.79	0.45
KVARY	Parameter which affects the behavior of groundwater recessionflow	1/in	0.0~3.0				3.00	0	0~0.9	0.0~0.2

The Results of Discharge Calibration & Validation

The calibration was performed for the observed streamflow of the watershed outlet. Figures 4-34 shows the observed versus simulated daily streamflow for the calibration period (2009 ~ 2010). In this study, calibration was carried out and parameters determinded by the calibration process were used for validation of the model (Table 4-15). The values for R^2 of discharge during the calibration period were 0.63~0.95 for Nakdong River watershed. Also, performance of the HSPF model was tested by calculating the NSE and percent difference. The observed and the simulated annual discharge volumes are compared and the results are shown in Table 4-15. The percent differences between the observed and simulated volumes for each annual discharge, as well as summer, and spring discharge over a 2-year time period were calculated for each of the 6 streams in the Nakdong River Watershed.

Of the 6 streams used in this calibration and validation test, the results for Andong were very good. The percent difference was below 7.18 during the summer, and 25 % in the spring, NSE was less than 0.5 in the summer with spring values of over 0.6. The resulting R^2 valus were over 0.7 for all the modeled annual and seasonal discharges. Thus, the HSPF values for the Andong River watershed are acceptable. In case of Imha, the percent difference was slightly higher compared to Andong. This is due to the fact that the simulated data was overestimated during the rainfall seasons. NSE was over 0.61 and R^2 was over 0.74 for all modeled annual and seasonal discharges. Thus, the HSPF values are acceptable for Imha. Youngchun's percent difference ranged from 6.45 % ~ 22.28 %, NSE ranged from 0.60 ~ 0.83, and the R^2 0.71 ~ 0.89. Hapchun's percent difference ranged from 15.22 % ~ 101.99 %, the NSE ranged from -0.1 ~ 0.61, and R^2 from 0.63 ~ 0.95. Namgang's percent difference ranged from 24.50 % ~ 34.31 %, the NSE ranged from 0.66 ~ 0.78, and R^2 from 0.54 ~ 0.89. Finally, the Milyang's percent difference ranged from 20.02 % ~ 32.85 %, NSE ranging from 0.68 ~ 0.87, and R^2 from 0.75 ~ 0.86. Even though Hapchun's percent difference in 2009 was very high at 101.99 %, the R^2 was also remarkably high at 0.95 which means that the simulated data was changing in a similar trend as the measured data while the difference was staying relatively constant. Overall, eventhough the percent differences for each stream had significantly large ranges, R^2 was over 0.7 in 2009 and 2010 for all of the streams and modeled results are therefore considered acceptable as a good criterion (Donigan, 2000, Ouyang et al., 2012) .

Table 4-15: Simulated and observed discharge from 2009 to 2010 for streams in the Nakdong River watershed (The results of HSPF model).

Stream	Parameter	Observed (m^3)	Simulated (m^3)	Difference (%)	NSE	R^2
Andong	2009	4,955	4,969	0.28	0.80	0.89
	2010	5,867	5,678	3.22	0.67	0.71
	Summer (Jun-Aug)	5,014	5,374	7.18	0.49	0.82
	Spring(Mar-May)	2,669	2,001	25.03	0.67	0.81
Imha	2009	2,988	4,425	48.06	0.79	0.82
	2010	5,125	6,299	22.90	0.63	0.74
	Summer (Jun-Aug)	4,248	5,790	36.30	0.74	0.81
	Spring(Mar-May)	2,047	1,908	6.78	0.61	0.76
Youngchun	2009	558	682	22.28	0.83	0.89
	2010	1,168	994	19.15	0.61	0.71
	Summer (Jun-Aug)	1,000	936	6.45	0.72	0.84
	Spring(Mar-May)	355	234	34.17	0.60	0.75
Hapchun	2009	3,561	7,192	101.99	0.42	0.95
	2010	8,207	9,456	15.22	0.61	0.63
	Summer (Jun-Aug)	6,497	9,507	46.34	0.48	0.74
	Spring(Mar-May)	1,400	3,438	145.64	-0.1	0.91
Namgang	2009	16,815	12,695	24.50	0.78	0.82
	2010	39,271	28,529	27.35	0.77	0.89
	Summer (Jun-Aug)	34,641	22,755	34.31	0.78	0.84
	Spring(Mar-May)	7,668	5,175	32.51	0.66	0.54
Milyang	2009	698	927	32.85	0.85	0.86
	2010	947	1,213	28.06	0.84	0.85
	Summer (Jun-Aug)	1,015	1,242	22.43	0.87	0.87
	Spring(Mar-May)	372	446	20.02	0.68	0.75

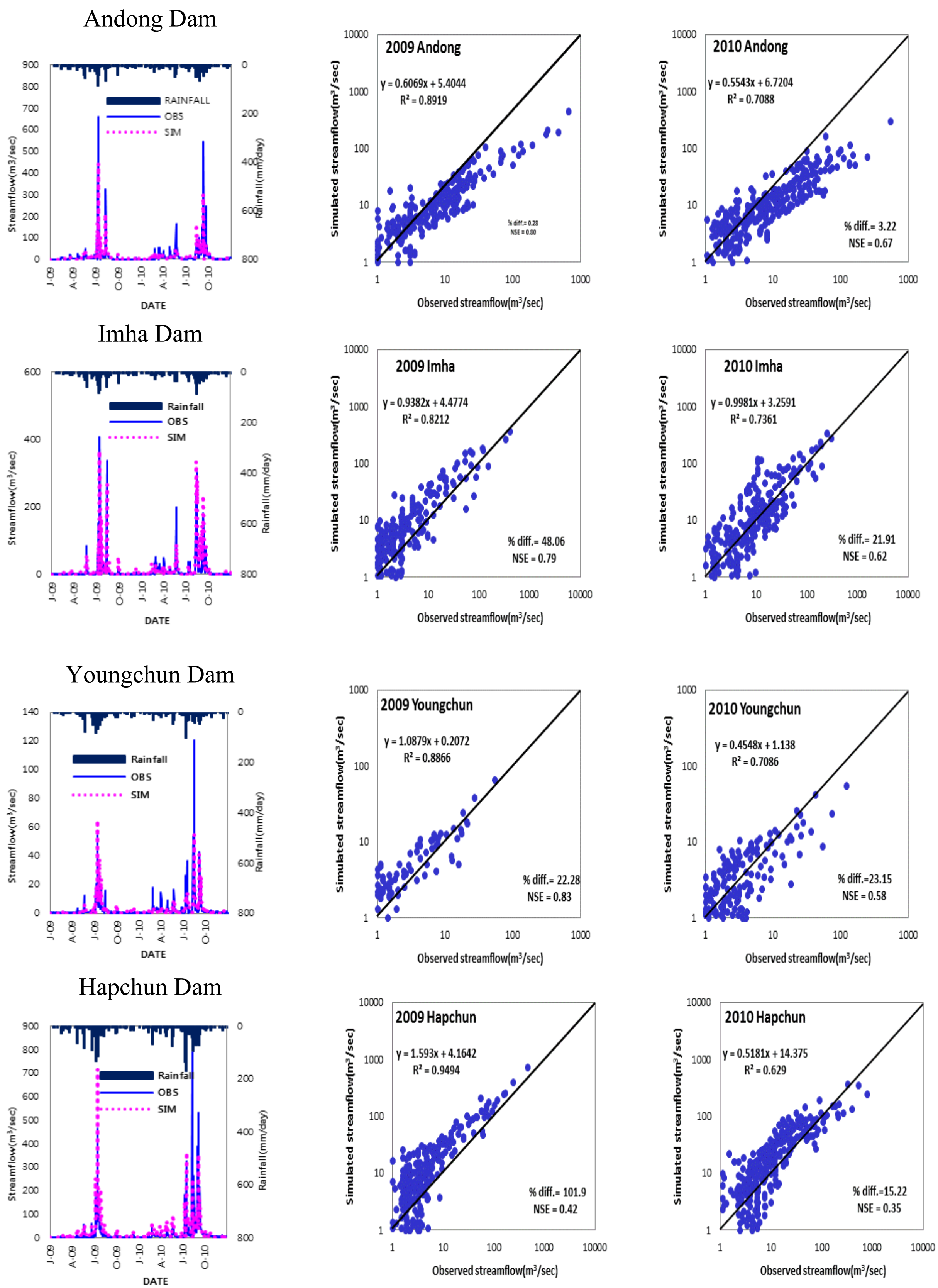


Figure 4-34: Model calibration results of Nakdong river watershed, HSPF (2009 – 2010) (1).

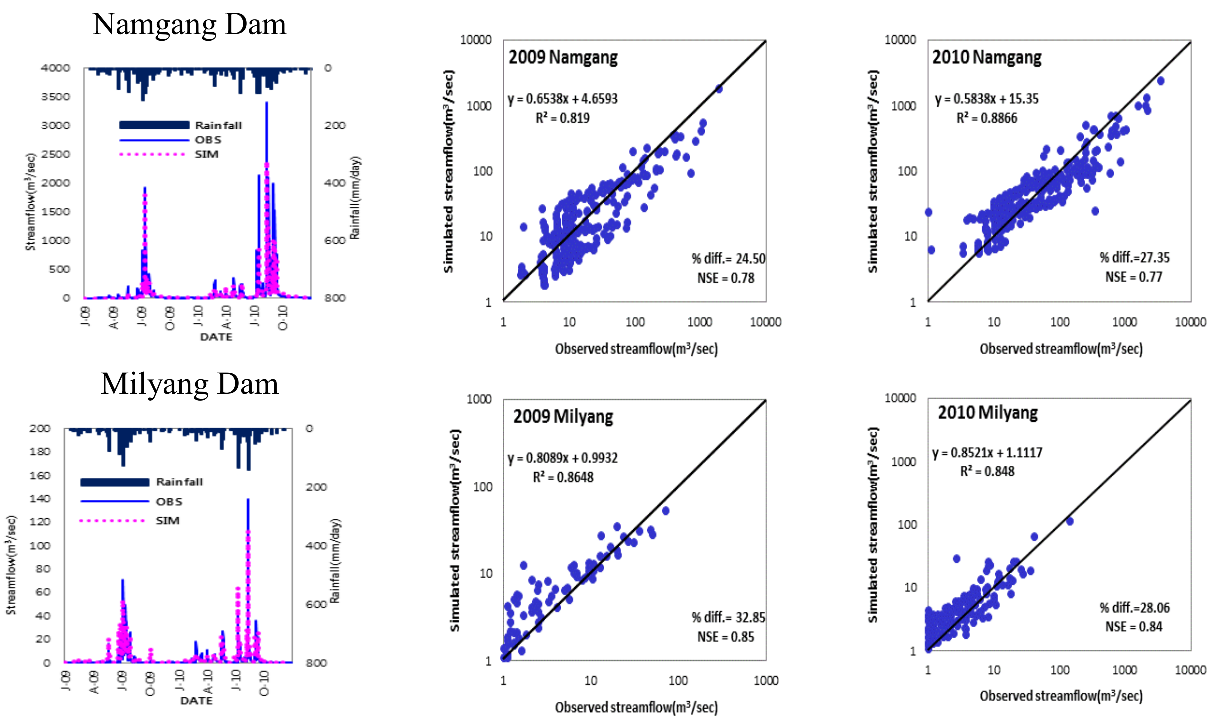


Figure 4-34: Model calibration results of Nakdong river watershed, HSPF (2009 – 2010) (2).

In the case of the Yongdam Dam's watershed, calibration was performed for the observed streamflow of the watershed outlet. Figure 4-35 shows the observed versus simulated daily streamflow for calibration and validation (2005–2006). The values for R^2 of streamflow during the calibration period were 0.68~0.96. Also, performance of the HSPF model was tested by calculating % difference and NSE.

The observed and the simulated annual discharge volumes were compared and the results are shown in Table 4-16. The percent differences between the observed and the simulated annual, summer, and spring discharge volumes over a 2-year time period from 2005 through 2006 were calculated for each of the 5 streams in the Yongdam Dam's watershed. Juja's percent difference ranged from 24.39 % to 48.69 % which is below fair, whereas the NSE ranged was from 0.61 ~ 0.77 which is more than fair with an R^2 of 0.68 ~ 0.91 tells us this model works well for this watershed and is good criterion for calibration except for during dry season. The reasons for having a high percent difference are due to the fact that the simulated data were underestimated compared to the observed data. Jeongja's percent difference was from 62.64 % to 90.07 % where, NSE ranged from -0.58 to 0.47, and the R^2 was 0.70 to 0.88. The reason for having such a high percent difference and a negative value for NSE is due to the overestimation of simulated data compared to observed data. Jinan's percent difference was 23.06 % ~ 44.14 % which is due to the underestimation of simulated data, while the NSE range was 0.60 ~ 0.78, and R^2 ranged from 0.67 ~ 0.86. Guryang's percent difference ranged from 2.44 % ~ 20.45 %, the NSE range 0.40 ~ 0.84 with an R^2 from 0.67 ~ 0.90. Geum's percent difference was 9.47 % ~ 36.41 %, where the NSE ranged from 0.4 ~ 0.84 with an R^2 from 0.67 ~ 0.90. Guryang and Geum's percent differences can be considered fair criteria for the model except for Guryang's and Geum's dry season values. Even though several percent differences in the comparison can be considered below fair criterion, the R^2 was over 0.7 in 2005 and 2006 for all of the streams compared. Therefore, using these streams is a good and acceptable as criterion for calibration (Donigan, 2000, Ouyang et al., 2012) .

Table 4-16: Simulated and observed discharge from 2005 to 2006 in the Yongdam Dam Watershed (The results of HSPF model).

Stream	Parameter	Observed (m^3)	Simulated (m^3)	Difference(%)	NSE	R^2
Juja	2005	955	511	48.69	0.61	0.91
	2006	848	641	24.39	0.70	0.71
	Summer (Jun-Aug)	1,544	922	40.27	0.65	0.79
	Spring(Mar-May)	174	110	36.72	0.77	0.68
Jungja	2005	586	954	62.64	0.47	0.88
	2006	499	949	90.07	-0.58	0.68
	Summer (Jun-Aug)	910	1,534	68.63	-0.09	0.75
	Spring(Mar-May)	103	186	81.00	0.24	0.70
Guryang	2005	1,672	1,977	18.25	0.71	0.96
	2006	1,423	1,183	16.88	0.87	0.95
	Summer (Jun-Aug)	2,593	2,656	2.44	0.79	0.95
	Spring(Mar-May)	293	233	20.45	0.82	0.74
Jinan	2005	355	273	23.06	0.78	0.80
	2006	302	169	44.14	0.60	0.81
	Summer (Jun-Aug)	550	358	34.88	0.68	0.81
	Spring(Mar-May)	62	40	35.39	0.76	0.67
Geum	2005	2,906	3,621	24.61	0.84	0.90
	2006	2,474	2,708	9.47	0.75	0.75
	Summer (Jun-Aug)	4,508	5,051	12.06	0.80	0.80
	Spring(Mar-May)	509	695	36.41	0.40	0.67

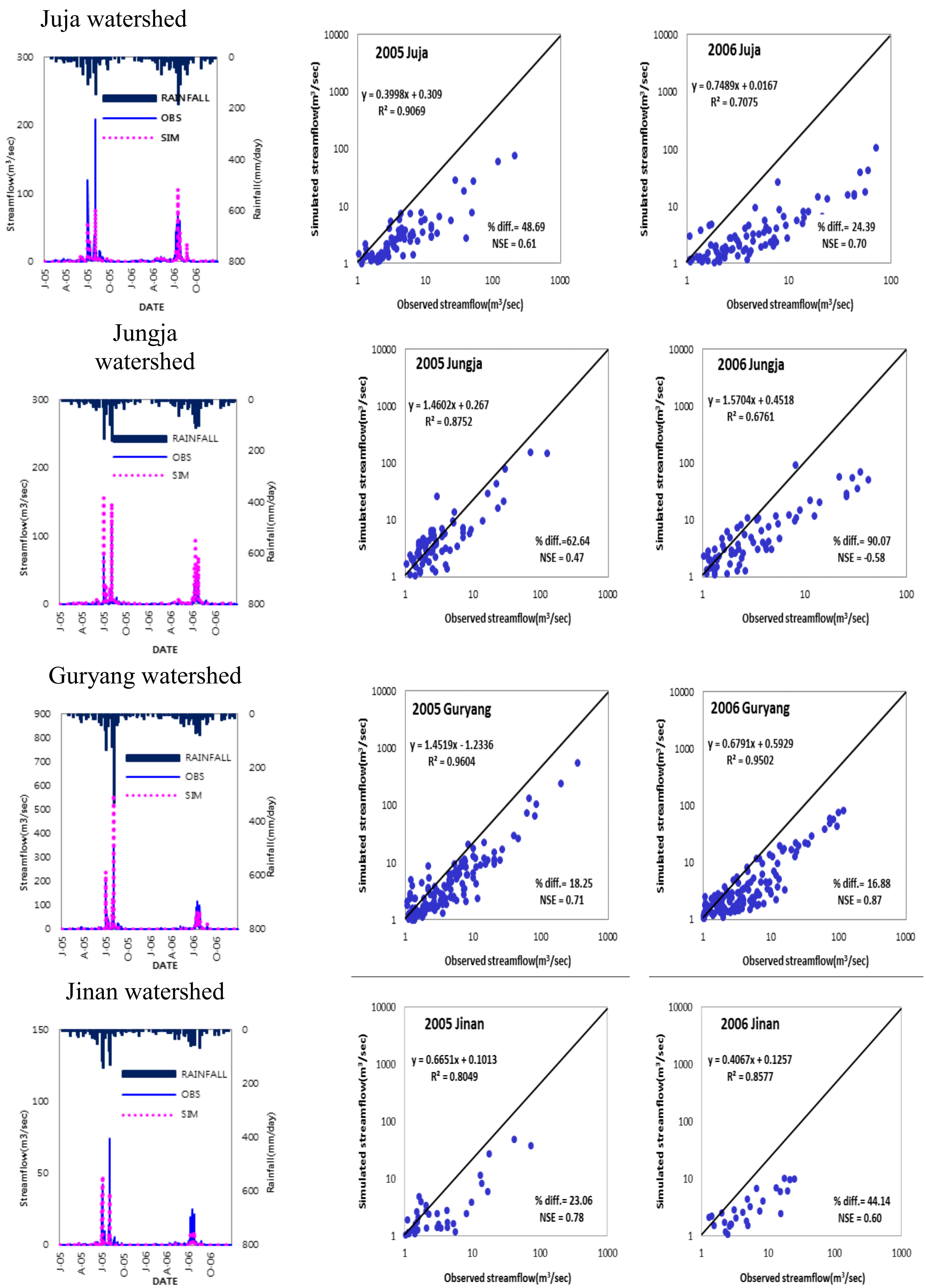


Figure 4-35: Model calibration results of Yongdam Dam's watershed, HSPF (2005 – 2006) (1).

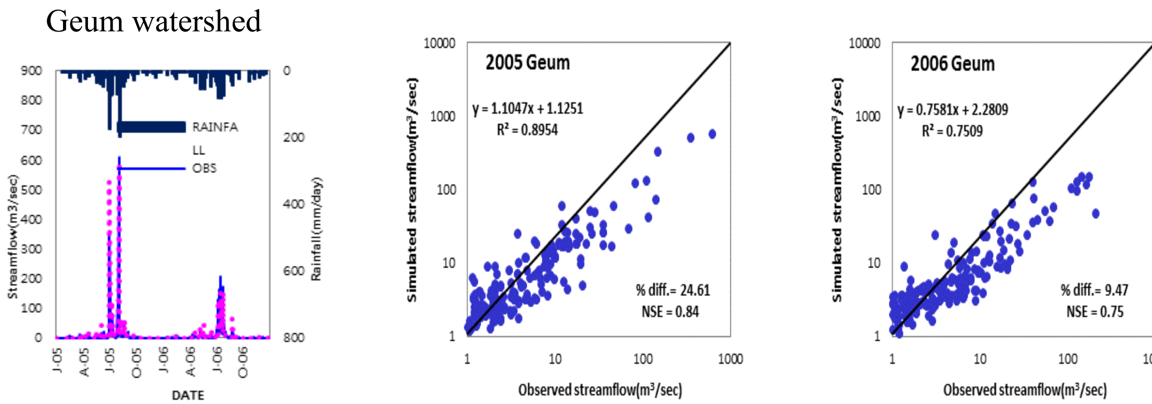


Figure 4-35: Model calibration results of Yongdam Dam's watershed, HSPF (2005 – 2006) (2).

Water Quality Calibration & Validation

Water quality simulation of HSPF is classified both pervious and impervious allowing the integrated simulation of land and soil contaminant runoff processes with in-stream hydraulic and sediment-chemical interaction. Especially pre-implemented water quantity (flow) simulation has a great relationship with water quality simulation because the water quality mechanism is impacted runoff.

In order to calibrate and validate the Nakdong River watershed model, water quality data from the Nakdong River Environment Research Center were used which surveyed at an eight day interval over thirty times per year. Water quality surveys are carried out mostly during non rainfall conditions. Therefore the simulation results during rainfall conditions were assumed to be equivalent to the surveyed data even though their conditions are much differnet. Calibration and validation points are shown in Figure 4-36.

In relation to Yongdam's calibration and validation results, water quality data from the Yongdam Dam Management office of K-water were used. This data includes surveys which were conducted approximately 30 times per year from 2005 to 2006. The same holds true for the Nakdong river survey. Water quality surveys were implemented mostly during non-precipitation conditions. The calibration and validation points are shown in Figure 4-33.

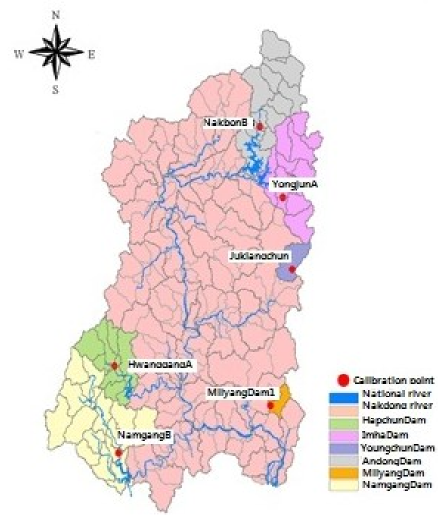


Figure 4-36: Calibration & validation point of each Dam's watershed.

The periods used for calibration and validation were 2009 to 2010 for the Nakdong River watershed model and 2005 to 2006 for the Yongdam Dam watershed model. In addition, to evaluate the applicability of calibration and validation results, the confidence range of the percent difference for each water quality parameter that was applied are shown in Table 4-17.

Table 4-17: The confidence range of the percent difference for each parameter.

Constituent	Very Good	Good	Fair
Hydrology/Flow	＜10	10 ~ 15	15 ~ 25
Sediment	＜20	20 ~ 30	30 ~ 45
Water Temperature	＜7	8 ~ 12	13 ~ 18
Water Quality/Nutrients	＜15	15 ~ 25	25 ~ 35
Pesticides/Toxics	＜20	20 ~ 30	30 ~ 40

Source: "Watershed Model Calibration and Validation: Issues and Procedures" from BASINS/HSPF Training Lecture No. 15.

When calibrating the HSPF model, firstly, Dissolved Oxygen were calibrated and then BOD, T-N, T-P were calibrated, respectively. The main parameters were water quality, water temperature, Dissolved Oxygen, Biochemical Oxygen Demand, Total Nitrogen, and Total Phosphorous are shown in Table 4-18 ~ 4-20.

The major parameters for water temperature simulation was PSTEMP module and IWATGAS module of PERLND and IMPLND section, KATRAD, KCOND, KEVAP, CFSAEX of HTRCH module of REACHES Section. Among these parameters, CFSAEX was a relatively high sensitivity parameter among these parameters because this parameter has the function of determining the amount of solar radiation to the river.

Table 4-18: The parameters in relation with water temperature simulation.

Parameter	Definition	unit	Typical Range	Possible range
ASLT	The surface layer temperature when the air temperature is 32 degrees F in Pervious land	deg F	0 ~ 100	40
BSLT	The slope of the surface layer temperature regression equation in Pervious land	deg F	0.001 ~ 0.2	0.3
ULTP1	The smoothing factor in upper layer temperature calculation	-		40
AWTF	The surface water temperature, when the air temperature is 32 degrees F in impervious land	deg F	0 ~ 100	40
BWTF	The slope of the surface water temperature regression equation in Impervious land	deg F	0.001 ~ 2	0.1
KATRAD	The longwave radiation coefficient	-	1~20	9.5
KCOND	The conduction-convection heat transfer coefficient	-	1~20	6.12
KEVAP	The evaporation coefficient		1~10	2.24
CFSAEX	The correction factor for solar radiation		0.001~2	0.95

Parameters in OXRX module were used for DO and BOD simulation and a few parameters for examples, CVBO, CVBPC, CVBPN in NUTRIX module were applied for calibration, as well which are shown in Table 4-19.

Table 4-19: The parameters in relation with DO and BOD.

Parameter	Definition	unit	Typical range	Hyesook Lee at al. (2007)	Wonmo Yang (2007)	Jyungwoon Han(2007)	Jae-Ho Jang (2010)	Ahyun Shin (2008)	Najung Jun (2011)
KBOD20	BOD decay rate at 20 ℃	1/hr	0.001 ~0.14	0.04~ 0.09	0.001~0.01	0.002~0.004	0.011~ 0.015	0.001~0.014	0.004~ 0.067
KODSET	Rate of BOD settling	ft/hr	> 0	0.004~ 0.02		0.0001~0.027	0.018~ 0.033	0.017~0.028	0.011~ 0.027
REAK	Reaeration coefficient	1/hr	-	0.5		0.2 ~0.726	0.48	0.2 ~0.7	0.05~ 0.2
TCBOD	Temperature correction coefficient for BOD decay	-	-	1.075	1.047				
BRBOD	Base release rate of BOD materials	mg/m²	>0.0001					0.001~5.001	0.001~ 150
BODOX	Dissolved oxygen	mg/L			19.8				
BOD	Biochemical oxygen demand				1.5				
CVBO	Conversion from milligrams biomass to milligrams oxygen	mg/mg	1.0~5.0			1.63-2.00		1.00 ~3.00	1.63
CVBPC	Conversion from biomass expressed as phosphorus to carbon	moles/mol	50~200			80-180		56 ~196	106
CVBPN	Conversion from biomass expressed as phosphorus to nitrogen	moles/mol				16-35		16-46	

For T-N and T-P calibration, the initial water quality value and accumulation rate of PQUAL module in PERLND Section and the parameters of NUTRX module in RCHRES Section were controlled to minimize the difference between observed data and simulated data. The parameters for T-N and T-P are shown in Table 4-20.

Table 4-20: The parameters in relation with TN and TP.

Parameter	Definition	unit	Typical range	Ribarova at al. (2008)	Hyesook Lee at al. (2007)	Najung Jung (2011)	Jae-Ho Jang (2010)	Wonmo Yang (2007)	Jungwoon Han(2007)	Ahyun Shin(2008)
KNO320	Denitrification rate of nitrate	1/hr	0.0001~	0.05	0.002	0.008	0.001	0.001~0.5	0.001~0.045	0.001~0.045
KTAM20	Oxidation rate of total ammonia	1/hr	0.0001~	0.05	0.055	0.045	0.025	0.001~10.05	0.015~0.05	0.001~0.055
KNO220	Oxidation rate of nitrites	1/hr	0.0001~	0.05	0.001	0.008	0.012		0.002~0.05	0.002~0.052
TCNIT	Temperature coefficient for the nitrogen oxidation rate	-		1.07				1.07~2	1.00~ 1.07	
TCDEN	Temperature coefficient for the denitrification rate	-		1.07					1.04	
DENOXT	Oxygen concentration threshold above which denitrification ceases	mg/L		2					1.00~ 5.00	
KDSAM	Ammonium desorption factor	1/day	0~none							
KIMNI	Nitrate immobilization factor	1/day	0~none							
TAM	Initial concentrations of total ammonia	mg/L	-					0.1		
PO4	Initial concentrations of total ortho-phosphorus	mg/L	-							
BROPO41	the benthal release rate of ortho-phosphate under aerobic conditions	mg/m²/hr								
BROPO42	the benthal release rate of ortho-phosphate under anaerobic conditions	mg/m²/hr								

The Results of Water Quality Calibration & Validation

The calibration (2009) and validation (2010) for six dams located in the Nakdong River watershed was performed with four water quality parameters: DO, BOD, T-N, and T-P which are shown in Table 4-21. On the whole, patterns within the observed and simulated data have similar tendencies. Data however, was not colleted during rainfall events; hence percent differences could not be compared during rainfall events but were analyzed for during non rainfall conditions. That is a possible reason why percent differences were so low for this particular calibration. Percent differences for all of the water quality parameters were below fair (25 % ~ 35 %) except for Andong Dam's BOD during the spring season (37.91%), for Hapchun Dam's TP in 2009 (63.33%), summer (55.54%), and spring (40.06%), for Imha Dam's TP spring (45.85%), and for Milyang Dam's TP in 2009 (139.33%), summer (58.27%), and spring (289.20%). Most of percent differences for DO, BOD, and TN were below fair. On the other hand, T-P percent differences of several spring seasons exceeded the fair criterion. The ratio between simulated and observed mean concentration for DO, BOD, and TN during 2009 and 2010 are mostly between 0.81 and 1.25 except for the spring and summer season simuation results which ranged from 0.31 to 1.14. The biggest differences were for TP. The ratio for TP was between 1.07 and 1.41 except for Milyang Dams in 2009 yr T-P ratio of 2.39 and spring and summer simulation results which ranged from 0.44 to 1.95 (Donigian, 2002).

Table 4-21: The results of water quality calibration and validation of Nakdong River watershed.

Dam	Water quality		Observed (average)	Simulated (average)	% Difference	Criteria	Ratio*
Andong Dam	DO (mg/L)	2009	12.1	11.7	2.92	very good	0.97
		2010	11.7	11.6	1.29	very good	1.00
		Summer	10.0	9.9	0.77	very good	0.99
		Spring	12.7	12.2	3.49	very good	0.96
	BOD (mg/L)	2009	0.66	0.62	7.11	very good	0.93
		2010	0.79	0.73	18.9	good	0.92
		Summer	1.02	1.11	8.69	very good	1.09
		Spring	1.75	0.54	37.91	below fair	0.31
	T-N (mg/L)	2009	2.08	2.09	0.72	very good	1.01
		2010	2.11	2.16	1.14	very good	1.02
		Summer	1.8	1.6	6.13	very good	0.94
		Spring	3.8	2.0	1.71	very good	0.51

Table 4-21: The results of water quality calibration and validation of Nakdong River watershed (Continued).

Dam	Water quality		Observed (average)	Simulated (average)	% Difference	Criteria	Ratio*
Andong Dam	T-P (mg/L)	2009	0.014	0.017	21.09	good	1.21
		2010	0.019	0.020	1.33	very good	1.08
		Summer	0.026	0.030	17.52	good	1.17
		Spring	0.035	0.015	12.02	very good	0.44
Imha Dam	DO (mg/L)	2009	12.2	10.7	12.81	very good	0.87
		2010	11.8	10.7	10.65	very good	0.91
		Summer	10.0	8.3	16.84	good	0.83
		Spring	12.8	10.5	17.92	good	0.82
	BOD (mg/L)	2009	1.01	0.88	13.22	very good	0.87
		2010	0.79	0.81	4.07	very good	1.02
		Summer	1.04	0.82	21.50	good	0.79
		Spring	2.02	0.99	1.10	very good	0.49
	T-N (mg/L)	2009	1.82	1.97	8.43	very good	1.08
		2010	2.35	1.89	24.96	good	0.81
		Summer	2.1	1.6	22.77	good	0.77
		Spring	4.8	1.8	30.79	Fair	0.38
Imha Dam	T-P (mg/L)	2009	1.155	1.479	28.10	fair	1.28
		2010	0.874	1.086	24.28	good	1.41
		Summer	0.031	0.033	7.00	very good	1.06
		Spring	0.051	0.037	45.85	below fair	0.73
Young-Chun Dam	DO (mg/L)	2009	10.7	9.6	10.79	very good	0.89
		2010	10.5	10.7	4.39	very good	1.03
		Summer	9.3	8.9	4.84	very good	0.95
		Spring	11.2	9.9	10.91	very good	0.89
	BOD (mg/L)	2009	0.61	0.60	1.88	very good	0.98
		2010	0.58	0.54	16	good	0.93
		Summer	0.48	0.43	10.10	very good	0.90
		Spring	1.40	0.74	5.31	very good	0.53
	T-N (mg/L)	2009	1.66	1.63	1.79	very good	0.98
		2010	1.65	1.59	4.29	very good	0.96
		Summer	2.3	1.8	18.52	good	0.81
		Spring	3.7	1.9	5.95	very good	0.53
	T-P (mg/L)	2009	0.013	0.014	15.4	good	1.15
		2010	0.013	0.014	9.42	very good	1.07
		Summer	0.065	0.060	7.08	very good	0.91
		Spring	0.063	0.071	12.70	very good	0.49
Hap-Chun Dam	DO (mg/L)	2009	12.2	10.2	16.92	good	0.89
		2010	11.3	10.6	8.05	very good	1.03
		Summer	11.1	8.5	23.88	good	0.95
		Spring	11.6	10.1	12.81	very good	0.89
	BOD (mg/L)	2009	1.56	1.61	3.07	very good	0.98
		2010	1.33	1.60	33.99	fair	0.93
		Summer	1.40	1.71	21.98	good	0.90
		Spring	3.59	2.28	26.82	fair	0.53
	T-N (mg/L)	2009	2.70	2.06	23.69	good	0.98
		2010	2.70	2.30	17.17	good	0.96
		Summer	2.3	1.8	20.66	good	0.81
		Spring	4.7	1.9	18.87	good	0.53

*Ratios calculated from Simulated and Observed concentrations prior to rounding (Love et al., 2002)

Table 4-21: The results of water quality calibration and validation of Nakdong River watershed (Continued).

Dam	Water quality		Observed (average)	Simulated (average)	% Difference	Criteria	Ratio*
	T-P (mg/L)	2009	0.179	0.066	63.33	below fair	1.15
		2010	0.097	0.079	15.49	good	1.07
		Summer	0.172	0.076	55.54	below fair	0.91
		Spring	0.315	0.094	40.06	below fair	0.49
Nam-Gang Dam	DO (mg/L)	2009	11.4	9.5	16.45	good	0.84
		2010	11.0	9.9	12.56	very good	0.89
		Summer	9.7	7.8	19.90	good	0.80
		Spring	11.3	9.4	17.11	good	0.83
	BOD (mg/L)	2009	1.19	1.18	9.27	very good	0.91
		2010	1.10	1.28	21.78	good	1.17
		Summer	1.33	1.39	4.45	very good	1.04
		Spring	2.86	1.41	1.47	very good	0.49
	T-N (mg/L)	2009	1.29	1.54	19.36	good	1.19
		2010	1.56	1.54	6.31	very good	1.07
		Summer	1.3	1.3	4.82	very good	0.95
		Spring	2.7	1.6	16.42	good	0.58
	T-P (mg/L)	2009	0.029	0.036	25.04	fair	1.25
		2010	0.030	0.036	24.26	good	1.21
		Summer	0.050	0.041	17.99	good	0.81
		Spring	0.072	0.040	10.33	very good	0.55
Milyang Dam	DO (mg/L)	2009	9.5	11.0	15.37	good	1.15
		2010	11.2	11.0	1.56	very good	0.98
		Summer	9.7	9.6	1.03	very good	0.99
		Spring	10.8	11.9	9.54	very good	1.10
	BOD (mg/L)	2009	0.80	0.78	2.14	very good	0.98
		2010	0.82	1.02	24.19	good	1.25
		Summer	0.78	0.88	14.03	very good	1.14
		Spring	1.43	0.84	17.70	good	0.59
	T-N (mg/L)	2009	0.88	0.83	4.79	very good	0.95
		2010	0.97	0.86	15.98	good	0.89
		Summer	0.9	0.8	18.84	good	0.85
		Spring	1.9	0.9	5.78	very good	0.47
	T-P (mg/L)	2009	0.005	0.012	139.33	below fair	2.39
		2010	0.015	0.017	12.86	very good	1.14
		Summer	0.009	0.014	58.27	below fair	1.58
		Spring	0.008	0.016	289.20	below fair	1.95

The graphs for calibration (2009) and validation (2010) of the six dams located in the Nakdong River watershed were shown in Table 4-22. This table presents the graphical comparison between simulated and observed water quality parameters including the coefficient of determination (R^2) between simulated and observed data in 2009 and 2010.

Table 4-22: The results of water quality calibration of Nakdong River watershed.

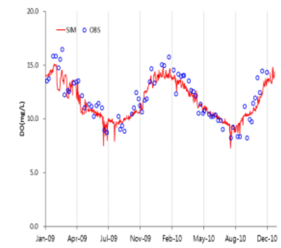
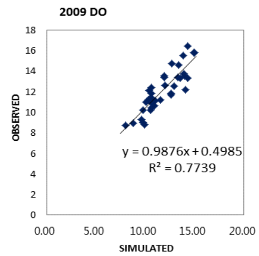
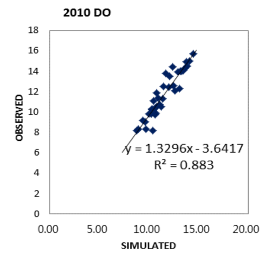
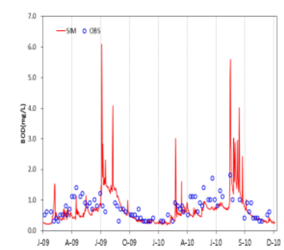
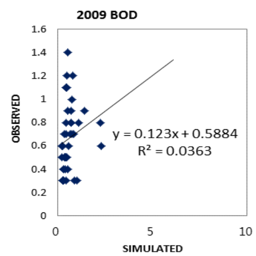
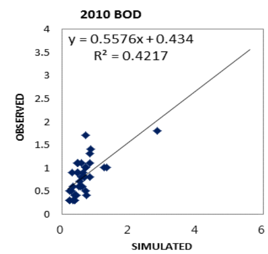
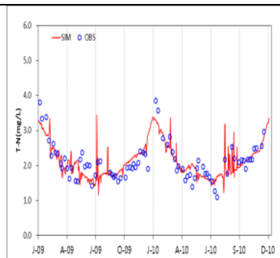
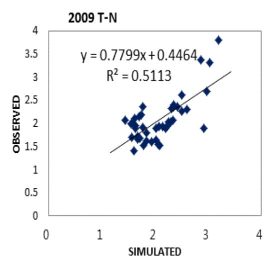
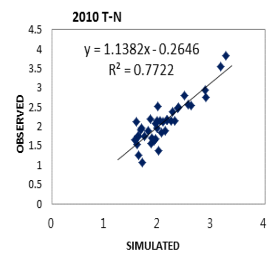
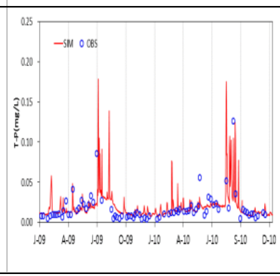
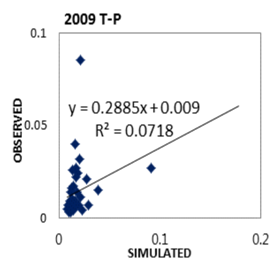
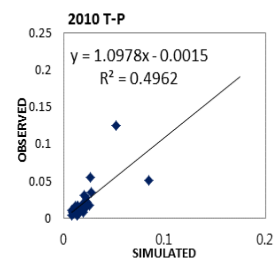
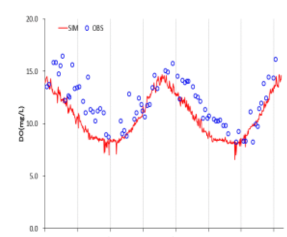
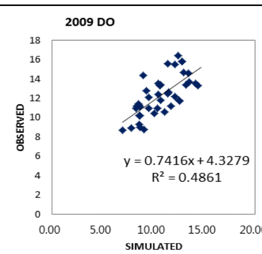
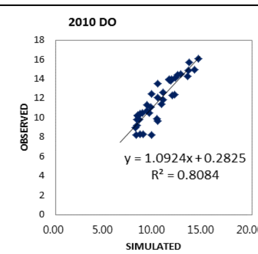
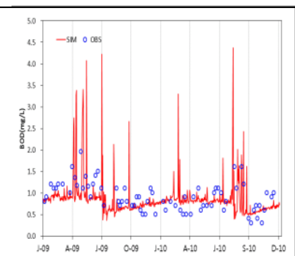
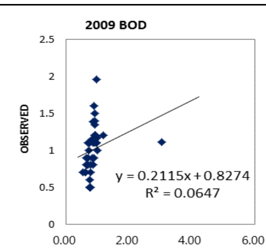
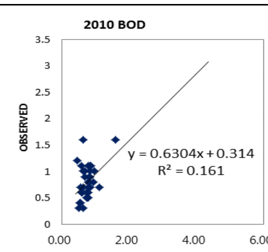
Dam	Water quality	Simulation/observation	2009 year	2010 year
An-Dong Dam	DO (mg/L)			
	BOD (mg/L)			
An-Dong Dam	T-N (mg/L)			
	T-P (mg/L)			
Im-Ha Dam	DO (mg/L)			
	BOD (mg/L)			

Table 4-22: The results of water quality calibration of Nakdong River watershed (Continued).

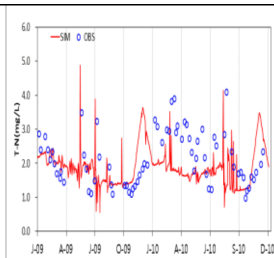
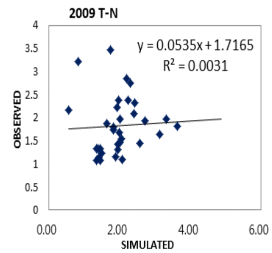
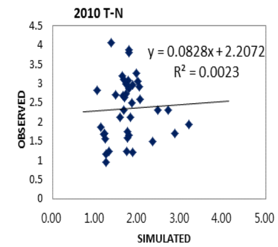
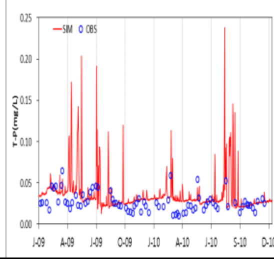
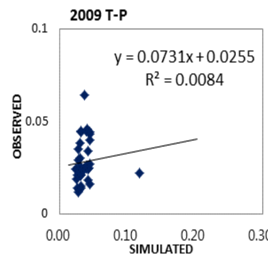
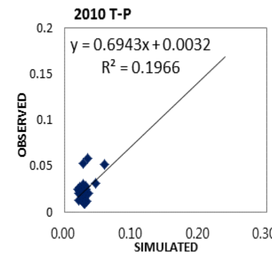
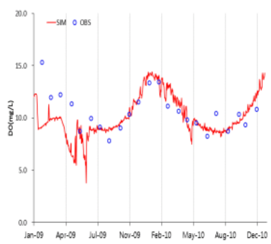
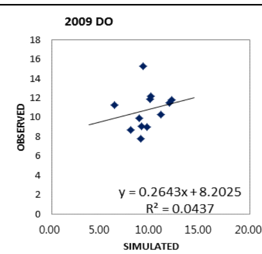
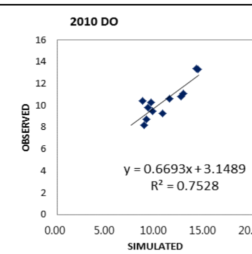
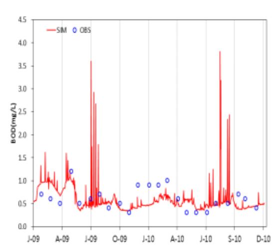
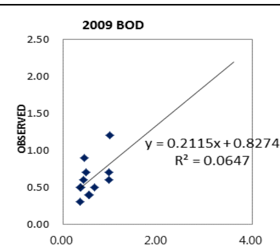
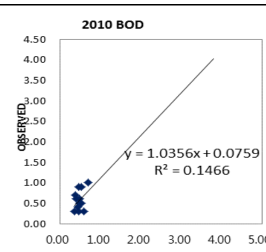
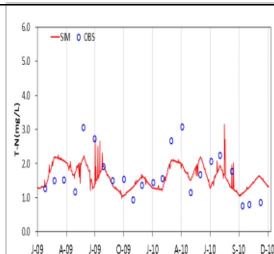
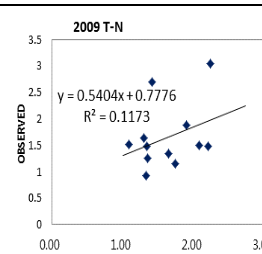
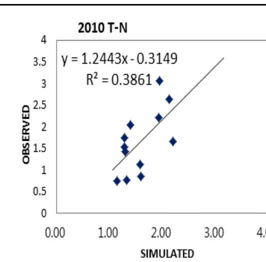
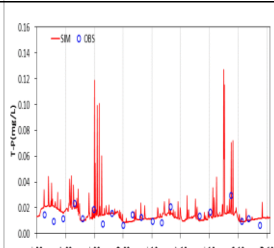
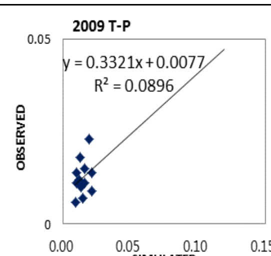
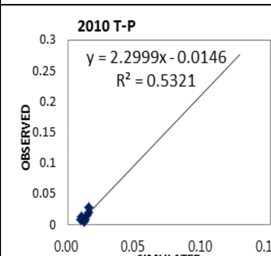
Dam	Water quality	Simulation/observation	2009 year	2010 year
Im-Ha Dam	T-N (mg/L)			
	T-P (mg/L)			
Youngchun Dam	DO (mg/L)			
	BOD (mg/L)			
	T-N (mg/L)			
	T-P (mg/L)			

Table 4-22: The results of water quality calibration of Nakdong River watershed (Continued).

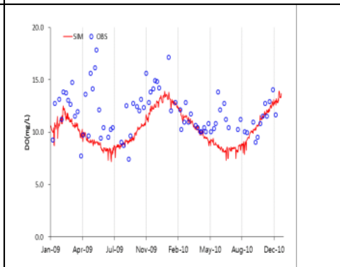
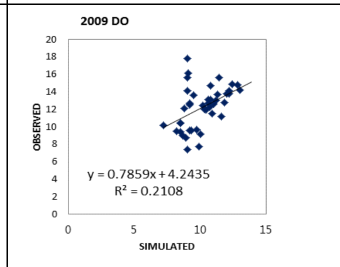
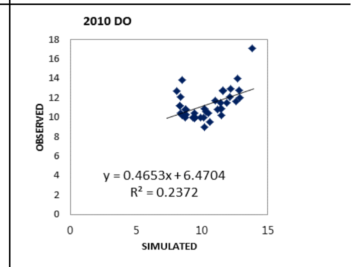
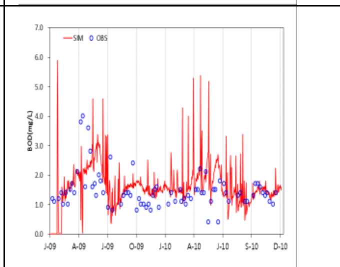
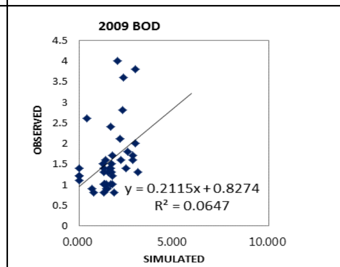
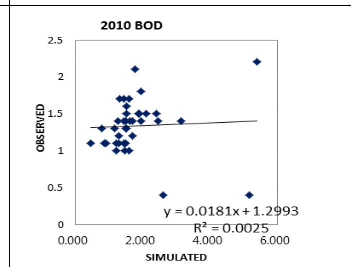
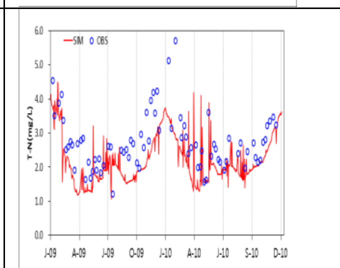
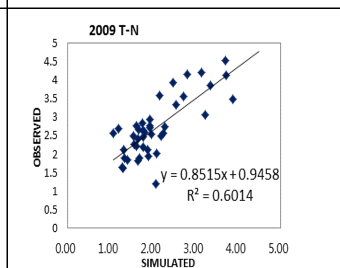
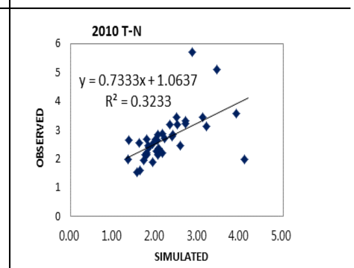
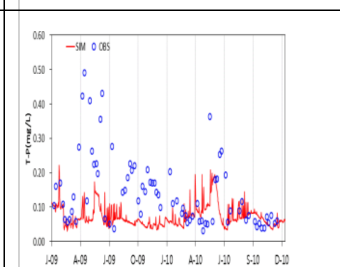
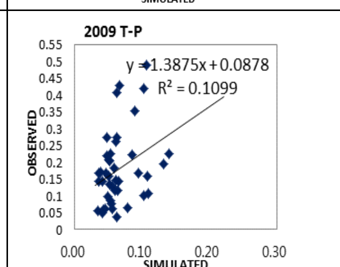
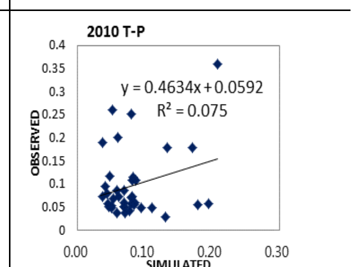
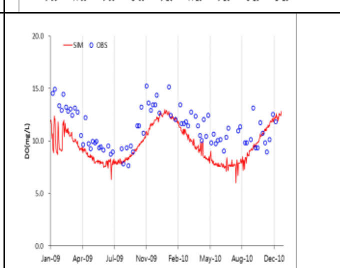
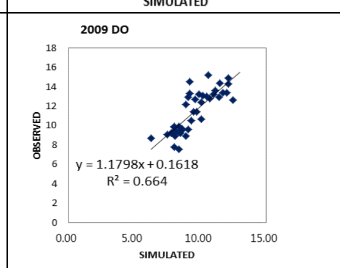
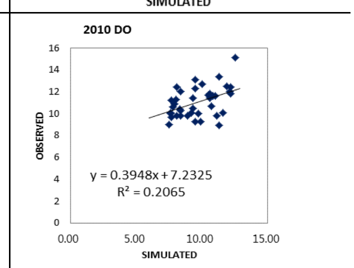
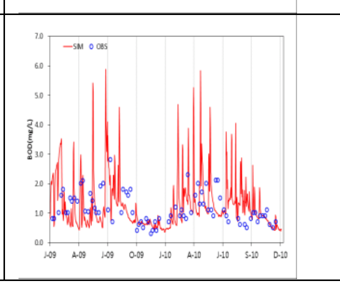
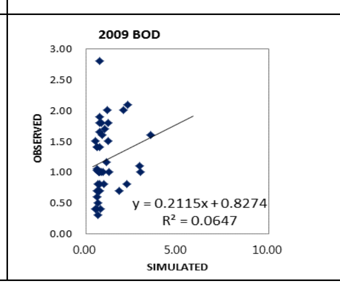
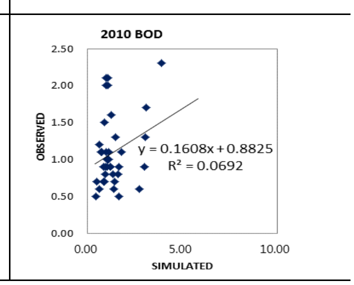
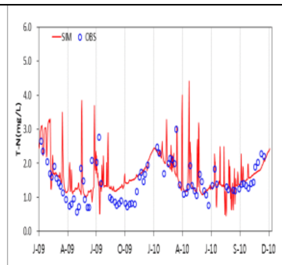
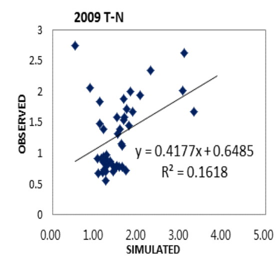
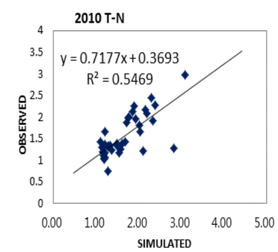
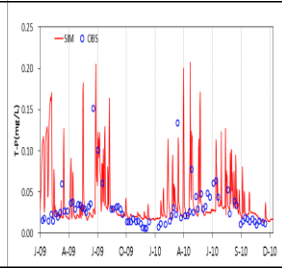
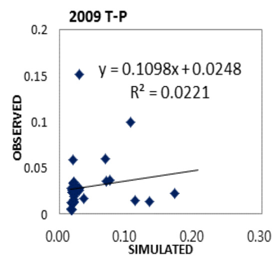
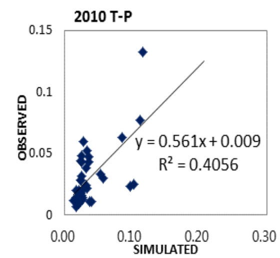
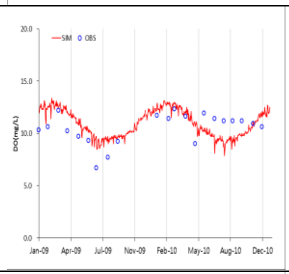
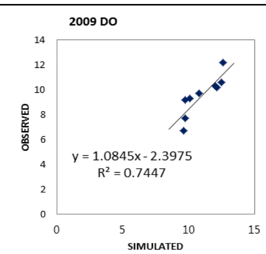
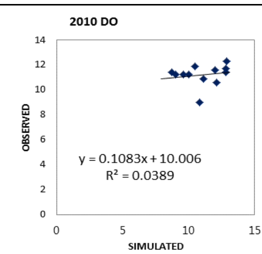
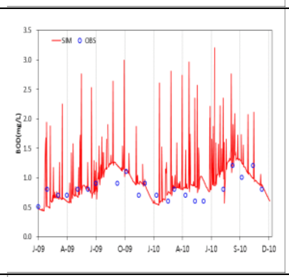
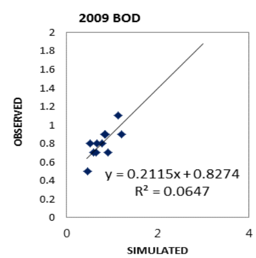
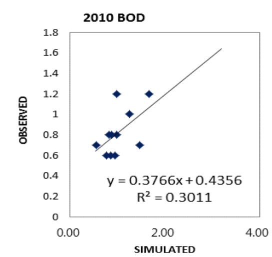
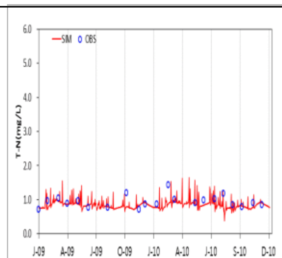
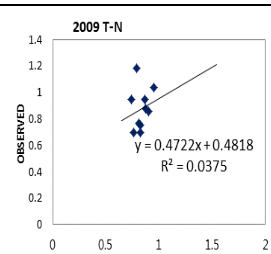
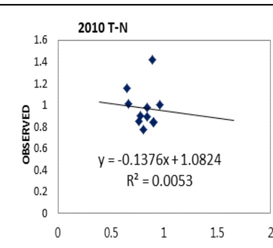
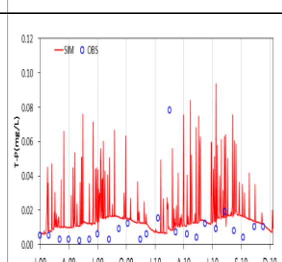
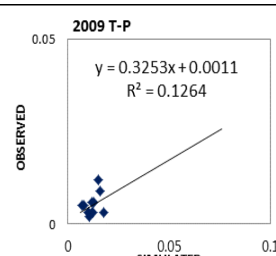
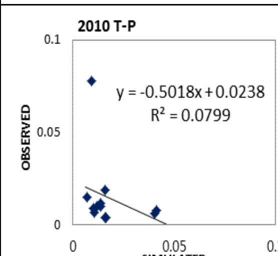
Dam	Water quality	Simulation/observation	2009 year	2010 year
Hap-chun Dam	DO (mg/L)			
	BOD (mg/L)			
	T-N (mg/L)			
	T-P (mg/L)			
Nam-gang Dam	DO (mg/L)			
	BOD (mg/L)			

Table 4-22: The results of water quality calibration of Nakdong River watershed (Continued).

Dam	Water quality	Simulation/observation	2009 year	2010 year
Nam-gang Dam	T-N (mg/L)			
	T-P (mg/L)			
Mil-yang Dam	DO (mg/L)			
	BOD (mg/L)			
	T-N (mg/L)			
	T-P (mg/L)			

The calibration for five sub-watersheds located at Yongdam Dam's watershed was performed on four water quality parameters: DO, BOD, T-N, and T-P shown in Table 4-23. On the whole, patterns of both observed and simulated data have similar tendencies as those found in the Nakdong watershed simulation results. Data was not collected during rainfall events, hence the percent differences could not be compared during rainfall events but analyzed for only during non rainfall conditions. That is a possible reason why percent differences were so low for this particular calibration. Percent differences for most of the water quality parameters were very good, good and fair except for T-P. Parameters that fell outside of very good, good, and fair include Juja's T-P during 2005, 2006, summer, and spring, the Jungja's BOD in 2006, TN during 2006, summer, and spring, TP during 2005, and spring, the Jinan's BOD and TP in the summer, the Guryang's BOD and TP during 2005, 2006, summer, and spring, the Geum's TP during 2005, 2006, and spring.

76.2 % of the percent differences for BOD, TN, and TP were below fair. The ratio between simulated and observed mean concentration during 2005, 2006, summer, and spring for BOD were between 0.28 and 1.07, while T-N were between 0.28 and 1.12, and T-P were between 0.18 and 2.47. The biggest differences and thus the least confidence for this calibration were for TP (Donigian, 2002).

Table 4-23: The results of water quality calibration and validation of Yongdam Dam watershed.

Dam	Water quality		Observed (average)	Simulated (average)	% Difference	Criteria	Ratio
Juja	DO (mg/L)	2005	10.1	9.7	3.53	Very good	0.96
		2006	9.3	10.6	0.47	Very good	1.13
		Summer	9.2	8.8	3.87	Very good	0.96
		Spring	10.1	10.8	7.21	Very good	1.07
	BOD (mg/L)	2005	0.86	0.83	2.85	Very good	0.97
		2006	1.17	0.98	29.35	Fair	0.84
		Summer	1.20	0.83	31.09	Fair	0.69
		Spring	1.41	0.96	31.37	Fair	0.68
	T-N (mg/L)	2005	1.32	1.39	5.51	Very good	1.06
		2006	1.62	1.36	29.84	Fair	0.84
		Summer	1.60	1.20	26.56	Fair	0.75
		Spring	3.49	1.36	23.89	Good	0.39

Table 4-23: The results of water quality calibration and validation of Yongdam Dam watershed (Continued).

Dam	Water quality		Observed (average)	Simulated (average)	% Difference	Criteria	Ratio
Juja	T-P (mg/L)	2005	0.012	0.029	147.26	-	2.47
		2006	0.015	0.026	73.29	-	1.69
		Summer	0.018	0.034	87.14	-	1.87
		Spring	0.018	0.025	161.66	-	1.38
JungJa	DO (mg/L)	2005	10.3	9.8	5.01	Very good	0.95
		2006	9.0	10.4	1.94	Very good	1.15
		Summer	9.1	8.7	4.76	Very good	0.95
		Spring	10.1	10.1	0.25	Very good	1.01
	BOD (mg/L)	2005	0.72	0.77	7.18	Very good	1.07
		2006	1.04	0.84	40.53	-	0.81
		Summer	0.89	0.71	21.40	Good	0.79
		Spring	1.81	0.66	31.66	Fair	0.36
	T-N (mg/L)	2005	2.04	1.44	29.45	Fair	0.71
		2006	2.58	1.49	52.80	-	0.58
		Summer	2.7	1.2	54.63	-	0.46
		Spring	5.2	1.4	46.41	-	0.28
	T-P (mg/L)	2005	0.014	0.033	128.93	-	2.29
		2006	0.026	0.034	8.79	Very good	1.32
		Summer	0.026	0.030	16.00	Good	1.16
		Spring	0.023	0.026	109.11	-	1.13
Jinan	DO (mg/L)	2005	10.1	10.0	1.75	Very good	0.98
		2006	8.9	10.6	3.49	Very good	1.19
		Summer	8.9	8.7	1.66	Very good	0.98
		Spring	10.0	10.2	1.26	Very good	1.02
	BOD (mg/L)	2005	1.63	1.38	15.31	Good	0.85
		2006	1.26	1.81	30.54	Fair	0.64
		Summer	2.11	0.91	56.79	-	0.43
		Spring	3.07	1.43	5.06	Very good	0.47
	T-N (mg/L)	2005	2.35	2.64	12.47	Very good	1.12
		2006	2.17	2.33	7.41	Very good	1.07
		Summer	2.03	2.26	10.59	Very good	1.11
		Spring	5.66	3.33	18.02	Good	0.59
	T-P (mg/L)	2005	0.065	0.076	15.60	Good	1.16
		2006	0.076	0.096	13.61	Very good	1.25
		Summer	0.099	0.053	46.04	-	0.54
		Spring	0.117	0.080	27.88	Fair	0.68
Gu-ryang	DO (mg/L)	2005	10.8	8.8	18.71	Good	0.81
		2006	9.3	9.6	11.91	Very good	1.04
		Summer	9.4	7.7	17.42	Good	0.83
		Spring	10.5	9.1	14.05	Very good	0.87
	BOD (mg/L)	2005	2.24	1.25	44.17	-	0.56
		2006	2.45	0.94	61.68	-	0.38
		Summer	2.49	0.80	68.23	-	0.32
		Spring	5.20	1.46	47.13	-	0.28
	T-N (mg/L)	2005	2.77	2.73	1.56	Very good	0.98
		2006	2.70	2.41	10.71	Very good	0.89
		Summer	2.63	2.39	9.46	Very good	0.91
		Spring	6.63	3.22	4.10	Very good	0.49

Table 4-23: The results of water quality calibration and validation of Yongdam Dam watershed (Continued).

Dam	Water quality		Observed (average)	Simulated (average)	% Difference	Criteria	Ratio
Gu-ryang	T-P (mg/L)	2005	0.119	0.071	40.14	-	0.60
		2006	0.129	0.063	69.92	-	0.49
		Summer	0.136	0.064	53.59	-	0.47
		Spring	0.267	0.047	67.28	-	0.18
Geum	DO (mg/L)	2005	10.1	8.7	14.00	Very good	0.86
		2006	9.1	9.3	10.14	Very good	1.03
		Summer	8.9	7.9	10.68	Very good	0.89
		Spring	10.1	8.6	15.02	Good	0.86
	BOD (mg/L)	2005	2.05	1.81	11.66	Very good	0.88
		2006	2.06	1.72	28.95	Fair	0.83
		Summer	2.36	1.67	29.19	Fair	0.71
		Spring	4.77	1.57	37.58	Fair	0.33
	T-N (mg/L)	2005	2.79	3.02	8.21	Very good	1.08
		2006	2.67	2.83	0.85	Very good	1.06
		Summer	2.57	2.65	2.68	Very good	1.03
		Spring	6.55	3.75	12.61	Very good	0.57
	T-P (mg/L)	2005	0.052	0.074	43.16	-	1.43
		2006	0.086	0.060	36.77	-	0.63
		Summer	0.096	0.076	22.66	Good	0.79
		Spring	0.156	0.045	43.40	-	0.29

The calibration (2005) and validation (2006) graphs for five streams located in the Yongdam Dam watershed are shown in Table 4-24. This table presents graphical comparisons between simulated and observed water quality parameters including the coefficient of determination (R^2) between simulated and observed data in 2005 and 2006.

Table 4-24: The results of water quality calibration and validation for the Yongdam Dam watershed.

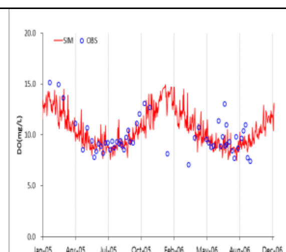
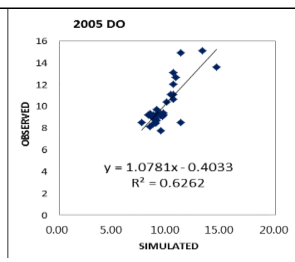
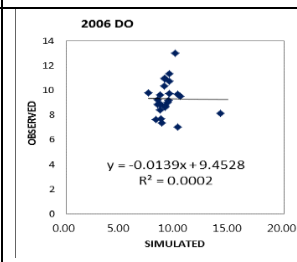
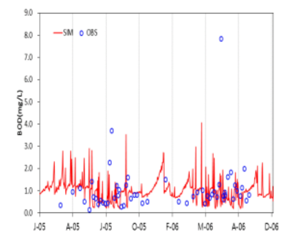
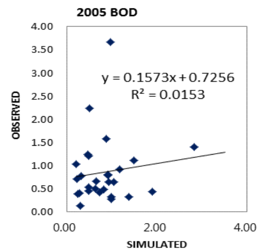
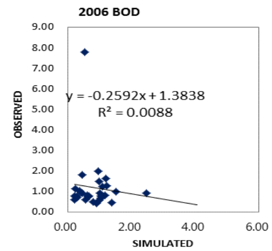
Dam	Water quality	Simulation/observation	2005 year	2006 year
Juja	DO (mg/L)			

Table 4-24: The results of water quality calibration and validation for the Yongdam Dam watershed (Continued).

<table>
<tr><th>Dam</th><th>Water quality</th><th>Simulation/observation</th><th>2005 year</th><th>2006 year</th></tr>
<tr><td rowspan="3"></td><td>BOD (mg/L)</td><td>
</td><td>
</td><td>
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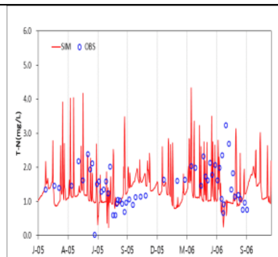
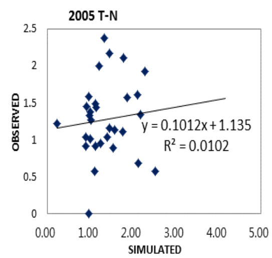
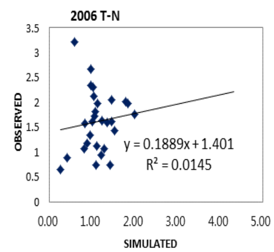
<tr><td>T-N (mg/L)</td><td>
</td><td>
</td><td>
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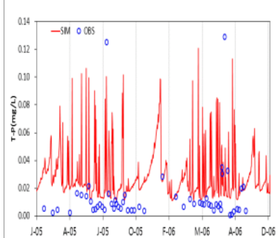
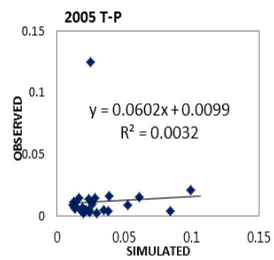
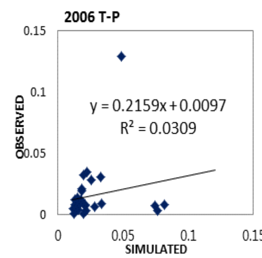
<tr><td>T-P (mg/L)</td><td>
</td><td>
</td><td>
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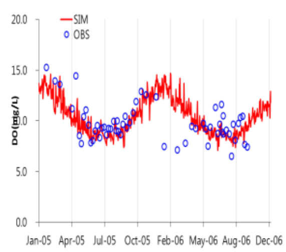
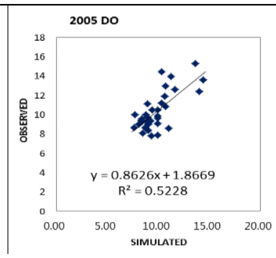
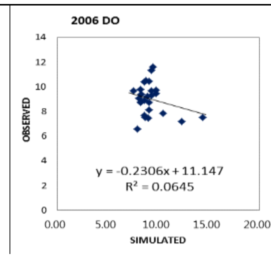
<tr><td rowspan="2">Jung Ja</td><td>DO (mg/L)</td><td>
</td><td>
</td><td>
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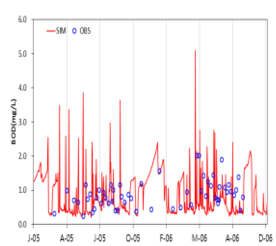
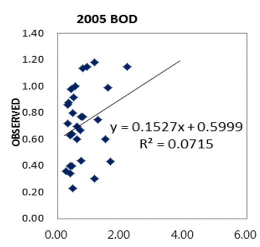
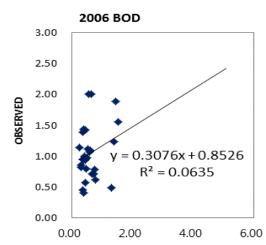
<tr><td>BOD (mg/L)</td><td>
</td><td>
</td><td>
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Table 4-24: The results of water quality calibration and validation for the Yongdam Dam watershed (Continued).

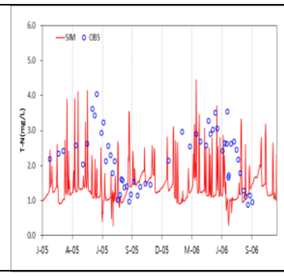
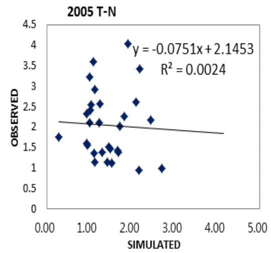
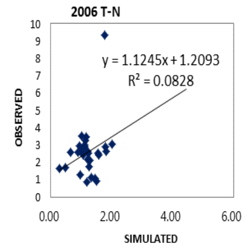
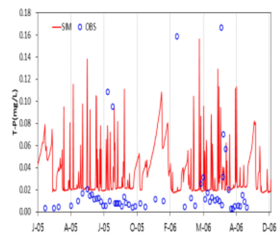
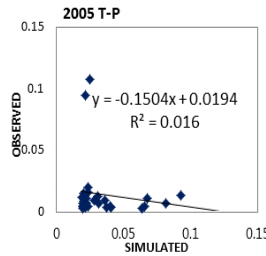
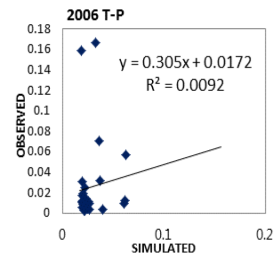
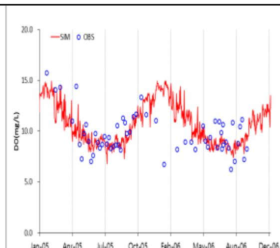
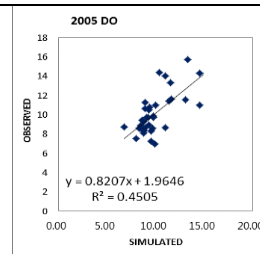
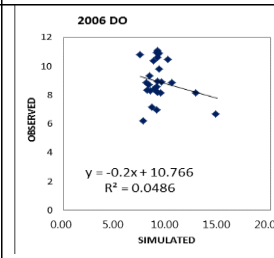
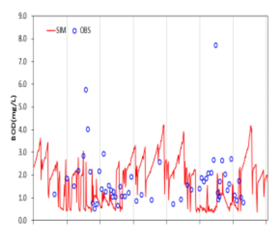
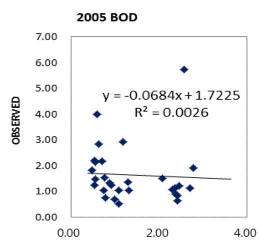
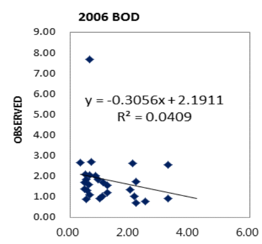
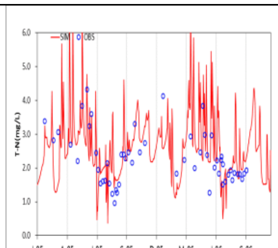
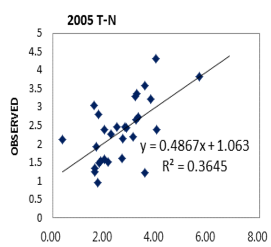
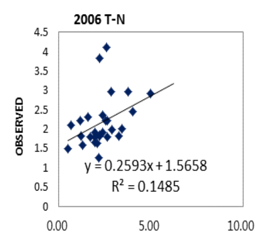
Dam	Water quality	Simulation/observation	2005 year	2006 year
	T-N (mg/L)			
	T-P (mg/L)			
	DO (mg/L)			
Jinan	BOD (mg/L)			
	T-N (mg/L)			

Table 4-24: The results of water quality calibration and validation for the Yongdam Dam watershed (Continued).

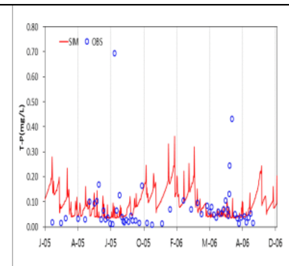
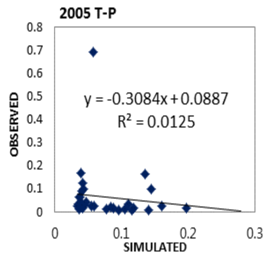
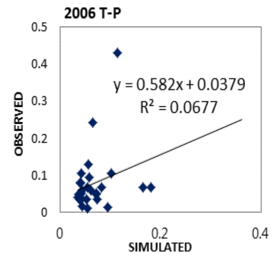
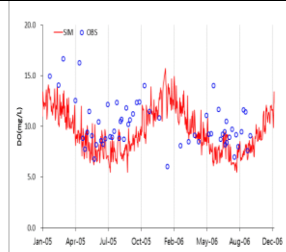
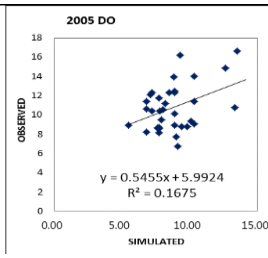
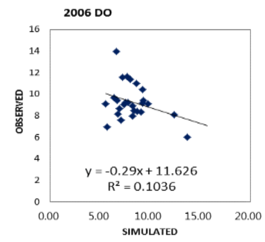
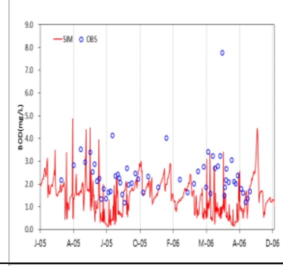
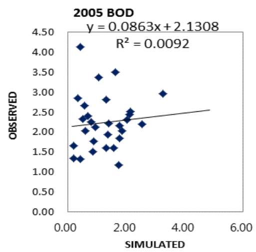
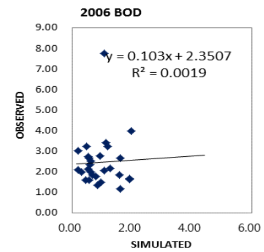
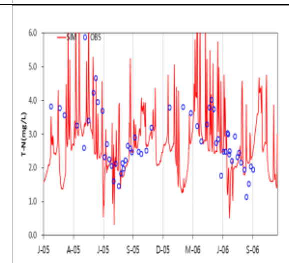
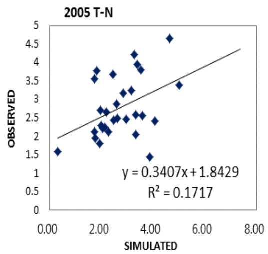
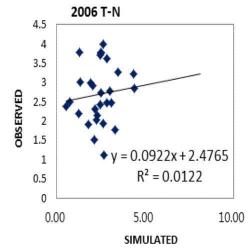
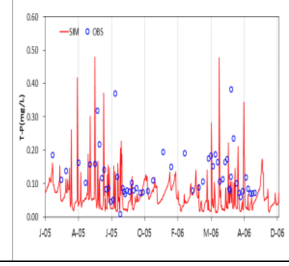
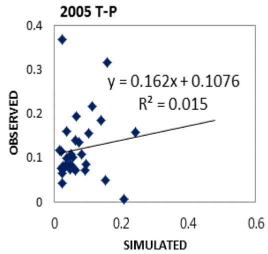
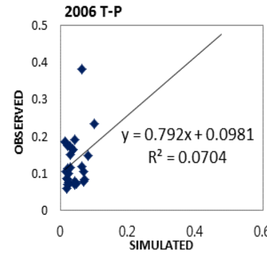
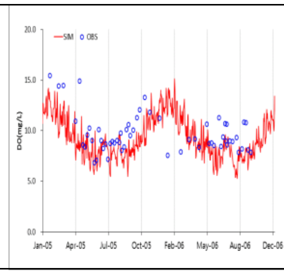
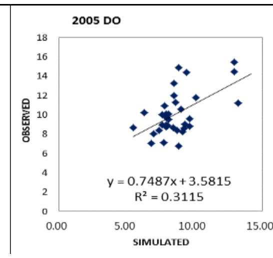
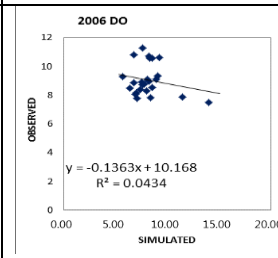
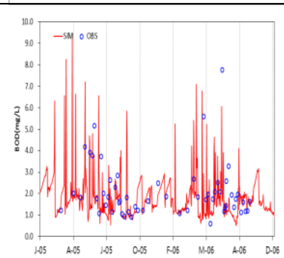
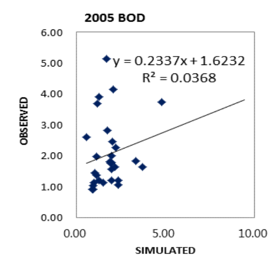
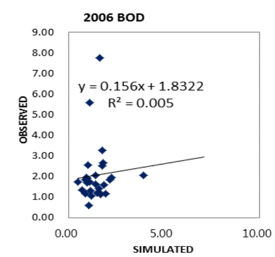
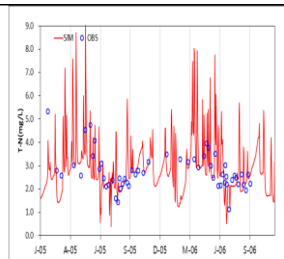
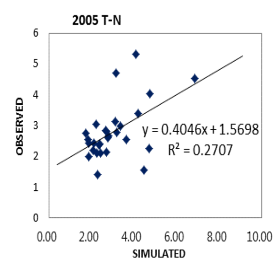
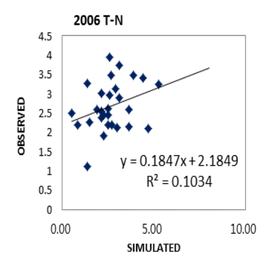
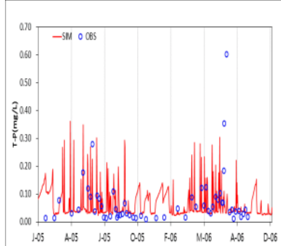
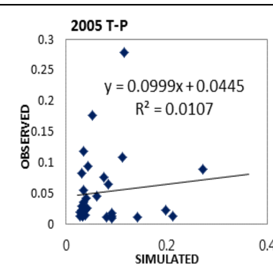
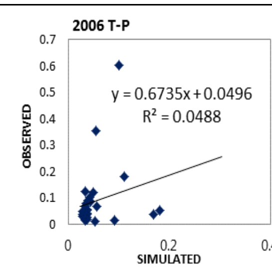
Dam	Water quality	Simulation/observation	2005 year	2006 year
Jinan	T-P (mg/L)			
Gu-ryang	DO (mg/L)			
	BOD (mg/L)			
	T-N (mg/L)			
	T-P (mg/L)			

Table 4-24: The results of water quality calibration and validation for the Yongdam Dam watershed (Continued).

Dam	Water quality	Simulation/observation	2005 year	2006 year
Geum	DO (mg/L)			
Geum	BOD (mg/L)			
	T-N (mg/L)			
	T-P (mg/L)			

4.3.5 SIMPLE EQUATION APPLICATION FOR NAKDONG RIVER WATERSHED AND YOUNGDAM DAM WATERSHED

The simple equations to apply to the Nakdong River watershed and Yongdam watershed were established using by Excel SOLVER, SAS (Statistical Analysis Systems), and Data Mining (M5P, ANN, and RBF). The results are displayed in Tables 4-25 ~ 4-27.

Excel SOLVER and SAS determined simple equations can use input data such as land usage, rainfall, slope, etc. based upon the watershed area.

Table 4-25: Simple equations for Nakdong and Geum-Sum-Youngsan river watershed used by excel solver.

Watershed	parameters	Area (km^2)	Equation	Simple Equation						Normality (Shapiro)		para-meter	SSE	Selection (Akaike)	Attri-bute
				R^2	Adj R^2	F	p-value	n	d.f.	w	p-value			AIC	
Nakdong river watershed	impervious	0-200	$BOD(mg/L)= 0.01\ IP^{1.97}$	0.319	0.284	9	0.008	21	19	0.888	0.021	1	13.03	-8.03	%
	impervious	200-500	$BOD(mg/L)= 0.00\ IP^{2.16}$	0.335	0.313	15	0.001	32	30	0.893	0.004	1	13.98	-24.50	%
	landusage/rainfall	500-	$BOD(mg/L)= 1.91\ Ur^{0.39}\ Ag^{-0.06}\ Fo^{-0.65}\ Gr^{0.45}\ Wet^{-0.07}\ Ba^{-0.61}\ Wa^{0.28}\ Ra^{0.47}$	0.985	0.983	573	0.000	11	9	0.775	0.004	8	0.09	-36.50	%
	impervious	0-200	$COD(mg/L)= 5.50\ IP^{0.02}$	0.471	0.442	16	0.001	20	18	0.96	0.63	1	34.09	12.67	%
	land usage/rainfall	200-500	$COD(mg/L)= 5.08\ Ur^{0.46}\ Ag^{0.02}\ Fo^{0.31}\ Gr^{0.08}\ Wet^{0.17}\ Ba^{-0.17}\ Wa^{0.15}\ Ra^{-0.48}$	0.621	0.609	51	0.000	33	31	0.86	0.00	8	35.81	18.70	%
	landusage/rainfall	500-	$COD(mg/L)= 4.06\ Ur^{0.47}\ Ag^{-0.09}\ Fo^{-0.11}\ Gr^{0.57}\ Wet^{-0.48}\ Ba^{-0.53}\ Wa^{0.29}\ Ra^{-0.06}$	0.995	0.994	1682	0.000	11	9	0.83	0.02	8	0.13	-32.90	km2
	impervious	0-200	$TN(mg/L)= 0.52\ IP^{0.56}$	0.251	0.210	6.039	0.024	20	18	0.953	0.421	1	12.490	-7.42	%
	land usage/rainfall	200-500	$TN(mg/L)= 3.35\ Ur^{0.65}\ Ag^{0.23}\ Fo^{0.61}\ Gr^{-0.05}\ Wet^{0.11}\ Ba^{-0.04}\ Wa^{-0.13}\ Ra^{-0.91}$	0.602	0.589	46.860	0.000	33	31	0.856	0.000	8	23.830	5.26	%
	landusage/rainfall/slope	500-	$TN(mg/L)= 4.14\ Ur^{-0.75}\ Ag^{-0.07}\ Fo^{-1.00}\ Gr^{-0.31}\ Wet^{-1.91}\ Ba^{0.08}\ Wa^{1.65}\ Ra^{1.52}\ Sl^{-1.05}$	0.979	0.977	421.100	0.000	11	9	0.961	0.784	9	0.327	-20.67	%
	impervious	0-200	$TP(mg/L)= 0.12\ IP^{0.02}$	0.192	0.148	4	0.053	20	18	0.964	0.633	1	0.098	-104.37	%
	land usage	200-500	$TP(mg/L)= 0.10\ Ur^{1.08}\ Ag^{-0.27}\ Fo^{-0.23}\ Gr^{0.26}\ Wet^{-0.23}\ Ba^{-0.30}\ Wa^{-0.25}$	0.654	0.642	58	0.000	33	31	0.648	0.000	7	0.127	-169.51	%
	landusage/rainfall	500-	$TP(mg/L)= 0.11\ Ur^{0.19}\ Ag^{1.81}\ Fo^{-0.54}\ Gr^{-0.15}\ Wet^{-0.19}\ Ba^{-0.52}\ Wa^{0.87}\ Ra^{-1.64}$	0.989	0.987	779	0.000	11	9	0.851	0.044	8	0.001	-91.10	km2
Geum -Sum -Youngsan river watershed	land usage/rainfall/slope	0-100	$BOD(mg/L)= 3.32\ Ur^{0.48}\ Ag^{-0.98}\ Fo^{2.04}\ Gr^{-0.69}\ Wet^{0.22}\ Ba^{-0.40}\ Wa^{0.09}\ Ra^{0.27}\ Sl^{-2.24}$	0.863	0.851	75	0.000	14	12	0.856	0.027	9	1.26	-15.70	km2
	land usage/slope	100-150	$BOD(mg/L)= 1.95\ Ur^{0.00}\ Ag^{0.33}\ Fo^{2.62}\ Gr^{0.21}\ Wet^{-0.51}\ Ba^{0.00}\ Wa^{-0.28}\ Sl^{-3.63}$	0.919	0.912	136	0.000	14	12	0.886	0.071	8	2.61	-7.51	%
	landusage/rainfall	150-200	$BOD(mg/L)= 2.85\ Ur^{1.16}\ Ag^{-0.40}\ Fo^{1.54}\ Gr^{0.10}\ Wet^{-0.55}\ Ba^{-0.71}\ Wa^{1.63}\ Ra^{-1.99}$	0.998	0.998	4296	0.000	11	9	0.882	0.111	8	0.02	-52.36	km2
	pervious/impervious	200 -	$BOD(mg/L)= 3.45\ P^{-1.98}\ IP^{2.38}$	0.643	0.632	61	0.000	36	34	0.832	0.000	2	21.16	-15.13	km2
	land usage/slope	0-100	$COD(mg/L)= 5.54\ Ur^{0.32}\ Ag^{-0.51}\ Fo^{0.97}\ Gr^{-0.47}\ Wet^{0.16}\ Ba^{-0.12}\ Wa^{0.33}\ Sl^{-0.93}$	0.919	0.913	137	0.000	14	12	0.92	0.19	8	2.61	-7.53	km2
	slope	100-150	$COD(mg/L)= 155.40\ Sl^{-1.09}$	0.780	0.763	46	0.000	15	13	0.78	0.00	1	18.62	5.24	km2
	landusage/rainfall/slope	150-200	$COD(mg/L)= 5.93\ Ur^{0.44}\ Ag^{-0.19}\ Fo^{0.48}\ Gr^{-0.15}\ Wet^{-0.21}\ Ba^{-0.15}\ Wa^{0.88}\ Ra^{-0.77}\ Sl^{0.13}$	0.962	0.958	228	0.000	11	9	0.89	0.14	9	0.78	-11.11	km2
	land usage	200 -	$COD(mg/L)= 5.21\ Ur^{-0.02}\ Ag^{0.33}\ Fo^{-0.33}\ Gr^{-0.01}\ Wet^{0.00}\ Ba^{0.17}\ Wa^{0.13}$	0.771	0.764	114	0.000	36	34	0.90	0.00	7	20.21	-6.78	%
	impervious/slope	0-100	$TN(mg/L)= 2.23\ IP^{0.32}\ Sl^{-0.23}$	0.362	0.309	6.814	0.023	14	12	0.944	0.477	2	12.652	2.58	km2
	land usage/rainfall/slope	100-150	$TN(mg/L)= 4.79\ Ur^{-0.02}\ Ag^{-0.14}\ Fo^{2.48}\ Gr^{0.03}\ Wet^{-0.04}\ Ba^{0.82}\ Wa^{-0.17}\ Ra^{-0.46}\ Sl^{-2.67}$	0.983	0.982	744.000	0.000	15	13	0.800	0.004	9	1.890	-13.07	km2
	slope	150-200	$TN(mg/L)= 10.45\ Sl^{-0.40}$	0.276	0.196	3.435	0.097	11	9	0.935	0.464	1	5.026	-6.62	%
	pervious/impervious	200 -	$TN(mg/L)= 8.87\ P^{-1.97}\ IP^{2.26}$	0.677	0.668	71.360	0.000	36	34	0.832	0.000	2	27.800	-5.31	km2
	land usage/slope	0-100	$TP(mg/L)= 0.15\ Ur^{0.71}\ Ag^{-0.92}\ Fo^{2.62}\ Gr^{-0.70}\ Wet^{0.34}\ Ba^{-0.51}\ Wa^{0.25}\ Sl^{-2.68}$	0.964	0.961	317	0.000	14	12	0.917	0.198	8	0.002	-108.74	km2
	land usage/rainfall/slope	100-150	$TP(mg/L)= 0.08\ Ur^{-0.13}\ Ag^{-0.33}\ Fo^{9.73}\ Gr^{0.35}\ Wet^{-0.25}\ Ba^{0.47}\ Wa^{-0.71}\ Ra^{-1.82}\ Sl^{-9.11}$	0.996	0.995	2851	< 2.2e-16	15	13	0.747	0.001	9	0.002	-120.16	%
	land usage/rainfall/slope	150-200	$TP(mg/L)= 0.14\ Ur^{0.08}\ Ag^{0.51}\ Fo^{8.61}\ Gr^{-0.53}\ Wet^{-0.85}\ Ba^{0.46}\ Wa^{0.27}\ Ra^{-5.56}\ Sl^{-3.56}$	0.999	0.999	7368	0.000	11	9	0.677	0.000	9	0.000	-102.07	%
	pervious/impervious	200 -	$TP(mg/L)= 0.68\ P^{-3.25}\ IP^{3.63}$	0.659	0.649	66	0.000	36	34	0.744	0.000	2	0.126	-199.69	km2

* COD, BOD, TN, TP= predicted water quality concentration (mg/L)

* P= pervious, IP= impervious, Ra= rainfall, Sl= slope, Ur= urban, Ag=agriculture, Fo=forest, Gr=grass, Wet=wetland, Ba= barren, and Wa= water

Table 4-26: Simple equations for Nakdong and Geum-Sum-Youngsan river watershed used by SAS (Statistical Analysis Systems).

Watershed	Scenarios	Simple Equations	RMSE	R^2	Adj R^2	coeff var	p-value	km^2/%
Nakdong river watershed	200 below	BOD(mg/L)= -2.742 + 0.217 imp	0.760	0.427	0.397	34.475	0.0013	%
	200~500	BOD(mg/L)= 1.799 - 0.056 imp + 0.061 ur + 0.664 gr	0.700	0.471	0.414	42.663	0.0004	%
	500 over	BOD(mg/L)= -0.020 - 0.004 ur - 0.026 gr + 0.108 we + 0.115 wa	0.534	0.777	0.628	38.427	0.0372	km^2
	200 below	COD(mg/L)= -4.009 + 0.404 imp	1.396	0.433	0.403	26.886	0.0013	%
	200~500	COD(mg/L)= 3.042 - 0.062 imp + 0.130 ur + 1.373 gr	1.406	0.538	0.489	36.242	0.0004	%
	500 over	COD(mg/L)= -1.758 + 0.003 ar + 0.658 gr + 0.916 we + 1.266 wa	1.071	0.799	0.664	29.701	0.0441	%
	200 below	TN(mg/L)= -0.221 + 0.142 imp	0.841	0.206	0.164	27.952	0.039	%
	200~500	TN(mg/L)= 2.352 - 0.009 imp + 0.079 ur - 0.079 gr	1.183	0.445	0.385	43.977	0.001	km^2
	500 over	TN(mg/L)= -1.310 + 0.002 ar + 0.107 ag	0.945	0.638	0.548	32.565	0.017	%
	200 below	TP(mg/L)= -0.111 + 0.010 imp	0.074	0.151	0.106	59.354	0.451	km^2
	200~500	TP(mg/L)= 0.090 - 0.001 imp + 0.006 ur + 0.003 gr	0.074	0.587	0.543	74.154	0.001	km^2
	500 over	TP(mg/L)= -0.052 + 0.001 imp - 0.001 ur - 0.00010 ag - 0.002 gr - 0.020 we + 0.015 wa	0.025	0.960	0.899	28.410	0.009	km^2
Geum-Sum-Youngsan river watershe	100 below	BOD(mg/L)= 0.218 + 0.080 imp + 0.017 ag + 0.215 we	0.720	0.436	0.267	32.318	0.1121	km^2
	100-150	BOD(mg/L)= -7.682 + 0.458 imp - 0.054 ur + 0.006 gr + 0.099 ba	0.905	0.770	0.667	41.572	0.006	%
	150-200	BOD(mg/L)= 0.116 + 0.026 imp + 0.036 ag + 0.415 wa	0.744	0.651	0.476	31.397	0.08	%
	200 over	BOD(mg/L)= 1.041 - 0.090 imp + 0.164 ur + 0.058 ag + 0.469 ba	0.700	0.744	0.711	34.177	<.0001	%
	100 below	COD(mg/L)= 2.231 + 0.023 ag + 0.945 we + 0.562 wa	0.985	0.700	0.609	21.527	0.0057	km^2
	100-150	COD(mg/L)= -14.540 + 0.924 imp - 0.363 ur + 0.078 ga + 0.664 ba	1.363	0.800	0.711	28.941	0.0033	%
	150-200	COD(mg/L)= 1.870 + 0.017 ag + 0.850 wa	0.774	0.770	0.705	15.676	0.08	km^2
	200 over	COD(mg/L)= 13.917 - 0.880 imp + 0.376 ur + 0.221 ag + 1.443 ba	0.701	0.827	0.805	15.950	<.0001	%
	100 below	TN(mg/L)= 0.690 + 0.098 imp + 0.922 we	1.000	0.445	0.345	32.203	0.039	km^2
	100-150	TN(mg/L)= -6.839 + 0.299 imp + 0.038 ur + 1.129 ba	0.839	0.933	0.913	21.325	<.0001	km^2
	150-200	TN(mg/L)= 2.063 + 0.011 ag + 0.250 wa	0.762	0.335	0.145	23.468	0.240	km^2
	200 over	TN(mg/L)= 5.393 - 0.363 imp + 0.285 ur + 0.110 ag + 0.760 ba	0.913	0.700	0.662	32.903	<.0001	%
	100 below	TP(mg/L)= 0.018 + 0.000 ag + 0.067 we + 0.01468 wa	0.041	0.666	0.565	40.012	0.010	km^2
	100-150	TP(mg/L)= -0.230 + 0.008 imp + 0.015 ur + 0.000734 gr + 0.027 ba	0.057	0.908	0.868	40.677	0.000	km^2
	150-200	TP(mg/L)= 0.184 - 0.011 imp + 0.007 ag	0.119	0.383	0.207	82.968	0.080	%
	200 over	TP(mg/L)= 0.105 - 0.012 imp + 0.018 ur + 0.00405 ag + 0.038 ba	0.058	0.719	0.682	62.076	<.0001	%

Table 4-27: Simple equations for Nakdong and Geum-Sum-Youngsan river watershed used by Data Mining (M5P, ANN, and RBF).

Water quality	Model	Scenario	No.of Instances	No.of Rules/hidden/cluster	Evaluation on test split						km^2/%
					C.C	M.A.E	R.M.S.E	R.A.E	R.R.S.E	Total No. Of instances	
BOD	nakdong(M5P)_200	3	21	2	0.7428	0.6569	0.6923	79.62%	77.21%	8	%
	nakdong(ANN)_500	8	32	6	0.7651	0.5259	0.5861	68.98%	66.82%	11	km
	nakdong(RBF)_500over	9	11	3	0.8828	0.3331	0.404	49.88%	49.07%	4	%
	gsy(M5P)_100	9	14	2	0.9943	0.2044	0.2401	40.52%	42.45%	5	km
	gsy(ANN)_150	2	14	6	0.959	1.1982	1.4216	67.07%	63.91%	5	km
	gsy(ANN)_200	5	10	6	0.9374	0.3663	0.4321	38.89%	34.00%	4	km
	gsy(RBF)_200over	7	36	6	0.9192	0.2501	0.3272	28.52%	35.09%	13	%
COD	nakdong(M5P)_200	3	21	2	0.9591	0.3172	0.3503	55.98%	55.46%	6	km
	nakdong(M5P)_500	6	23	2	0.7361	2.046	2.6269	99.84%	95.25%	8	km
	nakdong(ANN)_500over	2	11	5	0.9471	0.5433	0.7336	41.91%	44.44%	4	%
	gsy(ANN)_100	7	14	7	0.9797	0.3207	0.437	20.30%	26.83%	5	km
	gsy(ANN)_150	5	14	6	0.9486	0.8815	1.1354	26.62%	30.10%	5	km
	gsy(ANN)_200	5	10	6	0.9787	0.4142	0.4792	33.14%	36.43%	4	km
	gsy(ANN)_200over	6	36	6	0.9612	0.5482	0.6887	44.50%	50.16%	13	%
T-N	nakdong(RBF)_200	5	21	5	0.6812	0.6489	0.7179	90.58%	90.35%	8	km
	nakdong(RBF)_500	7	32	2	0.4579	1.0166	1.1383	92.86%	88.67%	11	%
	nakdong(ANN)_500over	9	11	6	0.8285	0.7515	0.8961	48.21%	47.84%	4	%
	gsy(ANN)_100	9	14	7	0.9138	0.754	0.9051	53.44%	58.59%	5	km
	gsy(ANN)_150	1	14	7	0.9955	1.5211	1.9738	45.81%	43.62%	5	%
	gsy(RBF)_200	8	10	2	0.5868	0.3753	0.4215	94.12%	87.23%	4	km
	gsy(M5P)_200over	10	36	15	0.9092	0.5854	0.6454	50.50%	52.78%	13	km
T-P	nakdong(ANN)_200	3	21	5	0.7478	0.0718	0.0836	124.69%	136.00%	8	km
	nakdong(RBF)_500	7	32	2	0.6127	0.0507	0.0606	88.35%	90.07%	11	%
	nakdong(RBF)_500over	3	11	3	0.7268	0.0485	0.0578	64.12%	73.60%	4	%
	gsy(RBF)_100	8	14	2	0.9245	0.0377	0.0439	72.48%	70.32%	5	km
	gsy(M5P)_150	9	14	5	0.9922	0.0318	0.0393	17.79%	16.61%	5	%
	gsy(RBF)_200	8	10	2	0.9382	0.1176	0.1901	92.75%	93.70%	4	km
	gsy(M5P)_200over	10	36	13	0.9697	0.0315	0.0521	48.55%	75.31%	13	km

The simple equations based on Data Mining (M5P, ANN, and RBF) were created by the Weka program. In order to simulate water quality, the "Re-evaluate model on current test set" option of the Weka program could be used based on Table 4-27's simple equations.

Data sets for simulation of Geum-Sum-Youngsan River watershed and Nakdong River watershed are shown in Tables 4-28 ~ 4-29 which include pervious, impervious, rainfall, slope, and land usage.

Table 4-28: Data sets for water quality simulation using simple equations (Geum-Sum-Youngsan river watershed).

watershed	sub-watershed	pervious	impervious	rainfall (mm/month)	slope (%)	Land use							
						urban	agriculture	forest	grass	wetland	barren	water	total
Geum-Sum-Youngsan river Watershed	Geum River (km2)	224	57.70	112.4	32.87	8.43	74.52	178.14	16.61	1.03	3.42	2.24	282.157
	Geum River (%)	80	20	112.4	32.87	2.99	26.41	63.13	5.89	0.37	1.21	0.79	100
	Guryang Stream(km^2)	129	33.23	146.9	29.75	4.59	44.67	109.23	2.59	0.21	1.33	0.98	162.629
	Guryang Stream (%)	80	20	146.9	29.75	2.82	27.47	67.17	1.59	0.13	0.82	0.60	100
	Jinan Stream (km^2)	27	7.63	113.7	26.98	1.99	10.74	20.39	1.12	0.16	0.13	0.20	34.517
	Jinan Stream (%)	78	22	113.7	26.98	5.77	31.11	59.07	3.24	0.46	0.36	0.57	100
	Jeongja Stream (km^2)	80	16.68	134.4	40.46	1.34	11.71	81.95	1.64	0.15	0.17	0.48	96.954
	Jeongja Stream (%)	83	17	134.4	40.46	1.38	12.08	84.52	1.69	0.15	0.18	0.49	100
	Juja stream (km^2)	48	9.40	137.8	40.23	0.62	5.21	50.22	0.74	0.10	0.16	0.35	57.038
	Juja stream (%)	84	16	137.8	40.23	1.08	9.14	88.04	1.29	0.17	0.28	0.61	100

Table 4-29: Data sets for water quality simulation using simple equations (Nakdong river watershed).

watershed	sub-watershed	pervious	impervious	rainfall (mm/month)	slope (%)	Land use							
						urban	agriculture	forest	grass	wetland	barren	water	total
Nakdong River Watershed	Milyang Dam(km^2)	87	17	122.5	22.43	0.99	4.62	92.50	1.97	0.16	1.31	1.93	103
	Milyang Dam(%)	84	16	122.5	22.43	0.95	4.46	89.40	1.91	0.15	1.26	1.87	100
	Namgang Dam(km^2)	1,852	441	163.3	23.97	54.44	452.82	1685.48	23.58	20.05	22.96	33.73	2,293
	Namgang Dam(%)	81	19	163.3	23.97	2.37	19.75	73.50	1.03	0.87	1.00	1.47	100
	Andong Dam(km^2)	1,314	277	120.8	22.43	22.54	189.10	1308.53	6.38	9.82	15.72	38.62	1,591
	Andong Dam(%)	83	17	120.8	22.43	1.42	11.89	82.26	0.40	0.62	0.99	2.43	100
	Youngchun Dam(km^2)	195	39	94.2	22.43	2.29	22.05	201.61	0.26	1.53	1.35	5.44	235
	Youngchun Dam(%)	83	17	94.2	22.43	0.97	9.40	85.96	0.11	0.65	0.57	2.32	100
	Imha Dam(km^2)	1,124	244	104.2	22.43	18.82	204.64	1091.63	5.45	6.18	8.10	32.87	1,368
	Imha Dam(%)	82	18	104.2	22.43	1.38	14.96	79.82	0.40	0.45	0.59	2.40	100
	Hapchu Dam(km^2)	745	184	152.5	22.43	23.77	207.25	658.90	4.35	3.81	11.99	18.85	929
	Hapchun Dam(%)	80	20	152.5	22.43	2.56	22.31	70.93	0.47	0.41	1.29	2.03	100

The result of water quality simulation based on simple equation were displayed Table 4-30 ~ 4-31.

Table 4-30: The results of water quality simulation for Yongdam Dam watershed using simple equations.

sub-watershed	BOD (mg/L)						T-N (mg/L)						T-P (mg/L)					
	Excel Solver	SAS	Data Mining			Observed	Excel Solver	SAS	Data Mining			Observed	Excel Solver	SAS	Data Mining			Observed
			M5P	ANN	RBF				M5P	ANN	RBF				M5P	ANN	RBF	
Geum River	0.80	1.80	-	-	1.46	2.12	1.44	2.63	1.89	-	-	2.72	0.039	0.076	0.030	-	-	0.151
Guryang Stream	0.47	1.88	-	1.90	-	2.45	2.71	2.78	-	-	3.12	2.68	0.077	0.154	-	-	0.148	0.158
Jinan Stream	0.57	1.04	1.03	-	-	1.93	2.02	1.58	-	1.23	-	1.86	0.010	0.036	-	-	0.110	0.096
Jeongja Stream	2.25	1.78	1.04	-	-	1.29	2.38	2.46	-	1.49	-	2.58	0.068	0.040	-	-	0.085	0.026
Juja stream	2.03	1.08	0.80	-	-	1.17	1.98	1.70	-	1.03	-	1.62	0.034	0.032	-	-	0.085	0.015
sum	6.13	7.58			6.23	8.97	10.53	11.15			8.77	11.45	0.227	0.339			0.458	0.446
% difference	31.66	15.55			30.62	-	8.08	2.66			23.44	-	48.948	24.009			2.786	-

Comparing simple equations to observed data for the case of the BOD simulation, the results of data mining almost have the same trend as the observed data. Otherwise, the other simple equations: Excel Solver and SAS displayed different trends.

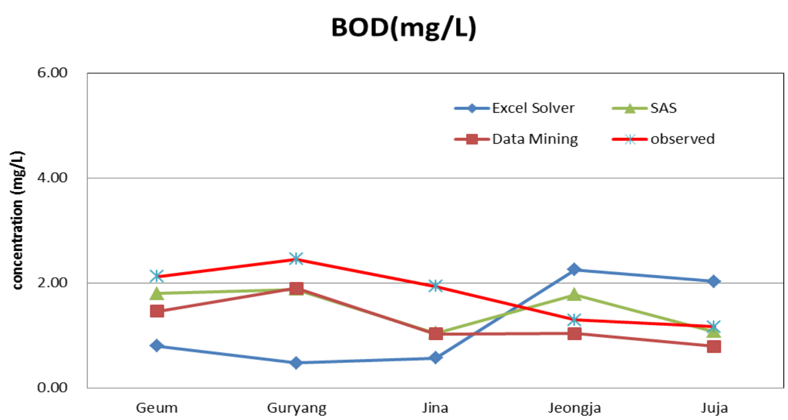


Figure 4-37: BOD simulation results based on simple equations (Yongdam watershed).

In case of the T-N simulation, the result of SAS and Data Mining resulted in similar trends with the observed data except in the case of the Excel SOLVER equation. The results generated by the SAS derived equations especially had a strong correlation with the observed data.

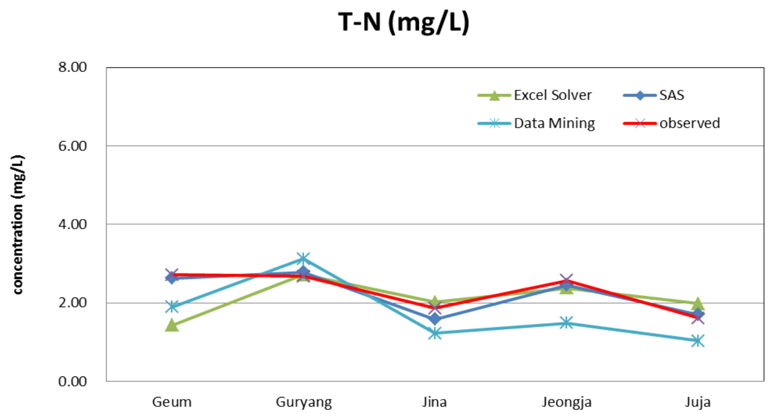


Figure 4-38: T-N simulation results based upon simple equations (Yongdam watershed).

The T-P simulation results determined using the equations developed using Data Mining and SAS have the same trend as the observed data. On the other hand, the results of Excel SOLVER did not match well with the observed data.

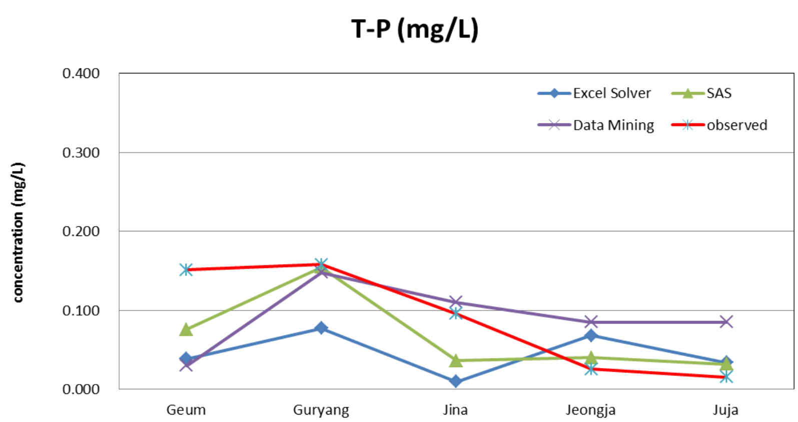


Figure 4-39: T-P simulation results based upon simple equations (Yongdam watershed).

Table 4-31: The results of water quality simulation for Nakdong river watershed using simple equations.

sub-watershed	BOD (mg/L)						T-N (mg/L)						T-P (mg/L)					
	Excel solver	SAS	Data Mining			Observed	Excel solver	SAS	Data Mining			Observed	Excel solver	SAS	Data Mining			Observed
			M5P	ANN	RBF				M5P	ANN	RBF				M5P	ANN	RBF	
Milyang Dam	1.23	6.28	0.90	-	-	0.93	2.49	2.09	-	-	3.14	0.90	0.000	0.064	-	0.019	-	0.010
Namgang Dam	1.68	1.96	-	-	2.20	1.23	4.73	6.07	-	1.37	-	1.77	0.001	0.256	-	-	0.150	0.033
Andong Dam	0.89	4.33	-	-	1.64	0.72	26.17	3.62	-	3.11	-	2.23	0.001	0.501	-	-	0.150	0.024
Youngchun Dam	5.75	0.99	-	-	1.42	0.68	1.28	2.16	-	-	2.35	1.85	0.000	0.053	-	-	0.065	0.007
Imha Dam	1.14	3.45	-	-	1.64	0.90	37.22	3.43	-	3.80	-	2.78	0.003	0.463	-	-	0.105	0.025
Hapchu Dam	1.18	1.74	-	-	1.64	1.45	42.02	3.20	-	5.22	-	2.66	0.002	0.248	-	-	0.150	0.048
Sum	11.88	18.75	9.44			5.91	113.91	20.57	18.99			12.20	0.01	1.59	0.639			0.15
% difference	101.09	217.36	59.80			-	833.71	68.64	55.62			-	95.557	979.384	335.083			-

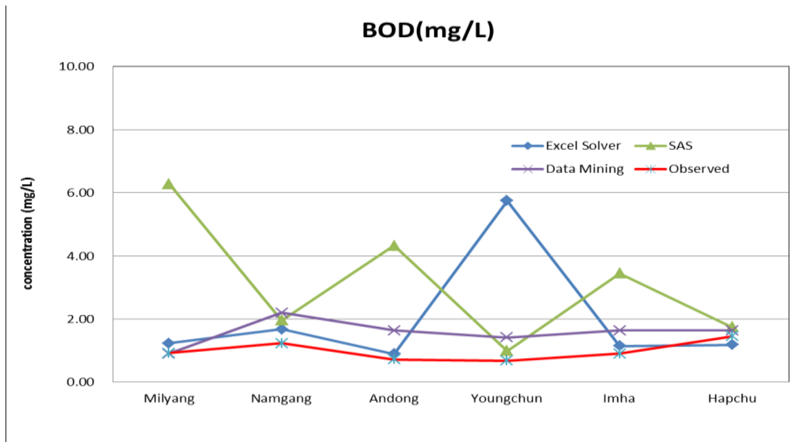


Figure 4-40: BOD simulation results based on simple equations (Nakdong watershed).

According to the BOD simulation for Nakdong River watershed, the results of Data Mining and Excel SOLVER produced a strong match with the observed data. However, results determined using the equations developed in SAS did not match the observed data.

The results of the T-N simulation using equations determined with Excel SOLVER produced results that were extremely different than the observed data. Results produced by the equations developed using data mining techniques had more similarities to the observed data but still resulted in a poor fit to the data.

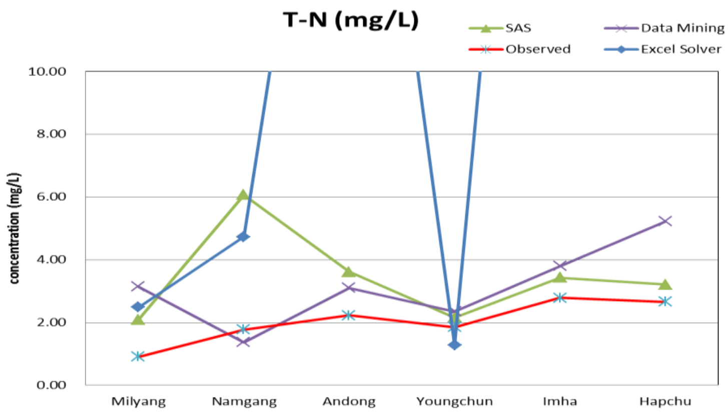


Figure 4-41: T-N simulation results based on simple equations (Nakdong watershed).

The T-P simulation based on equations determined through SAS had a totally different trend in comparison with the observed data, but the results of Data Mining and Excel SOLVER had similar trends as the observed data.

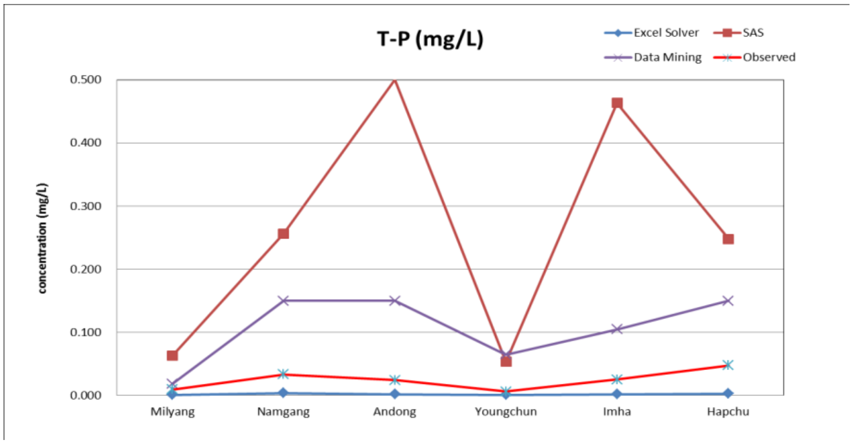


Figure 4-42: T-P simulation results based on simple equations (Nakdong watershed).

In brief, water quality simulations based upon the simple equation using Excel SOLVER, SAS, and Data Mining (M5P, ANN, and RBF) produced fairly good results with correlations to observed data. Results showed that different simple equations can be applied to different watersheds and water quality simulations. Therefore, in order to determine the priority of simple equations, the percent differences were considered. The percent differences of Yongdam Dam watershed's BOD were 25.55 %, 15.55 %, and 30.62% from excel solver, SAS, and Data Mining, respectively. SAS and excel solver are ranked first and second in terms of percent difference, however the trend of excel sover is reversed. Therefore SAS and Data Mining were recommended for BOD simulation of Yongdam watershed. For the T-N simulation of the Yongdam Dam watershed, SAS is recommended because it was ranked first in terms of percent difference. For the T-P simulation, Data Mining and SAS were recommended because percent difference is 2.79 % (very good) and 24.01 % (good), respectively. For the Nakdong River watershed water quality simuation, Data Mining is recommended for BOD and T-N simuation based upon the percent differences. For the T-P simulation, excel solver and Data Mining are recommended based upon the first and second rank of percent difference. The recommended simple equations for each watershed are shown in Table 4-32.

Table 4-32: Appropriate development method to create simple equations for each watershed.

Watershed	BOD simulation	T-N simulation	T-P simulation
Yongdam Dam watershed	SAS, Data Mining	SAS	SAS, Data Mining
Nakdong river watershed	Data Mining	Data Mining	Data Mining & Excel Solver

4.3.6 COMPARING HSPF AND SIMPLE EQUATIONS APPLICABILITY FOR NAKDONG RIVER WATERSHED AND YOUNGDAM DAM WATERSHED

In order to achieve the credibility of simple equations, the HSPF and simple equations were applied to Nakdong River watershed and Yongdam Dam watershed. The HSPF models for Nakdong River watershed and Yongdam Dam watershed were implemented based on data collectd from 2009 to 2010 and from 2005 to 2006, respectively. Simple equations were developed using several tools: Excel SOLVER, SAS, and Data Mining (M5P, ANN, and RBF) were adapted. The most appropriate methods are shown Table 4-32.

The water quality simulation results for Yongdam Dam watershed are shown in Table 4-33 and Figures 4-43, 44, and 45. According to the BOD simulation results, % difference of Data mining was smaller than the HSPF results. T-N and T-P results of Data Mining also had small % differences compared with the results from the HSPF models. In addition, the Data Mining fit of BOD was systematically biased, therefore, a best fit was determined by adding a constant of 0.5 (DM+0.5) through which a 2.76 % difference was achieved based on the Data Mining Simulation.

Table 4-33: The results of water quality simulation for Yongdam Dam watershed based upon HSPF and simple equations.

watershed	BOD (mg/L)					T-N (mg/L)			T-P (mg/L)			
	SAS	Data Mining	DM+0.5	HSPF	observed	SAS	HSPF	observed	SAS	Data Mining	HSPF	observed
Geum	1.80	1.46	1.96	1.46	2.12	2.63	2.65	2.72	0.076	0.030	0.055	0.151
Guryang	1.88	1.90	2.40	0.90	2.45	2.78	2.40	2.68	0.154	0.148	0.038	0.158
Jinan	1.04	1.03	1.53	1.20	1.93	1.58	2.60	1.86	0.036	0.110	0.069	0.096
Jeongja	1.78	1.04	1.54	0.62	1.29	2.46	1.22	2.58	0.040	0.085	0.028	0.026
Juja	1.08	0.80	1.30	0.83	1.17	1.70	1.13	1.62	0.032	0.085	0.027	0.015
Sum	7.58	6.23	8.73	5.02	8.97	11.15	10.00	11.45	0.339	0.458	0.217	0.446
% difference	15.52	30.62	**2.76**	**44.10**	-	**2.66**	**12.69**	-	24.03	**2.79**	**51.36**	-

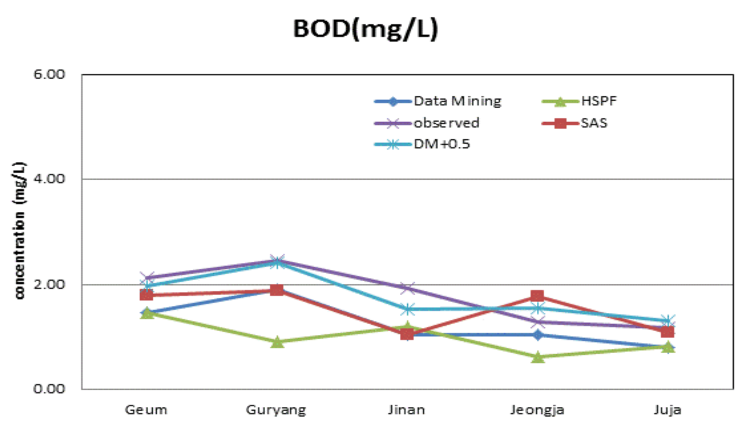


Figure 4-43: The results of BOD simulation for Yongdam Dam watershed based upon HSPF and simple equation.

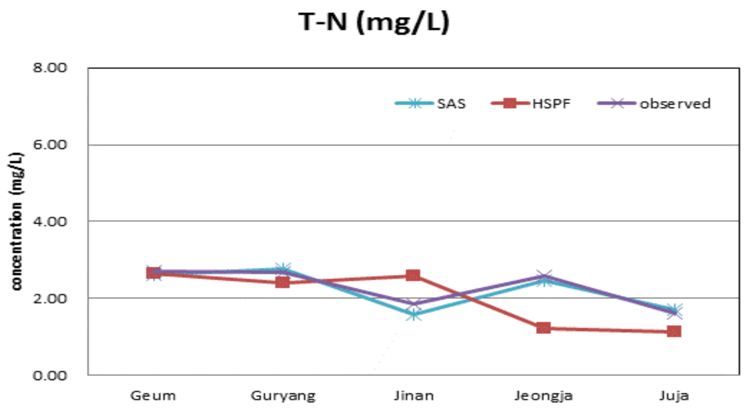


Figure 4-44: The results of T-N simulation for Yongdam Dam watershed based upon HSPF and simple equation.

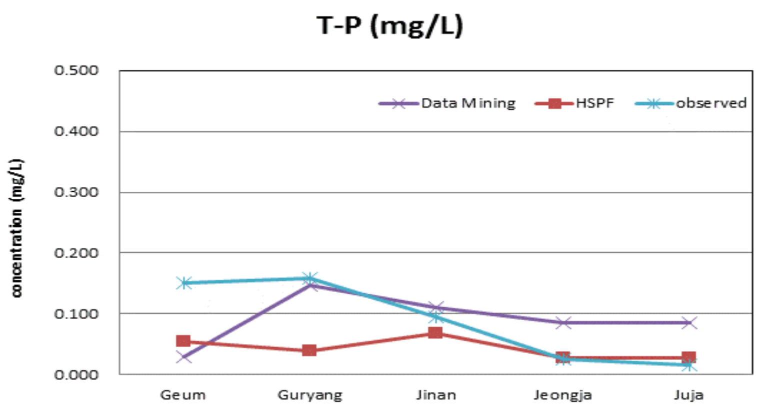


Figure 4-45: The results of T-P simulation for Yongdam Dam watershed based upon HSPF and simple equation.

The simulation results of Nakdong river watershed are shown in Table 4-34 and Figures 4-46, 4-47, and 4-48. The percent differences of HSPF were smaller than those found with the simple equations. However, the Data Mining and Excel SOLVER fits were systemically biased like the Yongdam simple equation was. Therefore, by subtracting a constant of 0.5 (DM-0.5) from the Data Mining Simulation for BOD, a 9.01 % difference was achieved. This is a very good result according to Table 4-27. For the T-N simulation, by subtracting a constant of 1.0 (DM-1.0) from the Data Mining Simulation, the percent difference was smaller than the HSPF model. For the T-P simulation, by adding a constant of 0.02 (ES+0.02) from the Data Mining Simulation, the percent difference was almost same as with the HSPF model.

Table 4-34: The results of water quality simulation for Nakdong river watershed based upon HSPF and simple equations.

watershed	BOD (mg/L)				T-N (mg/L)				T-P (mg/L)					
	Data Mining	DM-0.5	HSPF	Observed	Data Mining	DM-1	HSPF	Observed	Excel Solver	ES+0.02	Data Mining	DM-0.1	HSPF	Observed
Milyang	0.90	0.40	0.97	0.93	3.14	2.14	0.86	0.90	0.000	0.020	0.019	-0.041	0.019	0.010
Namgang	2.20	1.70	1.17	1.23	1.37	0.37	1.60	1.77	0.001	0.021	0.150	0.090	0.033	0.033
Andong	1.64	1.14	0.91	0.72	3.11	2.11	2.12	2.23	0.001	0.021	0.150	0.090	0.024	0.024
Youngchun	1.42	0.92	0.64	0.68	2.35	1.35	1.61	1.85	0.000	0.020	0.065	0.005	0.006	0.007
Imha	1.64	1.14	0.72	0.90	3.80	2.80	1.72	2.78	0.003	0.023	0.105	0.045	0.028	0.025
Hapchun	1.64	1.14	1.55	1.45	5.22	4.22	2.13	2.66	0.002	0.022	0.150	0.090	0.107	0.048
Sum	9.44	6.44	5.96	5.91	18.99	12.99	10.04	12.20	0.007	0.127	0.639	0.279	0.216	0.147
% difference	59.80	**9.01**	**0.88**	-	55.62	**6.44**	**17.68**	-	95.557	**13.851**	335.083	89.966	**46.823**	-

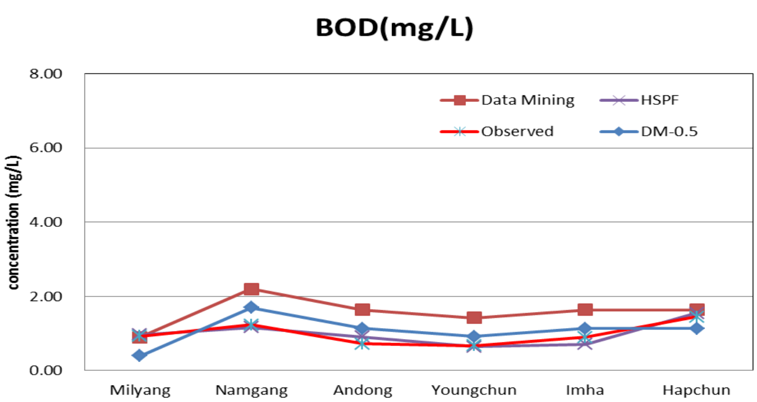


Figure 4-46: The results of BOD simulation for Nakdong river watershed based upon HSPF and simple equation.

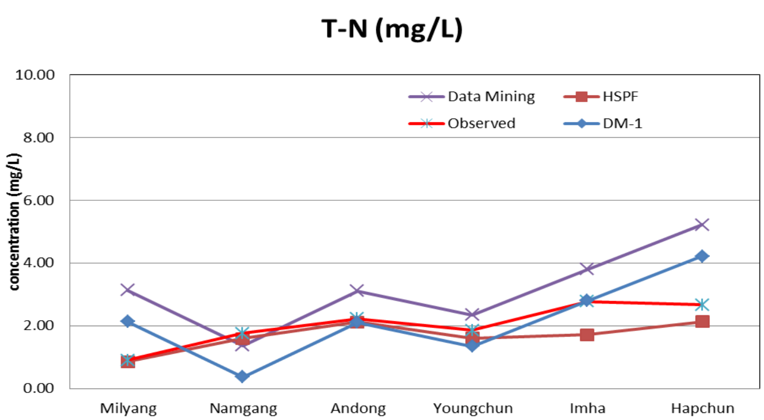


Figure 4-47: The results of T-N simulation for Nakdong river watershed based upon HSPF and simple equation.

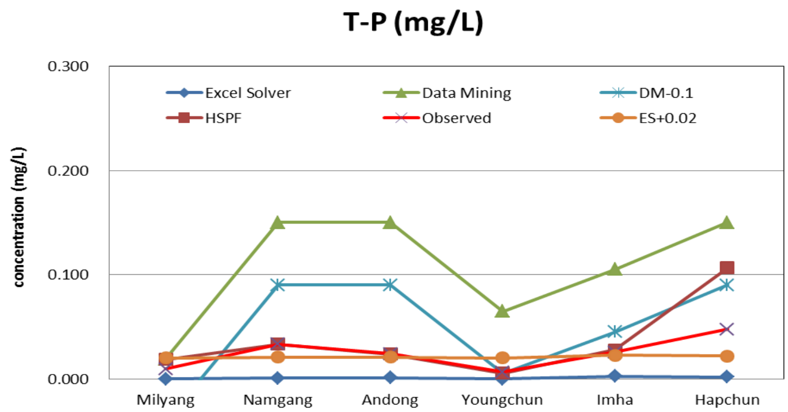


Figure 4-48: The results of T-P simulation for Nakdong river watershed based upon HSPF and simple equation.

The simulation results of the developed simple equations were better when applied to the Yongdam Dam watershed in comparison to those of the Nakdong River watershed. Otherwise, the results of simple equations for water quality simulation were found to be "systematically biased". Therefore, when adding and subtracting the appropriate constants, shown in Table 4-35, the results of the simple equation improved. Using this adjustment, the results are much more accurate than with the HSPF model in Yongdam Dam watershed and were very similar in terms of accuracy with the HSPF model in Nakdong River watershed.

Table 4-35: The % difference of water quality simulation for Yongdam Dam and Nakdong river watershed based upon simple equations and HSPF model.

Water-shed	Yongdam Dam							Nakdong River								
Water quality	BOD			T-N		T-P		BOD			T-N			T-P		
Models	DM*	DM - 0.5	HSPF	SAS	HSPF	DM	HSPF	DM	DM - 0.5	HSPF	DM	DM - 1	HSPF	ES*	ES+0.01	HSPF
% differ.	30.6	**2.8**	44.1	**2.7**	12.7	**2.8**	51.4	59.8	**9.0**	0.9	55.6	**6.4**	17.7	95.6	**13.9**	46.8

*DM: Data Mining, ES: Excel Solver

4.3.7 SUMMARY AND CONCLUSION

The purpose of this chapter was to verify the simple equations determined in Chapter 3 by modeling two watersheds—the Yongdam Dam's watershed and the Nakdong River watershed—in the HSPF watershed model and comparing their results with those from the simple equations.

The Yongdam Dam's watershed was divided into five sub-watersheds and the Nakdong River watershed was divided into six sub-watersheds. Watershed parameters were generated through HSPF pre-processing which included the generation of the river network, waterhed delineation and land use overlay. At the end of pre-processing, a BASINS *.wsd file was produced. A new project was created and the *.wsd file was input into BASINS. The *.wdm file containing weather data, point pollution loads, and dam effluent was then input into the Met WDM files. Finally, a new *.wdm file for accumulating HSPF results was created.

Using the HSPF results, calibration and validation of discharge for both Nakdong River's watershed and Yongdam Dam's watershed were performed between observed and simuate flow. In Nakdong River's watershed, the value of R^2 of discharge during 2009 to 2010 were 0.63 ~ 0.95, the percent differences during 2009 to 2010 were 0.28 ~ 101.99. In Yongdam Dam's watershed, the value of R^2 of discharge during 2005 to 2006 were 0.68 to 0.96, the percent differences during 2005 to 2006 were 9.47 ~ 90.07. Overall, even though the percent differences for each stream had significantly large ranges, R^2 was over around 0.7 for all of the streams and modeled results are therefore considered acceptable as a good criterion.

According to the results of water quality calibration and validation, most of the percent differences for DO, BOD, and T-N during 2009 to 2010 were below fair criterion (25 ~ 35 percent difference) except T-P simulation and the ratio between simulated and observed mean concentration for DO, BOD, T-N during 2009 to 2010. The ratio between simulated and observed mean concentration for the parameters in the previous sentence were mostly between 0.81 and 1.25 and T-P was 1.07 to 1.41 in the Nakdong River watershed. In the case of the

Yongdam Dam's watershed, 76.2 % of the percent differences for BOD, T-N, and T-P were below fair. The ratio between simulated and observed mean concentration for BOD was 0.28 ~ 1.07, whie T-N was 0.28 to 1.12 and T-P was 0.18 to 2.47.

Simple equations generated using Excel Solver, SAS, and Data Mining processes were applied to the Nakdong and Yongdam Dam watersheds. The data sets used as inputs to the equations included pervious area, impervious area, rainfall, slope, and land usage which was harvested from the HSPF input data.

Water quality results simulated through the simple equations produced fairly good correlation to observed data. The percent difference of Yongdam Dam watershed's BOD were 25.55% (Excel Solver), 15.55% (SAS), and 30.62 % (Data Mining). In the case of T-N, the percent differences were 8.42 % (Excel Solver), 2.66 % (SAS), and 23.44 % (Data Mining). In the case of T-P, the percent differences were 61.84 % (Excel Solver), 24.0 % (SAS), and 2.79 % (Data Mining).

The percent difference of Nakdong River watershed's BOD were 85.20 % (Excel Solver), 217.36% (SAS), and 59.80 % (Data Mining). In the case of T-N, the percent differences were 832.08 % (Excel Solver), 68.64 % (SAS), and 55.62 % (Data Minging). In the case of T-P, the percent differences were 80.70 % (Excel Solver), 979.3 % (SAS), and 335.08 % (Data Mining).

Based on these results, SAS and Data Mining are recommended for the simulation of BOD, SAS is recommended for T-N simulation, and SAS and Data Mining are recommended for T-P simulation in the Yongdam Dam's watershed. In the case of the Nakdong River watershed, Data Mining is recommend for the simulation of BOD and T-N, and Data Mining and Excel Solver are recommended for the simulation of T-P.

Results generated from the simple equations and HSPF modeling were compared. It was determined that the fits generated by the equations developed through Data Mining were systematically biased for BOD and T-P for the Yongdam Dam watershed and for BOD, T-N, and

T-P for the Nakdong River watershed. Therefore, a best fit was determined by adding and subtracting a constant of 0.01, 0.1, 0.5, and 1.0.

The best percent difference for BOD simulation in the case of Yongdam Dam's watershed was 2.79 % when 0.5 was added to the Data Mining result. The percent different for the same parameter using HSPF was 44.10 %. The percent difference for T-N was 2.66 % using the SAS results and 12.69 % using the HSPF results. The percent difference for T-P was 2.79 % for the SAS results and 51.36 % for the HSPF results for the Yongdam Dam's watershed.

For Nakdong River Watershed, the percent difference of BOD simulation became 9.01% when 0.5 was subtracted from the Data Mining results. The HSPF results had a 0.88 % percent different in the case of BOD for this watershed. The percent difference for T-N was 6.44 % when 1.0 was subtracted from the Data Mining result. This compares favorily to the 17.68 % different obtained by the HSPF results. The percent different for T-P was 49.43 % using the Excel Solver results pluse 0.01. This was similar to the 46.82 % difference obtained for T-P for the HSPF results.

In conclusion, the developed simple equations produced better or similar water quality results compared with those produced by the HSPF model. This illustrates that these equations can be used instead of a physically-based model like HSPF to forecast water quality conditions in a watershed using watershed parameters as input data. This was illustrated in the case of the Geum-Sum-Youngsan River watershed and Nakdong River watershed.

This chapter proved the final hypothesis of this dissertation, that water-quality results generated by the simple equations could be verified against the results from a physically-based watershed model and be comparable. This proves that the simple equations relating watershed parameters to watershed water quality can be used as a screening device to aid in the determination of the best restoration locations.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

Philosophically speaking, watersheds and the quality of water they provide delineate the boundaries of life for people who life in them. These boundaries are different for different people as water quality needs and conditions are different between watersheds. In order to evaluate and estimate water quality in a watershed, generally, a mechanical watershed model is used even though we don't have enough data to properly calibrate prior to use. That's the main reason why the estimations and evaluations for watersheds are often incorrect. Based on literature review of thirty three watershed models that are currently available models that are designed for the purpose of developing flow and water quality management plans, they require too much data and application effort to be used to prioritize watersheds with respect to their relative contribution to environmental degradation within a multiwatershed basin.

In Chapter 2, numerous watersheds models, which have their own unique characteristics, were reviewed to determine each model's mechanisms and functions. Furthermore, about 217 references examples, which have been applied to the watershed models, were reviewed and analyzed with a focus on their applicability.

Based on this study's literature review, currently available watershed models designed for the purpose of developing flow and water quality management plans at a watershed scale require too much data and application effort to be used to prioritize watersheds with respect to their relative contribution to environmental degradation within a multiwatershed basin. Therefore, as was hypothesized in Chapter 1, simple equations relating easily obtained data to watershed water quality impacts need to be developed to sufficiently prioritize target restoration areas in the feasibility phase of spatially large projects (i.e. national scale).

In addition, a model selection program is needed to aid the engineer in the selection of the best watershed model to use in future complex modeling following the feasibility phase. Eight variables were chosen considering five factors from Leslie et al. (2005) and the reviewed literature such as land use, event or continuous, time steps, water quality, distributed or lumped, subsurface, overland sediment, and BMP. Using these eight variables as input, the selection program developed in this dissertation screens available watershed models for the best model for the user's needs.

The watershed selection program described in this dissertation could be highly useful to many watershed modelers. In addition, this program could be upgraded by anyone who knows how to apply state-of-art data that has been collected from a watershed model. This program is still not perfect because we could not obtain the entire data for each watershed model. Finally this program is going to be upgraded continuously to fulfill the needs of users of watershed models.

In Chapter 3, to find out the co-relationship between water quality and watershed parameters, parameters were separated into ten scenarios: 1) impervious, 2) impervious+pervious, 3) impervious+rainfall, 4) impervious+slope, 5) impervious+rainfall+slope, 6) slope, 7) land usage, 8) lang usage+rainfall, 9) land usage+slope, 10) land usage+rainfall+slope.

The Simple equations were established through the application of the three cases and ten scenarios in Excel Solver, SAS (Statistical Analysis System), Model Tree, ANN (Artificial Neural Network), and RBF (Radial Basis Function). The best simple equations were then identified from the generated equations using statistical methods (R^2, adj. R2, F-AIC, VIF, Shapiro-wilk test, etc.).

Based on the collected results from Excel Solver, the SAS, and Data Mining, the first steps' results are much better than the second and third step's results. Therefore, these simple equations generated from the first step are the best to apply to real-based watersheds. This chapter proved the hypothesis that simple equations can be determined correlating water quality and phycial watershed parameters.

In Chpater 4, to verify the simple equations determined in Chapter 3 by modeling two watersheds—the Yongdam Dam's watershed and the Nakdong River watershed—in the HSPF watershed model and comparing their results with those from the simple equations.

Results generated from the simple equations and HSPF modeling were compared. It was determined that the fits generated by the equations developed through Data Mining were systematically biased for BOD and T-P for the Yongdam Dam watershed and for BOD, T-N, and T-P for the Nakdong River watershed. Therefore, a best fit was determined by adding and subtracting a constant of 0.02, 0.1, 0.5, and 1.0.

The best percent difference for BOD simulation in the case of Yongdam Dam's watershed was 2.79 % when 0.5 was added to the Data Mining result. The percent different for the same parameter using HSPF was 44.10 %. The percent difference for T-N was 2.66 % using the SAS results and 12.69 % using the HSPF results. The percent difference for T-P was 2.79 % for the SAS results and 51.36 % for the HSPF results for the Yongdam Dam's watershed.

For Nakdong River Watershed, the percent difference of BOD simulation became 9.01% when 0.5 was subtracted from the Data Mining results. The HSPF results had a 0.88 % percent different in the case of BOD for this watershed. The percent difference for T-N was 6.44 % when 1.0 was subtracted from the Data Mining result. This compares favorily to the 17.68 % different obtained by the HSPF results. The percent different for T-P was 13.85 % using the Excel Solver results pluse 0.02. This was similar to the 46.82 % difference obtained for T-P for the HSPF results.

In conclusion, the developed simple equations produced better or similar water quality results compared with those produced by the HSPF model. This illustrates that these equations can be used instead of a physically-based model like HSPF to forecast water quality conditions in a watershed using watershed parameters as input data. This was illustrated in the case of the Geum-Sum-Youngsan River watershed and Nakdong River watershed.

This research proved the final hypothesis of this dissertation, that water-quality results generated by the simple equations could be verified against the results from a physically-based watershed model and be comparable. This proves that the simple equations relating watershed parameters to watershed water quality can be used as a screening device to aid in the determination of the best restoration locations.

Recommendation for Future Research

Recently, in order to ensure and improve water quality, river restoration projects were implemented in Korea. A total of 16 weirs and other facilities were installed in four of the largest rivers in Korea for the purpose of implementing advanced water quality management for the watersheds and dams which are located in the upstream, and the weirs. Algal blooms have become a major issue because of increasing retention times due to the installation of weirs in the main river.

As a result of needs to collect and monitor the water quality and the issues that can arise due to the methods of collecting that data, a variety of measures have been implemented as follows;

i. Establishment of standards for water quality monitoring.
ii. Enforcement of water quality surveys.
iii. Establishment of real time water quality surveys based upon weir operations.
iv. Establishment and implementation of integrated national rivers management.

v. Introduced physical and chemical treatment measures for decreasing the algal blooms.
vi. Water quality improvement based upon the integration of operations from weir to weir and from dam to weir.
vii. Secure discharges to maintain and improve environmental quality of the four river environment.
viii. Mapped distribution of algae species found within each river and conducting research to determine optimal weir operations to resolve algal blooms.

A significant amount of research has been devoted to gathering information and predicting future water quality. Thus three dimensional water quality models can and have been implemented. However, application of these models limited by the requirement for massive amounts of data. As a result, they have reached a limit in terms of existing data. Hence, according to this research, a simple equation could be used with confidence to predict water quality based upon watershed land usage. Furthermore, the simple equations method could be used to analyze, evaluate, and prioritize sub-watersheds of the four major rivers that could benefit from land usage improvement using Best Management Practices and Low Impact Development. The schematic in Figure 5-1 represents the flow or process of analysis and prioritization for determing priority subwatersheds and identification of specific needs for water quality improvements.

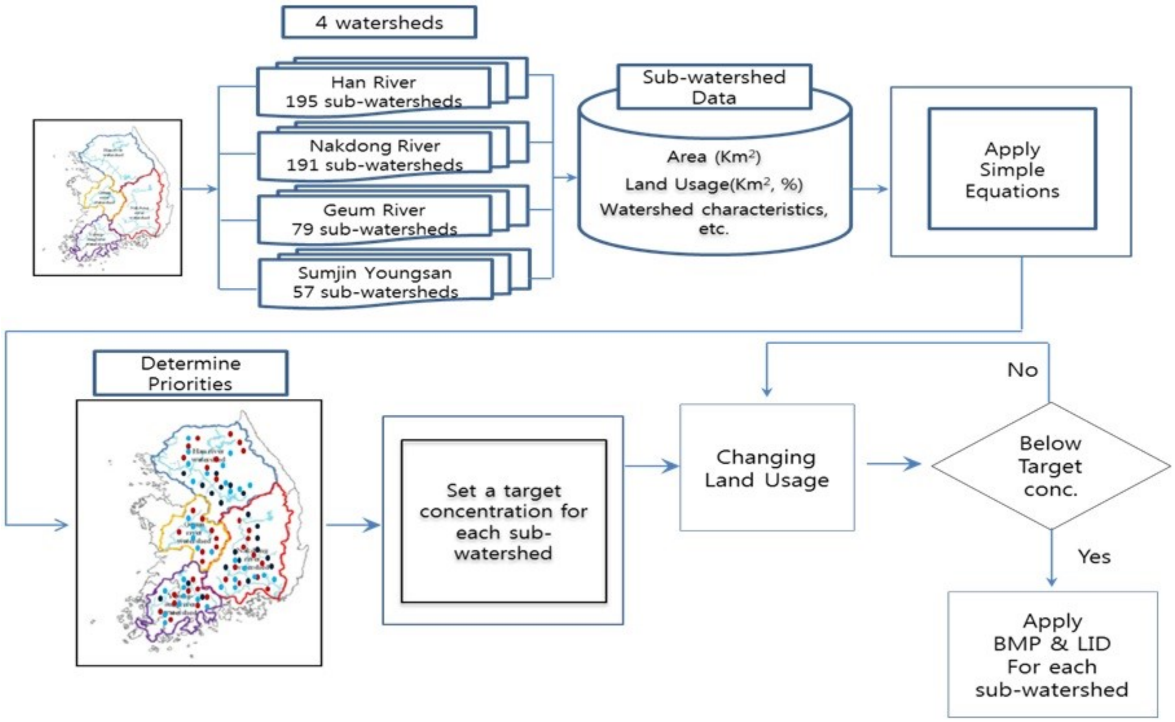


Figure 5-1: Future research schematic for sub-watershed management based upon Simple Equations.

Recommendation for developing the "Simple Equation"

As has been mentioned in this research, the Simple Equation can be easily assessed for priority analysis in order to restore and rehabilitate a specific watershed among whole nations. And the Simple Equation could be developed using the relationships between water quality and watershed characteristics such as land usage, rainfall, and slope which have been mentioned in this dissertation. Therefore, I would like to recommend that countries which have insufficient data bases to run physically based and mechanica models to follow the process (Figure 5-2) to develope "Simple Equations" using existing data and then evaluate and analyze the whole nation for considering water quality aspects.

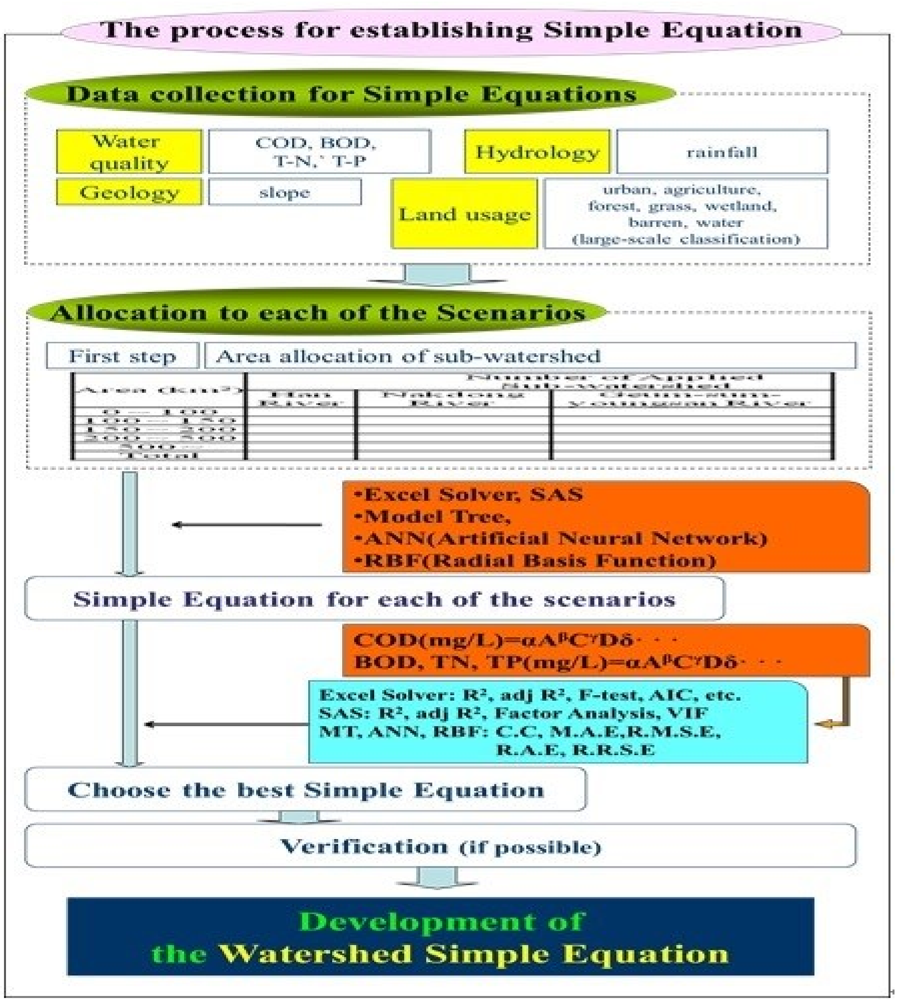


Figure 5-2: The process to establish Simple Equation to the new watersheds

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APPENDIX A –DESCRIPTION OF MATHEMATICAL MODELS CONSIDERED FOR SIMULATION WATERSHED HYDROLOGY AND WATER QUALITY.

AGNPS

AGNPS (Agricultural Nonpoint Source Pollution) is an event-based model simulating water runoff, sediments, chemical oxygen demand (COD), pesticides, and transport of nitrogen (N), phosphorous (P) (Borah et al., 2003b). Technically, erosion modeling is based on USLE (Universal Soil Loss Equation) and hydrology is based on SCS (Soil Conservation Service curve number technique). In the Lake Decatur watershed, AGNPS was used to evaluate the effects of different BMP scenarios for reducing nitrate-N discharge (periodically exceeding the 10 mg/L drinking water) into the lake from 2,400-square-kilometer Lake Decatur agricultural watershed (Deva, 2002).

AnnAGNPS

AnnAGNPS (Annualized Agricultural Nonpoint Source Pollution Model) is a continuous simulation watershed-scale program developed based on the AGNPS. The model simulates the quantities of surface water, sediment, nutrients and pesticides leaving the land areas and their subsequent travel through the watershed (www.epa.gov/nrmrl/pubs/600r05149/600r05149annagnps.pdf, www.ars.usda.gov/Research/docs.htm?docid=5222). AnnAGNPS was used to evaluate the performance and suitability regarding the runoff, sediment loading and nutrient loading (A. Shamshad et al., 2008). AnnAGNPS has advantages in detailed emission assessment and scenario development for BMP, etc. when compared with GIS-based empirical models which doesn't conclude the process of sediment and pollutant, transport, and retention (Polyakov, 2007). This model performs well in simulating runoff volumes but the estimations for peak flow and sediment yields have some problems (Shrestha, 2005**).**

ANSWERS

ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation) was developed for agricultural watersheds and covers construction sites that have not had any major modifications as well. The original ANSWERS model included only surface water hydrology (Huggins et al., 1966) and was developed to include erosion and sediment transport (Beasley et al., 1980). ANSWERS is a distributed parameter model integrated with spatial variability of the controlling parameters such as topography, soil type, land use, etc. There are two advantages, first is that it has the potential to provide a more accurate simulation of natural catchment behaviors and it can simulate simultaneously conditions at all points within the watershed. The overall model's structure consists of a hydrologic model, a sediment detachment, a transport model, and several routing components for describing the movement of overland water, subsurface, and channel flow phase. Soil moisture of a watershed is simulated by using the soil water balance equation and soil detachment, transport, and deposition are implemented by the precipitation and runoff processes (Beasley et al., 1980). ANSWERS is available to simulate runoff, peak flow and sediment yield from a watershed with the acceptable level of deviation (Ramadhar et al., 2005).

BASINS

BASINS (Better Assessment Science Integration point and Nonpoint Sources) is a decision support system for multipurpose environmental analysis by regional, state, and local agencies performing watershed and water-quality based studies. It is mainly used to meet the

TMDL (Total Maximum Daily Load) process, which was developed by EPA researchers (www.epa.gov/waterscience/basins). In addition, BASINS supports cost-effective watershed management and environmental protection and is configured to support environmental and ecological studies. The main interface of BASIN is a Geographic Information System (GIS) which provides tools to display and analyze spatial information and includes the national database, watershed delineation tools, classification utilities, characterization reports, two watershed loading & transport model (HSPF and SWAT), a simplified GIS model, PLOAD, used to estimate annual average nonpoint loads, the automated Geospatial Watershed Assessment (AGWA) tool, a GIS-based hydrologic modeling tool, and model calibration tool, parameter estimation (PEST) tool.

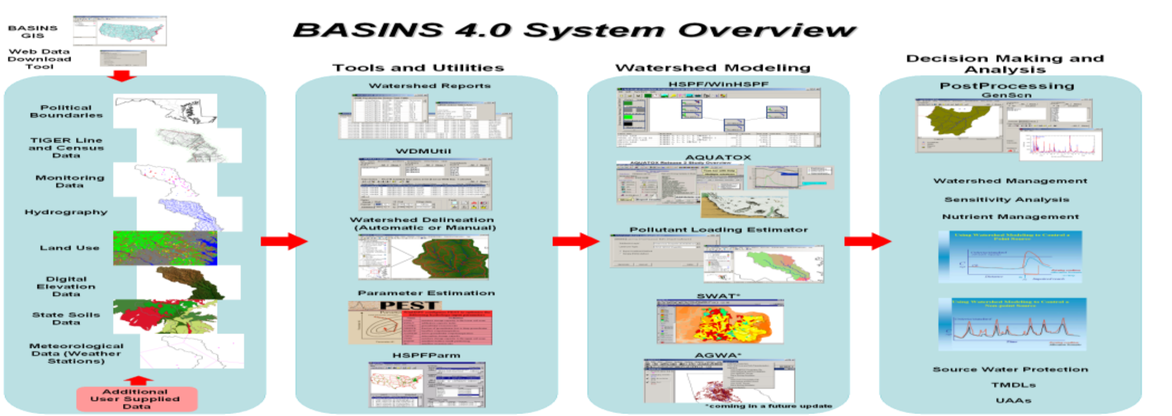

Figure A-1: BASINS system overview (**http://www.basinslive.org/**).

BASINS was used to help develop a bacteria TMDL for Cottonwood Creek watershed, Idaho Country, Idaho (EPA, 2000). Lately, climate change has been a primary consideration of environmental variables, hence watershed models should take into consideration that climate variables are much more important. BASIN CAT (Climate Assessment tool) model uses modified historical climate data and conducts a systematic sensitivity analysis of specific hydrologic and water quality endpoints to change in climate using the BASINS model (HSPF) (Imhoff, et al., 2007).

CASC2D

CASC2D is the runoff and soil erosion modeling and a state-of-art hydrologic model based on GIS (Geographic Information Systems) and remote sensing. The model's characteristics are a fully-unsteady, physically-based which consists of the equations of conservation of mass and energy to determine the timing and path of runoff in watersheds, distributed-parameter, raster (square-grid), two-dimensional, infiltration-excess (Hortonian), hydrologic model. The major components are continuous soil-moisture accounting, rainfall interception, infiltration, surface and channel runoff routing, soil erosion and sediment transport. CASC2D is capable of describing a variety of subwatershed characteristics compared to HEC-1 which assumes subcatchments are hierologically uniform (http://gcmd.nasa.gov/records/CASC2D.html).

CASC2D was applied to the Goodwin Creek Watershed, covering 21.4km^2 in Mississippi. In this research, overland and channel flow were simulated simultaneously. (Julien, 1998)

DIAS/IDLMAS

DIAS/IDLMAS (Dynamic Information Architecture System/Integrated Dynamic Landscape Modeling and Analysis System) is one-dimensional grid of subwatershed overland. DIAS is an object-based software framework for modeling and simulation application and allows many disparate simulation models and other applications to interpolate to address a complex problem based on the context of the specific problem (Leslie et al, 2005). DIAS embraces and extends the object paradigm with its own attributes and dynamic behaviors from parent object classes, thereby promoting code reuse and extensibility. In addition, DIAS has been applied to so many fields such as dynamic weather and terrain influence unit mobility, route planning and IPB analysis, Integrated land management and land use planning at military training bases, agricultural and social sustainability of ancient urban centers, Integrated oceanic systems simulation, Health care (integrated physiological, clinical and logistical simulations) and understanding the chemical “language” of cellular division (Hummel et al, 2002). IDLAMS could be classified by two features; GIS-IDLAMS and OO-IDLAMS (Object-Oriented) (Sydelko et al., 2000).

DRAINMOD

DRAINMOD (A Hydrological Model for Poorly Drained Soils) originally was used to simulate the performance of drainage and related water management system on a field scale. The input data for DRAINMOD are soil properties, crop parameters, drainage systems parameters, weather and irrigation data, and so on. This model could be operated based on day-by-day and hour-by-hour data and calculate infiltration, ET(evapotranspiration), drainage, surface runoff, subirrigation, deep seepage, water table depth, and soil water status at each time interval (Sinai, 2006). The water balance for a time increment Δt is expressed as,

$$\Delta V = D + ET + DS + LS - F \qquad \text{Equation A-1}$$

Where ΔV= the change in the water free pore space or air volume (cm) D = the drainage from (or subirrigation into) the section (cm) ET= the evapotranspiration (cm) DS= the deep seepage (cm) LS= the lateral seepage (cm) F = the infiltration (cm) entering the section

The infiltration of water into a soil’s profile is computed by the Green and Ampt equation in this model and the subsurface drainage rate is calculated by the Hoogoudt equation (Leslie et al., 2005, Sinai et al., 2006). This model is an excellent tool that was used for the simulation of field-scale hydrological parameters in the southwestern Quebec regions (Helwig et al., 2002) and achieved excellent results in regards to the drain flow especially long-term DRAINMOD runs gave better average yield predictions to reasonably guide spacing design than short-term DRAINMOD (Wang et al., 2006). Otherwise, DRAINMOD can be used to design and evaluate subsurface drainage system in semi-arid conditions with some future evaluation (Gupta et al, 1993).

DWSM

DWSM (Dynamic Watershed Simulation Model) uses physically based governing equations and simulates surface and subsurface storm water runoff, flood waves, soil erosion, entrainment and transport of sediment, and agricultural chemicals in agricultural watersheds. This model has three compounds; first is DWSM-Hydrology (Hydro) simulating watershed hydrology, second is DWSM-Sediment (Sed) simulating soil erosion and sediment transport, third is DWSM-Agricultural chemical (Agchem) simulating agricultural chemical (nutrients and pesticides) transport.

The DWSM predicted the water and sediment discharges reasonably well with only a few minor discrepancies at the Upper Sangamon River basin (Borah, et al, 2001A). This model computes soil erosion due to the raindrop impact by using the sediment continuity equation which keeps track of erosion, deposition, and sediment discharge along the flow segments (Borah et al., 2001B). DWSM was applied to the Big Ditch Watershed (100 km^2) in Illinois which is a tributary subwatershed of the 2,400 km^2 Upper Sangamon River watershed. The interception-infiltration method was employed to compute the rainfall excess (Kim et al.,2003). DWSM-Agchem simulates the mixing of nutrients and pesticides and transportation of chemicals with surface runoff in a dissolved form, and with sediment in transport components. (Ashraf, et al., 1992).

EPIC

EPIC (Erosion Productivity Impact Calculator) is a tool used for determining the effects of soil erosion on crop production. EPIC has several components for simulating; erosion, plant growth, related processes, and economic components for assessing the cost of erosion and components for determining optimal management strategies and also has nine divisions as well; hydrology, weather, erosion, nutrients (nitrogen and phosphorus losses from fertilizer and manure applications), plant growth, plant environmental control), soil temperature, tillage, and economic budgets (Williams, 1990). In addition, the temporal scale used is a daily time step and a long-term simulation (1 to 4000 years), but the drainage area is so small (about 1hectare) like agricultural field/farm scale (Williams et al., 1983, Martin et al., 1993, Gassman et al, 2004, Leslie et al., 2005).

EPIC should be supplemented due to the lack of both an upward capillary transport mechanism and a preferential flow component in EPIC influence (Warner et al., 1997). In addition, EPIC has the following errors as well; using a daily-time step rather than a more refined time-step such as hourly, nitrogen transformation routines that may not adequately reflect all of the processes that occur in the field (Chung et al., 2002). When this model was evaluated under two different conditions; rain-fed conditions and irrigated conditions, under rain-fed conditions, EPIC simulated fairly well when compared with the irrigation conditions (Guerra et al., 2002).

GISPLM

GISPLM (GIS-based Phosphorus Loading Model) is a tool used for developing cost-effective strategies to reduce phosphorus loads from watersheds. Flow and phosphorus loads could be calculated by watershed features from GIS, climatological data, and other local data. The main sources of phosphorus are from runoff, farm animal populations, and point discharges. This model is composed of HYDRO and LOADS; HYDRO (a compiled Fortran Program) predicts surface runoff from pervious areas on a daily base, LOADS (a compiled Fortran Program) calculates flows and phosphorus loads based on watershed features such as segment numbers (index), model land use codes, existing BMP codes, soil groups, soil origins, slopes, stream proximities, and so on. Flow and loads from each source category (runoff, animal units, and point source) are summed by model segment, adjusted by existing phosphorus and then summed by segment until the mouth of the watershed (GeoEngineers 2010, Leslie et al. 2005, William W. W., 1997). An empirical model (Walker, W. W. 1987) was used for the retention of phosphorus in impoundments and lakes which is shown Figure A-2.

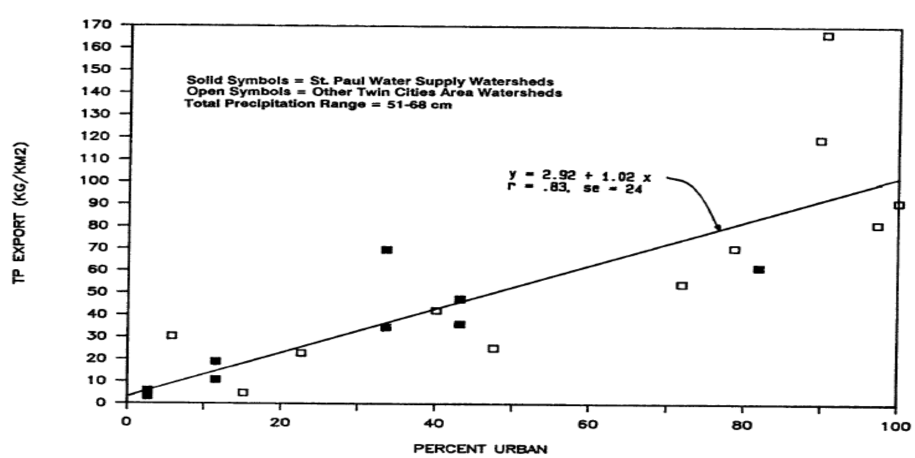

Figure A-2: Phosphorus export vs. urban land use for twin cities watersheds (Sources: Walker, W. W, 1985).

Point and non-point sources for the GISPLM model are controlled by up to 3 treatment levels based on effluent phosphorus concentration and flow-dependent cost and up to 12 land use categories, respectively (William W. W., 1997)

GLEAMS

GLEAMS (Groundwater Loading Effects of Agricultural Management Systems) is a mathematical model for field-size areas to evaluate the effects of agricultural management system and could predict the movement of agricultural chemicals within and through the plant root zone (Leonard et al., 1987). The GLEAMS model was modified by hydrology, plant nutrient, and pesticide components of CREAMS (Leonard et al., 1987). Actually, the CREAM model (Chemical, Runoff and Erosion from Agricultural Management System) could reflect differences in water, sediment, and chemical responses from different management practices (Foster et al., 1981; Knisel, 1980; Leonard et al., 1987). Knisel (1993) added to the model to simulate nitrogen and phosphorus cycles in the soil.(Knisel et al., 1999)

The GLEAMS model consists of four components; hydrology, erosion/sediment yield, pesticides, and plant nutrients. For the hydrology components, soil profile and crop data were used to estimate the effective rooting depth (the upper portion of the root zone where plant get most of their water. Effective root zones are estimated as one-half the maximum rooting zone) such as maximum 12 computational layers with input maximum 5 soil horizons (Leonard et al., 1987; Knisel et al., 1999). ET was calculated by the Priestley-Taylor (PT) model (Priestley and Taylor, 1972) or by a modification of the Penman-Monteith (PM) equations (Jensen et al., 1990; Monteith, 1965). Soil Conservation Service (SCS) curve number method was used for calculating runoff. A storage-routing technique was used for percolation out of the below root zone and redistribution of infiltrated water within seven computational layers in the root zone (Leonard et al., 1989).

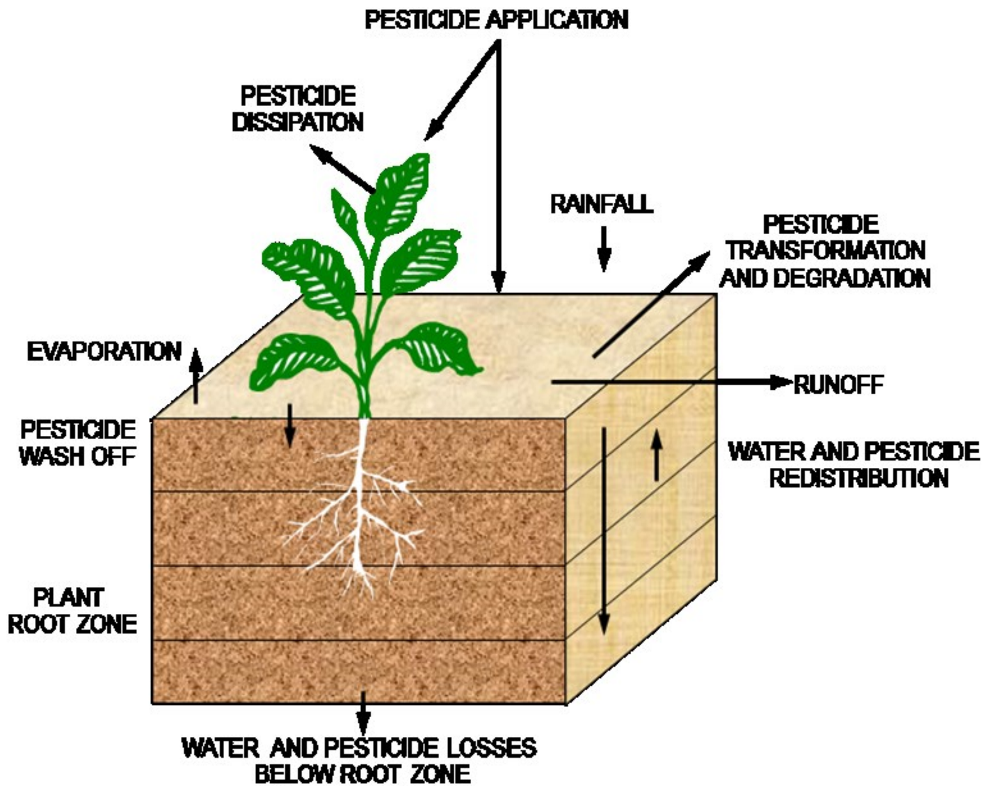

Figure A-3: The physical system and processes represented in GLEAMS.

For the erosion/sediment components, in order to define aggregate sizes and their respective fractions in the detached soil, additional data was used based on the fraction of clay in the matrix soil, the fraction of primary clay, silt, and sand particle, the fraction of small and large aggregates, and the primary particle composition of five sediment class (Foster et al., 1985, Leonard et al., 1987). The erosion component is the Onstad-Foster (Onstad et al., 1975, Knisel, 1999) which was modified by USLE (Universal Soil Loss Equation) for storm-by-storm simulation. Non-uniform slope was used for rill and inter-rill erosion (Leonard et al., 1989).

For the pesticide component, the primary purpose of this model is to simulate the effects of management practices on pesticide movement within and through the root zone. The mechanisms of pesticide in nature is adsorption/desorption onto soil and organic carbon, adsorption and wash-off from living and dead plant tissue, and degradative characteristics from foliage, surface soil, and root zone. And these mechanism's impacts are different depending on the kind of pesticides and the surround environment. The impacted surface layer's thickness could be diverse based on soil characteristics such as crusted surface layer in a no-till system, compacted surface due to continuous animal gazing of a pasture or rangeland (effective surface layer; a few millimeters), and cloddy surface (effective surface layer; 2~3cm), however there is no good relationship, therefore the surface layer in GLEAMS assumed a constant 1 cm thickness (Leonard et al., 1987, 1989).

The GLEAMS and CREAMS model were simulated to compare simulation results and observed surface pesticide (atrazine and paraquat) losses at Watkinsville, GA. from 1973 to 1975. GLEAMS model could get the closer result than CREAMS model (Leonard et al., 1987). In southern Finland, the GREAMS model could be used for depicting clay soils, crops, climate, and management (Knisel et al., 1999). Slightly changing water balance components (rooting depth, curve number, porosity, and field capacity) could improve simulated runoff, percolation, and evaporation so the calibration of the GLEAMS hydrology component does not require alternative management practices to be assessed (Knisel et al., 1991). The GLEAMS model was applied at agricultural areas in Hungary (Leone et al, 2007). The results were satisfactory at least in terms of management purposes because three of the area (orchard, arable, forest) simulations were quite similar to the real situation. In addition, the leaching rate of the orchard and arable areas were relatively high, but the forest was so slow, as well.

GSSHA

GSSHA (Gridded Surface/Subsurface Hydrologic Analysis) model is a reformulation and enhancement of the two-dimensional physically based model CASC2D, sediment and water quality transport and coupled to one-dimensional stream flow (Ogden et al., 2008). This model is better at representing spatially-varied land surface parameters compared to the lumped-parameter modeling approach (Sharif et al., 2010). The model has been successfully applied to a number of watersheds from 0.016 to 2,300km^2 (Niedzialek et al., 2003). This model is generated using four components; infiltration-excess, saturation-excess, exfiltration, and groundwater discharge to streams. The additional processes of the GSSHA model are snow accumulation and melting (Energy Balance), lateral groundwater flow (2D vertically averaged), stream/groundwater interaction (Darcy's law), and exfiltration (Darcy's law) when compared with CASC2D. Vadose zone's (unsaturated zone is located on the upper groundwater surface) analysis is very important for surface water hydrology, infiltration, ET, and groundwater recharge. Therefore, Rechard's Equations (RE) were used in this model. In addition, this model is extending the capability of the model to all seasons by including precipitation freezing and melting and seasonality change of ET parameters (Downer et al., 2004).

The GSSHA has a capability of predicting discharge, stream depths, soil moistures, and the location of saturated areas in watersheds and accurately reproduces event peaks, runoff volumes, and hourly flows (Downer et al., 2004).

In the Bull Creek Watershed which is 55 km^2 partially urbanized watershed, both rain gauges and spatial & temporal distribution of rainfall (30-m square grid) were compared. The model simulation, which is driven by rain gauges, overestimated the peak flow and volume of runoff, while on the other hand spatial & temporal distribution (GSSHA model) was more accurate than the rain gauges. However, the GSSHA model needs more detailed data about spatial & temporal information of watershed (Sharif et al., 2010, Niedzialek et al., 2003). Furthermore, when the GSSHA model was compared with HEC-1 at Storrs Campus (0.98km^2, 0.4mi^2) in University of Connecticut, GSSHA could achieve better quality results than the lumped model HEC-1 regarding runoff model and flood predictions in a small, urbanized watershed (Niedzialek et al., 2003). Ogden et al., (2008) applied advanced methods for a more detailed simulation of sediment runoff; detachment by raindrops, detachment by surface runoff, sediment transport capacity of surface runoff, and sediment transport in channels with breakpoint cross-sections. The advanced GSSHA model achieved good results for predicting sediment runoff volumes.

GWLF

GWLF (Generalized Watershed Loading Functions) was a middle ground between the empiricism of export coefficients and the complexity of chemical simulation models (Medina, 2005). The structure of the model is composed of dissolved and solid-phase nitrogen, phosphorus in stream flow and primary parameters such as runoff, erosion, nutrient loads etc. are shown in Table A-1.

Table A-1: The mechanism for GWLF model's parameters (Haith, 1992).

Division	Composing for calculating		Equations
Rural Runoff Loads	Dissolved	multiplying runoff by dissolved concentrations	$LD_m = 01.\sum_{k}\sum_{t=1}^{dm} CdkQktARk$ Where LD_m: dissolved nutrient loads, Cd_k: nutrient concentration, Q_{kt}: runoff, AR_k: area, d_m: number of day
	Solid-Phase	The product of monthly watershed sediment yields and average sediment nutrient concentrations	$SR_m = 0.001C_sY_m$ Where SR_m = Solid-phase rural nutrient loads, Cs: average sediment nutrient concentrations, Ym: the product of monthly watershed sediment yields
Urban Runoff	General accumulation	The exponential accumulation function was subsequently used in SWMM	$\frac{dN_k}{dt} = n_k - \beta N_k$ Where N_k: the accumulated nutrient load, n_k: a constant accumulation rate, β: a depletion rate constant,
	Wash-off relationships	The wash-off function is used in both SWMM and STORM	$W_{kt} = 1 - e^{-1.81Q_{kt}}$ Where Wkt: runoff nutrient load from land use k on day t,
Ground-water sources	Groundwater discharge is described by the lumped parameter. The groundwater discharge from shallow saturated zone is added to the total watershed runoff.		$DG_m = 0.1C_gAT\sum_{t=1}^{d_m} G_t$ Where DGm: monthly groundwater nutrient load, Cg: nutrient concentration in groundwater, AT: watershed area, Gt:groundwater discharge to the stream on day t
Septic	Normal	On-site wastewater disposal system (USEPA)	$DS_{1m} = \frac{DR_m\sum_{m=1}^{12} SL_{1m}}{\sum_{m=1}^{12} GR_m}$ Where DS_{1m}=the dissolved nutrient load to stream-flow from normal systems, DR_m = total groundwater discharge to streamflow in month,SL_{1m} = the nitrogen load to ground water from normal system in month
	Short-circuited	Located close enough to surface water (about 15m)	$DS_{2m} = 0.001a_{2m}d_m(e - U_m)$ Where DS_{2m}= the dissolved nutrient load to stream-flow from short-circuited systems, a_{2m}=per capita effluent loads and monthly populations served a_{jm} for each systems, e=per capita daily nutrient load in septic tank effluent, U_m=per capita daily nutrient uptake by plants in month
	Ponded	These systems exhibit hydraulic failure of the tank's absorption field and resulting surfacing of the effluent	$DS_{3m} = 0.001\sum_{t=1}^{d_m} PN_t$ Where DS3m: the dissolved nutrient load to stream-flow from ponded systems, PNt: watershed nutrient load in runoff from ponded systems on day
	Direct discharge	Illegal discharge from septic tank effluent directly into surface waters	$DS_{4m} = 0.001a_{4m}d_me$ Where DS_{3m}: the dissolved nutrient load to stream-flow from direct discharge
Land use	Runoff source areas are identified from land use maps, soil surveys and aerial or satellite photography		
Weather	Daily precipitation and temperature data are obtained from meteorological records and assembled in the data file WEATHER.DAT.		

This model was used in the Linthipe River catchment of Lake Malawi basin. According to the results, anthropogenic activities (agriculture and deforestation) create/cause much more sediments and nutrients from the catchment, especially during the rainy season (Chikondi, 2010). Limbrunner (2005) tried to upgrade this model to include daily simulations of BMPs as well as a structure to allow for convenient interface with an optimization algorithm to optimally select BMPs for each land use class, using the so called Tufts Watershed Loading Function (TWLF). In order to assess soil erosion and non-point source pollution impact, the GWLF model was used in the Kao-Ping River Basin in Southern part of Taiwan (Ning, 2005).

HSPF

HSPF (Hydrologic Simulation Program Fortran) is a comprehensive model for simulating the quantity and quality of streamflow, reservoir system operations, ground water development and protection, surface water and ground water conjunctive use management, water distribution systems, water use, and a range of water resources management activities on pervious and impervious land segments and river channels (Leslie et al., 2005, Said et al., 2007, Ryu, 2009). The model was composed of the following models: Stanford Watershed Model (SWM), advanced process conceptual models, and several water quality models (Lohani et al., 2000). Especially SWM was used to determine the water balance of soil or storage from different layers of hydrology. The advantages of the HSPF model are cell-based representation of land segments and drainage channels, subdivided storage columns to denote the water that is available for infiltration, runoff, and groundwater recharge, and automatic calibration tools to optimize model performance by adjusting hydrologic parameters (Ryu, 2009). Therefore a subwatershed is classified by a group of various land uses such as pervious land segments, forests, agricultural and urban built-up, impervious land segment (urban built-up), and stream or mixed reservoir segments which are all routed to a representative stream segments (Leslie et al., 2005, Ryu, 2009). Specifically, interception, infiltration, evapotranspiration, interflow, groundwater loss, and overland flow processes are calculated based on the empirical equations. The primary parameter modules are composed of three representative modules such as PERLND, IMPLND, and RCHRES (Bicknell et al., 2001). The main functions of PERLND are the simulation of snow accumulation and melt (SNOW), the water budget (PWATER), sediment produced by land surface erosion (SEDMNT), and water quality constituents by various methods (PQUAL). IMPLND also has the following functions: simulating the retention, routing, and evaporation of water from impervious land water without infiltration and subsurface processes (IWATER), simulating the accumulation and removal of solids by runoff and other means from the impervious land segment (SOLIDS), estimating the water temperature and concentrations of dissolved oxygen and carbon dioxide in the outflow from the impervious land segment (IWYGAS), and simulating water quality constituents or pollutants in the outflows from an impervious land segment using simple relationships with water yield and/or solids (IQUAL). RCHRES module simulates the flow of water in a single reach of an open or closed channel or a completely mixed lake which is a one-dimensional fluid dynamic model (Ryu, 2009, Bicknell et al., 2001).

The HSPF model was used a lot for research and engineering practice fields, therefore there are so many simulated data and resolutions we can find in the literature: sediment transport modeling in the watershed, sediment yield simulation by typhoon events, stream water temperature modeling, herbicide transport simulation, and nutrient simulation (Bai, 2010). When the HSPF and SWAT models were applied based on the same topographic, hydrographic, land use, soil type data, and hydrologic data. The HSPF model outperformed the SWAT model for daily and monthly flow (Yanqing, 2007). The HSPF-Paddy model, a modified version of HSPF (Jeon, 2007), simulates rice paddy fields and the watershed reasonably well (Mishra, 2009). The

HSPF model was used to decide most appropriate management options for protecting the water resources from NPS pollution and minimizing nutrient losses from the agricultural fields (Ribarova, 2008). Hayashi (2004) used HSPF in order to simulate runoff and sediment load in the upper region of the Changjiang (Yangtze River) basin, HSPF is suitable for simulating runoff and sediment load over a short time interval in this research area. The HSPF model was applied to find out how watershed outflow has been affected due to the climate change (air temperature increases) at the Seydi suyu stream, Turkey. The result is that we need to consider the relationship among vegetation, evapotranspiration, stream flow et al. through HSPF model in order to cope with climate change (Albek, 2003).

HEC-HMS

HEC-HMS (Hydrologic Engineering Center Hydrologic modeling system) is capable of simulating the rainfall-runoff processes of networked watershed systems as a successor to HEC-1 and includes large river basin water supply and flood hydrology, and small urban or natural watershed runoff. There are so many kinds of functions in this model such as reservoir simulation, lateral weirs, pump stations, channel loss methods, snowmelt and improved computational speed among many others (Scharffenberg et al., 2008, Leslie et al., 2005). The capabilities and applied method of HEC-HMS watershed model are shown in Table A-2.

Table A-2: The capabilities and applied method of HEC-HMS watershed model (Source: HEC-HMS user's manual, 2009).

Division	The applied methods for simulate each mechanism	
Watershed Physical Description	elements for simulate runoff	Subbasin, reach, junction, reservoir, diversion, source and sink
	Infiltration losses	**Event model include initial constant**: SCS curve number, grided SCS curve number, exponential, Green Ampt, Smith Parlange **Simple continuous model(Gridded methods)**: the one-layer deficit constant method, the five-layer soil moisture accounting method(infiltration and evaportranspiration),
	Runoff into surface runoff	**Unit hydrograph methods**: the Clark, Snyder, and SCS techniques User-specified unit hydrograph or s-graph ordinates The modified Clark method and Kinematic Wave method
	Baseflow to subbasin outflow	The recession method of single event or multiple sequential events, the constant monthly method, the linear reservoir method, and the non linear Boussinesq method
	Open channels	**Lag methods**: routing with no attenuation **The traditional Muskingum method**: with attenuation **The modified plus method**: cascade, pool with a user-specified storage-discharge relationship **Kinematic wave or Muskingum-Cunge methods**: trapezoidal, rectangular, triangular, circular cross sections, and overbank areas Modified Plus: routing method while percolation method
	Water impoundments	**Lake**: a user-entered storage-discharge relationship **Reservoir**: simulated by describing the physical spillway and outlet structures. **Pumps**: interior flood area, collection pond etc.
Meteorology description	Precipitation	**Historical precipitation methods**: The user-specified hyetograph method, the gage weights method, the Thiessen technique, the inverse distance method (dynamic data problems), the gridded precipitation method **Synthetic precipitation methods**: The standard project storm method, the SCS hypothetical storm method,
	Potential evaportranspiration	The constant monthly method, the new Priestly Taylor method, and the gridded Priestly Taylor method. *computed using monthly average values
	Snowmelt	A temperature index method and a gridded snowmelt method
Hydrologic simulation	Control specification	A starting data and time, ending date and time, and a time interval
	Simulation run	Combining a basin model, meteorologic model, and control specifications.
	Simulation results	Global and element summary tables include information on peak flow and total flow.
Parameter estimation	Objective function	Estimating the goodness-of-fit between the computed results and observed discharge - The peak-weighted RMS error function, the sum of squared residuals function, the sum of absolute residuals function, the percent error in peak flow function, the percent error in volume function etc.
	Search methods	Minimizing objective function -The univariate gradient method, and the Nelder and Mead method
Analyzing simulation	Working with simulation runs to provide additional information or processing.	
GIS connection	Hundreds of hydrologic elements could be represented easily using a geographic information system (GIS).	

Chu (2009) suggested that the HEC-HMS model could improve the results through both events and continuous hydrologic modeling, especially for the small subbasins. Anderson et al. (2002) applied the MM5[13] model to link the Eta model precipitation forecast results to the watershed model HEC-HMS. Using this procedure, runoff predictions were also improved and result in an improved lead-time for better reservoir operations and emergency management results.

Goodell (2005) compared both the HEC-RAS and HEC-HMS models for dam break simulation of Tandem Reservoirs. Both models produced similar results of dam break simulations. However the HEC-RAS model needs more time to construct and run for simulations than the HEC-HMS model.

KINEROS2

KINEROS2 (Kinematic Runoff and Erosion Model v2) is a physically based, distributed, rainfall-runoff model describing the processes of interception, infiltration, surface runoff and erosion from small agricultural and urban watersheds in arid and semi-arid zone catchment (Aisha et al., 2008, http://www.tucson.ars.ag.gov/kineros). The model's basic structures are composed of runoff surface, rainfall excess calibration, Hortonian overland flow when rainfall rates exceed the infilterability, surface erosion and sediment transport, channel erosion and sediment transport (Woolhiser et al., 1990). The watershed for KINEROS 2 model was divided into many rectangular planes and straight-line channels which each having a specific a set of

[13] *MM5 model is that The Fifth-Generation NCAR / Penn State Mesoscale Model (MM5) is the latest in a series that developed from a mesoscale model used by Anthes at Penn State in the early 70's (http://www.mmm.ucar.edu/mm5/overview.html).*

parameters. Surface flow was simulated for all planes and the channel 1 D kinematic wave equation solved by finite-difference techniques and wave movement and depth are controlled by slope, channel geometry, Manning's coefficient (n), and two relief parameters. Interception was specified with the percentage of a plane area. The infiltration rate is the same as the rainfall rate until an infiltration limit is reached and is governed by the following parameters: Saturated hydraulic conductivity (ks), capillary length scale (g), soil porosity (Θ), and a scaling parameters (Woolhiser et al., 2000, Aisha et al., 2008, Duru, 1993).

The KINEROS2 model provides useful estimates of relative change in peak-runoff when physically-realistic values of roughness are used (Canfield et al., 2005). The dynamic and spatially distributed simulation performed well (Smith et al., 1999). KINEROS2 was used to simulate badland erosion at the Cal'lsard catchment in the Mediterranean. Generally, this model simulates with reasonable accuracy using realistic parameter values. However, in order to more accurately perform a simulation, more representation data for calibrating the watershed and relevant role of sediment sources are needed (Martinez-Carreras et al., 2006).

LSPC

LSPC (Loading Simulation Program in C++) is a comprehensive data management and watershed modeling system which includes HSPF algorithms for simulating hydrology, sediment, and general water quality on land as well as a simplified stream transport model (LSPC Users' Manual, Lu et al., 2005). LSPC is a modified version of Mining Data Analysis System developed by the U.S. EPA to deal with Total Maximum Daily Load especially for mining-related metals and pH impairments (Shen et al., 2004, Henry et al., 2002). The key design considerations are the potential for very large-scale modeling like statewide, increase efficiency of model setup and execution, simplified model output by eliminating unnecessary and repetitive user input, simplified model output, tailored for TMDL development, and highly adaptable design and program for future improvement (Johh Riverson). In addition, LSPC has the following components: a WCS (Watershed Characterization System) extension for efficient model setup, an interactive, stand-alone GIS control center, data management tools, data inventory tools, data analysis tools, a dynamic watershed model, TMDL calibration, and model result analysis (users' manual http://www.epa.gov/athens/wwqtsc/html/lspc.html).

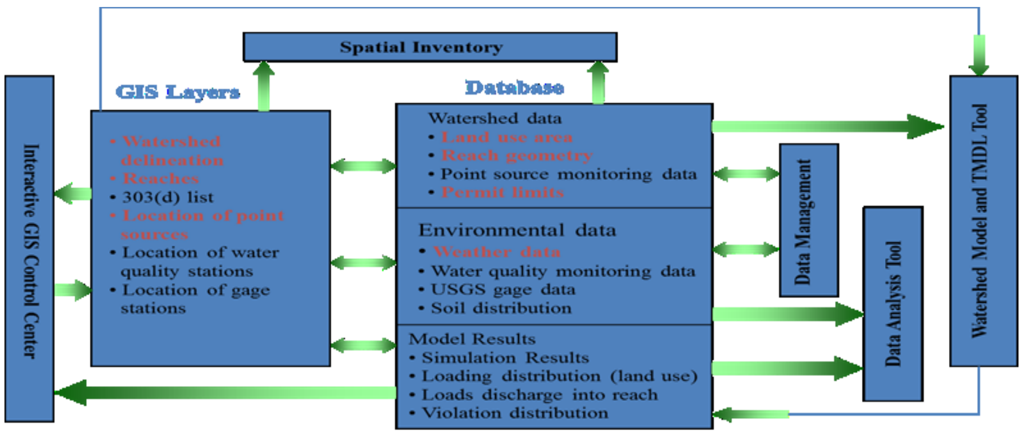

Figure A-4: LSPC (Loading Simulation Program in C++) Data Flow Schematic (Source: John Riverson).

In order to manage data and analysis (point source, simulation time, land use, weather stations etc.) through LSPC watershed modeling, data should flow according to the Figure A-4.

LSPC watershed modeling has been applied to many cases for TMDL studies and achieved successful simulation results (Shen et al., 2005 a, b; Wang, T. et al., 2005). Additionally, LSPC was linked to EFDC (Environmental Fluid Dynamics Code) for simulating the flow and pollutant loading simulation (Zou et al., 2007, Lu et al., 2005). LSPC, EFDC, WASP (Water Quality Analysis Simulation Program), three water quality models, were selected to be used in developing a Total Maximum Daily load (TMDL) for chlorophyll a (Georgia

Department of Natural Resources, 2005). Steg et al. (2008) used LSPC to simulate hydrology, salinity, and the sodium adsorption ratio (SAR) of the Tongue River.

Mercury Loading Model

Mercury Loading Model (Watershed Characterization System-Mercury Loading Model) is a distributed grid-based watershed mercury loading model which represents the spatial and temporal dynamics of mercury from both point and nonpoint sources with long-term average hydrology and sediment yield and mercury transport. This model has six major components: an ArcGIS interface for processing spatial input data, a basic hydrologic module, a sediment transport module, a mercury transport and transformation module, a spread sheet-based model post-processor, and links to other models such as WASP and WHAEM 2000 (Dai et al., 2005, Knightes). Mercury comes from atmospheric wet and dry depositions, followed by the flow of surface watr, impervious surfaces, and Hg II in the soil, respectively. And then the mercury in the water surface exports to the tributaries, impervious surface runoffs to the tributaries, and Hg II in soil runoffs and erosion to tributaries or leaching to subsurface. The schematics of the mercury mechanism are shown in Figure A-5 (Ambrose, 2005).

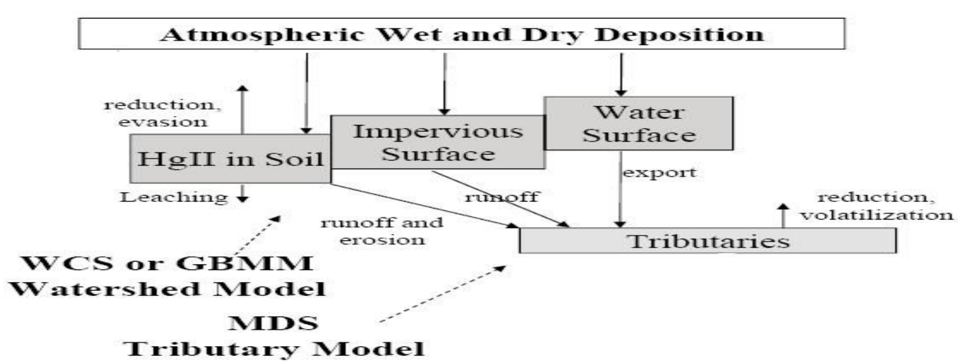

Figure A-5: Mercury's movement and available models from the watershed to tributaries (source Ambrose, 2005).

Knightes et al. used the WCS Mercury Loading model to simulate watershed loading of mercury in systems with large watershed to water surface area ratios (a farm pond, a seepage lake, a stratified lake, a drainage lake, and a coastal plain lake) for application of ecosystem scale fate and bioaccumulation to predict fish mercury response time to changes in atmospheric deposition. In addition, the WCS model was used in the middle and lower parts of the Savannah River Watershed (U.S. EPA, 2001) and in the Canoochee River Watershed (U.S. EPA, 2004) to simulate total mercury in fish tissue residue.

WCS MLM has generally been used for mercury simulations from watersheds and it is a non-dynamic annual mass-balance GIS model and provides yearly-average concentration. To supplement these deficiencies, GBMM (Gride-Based Watershed Mercury Loading Model) was developed with a daily time step concentration, user-specified grid, a simple forest and wetland transport and transformation algorithms for mercury, a bedrock weathering algorithm, a mercury reduction algorithm and a stream network pre-processor for WASP, and a link to WhAEM2000. It is a developmental model (Ambrose, 2005; Dai et al, 2005).

MIKE SHE

MIKE SHE, developed by DHI Water and Environment, is a physically based, spatially distributed hydrological model and combining four components such as overland flow (two-dimensional saint-venant equation), river flow (one-dimensional saint-venant equation), soil profile (one-dimensional Richards' equation), and ground water flow (three-dimensional Boussinesq equation) (Christiaens et al., 2001, 2002). It has the ability to model both surface and ground water dynamics in an area with large wetlands, urban areas, irrigated agricultural lands, and complex hydraulic structures (Copp, 2004). Especially, for simulating forest wetland, the unsaturated zone process which acts like a conduit for water flow is the vital role in order to couple the surface flow system to the saturated zone (CUI, 2005).

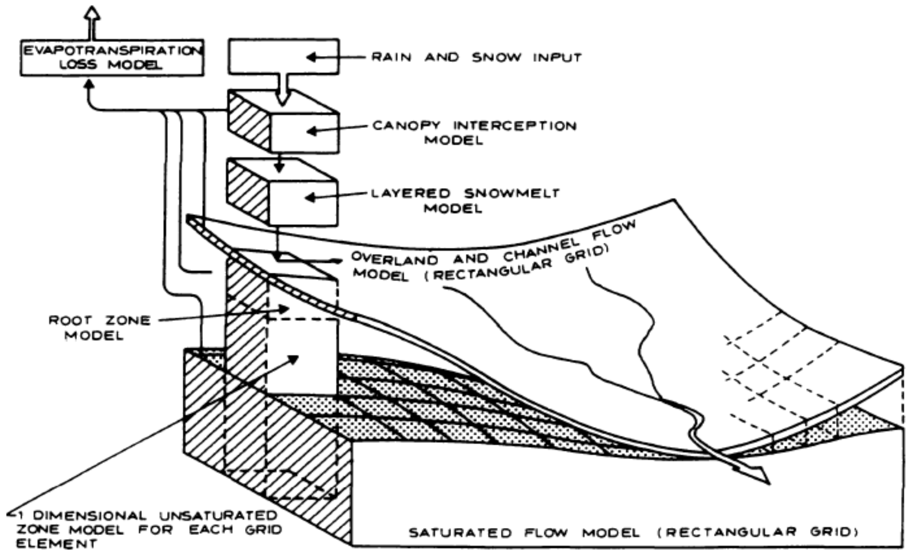

Figure A-6: Schematic Representation of MIKE SHE model (Refsgaard and Storm, 1995).

This model could link MIKE 11 to simulate channel flow which includes complex channel networks, lakes, reservoirs, and river structures (gates, sluices, and weirs) and MOUSE sewer model to simulate the interaction between urban storm water and sanitary sewer networks and groundwater (DHI, 2007).

MIKE SHE has been a widely used model for analyzing, planning, and management against water resources, environmental and ecological problems related to surface water and ground water (DHI, 2007; Leslie, 2005). MIKE SHE/MIKE 11 was used as integrated surface and ground water models for the Picayune Strand Restoration Project (PSRP) in Collier Country, Florida. This area is experiencing over-drainage due to land development projects in the 1950s and is affected by several ecological and hydrologic factors (Copp et al., 2007). Copp et al (2004) applied MIKE SHE/MIKE 11 to evaluate the effectiveness of structural measures for restoration of the wetlands in Southern Golden Gate Estates, which is a part of the Big Cypress Basin. Im et al., (2008) also applied MIKE SHE/MIKE 11 to analyze the impact of forest-to-urban land use conversion on watershed hydrology and water availability at the watershed outlet. MIKE SHE was also linked with Wetland-DNDC for carbon dynamics and greenhouse gases (GHGs) in the forest wetlands, the change in the water table was a very important point for GHGs fluxes which were based on the MIKE SHE and Wetland-DNDC linkage model (Cui, 2005). Wakool Irrigation District (74,000 ha of agricultural Land) in New South Wales, Austria had problems such as rising water table levels and land salinisation, So Demetriou et al. (1998) applied MIKE SHE for analysis of the complex hydrogeological regime in the region, the prediction of the environmental impacts of various management options, and the selection of the best options for restoration were chosen. In addition, MIKE SHE was linked to Remote Sensing derived data and GIS managed data for applying to a major irrigation project (Gupta, 2008).

MUSIC

MUSIC (Model for Urban Stormwater Improvement Conceptualization) is a decision support system which was developed by Monash University and Cooperative Research Center for Catchment Hydrology and is not a detailed design. This model could be operated based on temporal and spatial scales from 0.01km^2 to 100km^2 watershed areas and 6 minutes to 24 hours for time steps and has a user-friendly interface to provide quick and efficient simulation for complex stormwater management scenarios and the results were based on a graphical and tabular format. MUSIC was developed in order to improve and integrate the urban stormwater management measures because only models based on ad-hoc or single-focus approaches existed. Hence MUSIC has the following capabilities to manage urban catchment; (1) Conceptual Design to generate the most efficient and cost effective urban stormwater systems and integrated stormwater management plan for each catchment against a range of water quality standards, (2) Evaluation and Assessment if urban subdivision proposals and development applications are available to meet water quality objectives and urban drainage regulations, (3) System planning and Management for treatment strategies and measurement and monitoring of new and existing drainage schemes, (4) Regulation for development guidelines for the urban water management industry (Wong et al., 2002; MUSIC brochure version 4; Leslie et al., 2005).

The framework of MUSIC is shown in Figure A-7 and includes contaminant load characteristics, structural and non-structural stormwater BMP models, Stormwater management criteria, and so on.

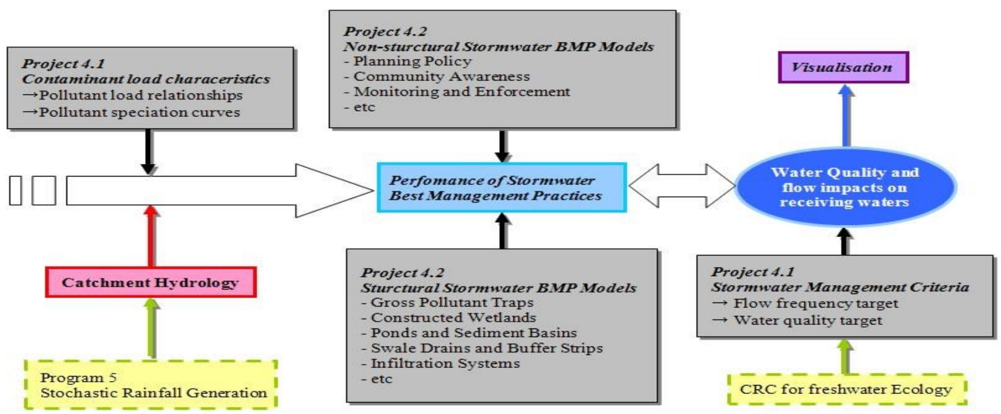

Figure A-7: Framework of the MUSIC model (Source: Wong et al., 2002)
The engine of MUSIC is the Universal Stormwater Treatment Model (USTM).

In addition, the hydraulic efficiency of stormwater treatment systems is calculated by two-dimensional hydrodynamic modeling based on λ values which is different with a number of pond or wetland shapes and depends on the inlet/outlet and length to width configuration (Persson et al., 1999; Wong et al., 2002)

MUSIC hydrology algorithm was developed by Chiew et al.(1997). It is largely two flows; one is runoff contributed from an impervious surface and the other is baseflow which is influenced by sub-surface soil moisture and groundwater level.

MUSIC was applied in an Australian city for comparing a number of options of retrofitting stormwater quality improvement measures (Wong et al., 2002).

P8-UCM

P8-UCM (Program for Predicting Polluting Particle Passage through Pits, Puddles, and Ponds-Urban Catchment Model) is a hydrologic and BMP model for predicting the generation and transport of stormwater runoff pollutants in urban watersheds (Leslie et al., 2005, Tetra Tech, Inc., 2007) and is simulated by continuous water-balance and mass-balance through a user-defined system. There are four components of P8; watersheds, devices (runoff storage, treatment areas, BMP's), particle classes, and water quality components which are simulated by hourly rainfall and daily air temperature time series data (William, 1990, Tetra Tech, Inc., 2005).

In order to simulate the P8-UCM model, site-specific input data which are familiar to local engineers and planners and initial calibration of certain water-quality parameters such as particle settling velocities, particle build up/wash off, and particle contaminant contents are needed and it simulates a variety of treatment device including swales, buffer strips, detention ponds (dry, wet, extended), flow splitters, infiltration basins (offline, online) (William, 1990). The following figure (Figure A-8) shows the simple P8-UCM set up.

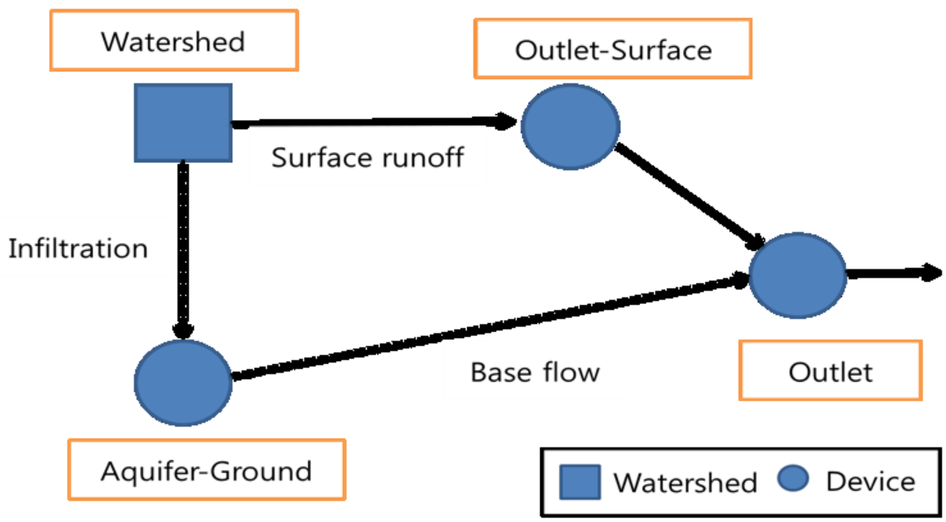

Figure A-8: Simple P8-UCM set up (Source: Tetra Tech, Inc., 2005).

Numerous Vermont watersheds did not meet Vermont's aquatic life standards because of the urban drainage and suburban storm runoff, so Four models (GWLF, SLAMM, P8-UCM, SWMM) were used to investigate the project needs, data availability, and the level of effort required for model implementation. SWMM and P8-UCM achieved the highest ranks but when comparing calibrations, developing flow duration curves, and many urban pollutants as well as urban BMP, P8-UCM was chosen as the best model for Vermont's watersheds and is suitable to simulate both event based and long-term hydrological simulations for relative variability among watersheds and drainage areas (Tetra Tech inc., 2005b).

P8-UCM was used for evaluating the amount of groundwater recharging when diverting to an infiltration-type BMP from completely impervious drainage (100% impervious) (Tetra Tech. Inc., 2007).

PCSWMM

PCSWMM (Storm Water Management Model) is a commercial software package with the computational engine of the U.S. EPA's Software Water Management Model version 5 (EPA SWMM 5) and a graphical interface of SWMM to simulate runoff and hydraulics in pipe networks having the capacity to create a storm sewer network and massive database management with relative ease (Sands et al., 2004, nhc, 2010)

A spatially-distributed rainfall method was applied to simulate rainfall and non-linear reservoir routing, subcatchment to subcatchment routing, triangular unit hydrograph, groundwater interflow, and inflow from other hydrologic models were used for runoff simulation. Especially, time-varying rainfall, for the non-linear reservoir routing of overland flow, rainfall interception from depression storage, evaporation of standing surface water, snow accumulation and melting, infiltration of rainfall into unsaturated soil layers (Horton, Green-Ampt, and SCS curve number), percolation of infiltrated water into groundwater layers, interflow between groundwater and the drainage system, and overland sheet flow (Manning's formula) were included in this model. There were three routing runoff methods used (dynamic wave routing, kinematic wave routing, steady-state routing), RDII, DWF, and external inflows through the pipes, channels, storage/treatment units and diversion structures which is includes the following abilities: handle networks of unlimited size, use a wide variety of standardized closed and open conduit shapes as well as natural channels, model special elements such as storage/treatment units, flow dividers, pumps, weirs, and orifices, apply external flows and water quality inputs from surface runoff, groundwater interflow, compute rainfall dependent infiltration/inflow (RDII), dry weather sanitary flow (DWF), and user-defined inflow, utilize either kinematic water or full dynamic water flow routing methods, model various flow regimes, such as backwater, surcharging, reverse flow, and surface ponding, and apply priority-based, dynamic control rules to simulate the operation of pumps, orifice openings, and weir crest levels (PCSWMM Brochure, www.chiwater.com/software/PCSWMM.NET).

PCSWMM contains a genetic algorithm (GA)-based software tool for the calibration of the Storm Water Management Model (SWMM). Through this GA calibration tool, the effort for general calibration and design optimization was significantly reduced (James, 2002). In addition, PCSWMM's genetic algorithm routine could examine the best management practices such as infiltration, detention, and retention systems and select the best combination of urban stormwater infrastructure and their sizes. James (2003) compared several different BMPs (Best Management Practices) with PCSWMM's genetic algorithm against several constraints, for instance, local quantity and quality regulations, sewer capacities, not exceeding predevelopment flow rates and could systematically decrease the total drainage cost.

Heier et al. (2003) used PCSWMM for predicting the sediment yield changes between the pre-construction and construction period of an 18-hole champion golf course which is located near Manhattan, Kansas, on the Little Kitten Creek watershed. PCSWMM was used for the establishment of an integrated watershed management plan for the Mokgamcheon watershed in South Korea (Hong, 2008).

PGC-BMP

PGC-BMP (Prince George's County Best Management Practice Module), BMP ToolBox model, was developed by Tetra Tech and Prince George's County in Maryland, USA, in order to evaluate BMP applications before and after the development and effectiveness of structural BMP (Tetra Tech, 2003). BMP could be classified based on the structural mechanisms which are divided into classes A and B: class A (retention, interception, and vegetation), class B (open channel units, infiltration, and filtration) which is shown at Figure A-9.

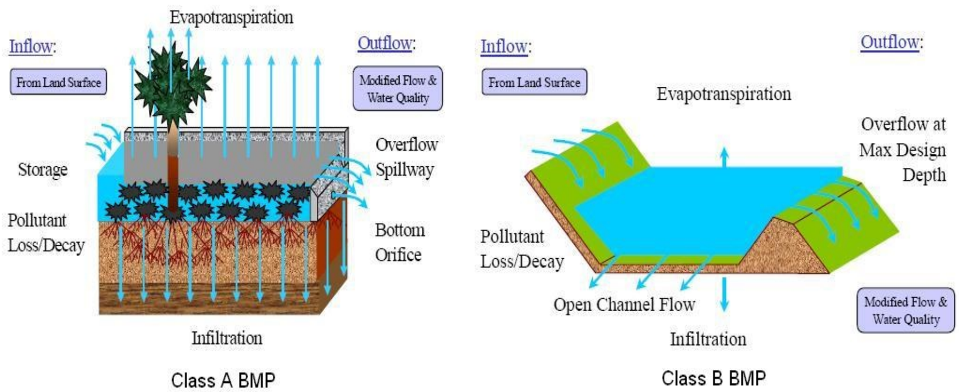

Figure A-9: BMP types of BMP Toolbox model (Cheng et al., 2004, 2009).

The PGC-BMP module could evaluate detention basins, infiltration trenches, dry wells, porous pavement, wetlands, swale, filter strips, bioretention, etc., and the treatment processes are composed of several mechanisms like storage, infiltration, overflow/outlet flow, decay process, and soil media pollutant removal as well. The algorithms of this module used the following methods: Storage routing, Holtan's equation, weir/orifice, and first-order decay and the water quality were applied by user-defined pollutants (Riverson, 2004).

Chen et al. (2010) applied the BMP ToolBox model to the study site of Feitsui reservoir watershed (total treatment area is 2,953 m^2, and the total hydraulic retention time was 5.24 days), the Feitsui reservoir was in a mesotrophic status due to nonpoint source pollution. Lately, BMPDSS (BMP Decision Support System) has been used. It is a state of art decision supporting system for placing BMPs at strategic locations in urban watersheds on the basis of integrated data collection and hydrologic, hydraulic, and water quality modeling. And this system could compare the trade-off relationship between BMP costs and excavation volume (Cheng et al., 2009, Zhen et al., 2010).

SHETRAN

SHETRAN (Système Hydrologique Europeén TRANsport) is a 3D coupled surface/subsurface PBSD (Physically Based Spatially Distributed) finite-difference model for coupled water flow, multi fraction sediment transport, and multiple, reactive solute transport in river basins. There are three major components in this model: water flow, sediment transport, and solute transport. They are not affected by each other, as the three components depend on the natural situation. SHETRAN is capable of integrating flow and transport of both surface and subsurface with major hydrological cycle factors such as interception, evapotranspiration, snowmelt, overland and channel flow, unsaturated and saturated zone flow (Ewen et al., 2000, Lukey et al., 2000)

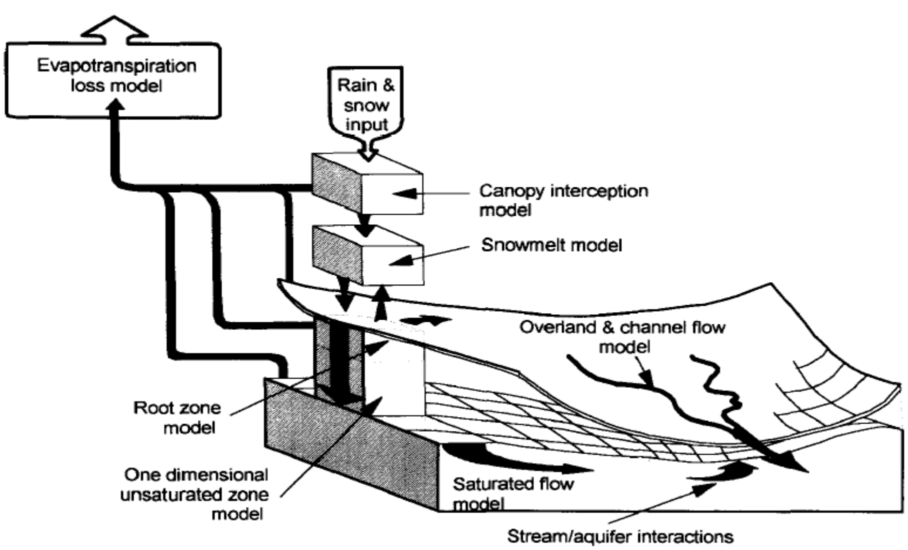

Figure A-10: Flow schematic diagram of SHETRAN model (Source: Dunn et al., 1996).

SHETRAN could be suitable to simulate the flow processes in Karst aquifers allowing both surface and subsurface processes to be modeled. Adams et al. (2002) applied the VSS (A Variably Saturated Subsurface) – NET to the SHETRAN model for the Karst aquifers' simulation. Dunn et al. (1996) implemented the SHETRAN model to simulate the hydrological impact of open ditch drainage and the most import processes according to the results of the simulation are the sub-surface and under near saturated conditions, interaction between sub-surface and stream network, and the speed of the surface runoff. In addition, Dunn et al., (1995) assessed how variations such as climate and land use in evaportranspiration affect the hydrology of a region in the Tyne Basin in North East England through the SHETRAN model as well.

The SHETRAN model is like physically based, spatially distributed models which have been criticized and the model parameterizations have to be validated and incorporated with internal response data and demonstration of a model's fitness, so Bathurst et al (2004) tested several scenarios to validate the SHETRAN model for predicting land-use and climate change impacts at the Slapton Wood catchment (there have been many researches implemented to simulate water flow and water quality because it is a complicated catchment with a combination of various land cover) in Southwest England. SHETRAN was also used to find the depth of subsurface flow at the Slapton Wood catchment (Birkinshaw et al., 2010). Birkinshaw et al. (2000) used the SHETRAN model to simulate nitrate transport at the Slapton Wood catchment and this model can also simulate the landslide erosion and sediment transport, Burton et al. (1998) applied SHETRAN at the Kirton research catchment in Balquhidder, Scotland to simulate shallow landslide erosion and sediment yield components.

SLAMM

SLAMM (Source Loading and Management Model) was developed to enhance the understanding of the relationship between sources of urban runoff pollutants and runoff quality and is an urban rainfall runoff water quality model which does not deal with agricultural areas, etc. It is a multi-scale model controlled from individual lots to whole communities. This model includes many source areas and outfall control practices such as infiltration practices, wet detention ponds, porous pavement, street cleaning, catchment cleaning, grass swales (Pitt et al., 2002). Land use could be classified for up to 6 different land uses, 14 source area types and it is permitted to simulate additional sub-areas or different management scenarios. Runoff volumes and urban pollutant loadings could be calculated annually as well as seasonal pollutant loads and event pollutant probability distributions using long-term rainfall records (Source: SLAMM)

SLAMM considers many kind sources of pollutions and simulate the urban area's flow routing like in Figure A-11. From unconnected sources to directly connected impervious areas, gutters, sewerage systems, and receiving water each have their own characteristics and removal system which can be applied to compose SLAMM (Pitt et al., 2000).

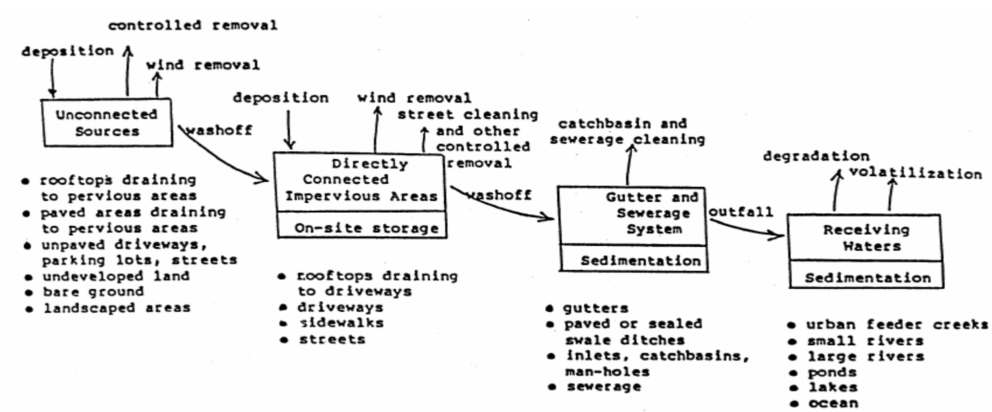

Figure A-11: The mechanism of pollutant deposition and removal at sources areas for SLAMM (Source: Pitt et al., 2000).

Another unique characteristic of the SLAMM model is the wash-off model which can predict the losses of suspended solids from different surfaces based on an individual first-flush (exponential) relationship (Pitt et al., 2002).

WinSLAMM could use as a decision analysis program for finding out the best alternatives before starting urbanization plans. Pitt et al.(a) and Pitt et al. (2007) applied WinSLAMM as a systematic procedure for trade-offs among multiple and usually conflicting program objectives by comparing both the costs and effectiveness.

SLAMM was used as a planning tool for BMP implementation. Furthermore, this model includes a cost analysis tool in order to compare the costs for different BMP as well (Kabbes et al, 2008). And Neilson et al. (2010) used SCS based WinSLAMM modeling for green infrastructure sizing, water quality treatment, and to input the following various parameters in order to achieve the best predictions.

SPARROW

SPARROW (SPAtially Referenced Regression On Watershed attributes) is a watershed modeled used to set up mathematical relationships between water quality measurements and the attributes of watersheds. SPARROW is a statistically calibrated regression model composed of both mechanistic components and mass-balance constraints and there are two main functions; one is the empirical rate of nutrient delivery from point and diffused sources to streams, lakes, and watershed outlets. The other is the spatial referencing of stream monitoring stations, nutrient sources, and the climatic and hydrogeologic properties of catchments based on the landscape and surface-water features (Schwarz et al., 2006, Alexander et al., 2004). The model structure, including the two main functions that were just mentioned, are shown in Figure A-12 and demonstrates the functional linkage between the major spatial components of the SPARROW model. Sparrow is mainly composed of two steps, like two main functions. First is the pre-processing step for getting reach-level information and the second is the monitoring of station flux estimations for estimating the long-term flux.

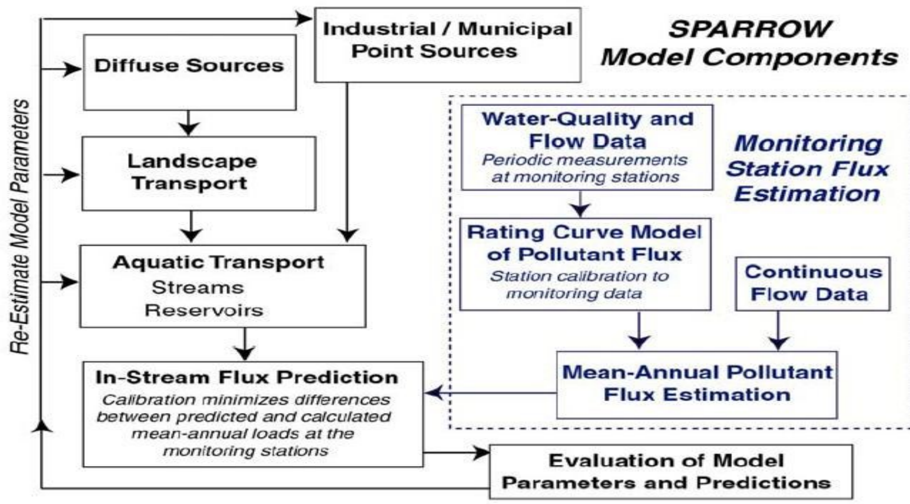

Figure A-12: Schematics of the major SPARROW model components (Source: Schwarz et al., 2006).

The following two components could display the contaminant load or flux leaving a reach: load generated within upstream reaches and transported to the reach via the stream network and load originating within the reach's incremental watershed and delivered to the reach segment. Based on the two components, the formula is shown in the below in Equation 14 (Goodall et al., 2010)

$$L_i = \sum_{n=1}^{N} \sum_{j \in J(i)} S_{n,j} D(Z_j) K(T_{ij}) \qquad \text{Equation A-2}$$

Where, Li = the mass loading of reach i, measured in metric tons; n, N= source index where N is the total number of individual n sources; J(i)= set of all reaches upstream and includes reach I, except reaches at or above the monitoring stations upstream from reach i; Sn,j= transported to downstream reach i according to the two nonlinear processes; D(Zj)= first process;

transported load from the land surface to the stream which is a function of the watershed properties for reach j; K(Tij)= second process; instream transport from reach j to reach i which is a function of the flow path properties between i and j.

The SPARROW model has a hybrid-statistical-process structure and deals with pure statistical and regression-based models by combining nutrient transport components like flow paths, first-order loss functions, and mass-balance constraints and reduces problems related to the data interpretation caused by sparse stream sampling measurement networks, network sampling biases and basin heterogeneity (Alexander et al., 2002a, 2004, Robert et al., 2010, Smith et al., 1997, 2003).

Goodall et al. (2010) used the SPARROW model for the Upper Neuse River Basin to answer the following questions: First, how much load is provided by a unit area? Second, what portion of the incremental load from each watershed is transported to the river basin outlet? Third, how would a 10% increase in fertilizer application impact loading at the watershed outlet? Through solving these problems with the SPARROW model, it proves detains about which subwatersheds are potential pollution areas. Brakebill et al. (2003) improved the hydrologic network system according to the application of the 30 m DEM (Digital Elevation Models) from the 1 km DEM. Alexander (2002) compared the six nitrogen export models (SPARROW, LS1-GLOBAL, LS2-GLOBAL, GLOBAL, PEIERLS, HOWARTH) to find out the accuracy (bias and precision) of each model. The resolution showed that 5 models, except the SPARROW model, had significantly negative correlations between prediction errors and runoff and suggested the improvement of the ability by combining both the mechanistic description of process in the deterministic model and the statistical model. The SPARROW model is good at applying the TMDL (Total Maximum Daily Load) program. McMahon et al. (2002) applied the SPARROW model to TMDL for Eastern North Carolina- Cape Fear, Neuse, and Tar-Pamlico.

Alexander et al. (2008) also applied the SPARROW model to find out the differences both phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. In addition, Alexander et al. (2006) estimated TN and TP's trends from 1975 to 1994 in the United States through the SPARROW model

STORM

STORM (Storage, Treatment, Overflow, Runoff Model) was developed by the Hydrologic Engineering Center (HEC) in the early 1970's (Deliman, 1999, Abbott, 1997). This model provides predictions of wet-weather pollutographs (Mass Loading curves for use in a receiving water assessment model) and preliminary sizing of storage and treatment facilities to satisfy the desired criteria for control of stormwater runoff. STORM considers seven storm water elements which are shown in Figure A-13: rainfall/snowmelt, runoff, dry weather flow, pollutant accumulation and wash off, land surface erosion, treatment rates, and detention reservoir storage. The following are the four major steps: the first is the computation of runoff quantity, the second is the computation of runoff quality, the third is the computation of treatment, storage, and overflow, and the last is the computation of land surface erosion. For the computation of the quantity of runoff, the coefficient method, the U.S. Soil Conservation Service Curve Number technique or combination method (the coefficient method for impervious land and SCS for pervious land) were used. For the quality of runoff, the dust and dirt method (assumes that all pollutants are associated with the dust and dirt accumulation in the street) and the daily pollutant accumulation (mainly non-urban areas) were used.

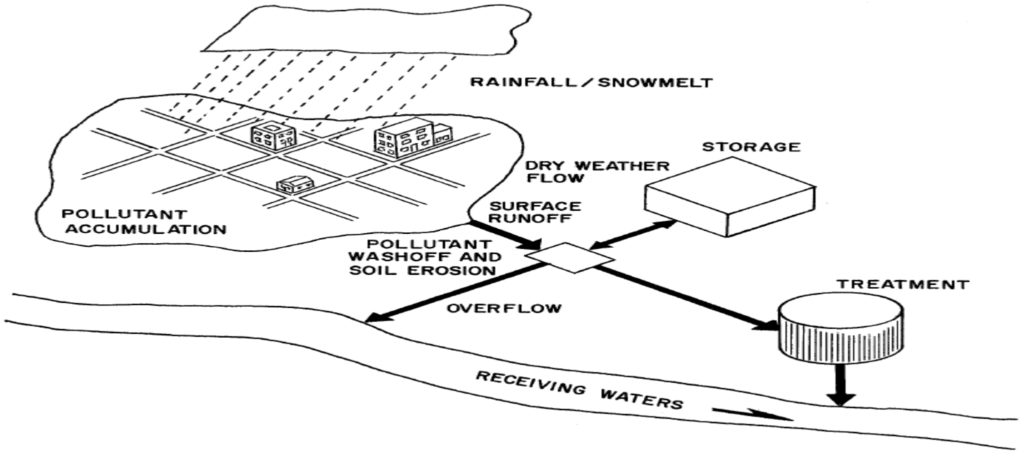

Figure A-13: The schematics of STORM model's flow mechanism (U.S. ACE, 1997).

Heineman (2005) used NetSTORM and STORM DLL (dynamic-link library file) to show the capabilities of cost optimization and detention pond sizing's determination. Baerenklaus et al (2008) also used STORM for estimating the costs for land, construction, maintenance expenses, and rehabilitation costs. When compared between decentralized and centralized BMPs (Best Management Practices), decentralized BMP's costs were much less than centralized BMPs because the latter needs additional fees to obtain BMP's land.

Najjar et al. (1995) researched the water quality model at the Lakes Bay Estuarine Embayment (Lake: surface area, 8.90 X 106 m^2, average depth, 1.5 m, volume, 13.2 and Drainage area: 16.2 X 106 m^2) to develop a mathematical model for estimating the expected pollutant loading, to simulate water quality of tidal embayment systems, to perform field studies for the collection of data to calibrate and refine, and to calibrate and verify the model for creating a useful management tool for limited land use situations. Warwick et al. (1990) used Monte Carlo simulation techniques to ascertain in probable ranges of STORM water quality predictions in regards to both water quantity and quality input parameter uncertainties (BOD_5, TSS, Orthophosphate, T-N) because there was not enough water quality data in the research areas.

SWAT

SWAT (Soil and Water Assessment Tool) was developed by USDA Agricultural Research Service (ARS) and is mainly adapted as parts of the U.S. EPA BASINS (Better Assessment Science Integrating Point and Non-point Sources). SWAT has grown as a multidiscipline model and includes following models: GLEAMS for pesticide components, GREAMS for daily rainfall hydrology components, EPIC for crop growth components, SWRRB for multiple subbasins and other components, Qual2E for instream kinetics, and ROTO for routing structures. The schematic of SWAT's development is shown in Figure A-14 (Gassman et al., 2007).

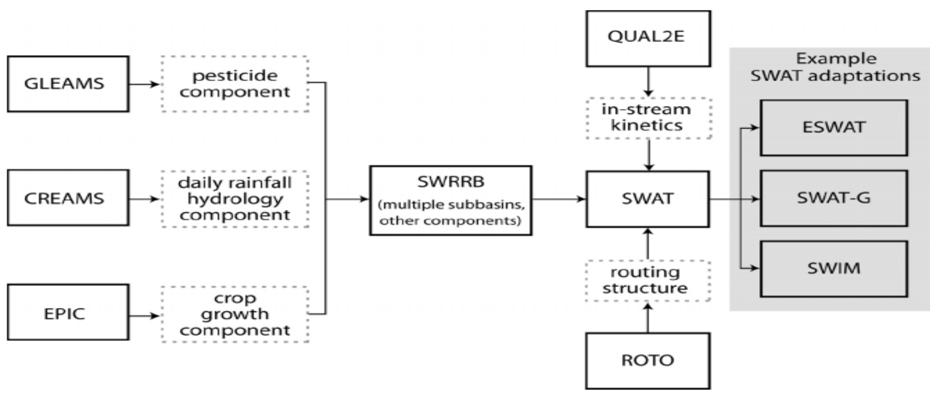

Figure A-14: The Schematic of SWAT's development (Source: Gassman et al, 2007).

Rainfall may be intercepted and held in a vegetation canopy or fall to the soil surface and then infiltrated, interflowed and runoff through aquifer and surface. The potential pathway of water from precipitation to stream flow including irrigation, surface runoff, aquifer, etc., is shown in Figure A-15 (Neitsch et al., 2005).

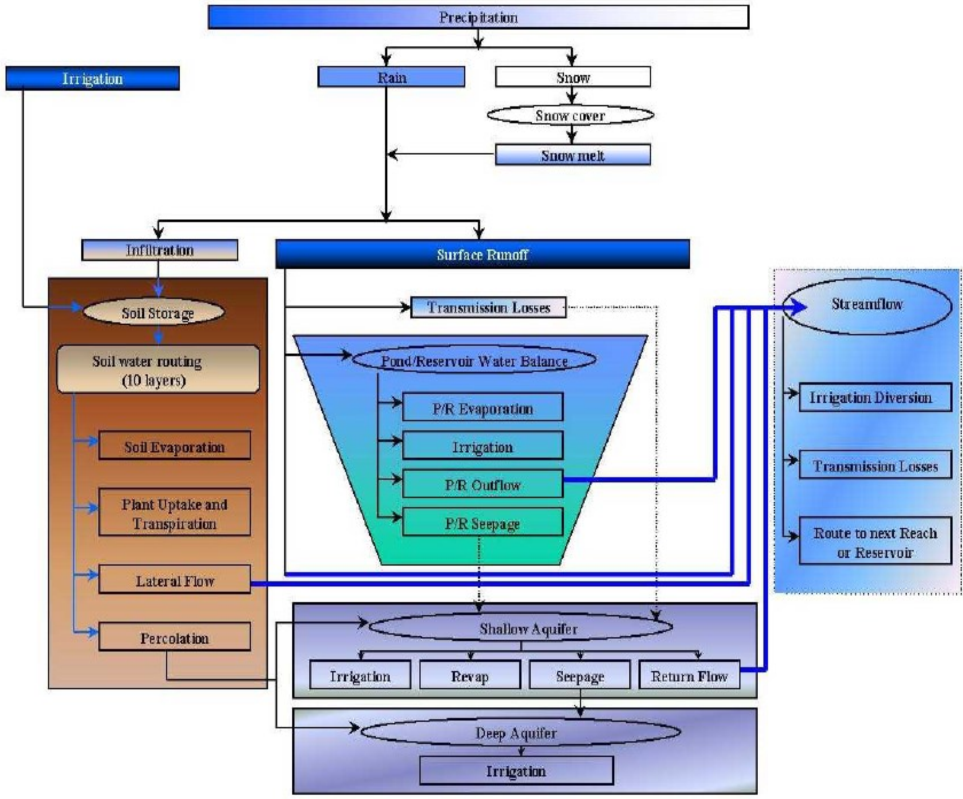

Figure A-15: The Schematic of a potential water pathway of the SWAT model (Neitsch et al., 2005).

In this model, the watershed could be divided into a number of subwatersheds or subbasins which are grouped depending on climate, HRU, ponds, groundwater and main channels.

SWAT and AnnAGNPS were compared by Heathman et al. (2008) to apply uncalibrated (for eliminating bias due to parameter optimization) to the Cedar Creek watershed within the St. Joseph River watershed in northeastern Indiana to predict streamflow and atrazine losses. As a result, the SWAT model's performance was remarkably superior to AnnAGNPS in estimating streamflow.

Fitz Hugh et al. (2001) used the SWAT model to compare the impaction of subwatershed partitioning on modeled sources and transport-limited[14] sediment yield with other factors such as slope gradient, slope length, and HRU (Hydrologic response units) area. In addition, in order to delineate subwatershed moderately, Gong et al. (2010) analyzed the parameter uncertainty of subwatersheds with the newly developed sequential uncertainty fitting version-2 (SUFI-2) procedure to supplement any shortcomings in existing parameter uncertainty analysis method (sensitivity analysis, first-order error analysis, and the Monte Carlo method).

SWAT was also used for estimating the comprehensive and economically viable solutions of the P reduction from dairy agriculture near the Cannonsville Reservoir by Ghebremichael et al. (2008). Ullrich et al. (2009) applied the SWAT model to predict the impact of alternative management practices on water quality and quantity in the state of Saxony in Central Germany has a drainage are of about 315km^2. This was the first time research for a sensitivity analysis for conservation management parameters such as tillage depth, mechanical soil mixing efficiency, biological soil mixing efficiency, curve numbers, Manning's roughness coefficient for overland flow,

SWMM

SWMM (Storm Water Management Model) is a dynamic rainfall-runoff simulation model for water quality and quantity and is used primarily for urban areas. This model could be used for single events or long-term (continuous) simulations. SWMM was developed by the U.S. Environmental Protection Agency from 1969-71 and Camp Dresser & McKee Inc. are

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[14] **Source-limited watershed**: more material can be transported away than can be detached
Transport-limited watershed: more material can be detached than can be carried away by way of transport processes.

researching and controlling the SWMM model presently. The purposes of this model are for planning, analysis and design of urban watersheds, including rainfall-runoff, flow routing, water quality, storage/treatment, and sewer-systems, especially flow routing of an urban watershed as it transports through a system of pipes, channels, storage/treatment devices, pumps and regulators (Rossman, 2010, Huber, 2003).

SWMM has a variety of capabilities for urban areas, including various hydrologic processes as follows: time-varying rainfall, evaporation of standing surface water, snow accumulation and melting, rainfall interception from depression storage, infiltration of rainfall into unsaturated soil layers, percolation of infiltrated water into groundwater layers, interflow between groundwater and the drainage system, nonlinear reservoir routing of overland flow, and capture and retention of rainfall/runoff with various types of low impact development (LID) practices (Rossman, 2010).

The SWMM model simulates the hydrology, hydraulics, and water quality transport behavior of a drainage system as shown in Figure A-16.

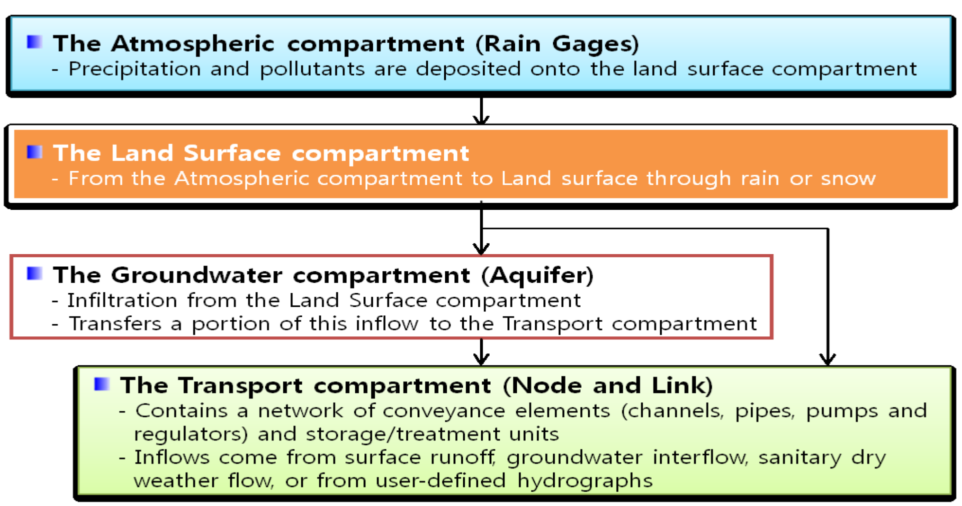

Figure A-16: The SWMM model's Schematic (Source: Rossman, 2010).

The SWMM model simulates LID (Low Impact Development) units such as bio-retention cells, porous pavement, infiltration trenches, rain barrels, and vegetation swale. In detail, each layer (surface, pavement, soil, storage, underdrain) could be used separately based on the different types of LID.

The SWMM model was used for integrating the collection systems for Hartford, Connecticut (Heineman et al., 2010). Originally, the Hartford Water Pollution Control Facility controlled individual collection systems such as combined sewers, sanitary sewers, storm drains, and open channel drainage. After integrating the collection systems, it is easy to access, modify and upgrade the drainage system in regards to items such as CSO estimations and long term control plans, sanitary sewer overflow, etc. Jawdy et al. (2010) used the SWMM model to analyze the effects of Green Infrastructure (GI) practices for reducing combined sewer overflows in Nashville, Tennessee. 103 prototype models including bio-retention cells, pervious pavements, green roofs and tree planters having a various media depths, ratio of run-on areas to facility areas, deep percolation rates, media and plantings were run and evaluated for the volume of runoff. Alfredo et al. (2010) also researched the hydrologic performance of green roofs under variable precipitation conditions: steady, low-intensity rainfall and short duration, and high-intensity rainfall. Green roofs were installed with both control membrane roofs and prototype green roofs (2.5, 6.3, 10.1 cm depth). Roehr et al. (2010) also used the SWMM model to simulate runoff generated by impervious roofs and green roofs by integrating the Green-Ampt method and evapotranspiration of green roofs because the Green-Ampt method cannot accurately simulate green roof runoff. Lucas (2010) designed integrated bioinfiltration-detention urban retrofits (a bioretention planter/trench infiltration-detention system) with the SWMM model. McCutcheon et al. (2010) tried to make an exfiltration modified SWMM source code to allow the simulation of the storm hydrograph for controlled partial exfiltration from the sewers. Moreover, the SWMM model was used to estimate the distribution of particulate-bound metals for source area snow in the Lake Tahoe watershed (Magill et al., 2010).

TOPMODEL

TOPMODEL is a semi-distributed variable contributing area hydrological model (rainfall-runoff model) which provides distributed predictions of catchment response to rainfall based on the a simple theory of hydrological similarities of points in a catchment with the topographic index ln (α/tan β), where α is the area of the hillslope per unit contour length that drains through the given point, used as the index for hydrological similarities. This model used simple parameters because it has a simple structure, so there are several basin model assumptions which are as followings; 1. Dynamics of the saturated zone can be approximated by successive steady-state representations, 2. Hydraulic gradient of the saturated zone can be approximated by the local surface topographic slope, tan β; groundwater table and saturated flow are parallel to the local surface slope, 3. Distribution of downslope transmissivity with depth is an exponential function of storage deficit or depth to the water table. Based on these assumptions, a correlation could be found between the catchment mean water table (storage deficit) and local water table level (storage deficit) (Wu et al., 2007, Gallart et al., 2007, Candela et al., 2005, Xiong et al., 2004, Holko et al., 1997).

Major hydrologic behaviors of the TOPMODEL are precipitation (snow and rain), infiltration, snowmelt, and evaporation which were shown in Figure A-17. And the parameter's mechanism is simply divided into topography, saturated store, root zone and unsaturated store, and flow routing.

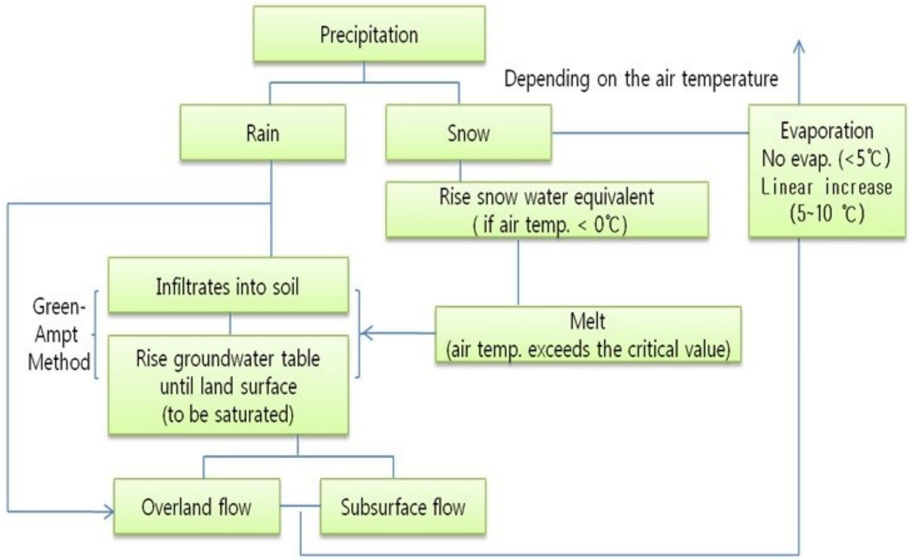

Figure A-17: Hydrological behavior of the catchment in TOPMODEL (Source: Holko et al, 1997).

TOPMODEL is significantly sensitive to the scale of topography including the terrain attributes. Especially, grid sizes could be compared to determine the impaction using TOPMODEL. According to the Brasington et al., (1998) research, 100 ~ 200m grid size is the range in which rapid deterioration occurs in the information content of the DEM. The scale of topography should be investigated based on the watershed's characteristics. Cameron et al. (1999) researched the possibility of deriving frequency distributions of extreme discharge by continuous simulation through the rainfall-runoff model TOPMODEL is implemented by GLUE (Generalized Likelihood Uncertainty Estimation). Xiong et al. (2004) used TOPMODEL to simulate the relationship between rainfall and runoff based on a variety runoff coefficients from 0.333 to 0.733 during flood seasons in the semi-arid Yihe catchment (2,623km^2) in the Yellow River basin of China.

TOPMODEL had limitations when applied to semi-arid catchments, because the way in which semi-arid catchment's land is used is totally different with general catchments. So Candela et al. (2005) applied to modify the TOPMODEL routing algorithms to consider different patterns of routing between hillslope & channel even though TOPMODEL is applied to a semi-arid area. In order to adapt the semiarid characteristics, surface roughness was applied based on the routing velocity for each pixel of the watershed linked to the watershed land use which is through the different roughness derived on the basis of Engman's table (Engman, 1986).

TOPMODEL has generally been considered a simplified model of the saturated zone so far. However in order to complete a continuous simulation model, it needs more component mechanisms such as interception, snow accumulation and melt, infiltration, evapotranspiration, the unsaturated zone and flow routing (Beven, 1997).

WAM*View*

WAM*View* (Watershed Assessment Model with an ArcView Interface) is a process-based model with GIS (Geographic Information System) interface to simulate watershed hydrologic and pollutant transport. This model includes the following features: ① Source cell mapping of TSS and nutrient surface and groundwater loads, ② Flow/constituent transport modeling of land source areas on a spatial scale/grid of 1ha or less, ③ Unique cell recognition for faster run times, ④ Tabular ranking of land uses by constituent contributions, ⑤ Overland, wetland, and stream load attenuation mapped back to source cells, ⑥ Optional Index Model for Toxins, BOD, and bacteria for source mapping, ⑦ Hydrodynamic stream routing of flow and constituents (N, P, BOD, Dissolved Oxygen, Chlorophyll-A if WASP Linkage is used) with annual, daily, or hourly outputs, ⑧ Optional Index Model for Toxins, BOD, and bacteria for source mapping, ⑨ Ground water flow modeling with well withdrawals and surface/groundwater interactions, ⑩ Allows time series of point source inflows and wastewater treatment plant service area coverage used to determine on-site septic usage, ⑪ Available to link with WASP6 to simulate in-stream DO, chlorophyll A, N, P, and BOD, ⑫ Wetland indexing model for wildlife diversity impacts, ⑬ Flood proneness model, ⑭ User interface to run and edit land use and BMP scenarios (Bottcher and Hiscock, Bottcher, 2003).

The loads and flows from each cell are distributed by BUCSHELL (the Basin Unique Cell Shell program) between runoff and groundwater percolation. WAM will follow the distance that surface flow travels over an upland use type, until it enters a reach, wetland, or depression. As can be seen in Figure A-18, WAM will track the distance that surface flow travels over an upland land use type, until it enters a reach, wetland or depression (WAM documentation from www.swet.com).

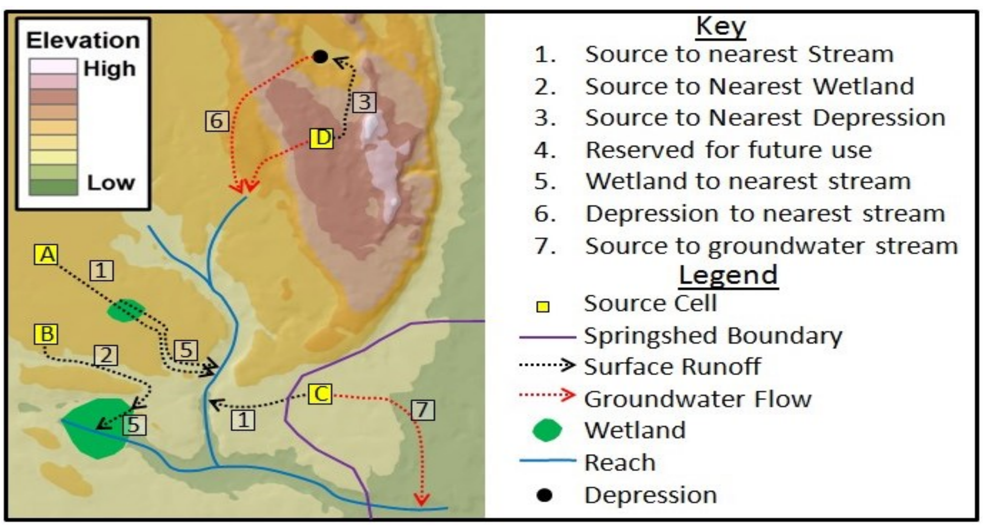

Figure A-18: The distance grid creation of flow and load generation.

Bottcher et al., used WAMView to simulate modified land use scenarios and compare the results side-by-side with the results of the existing land use over 30,000km^2 of northern Florida and New Zealand. WAM provides an excellent tool for regional planners to determine and rank current areas under environmental stress, estimate future impacts of land use management decisions, determine achievable pollution load reduction goals and establish Total Maximum Daily Loads (TMDLs). Bottcher et al. (2003) also simulated flow and water quality constituents for several Florida watersheds in terms of Florida's TMDL program and other watershed restoration projects. The WAM model has been successfully applied to multiple basins within Florida for the development of TMDLs and for alternative assessments to meet the flow and water quality goals of impaired water bodies.

Lake Okeechobee is a large, shallow freshwater lake located in southern Florida. In an effort to reduce phosphorus loads, phosphorus loading to Lake Okeechobee was set to be reduced by 40% through the 1987 Surface Water Improvement and Management (SWIM) Act. So WAM was applied to determine the detention volume (water detention depth) depending upon typical land uses such as abandoned dairies, citrus groves, daily pastures, field crops, improved/unimproved/woodland pastures, row crops, and other land uses (Zhang et al., 2005). Zhang et al. (2006) also studied about the detention depth of Buck Island Ranch which is located at the MacArthur Agro-ecology Research Center, near Lake Placid, Florida.

WARMF

WARMF (Watershed Analysis Risk Management Framework) is a watershed model and analysis tool with short and long term predictions capabilities. WARMF has a variety of functions such as the ability to calculate TMDL, evaluate water quality management for a river basin, simulating flow, water quality constituents (Temp, TSS, Coliform, Bacteria), BOD, DO, nutrients (phosphorus & nitrogen species), and Chlorophyll. In addition, decision support capabilities, sensitivities and uncertainties, and analyses of WARMF projects have been studied continuously by EPRI (the Electric Power Research Institute). This model has five integrated modules such as Engineering, Consensus, TMDL, Data, and Knowledge: the Engineering module performs hydrologic and water quality simulations using data files from the DATA module and contains a dynamic watershed simulation model. It calculates daily surface runoff, groundwater flow, non-point source loads, hydrology, water quality of river segments, and stratified reservoirs. Watersheds are divided into a network of land catchments, river segments, and reservoir layers. In order to promote the water routing from land, land catchments are classified by land surface (land use and cover) and soil layer (air, water, and solid fractions) which are shown in Figure A-19. The TMDL module is a decision module based on a step-by-step procedure and can decide multiple possible solutions for a TMDL. The consensus module guides stakeholders to select a preferable TMDL which takes into consideration the following factors: costs, pollution trading, social and political factors (Keller, 2007, Chen et al., 2004, 2000 A, B).

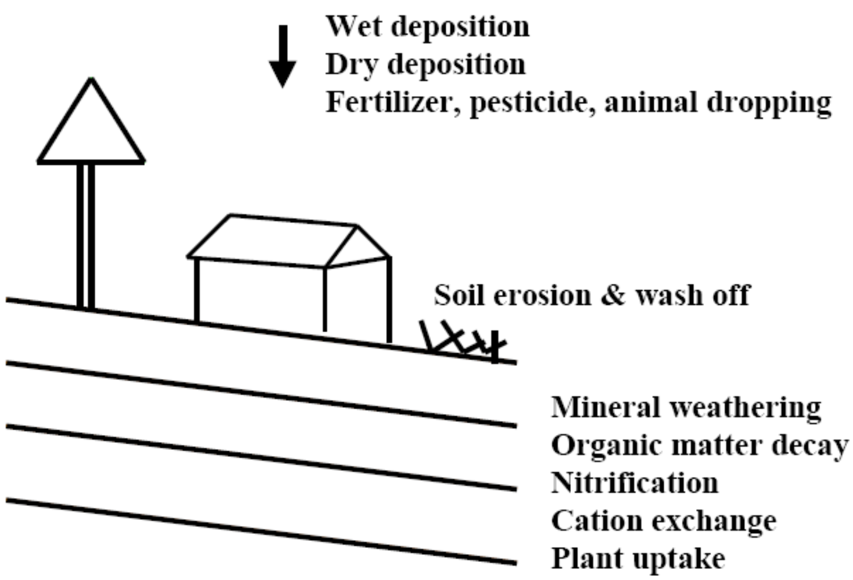

Figure A-19: Components of land catchments (Chen et al., 2000).

WARMF was used to investigate the impact of a thermal power plant on the phosphorus TMDL of a reservoir (Chen et al., 2000B). Chen et al., (2005) applied the WARMF model to a forest watershed at the Mica Creek Watershed in Idaho by comparing with the HSPF model. Geza et al., (2009) performed a study on a sensitive analysis of WARMF for automated parameter estimations and prediction uncertainties for a WARMF model. Geza et al. (2010) also researched the parameter sensitivities and model calibrations for watershed-scale impacts of Nitrogen from the on-site wastewater system. WARMF was included in the decision support system "the ZeroNet Water-energy" which is focused on drought planning and economic analysis. It has three major components which are shown in Figure A-20: 1) watershed tools based on the WARMF, 2) a Quick Scenario Tool, and 3) a knowledge base

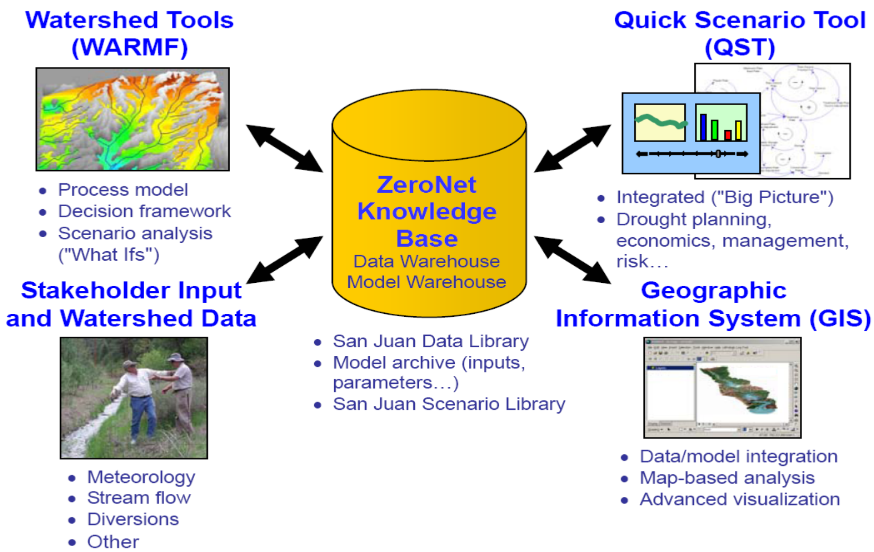

Figure A-20: The ZeroNet Decision Support System (Source: Rich et al., 2005).

The functions of WARMF for ZeroNet are to model surface flows for both the natural and controlled as well as water withdrawals via an engineering module and to analyze and visualize results via a stakeholder module. The R^2 value of the WARMF simulation between simulated and observed flow (cms) for the San Juan Basin was 0.9738 (wet year), 0.9772

(Normal year), and 0.8853 (dry year) (Rich et al., 2005). Weintraub et al., (2004) used WARMF for TN/TP loading and transport of nutrients from OWS in the 840 km^2 Dillon River Watershed in Colorado. The R^2 value of the comparison of simulated and observed stream flow was 0.816~0.835

WEPP

WEPP (Water Erosion Prediction Project) is a process-based distributed parameter model. It is a continuous simulation computer program used to predict soil loss (erosion) and sediment deposition (delivery) based on the overland flow on hillslopes, the concentrated flow in small channels, and the sediment deposition in compounds. This model is composed of several components: a climate component, a hydrology component, a daily water balance component, a plant growth and residue decomposition component, and an irrigation component. These components are computed by spatial and temporal distributions of soil loss and decomposition by single events and longer time periods, respectively (Flanagan et al., 1995, Abaci et al., 2007).

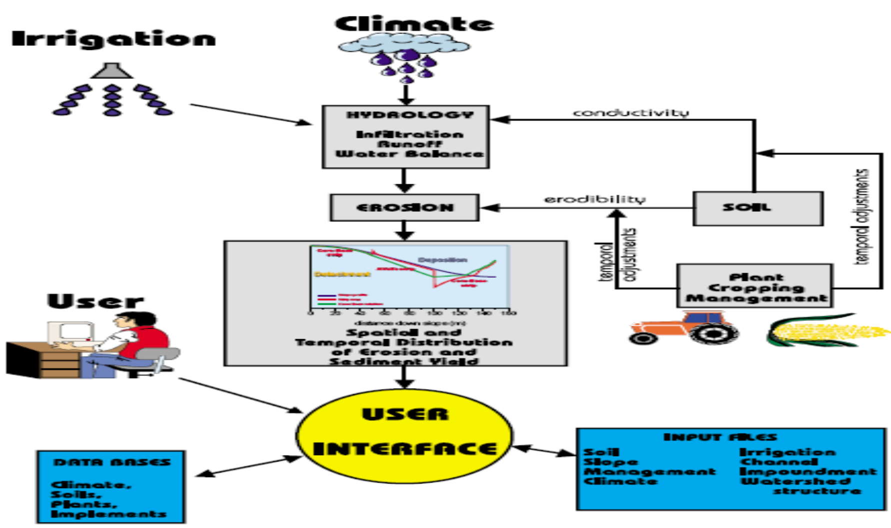

Figure A-21: The process schematic of the WEPP model (Source: Flanagan et al., 1995).

Like in Figure A-21, the WEPP model processes the following components: infiltration (Green-Ampt model), different land management practices (e.g. tillage, contouring), plant growth, residue decomposition, freezing and thawing, percolation, evaporation and transpiration. For a stochastic weather data generator, WEPP utilizes CLIGEN version 4.3 to generate daily input data (Flanagan et al., 1995, Abaci et al., 2007, 2008).

SDR (Sediment Delivery Ratio) is vital for predicting the sediment runoff from watersheds. Abaci et al. (2008) applied the WEPP model to a 26 km^2 watershed even though it is 10 times larger than the maximum size 2.6 km^2 documented in the literature. According the results, WEPP is suitable for and can be applied to larger sized watersheds than documented in the literature.

Nutrients (N, P) carried by runoff and sediments have impacted the proliferation of algae and aquatic plants in the Iowa catchment, so Abaci et al., (2007) researched to identify and understand critical nonpoint source pollution under equilibrium conditions in order to enhance best management practices (BMP). Baigorria et al. (2006) upgraded the availability of the WEPP model by adding GEMSE (Geospatial Modelling of Soil Erosion) in order to analyze the spatial variations of runoff and soil loss.

APPENDIX B - THE OBSERVATION DATA OF EACH SUB-WATERSHED

Table B-1: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Han River watershed (0 ~ 200km^2) for first step

	Station	Total Area	Pervious		Impervious		Rainfall	Slope	Large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age (%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
0 ~ 100km^2	Hongjechun	51.0	30.9	60.5	20.1	39.5	116.2	18.5	32.4	63.7	0.0	0.1	13.9	27.2	0.6	1.2	0.2	0.4	3.8	7.4	0.0	0.0	12.1	3.6	4.9	6.710	0.172
	Norangjin	51.0	32.1	62.9	18.9	37.1	111.3	10.3	33.9	66.5	0.5	1.1	8.7	17.0	0.8	1.5	0.0	0.1	1.2	2.4	5.8	11.5	9.0	3.5	5.5	5.669	0.260
	hwayangchun	56.3	43.3	76.8	13.0	23.2	100.3	39.7	2.1	3.7	21.9	39.0	30.4	54.0	0.8	1.3	0.2	0.3	0.2	0.4	0.7	1.3	11.3	0.7	1.6	2.138	0.022
	joyanggang	74.1	60.8	82.1	13.2	17.9	94.8	48.6	1.3	1.7	8.9	12.0	62.1	83.8	0.2	0.3	0.1	0.1	0.5	0.7	1.1	1.5	11.0	0.8	2.3	2.652	0.027
	yeuju2	76.1	57.6	75.7	18.5	24.3	103.1	10.3	6.1	8.0	30.1	39.5	29.3	38.5	1.4	1.9	3.2	4.2	1.8	2.4	4.2	5.5	10.8	1.6	3.5	2.834	0.061
	chungjujojungji	84.4	64.3	76.3	20.0	23.7	100.5	20.8	7.6	9.0	24.5	29.0	36.7	43.5	6.0	7.1	0.1	0.2	1.9	2.2	7.5	8.9	11.9	1.4	2.4	2.483	0.028
	damchun3	86.2	68.0	78.9	18.2	21.1	94.5	25.6	2.6	3.0	27.8	32.2	50.9	59.0	1.3	1.6	0.6	0.7	0.2	0.2	2.8	3.2	10.4	1.1	2.9	2.389	0.035
	sukmunchun	99.2	79.9	80.6	19.3	19.4	93.0	39.9	3.0	3.0	18.2	18.4	75.3	75.9	0.4	0.4	0.5	0.5	1.2	1.2	0.6	0.6	11.8	1.3	2.7	3.713	0.104
100 ~ 150km^2	sumgang2	108.1	84.8	78.5	23.3	21.5	107.7	25.9	7.5	7.0	25.7	23.7	68.8	63.6	2.0	1.8	1.1	1.0	1.1	1.0	1.9	1.8	10.7	1.5	3.2	2.360	0.053
	segokchun	113.5	89.0	78.4	24.5	21.6	105.4	29.2	6.9	6.1	27.1	23.9	74.9	66.0	1.5	1.3	0.3	0.3	1.3	1.1	1.5	1.3	10.6	1.6	3.6	4.646	0.129
	dongjinchun2	124.0	98.2	79.2	25.8	20.8	96.4	29.7	3.8	3.1	31.1	25.1	83.7	67.5	1.9	1.6	0.0	0.0	1.6	1.3	1.8	1.4	10.4	1.4	2.5	2.340	0.036
	hangju	124.9	88.6	70.9	36.3	29.1	111.4	14.0	38.1	30.5	23.6	18.9	43.7	35.0	4.7	3.7	0.5	0.4	5.3	4.2	9.1	7.3	8.8	4.0	6.2	7.036	0.356
	gulpochun3	131.8	77.6	58.9	54.2	41.1	99.9	6.7	67.3	51.1	32.3	24.5	17.5	13.3	6.6	5.0	0.1	0.1	5.9	4.5	1.9	1.4	3.1	11.4	13.9	18.632	1.760
	paldangdam	132.5	109.5	82.6	23.0	17.4	103.3	28.7	4.5	3.4	18.1	13.7	92.3	69.7	1.7	1.3	2.7	2.1	1.0	0.8	12.1	9.1	10.9	1.3	3.6	2.121	0.048
	yeumsungchun	143.2	110.0	76.8	33.2	23.2	101.0	24.6	6.9	4.8	51.9	36.2	77.9	54.4	2.5	1.7	0.5	0.3	1.2	0.9	2.4	1.7	11.0	1.8	3.3	2.526	0.064
150 ~ 200km^2	yodochun	150.6	114.9	76.3	35.6	23.7	102.2	20.9	7.8	5.2	56.8	37.7	76.9	51.1	3.2	2.2	1.0	0.6	2.3	1.5	2.5	1.7	10.7	2.4	4.0	2.727	0.105
	damchul5	152.2	116.3	76.5	35.8	23.5	97.2	30.8	13.8	9.0	44.0	28.9	81.4	53.5	4.9	3.2	1.4	0.9	2.6	1.7	4.1	2.7	10.2	1.8	3.8	2.865	0.089
	wonjuchun	153.0	117.3	76.7	35.6	23.3	110.5	31.1	19.5	12.7	29.4	19.2	98.5	64.4	1.0	0.6	0.8	0.5	2.7	1.8	1.2	0.8	9.3	7.5	8.5	10.386	0.758
	geumgyechun	155.4	126.9	81.7	28.5	18.3	109.1	39.6	2.0	1.3	23.8	15.3	127.0	81.7	0.3	0.2	0.0	0.0	0.8	0.5	1.4	0.9	10.8	0.9	1.8	2.500	0.033
	junchun	170.7	137.7	80.7	33.0	19.3	108.0	32.6	5.2	3.0	28.2	16.5	133.7	78.3	1.2	0.7	0.4	0.2	1.0	0.6	1.1	0.7	9.8	1.2	2.0	1.295	0.023
	sangchun	182.3	149.2	81.8	33.2	18.2	98.5	43.3	2.9	1.6	26.3	14.4	149.2	81.8	0.7	0.4	0.7	0.4	1.3	0.7	1.3	0.7	11.1	1.0	2.2	2.488	0.034
	chunsunggyo	189.4	155.4	82.1	34.0	17.9	108.2	38.7	4.3	2.3	19.7	10.4	154.6	81.6	4.1	2.2	0.1	0.1	2.3	1.2	4.2	2.2	10.8	1.2	3.1	1.667	0.030

Table B-2: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Han River watershed (200 ~ 500 km^2) for first step

	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age (%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
200 ~ 500km^2	yeamdam	228.0	176.5	77.4	51.5	22.6	105.2	24.8	26.1	11.4	48.1	21.1	131.6	57.7	4.0	1.8	0.4	0.2	3.6	1.6	14.2	6.2	10.5	1.1	2.8	1.657	0.030
	damchun1	256.8	203.4	79.2	49.1	19.1	96.5	33.1	6.4	2.5	51.2	19.9	189.7	73.9	1.4	0.5	0.8	0.3	0.6	0.2	2.4	1.0	10.6	0.9	2.7	1.841	0.028
	jojongchun3	260.6	214.6	82.4	46.0	17.6	115.9	38.1	5.6	2.2	29.9	11.5	213.9	82.1	4.5	1.7	0.0	0.0	1.2	0.5	5.3	2.0	11.0	1.1	2.6	3.298	0.057
	gokneungchun3	261.5	193.5	74.0	67.9	26.0	106.2	17.0	31.0	11.8	84.4	32.3	116.2	44.5	13.5	5.1	1.3	0.5	11.4	4.3	3.7	1.4	9.4	7.4	9.8	8.298	0.268
	jechuchun2	268.4	212.1	79.1	56.2	20.9	109.6	32.0	14.9	5.5	54.1	20.2	193.4	72.1	0.6	0.2	0.2	0.1	3.5	1.3	1.6	0.6	11.5	1.8	3.8	5.667	0.272
	soyangdam5	278.2	233.5	83.9	44.7	16.1	98.8	45.2	3.9	1.4	14.3	5.1	245.0	88.1	1.3	0.5	6.8	2.5	0.9	0.3	6.1	2.2	9.9	1.2	2.4	1.705	0.022
	ananyangchun5	281.2	182.6	65.0	98.6	35.0	103.0	15.5	130.4	46.4	32.1	11.4	104.2	37.1	3.9	1.4	0.2	0.1	6.9	2.5	3.5	1.2	6.1	9.8	11.1	18.217	0.972
	gyechun2	283.7	234.6	82.7	49.1	17.3	114.0	43.7	1.4	0.5	36.0	12.7	243.0	85.7	0.4	0.1	0.1	0.0	0.8	0.3	2.0	0.7	10.2	0.8	2.1	1.798	0.013
	tanchun5	302.8	215.6	71.2	87.1	28.8	105.3	18.9	92.8	30.6	36.9	12.2	146.6	48.4	7.3	2.4	2.4	0.8	13.1	4.3	3.7	1.2	6.9	17.9	11.9	15.417	1.047
	gapyungchun5	305.4	254.1	83.2	51.3	16.8	111.0	48.3	5.3	1.7	18.5	6.1	274.1	89.7	2.2	0.7	0.2	0.1	2.1	0.7	3.1	1.0	11.0	0.9	2.0	2.507	0.035
	bokhachun3	309.5	227.4	73.5	82.2	26.5	110.3	12.9	31.4	10.2	135.5	43.8	124.5	40.2	7.3	2.4	1.8	0.6	3.2	1.0	5.6	1.8	9.7	4.2	5.5	6.322	0.214
	heukchun3	314.1	252.2	80.3	61.8	19.7	113.5	33.3	13.0	4.1	57.2	18.2	232.8	74.1	3.7	1.2	1.3	0.4	2.8	0.9	3.2	1.0	10.3	1.1	2.8	2.858	0.035
	gyesandam3	315.3	257.3	81.6	58.0	18.4	97.0	38.5	5.3	1.7	50.4	16.0	252.2	80.0	1.1	0.3	1.2	0.4	1.0	0.3	4.2	1.3	9.7	1.2	3.0	1.834	0.025
	deokyeunlee	317.1	250.0	78.8	67.1	21.2	101.0	27.6	10.6	3.3	83.0	26.2	200.0	63.1	10.0	3.2	0.8	0.3	5.2	1.6	7.5	2.4	10.8	1.2	2.9	2.445	0.038
	sumgang3	319.9	261.1	81.6	58.9	18.4	107.8	33.9	5.1	1.6	48.8	15.2	254.3	79.5	3.3	1.0	1.2	0.4	2.9	0.9	4.3	1.3	10.2	1.8	4.0	4.454	0.195
	jungryangchun4	350.4	246.7	70.4	103.7	29.6	111.3	16.2	111.3	31.8	55.3	15.8	157.8	45.0	6.4	1.8	2.3	0.7	12.1	3.4	5.1	1.5	7.9	12.1	11.2	17.647	1.439
	deokchun	371.5	305.9	82.4	65.5	17.6	93.1	48.8	5.8	1.6	39.5	10.6	316.3	85.1	1.1	0.3	0.9	0.2	3.4	0.9	4.4	1.2	10.7	1.0	2.7	2.965	0.034
	paldamdam4	380.3	309.7	81.4	70.6	18.6	107.9	33.4	15.0	4.0	42.1	11.1	295.1	77.6	7.4	1.9	0.4	0.1	5.9	1.6	14.3	3.8	11.0	1.2	3.2	1.800	0.032
	soyangdam1	400.5	342.6	85.5	57.9	14.5	103.7	46.9	2.5	0.6	12.0	3.0	339.4	84.7	0.9	0.2	0.5	0.1	2.4	0.6	42.8	10.7	9.1	0.9	2.2	1.459	0.018
	pyungchanggang1	402.5	332.2	82.5	70.3	17.5	111.4	39.2	4.3	1.1	40.5	10.1	350.6	87.1	2.6	0.7	0.1	0.0	2.3	0.6	2.0	0.5	11.1	0.8	1.8	3.598	0.027
	guri	413.6	319.3	77.2	94.3	22.8	105.2	23.4	39.8	9.6	89.1	21.5	249.0	60.2	11.5	2.8	0.4	0.1	10.1	2.4	13.7	3.3	10.7	1.5	3.7	2.478	0.052
	odaechun2	451.7	375.9	83.2	75.8	16.8	105.7	46.3	4.7	1.0	33.2	7.4	407.2	90.1	2.0	0.5	1.9	0.4	1.1	0.2	1.6	0.4	11.2	0.8	2.3	3.478	0.037
	okdongchun2	495.3	414.0	83.6	81.2	16.4	97.0	50.9	3.5	0.7	25.6	5.2	459.7	92.8	1.5	0.3	0.3	0.1	3.4	0.7	1.3	0.3	11.3	0.7	1.5	1.671	0.013

Table B-3: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Han River watershed (500 km^2 ~) for first step

	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age (%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
500km^2 ~	chungjudam4	502.1	403.1	80.3	92.2	18.4	103.6	43.7	13.0	2.6	57.5	11.4	401.1	79.9	2.1	0.4	3.5	0.7	12.1	2.4	6.0	1.2	11.1	1.3	2.2	2.479	0.022
	paldangdam1	505.1	382.4	75.7	122.7	24.3	110.7	20.8	35.5	7.0	197.7	39.1	230.2	45.6	10.9	2.2	3.4	0.7	8.6	1.7	18.9	3.7	11.3	1.6	3.7	2.502	0.058
	yeju1	536.0	427.3	79.7	108.7	20.3	101.7	25.8	17.6	3.3	123.9	23.1	354.4	66.1	14.4	2.7	5.4	1.0	5.9	1.1	14.5	2.7	10.0	1.4	3.3	2.822	0.060
	gyunganchun6	561.1	433.2	77.2	128.0	22.8	105.6	26.5	63.3	11.3	92.9	16.6	364.1	64.9	17.2	3.1	1.6	0.3	11.1	2.0	10.9	1.9	9.9	3.9	6.6	5.066	0.166
	chungmichun3	596.6	447.9	75.1	148.7	24.9	104.0	17.3	34.3	5.7	257.8	43.2	262.3	44.0	15.4	2.6	3.3	0.5	10.6	1.8	13.0	2.2	10.9	2.9	5.1	3.767	0.101
	juchungang2	607.4	496.5	81.7	110.9	18.3	113.1	36.7	7.8	1.3	87.1	14.3	499.0	82.2	2.1	0.3	1.4	0.2	5.4	0.9	4.6	0.8	11.0	0.9	2.1	2.988	0.016
	inbukchun2	660.1	414.9	62.9	89.3	13.5	93.1	40.4	13.4	2.0	39.5	6.0	432.6	65.5	8.9	1.4	0.8	0.1	4.5	0.7	4.6	0.7	11.1	0.9	2.4	1.739	0.026
	chunchendam2	774.9	645.5	83.3	129.4	16.7	104.2	44.1	18.7	2.4	56.6	7.3	672.1	86.7	4.8	0.6	1.4	0.2	4.1	0.5	17.2	2.2	9.7	0.9	2.4	1.315	0.020
	youngwol2	809.2	654.4	80.9	154.9	19.1	102.2	41.0	19.0	2.3	128.7	15.9	631.1	78.0	5.0	0.6	3.0	0.4	14.6	1.8	7.9	1.0	11.0	0.9	2.3	2.976	0.034
	chungpyungdam1	818.4	670.2	81.9	148.2	18.1	109.8	37.0	17.0	2.1	106.8	13.1	660.5	80.7	7.9	1.0	2.3	0.3	7.9	1.0	15.9	1.9	10.4	1.0	3.0	1.969	0.033
	chungjudam	833.6	686.6	82.4	147.1	17.6	101.4	41.6	15.9	1.9	117.1	14.0	627.0	75.2	2.5	0.3	1.4	0.2	11.3	1.4	58.5	7.0	9.0	0.8	2.2	2.236	0.021
	choyanggang	918.7	753.6	82.0	165.0	18.0	109.4	43.0	11.9	1.3	126.2	13.7	760.0	82.7	4.4	0.5	3.0	0.3	5.3	0.6	7.7	0.8	11.0	0.8	2.3	2.652	0.027
	hongchungang1	1006.1	819.0	81.4	187.0	18.6	109.0	37.4	47.5	4.7	105.8	10.5	826.4	82.1	3.3	0.3	2.3	0.2	7.6	0.8	13.1	1.3	10.6	0.9	2.3	2.423	0.023
	youngwol1	1022.9	840.4	82.2	182.3	17.8	97.6	49.8	17.9	1.8	106.8	10.4	867.7	84.8	6.6	0.6	1.8	0.2	12.3	1.2	9.5	0.9	10.8	0.9	2.3	2.834	0.069
	naelinchun1	1084.4	908.7	83.8	175.7	16.2	105.7	45.9	5.8	0.5	57.4	5.3	1004.4	92.6	5.7	0.5	1.4	0.1	4.0	0.4	5.8	0.5	11.1	0.6	1.7	2.180	0.014
	hawchundam1	1265.7	863.6	68.2	181.6	14.4	95.0	43.0	23.0	1.8	111.7	8.8	949.5	75.0	21.0	1.7	2.3	0.2	5.1	0.4	36.9	2.9	9.8	0.8	2.0	1.121	0.027

Table B-4: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Nakdong River watershed (0 ~ 500 km^2) for first step

	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001~2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	average(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
0~ 200km^2	youngsun	17.0	13.2	77.9	3.8	22.1	90.3	22.4	0.5	3.2	5.5	32.2	8.8	51.8	0.1	0.5	0.2	1.0	0.7	4.1	1.2	7.2	9.6	0.9	3.3	2.320	0.052
	andong3	38.0	29.3	77.2	8.6	22.8	87.4	20.3	1.7	4.6	13.4	35.3	21.3	56.1	0.3	0.9	0.0	0.1	0.2	0.6	1.0	2.5	7.5	0.8	2.9	1.484	0.028
	nakdonghagu2	54.7	37.7	69.0	17.0	31.0	120.9	14.4	19.5	35.7	7.3	13.4	15.5	28.4	1.1	2.0	1.1	2.1	1.2	2.2	8.8	16.1	10.5	2.6	6.3	3.318	0.129
	gupo	72.1	54.8	76.0	17.3	24.0	114.9	22.3	11.5	16.0	14.3	19.9	38.8	53.8	0.5	0.7	0.1	0.2	1.3	1.7	5.6	7.8	10.2	2.6	6.0	3.109	0.132
	deokchungang1	106.3	87.8	82.7	18.4	17.3	158.5	47.1	1.8	1.6	7.3	6.9	93.8	88.3	0.7	0.7	0.3	0.3	1.7	1.6	0.6	0.6	10.1	0.6	1.4	1.198	0.037
	gyesungchun	107.1	81.8	76.3	25.3	23.7	94.9	23.9	5.4	5.1	42.9	40.0	53.2	49.7	1.2	1.1	0.9	0.9	0.6	0.5	2.9	2.7	8.6	3.4	8.0	5.392	0.365
	imheajin	107.2	82.0	76.5	25.2	23.5	94.5	27.0	5.1	4.7	42.4	39.5	48.4	45.1	1.3	1.2	2.0	1.8	2.6	2.4	5.6	5.3	10.6	2.7	6.1	3.144	0.148
	yangsanchun3	107.3	79.0	74.0	27.8	26.0	114.1	28.6	15.3	14.2	14.5	13.5	64.3	60.0	3.9	3.6	0.9	0.8	6.2	5.8	1.6	1.5	10.1	3.8	7.1	4.278	0.246
	hyunpung	109.2	84.6	77.5	24.5	22.5	98.4	30.4	8.6	7.9	22.2	20.3	70.8	64.9	1.5	1.4	0.4	0.4	2.1	2.0	3.5	3.2	10.9	2.9	6.7	4.217	0.207
	yeryungchun	114.4	91.0	79.5	23.4	20.5	106.9	36.1	4.6	4.0	26.8	23.4	79.6	69.6	1.0	0.8	0.6	0.5	0.4	0.3	1.4	1.3	9.2	2.1	7.1	2.542	0.104
	sungju	120.1	91.9	76.5	28.3	23.5	84.5	20.6	9.6	8.0	32.1	26.8	63.0	52.4	2.0	1.7	1.9	1.5	5.4	4.5	6.1	5.1	11.0	2.1	5.0	2.996	0.095
	hwapochun	138.1	101.2	73.3	36.9	26.7	106.6	23.4	13.8	10.0	51.3	37.2	61.5	44.5	3.5	2.5	1.8	1.3	3.8	2.8	2.4	1.8	8.6	3.5	7.2	3.313	0.150
	yangsanchun1	138.9	112.0	80.7	26.8	19.3	118.4	36.7	6.1	4.4	17.3	12.4	108.4	78.0	4.5	3.2	0.3	0.2	1.2	0.9	1.2	0.9	9.8	1.1	2.7	2.542	0.074
	dalsung	155.5	122.0	78.5	33.5	21.5	92.5	24.3	5.8	3.7	45.9	29.5	93.7	60.3	1.5	1.0	1.6	1.0	2.5	1.6	4.5	2.9	11.2	2.1	5.2	2.927	0.096
	gwangryuchun3	158.0	121.3	76.8	36.7	23.2	102.5	31.7	11.3	7.1	40.7	25.7	96.9	61.3	1.4	0.9	1.9	1.2	4.0	2.5	1.9	1.2	9.8	3.0	5.9	2.553	0.150
	daeam	189.6	145.6	76.8	44.0	23.2	96.4	25.4	8.0	4.2	68.6	36.2	96.3	50.8	1.8	1.0	1.8	1.0	5.0	2.6	8.1	4.3	11.2	3.1	6.9	4.116	0.193
	milyanggang3	193.4	200.2	80.5	48.6	19.5	94.6	38.8	5.8	3.0	51.9	26.8	181.3	93.7	2.2	1.1	1.8	0.9	2.4	1.2	3.5	1.8	10.6	2.3	4.4	3.013	0.120
200 ~ 500km^2	goryung	210.6	149.7	71.1	60.9	28.9	93.7	20.1	47.9	22.8	43.2	20.5	96.6	45.9	5.8	2.8	3.1	1.5	6.7	3.2	7.2	3.4	10.7	2.9	6.8	4.178	0.215
	hamanchun2	216.2	167.0	77.2	49.3	22.8	103.8	26.4	10.5	4.9	75.2	34.8	117.3	54.3	2.5	1.2	2.9	1.4	1.7	0.8	6.0	2.8	10.1	3.0	6.5	4.780	0.194
	ianchun	242.3	193.3	79.8	49.0	20.2	99.0	31.5	7.0	2.9	53.9	22.2	173.3	71.5	1.7	0.7	0.9	0.4	2.9	1.2	2.7	1.1	6.2	0.7	1.6	1.018	0.015
	mulgeum	254.8	204.8	80.4	50.0	19.6	107.6	37.4	9.4	3.7	44.6	17.5	179.0	70.3	3.3	1.3	1.6	0.6	4.9	1.9	12.0	4.7	10.3	2.6	6.0	3.022	0.130
	hanchun	256.5	200.0	78.0	56.4	22.0	99.3	27.0	9.5	3.7	82.7	32.3	157.7	61.5	2.4	0.9	1.0	0.4	0.9	0.4	2.2	0.9	10.3	1.4	3.6	3.114	0.110
	ramchun2	264.1	211.6	80.1	52.5	19.9	124.0	34.4	6.5	2.5	60.9	23.1	189.3	71.7	3.7	1.4	1.1	0.4	0.5	0.2	2.2	0.8	9.4	1.2	2.8	1.594	0.056
	nakdonghagu1	288.6	206.8	71.7	81.8	28.3	115.3	17.5	38.8	13.4	109.1	37.8	104.0	36.0	7.7	2.7	1.5	0.5	13.3	4.6	14.2	4.9	10.5	2.2	5.4	3.293	0.110
	beakchun	289.1	223.2	77.2	65.9	22.8	89.9	25.0	11.2	3.9	99.2	34.3	168.8	58.4	2.3	0.8	0.6	0.2	4.1	1.4	3.0	1.0	7.9	1.2	2.8	1.746	0.057
	woonmumdam1	302.0	249.8	82.7	52.2	17.3	101.7	44.3	3.7	1.2	32.5	10.8	252.8	83.7	1.7	0.6	1.9	0.6	2.9	1.0	6.4	2.1	8.8	1.4	2.6	1.271	0.018
	imhaho1	303.0	249.1	82.2	53.9	17.8	79.5	35.2	5.2	1.7	53.9	17.8	215.8	71.2	2.9	0.9	1.4	0.4	1.6	0.5	22.3	7.3	8.2	2.0	3.4	1.501	0.028
	geumchun	313.1	245.9	78.5	67.2	21.5	99.4	34.1	10.2	3.3	97.6	31.2	194.2	62.0	2.2	0.7	1.2	0.4	1.3	0.4	6.4	2.0	3.5	0.4	3.2	0.534	0.018
	sinbanchun	327.9	158.0	48.2	36.7	11.2	105.6	39.0	4.3	1.3	36.2	11.0	147.8	45.1	1.0	0.3	2.3	0.7	0.9	0.3	2.3	0.7	10.3	1.6	3.2	2.446	0.066
	byungsungchun	341.0	258.1	75.7	82.8	24.3	97.5	31.3	19.2	5.6	137.4	40.3	167.6	49.2	4.3	1.3	2.5	0.7	4.0	1.2	5.9	1.7	10.2	1.7	4.5	3.883	0.211
	geumhogang4	344.8	166.0	48.2	47.4	13.7	94.3	22.3	22.4	6.5	31.1	9.0	146.9	42.6	5.0	1.4	1.0	0.3	3.5	1.0	3.5	1.0	12.0	3.7	8.2	5.062	0.293
	milyanggang1	349.3	271.8	77.8	76.5	21.9	103.4	41.9	40.1	11.5	40.9	11.7	247.4	70.8	5.2	1.5	2.7	0.8	6.8	1.9	5.4	1.5	10.1	1.0	2.4	2.358	0.046
	andong5	363.2	284.6	78.3	78.7	21.7	89.0	26.6	11.2	3.1	115.2	31.7	221.7	61.0	3.4	0.9	2.8	0.8	3.0	0.8	6.0	1.7	3.3	0.3	1.3	0.690	0.012
	youngjuseochun2	364.6	282.2	77.4	82.4	22.6	101.9	28.1	19.2	5.3	110.0	30.2	224.6	61.6	1.5	0.4	1.8	0.5	4.1	1.1	3.4	0.9	8.2	1.8	3.4	5.118	0.216
	michun	374.5	302.2	80.7	72.3	19.3	86.3	34.1	8.7	2.3	71.8	19.2	283.0	75.6	2.3	0.6	2.4	0.6	2.3	0.6	4.0	1.1	11.1	1.2	3.6	3.585	0.048
	weechun1	392.8	312.7	79.6	80.1	20.4	92.8	31.6	12.9	3.3	93.6	23.8	273.1	69.5	3.6	0.9	2.4	0.6	2.6	0.7	4.6	1.2	11.8	1.4	3.8	4.035	0.069
	youngjunchun1	397.8	325.8	81.9	72.0	18.1	85.0	40.4	5.7	1.4	56.5	14.2	324.1	81.5	1.5	0.4	1.7	0.4	3.4	0.9	4.9	1.2	9.7	1.5	2.0	1.751	0.025
	weechun6	408.4	338.4	82.9	97.8	23.9	83.5	19.1	13.8	3.4	160.5	39.3	238.3	58.3	4.4	1.1	4.1	1.0	4.0	1.0	11.2	2.7	4.2	0.6	1.9	1.016	0.020
	andong1	425.7	349.6	82.1	76.1	17.9	84.1	36.8	5.0	1.2	76.3	17.9	297.9	70.0	1.1	0.2	5.6	1.3	7.9	1.9	31.8	7.5	9.6	0.9	3.6	1.669	0.043
	samrangjin	435.8	322.1	73.9	113.7	26.1	100.5	20.4	32.0	7.3	211.3	48.5	149.0	34.2	6.1	1.4	6.3	1.5	8.9	2.0	22.3	5.1	10.4	2.8	5.9	3.089	0.163
	namji	467.2	361.3	77.3	106.0	22.7	99.4	25.4	18.7	4.0	171.3	36.7	236.8	50.7	9.0	1.9	5.4	1.2	6.1	1.3	19.9	4.3	10.3	2.7	6.0	3.239	0.159
	geumhogang6	468.8	209.0	44.6	77.9	16.6	97.9	26.1	67.1	14.3	34.2	7.3	163.2	34.8	7.4	1.6	2.3	0.5	6.8	1.5	5.8	1.2	10.2	3.8	9.3	7.244	0.543
	ssanggyechun	480.3	385.0	80.2	95.1	19.8	91.0	31.4	13.6	2.8	104.0	21.7	348.8	72.6	2.2	0.5	3.0	0.6	2.6	0.5	6.1	1.3	11.7	1.6	4.5	3.226	0.052
	namgangdam1	484.8	394.0	81.3	90.8	18.7	136.8	34.5	11.4	2.4	87.9	18.1	346.3	71.4	4.1	0.8	9.8	2.0	6.8	1.4	18.4	3.8	8.9	1.2	2.7	1.247	0.027
	hapchundam1	491.6	395.2	80.4	96.4	19.6	107.7	30.2	11.7	2.4	106.2	21.6	345.3	70.2	2.0	0.4	2.9	0.6	6.9	1.4	16.6	3.4	8.6	1.5	2.5	1.723	0.017

Table B-5: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Nakdong River watershed (500 km^2 ~) for first step

	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001~2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
500 km^2~	wegwan	500.7	369.4	73.8	131.3	26.2	86.7	20.4	54.7	10.9	164.6	32.9	239.8	47.9	5.9	1.2	4.3	0.9	17.1	3.4	14.2	2.8	10.2	1.8	4.5	3.041	0.108
	dosan	617.9	507.7	82.2	110.2	17.8	92.3	46.4	7.0	1.1	85.8	13.9	514.0	83.2	2.0	0.3	2.7	0.4	1.9	0.3	4.4	0.7	11.5	0.8	2.5	2.360	0.044
	gilanchun1	652.4	424.5	65.1	94.9	14.6	85.7	41.0	7.9	1.2	75.6	11.6	421.1	64.6	3.0	0.5	2.1	0.3	4.3	0.7	5.3	0.8	6.8	0.5	1.6	2.109	0.010
	younggang2	672.1	542.5	80.7	129.6	19.3	104.7	36.4	19.1	2.8	113.3	16.9	518.5	77.1	4.5	0.7	3.6	0.5	7.6	1.1	5.5	0.8	11.1	1.2	2.8	2.010	0.035
	gyechangdongchun2	679.3	155.4	22.9	42.6	6.3	98.1	32.9	5.6	0.8	57.0	8.4	129.7	19.1	0.8	0.1	0.3	0.0	3.3	0.5	1.3	0.2	10.2	1.1	2.9	2.906	0.079
	namgang3	711.9	552.6	77.6	159.3	22.4	120.4	28.2	43.3	6.1	210.7	29.6	420.0	59.0	6.5	0.9	6.9	1.0	6.7	0.9	17.7	2.5	10.1	2.7	5.5	3.018	0.124
	banbyunchun1A	747.0	465.4	62.3	116.8	15.6	80.8	42.6	40.3	5.4	74.5	10.0	452.7	60.6	2.1	0.3	2.1	0.3	5.6	0.7	4.9	0.7	3.3	0.3	1.2	0.338	0.005
	naesungchun1	794.2	623.8	78.5	170.4	21.5	94.7	27.6	21.1	2.7	237.6	29.9	509.8	64.2	4.3	0.5	3.8	0.5	9.1	1.2	8.4	1.1	10.6	1.0	2.6	4.232	0.095
	bonghwa	1114.7	299.4	26.9	57.8	5.2	95.4	49.1	2.4	0.2	16.1	1.4	332.6	29.8	1.1	0.1	1.0	0.1	1.9	0.2	2.1	0.2	11.5	0.8	2.4	1.968	0.037
	gamchun2	1162.4	910.4	78.3	252.0	21.7	89.7	29.1	41.7	3.6	327.0	28.1	743.4	64.0	8.2	0.7	5.6	0.5	21.1	1.8	15.5	1.3	10.1	1.1	3.6	4.348	0.159
	gyunghogang2	1257.4	835.3	66.4	206.9	16.5	113.3	34.0	25.8	2.1	221.4	17.6	755.8	60.1	10.9	0.9	6.7	0.5	11.5	0.9	9.9	0.8	10.4	1.2	3.4	1.596	0.042
	imchun	1558.8	178.3	81.7	39.9	18.3	129.3	41.5	3.2	0.2	33.9	2.2	175.1	11.2	1.7	0.1	1.3	0.1	1.6	0.1	1.5	0.1	10.4	0.9	2.7	1.390	0.052
	geumhogang3	1573.4	1230.5	78.2	342.9	21.8	90.6	29.0	80.6	5.1	306.1	19.5	508.1	32.3	18.1	1.2	8.8	0.6	16.1	1.0	24.0	1.5	10.8	3.2	7.7	5.192	0.268
	gyechangweechun2	1719.1	192.9	11.2	46.5	2.7	108.1	35.3	6.5	0.4	44.1	2.6	184.0	10.7	1.6	0.1	0.6	0.0	1.7	0.1	0.9	0.1	10.5	1.1	2.8	1.787	0.054
	andong2	1858.3	145.8	7.8	42.0	2.3	80.3	28.1	15.1	0.8	40.0	2.2	112.6	6.1	2.1	0.1	4.2	0.2	6.9	0.4	6.9	0.4	10.8	1.0	4.0	1.889	0.046
	yechun1	2053.5	199.7	9.7	55.9	2.7	88.9	22.9	6.8	0.3	88.0	4.3	141.9	6.9	3.3	0.2	3.8	0.2	3.8	0.2	8.0	0.4	4.3	0.4	1.5	0.970	0.012
	sangju2	2450.7	158.8	6.5	48.3	2.0	91.2	19.1	7.0	0.3	79.4	3.2	105.7	4.3	1.6	0.1	1.7	0.1	5.4	0.2	6.3	0.3	10.1	0.9	3.4	2.491	0.059
	chungdochun	2917.1	408.1	14.0	109.9	3.8	98.1	34.2	18.0	0.6	145.1	5.0	337.0	11.6	3.5	0.1	2.7	0.1	4.3	0.1	7.4	0.3	11.4	1.6	4.2	3.686	0.063
	hamyangweechun2	6227.7	141.8	79.7	36.1	20.3	115.7	34.8	5.8	0.1	41.4	0.7	125.4	2.0	2.4	0.0	0.8	0.0	0.8	0.0	1.2	0.0	10.9	1.5	3.7	3.123	0.121

Table B-6: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Geum-Sum-Youngsan River watershed (0 ~ 150 km^2) for first step

	Station	Total Area	pervious		impervious		rainfall	slope	large scale classification														yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001-2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
0~ 100 km^2	bakgokchun2	39.8	29.4	73.9	10.4	26.1	105.0	15.2	5.8	14.5	32.3	81.1	74.0	186.1	1.3	3.3	1.0	2.5	1.8	4.4	4.3	10.8	11.4	1.8	3.3	2.553	0.074
	hyundo	43.3	31.5	72.7	11.8	27.3	102.7	20.2	6.5	15.0	24.6	56.8	111.1	256.3	0.5	1.1	0.6	1.4	1.3	3.0	0.9	2.0	10.1	0.8	3.7	1.814	0.026
	youdengchun5	59.2	37.2	62.8	22.1	37.2	110.7	14.7	8.5	14.4	24.1	40.8	115.9	195.7	5.1	8.6	0.6	1.0	1.6	2.6	1.2	2.0	11.3	2.9	4.2	3.061	0.092
	sungdong	65.1	49.2	75.7	15.8	24.3	106.6	12.0	2.5	3.8	23.9	36.8	36.7	56.4	1.1	1.7	0.2	0.3	0.6	0.9	0.9	1.4	9.3	3.2	6.8	3.835	0.162
	daegyochun	65.9	51.0	77.3	15.0	22.7	106.6	21.6	14.7	22.2	86.3	130.8	101.8	154.3	6.9	10.5	2.0	3.1	4.5	6.8	4.5	6.8	10.6	2.0	3.5	2.119	0.050
	jusukchun4	82.9	59.1	71.3	23.8	28.7	111.0	11.1	7.6	9.2	49.7	59.9	20.5	24.7	0.4	0.5	1.4	1.7	1.3	1.6	2.0	2.4	11.0	2.7	5.6	3.400	0.146
	bakgokchun1	85.7	70.6	82.5	15.0	17.5	102.2	34.1	2.2	2.6	18.7	21.8	62.4	72.8	1.0	1.2	0.3	0.3	2.1	2.5	3.3	3.8	11.5	1.3	2.5	2.389	0.042
	yungi	86.1	65.1	75.5	21.1	24.5	104.2	15.2	5.0	5.8	19.1	22.2	66.7	77.4	1.5	1.8	1.2	1.4	1.6	1.9	3.6	4.2	10.0	3.2	6.8	5.315	0.218
	daejeonchun3	89.4	63.7	71.3	25.7	28.7	107.2	29.4	11.6	13.0	77.9	87.2	117.6	131.5	4.9	5.5	2.2	2.4	2.4	2.7	3.7	4.2	12.0	2.6	3.9	4.745	0.117
	jewon	89.9	72.0	80.0	18.0	20.0	99.0	33.1	4.4	4.9	28.0	31.1	105.3	117.1	1.5	1.7	0.3	0.4	1.5	1.7	0.8	0.9	10.3	1.0	3.7	1.765	0.029
	gapchun2	93.9	71.6	76.2	22.3	23.8	110.7	23.7	16.6	17.7	146.7	156.2	377.2	401.7	23.0	24.5	1.8	1.9	5.7	6.0	4.2	4.4	10.6	2.2	3.7	2.907	0.091
	yongsuchun	95.1	75.6	79.4	19.6	20.6	118.1	32.7	30.9	32.4	57.5	60.4	97.1	102.0	3.9	4.1	1.8	1.9	4.7	4.9	1.6	1.7	8.1	1.7	2.8	1.376	0.054
	buyeu1	96.9	74.8	77.1	22.2	22.9	109.0	19.8	5.3	5.5	18.4	19.0	66.7	68.8	2.4	2.5	0.7	0.7	0.9	0.9	0.7	0.8	10.4	3.1	6.8	4.146	0.162
	gongju1	98.7	79.0	80.0	19.7	20.0	113.3	28.9	11.8	12.0	73.9	74.8	155.1	157.2	2.1	2.2	0.4	0.4	2.1	2.2	1.9	1.9	10.2	2.9	6.6	4.323	0.182
100 ~ 150km^2	gapchun5-1	107.6	75.2	69.9	32.4	30.1	111.5	15.1	5.5	5.1	51.8	48.2	279.1	259.4	7.6	7.1	0.9	0.8	6.9	6.4	3.3	3.1	9.4	5.5	9.9	11.938	0.570
	naju	111.3	79.3	71.3	31.9	28.7	110.7	8.2	7.8	7.0	73.4	66.0	22.7	20.4	0.9	0.8	1.4	1.3	1.5	1.4	3.5	3.1	10.3	5.3	6.5	6.961	0.454
	hwasunchun	127.7	100.1	78.3	27.7	21.7	120.2	31.3	7.3	5.7	30.7	24.0	83.5	65.3	3.0	2.3	0.8	0.6	1.4	1.1	1.2	0.9	10.5	2.1	4.2	2.477	0.064
	gilsanchun	113.0	84.0	74.3	29.0	25.7	101.8	14.1	19.5	17.2	106.9	94.6	429.0	379.6	5.2	4.6	3.6	3.2	4.2	3.8	55.6	49.2	9.1	3.5	7.3	1.889	0.109
	bochungchun4	113.6	90.4	79.6	23.2	20.4	94.2	32.4	4.5	4.0	28.8	25.3	23.2	20.4	0.5	0.4	0.4	0.4	1.3	1.1	6.5	5.7	10.5	1.1	2.7	2.029	0.035
	woosan	120.4	94.4	78.4	26.0	21.6	101.3	30.6	3.4	2.8	17.8	14.8	16.6	13.8	0.3	0.2	0.3	0.3	0.7	0.5	0.7	0.6	10.1	1.0	3.7	2.339	0.044
	mokmyun	120.6	94.6	78.4	26.1	21.6	107.9	26.1	7.1	5.9	64.9	53.8	164.9	136.7	4.0	3.3	1.4	1.2	0.8	0.7	3.3	2.7	11.6	3.6	7.4	4.949	0.188
	ganggyungchun	123.5	88.5	71.7	35.0	28.3	96.5	10.8	5.9	4.8	41.7	33.8	270.9	219.4	3.1	2.5	0.5	0.4	1.8	1.4	1.7	1.4	9.8	5.9	10.4	9.033	0.453
	mihochun6-1	125.6	92.7	73.8	32.9	26.2	101.2	13.3	2.2	1.8	16.7	13.3	104.5	83.2	0.4	0.3	0.7	0.5	1.5	1.2	1.7	1.4	9.8	4.8	9.2	6.424	0.264
	younpo	127.7	104.4	81.8	23.3	18.2	96.6	43.1	1.1	0.8	11.0	8.6	68.5	53.6	2.5	2.0	0.1	0.1	0.3	0.2	2.3	1.8	9.9	0.9	3.5	1.662	0.020
	chungwon1	129.8	97.5	75.1	32.3	24.9	97.4	19.6	25.0	19.3	19.6	15.1	41.6	32.0	10.5	8.1	0.8	0.6	7.4	5.7	2.7	2.1	10.9	2.4	6.0	5.690	0.216
	chopyungchun	132.6	108.2	81.6	24.4	18.4	100.5	32.1	5.8	4.4	32.3	24.3	74.0	55.9	1.3	1.0	1.0	0.8	1.8	1.3	4.3	3.2	10.7	1.1	2.3	1.580	0.034
	jochun	136.3	105.2	77.2	31.1	22.8	102.7	23.1	22.9	16.8	11.9	8.8	49.3	36.2	2.0	1.4	0.6	0.4	2.2	1.6	0.5	0.3	9.9	3.6	5.1	4.421	0.284
	bochungchun2	140.6	111.5	79.3	29.1	20.7	188.1	29.9	8.3	5.9	75.8	54.0	74.8	53.2	1.1	0.8	1.0	0.7	1.0	0.7	3.2	2.2	10.2	1.1	2.1	2.115	0.031
	youdengchun-a	141.9	113.6	80.0	28.3	20.0	108.3	40.0	8.1	5.7	24.9	17.5	53.3	37.6	2.2	1.5	1.0	0.7	2.8	1.9	1.7	1.2	11.9	0.9	2.2	2.924	0.031
	donggye	144.4	116.6	80.8	27.7	19.2	116.1	35.4	2.2	1.6	28.8	19.9	101.5	70.3	7.9	5.5	1.7	1.2	0.6	0.4	1.6	1.1	9.7	1.1	3.6	1.445	0.043
	youngdongchun2	145.4	116.6	80.2	28.8	19.8	92.2	35.7	8.8	6.1	67.6	46.5	197.4	135.7	3.0	2.1	2.2	1.5	1.2	0.8	2.5	1.7	10.5	1.4	4.1	5.061	0.123

Table B-7: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Geum-Sum-Youngsan River watershed (150 km^2 ~) for first step

	Station	Total Area	pervious		impervious		rainfall	slope	large scale classification														yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001-2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
150 ~ 200km^2	suksungchun	152.2	111.3	73.2	40.8	26.8	103.5	12.4	5.3	3.5	36.8	24.2	36.5	24.0	1.1	0.7	2.0	1.3	1.1	0.7	3.3	2.2	8.7	4.2	7.0	4.574	0.345
	naju	152.8	100.7	65.9	52.1	34.1	113.1	7.7	62.1	40.6	23.1	15.1	52.1	34.1	7.7	5.0	1.9	1.2	4.2	2.8	1.8	1.2	11.4	5.3	6.5	6.961	0.454
	bonggok 2 gyo	156.9	125.3	79.9	31.6	20.1	107.7	32.8	11.3	7.2	39.2	25.0	79.6	50.7	2.1	1.3	1.2	0.8	1.3	0.9	1.5	0.9	11.2	1.9	3.3	3.396	0.193
	bogangchun	157.6	118.0	74.9	39.6	25.1	99.3	19.2	4.6	2.9	32.9	20.9	53.3	33.8	0.5	0.3	0.2	0.1	2.2	1.4	3.3	2.1	10.5	1.8	3.6	3.621	0.087
	hadong	156.3	126.5	80.9	29.8	19.1	143.1	39.8	5.4	3.4	21.9	14.0	120.3	77.0	1.7	1.1	1.0	0.6	3.1	2.0	2.9	1.8	9.0	1.2	4.8	2.275	0.047
	goksung	183.4	147.4	241.2	36.0	58.8	113.7	32.4	4.7	2.5	38.7	21.1	130.2	71.0	3.1	1.7	2.3	1.2	1.7	0.9	2.8	1.5	10.0	1.4	4.0	2.521	0.066
	deokyeun	184.2	154.9	84.1	29.3	15.9	143.0	45.3	1.8	1.0	5.4	2.9	173.2	94.0	1.5	0.8	0.6	0.3	0.5	0.3	1.3	0.7	9.6	1.3	3.4	2.298	0.046
	yochuun A	191.7	158.5	82.7	33.2	17.3	112.9	46.5	3.2	1.7	17.5	9.1	163.5	85.3	3.4	1.8	1.3	0.7	0.8	0.4	2.1	1.1	3.4	0.3	0.7	0.676	0.005
	geumchun	165.2	124.3	75.3	40.9	24.7	96.3	18.6	6.6	4.0	79.9	48.4	201.8	122.2	2.1	1.3	0.8	0.5	4.1	2.5	4.2	2.6	9.9	3.3	6.1	2.511	0.088
	gongju2	171.4	135.0	78.7	36.5	21.3	109.2	24.2	5.3	3.1	37.7	22.0	169.9	99.1	1.0	0.6	1.6	0.9	3.0	1.7	4.4	2.5	10.3	3.3	7.1	4.476	0.174
	geumganggapmun	194.8	151.3	77.6	43.6	22.4	100.6	13.8	13.1	6.7	142.1	72.9	493.5	253.3	5.2	2.7	1.6	0.8	2.7	1.4	6.5	3.3	3.2	0.9	2.2	1.312	0.039
	musimchun3	197.3	144.5	73.2	52.9	26.8	98.4	20.1	5.2	2.7	43.3	21.9	160.2	81.2	2.0	1.0	0.7	0.3	0.6	0.3	7.4	3.8	11.0	2.2	4.2	3.173	0.081
	gomnaru	197.7	153.7	77.8	44.0	22.2	104.9	26.6	8.9	4.5	58.0	29.3	385.2	194.9	3.8	1.9	1.6	0.8	3.7	1.8	2.9	1.5	10.1	3.1	6.5	4.321	0.171
200km^2~	nosungchun	202.5	150.5	74.4	51.9	25.6	105.3	17.7	11.1	5.5	44.7	22.1	64.9	32.1	2.6	1.3	1.2	0.6	2.1	1.0	3.2	1.6	10.6	2.6	4.6	2.125	0.068
	nonsanchun1	219.4	177.9	81.1	41.6	18.9	110.3	34.0	22.4	10.2	157.7	71.9	91.8	41.9	6.2	2.8	2.9	1.3	4.4	2.0	3.4	1.5	10.4	1.2	3.1	3.576	0.034
	byungchunchun	220.3	169.1	76.8	51.2	23.2	102.9	19.4	12.0	5.5	98.9	44.9	84.0	38.1	2.6	1.2	0.8	0.4	1.1	0.5	3.0	1.4	10.5	2.2	3.8	2.709	0.060
	mihochun4	220.7	165.8	75.1	54.9	24.9	101.6	18.7	10.6	4.8	78.8	35.7	75.7	34.3	2.3	1.0	2.1	0.9	1.0	0.4	24.5	11.1	10.2	2.7	5.8	4.031	0.191
	youngdong	222.8	180.9	81.2	41.9	18.8	173.9	36.4	11.4	5.1	55.4	24.9	119.6	53.7	2.3	1.0	1.6	0.7	4.0	1.8	3.4	1.5	10.2	1.1	3.7	2.132	0.036
	nonsanchun4	244.2	171.5	70.2	72.7	29.8	97.0	9.1	2.8	1.1	24.3	9.9	97.1	39.8	1.5	0.6	0.8	0.3	0.3	0.1	5.8	2.4	4.1	1.6	3.0	2.377	0.085
	jichun	246.4	195.8	79.5	50.6	20.5	104.8	26.7	26.1	10.6	4.1	1.7	19.9	8.1	2.9	1.2	0.4	0.2	5.3	2.1	0.6	0.2	10.6	1.9	3.6	2.212	0.048
	bonghwangchun	247.4	192.1	77.6	55.3	22.4	143.4	30.7	10.3	4.2	59.0	23.8	45.7	18.5	2.8	1.1	2.2	0.9	2.2	0.9	3.3	1.3	10.3	1.5	3.7	3.337	0.118
	youguchun	282.6	225.5	79.8	57.1	20.2	105.1	31.4	7.4	2.6	10.3	3.6	21.2	7.5	1.6	0.5	0.2	0.1	1.0	0.3	1.7	0.6	10.2	1.7	2.8	1.785	0.037
	mihochun3	288.8	207.8	71.9	81.0	28.1	98.2	14.3	6.8	2.3	56.9	19.7	43.4	15.0	1.5	0.5	0.5	0.2	0.3	0.1	3.7	1.3	10.2	3.1	6.3	4.479	0.173
	bochungchun3	299.5	237.8	79.4	61.7	20.6	99.6	31.3	8.3	2.8	85.7	28.6	50.2	16.8	2.1	0.7	0.0	0.0	3.0	1.0	2.8	0.9	10.7	1.2	2.6	2.457	0.036
	gamak	313.5	247.2	78.9	66.2	21.1	109.1	34.6	8.8	2.8	78.6	25.1	201.1	64.2	17.4	5.5	1.1	0.4	3.9	1.3	2.6	0.8	7.8	0.8	2.2	2.085	0.025
	mujunamdaechun	325.5	266.2	81.8	59.3	18.2	187.4	43.4	12.2	3.8	69.8	21.5	34.8	10.7	2.9	0.9	0.0	0.0	1.9	0.6	1.7	0.5	9.9	0.8	2.7	2.333	0.024
	daegang	204.3	157.2	77.0	47.1	23.0	112.2	22.3	7.9	3.8	77.3	37.8	107.9	52.8	5.3	2.6	2.0	1.0	1.3	0.7	2.6	1.2	3.3	0.5	1.4	0.569	0.016
	namwon	227.0	178.9	78.8	48.2	21.2	113.7	26.6	6.7	3.0	69.4	30.6	134.0	59.0	6.6	2.9	3.9	1.7	1.6	0.7	4.9	2.1	10.4	1.4	3.8	1.664	0.052
	bosungchun-1	283.8	228.2	80.4	55.5	19.6	122.3	35.3	6.1	2.1	61.9	21.8	201.2	70.9	8.1	2.8	2.6	0.9	0.9	0.3	3.0	1.1	4.2	0.4	1.3	0.496	0.011
	yochun	294.8	227.1	77.0	67.7	23.0	113.3	22.8	15.7	5.3	97.4	33.0	163.4	55.4	5.4	1.8	4.4	1.5	3.9	1.3	4.7	1.6	10.2	1.6	4.0	2.707	0.161
	jinwol	298.9	238.3	319.4	60.5	80.6	139.3	32.4	11.0	3.7	67.9	22.7	202.6	67.8	4.4	1.5	2.0	0.7	2.3	0.8	8.6	2.9	3.6	0.5	1.4	0.457	0.016
	bosunggang 1	327.0	257.8	78.9	69.1	21.1	123.7	26.9	10.5	3.2	92.6	28.3	205.3	62.8	8.6	2.6	2.1	0.6	2.1	0.6	5.8	1.8	4.1	0.5	1.3	0.342	0.013
	churyungchun	355.9	284.3	79.9	71.6	20.1	111.9	31.8	10.3	2.9	79.5	22.3	249.9	70.2	8.9	2.5	1.8	0.5	1.6	0.4	3.9	1.1	3.7	0.3	0.8	0.845	0.005
	osuchun	371.3	289.6	78.0	81.3	21.9	112.9	24.6	11.6	3.1	124.3	33.5	220.6	59.4	5.0	1.4	3.5	0.9	1.6	0.4	4.3	1.1	10.9	1.5	3.8	2.010	0.060
	imsil	429.3	351.1	81.8	78.2	18.2	114.2	34.0	9.3	2.2	77.3	18.0	310.4	72.3	4.9	1.2	2.1	0.5	1.0	0.2	24.3	5.7	10.8	1.1	3.3	1.608	0.038
	gurye	489.0	391.8	80.1	97.2	19.9	120.0	36.6	13.9	2.8	108.7	22.2	343.0	70.1	9.6	2.0	5.0	1.0	2.2	0.5	6.5	1.3	10.0	1.3	3.7	2.382	0.053
	juamdam	702.4	578.8	82.4	123.7	17.6	119.8	34.6	9.7	1.4	104.6	14.9	527.1	75.0	23.2	3.3	4.0	0.6	1.6	0.2	32.1	4.6	3.7	0.4	1.4	0.443	0.006
	jisukchun2	215.8	174.2	80.7	41.6	19.3	111.9	29.7	5.6	2.6	44.7	20.7	147.5	68.4	3.7	1.7	2.1	1.0	2.7	1.3	9.6	4.4	10.8	2.2	4.4	2.674	0.109
	gomakwonchun2	219.0	164.4	75.1	54.5	24.9	110.7	18.4	12.3	5.6	105.2	48.0	91.6	41.8	2.0	0.9	1.9	0.9	1.8	0.8	4.3	2.0	10.2	2.9	5.9	2.653	0.070
	jisukpo	237.7	191.6	80.6	45.9	19.3	116.0	32.9	5.8	2.5	45.4	19.1	170.8	71.9	7.8	3.3	2.1	0.9	1.6	0.7	4.0	1.7	10.2	1.4	3.1	1.367	0.038
	youngsanpo	309.9	227.9	73.5	82.1	26.5	110.4	14.7	19.2	6.2	166.1	53.6	108.1	34.9	3.4	1.1	2.3	0.8	3.1	1.0	7.7	2.5	9.6	5.6	6.5	6.624	0.435
	gwangju1	562.0	422.5	75.2	139.5	24.8	112.8	25.5	46.0	8.2	206.2	36.7	268.9	47.8	13.5	2.4	5.7	1.0	8.2	1.5	13.5	2.4	10.6	3.7	5.8	2.793	0.103
	hwangryong3	565.0	443.7	78.5	121.4	21.5	114.9	27.7	28.4	5.0	152.4	27.0	350.9	62.1	6.8	1.2	4.5	0.8	4.8	0.8	17.3	3.1	10.1	3.0	4.6	1.733	0.063
	mooan2	885.4	661.7	74.7	223.7	25.3	101.8	15.1	42.2	4.8	470.0	53.1	291.8	33.0	8.7	1.0	8.9	1.0	10.3	1.2	53.5	6.0	9.9	2.0	5.7	4.194	0.133
	youngdam2	355.1	288.0	81.1	67.1	18.9	112.1	40.3	4.4	1.2	33.8	9.5	74.7	21.0	1.8	0.5	0.3	0.1	2.7	0.8	2.8	0.8	3.3	0.2	1.0	0.507	0.006
	mujunamdaechun1	464.1	379.6	81.8	84.5	18.2	200.0	43.6	26.2	5.6	149.2	32.2	55.3	11.9	4.9	1.1	0.8	0.2	3.9	0.9	3.8	0.8	4.3	0.4	1.2	0.871	0.016
	mihochun5	471.5	355.8	75.5	115.7	24.5	102.5	18.5	33.4	7.1	271.8	57.6	180.9	38.4	5.4	1.1	4.4	0.9	2.5	0.5	38.1	8.1	9.7	4.4	8.2	5.526	0.288
	geumganggapmun	536.6	400.9	74.7	135.7	25.3	100.3	12.4	5.0	0.9	35.8	6.7	96.3	17.9	0.6	0.1	0.5	0.1	0.9	0.2	1.5	0.3	3.2	0.9	2.2	1.312	0.039
	yongdam4	575.2	453.9	78.9	121.3	21.1	106.1	35.2	5.1	0.9	51.4	8.9	103.9	18.1	2.1	0.4	1.4	0.2	2.2	0.4	5.3	0.9	8.0	1.1	2.6	1.539	0.022
	daechung	624.1	511.2	81.9	112.9	18.1	104.1	34.2	37.4	6.0	157.2	25.2	243.4	39.0	10.3	1.7	3.5	0.6	12.2	1.9	7.6	1.2	2.9	0.2	1.1	0.575	0.006
	chogang2	664.6	535.0	80.5	129.6	19.5	96.2	34.0	2.9	0.4	28.2	4.2	77.2	11.6	1.1	0.2	0.7	0.1	1.5	0.2	2.1	0.3	10.4	1.1	3.4	2.251	0.029

Table B-8: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Hangang River watershed (0 ~ 20%) for second step

	Station	Total Area	Pervious		Impervious		Rainfall	Slope	Large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km²	km²	(%)	km²	(%)	yearly	aver-age (%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)	DO	BOD	COD	TN	TP
0 ~ 20 %	inbukchun2	660.1	414.9	62.9	89.3	13.5	93.1	40.4	13.4	2.0	39.5	6.0	432.6	65.5	8.9	1.4	0.8	0.1	4.5	0.7	4.6	0.7	11.1	0.9	2.4	1.739	0.026
	hawchundam1	1265.7	863.6	68.2	181.6	14.4	95.0	43.0	23.0	1.8	111.7	8.8	949.5	75.0	21.0	1.7	2.3	0.2	5.1	0.4	36.9	2.9	9.8	0.8	2.0	1.121	0.027
	soyangdam1	400.5	342.6	85.5	57.9	14.5	103.7	46.9	2.5	0.6	12.0	3.0	339.4	84.7	0.9	0.2	0.5	0.1	2.4	0.6	42.8	10.7	9.1	0.9	2.2	1.459	0.018
	soyangdam5	278.2	233.5	83.9	44.7	16.1	98.8	45.2	3.9	1.4	14.3	5.1	245.0	88.1	1.3	0.5	6.8	2.5	0.9	0.3	6.1	2.2	9.9	1.2	2.4	1.705	0.022
	naelinchun1	1084.4	908.7	83.8	175.7	16.2	105.7	45.9	5.8	0.5	57.4	5.3	1004.4	92.6	5.7	0.5	1.4	0.1	4.0	0.4	5.8	0.5	11.1	0.6	1.7	2.180	0.014
	okdongchun2	495.3	414.0	83.6	81.2	16.4	97.0	50.9	3.5	0.7	25.6	5.2	459.7	92.8	1.5	0.3	0.3	0.1	3.4	0.7	1.3	0.3	11.3	0.7	1.5	1.671	0.013
	chunchendam2	774.9	645.5	83.3	129.4	16.7	104.2	44.1	18.7	2.4	56.6	7.3	672.1	86.7	4.8	0.6	1.4	0.2	4.1	0.5	17.2	2.2	9.7	0.9	2.4	1.315	0.020
	odaechun2	451.7	375.9	83.2	75.8	16.8	105.7	46.3	4.7	1.0	33.2	7.4	407.2	90.1	2.0	0.5	1.9	0.4	1.1	0.2	1.6	0.4	11.2	0.8	2.3	3.478	0.037
	gapyungchun5	305.4	254.1	83.2	51.3	16.8	111.0	48.3	5.3	1.7	18.5	6.1	274.1	89.7	2.2	0.7	0.2	0.1	2.1	0.7	3.1	1.0	11.0	0.9	2.0	2.507	0.035
	gyechun2	283.7	234.6	82.7	49.1	17.3	114.0	43.7	1.4	0.5	36.0	12.7	243.0	85.7	0.4	0.1	0.1	0.0	0.8	0.3	2.0	0.7	10.2	0.8	2.1	1.798	0.013
	paldangdam	132.5	109.5	82.6	23.0	17.4	103.3	28.7	4.5	3.4	18.1	13.7	92.3	69.7	1.7	1.3	2.7	2.1	1.0	0.8	12.1	9.1	10.9	1.3	3.6	2.121	0.048
	pyungchanggang1	402.5	332.2	82.5	70.3	17.5	111.4	39.2	4.3	1.1	40.5	10.1	350.6	87.1	2.6	0.7	0.1	0.0	2.3	0.6	2.0	0.5	11.1	0.8	1.8	3.598	0.027
	deokchun	371.5	305.9	82.4	65.5	17.6	93.1	48.8	5.8	1.6	39.5	10.6	316.3	85.1	1.1	0.3	0.9	0.2	3.4	0.9	4.4	1.2	10.7	1.0	2.7	2.965	0.034
	jojongchun3	260.6	214.6	82.4	46.0	17.6	115.9	38.1	5.6	2.2	29.9	11.5	213.9	82.1	4.5	1.7	0.0	0.0	1.2	0.5	5.3	2.0	11.0	1.1	2.6	3.298	0.057
	chungjudam	833.6	686.6	82.4	147.1	17.6	101.4	41.6	15.9	1.9	117.1	14.0	627.0	75.2	2.5	0.3	1.4	0.2	11.3	1.4	58.5	7.0	9.0	0.8	2.2	2.236	0.021
	youngwol1	1022.9	840.4	82.2	182.3	17.8	97.6	49.8	17.9	1.8	106.8	10.4	867.7	84.8	6.6	0.6	1.8	0.2	12.3	1.2	9.5	0.9	10.8	0.9	2.3	2.834	0.069
	joyanggang	74.1	60.8	82.1	13.2	17.9	94.8	48.6	1.3	1.7	8.9	12.0	62.1	83.8	0.2	0.3	0.1	0.1	0.5	0.7	1.1	1.5	11.0	0.8	2.3	2.652	0.027
	chunsunggyo	189.4	155.4	82.1	34.0	17.9	108.2	38.7	4.3	2.3	19.7	10.4	154.6	81.6	4.1	2.2	0.1	0.1	2.3	1.2	4.2	2.2	10.8	1.2	3.1	1.667	0.030
	choyanggang	918.7	753.6	82.0	165.0	18.0	109.4	43.0	11.9	1.3	126.2	13.7	760.0	82.7	4.4	0.5	3.0	0.3	5.3	0.6	7.7	0.8	11.0	0.8	2.3	2.652	0.027
	chungpyungdam1	818.4	670.2	81.9	148.2	18.1	109.8	37.0	17.0	2.1	106.8	13.1	660.5	80.7	7.9	1.0	2.3	0.3	7.9	1.0	15.9	1.9	10.4	1.0	3.0	1.969	0.033
	sangchun	182.3	149.2	81.8	33.2	18.2	98.5	43.3	2.9	1.6	26.3	14.4	149.2	81.8	0.7	0.4	0.7	0.4	1.3	0.7	1.3	0.7	11.1	1.0	2.2	2.488	0.034
	juchungang2	607.4	496.5	81.7	110.9	18.3	113.1	36.7	7.8	1.3	87.1	14.3	499.0	82.2	2.1	0.3	1.4	0.2	5.4	0.9	4.6	0.8	11.0	0.9	2.1	2.988	0.016
	geumgyechun	155.4	126.9	81.7	28.5	18.3	109.1	39.6	2.0	1.3	23.8	15.3	127.0	81.7	0.3	0.2	0.0	0.0	0.8	0.5	1.4	0.9	10.8	0.9	1.8	2.500	0.033
	chungjudam4	502.1	403.1	80.3	92.2	18.4	103.6	43.7	13.0	2.6	57.5	11.4	401.1	79.9	2.1	0.4	3.5	0.7	12.1	2.4	6.0	1.2	11.1	1.3	2.2	2.479	0.022
	gyesandam3	315.3	257.3	81.6	58.0	18.4	97.0	38.5	5.3	1.7	50.4	16.0	252.2	80.0	1.1	0.3	1.2	0.4	1.0	0.3	4.2	1.3	9.7	1.2	3.0	1.834	0.025
	sumgang3	319.9	261.1	81.6	58.9	18.4	107.8	33.9	5.1	1.6	48.8	15.2	254.3	79.5	3.3	1.0	1.2	0.4	2.9	0.9	4.3	1.3	10.2	1.8	4.0	4.454	0.195
	paldamdam4	380.3	309.7	81.4	70.6	18.6	107.9	33.4	15.0	4.0	42.1	11.1	295.1	77.6	7.4	1.9	0.4	0.1	5.9	1.6	14.3	3.8	11.0	1.2	3.2	1.800	0.032
	hongchungang1	1006.1	819.0	81.4	187.0	18.6	109.0	37.4	47.5	4.7	105.8	10.5	826.4	82.1	3.3	0.3	2.3	0.2	7.6	0.8	13.1	1.3	10.6	0.9	2.3	2.423	0.023
	damchun1	256.8	203.4	79.2	49.1	19.1	96.5	33.1	6.4	2.5	51.2	19.9	189.7	73.9	1.4	0.5	0.8	0.3	0.6	0.2	2.4	1.0	10.6	0.9	2.7	1.841	0.028
	youngwol2	809.2	654.4	80.9	154.9	19.1	102.2	41.0	19.0	2.3	128.7	15.9	631.1	78.0	5.0	0.6	3.0	0.4	14.6	1.8	7.9	1.0	11.0	0.9	2.3	2.976	0.034
	junchun	170.7	137.7	80.7	33.0	19.3	108.0	32.6	5.2	3.0	28.2	16.5	133.7	78.3	1.2	0.7	0.4	0.2	1.0	0.6	1.1	0.7	9.8	1.2	2.0	1.295	0.023
	sukmunchun	99.2	79.9	80.6	19.3	19.4	93.0	39.9	3.0	3.0	18.2	18.4	75.3	75.9	0.4	0.4	0.5	0.5	1.2	1.2	0.6	0.6	11.8	1.3	2.7	3.713	0.104
	heukchun3	314.1	252.2	80.3	61.8	19.7	113.5	33.3	13.0	4.1	57.2	18.2	232.8	74.1	3.7	1.2	1.3	0.4	2.8	0.9	3.2	1.0	10.3	1.1	2.8	2.858	0.035

Table B-9: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Hangang River watershed (20 % ~) for second step

	Station	Total Area	Pervious		Impervious		Rainfall	Slope	Large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km²	km²	(%)	km²	(%)	yearly	average	km²	(%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)	km²	(%)	DO	BOD	COD	TN	TP
20 % ~ 25 %	yeju1	536.0	427.3	79.7	108.7	20.3	101.7	25.8	17.6	3.3	123.9	23.1	354.4	66.1	14.4	2.7	5.4	1.0	5.9	1.1	14.5	2.7	10.0	1.4	3.3	2.822	0.060
	dongjinchun2	124.0	98.2	79.2	25.8	20.8	96.4	29.7	3.8	3.1	31.1	25.1	83.7	67.5	1.9	1.6	0.0	0.0	1.6	1.3	1.8	1.4	10.4	1.4	2.5	2.340	0.036
	jechuchun2	268.4	212.1	79.1	56.2	20.9	109.6	32.0	14.9	5.5	54.1	20.2	193.4	72.1	0.6	0.2	0.2	0.1	3.5	1.3	1.6	0.6	11.5	1.8	3.8	5.667	0.272
	damchun3	86.2	68.0	78.9	18.2	21.1	94.5	25.6	2.6	3.0	27.8	32.2	50.9	59.0	1.3	1.6	0.6	0.7	0.2	0.2	2.8	3.2	10.4	1.1	2.9	2.389	0.035
	deokyeunlee	317.1	250.0	78.8	67.1	21.2	101.0	27.6	10.6	3.3	83.0	26.2	200.0	63.1	10.0	3.2	0.8	0.3	5.2	1.6	7.5	2.4	10.8	1.2	2.9	2.445	0.038
	sumgang2	108.1	84.8	78.5	23.3	21.5	107.7	25.9	7.5	7.0	25.7	23.7	68.8	63.6	2.0	1.8	1.1	1.0	1.1	1.0	1.9	1.8	10.7	1.5	3.2	2.360	0.053
	segokchun	113.5	89.0	78.4	24.5	21.6	105.4	29.2	6.9	6.1	27.1	23.9	74.9	66.0	1.5	1.3	0.3	0.3	1.3	1.1	1.5	1.3	10.6	1.6	3.6	4.646	0.129
	yeamdam	228.0	176.5	77.4	51.5	22.6	105.2	24.8	26.1	11.4	48.1	21.1	131.6	57.7	4.0	1.8	0.4	0.2	3.6	1.6	14.2	6.2	10.5	1.1	2.8	1.657	0.030
	guri	413.6	319.3	77.2	94.3	22.8	105.2	23.4	39.8	9.6	89.1	21.5	249.0	60.2	11.5	2.8	0.4	0.1	10.1	2.4	13.7	3.3	10.7	1.5	3.7	2.478	0.052
	gyunganchun6	561.1	433.2	77.2	128.0	22.8	105.6	26.5	63.3	11.3	92.9	16.6	364.1	64.9	17.2	3.1	1.6	0.3	11.1	2.0	10.9	1.9	9.9	3.9	6.6	5.066	0.166
	hwayangchun	56.3	43.3	76.8	13.0	23.2	100.3	39.7	2.1	3.7	21.9	39.0	30.4	54.0	0.8	1.3	0.2	0.3	0.2	0.4	0.7	1.3	11.3	0.7	1.6	2.138	0.022
	yeumsungchun	143.2	110.0	76.8	33.2	23.2	101.0	24.6	6.9	4.8	51.9	36.2	77.9	54.4	2.5	1.7	0.5	0.3	1.2	0.9	2.4	1.7	11.0	1.8	3.3	2.526	0.064
	wonjuchun	153.0	117.3	76.7	35.6	23.3	110.5	31.1	19.5	12.7	29.4	19.2	98.5	64.4	1.0	0.6	0.8	0.5	2.7	1.8	1.2	0.8	9.3	7.5	8.5	10.386	0.758
	damchul5	152.2	116.3	76.5	35.8	23.5	97.2	30.8	13.8	9.0	44.0	28.9	81.4	53.5	4.9	3.2	1.4	0.9	2.6	1.7	4.1	2.7	10.2	1.8	3.8	2.865	0.089
	yodochun	150.6	114.9	76.3	35.6	23.7	102.2	20.9	7.8	5.2	56.8	37.7	76.9	51.1	3.2	2.2	1.0	0.6	2.3	1.5	2.5	1.7	10.7	2.4	4.0	2.727	0.105
	chungjujojungji	84.4	64.3	76.3	20.0	23.7	100.5	20.8	7.6	9.0	24.5	29.0	36.7	43.5	6.0	7.1	0.1	0.2	1.9	2.2	7.5	8.9	11.9	1.4	2.4	2.483	0.028
	paldangdam1	505.1	382.4	75.7	122.7	24.3	110.7	20.8	35.5	7.0	197.7	39.1	230.2	45.6	10.9	2.2	3.4	0.7	8.6	1.7	18.9	3.7	11.3	1.6	3.7	2.502	0.058
	yeuju2	76.1	57.6	75.7	18.5	24.3	103.1	10.3	6.1	8.0	30.1	39.5	29.3	38.5	1.4	1.9	3.2	4.2	1.8	2.4	4.2	5.5	10.8	1.6	3.5	2.834	0.061
	chungmichun3	596.6	447.9	75.1	148.7	24.9	104.0	17.3	34.3	5.7	257.8	43.2	262.3	44.0	15.4	2.6	3.3	0.5	10.6	1.8	13.0	2.2	10.9	2.9	5.1	3.767	0.101
25 % ~	gokneungchun3	261.5	193.5	74.0	67.9	26.0	106.2	17.0	31.0	11.8	84.4	32.3	116.2	44.5	13.5	5.1	1.3	0.5	11.4	4.3	3.7	1.4	9.4	7.4	9.8	8.298	0.268
	bokhachun3	309.5	227.4	73.5	82.2	26.5	110.3	12.9	31.4	10.2	135.5	43.8	124.5	40.2	7.3	2.4	1.8	0.6	3.2	1.0	5.6	1.8	9.7	4.2	5.5	6.322	0.214
	tanchun5	302.8	215.6	71.2	87.1	28.8	105.3	18.9	92.8	30.6	36.9	12.2	146.6	48.4	7.3	2.4	2.4	0.8	13.1	4.3	3.7	1.2	6.9	17.9	11.9	15.417	1.047
	hangju	124.9	88.6	70.9	36.3	29.1	111.4	14.0	38.1	30.5	23.6	18.9	43.7	35.0	4.7	3.7	0.5	0.4	5.3	4.2	9.1	7.3	8.8	4.0	6.2	7.036	0.356
	jungryangchun4	350.4	246.7	70.4	103.7	29.6	111.3	16.2	111.3	31.8	55.3	15.8	157.8	45.0	6.4	1.8	2.3	0.7	12.1	3.4	5.1	1.5	7.9	12.1	11.2	17.647	1.439
	ananyangchun5	281.2	182.6	65.0	98.6	35.0	103.0	15.5	130.4	46.4	32.1	11.4	104.2	37.1	3.9	1.4	0.2	0.1	6.9	2.5	3.5	1.2	6.1	9.8	11.1	18.217	0.972
	Norangjin	51.0	32.1	62.9	18.9	37.1	111.3	10.3	33.9	66.5	0.5	1.1	8.7	17.0	0.8	1.5	0.0	0.1	1.2	2.4	5.8	11.5	9.0	3.5	5.5	5.669	0.260
	Hongjechun	51.0	30.9	60.5	20.1	39.5	116.2	18.5	32.4	63.7	0.0	0.1	13.9	27.2	0.6	1.2	0.2	0.4	3.8	7.4	0.0	0.0	12.1	3.6	4.9	6.710	0.172
	gulpochun3	131.8	77.6	58.9	54.2	41.1	99.9	6.7	67.3	51.1	32.3	24.5	17.5	13.3	6.6	5.0	0.1	0.1	5.9	4.5	1.9	1.4	3.1	11.4	13.9	18.632	1.760

Table B-10: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Nakdong River watershed (0 ~ 20 %) for second step

	Station	Total Area	Pervious		Impervious		Rainfall	Slope	Large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
0 ~ 20 %	bonghwa	357.2	299.4	83.8	57.8	16.2	98.0	49.1	2.4	0.7	16.1	4.5	332.6	93.1	1.1	0.3	1.0	0.3	1.9	0.5	2.1	0.6	11.5	0.8	2.4	1.968	0.037
	woonmundam1	302.0	249.8	82.7	52.2	17.3	101.7	44.3	3.7	1.2	32.5	10.8	252.8	83.7	1.7	0.6	1.9	0.6	2.9	1.0	6.4	2.1	8.8	1.4	2.6	1.271	0.018
	deokchungang1	106.3	87.8	82.7	18.4	17.3	158.5	47.1	1.8	1.6	7.3	6.9	93.8	88.3	0.7	0.7	0.3	0.3	1.7	1.6	0.6	0.6	10.1	0.6	1.4	1.198	0.037
	imhaho1	303.0	249.1	82.2	53.9	17.8	79.5	35.2	5.2	1.7	53.9	17.8	215.8	71.2	2.9	0.9	1.4	0.4	1.6	0.5	22.3	7.3	8.2	2.0	3.4	1.501	0.028
	dosan	617.9	507.7	82.2	110.2	17.8	92.3	46.4	7.0	1.1	85.8	13.9	514.0	83.2	2.0	0.3	2.7	0.4	1.9	0.3	4.4	0.7	11.5	0.8	2.5	2.360	0.044
	andong1	425.7	349.6	82.1	76.1	17.9	84.1	36.8	5.0	1.2	76.3	17.9	297.9	70.0	1.1	0.2	5.6	1.3	7.9	1.9	31.8	7.5	9.6	0.9	3.6	1.669	0.043
	yongjunchun1	397.8	325.8	81.9	72.0	18.1	85.0	40.4	5.7	1.4	56.5	14.2	324.1	81.5	1.5	0.4	1.7	0.4	3.4	0.9	4.9	1.2	9.7	1.5	2.0	1.751	0.025
	ilanchun1	519.5	424.5	81.7	94.9	18.3	85.3	41.0	7.9	1.5	75.6	14.6	421.1	81.1	3.0	0.6	2.1	0.4	4.3	0.8	5.3	1.0	11.4	0.8	2.7	3.515	0.017
	imchun	218.2	178.3	81.7	39.9	18.3	129.3	41.5	3.2	1.4	33.9	15.5	175.1	80.2	1.7	0.8	1.3	0.6	1.6	0.7	1.5	0.7	10.4	0.9	2.7	1.390	0.052
	namgangdam1	484.8	394.0	81.3	90.8	18.7	136.8	34.5	11.4	2.4	87.9	18.1	346.3	71.4	4.1	0.8	9.8	2.0	6.8	1.4	18.4	3.8	8.9	1.2	2.7	1.247	0.027
	sinbanchun	194.7	158.0	81.1	36.7	18.9	105.7	39.0	4.3	2.2	36.2	18.6	147.8	75.9	1.0	0.5	2.3	1.2	0.9	0.5	2.3	1.2	10.3	1.6	3.2	2.446	0.066
	youngang2	672.1	542.5	80.7	129.6	19.3	104.7	36.4	19.1	2.8	113.3	16.9	518.5	77.1	4.5	0.7	3.6	0.5	7.6	1.1	5.5	0.8	11.1	1.2	2.8	2.010	0.035
	michun	374.5	302.2	80.7	72.3	19.3	86.3	34.1	8.7	2.3	71.8	19.2	283.0	75.6	2.3	0.6	2.4	0.6	2.3	0.6	4.0	1.1	11.1	1.2	3.6	3.585	0.048
	yangsanchun1	138.9	112.0	80.7	26.8	19.3	118.4	36.7	6.1	4.4	17.3	12.4	108.4	78.0	4.5	3.2	0.3	0.2	1.2	0.9	1.2	0.9	9.8	1.1	2.7	2.542	0.074
	guchangweechun2	239.4	192.9	80.6	46.5	19.4	111.3	35.3	6.5	2.7	44.1	18.4	184.0	76.9	1.6	0.7	0.6	0.2	1.7	0.7	0.9	0.4	10.5	1.1	2.8	1.787	0.054
	milyanggang3	248.8	200.2	80.5	48.6	19.5	94.6	38.8	5.8	2.3	51.9	20.9	181.3	72.9	2.2	0.9	1.8	0.7	2.4	1.0	3.5	1.4	10.6	2.3	4.4	3.013	0.120
	mulgeum	254.8	204.8	80.4	50.0	19.6	107.6	37.4	9.4	3.7	44.6	17.5	179.0	70.3	3.3	1.3	1.6	0.6	4.9	1.9	12.0	4.7	10.3	2.6	6.0	3.022	0.130
	hapchundam1	491.6	395.2	80.4	96.4	19.6	107.7	31.1	11.7	2.4	106.2	21.6	345.3	70.2	2.0	0.4	2.9	0.6	6.9	1.4	16.6	3.4	8.6	1.5	2.5	1.723	0.017
	ssanggyechun	480.3	385.0	80.2	95.1	19.8	91.0	31.4	13.6	2.8	104.0	21.7	348.8	72.6	2.2	0.5	3.0	0.6	2.6	0.5	6.1	1.3	11.7	1.6	4.5	3.226	0.052
	gyunghogang2	1042.1	835.3	80.1	206.9	19.9	113.3	34.0	25.8	2.5	221.4	21.2	755.8	72.5	10.9	1.0	6.7	0.6	11.5	1.1	9.9	1.0	10.4	1.2	3.4	1.596	0.042
	ramchun2	264.1	211.6	80.1	52.5	19.9	124.0	34.4	6.5	2.5	60.9	23.1	189.3	71.7	3.7	1.4	1.1	0.4	0.5	0.2	2.2	0.8	10.5	1.3	3.1	1.771	0.062

Table B-11: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Nakdong River watershed (20 % ~) for second step

	Station	Total Area	Pervious		Impervious		Rainfall	Slope	Large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
20 ~ 25%	banbyunchun1a	583.2	465.4	79.8	116.8	20.0	81.3	42.6	40.3	6.9	74.5	12.8	452.7	77.6	2.1	0.4	2.1	0.4	5.6	1.0	4.9	0.8	11.1	1.1	4.1	1.128	0.018
	ianchun	242.3	193.3	79.8	49.0	20.2	99.0	31.5	7.0	2.9	53.9	22.2	173.3	71.5	1.7	0.7	0.9	0.4	2.9	1.2	2.7	1.1	10.3	1.1	2.7	1.697	0.025
	hamyangweechun2	177.9	141.8	79.7	36.1	20.3	115.7	34.8	5.8	3.3	41.4	23.3	125.4	70.5	2.4	1.4	0.8	0.5	0.8	0.5	1.2	0.7	10.9	1.5	3.7	3.123	0.121
	weechun1	392.8	312.7	79.6	80.1	20.4	92.8	31.6	12.9	3.3	93.6	23.8	273.1	69.5	3.6	0.9	2.4	0.6	2.6	0.7	4.6	1.2	11.8	1.4	3.8	4.035	0.069
	yeryungchun	114.4	91.0	79.5	23.4	20.5	106.9	36.1	4.6	4.0	26.8	23.4	79.6	69.6	1.0	0.8	0.6	0.5	0.4	0.3	1.4	1.3	9.2	2.1	7.1	2.542	0.104
	chungdochun	518.0	408.1	78.8	109.9	21.2	99.1	34.2	18.0	3.5	145.1	28.0	337.0	65.1	3.5	0.7	2.7	0.5	4.3	0.8	7.4	1.4	11.4	1.6	4.2	3.686	0.063
	naesungchun1	794.2	623.8	78.5	170.4	21.5	94.7	27.6	21.1	2.7	237.6	29.9	509.8	64.2	4.3	0.5	3.8	0.5	9.1	1.2	8.4	1.1	10.6	1.0	2.6	4.232	0.095
	gyuchangdongchun2	197.9	155.4	78.5	42.6	21.5	100.2	32.9	5.6	2.8	57.0	28.8	129.7	65.5	0.8	0.4	0.3	0.1	3.3	1.7	1.3	0.7	10.2	1.1	2.9	2.906	0.079
	dalsung	155.5	122.0	78.5	33.5	21.5	92.5	24.3	5.8	3.7	45.9	29.5	93.7	60.3	1.5	1.0	1.6	1.0	2.5	1.6	4.5	2.9	11.2	2.1	5.2	2.927	0.096
	andong5	363.2	284.6	78.3	78.7	21.7	89.0	26.6	11.2	3.1	115.2	31.7	221.7	61.0	3.4	0.9	2.8	0.8	3.0	0.8	6.0	1.7	11.0	1.0	4.2	2.300	0.040
	gamchun2	1162.4	910.4	78.3	252.0	21.7	89.7	29.1	41.7	3.6	327.0	28.1	743.4	64.0	8.2	0.7	5.6	0.5	21.1	1.8	15.5	1.3	10.1	1.1	3.6	4.348	0.159
	geumhogang3	1573.4	1230.5	78.2	342.9	21.8	90.6	27.5	80.6	5.1	306.1	19.5	508.1	32.3	18.1	1.2	8.8	0.6	16.1	1.0	24.0	1.5	10.8	3.2	7.7	5.192	0.268
	yechun1	255.6	199.7	78.1	55.9	21.9	88.0	22.9	6.8	2.7	88.0	34.4	141.9	55.5	3.3	1.3	3.8	1.5	3.8	1.5	8.0	3.1	10.8	1.0	3.8	2.425	0.029
	milyanggang1	349.3	271.8	77.8	76.5	21.9	103.4	41.9	40.1	11.5	40.9	11.7	247.4	70.8	5.2	1.5	2.7	0.8	6.8	1.9	5.4	1.5	10.1	1.0	2.4	2.358	0.046
	hanchun	256.5	200.0	78.0	56.4	22.0	99.3	27.0	9.5	3.7	82.7	32.3	157.7	61.5	2.4	0.9	1.0	0.4	0.9	0.4	2.2	0.9	10.3	1.4	3.6	3.114	0.110
	youngsun	17.0	13.2	77.9	3.8	22.1	90.3	22.4	0.5	3.2	5.5	32.2	8.8	51.8	0.1	0.5	0.2	1.0	0.7	4.1	1.2	7.2	10.7	1.0	3.6	2.578	0.058
	geumhogang4	213.4	166.0	77.8	47.4	22.2	98.6	22.3	22.4	10.5	31.1	14.6	146.9	68.8	5.0	2.3	1.0	0.5	3.5	1.6	3.5	1.6	12.0	3.7	8.2	5.062	0.293
	andong	187.8	145.8	77.7	42.0	22.3	83.8	28.1	15.1	8.1	40.0	21.3	112.6	59.9	2.1	1.1	4.2	2.2	6.9	3.7	6.9	3.7	10.8	1.0	4.0	1.889	0.046
	namgang3	711.9	552.6	77.6	159.3	22.4	120.4	28.2	43.3	6.1	210.7	29.6	420.0	59.0	6.5	0.9	6.9	1.0	6.7	0.9	17.7	2.5	10.1	2.7	5.5	3.018	0.124
	weechun6	436.2	338.4	77.6	97.8	22.4	83.6	19.1	13.8	3.2	160.5	36.8	238.3	54.6	4.4	1.0	4.1	0.9	4.0	0.9	11.2	2.6	10.4	1.4	4.7	2.539	0.049
	hyunpung	109.2	84.6	77.5	24.5	22.5	98.4	30.4	8.6	7.9	22.2	20.3	70.8	64.9	1.5	1.4	0.4	0.4	2.1	2.0	3.5	3.2	10.9	2.9	6.7	4.217	0.207
	youngjusuchun2	364.6	282.2	77.4	82.4	22.6	101.9	28.1	19.2	5.3	110.0	30.2	224.6	61.6	1.5	0.4	1.8	0.5	4.1	1.1	3.4	0.9	9.1	2.0	3.8	5.687	0.240
	namji	467.2	361.3	77.3	106.0	22.7	99.4	25.4	18.7	4.0	171.3	36.7	236.8	50.7	9.0	1.9	5.4	1.2	6.1	1.3	19.9	4.3	10.3	2.7	6.0	3.239	0.159
	andong3	38.0	29.3	77.2	8.6	22.8	87.4	20.3	1.7	4.6	13.4	35.3	21.3	56.1	0.3	0.9	0.0	0.1	0.2	0.6	1.0	2.5	10.7	1.1	4.1	2.120	0.040
	hamanchun2	216.2	167.0	77.2	49.3	22.8	103.8	26.4	10.5	4.9	75.2	34.8	117.3	54.3	2.5	1.2	2.9	1.4	1.7	0.8	6.0	2.8	10.1	3.0	6.5	4.780	0.194
	bakchun	289.1	223.2	77.2	65.9	22.8	89.9	25.0	11.2	3.9	99.2	34.3	168.8	58.4	2.3	0.8	0.6	0.2	4.1	1.4	3.0	1.0	11.2	1.7	4.0	2.494	0.082
	gwangryuchun3	158.0	121.3	76.8	36.7	23.2	102.5	31.7	11.3	7.1	40.7	25.7	96.9	61.3	1.4	0.9	1.9	1.2	4.0	2.5	1.9	1.2	9.8	3.0	5.9	2.553	0.150
	daeam	189.6	145.6	76.8	44.0	23.2	96.4	25.4	8.0	4.2	68.6	36.2	96.3	50.8	1.8	1.0	1.8	1.0	5.0	2.6	8.1	4.3	11.2	3.1	6.9	4.116	0.193
	sangju2	207.2	158.8	76.7	48.3	23.3	92.2	19.1	7.0	3.4	79.4	38.3	105.7	51.0	1.6	0.8	1.7	0.8	5.4	2.6	6.3	3.0	10.1	0.9	3.4	2.491	0.059
	imhaejin	107.2	82.0	76.5	25.2	23.5	94.5	27.0	5.1	4.7	42.4	39.5	48.4	45.1	1.3	1.2	2.0	1.8	2.6	2.4	5.6	5.3	10.6	2.7	6.1	3.144	0.148
	sungju	120.1	91.9	76.5	28.3	23.5	84.5	20.6	9.6	8.0	32.1	26.8	63.0	52.4	2.0	1.7	1.9	1.5	5.4	4.5	6.1	5.1	11.0	2.1	5.0	2.996	0.095
	gyesungchun	107.1	81.8	76.3	25.3	23.7	94.9	23.9	5.4	5.1	42.9	40.0	53.2	49.7	1.2	1.1	0.9	0.9	0.6	0.5	2.9	2.7	8.6	3.4	8.0	5.392	0.365
	gupo	72.1	54.8	76.0	17.3	24.0	114.9	22.3	11.5	16.0	14.3	19.9	38.8	53.8	0.5	0.7	0.1	0.2	1.3	1.7	5.6	7.8	10.2	2.6	6.0	3.109	0.132
	byungsungchun	341.0	258.1	75.7	82.8	24.3	97.5	31.3	19.2	5.6	137.4	40.3	167.6	49.2	4.3	1.3	2.5	0.7	4.0	1.2	5.9	1.7	10.2	1.7	4.5	3.883	0.211
	geumchun	165.2	124.3	75.3	40.9	24.7	96.3	18.6	8.3	5.0	75.8	45.9	74.8	45.3	1.1	0.7	1.0	0.6	1.0	0.6	3.2	1.9	9.9	3.3	6.1	2.511	0.088
25 % ~	yangsanchun3	107.3	79.0	74.0	27.8	26.0	114.1	28.6	15.3	14.2	14.5	13.5	64.3	60.0	3.9	3.6	0.9	0.8	6.2	5.8	1.6	1.5	10.1	3.8	7.1	4.278	0.246
	samrangjin	435.8	322.1	73.9	113.7	26.1	100.5	20.4	32.0	7.3	211.3	48.5	149.0	34.2	6.1	1.4	6.3	1.5	8.9	2.0	22.3	5.1	10.4	2.8	5.9	3.089	0.163
	wegwan	500.7	369.4	73.8	131.3	26.2	86.7	20.4	54.7	10.9	164.6	32.9	239.8	47.9	5.9	1.2	4.3	0.9	17.1	3.4	14.2	2.8	10.2	1.8	4.5	3.041	0.108
	hwapochun	138.1	101.2	73.3	36.9	26.7	106.6	23.4	13.8	10.0	51.3	37.2	61.5	44.5	3.5	2.5	1.8	1.3	3.8	2.8	2.4	1.8	8.6	3.5	7.2	3.313	0.150
	geumhogang6	287.2	209.0	72.8	77.9	27.1	91.1	26.1	67.1	23.4	34.2	11.9	163.2	56.8	7.4	2.6	2.3	0.8	6.8	2.4	5.8	2.0	10.2	3.8	9.3	7.244	0.543
	nakdongganghagu1	288.6	206.8	71.7	81.8	28.3	115.3	17.5	38.8	13.4	109.1	37.8	104.0	36.0	7.7	2.7	1.5	0.5	13.3	4.6	14.2	4.9	10.5	2.2	5.4	3.293	0.110
	goryung	210.6	149.7	71.1	60.9	28.9	93.7	20.1	47.9	22.8	43.2	20.5	96.6	45.9	5.8	2.8	3.1	1.5	6.7	3.2	7.2	3.4	10.7	2.9	6.8	4.178	0.215
	nakdongganghagu2	54.7	37.7	69.0	17.0	31.0	120.9	14.4	19.5	35.7	7.3	13.4	15.5	28.4	1.1	2.0	1.1	2.1	1.2	2.2	8.8	16.1	10.5	2.6	6.3	3.318	0.129

Table B-12: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Geum-sum-youngsan River watershed (0% ~ 25 %) for second step

	Station	Total Area	Pervious		Impervious		Rainfall	Slope	Large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	TN (mg/L)	TP (mg/L)
0 ~ 20 %	deokeun	184.2	154.9	84.1	29.3	15.9	143.0	45.3	1.8	1.0	5.4	2.9	173.2	94.0	1.5	0.8	0.6	0.3	0.5	0.3	1.3	0.7	9.6	1.3	3.4	2.298	0.046
	bakgokchun1	85.7	70.6	82.5	15.0	17.5	102.2	34.1	1.1	1.3	11.0	12.8	68.5	80.0	2.5	2.9	0.1	0.1	0.3	0.3	2.3	2.6	11.5	1.3	2.5	2.389	0.042
	juamdam	702.4	578.8	82.4	123.7	17.6	119.8	34.6	9.7	1.4	104.6	14.9	527.1	75.0	23.2	3.3	4.0	0.6	1.6	0.2	32.1	4.6	7.5	0.9	2.8	0.886	0.013
	daechung	624.1	511.2	81.9	112.9	18.1	104.1	34.2	19.5	3.1	106.9	17.1	429.0	68.7	5.2	0.8	3.6	0.6	4.2	0.7	55.6	8.9	9.8	0.8	3.5	1.915	0.018
	mujunamdaechun-1	464.1	379.6	81.8	84.5	18.2	200.0	43.6	8.9	1.9	58.0	12.5	385.2	83.0	3.8	0.8	1.6	0.3	3.7	0.8	2.9	0.6	10.7	1.1	3.0	2.177	0.039
	imsil	429.3	351.1	81.8	78.2	18.2	114.2	34.0	9.3	2.2	77.3	18.0	310.4	72.3	4.9	1.2	2.1	0.5	1.0	0.2	24.3	5.7	10.8	1.1	3.3	1.608	0.038
	yongpo	127.7	104.4	81.8	23.3	18.2	96.6	43.1	2.2	1.7	16.7	13.1	104.5	81.8	0.4	0.3	0.7	0.5	1.5	1.1	1.7	1.4	9.9	0.9	3.5	1.662	0.020
	chopyungchun	132.6	108.2	81.6	24.4	18.4	100.5	32.1	2.8	2.1	24.3	18.3	97.1	73.3	1.5	1.1	0.8	0.6	0.3	0.2	5.8	4.4	10.7	1.1	2.3	1.580	0.034
	youngdong	222.8	180.9	81.2	41.9	18.8	173.9	36.4	5.3	2.4	37.7	16.9	169.9	76.3	1.0	0.4	1.6	0.7	3.0	1.3	4.4	2.0	10.2	1.1	3.7	2.132	0.036
	yongdam	355.1	288.0	81.1	67.1	18.9	112.1	40.3	5.5	1.5	51.8	14.6	279.1	78.6	7.6	2.1	0.9	0.2	6.9	1.9	3.3	0.9	10.9	0.8	3.3	1.691	0.018
	nonsanchun1	219.4	177.9	81.1	41.6	18.9	110.3	34.0	5.2	2.4	43.3	19.7	160.2	73.0	2.0	0.9	0.7	0.3	0.6	0.3	7.4	3.4	10.4	1.2	3.1	3.576	0.034
	hadong	156.3	126.5	80.9	29.8	19.1	143.1	39.8	5.4	3.4	21.9	14.0	120.3	77.0	1.7	1.1	1.0	0.6	3.1	2.0	2.9	1.8	9.0	1.2	4.8	2.275	0.047
	donggye	144.4	116.6	80.8	27.7	19.2	116.1	35.4	2.2	1.6	28.8	19.9	101.5	70.3	7.9	5.5	1.7	1.2	0.6	0.4	1.6	1.1	9.7	1.1	3.6	1.445	0.043
	jisukchun2	215.8	174.2	80.7	41.6	19.3	111.9	29.7	5.6	2.6	44.7	20.7	147.5	68.4	3.7	1.7	2.1	1.0	2.7	1.3	9.6	4.4	10.8	2.2	4.4	2.674	0.109
	jisukchun1	237.7	191.6	80.6	45.9	19.3	116.0	32.9	5.8	2.5	45.4	19.1	170.8	71.9	7.8	3.3	2.1	0.9	1.6	0.7	4.0	1.7	10.2	1.4	3.1	1.367	0.038
	chogang2	664.6	535.0	80.5	129.6	19.5	96.2	34.0	13.1	2.0	142.1	21.4	493.5	74.3	5.2	0.8	1.6	0.2	2.7	0.4	6.5	1.0	10.4	1.1	3.4	2.251	0.029
	bosungchun-1	283.8	228.2	80.4	55.5	19.6	122.3	35.3	6.1	2.1	61.9	21.8	201.2	70.9	8.1	2.8	2.6	0.9	0.9	0.3	3.0	1.1	10.4	1.0	3.1	1.240	0.028
	youngdongchun2	145.4	116.6	80.2	28.8	19.8	92.2	35.7	6.5	4.5	24.6	16.9	111.1	76.4	0.5	0.3	0.6	0.4	1.3	0.9	0.9	0.6	10.5	1.4	4.1	5.061	0.123
	guryu	489.0	391.8	80.1	97.2	19.9	120.0	36.6	13.9	2.8	108.7	22.2	343.0	70.1	9.6	2.0	5.0	1.0	2.2	0.5	6.5	1.3	10.0	1.3	3.7	2.382	0.053
	youdeungchun A	141.9	113.6	80.0	28.3	20.0	108.3	40.0	4.4	3.1	28.0	19.7	105.3	74.2	1.5	1.1	0.3	0.2	1.5	1.1	0.8	0.6	11.9	0.9	2.2	2.924	0.031
	jewon	89.9	72.0	80.0	18.0	20.0	99.0	33.1	2.2	2.4	18.7	20.8	62.4	69.4	1.0	1.2	0.3	0.3	2.1	2.3	3.3	3.6	10.3	1.0	3.7	1.765	0.029
20 % ~ 25%	gongju1	98.7	79.0	80.0	19.7	20.0	113.3	28.9	5.0	5.1	19.1	19.4	66.7	67.6	1.5	1.5	1.2	1.2	1.6	1.6	3.6	3.7	10.2	2.9	6.6	4.323	0.182
	churyungchun	355.9	284.3	79.9	71.6	20.1	111.9	31.8	10.3	2.9	79.5	22.3	249.9	70.2	8.9	2.5	1.8	0.5	1.6	0.4	3.9	1.1	11.1	0.9	2.6	2.818	0.017
	bonggok2gyo	156.9	125.3	79.9	31.6	20.1	107.7	32.8	8.5	5.4	24.1	15.4	115.9	73.9	5.1	3.2	0.6	0.4	1.6	1.0	1.2	0.7	11.2	1.9	3.3	3.439	0.182
	youguchun	282.6	225.5	79.8	57.1	20.2	105.1	31.4	8.8	3.1	67.6	23.9	197.4	69.8	3.0	1.1	2.2	0.8	1.2	0.4	2.5	0.9	10.2	1.7	2.8	1.785	0.037
	bochungchun4	113.6	90.4	79.6	23.2	20.4	94.2	32.4	2.9	2.5	28.2	24.8	77.2	68.0	1.1	0.9	0.7	0.6	1.5	1.3	2.1	1.9	10.5	1.1	2.7	2.029	0.035
	jichun	246.4	195.8	79.5	50.6	20.5	104.8	26.7	7.1	2.9	64.9	26.3	164.9	66.9	4.0	1.6	1.4	0.6	0.8	0.3	3.3	1.3	10.6	1.9	3.6	2.212	0.048
	yongsuchun	95.1	75.6	79.4	19.6	20.6	118.1	32.7	5.3	5.6	18.4	19.3	66.7	70.1	2.4	2.5	0.7	0.7	0.9	1.0	0.7	0.8	8.1	1.7	2.8	1.376	0.054
	bochungchun3	299.5	237.8	79.4	61.7	20.6	99.6	31.3	6.6	2.2	79.9	26.7	201.8	67.4	2.1	0.7	0.8	0.3	4.1	1.4	4.2	1.4	11.4	1.2	3.6	2.470	0.047
	bochungchun2	140.6	111.5	79.3	29.1	20.7	188.1	29.9	5.0	3.5	35.8	25.5	96.3	68.5	0.6	0.4	0.5	0.4	0.9	0.6	1.5	1.1	10.2	1.1	2.1	2.115	0.031
	yongdamdam4	575.2	453.9	78.9	121.3	21.1	106.1	35.2	16.6	2.9	146.7	25.5	377.2	65.6	23.0	4.0	1.8	0.3	5.7	1.0	4.2	0.7	8.7	1.2	2.8	1.658	0.022
	bosunggang-1	327.0	257.8	78.9	69.1	21.1	123.7	26.9	10.5	3.2	92.6	28.3	205.3	62.8	8.6	2.6	2.1	0.6	2.1	0.6	5.8	1.8	10.2	1.2	3.4	0.854	0.031
	namwon	227.0	178.9	78.8	48.2	21.2	113.7	26.6	6.7	3.0	69.4	30.6	134.0	59.0	6.6	2.9	3.9	1.7	1.6	0.7	4.9	2.1	10.4	1.4	3.8	1.664	0.052
	gongju2	171.4	135.0	78.7	36.5	21.3	109.2	24.2	5.1	3.0	51.4	30.0	103.9	60.6	2.1	1.2	1.4	0.8	2.2	1.3	5.3	3.1	10.3	3.3	7.1	4.476	0.174
	hwangryonggang3	565.0	443.7	78.5	121.4	21.5	114.9	27.7	28.4	5.0	152.4	27.0	350.9	62.1	6.8	1.2	4.5	0.8	4.8	0.8	17.3	3.1	10.1	3.0	4.6	1.733	0.063
	woosan	120.4	94.4	78.4	26.0	21.6	101.3	30.6	5.8	4.8	32.3	26.8	74.0	61.5	1.3	1.1	1.0	0.8	1.8	1.5	4.3	3.6	10.5	0.9	3.6	1.999	0.039
	mokmyun	120.6	94.6	78.4	26.1	21.6	107.9	26.1	4.4	3.6	33.8	28.1	74.7	61.9	1.8	1.5	0.3	0.3	2.7	2.3	2.8	2.4	11.6	3.6	7.4	4.949	0.188

Table B-13: The observation data (pervious/impervious, rainfall, slope, land use, water quality) of Geum-sum-youngsan River watershed (20% ~) for second step

	Station	Total Area	Pervious		Impervious		Rainfall	Slope	Large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average from 2001 to 2010				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO (mg/L)	BOD (mg/L)	COD (mg/L)	TN (mg/L)	TP (mg/L)
20 % ~ 25%	hwasunchun	127.7	100.1	78.3	27.7	21.7	120.2	31.3	7.3	5.7	30.7	24.0	83.5	65.3	3.0	2.3	0.8	0.6	1.4	1.1	1.2	0.9	10.5	2.1	4.2	2.477	0.064
	osuchun	371.3	289.6	78.0	81.3	21.9	112.9	24.6	11.6	3.1	124.3	33.5	220.6	59.4	5.0	1.4	3.5	0.9	1.6	0.4	4.3	1.1	10.9	1.5	3.8	2.010	0.060
	gomnaru	197.7	153.7	77.8	44.0	22.2	104.9	26.6	11.4	5.8	55.4	28.0	119.6	60.5	2.3	1.2	1.6	0.8	4.0	2.0	3.4	1.7	10.1	3.1	6.5	4.321	0.171
	bonghwangchun	247.4	192.1	77.6	55.3	22.4	143.4	30.7	11.8	4.8	73.9	29.9	155.1	62.7	2.1	0.9	0.4	0.2	2.1	0.9	1.9	0.8	10.3	1.5	3.7	3.337	0.118
	daegyochun	65.9	51.0	77.3	15.0	22.7	106.6	21.6	2.5	3.8	23.9	36.3	36.7	55.7	1.1	1.7	0.2	0.3	0.6	0.9	0.9	1.3	10.6	2.0	3.5	2.119	0.050
	jochun	136.3	105.2	77.2	31.1	22.8	102.7	23.1	11.3	8.3	39.2	28.8	79.6	58.4	2.1	1.6	1.2	0.9	1.3	1.0	1.5	1.1	9.9	3.6	5.1	4.421	0.284
	buyoe1	96.9	74.8	77.1	22.2	22.9	109.0	19.8	4.6	4.7	32.9	33.9	53.3	55.0	0.5	0.5	0.2	0.2	2.2	2.2	3.3	3.4	10.4	3.1	6.8	4.146	0.162
	yochun	294.8	227.1	77.0	67.7	23.0	113.3	22.8	15.7	5.3	97.4	33.0	163.4	55.4	5.4	1.8	4.4	1.5	3.9	1.3	4.7	1.6	10.2	1.6	4.0	2.707	0.161
	daegang	204.3	157.2	77.0	47.1	23.0	112.2	22.3	7.9	3.8	77.3	37.8	107.9	52.8	5.3	2.6	2.0	1.0	1.3	0.7	2.6	1.2	10.9	1.8	4.5	1.895	0.052
	gapchun2	93.9	71.6	76.2	22.3	23.8	110.7	23.7	8.1	8.6	24.9	26.5	53.3	56.8	2.2	2.3	1.0	1.0	2.8	2.9	1.7	1.9	10.8	2.2	3.8	2.933	0.088
	sungdong	65.1	49.2	75.7	15.8	24.3	106.6	12.0	4.5	6.9	28.8	44.2	23.2	35.6	0.5	0.7	0.4	0.6	1.3	1.9	6.5	9.9	9.3	3.2	6.8	3.835	0.162
	yongi	86.1	65.1	75.5	21.1	24.5	104.2	15.2	5.3	6.2	36.8	42.8	36.5	42.4	1.1	1.3	2.0	2.3	1.1	1.2	3.3	3.9	10.0	3.2	6.8	5.315	0.218
	mihochun5	471.5	355.8	75.5	115.7	24.5	102.5	18.5	37.4	7.9	157.2	33.3	243.4	51.6	10.3	2.2	3.5	0.7	12.2	2.6	7.6	1.6	10.1	4.8	8.8	5.112	0.220
	geumchun	165.2	124.3	75.3	40.9	24.7	96.3	18.6	8.3	5.0	75.8	45.9	74.8	45.3	1.1	0.7	1.0	0.6	1.0	0.6	3.2	1.9	9.9	3.3	6.1	2.511	0.088
	gwangju1	562.0	422.5	75.2	139.5	24.8	112.8	25.5	46.0	8.2	206.2	36.7	268.9	47.8	13.5	2.4	5.7	1.0	8.2	1.5	13.5	2.4	10.6	3.7	5.8	2.793	0.103
	mihochun4	220.7	165.8	75.1	54.9	24.9	101.6	18.7	14.7	6.6	86.3	39.1	101.8	46.1	6.9	3.1	2.0	0.9	4.5	2.0	4.5	2.0	10.2	2.7	5.8	4.031	0.191
	chungwon-1	129.8	97.5	75.1	32.3	24.9	97.4	19.6	11.1	8.5	44.7	34.4	64.9	50.0	2.6	2.0	1.2	1.0	2.1	1.6	3.2	2.4	10.9	2.4	6.0	5.690	0.216
	gomakwonchun2	219.0	164.4	75.1	54.5	24.9	110.7	18.4	12.3	5.6	105.2	48.0	91.6	41.8	2.0	0.9	1.9	0.9	1.8	0.8	4.3	2.0	10.2	2.9	5.9	2.653	0.070
25 % ~	bogangchun	157.6	118.0	74.9	39.6	25.1	99.3	19.2	10.1	6.4	69.0	43.8	72.0	45.7	1.8	1.2	0.8	0.5	1.6	1.0	2.3	1.5	10.5	1.8	3.6	3.621	0.087
	muan2	885.4	661.7	74.7	223.7	25.3	101.8	15.1	42.2	4.8	470.0	53.1	291.8	33.0	8.7	1.0	8.9	1.0	10.3	1.2	53.5	6.0	9.9	2.0	5.7	4.194	0.133
	geumganggapmun	536.6	400.9	74.7	135.7	25.3	100.3	12.4	33.4	6.2	271.8	50.6	180.9	33.7	5.4	1.0	4.4	0.8	2.5	0.5	38.1	7.1	10.6	2.9	7.3	4.374	0.131
	nosungchun	202.5	150.5	74.4	51.9	25.6	105.3	17.7	12.0	5.9	98.9	48.8	84.0	41.5	2.6	1.3	0.8	0.4	1.1	0.6	3.0	1.5	10.6	2.6	4.6	2.125	0.068
	bakgokchun2	39.8	29.4	73.9	10.4	26.1	105.0	15.2	3.4	8.6	17.8	44.7	16.6	41.8	0.3	0.7	0.3	0.8	0.7	1.6	0.7	1.8	11.4	1.8	3.3	2.553	0.074
	mihochun6-1	125.6	92.7	73.8	32.9	26.2	101.2	13.3	10.3	8.2	59.0	47.0	45.7	36.4	2.8	2.2	2.2	1.8	2.2	1.7	3.3	2.6	9.8	4.8	9.2	6.424	0.264
	youngsanpo	309.9	227.9	73.5	82.1	26.5	110.4	24.4	19.2	6.2	166.1	53.6	108.1	34.9	3.4	1.1	2.3	0.8	3.1	1.0	7.7	2.5	9.6	5.6	6.5	6.624	0.435
	musimchun3	197.3	144.5	73.2	52.9	26.8	98.4	20.1	30.9	15.6	57.5	29.1	97.1	49.2	3.9	2.0	1.8	0.9	4.7	2.4	1.6	0.8	11.1	2.2	4.3	3.171	0.082
	suksungchun	152.2	111.3	73.2	40.8	26.8	103.5	12.4	8.3	5.5	85.7	56.3	50.2	33.0	2.1	1.4	0.0	0.0	3.0	2.0	2.8	1.8	8.3	4.2	6.5	3.838	0.495
	hyundo	43.3	31.5	72.7	11.8	27.3	102.7	20.2	7.4	17.0	10.3	23.8	21.2	48.9	1.6	3.6	0.2	0.5	1.0	2.3	1.7	4.0	10.5	0.7	3.8	1.530	0.023
	mihochun2	288.8	207.8	71.9	81.0	28.1	98.2	14.3	22.4	7.8	157.7	54.6	91.8	31.8	6.2	2.1	2.9	1.0	4.4	1.5	3.4	1.2	10.2	3.1	6.3	4.479	0.173
	jisukchun4	82.9	59.1	71.3	23.8	28.7	111.0	11.1	7.6	9.2	49.7	59.9	20.5	24.7	0.4	0.5	1.4	1.7	1.3	1.6	2.0	2.4	11.0	2.7	5.6	3.400	0.146
	daejeonchun3	89.4	63.7	71.3	25.7	28.7	107.2	29.4	22.9	25.6	11.9	13.4	49.3	55.2	2.0	2.2	0.6	0.7	2.2	2.5	0.5	0.5	12.0	2.6	3.9	4.745	0.117
	nonsanchun4	244.2	171.5	70.2	72.7	29.8	97.0	9.1	26.2	10.7	149.2	61.1	55.3	22.6	4.9	2.0	0.8	0.3	3.9	1.6	3.8	1.6	10.2	4.3	7.9	6.374	0.215
	gapchun5-1	107.6	75.2	69.9	32.4	30.1	111.5	15.1	25.0	23.2	19.6	18.2	41.6	38.6	10.5	9.7	0.8	0.7	7.4	6.9	2.7	2.5	9.4	5.5	9.9	11.938	0.570
	naju	264.1	180.0	68.2	84.1	31.8	112.1	8.0	69.9	26.5	96.5	36.6	74.8	28.3	8.5	3.2	3.3	1.3	5.8	2.2	5.3	2.0	10.3	5.3	6.5	6.961	0.454
	youdeungchun5	59.2	37.2	62.8	22.1	37.2	110.7	14.7	26.1	44.0	4.1	7.0	19.9	33.6	2.9	4.9	0.4	0.7	5.3	8.9	0.6	1.0	11.3	2.9	4.2	3.061	0.092
	goksung	183.4	147.4	241.2	36.0	58.8	113.7	32.4	4.7	2.5	38.7	21.1	130.2	71.0	3.1	1.7	2.3	1.2	1.7	0.9	2.8	1.5	10.0	1.4	4.0	2.521	0.066
	jinwol	298.9	238.3	319.4	60.5	80.6	139.3	32.4	11.0	3.7	67.9	22.7	202.6	67.8	4.4	1.5	2.0	0.7	2.3	0.8	8.6	2.9	9.0	1.2	3.6	1.144	0.040

Table B-14: The observation data of Hangang, Nakdong, and Geum-sum-youngsan river for third step (Area: 0 ~ 250 km^2, Imperviousness: 0 ~ 25 %)

Impervious	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001~2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
0 ~ 20 %	deokyeun	184.2	154.9	84.1	29.3	15.9	143.0	45.3	1.8	1.0	5.4	2.9	173.2	94.0	1.5	0.8	0.6	0.3	0.5	0.3	1.3	0.7	9.6	1.3	3.4	2.298	0.046
	deokchungang1	106.3	87.8	82.7	18.4	17.3	158.5	47.1	1.8	1.6	7.3	6.9	93.8	88.3	0.7	0.7	0.3	0.3	1.7	1.6	0.6	0.6	10.1	0.6	1.4	1.198	0.037
	yochuun A	191.7	158.5	82.7	33.2	17.3	112.9	46.5	3.2	1.7	17.5	9.1	163.5	85.3	3.4	1.8	1.3	0.7	0.8	0.4	2.1	1.1	3.4	0.3	0.7	0.676	0.005
	paldangdam	132.5	109.5	82.6	23.0	17.4	103.3	28.7	4.5	3.4	18.1	13.7	92.3	69.7	1.7	1.3	2.7	2.1	1.0	0.8	12.1	9.1	10.9	1.3	3.6	2.121	0.048
	bakgokchun1	85.7	70.6	82.5	15.0	17.5	102.2	34.1	2.2	2.6	18.7	21.8	62.4	72.8	1.0	1.2	0.3	0.3	2.1	2.5	3.3	3.8	11.5	1.3	2.5	2.389	0.042
	joyanggang	74.1	60.8	82.1	13.2	17.9	94.8	48.6	1.3	1.7	8.9	12.0	62.1	83.8	0.2	0.3	0.1	0.1	0.5	0.7	1.1	1.5	11.0	0.8	2.3	2.652	0.027
	chunsunggyo	189.4	155.4	82.1	34.0	17.9	108.2	38.7	4.3	2.3	19.7	10.4	154.6	81.6	4.1	2.2	0.1	0.1	2.3	1.2	4.2	2.2	10.8	1.2	3.1	1.667	0.030
	sangchun	182.3	149.2	81.8	33.2	18.2	98.5	43.3	2.9	1.6	26.3	14.4	149.2	81.8	0.7	0.4	0.7	0.4	1.3	0.7	1.3	0.7	11.1	1.0	2.2	2.488	0.034
	younpo	127.7	104.4	81.8	23.3	18.2	96.6	43.1	1.1	0.8	11.0	8.6	68.5	53.6	2.5	2.0	0.1	0.1	0.3	0.2	2.3	1.8	9.9	0.9	3.5	1.662	0.020
	geumgyechun	155.4	126.9	81.7	28.5	18.3	109.1	39.6	2.0	1.3	23.8	15.3	127.0	81.7	0.3	0.2	0.0	0.0	0.8	0.5	1.4	0.9	10.8	0.9	1.8	2.500	0.033
	chopyungchun	132.6	108.2	81.6	24.4	18.4	100.5	32.1	5.8	4.4	32.3	24.3	74.0	55.9	1.3	1.0	1.0	0.8	1.8	1.3	4.3	3.2	10.7	1.1	2.3	1.580	0.034
	youngdong	222.8	180.9	81.2	41.9	18.8	173.9	36.4	11.4	5.1	55.4	24.9	119.6	53.7	2.3	1.0	1.6	0.7	4.0	1.8	3.4	1.5	10.2	1.1	3.7	2.132	0.036
	nonsanchun1	219.4	177.9	81.1	41.6	18.9	110.3	34.0	22.4	10.2	157.7	71.9	91.8	41.9	6.2	2.8	2.9	1.3	4.4	2.0	3.4	1.5	10.4	1.2	3.1	3.576	0.034
	hadong	156.3	126.5	80.9	29.8	19.1	143.1	39.8	5.4	3.4	21.9	14.0	120.3	77.0	1.7	1.1	1.0	0.6	3.1	2.0	2.9	1.8	9.0	1.2	4.8	2.275	0.047
	donggye	144.4	116.6	80.8	27.7	19.2	116.1	35.4	2.2	1.6	28.8	19.9	101.5	70.3	7.9	5.5	1.7	1.2	0.6	0.4	1.6	1.1	9.7	1.1	3.6	1.445	0.043
	jisukchun2	215.8	174.2	80.7	41.6	19.3	111.9	29.7	5.6	2.6	44.7	20.7	147.5	68.4	3.7	1.7	2.1	1.0	2.7	1.3	9.6	4.4	10.8	2.2	4.4	2.674	0.109
	junchun	170.7	137.7	80.7	33.0	19.3	108.0	32.6	5.2	3.0	28.2	16.5	133.7	78.3	1.2	0.7	0.4	0.2	1.0	0.6	1.1	0.7	9.8	1.2	2.0	1.295	0.023
	yangsanchun1	138.9	112.0	80.7	26.8	19.3	118.4	36.7	6.1	4.4	17.3	12.4	108.4	78.0	4.5	3.2	0.3	0.2	1.2	0.9	1.2	0.9	9.8	1.1	2.7	2.542	0.074
	jisukpo	237.6	191.6	80.7	45.9	19.3	116.0	32.9	5.8	2.5	45.4	19.1	170.8	71.9	7.8	3.3	2.1	0.9	1.6	0.7	4.0	1.7	10.2	1.4	3.1	1.367	0.038
	sukmunchun	99.2	79.9	80.6	19.3	19.4	93.0	39.9	3.0	3.0	18.2	18.4	75.3	75.9	0.4	0.4	0.5	0.5	1.2	1.2	0.6	0.6	11.8	1.3	2.7	3.713	0.104
	milyanggang3	248.8	200.2	80.5	48.6	19.5	94.6	38.8	5.8	3.0	51.9	26.8	181.3	93.7	2.2	1.1	1.8	0.9	2.4	1.2	3.5	1.8	10.6	2.3	4.4	3.013	0.120
	goksung	183.4	147.4	80.4	36.0	19.6	113.7	32.4	4.7	2.5	38.7	21.1	130.2	71.0	3.1	1.7	2.3	1.2	1.7	0.9	2.8	1.5	10.0	1.4	4.0	2.521	0.066
	youngdongchun2	145.4	116.6	80.2	28.8	19.8	92.2	35.7	8.8	6.1	67.6	46.5	197.4	135.7	3.0	2.1	2.2	1.5	1.2	0.8	2.5	1.7	10.5	1.4	4.1	5.061	0.123
20 ~ 25%	youdengchun-a	141.9	113.6	80.0	28.3	20.0	108.3	40.0	8.1	5.7	24.9	17.5	53.3	37.6	2.2	1.5	1.0	0.7	2.8	1.9	1.7	1.2	11.9	0.9	2.2	2.924	0.031
	jewon	89.9	72.0	80.0	18.0	20.0	99.0	33.1	4.4	4.9	28.0	31.1	105.3	117.1	1.5	1.7	0.3	0.4	1.5	1.7	0.8	0.9	10.3	1.0	3.7	1.765	0.029
	gongju1	98.7	79.0	80.0	19.7	20.0	113.3	28.9	11.8	12.0	73.9	74.8	155.1	157.2	2.1	2.2	0.4	0.4	2.1	2.2	1.9	1.9	10.2	2.9	6.6	4.323	0.182
	bonggok 2 gyo	156.9	125.3	79.9	31.6	20.1	107.7	32.8	11.3	7.2	39.2	25.0	79.6	50.7	2.1	1.3	1.2	0.8	1.3	0.9	1.5	0.9	11.2	1.9	3.3	3.396	0.193
	ianchun	242.3	193.3	79.8	49.0	20.2	99.0	31.5	7.0	2.9	53.9	22.2	173.3	71.5	1.7	0.7	0.9	0.4	2.9	1.2	2.7	1.1	6.2	0.7	1.6	1.018	0.015
	bochungchun4	113.6	90.4	79.6	23.2	20.4	94.2	32.4	4.5	4.0	28.8	25.3	23.2	20.4	0.5	0.4	0.4	0.4	1.3	1.1	6.5	5.7	10.5	1.1	2.7	2.029	0.035
	yeryungchun	114.4	91.0	79.5	23.4	20.5	106.9	36.1	4.6	4.0	26.8	23.4	79.6	69.6	1.0	0.8	0.6	0.5	0.4	0.3	1.4	1.3	9.2	2.1	7.1	2.542	0.104
	jichun	246.4	195.8	79.5	50.6	20.5	104.8	26.7	26.1	10.6	4.1	1.7	19.9	8.1	2.9	1.2	0.4	0.2	5.3	2.1	0.6	0.2	10.6	1.9	3.6	2.212	0.048
	yongsuchun	95.1	75.6	79.4	19.6	20.6	118.1	32.7	30.9	32.4	57.5	60.4	97.1	102.0	3.9	4.1	1.8	1.9	4.7	4.9	1.6	1.7	8.1	1.7	2.8	1.376	0.054
	bochungchun2	140.6	111.5	79.3	29.1	20.7	188.1	29.9	8.3	5.9	75.8	54.0	74.8	53.2	1.1	0.8	1.0	0.7	1.0	0.7	3.2	2.2	10.2	1.1	2.1	2.115	0.031
	dongjinchun2	124.0	98.2	79.2	25.8	20.8	96.4	29.7	3.8	3.1	31.1	25.1	83.7	67.5	1.9	1.6	0.0	0.0	1.6	1.3	1.8	1.4	10.4	1.4	2.5	2.340	0.036
	damchun3	86.2	68.0	78.9	18.2	21.1	94.5	25.6	2.6	3.0	27.8	32.2	50.9	59.0	1.3	1.6	0.6	0.7	0.2	0.2	2.8	3.2	10.4	1.1	2.9	2.389	0.035
	namwon	227.0	178.9	78.8	48.2	21.2	113.7	26.6	6.7	3.0	69.4	30.6	134.0	59.0	6.6	2.9	3.9	1.7	1.6	0.7	4.9	2.1	10.4	1.4	3.8	1.664	0.052
	gongju2	171.4	135.0	78.7	36.5	21.3	109.2	24.2	5.3	3.1	37.7	22.0	169.9	99.1	1.0	0.6	1.6	0.9	3.0	1.7	4.4	2.5	10.3	3.3	7.1	4.476	0.174
	dalsung	155.5	122.0	78.5	33.5	21.5	92.5	24.3	5.8	3.7	45.9	29.5	93.7	60.3	1.5	1.0	1.6	1.0	2.5	1.6	4.5	2.9	11.2	2.1	5.2	2.927	0.096
	sumgang2	108.1	84.8	78.5	23.3	21.5	107.7	25.9	7.5	7.0	25.7	23.7	68.8	63.6	2.0	1.8	1.1	1.0	1.1	1.0	1.9	1.8	10.7	1.5	3.2	2.360	0.053
	segokchun	113.5	89.0	78.4	24.5	21.6	105.4	29.2	6.9	6.1	27.1	23.9	74.9	66.0	1.5	1.3	0.3	0.3	1.3	1.1	1.5	1.3	10.6	1.6	3.6	4.646	0.129
	woosan	120.4	94.4	78.4	26.0	21.6	101.3	30.6	3.4	2.8	17.8	14.8	16.6	13.8	0.3	0.2	0.3	0.3	0.7	0.5	0.7	0.6	10.1	1.0	3.7	2.339	0.044
	mokmyun	120.6	94.6	78.4	26.1	21.6	107.9	26.1	7.1	5.9	64.9	53.8	164.9	136.7	4.0	3.3	1.4	1.2	0.8	0.7	3.3	2.7	11.6	3.6	7.4	4.949	0.188
	hwasunchun	127.7	100.1	78.3	27.7	21.7	120.2	31.3	7.3	5.7	30.7	24.0	83.5	65.3	3.0	2.3	0.8	0.6	1.4	1.1	1.2	0.9	10.5	2.1	4.2	2.477	0.064
	youngsun	17.0	13.2	77.9	3.8	22.1	90.3	22.4	0.5	3.2	5.5	32.2	8.8	51.8	0.1	0.5	0.2	1.0	0.7	4.1	1.2	7.2	9.6	0.9	3.3	2.320	0.052
	gomnaru	197.7	153.7	77.8	44.0	22.2	104.9	26.6	8.9	4.5	58.0	29.3	385.2	194.9	3.8	1.9	1.6	0.8	3.7	1.8	2.9	1.5	10.1	3.1	6.5	4.321	0.171
	bonghwangchun	247.4	192.1	77.6	55.3	22.4	143.4	30.7	10.3	4.2	59.0	23.8	45.7	18.5	2.8	1.1	2.2	0.9	2.2	0.9	3.3	1.3	10.3	1.5	3.7	3.337	0.118

Table B-15: The observation data of Hangang, Nakdong, and Geum-sum-youngsan river for third step (Area: 0 ~ 250 km^2, Imperviousness: 20 % ~)

Impervious	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001~2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
20 ~ 25%	geumganggapmun	194.8	151.3	77.6	43.6	22.4	100.6	13.8	13.1	6.7	142.1	72.9	493.5	253.3	5.2	2.7	1.6	0.8	2.7	1.4	6.5	3.3	3.2	0.9	2.2	1.312	0.039
	hyunpung	109.2	84.6	77.5	24.5	22.5	98.4	30.4	8.6	7.9	22.2	20.3	70.8	64.9	1.5	1.4	0.4	0.4	2.1	2.0	3.5	3.2	10.9	2.9	6.7	4.217	0.207
	yeamdam	228.0	176.5	77.4	51.5	22.6	105.2	24.8	26.1	11.4	48.1	21.1	131.6	57.7	4.0	1.8	0.4	0.2	3.6	1.6	14.2	6.2	10.5	1.1	2.8	1.657	0.030
	daegyochun	65.9	51.0	77.3	15.0	22.7	106.6	21.6	14.7	22.2	86.3	130.8	101.8	154.3	6.9	10.5	2.0	3.1	4.5	6.8	4.5	6.8	10.6	2.0	3.5	2.119	0.050
	andong3	38.0	29.3	77.2	8.6	22.8	87.4	20.3	1.7	4.6	13.4	35.3	21.3	56.1	0.3	0.9	0.0	0.1	0.2	0.6	1.0	2.5	7.5	0.8	2.9	1.484	0.028
	hamanchun2	216.2	167.0	77.2	49.3	22.8	103.8	26.4	10.5	4.9	75.2	34.8	117.3	54.3	2.5	1.2	2.9	1.4	1.7	0.8	6.0	2.8	10.1	3.0	6.5	4.780	0.194
	jochun	136.3	105.2	77.2	31.1	22.8	102.7	23.1	22.9	16.8	11.9	8.8	49.3	36.2	2.0	1.4	0.6	0.4	2.2	1.6	0.5	0.3	9.9	3.6	5.1	4.421	0.284
	buyeu1	96.9	74.8	77.1	22.2	22.9	109.0	19.8	5.3	5.5	18.4	19.0	66.7	68.8	2.4	2.5	0.7	0.7	0.9	0.9	0.7	0.8	10.4	3.1	6.8	4.146	0.162
	daegang	204.3	157.2	77.0	47.1	23.0	112.2	22.3	7.9	3.8	77.3	37.8	107.9	52.8	5.3	2.6	2.0	1.0	1.3	0.7	2.6	1.2	3.3	0.5	1.4	0.569	0.016
	hwayangchun	56.3	43.3	76.8	13.0	23.2	100.3	39.7	2.1	3.7	21.9	39.0	30.4	54.0	0.8	1.3	0.2	0.3	0.2	0.4	0.7	1.3	11.3	0.7	1.6	2.138	0.022
	gwangryuchun3	158.0	121.3	76.8	36.7	23.2	102.5	31.7	11.3	7.1	40.7	25.7	96.9	61.3	1.4	0.9	1.9	1.2	4.0	2.5	1.9	1.2	9.8	3.0	5.9	2.553	0.150
	yeumsungchun	143.2	110.0	76.8	33.2	23.2	101.0	24.6	6.9	4.8	51.9	36.2	77.9	54.4	2.5	1.7	0.5	0.3	1.2	0.9	2.4	1.7	11.0	1.8	3.3	2.526	0.064
	byungchunchun	220.3	169.1	76.8	51.2	23.2	102.9	19.4	12.0	5.5	98.9	44.9	84.0	38.1	2.6	1.2	0.8	0.4	1.1	0.5	3.0	1.4	10.5	2.2	3.8	2.709	0.060
	daeam	189.6	145.6	76.8	44.0	23.2	96.4	25.4	8.0	4.2	68.6	36.2	96.3	50.8	1.8	1.0	1.8	1.0	5.0	2.6	8.1	4.3	11.2	3.1	6.9	4.116	0.193
	wonjuchun	153.0	117.3	76.7	35.6	23.3	110.5	31.1	19.5	12.7	29.4	19.2	98.5	64.4	1.0	0.6	0.8	0.5	2.7	1.8	1.2	0.8	9.3	7.5	8.5	10.386	0.758
	imheajin	107.2	82.0	76.5	25.2	23.5	94.5	27.0	5.1	4.7	42.4	39.5	48.4	45.1	1.3	1.2	2.0	1.8	2.6	2.4	5.6	5.3	10.6	2.7	6.1	3.144	0.148
	sungju	120.1	91.9	76.5	28.3	23.5	84.5	20.6	9.6	8.0	32.1	26.8	63.0	52.4	2.0	1.7	1.9	1.5	5.4	4.5	6.1	5.1	11.0	2.1	5.0	2.996	0.095
	damchul5	152.2	116.3	76.5	35.8	23.5	97.2	30.8	13.8	9.0	44.0	28.9	81.4	53.5	4.9	3.2	1.4	0.9	2.6	1.7	4.1	2.7	10.2	1.8	3.8	2.865	0.089
	gyesungchun	107.1	81.8	76.3	25.3	23.7	94.9	23.9	5.4	5.1	42.9	40.0	53.2	49.7	1.2	1.1	0.9	0.9	0.6	0.5	2.9	2.7	8.6	3.4	8.0	5.392	0.365
	yodochun	150.6	114.9	76.3	35.6	23.7	102.2	20.9	7.8	5.2	56.8	37.7	76.9	51.1	3.2	2.2	1.0	0.6	2.3	1.5	2.5	1.7	10.7	2.4	4.0	2.727	0.105
	chungjujojungji	84.4	64.3	76.3	20.0	23.7	100.5	20.8	7.6	9.0	24.5	29.0	36.7	43.5	6.0	7.1	0.1	0.2	1.9	2.2	7.5	8.9	11.9	1.4	2.4	2.483	0.028
	gapchun2	93.9	71.6	76.2	22.3	23.8	110.7	23.7	16.6	17.7	146.7	156.2	377.2	401.7	23.0	24.5	1.8	1.9	5.7	6.0	4.2	4.4	10.6	2.2	3.7	2.907	0.091
	gupo	72.1	54.8	76.0	17.3	24.0	114.9	22.3	11.5	16.0	14.3	19.9	38.8	53.8	0.5	0.7	0.1	0.2	1.3	1.7	5.6	7.8	10.2	2.6	6.0	3.109	0.132
	yeuju2	76.1	57.6	75.7	18.5	24.3	103.1	10.3	6.1	8.0	30.1	39.5	29.3	38.5	1.4	1.9	3.2	4.2	1.8	2.4	4.2	5.5	10.8	1.6	3.5	2.834	0.061
	sungdong	65.0	49.2	75.7	15.8	24.3	106.6	12.0	2.5	3.8	23.9	36.8	36.7	56.4	1.1	1.7	0.2	0.3	0.6	0.9	0.9	1.4	9.3	3.2	6.8	3.835	0.162
	yungi	86.1	65.1	75.5	21.1	24.5	104.2	15.2	5.0	5.8	19.1	22.2	66.7	77.4	1.5	1.8	1.2	1.4	1.6	1.9	3.6	4.2	10.0	3.2	6.8	5.315	0.218
	geumchun	165.2	124.3	75.3	40.9	24.7	96.3	18.6	6.6	4.0	79.9	48.4	201.8	122.2	2.1	1.3	0.8	0.5	4.1	2.5	4.2	2.6	9.9	3.3	6.1	2.511	0.088
	mihochun4	220.7	165.8	75.1	54.9	24.9	101.6	18.7	10.6	4.8	78.8	35.7	75.7	34.3	2.3	1.0	2.1	0.9	1.0	0.4	24.5	11.1	10.2	2.7	5.8	4.031	0.191
	chungwon1	129.8	97.5	75.1	32.3	24.9	97.4	19.6	25.0	19.3	19.6	15.1	41.6	32.0	10.5	8.1	0.8	0.6	7.4	5.7	2.7	2.1	10.9	2.4	6.0	5.690	0.216
	gomakwonchun2	219.0	164.4	75.1	54.5	24.9	110.7	18.4	12.3	5.6	105.2	48.0	91.6	41.8	2.0	0.9	1.9	0.9	1.8	0.8	4.3	2.0	10.2	2.9	5.9	2.653	0.070
25 % ~	bogangchun	157.6	118.0	74.9	39.6	25.1	99.3	19.2	4.6	2.9	32.9	20.9	53.3	33.8	0.5	0.3	0.2	0.1	2.2	1.4	3.3	2.1	10.5	1.8	3.6	3.621	0.087
	nosungchun	202.5	150.5	74.4	51.9	25.6	105.3	17.7	11.1	5.5	44.7	22.1	64.9	32.1	2.6	1.3	1.2	0.6	2.1	1.0	3.2	1.6	10.6	2.6	4.6	2.125	0.068
	gilsanchun	113.0	84.0	74.3	29.0	25.7	101.8	14.1	19.5	17.2	106.9	94.6	429.0	379.6	5.2	4.6	3.6	3.2	4.2	3.8	55.6	49.2	9.1	3.5	7.3	1.889	0.109
	yangsanchun3	106.7	79.0	74.0	27.8	26.0	114.1	28.6	15.3	14.2	14.5	13.5	64.3	60.0	3.9	3.6	0.9	0.8	6.2	5.8	1.6	1.5	10.1	3.8	7.1	4.278	0.246
	bakgokchun2	39.8	29.4	73.9	10.4	26.1	105.0	15.2	5.8	14.5	32.3	81.1	74.0	186.1	1.3	3.3	1.0	2.5	1.8	4.4	4.3	10.8	11.4	1.8	3.3	2.553	0.074
	mihochun6-1	125.6	92.7	73.8	32.9	26.2	101.2	13.3	2.2	1.8	16.7	13.3	104.5	83.2	0.4	0.3	0.7	0.5	1.5	1.2	1.7	1.4	9.8	4.8	9.2	6.424	0.264
	hwapochun	138.1	101.2	73.3	36.9	26.7	106.6	23.4	13.8	10.0	51.3	37.2	61.5	44.5	3.5	2.5	1.8	1.3	3.8	2.8	2.4	1.8	8.6	3.5	7.2	3.313	0.150
	musimchun3	197.3	144.5	73.2	52.9	26.8	98.4	20.1	5.2	2.7	43.3	21.9	160.2	81.2	2.0	1.0	0.7	0.3	0.6	0.3	7.4	3.8	11.0	2.2	4.2	3.173	0.081
	suksungchun	152.2	111.3	73.2	40.8	26.8	103.5	12.4	5.3	3.5	36.8	24.2	36.5	24.0	1.1	0.7	2.0	1.3	1.1	0.7	3.3	2.2	8.7	4.2	7.0	4.574	0.345
	hyundo	43.3	31.5	72.7	11.8	27.3	102.7	20.2	6.5	15.0	24.6	56.8	111.1	256.3	0.5	1.1	0.6	1.4	1.3	3.0	0.9	2.0	10.1	0.8	3.7	1.814	0.026
	ganggyungchun	123.5	88.5	71.7	35.0	28.3	96.5	10.8	5.9	4.8	41.7	33.8	270.9	219.4	3.1	2.5	0.5	0.4	1.8	1.4	1.7	1.4	9.8	5.9	10.4	9.033	0.453
	naju	111.3	79.3	71.3	31.9	28.7	110.7	8.2	7.8	7.0	73.4	66.0	22.7	20.4	0.9	0.8	1.4	1.3	1.5	1.4	3.5	3.1	10.3	5.3	6.5	6.961	0.454
	jusukchun4	82.9	59.1	71.3	23.8	28.7	111.0	11.1	7.6	9.2	49.7	59.9	20.5	24.7	0.4	0.5	1.4	1.7	1.3	1.6	2.0	2.4	11.0	2.7	5.6	3.400	0.146
	daejeonchun3	89.4	63.7	71.3	25.7	28.7	107.2	29.4	11.6	13.0	77.9	87.2	117.6	131.5	4.9	5.5	2.2	2.4	2.4	2.7	3.7	4.2	12.0	2.6	3.9	4.745	0.117
	goryung	210.6	149.7	71.1	60.9	28.9	93.7	20.1	47.9	22.8	43.2	20.5	96.6	45.9	5.8	2.8	3.1	1.5	6.7	3.2	7.2	3.4	10.7	2.9	6.8	4.178	0.215
	hangju	124.9	88.6	70.9	36.3	29.1	111.4	14.0	38.1	30.5	23.6	18.9	43.7	35.0	4.7	3.7	0.5	0.4	5.3	4.2	9.1	7.3	8.8	4.0	6.2	7.036	0.356
	nonsanchun4	244.2	171.5	70.2	72.7	29.8	97.0	9.1	2.8	1.1	24.3	9.9	97.1	39.8	1.5	0.6	0.8	0.3	0.3	0.1	5.8	2.4	4.1	1.6	3.0	2.377	0.085
	gapchun5-1	107.6	75.2	69.9	32.4	30.1	111.5	15.1	5.5	5.1	51.8	48.2	279.1	259.4	7.6	7.1	0.9	0.8	6.9	6.4	3.3	3.1	9.4	5.5	9.9	11.938	0.570
	nakdonghagu2	54.7	37.7	69.0	17.0	31.0	120.9	14.4	19.5	35.7	7.3	13.4	15.5	28.4	1.1	2.0	1.1	2.1	1.2	2.2	8.8	16.1	10.5	2.6	6.3	3.318	0.129
	naju	152.8	100.7	65.9	52.1	34.1	113.1	7.7	62.1	40.6	23.1	15.1	52.1	34.1	7.7	5.0	1.9	1.2	4.2	2.8	1.8	1.2	11.4	5.3	6.5	6.961	0.454
	Norangjin	51.0	32.1	62.9	18.9	37.1	111.3	10.3	33.9	66.5	0.5	1.1	8.7	17.0	0.8	1.5	0.0	0.1	1.2	2.4	5.8	11.5	9.0	3.5	5.5	5.669	0.260
	youdengchun5	59.2	37.2	62.8	22.1	37.2	110.7	14.7	8.5	14.4	24.1	40.8	115.9	195.7	5.1	8.6	0.6	1.0	1.6	2.6	1.2	2.0	11.3	2.9	4.2	3.061	0.092
	Hongjechun	51.0	30.9	60.5	20.1	39.5	116.2	18.5	32.4	63.7	0.0	0.1	13.9	27.2	0.6	1.2	0.2	0.4	3.8	7.4	0.0	0.0	12.1	3.6	4.9	6.710	0.172
	gulpochun3	131.8	77.6	58.9	54.2	41.1	99.9	6.7	67.3	51.1	32.3	24.5	17.5	13.3	6.6	5.0	0.1	0.1	5.9	4.5	1.9	1.4	3.1	11.4	13.9	18.632	1.760

Table B-16: The observation data of Hangang, Nakdong, and Geum-sum-youngsan river for third step (Area: 250 km^2 ~, Imperviousness: 0 ~ 25 %)

Impervious	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001~2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
	soyangdam1	400.5	342.6	85.5	57.9	14.5	103.7	46.9	2.5	0.6	12.0	3.0	339.4	84.7	0.9	0.2	0.5	0.1	2.4	0.6	42.8	10.7	9.1	0.9	2.2	1.459	0.018
	soyangdam5	278.2	233.5	83.9	44.7	16.1	98.8	45.2	3.9	1.4	14.3	5.1	245.0	88.1	1.3	0.5	6.8	2.5	0.9	0.3	6.1	2.2	9.9	1.2	2.4	1.705	0.022
	bonghwa	357.2	299.4	83.8	57.8	16.2	95.4	49.1	2.4	0.2	16.1	1.4	332.6	29.8	1.1	0.1	1.0	0.1	1.9	0.2	2.1	0.2	11.5	0.8	2.4	1.968	0.037
	naelinchun1	1084.4	908.7	83.8	175.7	16.2	105.7	45.9	5.8	0.5	57.4	5.3	1004.4	92.6	5.7	0.5	1.4	0.1	4.0	0.4	5.8	0.5	11.1	0.6	1.7	2.180	0.014
	okdongchun2	495.3	414.0	83.6	81.2	16.4	97.0	50.9	3.5	0.7	25.6	5.2	459.7	92.8	1.5	0.3	0.3	0.1	3.4	0.7	1.3	0.3	11.3	0.7	1.5	1.671	0.013
	chunchendam2	774.9	645.5	83.3	129.4	16.7	104.2	44.1	18.7	2.4	56.6	7.3	672.1	86.7	4.8	0.6	1.4	0.2	4.1	0.5	17.2	2.2	9.7	0.9	2.4	1.315	0.020
	odaechun2	451.7	375.9	83.2	75.8	16.8	105.7	46.3	4.7	1.0	33.2	7.4	407.2	90.1	2.0	0.5	1.9	0.4	1.1	0.2	1.6	0.4	11.2	0.8	2.3	3.478	0.037
	gapyungchun5	305.4	254.1	83.2	51.3	16.8	111.0	48.3	5.3	1.7	18.5	6.1	274.1	89.7	2.2	0.7	0.2	0.1	2.1	0.7	3.1	1.0	11.0	0.9	2.0	2.507	0.035
	woonmumdam1	302.0	249.8	82.7	52.2	17.3	101.7	44.3	3.7	1.2	32.5	10.8	252.8	83.7	1.7	0.6	1.9	0.6	2.9	1.0	6.4	2.1	8.8	1.4	2.6	1.271	0.018
	gyechun2	283.7	234.6	82.7	49.1	17.3	114.0	43.7	1.4	0.5	36.0	12.7	243.0	85.7	0.4	0.1	0.1	0.0	0.8	0.3	2.0	0.7	10.2	0.8	2.1	1.798	0.013
	hawchundam1	1045.2	863.6	82.6	181.6	17.4	95.0	43.0	23.0	1.8	111.7	8.8	949.5	75.0	21.0	1.7	2.3	0.2	5.1	0.4	36.9	2.9	9.8	0.8	2.0	1.121	0.027
	pyungchanggang1	402.5	332.2	82.5	70.3	17.5	111.4	39.2	4.3	1.1	40.5	10.1	350.6	87.1	2.6	0.7	0.1	0.0	2.3	0.6	2.0	0.5	11.1	0.8	1.8	3.598	0.027
	juamdam	702.4	578.8	82.4	123.7	17.6	119.8	34.6	9.7	1.4	104.6	14.9	527.1	75.0	23.2	3.3	4.0	0.6	1.6	0.2	32.1	4.6	3.7	0.4	1.4	0.443	0.006
	deokchun	371.5	305.9	82.4	65.5	17.6	93.1	48.8	5.8	1.6	39.5	10.6	316.3	85.1	1.1	0.3	0.9	0.2	3.4	0.9	4.4	1.2	10.7	1.0	2.7	2.965	0.034
	jojongchun3	260.6	214.6	82.4	46.0	17.6	115.9	38.1	5.6	2.2	29.9	11.5	213.9	82.1	4.5	1.7	0.0	0.0	1.2	0.5	5.3	2.0	11.0	1.1	2.6	3.298	0.057
	chungjudam	833.6	686.6	82.4	147.1	17.6	101.4	41.6	15.9	1.9	117.1	14.0	627.0	75.2	2.5	0.3	1.4	0.2	11.3	1.4	58.5	7.0	9.0	0.8	2.2	2.236	0.021
	inbukchun2	504.3	414.9	82.3	89.3	17.7	93.1	40.4	13.4	2.0	39.5	6.0	432.6	65.5	8.9	1.4	0.8	0.1	4.5	0.7	4.6	0.7	11.1	0.9	2.4	1.739	0.026
	imhaho1	303.0	249.1	82.2	53.9	17.8	79.5	35.2	5.2	1.7	53.9	17.8	215.8	71.2	2.9	0.9	1.4	0.4	1.6	0.5	22.3	7.3	8.2	2.0	3.4	1.501	0.028
	youngwol1	1022.7	840.4	82.2	182.3	17.8	97.6	49.8	17.9	1.8	106.8	10.4	867.7	84.8	6.6	0.6	1.8	0.2	12.3	1.2	9.5	0.9	10.8	0.9	2.3	2.834	0.069
	dosan	617.9	507.7	82.2	110.2	17.8	92.3	46.4	7.0	1.1	85.8	13.9	514.0	83.2	2.0	0.3	2.7	0.4	1.9	0.3	4.4	0.7	11.5	0.8	2.5	2.360	0.044
	andong1	425.7	349.6	82.1	76.1	17.9	84.1	36.8	5.0	1.2	76.3	17.9	297.9	70.0	1.1	0.2	5.6	1.3	7.9	1.9	31.8	7.5	9.6	0.9	3.6	1.669	0.043
	choyanggang	918.5	753.6	82.0	165.0	18.0	109.4	43.0	11.9	1.3	126.2	13.7	760.0	82.7	4.4	0.5	3.0	0.3	5.3	0.6	7.7	0.8	11.0	0.8	2.3	2.652	0.027
	daechung	624.1	511.2	81.9	112.9	18.1	104.1	34.2	37.4	6.0	157.2	25.2	243.4	39.0	10.3	1.7	3.5	0.6	12.2	1.9	7.6	1.2	2.9	0.2	1.1	0.575	0.006
	youngjunchun1	397.8	325.8	81.9	72.0	18.1	85.0	40.4	5.7	1.4	56.5	14.2	324.1	81.5	1.5	0.4	1.7	0.4	3.4	0.9	4.9	1.2	9.7	1.5	2.0	1.751	0.025
	chungpyungdam1	818.4	670.2	81.9	148.2	18.1	109.8	37.0	17.0	2.1	106.8	13.1	660.5	80.7	7.9	1.0	2.3	0.3	7.9	1.0	15.9	1.9	10.4	1.0	3.0	1.969	0.033
	mujunamdaechun1	464.1	379.6	81.8	84.5	18.2	200.0	43.6	26.2	5.6	149.2	32.2	55.3	11.9	4.9	1.1	0.8	0.2	3.9	0.9	3.8	0.8	4.3	0.4	1.2	0.871	0.016
0 ~ 20 %	mujunamdaechun	325.5	266.2	81.8	59.3	18.2	187.4	43.4	12.2	3.8	69.8	21.5	34.8	10.7	2.9	0.9	0.0	0.0	1.9	0.6	1.7	0.5	9.9	0.8	2.7	2.333	0.024
	imsil	429.3	351.1	81.8	78.2	18.2	114.2	34.0	9.3	2.2	77.3	18.0	310.4	72.3	4.9	1.2	2.1	0.5	1.0	0.2	24.3	5.7	10.8	1.1	3.3	1.608	0.038
	juchungang2	607.4	496.5	81.7	110.9	18.3	113.1	36.7	7.8	1.3	87.1	14.3	499.0	82.2	2.1	0.3	1.4	0.2	5.4	0.9	4.6	0.8	11.0	0.9	2.1	2.988	0.016
	gilanchun1	519.4	424.5	81.7	94.9	18.3	85.7	41.0	7.9	1.2	75.6	11.6	421.1	64.6	3.0	0.5	2.1	0.3	4.3	0.7	5.3	0.8	6.8	0.5	1.6	2.109	0.010
	imchun	218.2	178.3	81.7	39.9	18.3	129.3	41.5	3.2	0.2	33.9	2.2	175.1	11.2	1.7	0.1	1.3	0.1	1.6	0.1	1.5	0.1	10.4	0.9	2.7	1.390	0.052
	gyesandam3	315.3	257.3	81.6	58.0	18.4	97.0	38.5	5.3	1.7	50.4	16.0	252.2	80.0	1.1	0.3	1.2	0.4	1.0	0.3	4.2	1.3	9.7	1.2	3.0	1.834	0.025
	sumgang3	319.9	261.1	81.6	58.9	18.4	107.8	33.9	5.1	1.6	48.8	15.2	254.3	79.5	3.3	1.0	1.2	0.4	2.9	0.9	4.3	1.3	10.2	1.8	4.0	4.454	0.195
	paldamdam4	380.3	309.7	81.4	70.6	18.6	107.9	33.4	15.0	4.0	42.1	11.1	295.1	77.6	7.4	1.9	0.4	0.1	5.9	1.6	14.3	3.8	11.0	1.2	3.2	1.800	0.032
	hongchungang1	1006.1	819.0	81.4	187.0	18.6	109.0	37.4	47.5	4.7	105.8	10.5	826.4	82.1	3.3	0.3	2.3	0.2	7.6	0.8	13.1	1.3	10.6	0.9	2.3	2.423	0.023
	chungjudam4	495.3	403.1	81.4	92.2	18.6	103.6	43.7	13.0	2.6	57.5	11.4	401.1	79.9	2.1	0.4	3.5	0.7	12.1	2.4	6.0	1.2	11.1	1.3	2.2	2.479	0.022
	namgangdam1	484.8	394.0	81.3	90.8	18.7	136.8	34.5	11.4	2.4	87.9	18.1	346.3	71.4	4.1	0.8	9.8	2.0	6.8	1.4	18.4	3.8	8.9	1.2	2.7	1.247	0.027
	sinbanchun	194.7	158.0	81.1	36.7	18.9	105.6	39.0	4.3	1.3	36.2	11.0	147.8	45.1	1.0	0.3	2.3	0.7	0.9	0.3	2.3	0.7	10.3	1.6	3.2	2.446	0.066
	youngdam2	355.1	288.0	81.1	67.1	18.9	112.1	40.3	4.4	1.2	33.8	9.5	74.7	21.0	1.8	0.5	0.3	0.1	2.7	0.8	2.8	0.8	3.3	0.2	1.0	0.507	0.006
	youngwol2	809.2	654.4	80.9	154.9	19.1	102.2	41.0	19.0	2.3	128.7	15.9	631.1	78.0	5.0	0.6	3.0	0.4	14.6	1.8	7.9	1.0	11.0	0.9	2.3	2.976	0.034
	younggang2	672.1	542.5	80.7	129.6	19.3	104.7	36.4	19.1	2.8	113.3	16.9	518.5	77.1	4.5	0.7	3.6	0.5	7.6	1.1	5.5	0.8	11.1	1.2	2.8	2.010	0.035
	michun	374.5	302.2	80.7	72.3	19.3	86.3	34.1	8.7	2.3	71.8	19.2	283.0	75.6	2.3	0.6	2.4	0.6	2.3	0.6	4.0	1.1	11.1	1.2	3.6	3.585	0.048
	gyechangweechun2	239.4	192.9	80.6	46.5	19.4	108.1	35.3	6.5	0.4	44.1	2.6	184.0	10.7	1.6	0.1	0.6	0.0	1.7	0.1	0.9	0.1	10.5	1.1	2.8	1.787	0.054
	damchun1	252.4	203.4	80.6	49.1	19.4	96.5	33.1	6.4	2.5	51.2	19.9	189.7	73.9	1.4	0.5	0.8	0.3	0.6	0.2	2.4	1.0	10.6	0.9	2.7	1.841	0.028
	chogang2	664.6	535.0	80.5	129.6	19.5	96.2	34.0	2.9	0.4	28.2	4.2	77.2	11.6	1.1	0.2	0.7	0.1	1.5	0.2	2.1	0.3	10.4	1.1	3.4	2.251	0.029
	bosungchun-1	283.8	228.2	80.4	55.5	19.6	122.3	35.3	6.1	2.1	61.9	21.8	201.2	70.9	8.1	2.8	2.6	0.9	0.9	0.3	3.0	1.1	4.2	0.4	1.3	0.496	0.011
	mulgeum	254.8	204.8	80.4	50.0	19.6	107.6	37.4	9.4	3.7	44.6	17.5	179.0	70.3	3.3	1.3	1.6	0.6	4.9	1.9	12.0	4.7	10.3	2.6	6.0	3.022	0.130
	hapchundam1	491.6	395.2	80.4	96.4	19.6	107.7	30.2	11.7	2.4	106.2	21.6	345.3	70.2	2.0	0.4	2.9	0.6	6.9	1.4	16.6	3.4	8.6	1.5	2.5	1.723	0.017
	heukchun3	314.1	252.2	80.3	61.8	19.7	113.5	33.3	13.0	4.1	57.2	18.2	232.8	74.1	3.7	1.2	1.3	0.4	2.8	0.9	3.2	1.0	10.3	1.1	2.8	2.858	0.035
	ssanggyechun	480.2	385.0	80.2	95.1	19.8	91.0	31.4	13.6	2.8	104.0	21.7	348.8	72.6	2.2	0.5	3.0	0.6	2.6	0.5	6.1	1.3	11.7	1.6	4.5	3.226	0.052
	gyunghogang2	1042.1	835.3	80.1	206.9	19.9	113.3	34.0	25.8	2.1	221.4	17.6	755.8	60.1	10.9	0.9	6.7	0.5	11.5	0.9	9.9	0.8	10.4	1.2	3.4	1.596	0.042
	ramchun2	264.1	211.6	80.1	52.5	19.9	124.0	34.4	6.5	2.5	60.9	23.1	189.3	71.7	3.7	1.4	1.1	0.4	0.5	0.2	2.2	0.8	9.4	1.2	2.8	1.594	0.056
	gurye	489.0	391.8	80.1	97.2	19.9	120.0	36.6	13.9	2.8	108.7	22.2	343.0	70.1	9.6	2.0	5.0	1.0	2.2	0.5	6.5	1.3	10.0	1.3	3.7	2.382	0.053

Table B-17: The observation data of Hangang, Nakdong, and Geum-sum-youngsan river for third step (Area: 250 km^2 ~, Imperviousness: 20 % ~)

Impervious	station	Total Area	pervious		impervious		rainfall	slope	large scale classification														Yearly water quality				
									Urban		Agriculture		Forest		Grass		Wetland		Barren		Water		Average(2001~2010)				
		km^2	km^2	(%)	km^2	(%)	yearly	aver-age(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	km^2	(%)	DO	BOD	COD	TN	TP
	banbyunchun1A	582.3	465.4	79.9	116.8	20.1	80.8	42.6	40.3	5.4	74.5	10.0	452.7	60.6	2.1	0.3	2.1	0.3	5.6	0.7	4.9	0.7	3.3	0.3	1.2	0.338	0.005
	churyungchun	355.9	284.3	79.9	71.6	20.1	111.9	31.8	10.3	2.9	79.5	22.3	249.9	70.2	8.9	2.5	1.8	0.5	1.6	0.4	3.9	1.1	3.7	0.3	0.8	0.845	0.005
	youguchun	282.6	225.5	79.8	57.1	20.2	105.1	31.4	7.4	2.6	10.3	3.6	21.2	7.5	1.6	0.5	0.2	0.1	1.0	0.3	1.7	0.6	10.2	1.7	2.8	1.785	0.037
	jinwol	298.9	238.3	79.8	60.5	20.2	139.3	32.4	11.0	3.7	67.9	22.7	202.6	67.8	4.4	1.5	2.0	0.7	2.3	0.8	8.6	2.9	3.6	0.5	1.4	0.457	0.016
	yeju1	536.0	427.3	79.7	108.7	20.3	101.7	25.8	17.6	3.3	123.9	23.1	354.4	66.1	14.4	2.7	5.4	1.0	5.9	1.1	14.5	2.7	10.0	1.4	3.3	2.822	0.060
	hamyangweechun2	177.9	141.8	79.7	36.1	20.3	115.7	34.8	5.8	0.1	41.4	0.7	125.4	2.0	2.4	0.0	0.8	0.0	0.8	0.0	1.2	0.0	10.9	1.5	3.7	3.123	0.121
	weechun1	392.8	312.7	79.6	80.1	20.4	92.8	31.6	12.9	3.3	93.6	23.8	273.1	69.5	3.6	0.9	2.4	0.6	2.6	0.7	4.6	1.2	11.8	1.4	3.8	4.035	0.069
	bochungchun3	299.5	237.8	79.4	61.7	20.6	99.6	31.3	8.3	2.8	85.7	28.6	50.2	16.8	2.1	0.7	0.0	0.0	3.0	1.0	2.8	0.9	10.7	1.2	2.6	2.457	0.036
	jechuchun2	268.4	212.1	79.1	56.2	20.9	109.6	32.0	14.9	5.5	54.1	20.2	193.4	72.1	0.6	0.2	0.2	0.1	3.5	1.3	1.6	0.6	11.5	1.8	3.8	5.667	0.272
	yongdam4	575.2	453.9	78.9	121.3	21.1	106.1	35.2	5.1	0.9	51.4	8.9	103.9	18.1	2.1	0.4	1.4	0.2	2.2	0.4	5.3	0.9	8.0	1.1	2.6	1.539	0.022
	gamak	313.5	247.2	78.9	66.2	21.1	109.1	34.6	8.8	2.8	78.6	25.1	201.1	64.2	17.4	5.5	1.1	0.4	3.9	1.3	2.6	0.8	7.8	0.8	2.2	2.085	0.025
	bosunggang 1	327.0	257.8	78.9	69.1	21.1	123.7	26.9	10.5	3.2	92.6	28.3	205.3	62.8	8.6	2.6	2.1	0.6	2.1	0.6	5.8	1.8	4.1	0.5	1.3	0.342	0.013
	deokyeunlee	317.1	250.0	78.8	67.1	21.2	101.0	27.6	10.6	3.3	83.0	26.2	200.0	63.1	10.0	3.2	0.8	0.3	5.2	1.6	7.5	2.4	10.8	1.2	2.9	2.445	0.038
	chungdochun	518.0	408.1	78.8	109.9	21.2	98.1	34.2	18.0	0.6	145.1	5.0	337.0	11.6	3.5	0.1	2.7	0.1	4.3	0.1	7.4	0.3	11.4	1.6	4.2	3.686	0.063
	naesungchun1	794.2	623.8	78.5	170.4	21.5	94.7	27.6	21.1	2.7	237.6	29.9	509.8	64.2	4.3	0.5	3.8	0.5	9.1	1.2	8.4	1.1	10.6	1.0	2.6	4.232	0.095
	geumchun	313.1	245.9	78.5	67.2	21.5	99.4	34.1	10.2	3.3	97.6	31.2	194.2	62.0	2.2	0.7	1.2	0.4	1.3	0.4	6.4	2.0	3.5	0.4	3.2	0.534	0.018
	hwangryong3	565.0	443.7	78.5	121.4	21.5	114.9	27.7	28.4	5.0	152.4	27.0	350.9	62.1	6.8	1.2	4.5	0.8	4.8	0.8	17.3	3.1	10.1	3.0	4.6	1.733	0.063
	gyechangdongchun2	197.9	155.4	78.5	42.6	21.5	98.1	32.9	5.6	0.8	57.0	8.4	129.7	19.1	0.8	0.1	0.3	0.0	3.3	0.5	1.3	0.2	10.2	1.1	2.9	2.906	0.079
	andong5	363.2	284.6	78.3	78.7	21.7	89.0	26.6	11.2	3.1	115.2	31.7	221.7	61.0	3.4	0.9	2.8	0.8	3.0	0.8	6.0	1.7	3.3	0.3	1.3	0.690	0.012
	gamchun2	1162.4	910.4	78.3	252.0	21.7	89.7	29.1	41.7	3.6	327.0	28.1	743.4	64.0	8.2	0.7	5.6	0.5	21.1	1.8	15.5	1.3	10.1	1.1	3.6	4.348	0.159
20 ~ 25 %	geumhogang3	1573.3	1230.5	78.2	342.9	21.8	90.6	29.0	80.6	5.1	306.1	19.5	508.1	32.3	18.1	1.2	8.8	0.6	16.1	1.0	24.0	1.5	10.8	3.2	7.7	5.192	0.268
	yechun1	255.6	199.7	78.1	55.9	21.9	88.9	22.9	6.8	0.3	88.0	4.3	141.9	6.9	3.3	0.2	3.8	0.2	3.8	0.2	8.0	0.4	4.3	0.4	1.5	0.970	0.012
	osuchun	370.9	289.6	78.1	81.3	21.9	112.9	24.6	11.6	3.1	124.3	33.5	220.6	59.4	5.0	1.4	3.5	0.9	1.6	0.4	4.3	1.1	10.9	1.5	3.8	2.010	0.060
	hanchun	256.5	200.0	78.0	56.4	22.0	99.3	27.0	9.5	3.7	82.7	32.3	157.7	61.5	2.4	0.9	1.0	0.4	0.9	0.4	2.2	0.9	10.3	1.4	3.6	3.114	0.110
	milyanggang1	348.4	271.8	78.0	76.5	22.0	103.4	41.9	40.1	11.5	40.9	11.7	247.4	70.8	5.2	1.5	2.7	0.8	6.8	1.9	5.4	1.5	10.1	1.0	2.4	2.358	0.046
	geumhogang4	213.4	166.0	77.8	47.4	22.2	94.3	22.3	22.4	6.5	31.1	9.0	146.9	42.6	5.0	1.4	1.0	0.3	3.5	1.0	3.5	1.0	12.0	3.7	8.2	5.062	0.293
	andong2	187.8	145.8	77.7	42.0	22.3	80.3	28.1	15.1	0.8	40.0	2.2	112.6	6.1	2.1	0.1	4.2	0.2	6.9	0.4	6.9	0.4	10.8	1.0	4.0	1.889	0.046
	namgang3	711.9	552.6	77.6	159.3	22.4	120.4	28.2	43.3	6.1	210.7	29.6	420.0	59.0	6.5	0.9	6.9	1.0	6.7	0.9	17.7	2.5	10.1	2.7	5.5	3.018	0.124
	weechun6	436.2	338.4	77.6	97.8	22.4	83.5	19.1	13.8	3.4	160.5	39.3	238.3	58.3	4.4	1.1	4.1	1.0	4.0	1.0	11.2	2.7	4.2	0.6	1.9	1.016	0.020
	youngjuseochun2	364.6	282.2	77.4	82.4	22.6	101.9	28.1	19.2	5.3	110.0	30.2	224.6	61.6	1.5	0.4	1.8	0.5	4.1	1.1	3.4	0.9	8.2	1.8	3.4	5.118	0.216
	namji	467.2	361.3	77.3	106.0	22.7	99.4	25.4	18.7	4.0	171.3	36.7	236.8	50.7	9.0	1.9	5.4	1.2	6.1	1.3	19.9	4.3	10.3	2.7	6.0	3.239	0.159
	beakchun	289.1	223.2	77.2	65.9	22.8	89.9	25.0	11.2	3.9	99.2	34.3	168.8	58.4	2.3	0.8	0.6	0.2	4.1	1.4	3.0	1.0	7.9	1.2	2.8	1.746	0.057
	guri	413.6	319.3	77.2	94.3	22.8	105.2	23.4	39.8	9.6	89.1	21.5	249.0	60.2	11.5	2.8	0.4	0.1	10.1	2.4	13.7	3.3	10.7	1.5	3.7	2.478	0.052
	gyunganchun6	561.1	433.2	77.2	128.0	22.8	105.6	26.5	63.3	11.3	92.9	16.6	364.1	64.9	17.2	3.1	1.6	0.3	11.1	2.0	10.9	1.9	9.9	3.9	6.6	5.066	0.166
	yochun	294.8	227.1	77.0	67.7	23.0	113.3	22.8	15.7	5.3	97.4	33.0	163.4	55.4	5.4	1.8	4.4	1.5	3.9	1.3	4.7	1.6	10.2	1.6	4.0	2.707	0.161
	sangju2	207.1	158.8	76.7	48.3	23.3	91.2	19.1	7.0	0.3	79.4	3.2	105.7	4.3	1.6	0.1	1.7	0.1	5.4	0.2	6.3	0.3	10.1	0.9	3.4	2.491	0.059
	paldangdam1	505.1	382.4	75.7	122.7	24.3	110.7	20.8	35.5	7.0	197.7	39.1	230.2	45.6	10.9	2.2	3.4	0.7	8.6	1.7	18.9	3.7	11.3	1.6	3.7	2.502	0.058
	byungsungchun	341.0	258.1	75.7	82.8	24.3	97.5	31.3	19.2	5.6	137.4	40.3	167.6	49.2	4.3	1.3	2.5	0.7	4.0	1.2	5.9	1.7	10.2	1.7	4.5	3.883	0.211
	mihochun5	471.5	355.8	75.5	115.7	24.5	102.5	18.5	33.4	7.1	271.8	57.6	180.9	38.4	5.4	1.1	4.4	0.9	2.5	0.5	38.1	8.1	9.7	4.4	8.2	5.526	0.288
	gwangju1	562.0	422.5	75.2	139.5	24.8	112.8	25.5	46.0	8.2	206.2	36.7	268.9	47.8	13.5	2.4	5.7	1.0	8.2	1.5	13.5	2.4	10.6	3.7	5.8	2.793	0.103
	chungmichun3	596.6	447.9	75.1	148.7	24.9	104.0	17.3	34.3	5.7	257.8	43.2	262.3	44.0	15.4	2.6	3.3	0.5	10.6	1.8	13.0	2.2	10.9	2.9	5.1	3.767	0.101
	mooan2	885.4	661.7	74.7	223.7	25.3	101.8	15.1	42.2	4.8	470.0	53.1	291.8	33.0	8.7	1.0	8.9	1.0	10.3	1.2	53.5	6.0	9.9	2.0	5.7	4.194	0.133
	geumganggapmun	536.6	400.9	74.7	135.7	25.3	100.3	12.4	5.0	0.9	35.8	6.7	96.3	17.9	0.6	0.1	0.5	0.1	0.9	0.2	1.5	0.3	3.2	0.9	2.2	1.312	0.039
	gokneungchun3	261.5	193.5	74.0	67.9	26.0	106.2	17.0	31.0	11.8	84.4	32.3	116.2	44.5	13.5	5.1	1.3	0.5	11.4	4.3	3.7	1.4	9.4	7.4	9.8	8.298	0.268
	samrangjin	435.8	322.1	73.9	113.7	26.1	100.5	20.4	32.0	7.3	211.3	48.5	149.0	34.2	6.1	1.4	6.3	1.5	8.9	2.0	22.3	5.1	10.4	2.8	5.9	3.089	0.163
	wegwan	500.7	369.4	73.8	131.3	26.2	86.7	20.4	54.7	10.9	164.6	32.9	239.8	47.9	5.9	1.2	4.3	0.9	17.1	3.4	14.2	2.8	10.2	1.8	4.5	3.041	0.108
	youngsanpo	309.9	227.9	73.5	82.1	26.5	110.4	14.7	19.2	6.2	166.1	53.6	108.1	34.9	3.4	1.1	2.3	0.8	3.1	1.0	7.7	2.5	9.6	5.6	6.5	6.624	0.435
25 % ~	bokhachun3	309.5	227.4	73.5	82.2	26.5	110.3	12.9	31.4	10.2	135.5	43.8	124.5	40.2	7.3	2.4	1.8	0.6	3.2	1.0	5.6	1.8	9.7	4.2	5.5	6.322	0.214
	geumhogang6	286.8	209.0	72.9	77.9	27.1	97.9	26.1	67.1	14.3	34.2	7.3	163.2	34.8	7.4	1.6	2.3	0.5	6.8	1.5	5.8	1.2	10.2	3.8	9.3	7.244	0.543
	mihochun3	288.8	207.8	71.9	81.0	28.1	98.2	14.3	6.8	2.3	56.9	19.7	43.4	15.0	1.5	0.5	0.5	0.2	0.3	0.1	3.7	1.3	10.2	3.1	6.3	4.479	0.173
	nakdonghagu1	288.6	206.8	71.7	81.8	28.3	115.3	17.5	38.8	13.4	109.1	37.8	104.0	36.0	7.7	2.7	1.5	0.5	13.3	4.6	14.2	4.9	10.5	2.2	5.4	3.293	0.110
	tanchun5	302.8	215.6	71.2	87.1	28.8	105.3	18.9	92.8	30.6	36.9	12.2	146.6	48.4	7.3	2.4	2.4	0.8	13.1	4.3	3.7	1.2	6.9	17.9	11.9	15.417	1.047
	jungryangchun4	350.4	246.7	70.4	103.7	29.6	111.3	16.2	111.3	31.8	55.3	15.8	157.8	45.0	6.4	1.8	2.3	0.7	12.1	3.4	5.1	1.5	7.9	12.1	11.2	17.647	1.439
	ananyangchun5	281.2	182.6	65.0	98.6	35.0	103.0	15.5	130.4	46.4	32.1	11.4	104.2	37.1	3.9	1.4	0.2	0.1	6.9	2.5	3.5	1.2	6.1	9.8	11.1	18.217	0.972

APPENDIX C – WATERSHED CHARACTERISTICS OF YONGDAM DAM'S WATERSHED

Watershed characteristics

An elevation distribution of the watershed is whon Figure C-1. The highest altitude in the watershed is EL 1,587.56 and elevations between EL. 400 ~ 600 m make up the largest distribution of elevations in the watershed. The second largest is EL. 300 ~ 400 m and the third is EL 600 ~ 800 m.

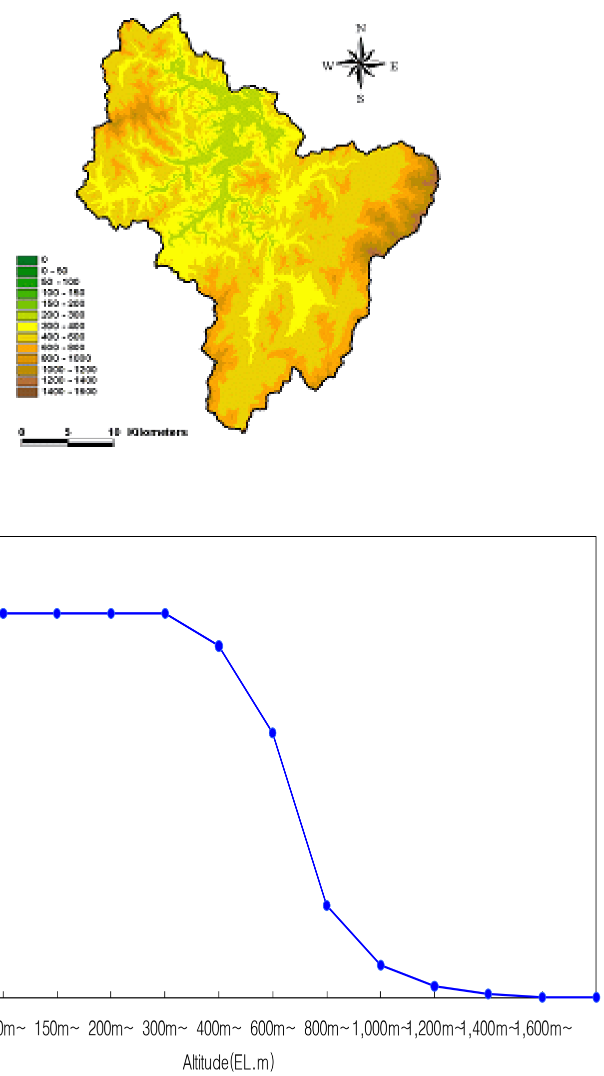

Figure C- 1: The altitude analysis map and the accumulative area ratio for the altitude analysis

Topography Characteristics

Yongdam Dam has changed the ecosystem of the Geum River because the water ecosystem is impacted by the changes in flow. Dam construction has affected geological characteristics, river length, water depth, surface water, and hydraulic retention time. In particular, due to its deep depth, the reservoir is stratified and does not mix smoothly. The Yongdam reservoir is 38.5 km in length, 1.2 km in the width, and 70 m at its deepest point. Stratification in the reservoir is a serious problem in the summer season and the average hydraulic retention time (t=V/Q) is 318 days. Five tributaries impact flow velocity of the reservoir, and it has complex geology.

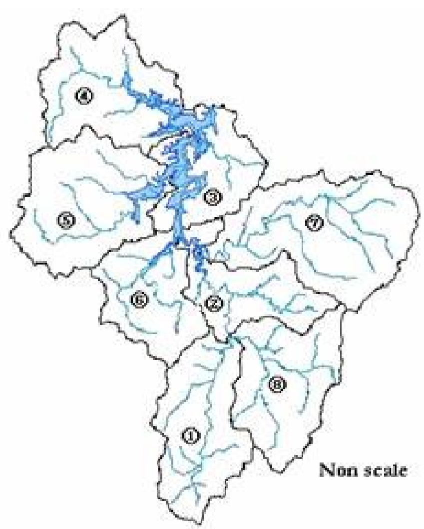

Figure C-2: A Watershed divisional map of Yongdam watershed

Table C-1 The inflow tributaries of Yongdam's reservoir

River	Watershed area (km^2)	River length (km)	Slope (%)
Keumgang 1	116.3	12.5	1.416
Keumgang 2	82.53	16.1	1.773
Keumgang 3	84.3	10.0	0.153
Juja-Cheon	126.4	16.4	1.714
Jeongja-Cheon	142.8	14.9	0.584
Jinan-Cheon	89.0	7.9	1.506
Guyang-Cheon	172.1	26.6	2.360
Jang-gyae-Cheon	114.2	8.5	2.270

Hydrology

The data describing Yongdam watershed's hydrology were collected from January 2005 to October 2007 as shown in Figure C-3 and Tables C-2 ~ C-4. In 2005, yearly rainfall was 1,474.8 mm. Annual average rainfall, excluding days without rainfall, was 9.0 mm and precipitation ranged from 0.1 to 186.0 mm. The maximum daily runoff was 180 mm in July. In addition, July was the largest rainfall month (519.9 mm) in 2005. There is a close relationship between inflow/outflow and rainfall patterns. The inflow range and average value were 0.1 ~ 1,979.8 m^3/s and 28.4 m^3/s, respectively and the outflow was 11.9 ~ 705.6 m^3/s and 29.9 m^3/s. The average water level of the reservoir was 250.9 m and the range was 241.2 ~ 261.7 m. The largest month of water level difference was in July.

In 2006, the total annual rainfall was 1,378.2 mm. Annual average rainfall, excluding days without rainfall, was 9.6 mm and the range was 0.1 ~ 85.0 mm. The 2006 results of inflow/outflow and rainfall patterns had a close relationship as well. The inflow range and average value were 0.1 ~ 671.3 m^3/s and 24.1 m^3/s, respectively and the outflow was 9.1 ~ 509.5 m^3/s and 19.8 m^3/s. The average water level of the reservoir was 250.0m and the range was 241.2 ~ 261.7 m. The largest month of water level difference was in July, which was the same as in 2005.

In 2007, the data was collected until October. It was an abundant year for water quantity because it rained continuously for a long period from June to August. The total rainfall was 1485.8 mm. Annual average rainfall and rainfall range, excluding days without rainfall, were 11.3 mm and 0.1~126.5mm, respectively.

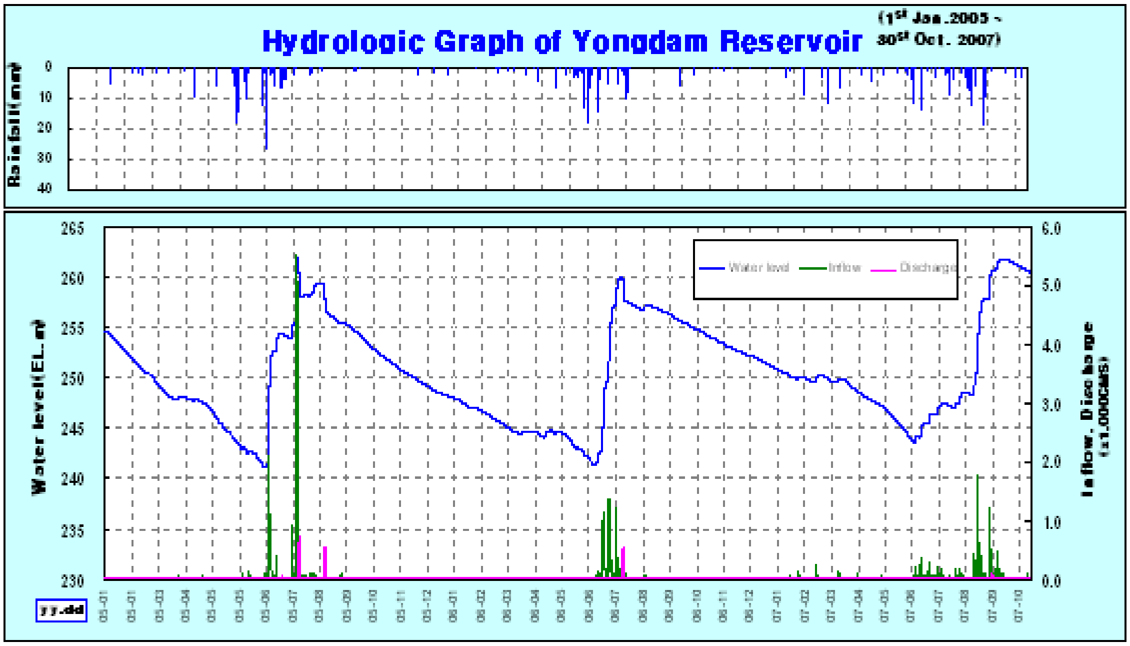

Figure C-3: Hydrology graph of Yongdam reservoir (2005 ~2007)

Table C-2: Hydrology of Yongdam's reservoir in 2005 (average ± standard deviation and maximum/minimum)

Factors\Season	Total	Pre-Monsoon (January-June)	Post-Monsoon (July-December)
Total rainfall (mm)	1,474.8	418.1	1,056.7
Average rainfall (mm)	9.0±22.9 (186.0/0.1)	6.2±10.6 (46.9/0.1)	10.9±28.4 (186.0/0.1)
Total inflow (m^3/s)	9,412.2	1,267.0	8,145.2
Average influent water (m^3/s)	28.4±134.4 (1979.8/0.1)	7.1±10.4 (62.7/0.1)	53.6±195.3 (1,979.8/0.3)
Total outflow (m^3/s)	10,903.3	4,313.6	6,589.7
Average effluent water (m^3/s)	29.9±60.5 (705.6/11.9)	23.8±4.5 (27.8/11.9)	35.8±84.8 (705.6/12.6)
Water level (EL. m)	250.9±4.6 (261.7/241.2)	247.8±3.7 (254.6/241.2)	253.9±3.2 (261.7/242.2)

Table C-3: Hydrology of Yongdam's reservoir in 2006 (average ± standard deviation and maximum/minimum)

Factors\Season	Total	Pre-Monsoon (January-June)	Post-Monsoon (July-December)
Total rainfall (mm)	1,378.2	417.5	960.7
Average rainfall (mm)	9.6±15.5 (85.0/0.1)	6.7±10.2 (49.4/0.1)	11.7±18.4 (85.0/0.1)
Total inflow (m^3/s)	8,013.4	1,451.9	6,561.5
Average influent water (m^3/s)	24.1±75.0 (671.3/0.1)	8.4±10.3 (67.0/0.1)	41.0±15.2 (671.3/0.1)
Total outflow (m^3/s)	7,237.9	2,985.6	4,252.4
Average effluent water (m^3/s)	19.8±30.6 (509.5/9.1)	16.5±4.9 (25.3/10.4)	23.1±42.7 (509.5/9.1)
Water level (EL. m)	250.0±5.3 (260.0/241.4)	245.5±1.9 (248.9/241.5)	254.3±3.7 (260.0/241.4)

Table C-4: Hydrology of Yongdam's reservoir in 2007 (average ± standard deviation and maximum/minimum)

Factors\Season	Total	Pre-Monsoon (January-June)	Post-Monsoon (July-December)
Total rainfall (mm)	1,485.5	479.8	1,005.7
Average rainfall (mm)	11.3±18.2 (126.5/0.1)	8.1±10.1 (38.4/0.1)	14.0±22.5 (126.5/0.1)
Total inflow (m^3/s)	8,779.1	1,655.3	7,123.8
Average influent water (m^3/s)	29.8±69.9 (640.6/0.2)	9.6±15.1 (120.7/0.2)	57.9±100.4 (640.6/2.9)
Total outflow (m^3/s)	6,087.6	3,453.8	2,633.8
Average effluent water (m^3/s)	20.0±7.1 (89.6/10.7)	19.1±4.9 (26.0/14.1)	21.4±9.2 (89.6/10.7)
Water level (EL. m)	251.7±5.1 (261.7/243.7)	248.7±2.2 (251.8/243.7)	253.6±6.6 (261.7/244.4)

River Characteristics

Stream order has been used to measure the relative size of streams. Strahler's (1952) stream order system is a simple method of classifying stream segments based on the number of tributaries upstream. A stream with no headwater stream is a first order stream. A second order stream is the segment downstream of the confluence of two first order streams. Therefore a n^{th} order stream is located downstream of the confluence of two $(n-1)^{th}$ order stream. Based on Strahler's stream order system, Yongdam watershed's stream order was drawn in Figure C-4.

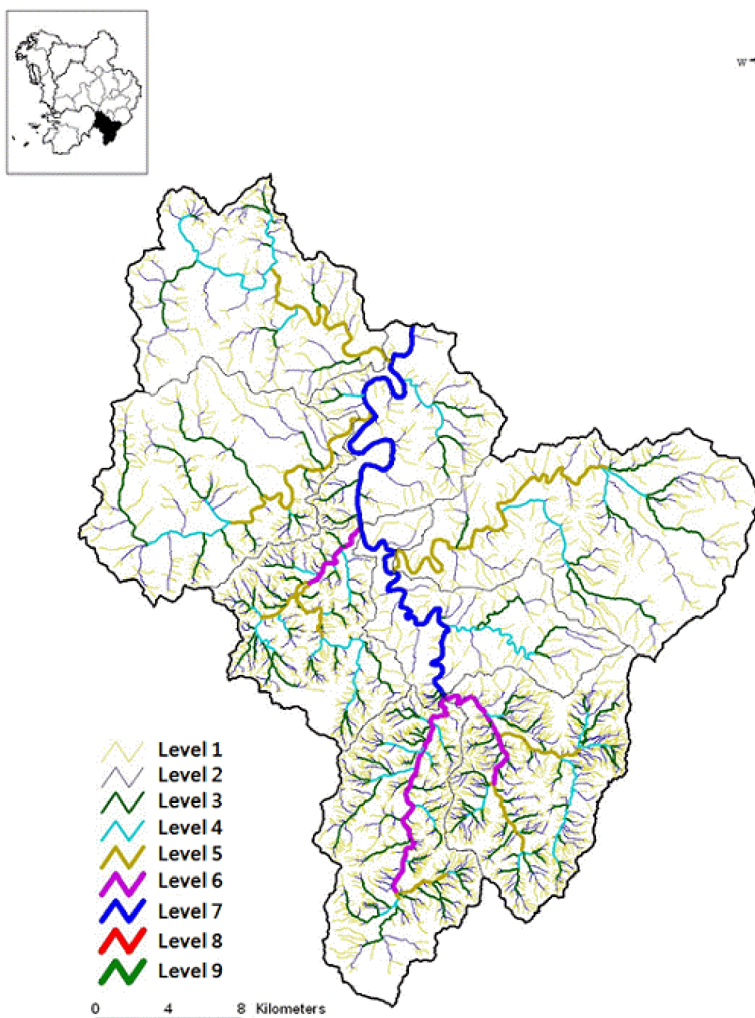

Figure C-4: The stream order map of Yongdam watershed

The basin length of the river channel and the length of river channel are 63.00 km and 62.58 km, respectively. The total length of river channel is 2,130.50 km. The characteristics of river are shown in Table C-5.

Table C-5: The river characteristics of Yongdam watershed

River\Characteristics	The basin length (㎞)	The length of river channel (km)	Total river channel(㎞)
Yong dam	63.00	62.58	2,130.50
Jang gye junction	21.28	20.86	390.22
Jang gye	16.06	15.62	445.96
Gu ryang	35.07	34.53	289.13
Jin ahn junction	-	-	138.36
Jin ahn	20.44	20.14	291.99
Jeong ja	30.92	30.07	227.24
Ju ja	20.84	20.52	195.61
Yong dam	-	-	151.99

According to the stream order analysis of Yongdam watershed, the maximum stream order is 7th which has shown in Table C-6 and Figure C-5. In general, first to third order streams are usually called headwater streams. Medium streams range from fourth to sixth order. Streams over the seventh order are termed rivers (http://www.cotf.edu/ete/modules/waterq3/WQassess4b.html.). Therefore, Yongdam watershed is composed of headwater streams, medium streams, and a river.

Table C-6: The stream orders of Yongdam watershed

Watershed division		Stream order									Total
		1st	2nd	3rd	4th	5th	6th	7th	8th	9th	
Yong dam		2,746	742	183	41	10	3	1	-	-	3,726
	Jang gye junction	649	176	43	11	2	2	1	-	-	884
	Jang gye	688	194	53	8	3	1	-	-	-	947
	Gu ryang	198	50	11	4	1	-	-	-	-	264
	Jin ahn junction	90	25	6	1	1	1	1	-	-	125
	Jin ahn	545	143	36	9	2	1	-	-	-	736
	Jeong ja	237	60	14	3	1	-	-	-	-	315
	Ju ja	181	48	11	3	1	-	-	-	-	244
	Yong dam	158	46	9	2	2	-	1	-	-	218

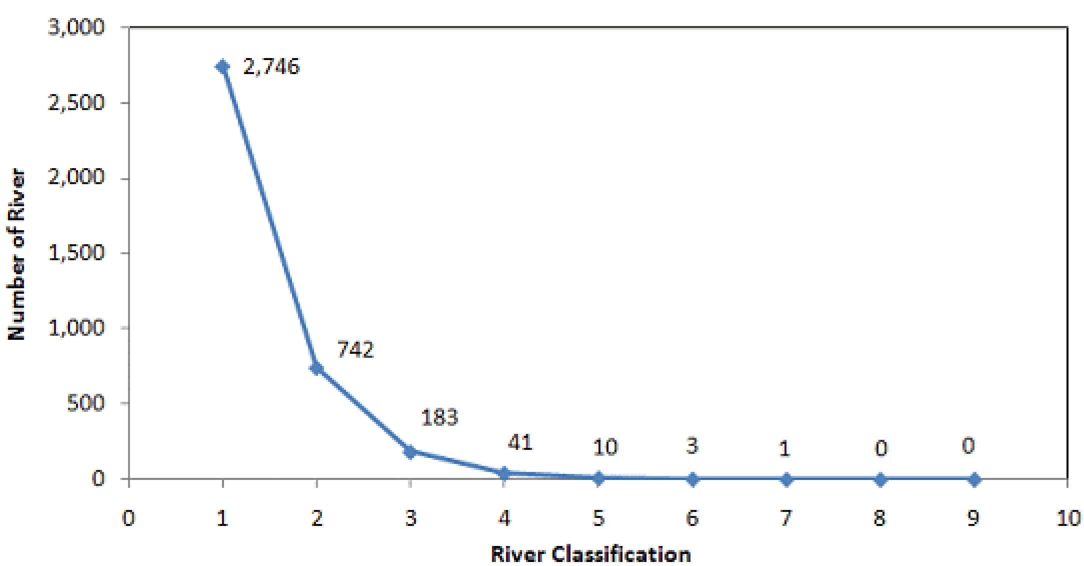

Figure C-5: The stream number of each stream order

Geographic & Topographic Characteristics

Yongdam watershed is located at the headwater of the Geumgan watershed and is the boundary (36°1′37″N) between Juchun myun, Jinangun, Jeollabuk-do and namimyun, geumsangun, chungcheongnam-do. It is a diamond-shaped watershed with a north-south length (49.3km) that is longer than the east-west length (39.4km) and the ratio of north-south and east-west is about 1.25. The northern part of this watershed slopes in a western direction. In addition, Yongdam dam at the outlet of the Yongdam watershed has been effectively used for water resources in order to supply water, generate electricity, and prevent flood damages.

The average slope of this watershed is 37.5%, Overland slopes below 10% and 40% make up 12.7% and 53.5% of the watershed, respectively. Slopes over 60% make up 15.6% of the watershed. This watershed's slope is very steep because it is located at the river headwaters in a hilly section of the landscape. The area ratio based on the slope distribution (%) is shown in Figure C-6.

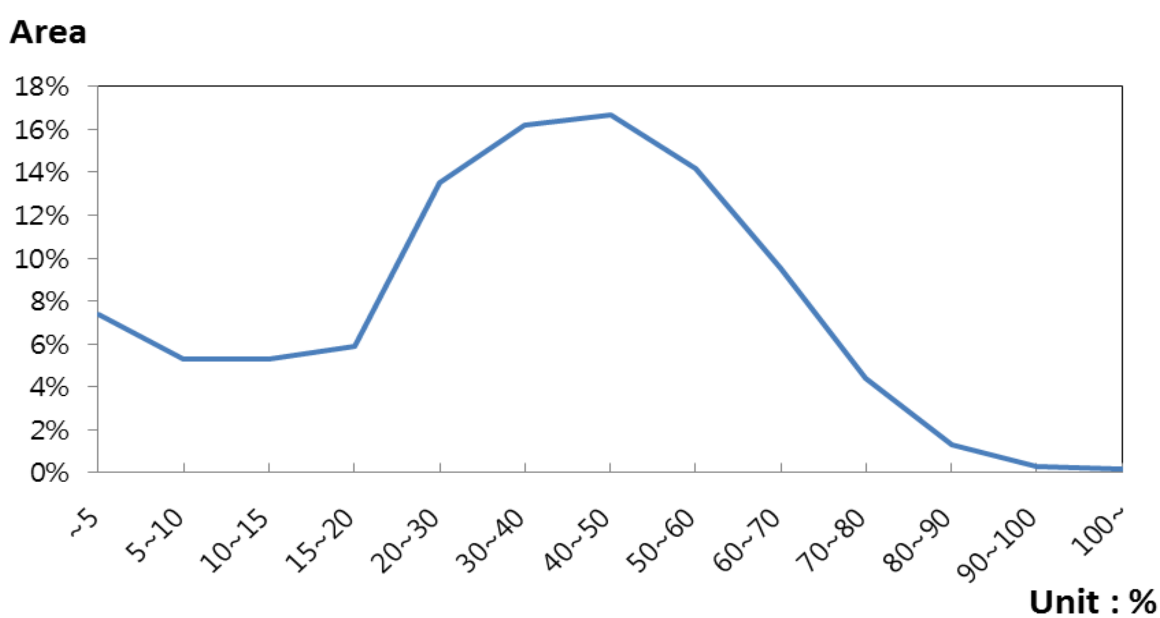

Figure C-6: The area ratio based on the slope distribution (%)

The slope map of Yongdam watershed is shown in Figure C-7.

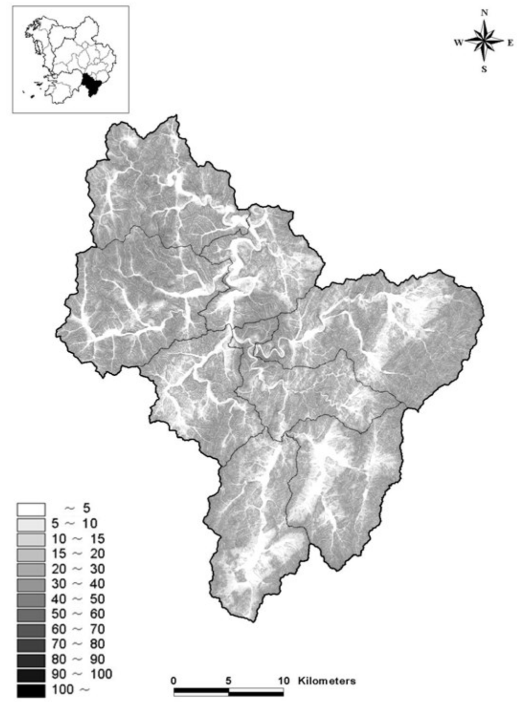

Figure C-7: The slope map of Yongdam watershed

The area ratio of slope direction distribution is shown in Figure C-8.

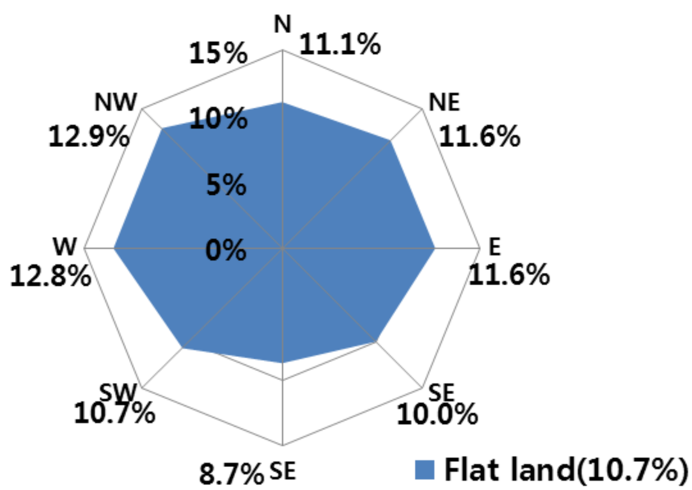

Figure C-8: The area ratio of slope direction distribution

APPENDIX D – WATERSHED CHARACTERISTICS OF NAKDONG RIVER WATERSHED

General Condition of River

There are a total of 803 rivers located in the Nakdong River watershed. The main River is shown in Table D-1. National River and Local River are thirteen and ten, respectively.

Table D-1: The river status of Nakdong watershed

Number	Name of river/stream	River Systems			River grade	Watershed area (㎢)	Length of River (㎞)
		Mainstream	First tributary	Second tributary			
1	Nakdong river	Nakdong river			Nation	23,384.21	510.36
2	Nakdong river	Nakdong river			Local	1,159.90	109.66
3	Banbyun stream	Nakdong river	Banbyun stream		Local	1,973.11	109.40
4	Naesung stream	Nakdong river	Naesung stream		Nation	1,814.71	108.20
5	Naesung stream	Nakdong river	Naesung stream		Local	1,159.01	80.29
6	Byungsung stream	Nakdong river	Byungsung stream		Local	434.06	32.30
7	Wee stream	Nakdong river	Wee stream		Local	1,403.06	113.50
8	Gam stream	Nakdong river	Gam stream		Nation	1,004.06	69.00
9	Geumho river	Nakdong river	Geumho river		Nation	2,107.87	116.00
10	Shin stream	Nakdong river	Geumho river	Shin stream	Local	179.97	28.30
11	Hwe stream	Nakdong river	Hwe stream		Local	781.42	78.00
12	Hwang river	Nakdong river	Hwang river		Nation	1,329.80	111.00
13	Guechangwee stream	Nakdong river	Hwang river	Guechangwee stream	Local	239.41	32.89
14	Nam river	Nakdong river	Nam river		Nation	3,467.52	185.60
15	Nam river	Nakdong river	Nam river		Local	500.47	40.20
16	Hamyangwee stream	Nakdong river	Nam river	Hamyangwee stream	Local	178.88	26.93
17	Deokchun river	Nakdong river	Nam river	Deokchun river	Nation	445.14	46.72
18	Haman stream	Nakdong river	Nam river	Haman stream	Nation	155.53	22.00
19	Milyang river	Nakdong river	Milyang river		Nation	1,421.26	101.50
20	Yangsna stream	Nakdong river	Yangsna stream		Nation	243.22	32.30
21	West Nakdong river	West Nakdong river			Nation	285.08	26.40
22	Pyunggang stream	West Nakdong river	Pyunggang stream		Nation	34.61	15.40
23	Maekdo river	West Nakdong river	Pyunggang stream	Maekdo river	Nation	6.21	11.60

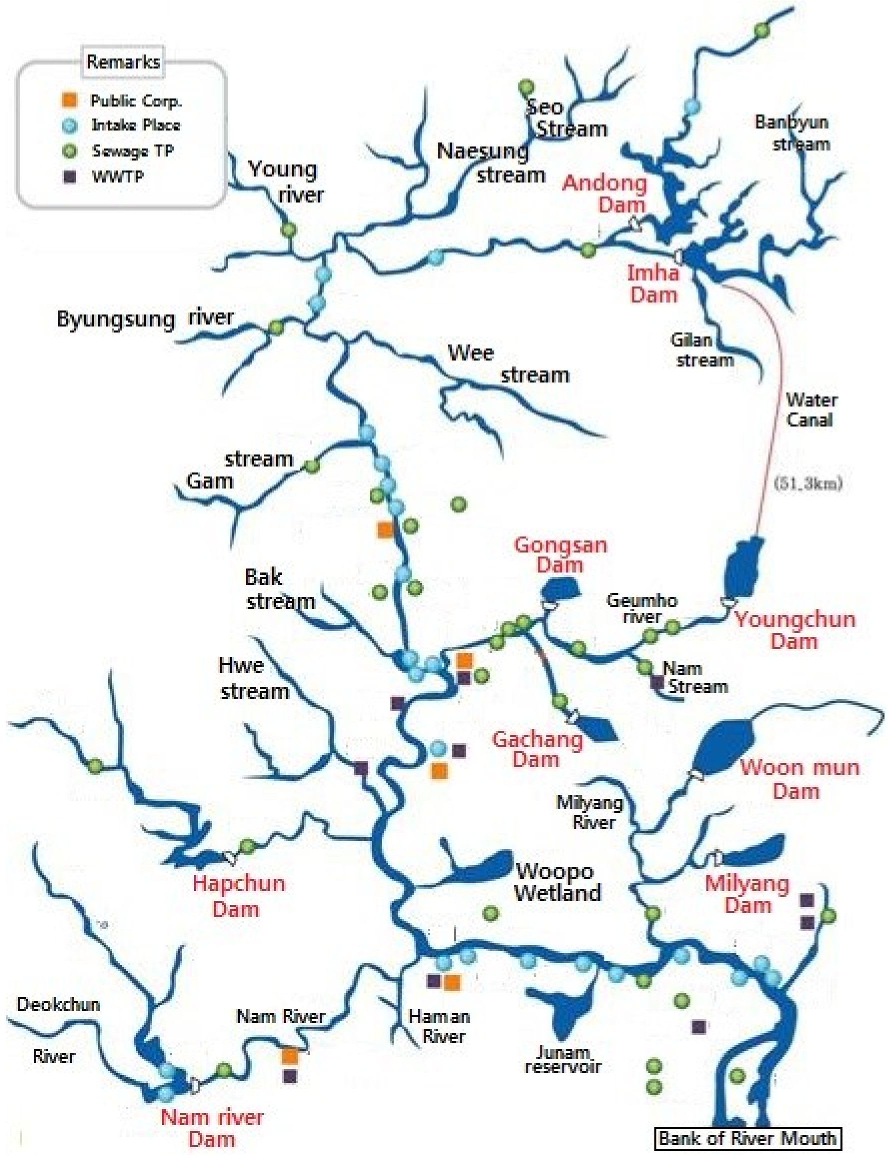

Figure D-1: Nakdong River Watershed

The Status of Main Dam

Tha Nakdong watershed contains five Multipurpose dams—Andong Dam, Imha Dam, Hapchun Dam, Milyang Dam—ten domestic & industry Dams, one hydroelectric Dam, and five thousands seven hundreds seventy one agriculture dams. The Monthly hydrology data of the main dams is shown at Table D-2.

Table D-2: Monthly hydrology data for Nakdong river watershed (as of 2010)

Division		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Tot/ Avg
An Dong Dam	Avg. rainfall (㎜)[1]	32.1	70.8	80.3	60.7	128.2	33.8	89.9	254.9	254.5	31.1	6.2	17.3	1,059.8
	Storage rate (%)[2]	37.1	34.8	37.3	36.5	33.9	31.8	25.3	26.9	43.4	52.1	50.3	48.0	38.1
	Inflow (m^3/s)[2]	3.1	17.4	34.2	24.4	42.2	9.3	9.6	47.5	110.9	10.9	3.6	2.9	26.3
	Outflow (m^3/s)[2]	16.9	18.0	22.8	41.3	37.4	46.2	28.2	12.1	12.5	13.9	13.9	15.2	23.2
Im Ha Dam	Avg. rainfall (㎜)	19.4	59.9	50.7	43.6	108.0	26.4	120.1	257.3	153.6	27.4	8.1	17.9	892.4
	Storage rate (%)	41.7	39.2	42.2	36.7	31.2	28.0	25.1	35.9	52.1	54.3	49.8	45.5	40.1
	Inflow (m^3/s)	1.5	12.6	19.0	14.2	24.1	3.3	8.9	50.5	34.6	3.7	1.2	1.3	14.6
	Outflow (m^3/s)[2]	8.5	9.9	21.4	31.7	22.4	23.7	5.7	5.3	12.0	12.4	11.4	10.3	14.6
Hap Chun Dam	Avg. rainfall (㎜)	21.9	90.5	68.0	90.0	113.1	22.8	294.7	544.4	246.7	57.0	9.1	30.8	1,589.0
	Storage rate (%)	34.0	31.9	31.6	29.4	28.2	24.3	27.3	53.8	83.6	84.0	79.7	74.4	48.5
	Inflow (m^3/s)	2.1	7.9	10.0	10.0	15.5	3.2	40.3	125.7	83.3	10.0	4.8	4.0	26.4
	Outflow (m^3/s)[2]	8.8	11.2	14.5	15.6	17.0	22.3	7.3	10.8	42.6	20.0	19.6	21.5	17.6
Nam Gang Dam	Avg. rainfall (㎜)	27.7	129.1	96.0	141.6	141.5	36.6	427.4	545.3	316.2	65.5	9.4	25.0	1,961.3
	Storage rate (%)	31.8	37.6	57.7	48.7	51.5	36.7	40.7	45.4	55.5	57.1	52.6	48.9	47.0
	Inflow (m^3/s)	7.5	42.1	46.0	77.9	72.7	12.6	242.1	423.5	310.0	26.0	12.6	11.3	107.0
	Outflow (m^3/s)[2]	8.0	11.8	55.8	55.5	76.7	45.7	220.9	433.2	282.3	33.7	16.7	16.2	104.7
Mil Yang Dam	Avg. rainfall (㎜)	41.7	105.0	72.9	102.9	159.3	40.2	289.4	321.3	190.5	42.6	14.4	22.3	1,402.5
	Storage rate (%)	52.5	50.4	56.0	53.2	54.0	47.7	50.3	70.0	81.7	78.8	73.3	68.3	61.4
	Inflow (m^3/s)	0.2	2.2	2.6	2.8	4.1	0.5	5.5	7.9	4.5	0.4	0.2	0.2	2.6
	Outflow (m^3/s)[2]	1.3	1.2	2.5	3.0	3.4	4.3	1.7	2.5	2.9	1.9	1.7	1.5	2.3
Young Chun Dam	Avg. rainfall (㎜)	15.7	78.3	71.6	63.8	131.0	30.8	198.4	290.6	175.2	34.6	4.5	22.9	1,117.4
	Storage rate (%)	26.8	26.9	32.7	36.2	37.1	36.8	32.0	44.0	56.3	50.6	42.3	37.9	38.3
	Inflow (m^3/s)	4.8	6.0	7.3	7.3	9.7	3.6	5.2	14.9	7.3	3.3	5.2	5.2	6.7
	Outflow (m^3/s)[2]	5.0	4.6	5.5	6.5	7.5	7.6	5.0	7.1	6.0	7.7	7.2	6.9	6.4

1) Average rainfall: the sum of the Month rainfall based on daily rainfall within Dam watershed.

2) Storage, Inflow, Outflow: daily average data.

The Status of Weather

Six weather stations were used in this study. Characteristics of these weather stations are shown in Table D-3. The weather data, average temperature, rainfall, evaporation, rainfall duration, average wind, average humidity, dew point temperature, vapor pressure, amount of clouds, and insolation were displayed in Table D-4.

Table D-3: The weather station of Nakdong river watershed

Weather station	watershed	Agency	Location		TM_X	TM_Y
Andong	Andong & Imha Dam	Korea Metrorological Administrative	Gyeongsangbuk-do			
Guchang	Hapchun Dam		Gyeongsangnam-do	Jeongjang-ri, Geochang-eup, Geochang-gun	341975.4556	282184.6521
Hapchun	Hapchun Dam		Gyeongsangnam-do	Hapcheon-ri, Hapcheon-eup	330449.3885	305802.4144
Milyang	Milyang Dam		Gyeongsangnam-do	Naei-dong, Miryang-si	323055.5046	357987.8181
Youngchun	Youngchun Dam		Gyeongsangbuk-do	Mangjeong-dong, Yeongcheon-si	377317.0166	375725.2739
Jinju	Namgang Dam		Gyeongsangnam-do	Pyeonggeo-dong, Jinju-si	285822.7331	294501.2589

Table D-4: The weather data of Nakdong river watershed

Weather Station	Yr.	Avg. Temp (℃)	Rainfall* (0.1㎜)	Evapo-ration (0.1㎜)	Rainfall duration (0.01 hr)	Avg. wind (0.1m/s)	Max Wind direction	Avg. humidity (0.1%)	Dew point temp. ℃)	Vapor pressure (0.1hpa)	Local pressure (0.1hpa)	Amount of cloud (%)	insolation (0.01MJ/m²)	Duriation of sunshine (0.1hr)
Gu chang	2010	11.8	1,549.0	-	-	15	-	699	-	-	-	520	-	19,601
	2009	12.0	975.3	-	65,960	15	N	660	46	109	9,893	500	-	21,035
	2008	12.1	615.7	-	4,402	15	NW	660	49	113	9,899	-	-	21,023
	2007	13.1	1,729.0	-	-	13	S	680	66	123	9,895	-	-	19,559
	2006	12.6	1,411.4	-	-	13	S	690	61	121	9,897	-	-	20,963
	2005	12.2	1,244.9	-	-	14	W	660	51	119	9,895	-	-	22,832
	2004	12.3	1,547.8	-	-	13	W	680	56	118	9,899	-	-	23,082
Avg./Sum[1)]		12.3	9,073.1	-	35,181	14	-	676	55	117	9,896	510	-	21,156

Table D-4: The weather data of Nakdong river watershed (Continued)

Weather Station	Yr.	Avg. Temp (℃)	Rainfall* (0.1㎜)	Evapo-ration (0.1㎜)	Rainfall duration (0.01 hr)	Avg. wind (0.1m/s)	Max Wind direction	Avg. humidity (0.1%)	Dew point temp. ℃)	Vapor pressure (0.1hpa)	Local pressure (0.1hpa)	Amount of cloud (%)	insolation (0.01MJ/m²)	Duriation of sunshine (0.1hr)
Mil yang	2010	13.7	1,252.0	-	-	17	-	641	-	-	-	-	-	20,748
	2009	14.5	1,130.8	-	-	16	S	620	60	120	10,141	-	-	21,639
	2008	13.6	807.5	-	-	14	SSW	640	57	117	10,147	-	-	21,756
	2007	13.7	1,061.0	-	-	14	N	630	59	118	10,143	-	-	18,873
	2006	13.1	1,324.5	-	-	13	S	630	54	114	10,145	-	-	19,563
	2005	13.2	971.5	-	-	13	WNW	610	47	115	10,144	-	-	22,165
	2004	14.4	1,377.4	-	-	14	WNW	630	64	124	10,148	-	-	23,495
Avg./Sum		13.7	7,924.7	-	-	14	-	629	57	118	10,145	-	-	21,177
Young chun	2010	12.5	1,030.0	-	-	19	-	645	-	-	-	-	-	20,307
	2009	12.7	866.6	-	980	20	WNW	620	45	107	10,042	-	-	21,179
	2008	12.7	774.3	-	-	20	WNW	650	54	115	10,048	-	-	21,683
	2007	13.1	1,142.1	-	-	16	WNW	690	67	125	10,056	-	-	21,684
	2006	12.7	1,363.0	-	-	17	NNE	680	63	121	10,058	-	-	22,436
	2005	12.5	772.8	-	-	18	WNW	600	44	111	10,056	-	-	24,553
	2004	13.2	1,116.9	-	-	17	N	620	53	112	10,059	-	-	24,018
Avg./Sum		12.8	7,065.7	-	980	18	-	644	54	115	10,053	-	-	22,266
Jinju	2010	13.2	1,896.0	-	-	12	-	675	-	-	-	490	-	21,095
	2009	13.8	1,608.9	11,091	66,158	13	WSW	650	62	118	10,120	470	540,589	21,860
	2008	14.0	885.6	11,685	60,938	12	WSW	660	68	125	10,126	480	472,019	22,318
	2007	14.0	1,701.0	11,040	87,985	12	W	700	79	134	10,122	490	546,936	21,617
	2006	13.6	1,674.0	11,013	92,342	13	WSW	680	72	130	10,124	490	518,964	21,607
	2005	13.3	1,113.7	10,649	62,256	16	NNE	650	60	128	10,132	450	523,641	23,628
	2004	14.0	1,575.0	10,884	70,563	16	NNW	660	69	129	10,136	430	519,542	23,699
Avg./Sum		13.7	10,454.2	11,060	73,374	13	-	668	68	127	10,127	471	520,282	22,261
Hap chun	2010	13.3	1,547.0	-	-	14	-	672	-	-	-	-	-	20,325
	2009	13.6	1,066.0	-	-	14	S	640	58	116	10,117	-	-	21,416
	2008	13.2	767.0	-	-	14	N	670	62	121	10,123	-	-	21,876
	2007	14.3	1,232.6	-	-	12	NE	700	79	133	10,119	-	-	20,073
	2006	13.8	1,306.6	-	-	12	NNE	680	73	127	10,122	-	-	20,043
	2005	13.5	1,119.6	-	-	12	NNE	650	62	124	10,120	-	-	22,582
	2004	14.0	1,477.4	-	-	11	NNE	680	73	127	10,127	-	-	22,845
Avg./Sum		13.7	8,516.2	-	-	13	-	670	68	125	10,121	-	-	21,309

1) Sum is the rainfall data