JIMMA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

JIMMA INSTITUTE OF TECHNOLOGY

HYDRAULIC AND WATER RESOURCES ENGINEERING DEPARTMENT

HYDRAULIC ENGINEERING MSC PROGRAM

Watershed Modeling Using Soil and Water Assessment Tool

(Case Study on Nashe Lake of Ethiopia)

Thesis submitted to the School of Graduate Studies of Jimma University in Partial fulfillment of the requirements for the Degree of Masters of Science in Hydraulic Engineering.

By

Abdena Yadessa Keno

Dec, 2019

Jimma, Ethiopia

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Advisor and Co-advisor Name and Signature

Dr .Eng. Tamene Adugna (PhD) ________________ _____________

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Mr. Megersa Kebede (MSc) ________________ ____________

(Co-Advisor)

CERTIFICATION

I, the undersigned, certify that I read and hereby recommend for acceptance by the Jimma University a thesis entitled: **"Watershed Modeling Using SWAT; Case Study on Nashe Lake of Ethiopia."** In partial fulfillment of the requirement for the Degree of Masters of Science in Hydraulic Engineering.

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Dr .Eng. Tamene Adugna (PhD)

Advisor

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DECLARATION

I, the undersigned, hereby declare that; this thesis entitled as **"Watershed Modeling Using SWAT; Case Study on Nashe Lake of Ethiopia."** Is my original work, and has not been presented by any other person for an award of a degree in this or any other university and all that sources of materials used for the thesis have been fully acknowledged.

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Abdena Yadessa Keno

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DEDICATION

I dedicated this work to my family with Love!

ABSTRACT

Fincha Amarti Nashe multi-purpose hydropower project, and above of 322km^2, dam volume more than 448 million cubic meters and (the project) is located about 364km North West of Addis Ababa from capital town of Ethiopia, 50km from Zonal capital Shambu, in the Blue Nile river basin and having the latitude 9°35' to 9°52'N and Longitudes 37°00' to 37°20'E. The spatially distributed data (GIS input) needed for the Arc SWAT interface include Digital Elevation Model (DEM, Resolution of 30mx30m), land use/cover data, soil and the weather (climate) data, and AVSWAT Hydro meteorological and hydrological data were the base data for Watershed modeling. ***.*** *The Sensitivity analysis of the lake Nashe is highly sensitive to Lake Precipitation, river inflow and Evaporation and the total twenty seven parameters were considered for the model of parameterization sensitivity analysis; only ten of them were effective for monthly flow simulation analysis. For this research 30 years historical data were used for Nashe watershed. However, the calibration was run for 17 years (1985-2001) where the first one-year 1985 is used to "Warm up" the model and the measured data of stream flow of 13 years period of (2002-2014) were used for the model validation process. During the stream flow calibration the coefficient of determination* R^2 *and the Nash-Sutcliffe equation has been applied for model testing between simulated and observed flows and calculated on the monthly basis was 0.81 and 0.80 respectively, and again the correlation coefficient (*$R^2 = 0.84$*) and the Nash-Sutcliffe (*$NS = 0.74$*) shows a good agreement validation for the between the observed and simulated values. Means the evaluates that the* R^2 *ranges from 0.0 to 1.0 with higher values indicating better agreement and the values of NS ranges minus infinity to 1.0, with higher values indicating better agreement.*

Key Word: *Hydrological modeling, Nashe Lake, SWAT.*

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List of Abbreviations

ARS	Agricultural Research Service
AVSWAT	ArcView Integrated SWAT Hydrological Model
Alpha BF	Alpha Base Factor [Days]
Alpha BFD	Alpha Base Flow Factor Deep Aquifer [Days]
CN2	Curve number of Moisture Condition II
DEM	Digital Elevation Model
Dr.	Doctor
EEPCO	Ethiopian Electric Power Corporation
EELPA	Ethiopian Electric Light and Power Authority
EFAP	Ethiopian Forestry Action Program
E	East direction
Eng.	Engineer
ET	Actual Evapotranspiration from HRU
FAN	Fincha Amartii Nashe
G.C	Gregorian calendar
GIS	Geographic Information System
GPS	Global Positioning System
GW DELAY	Groundwater Delay [Days]
GW REVAP	Groundwater "Revap" Coefficient
GW HT	Ground Water Height [M]
GW Sp Yld	Ground Water Specific Yield of the Shallow Aquifer [M3/M3]
GW Sol.P	Ground Water contribution of soluble phosphorus [mg)
GW_Q	Ground Water Contribution to Stream Flow
Ha	Hectare
HEP	Hydro Electric Power
HRU	Hydrological response unit
HSPFH	Hydrological simulation program fortan

Hrs.	Hours
HYMO	Hydrol-Morphological
H2O	Hydrogen and Oxygen (Water)
IGBP	International Geosphere-Biosphere Program
IHDP	International Human Dimension Program
Km2	Kilometer square
LULC	Land Use / Land Cover
LAT_Q	Lateral Flow Contribution to Stream Flow
MOA	Ministry of Agriculture.
MoWIE	Ministry of Water, Irrigation and Electricity
MW	Mega Watt
MWH	Montgomery Watson Harza
Mr.	Mister
MCM	million Cubic meters
MM	Millimeter
MM^2	Millimeter square
MSc	Masters of Science
MUSLE	Modified Universal Soil Loss Equation
M	Meter
M.a.s.l	Mean above sea level
NMSA	National Meteorological Service Agency
NSE	Nash-Sutcliffe Efficiency
N	North direction
NRCS-CN	Natural resources Conservation Service and Curve Number
Obs.	Observed Flow
PPU	Percentage prediction uncertainty
PhD	Philosophy of Doctor
Q	Discharge/Flow of Water
R^2	Coefficient of Determination

ROTO	Routing output to outlet
RSR	Ratio of square root
Sim.	Simulated flow
SCS-CN	Soil Conservation Curve Number
SCRP	Soil Conservation Research Project
SWRRB	Simulator for Water Resources in Rural Basins
SW	Soil Water Content
TLOSS	Transmission Losses, Water Lost From Tributary Channels
U.S	United State
USDA	United State Department Agriculture
Vol.	Volume of Flow
WWF	World Wildlife Fund
WGEN	Weather Generator
WXGEN	Weather parameter calculator
WND AV	Wind speed Average daily in month (m/sec)
WYLD	Water yield (Water yield=SURQ+LATQ+GWQ-TLOSS-Pond abstractions)

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CHAPTER ONE

1. INTRODUCTION

1.1.General Background

Water is the greatest gift to the human kind and the most essential natural resources for living species. Water resources are very crucial renewable resources that are the basis for survival and development of a society. The increased demand of water for agriculture, industries, domestic, water supply and power generation requires proper planning and management of water resources (Kebede et al.,2005), modeling of watershed is very important, and proper utilization of resource necessitates assessment and management of the quality and quantity of the water resources both spatially and temporally (Dilnesew,2003), and also operational water resources management point of view, hydrological models are developed to guide the formulation of water resource management strategies by understanding spatial and temporal distribution of water resources (Dingman et al., 2002;Liden and Harlin, 2000).

The Land use/Land cover changes of perhaps the most prominent of global environmental change (Turner et al., 1995). The land use pattern of an area is directly related with the level of technological advancement and the nature, degree of civilizations of its inhabitants. Additionally, it is dynamic phenomenon, and its value and pattern changes with varying efficiencies, ability, priority, and needs (Bisht and Tiwari, 1996). In the earlier day, assessment of the impact of land use changes on runoff was mainly done through catchment experiments and different result had been obtained, with some even opposing the findings of the others. (Langford, 1976 cited by Abdi, 2012), for example found out that there is no significant increase in runoff because of burning down of a stand of eucalyptus.

Land use change impacts on the water, sediment, solutes and nutrients can be evaluated (Slaymaker, 2003). Understanding how land use changes has influenced stream flow pattern may enable planners to formulate strategies to minimize the undesirable effects of future land use change, and (Alansi et al., 2009 cited by Abdi, 2012) studied the effect of land use changes on rainfall-runoff and runoff-sediment relations and showed that land use can be considered as one of the main reasons for increased runoff and sediment in tropical regions where the change in rainfall amount can be neglected.

Ethiopia losses about 1.3 billion metric tons of fertilizer soil every year and the degradation of land through soil erosion is increasing at a high rate (Hurni, 1988), the annual soil loss of about 1.5 billion tons from the high rate (Soil Conservation Research Project (SCRP, 1996) and call for immediate measures to save the physical quality of soil and water resources of the country. Setegn, S.G., (2010) indicated that the poor land use practices, improper management systems and lack of appropriate soil conservation measures have played a major role for causing land degradation problems in the country, because of the rugged terrain, the rates of soil erosion and land degradation in Ethiopia are high. These call the immediate measures to save the soil and water resources degradation of the country through modeling.

The loss of the organic matter rich surface soil (topsoil) decreases soil quality, which in turn reduces productivity (Verity and Anderson, 1990 cited by Lemma, 2015). The bare soil is more likely to be eroded by different soil erosion agents than soil with vegetation cover. Zemenfes, 1995; SCRP, 1996 estimated that the soil depth more than 34% of the land area is already less than 35cm, and 4% of the highlands are now so seriously eroded, not be economically productive again in a foreseeable future(Kruger et al., 1996).

Hydrology is the main governing backbone of all kinds of water movement, water-related pollutants and is essential to understand the hydrological response of a catchment (Taffese et al., 2013)**.** By applying hydrological model to hydrologic systems, non-topographic information can include description of soils, land use, ground cover, ground water conditions, as well as man-made systems and their characteristics on or below the land surface (Yibeltal A, 2008), Understanding the hydrology of a watershed ,quality of water, simulation of watershed hydrology are very important for assessing the environmental, economic well-being of the water resources planning and management (Manoj Jha, 2009).

Sediment yield refers to the amount of sediment exported by a basin over a period, which is also the amount that will enter a reservoir located at the downstream limit of the basin (Morris and Fan, 1998). The subject of sediment yield modeling has attracted the attention of many scientists but lack of data, resources and widely accepted methods to predict/estimate sediment yields are some of the barriers against this direction of research (Summer et al., 1992; Wasson, 2002; Lawrence et al., 2004; Ndomba et al., 2005, 2008b, 2009),and the sediment transport capacity of the stream could be determined by an empirical relationship between stream power and sediment load, since they are very important component in hydropower development in many countries (Doten et al., 2006).

A watershed is a hydrological unit, which produces water as a product by interaction of precipitation and the land surface. Vegetation types, soil properties, geology, terrain, climate, land use practices, and spatial patterns of interactions among the different factors (Richey et al., 1989; Laurence, 1998; Schulze, 2000; Fohrer et al., 2001; Zhang et al., 2001; Huang and Zhang, 2004; Brown et al., 2005) affect watershed hydrology. The most accessible water available for human consumption and the ecosystem are contained in the lakes and rivers. The volume of water bodies corresponding to 0.27% of the global fresh water and only 0.008% of the earth budget (Chow et al., 1998).

Watershed modeling is very important for water resources planning, development and management. The current review followed the classification system outlined in (Wheatear et al.,1993) and classifies hydrological models based on their structure (metric, conceptual, physics based, and hybrid), spatial representation (lumped, semi-distributed and distributed), process (deterministic and stochastic), time-scale and space-scale. Sustaining upland agriculture and food security is very much constrained by continuing land degradation brought by soil erosion due to lack of effective rainwater management strategies. Recently a large body of research evidence has established that significant potential exists to increase agricultural productivity through sustainable rainwater management interventions. Therefore, hydrological modeling of watershed is essential for future development as well as for managing the current water resource potential by using the Soil and Water Assessment Tool (SWAT) (Neitsch et al., 2002).

Large Irrigation and Hydropower projects that include large dams and reservoirs which modify the natural hydrological regime of the rivers (BCEOM, 1998). The creation of a large reservoir, which allows the storage of “excess” water during high flow periods to cover water demand during low flow periods is one and major activity in the Basin Master Plan (BCEOM, 1999 cited by Tensay,2011). In the future, water from the basin will be under pressure from competing uses of water such as irrigation and hydropower developments in Ethiopia and downstream riparian countries and Climate Change impacts is expected to affect the hydrological system in the basin. However, the likely impacts of upstream water storages for future development to downstream water use and availability have not been fully evaluated. Hence, the study of water resource systems under consideration of future climate change is vital.

Fincha Amarti Nashe (FAN) is one of the newly developed multipurpose hydropower project in Ethiopia, plays significant role for the sustainable economic growth, is being evaluated in light of its multipurpose potential, primarily irrigation and hydropower with the due attention paid to the issues of its long-term sustainability and socio economic issues (Montgomery Watson Harza, pre-feasibility study report August 2004, Volume 1). It is one of the most sensitive basins for changing climate. Hence, it is necessary improve our understanding of the problems involved due to the changing climate and water resources variability in the region. The lack of decision support tools and limitation of data concerning weather, hydrological, topographic, soil and land use; are factors that significantly hinder research and development in the area. There is a need for hydrological research of the Lake Nashe that can improve catchment management programs.

Appropriate decision support tools are needed for better assessment of the hydrology, soil erosion and Sediment yield in the upland watershed and downstream water body for planning and implementations of soil and water conservation measures. The tools concern various hydrological, soil erosion and Sediment yield models as well as Geographical Information System (GIS). The modeling tools will finally help to make appropriate planning and timely decision, which ultimately help to save the physical quality of the land and water recourses.

1.2. Statement of the Problem

Water stress is one of several current and future critical issues facing Africa. About 25% of the contemporary African population experience water stress, while 69% live under conditions of relative water abundance (Vörösmarty et al., 2005 cited in Yehun, 2009). Water supplies from rivers, lakes and rainfall are characterized by their unequal natural geographical distribution and accessibility, and unsustainable water use. Hydrological change has the potential to impose additional pressures on water availability and accessibility (IPCC, 2007). Therefore, the freshwater resource is a fundamental basis for the economic growth and social development for communities in the basin and in the riparian countries of East Africa.

Climate change can affect multiple features of water resources (e.g., quantity and quality, high and low flow extremes, timing of events, water temperature, etc.). All these aspects affect livelihoods in the basin but have not received attention in planning for future water allocation and design of water infrastructures yet (Kim *et al.*, 2008). However, the ongoing global climate change puts further constraint on the already limited water resources in the basin. Throughout the world, Land use/cover impacts are the main concern of water management and water use activity land use and land cover dynamics are widespread, accelerating and significant process driven by human actions but also producing changes that human impacts (Agarwal et al., 2000). Therefore, evaluation of water resources in light of future climate change is very important for sustainable planning and management of the water resources.

Today, the land use/cover change is seriously the problem that the whole world facing, the most crucial research in worldwide level (Wheater et al., 1993; Yang, et al., 2003). Throughout the world, hydrological are the main concern for sustainability of water management and water use activities. This is because it is often induced by changes in population trends and economic environments, and can be intimately linked to other forms of change, including changes in climate, biological diversity, and accelerated land degradation. It is now widely accepted that the land use/cover change is already happening and further change inevitable. The land use/cover change on reservoir and water resources are mainly reflected in changes in the water cycle, water quality and quantity (Shi, et al., 2000).

According to Jaroslav et al., (1996) indicated that a physical process varies both temporally and spatially. They consider the spatial and temporal changes of different factors. Physically based distributed watershed models play a major role in analyzing the impact of land management practices on water, sediment and agricultural chemical yields in the large complex watersheds. Many hydrological and soil erosion models are developed to describe the hydrology, erosion and sediment processes. These models are generally meant to describe the physical processes controlling the transformation of precipitation to runoff and de-tachment and transport of sediments. Hydrological models are tools that describe the physical processes controlling the transformation of precipitation to stream flows.

Ethiopia has ample water resources, which can be appropriately utilized to enhance socioeconomic development of its people. Due to under-development of this resource among others, the people of Ethiopia have been exposed to major problems such as impacts of drought and flood, land use change, shortage of clean water supply and inadequate energy supply (Haile Mariam, H. 1999; 2011 Cited by Mote, 2014). Agriculture could be effective only when it gets sufficient water at the right time. Therefore, to ensure sustainable agricultural, irrigation development, there should be reliable supply of land and water as well as land and water management systems. If people Engaged in agriculture get sufficient water throughout the year, it is possible to harvest higher yields from a smaller size of land and keep labor busy on production throughout the year. Soil erosion is a major watershed problem in developing countries including Ethiopia (Awulachew et al., 2008) and is a serious land degradation problem of the world, a dominant agent of soil degradation (Lal, 1996).

In Ethiopia, the sediment gauging stations are sparse. However, there is a big demand for sustainable utilization of water resources projects. The government proposed utilization of water resources for agriculture and power generation as a strategy for supplementing the economic growth of the country. The construction of the Dams was withdrawn because of sedimentation and seepage problems (Haregeweyn et al., 2008). The construction of Dam in Ethiopia caused social, environmental and economic problems by increasing the relocation of communities against their will and inducing watershed land degradation (Bezuayehu, 2006). Many farmers in Ethiopia highlands cultivate sloped or hilly land, causing topsoil to be washed away during the heavy rains of the rainy season. High intensity rain fall cause significant erosion and associated sedimentation, increasing the cost of operation, maintenance and shortening lifespan of water resources infrastructure (Tamene et al., 2005).

Millions of peoples living in the basin countries desperately need every drop of rain falling on the highlands of Ethiopia. Yet, the question of water balance simulation, which is always at the heart of any hydrological modeling, has not been adequately addressed. Therefore, it is difficult, if not impossible, to investigate the impacts of land and water use changes/ alternatives and climatic changes on the downstream flow pattern as well as to characterize the impacts on the water resources availability. This continuous change of hydrology, meteorology, land use, land cover has impact on water balance of the watershed by changing the magnitude and pattern of the components of stream flow, which are surface runoff, and ground water flow.

Therefore, to overcome the above conditions, this study mainly focuses on accurately estimating the inflow with the view of establishing accurate water resource management policies, strategy by modeling the hydrology watershed modeling of the basin using Soil and Water Assessment Tool, which will help to understand the hydrological process and to achieve proper planning, designing and managing of water resources, which is essential for future development , for managing current development of project in adaptive way.

1.3.Significance of the Study

The hydrology, meteorological, Land use, Land Cover change has significantly impacts on natural resources, socio economic, irrigation, Domestic, Power Generation, Industry and environmental systems. However, to assess this effect of change on stream flow, it is important to have an understanding of the land use and land cover patterns, the hydrological, and Meteorological processes of the catchments. By understanding the types and impact of hydrology, meteorology change is essential indicator for resource base analysis and development of effective and appropriate response strategies for sustainable management of natural resources in the country in general and at the study area in particular. A proper investigation of the sediment and runoff yield of the catchment is essential for management of sedimentation and utilization of water resource. If these are not investigated, the life of Nashe dam reservoir will be shortened by sedimentation.

Generally, the output of this study can be used as an input for the planner, Decision maker /Policy makers and any other person to understand the hydrology of watershed which will strongly assist to proper planning, development, management water resources and can provide scientific information on the future watershed development modeling and fill the gaps of other research works by incorporating the recommendation in other research works in the basin.

1.4. OBJECTIVE OF THE STUDY

1.4.1. General Objective

The main objective of this study is Watershed modeling of the Water balance components of the Nashe watershed-using semi distributed physically based model Geographic Information System (GIS) based tools version known as Soil and Water Assessment tools (SWAT).

1.4.2. Specific Objectives

In order to achieve the General objective of the study, the following specific objectives are set for the major indicators of the study.

1. To Develop Watershed Model for Lake Nashe Using SWAT Software
2. To Simulate Nashe Water balance components.
3. To model Sediment Yield of Nashe Lake.

The modeling exercise has been undertaken with physically based data, which can be considered a baseline of information available watersheds. By presenting a methodology, which can be reproduced in other watersheds, comparable results could be obtained for other areas. These results include quantifying the runoff, evapotranspiration and aquifer recharge, both spatially and temporally. The implementation provides the possibility of further investigation into changes of climate or land use on the Industries, supply, demand and safety of the water supply.

1.5.Research Questions

In order to meet the research objectives of the study, the research questions of the study are:

- How to Watershed Model Developed by Using SWAT Software?
- How water balance can simulated by using model SWAT software?
- How to model Sediment Yield in Lake Catchment?

1.6.Scope of the Study

The study attempts on hydrological modeling the study area watershed. Since it is not possible to cover the whole aspects of the study area, it is advisable to limit the scope of the problem to a manageable objective. Hence, the scope of this study attempts to address the method how to model watershed, to minimize the erosion, which produce or wearing a way of land surface by action of water, wind and gravity.

When we see the current situation of the Nashe watershed, the main issue of the Decision maker /Policy makers and any other person is the sediment yield due to high erosion expected from these small catchments and river systems. The study will model the watershed by physically based approach models and using Soil and Water Assessment Tool (SWAT).

1.7.Expected Outputs.

Information on land use/cover of an area and possibility for their optimal use is essential for the selection, planning and implementation of land use schemes to meet the increasing demands for basic human needs and welfare. The Hydrological processing model that performs well for that particular catchment.

Modeling of hydrology is essential to derive basic information for appropriate decision-making. The information obtained also assists in monitoring the dynamics of land use resulting out of changing demands of increasing population. The full information about the amount of sediment yield of watershed can be examined as well as the efficiency of SWAT model in predicting sediment yield by acquiring the most sensitive sediment parameters and its performance to simulate stream flow in the catchment will be examined.

Generally, the information obtained on the rate and extent of land use/cover change and its environmental impact will help policy makers at local, national and international levels for designing appropriate strategies for the sustainable development of the watershed. Therefore, by looking at long and short-term rates of change and its spatial distribution, land use analysis provides way to discriminate the rate of different variables and their importance at different scales.

At watershed scale, the information obtained from this study will help the local government and private organization or further assessment of the land and water resources degradation of the area and for designing cost effective soil and water conservation strategies. It is also used for designing suitable strategies that can reduce the total sediment loads entering the hydropower reservoirs and the analysis of sensitivity for different parameters.

At national level, the result of this study enables policy makers to formulate and implement appropriate land use and water resources management policies, design strategies for the optimum utilization and management of these precious resources in a sustainable way, and design effective and appropriate conservation strategies that can minimize the undesirable effects of future land use changes. At international level, the information obtained from this will help the concerned body for designing sound land and water resources management policies, which are environmentally friendly. As Nile River is trans boundary (because Fincha Amarti Nashe watershed is the tributary of Blue Nile River which contributes more than 85% flow to the main Nile River),the result of this study enhances all national and international efforts toward the efficient, equitable and optimum utilization of the available water resources of the area on sustainable basis.

1.8.Research Problem

Several limitations introduced during the course of this study. One of the major limitations was the spatial variability associated with precipitation. There was only one rain gauge station used in the Nashe watershed. This can cause considerable errors in runoff estimation if one gauge is used to represent an entire watershed, as SWAT requires spatially distributed data. The land use and soil data used were of low quality. The daily stream flow record and sediment yield also was available only for short period, which caused calibration process extremely difficult.

1.9. Thesis Outline

In this study the watershed modeling using physical based Semi distributed SWAT Model for thirty year historical data were presented. Chapter One, provides an introduction that includes general background, statement of the problems, Significance of study. In Chapter Two Presents the review of the main related facts from references used in the study and review of earlier studies in the basin. The Related Previous works by SWAT in Ethiopia also included under this chapter. Application of SWAT models, Sensitivity Analysis, Model, Model calibration and Validation, Calibration, Validation, Assessment of model performance. Under this Chapter three includes the Methodology of the study, Description of the SWAT model, Hydrological Component of SWAT, Land use of the Hydrological Cycle, the SWAT model Input datum. In Chapter Four the Result and Discussions. Chapter Five Ends by summarizing Conclusions of the research outcome and recommendations of for the further activities and studies.

CHAPTER TWO

2. LITERATURE REVIEW

2.1.General

Under this section, literatures were cited on relevant topics, such as: definition and concepts of land use and land cover change, Effect of Land use/Land cover on Hydrological cycle, land use and land cover change studies in Ethiopia, application of remote sensing on land use and land cover change, Introduction to hydrological models, worldwide perspective of the hydrological (SWAT) model, and SWAT model in Ethiopia, Classification of Watershed modeling. Generally, the reviews were focused on assessing the scientific works that are related to the subject of this study.

2.2. Land Use and Land Cover Change: Definitions and Concepts

Presently, the natural vegetation of the region is highly disturbed by man and livestock and partly cleared and replaced by permanent cultivated fields. Grass, shrub, woodland, wet land, exposed soil and exposed rocks were identified as dominant land use and cover types. In spite of this, Ojima et al.,1994 indicated that land use change has a direct impact on land management practices, economic health and social processes of concern at regional national and global level Land cover refers to the physical and biophysical cover over the surface of earth, including distribution of vegetation, water, bare soil and artificial structures whereas Land use refers to the intended use or management of the land cover type by human beings such as agriculture, forestry and building construction (IGBP-IHDP, 1999).

According to Meyer and Turner, 1994 the Land use and land cover change (LULCC) can group in to two broad categories: conversion and modification. Conversion refers to a change from one cover or use category to another (e.g. from forest to grassland). Modification, on the other hand, represents a change within one land use or land cover category (e.g. from rain fed cultivated area to irrigated cultivated area) due to changes in its physical or functional attributes. These changes in land use and land cover systems have important environmental consequences through their impacts on soil and water, biodiversity, and microclimate (Lambin *et al*., 2003).

In most developing countries like Ethiopia, population growth has been a dominant cause of land use and land cover change than other forces (Sage, 1994). Land cover changes have been influenced by both the increase and decrease of a given population (Lambin et al., 2003). There is a significant statistical correlation between population growth and land cover conversion in most of African, Asian, and Latin American countries (Meyer and Turner, 1994). Due to the increasing demands of food production, agricultural lands are expanding at the expense of natural vegetation and grasslands (Lambin *et al.,* 2003). The land use and land cover change assessment is an important step in planning sustainable land management that can help to minimize agro-biodiversity losses and land degradation, especially in developing countries like Ethiopia (Hadgu, 2008). Therefore, watershed modeling becomes essential to manage the water resource and the core in this study.

2.3.Effect of Land Use/Land Cover on Hydrological Cycle

Land use and land cover characteristics have many connections with hydrological cycle. (Houghton, 1995) identify that infiltration and runoff amount by following the falling of precipitation can be affected by land use and land cover. Types of land cover (Abebe, 2005) significantly affect both surface runoff and ground water flow. Surface runoff and Ground water flow are the two components of the stream flow. Surface runoff is mostly contributed directly from rainfall, whereas ground water flow is contributed from infiltrated water. However, the source of stream flow is mostly from surface runoff during the wet months, whereas during the dry months the stream flows from the ground water.

Legesse *et al.*, 2003 defines that deforestation has its own impact on hydrological processes, leading to declines in rainfall, and more rapid runoff after precipitation Increase of croplands and decrease of forest, results increase of stream flow because of the crop soil moisture demand. Crops need less soil moisture than forests; LULCC is one of the most important factors that affect runoff, evapotranspiration and surface erosion in a watershed. The LULCC some hydrological factors, such as interception by vegetation, soil water content and surface evapotranspiration; therefore, the hydrological regime and rainfall-runoff mechanism are also changed (Li et al., 2007).

2.4.Soil Erosion and Sedimentation

Soil erosion by water is one of the most important land degradation problems and a critical environmental hazard in worldwide (Saran *et al.*, 2001). Specially, accelerated erosion due to human-induced environmental alterations at global scale is causing extravagant increase of geomorphic process activity and sediment fluxes in many parts of the world (Turner *et al*., 1990).

Soil erosion is a major watershed problem in many developing countries (Awulachew et al., 2008). Soil erosion and sedimentation by water involves the processes of detachment, transportation, and deposition of sediment by raindrop impact and flowing water (Foster an Meyer, 1977; Wischmeier and Smith, 1978). The major forces originate from raindrop impact and flowing water. Soil erosion is the detachment and transportation of soil particles from their original place to further downstream by erosion agents such as water and wind. It is one of the normal aspects of landscape development.

Soil erosion is a serious problem affecting the quality of soil, land, water resources upon which man depends for his sustenance. Today, soil erosion is universally recognized as a major environmental and agricultural problem. Because, as the top soil is eroded by erosion agents such as water, wind, avalanches, etc. its fertility and nutrient content decreases. This eventually results in the loss of productivity. Loss of the organic matter rich surface soil (topsoil) is known to decrease soil quality, which in turn reduces productivity (Verity and Anderson, 1990).

2.5.Reservoir and Sedimentation

Reservoir sedimentation is one of the most important factors in the planning of a storage-dam, because uncontrolled soil erosion and land degradation resulting in heavy sediment transport in streams and rivers has caused significant reduction of the capacity of reservoirs and studies have shown that in Ethiopia billions of tons of soil are lost annually; particularly in the Ethiopian highlands soil erosion is a major problem with an estimated loss of 16-50 ton/hectare/year (Abegaz, 1995). High sediment rates leads to filling of reservoirs and loss of live storage, which eventually leads to loss of production potential. Furthermore, evacuation of sediments from reservoir is costly process that can have large environmental impacts.

Simulation of sediment yield can be a tool estimation sediment influx to reservoirs, and to assess how much sediment is generated from various land types. Reservoir sedimentation is phenomenon that also has positive impacts to water usage systems particularly to the downstream rivers. If contaminants and heavy metals are transported into a reservoir they will likely settle with the sediments in the reservoir, which improves the water quality of the rivers downstream of the reservoir but water behind the dam, may degrade over time as the concentrations of the contaminants and heavy metals increase (Randle et al., 2007).

Since the velocity of water in the reservoir is very low, sediments get deposited in the reservoir unless there must exists a facility to avoid the settlement. The sedimentation of reservoirs causes another serious problem by decreasing the capacity of reservoirs. The loss in capacity of reservoirs increases the probability of floods. Sedimentation in irrigation canals will hamper and endanger proper irrigation management. To tackle all the aforementioned problems caused by erosion and sedimentation, identifying erosion prone areas and proper application of management options on those areas is crucial.

In order to increase the life of the reservoir and to best achieve the purpose for which it has been constructed, reducing sediment inflow and removing sediment from the reservoir are substantial activities (Amare, 2005) and the Integrated watershed management measures help in achieving principles of water erosion control indicated by (Troeh et al., 1980) which includes reducing raindrop impact on the soil, reducing runoff volume and velocity and increasing the soils resistance to erosion.

Watershed development and management is an integration of technology within the natural boundary of a drainage area. The concept of integrated watershed development is that development and management of watershed resources should achieve sustainable production without causing deterioration to the resource base or causing any ecological imbalances. The concept of integrated watershed management needs to be incorporated into soil and water conservation components to obtain the maximum benefit for water resources (Minella et al., 2009). German et al., 2006) discussed that the integrations in watershed management may include integration of disciplines (technical, social and institutional dimensions) and objectives (conservation, food security and income generation).

Valentin et al., 2006 Conducted that in twenty seven watersheds of Southeast Asia showed that innovative conservation land-use practices. The improved fallow, direct sowing, grass strips and natural vegetation strips, terraces with grass risers are efficient in preventing erosion not only at the plot scale but also at the watershed scale. Investigation by Verbist et al., 2009 in Indonesia indicates that on erodible lithology's and steep slopes, forest cover and shade coffee systems are the best land use types to reduce sheet and rill erosion.

2.6.Sediment Yield

In recent time, there have augmentation of SWAT model application in tropical countries, several workers as reported in (Ndomba et al., 2008 and Birhanu, 2005) have satisfactorily applied SWAT model for sediment yield modeling in poorly gauged catchments in Tanzania and the region at large the sediment yield from any drainage system is calculated by averaging the data collected over a period of years. It is, therefore, an average of the results of many different hydrologic events. Collecting sediment flow data over a decade and periodic reservoir survey information are some resources demanding methods for estimating sediment yield rates at a catchment level (Silva *et al.,* 2007).

Others have also cautioned that long-term sediment monitoring of suspended sediment loads does not necessarily give better results (Summer *et al.,* 1992). Some workers have suggested that an excellent sediment-rating curve could be constructed from detailed sediment flow data of short period of sampling programs (Summer et al., 1992; Ndomba, 2007). However, Ferguson (1986) indicated that most of the sediment-rating curves underestimate the actual loads. Besides, other researchers such as Bogen and Bønsnes(2003) have cautioned that such relationships should be used on catchment where no significant landforms, land use and sediment supply source changes are expected.

Sediment yield is generally expressed in two ways: either as a volume or as a weight, as acre-feet (one-foot depth of material over one acre) or as tons. According to Altunkaynak (2009), estimation of sediment load is required in practical studies for the planning, design, operation and maintenance of water resources structures. The sediment transportation monitoring requires a good sample technique, which is very length, and costly (Pavanelli and Palgliarani, 2002). Therefore, it is important to develop a model that can estimate accurately the suspended sediment yield from the basin.

2.7.Hydrologic Soil Group

Soil is defined as the top layer of the earth’s crust and formed by mineral particles, organic matter, water, air and living organisms. The soil profile is sub-divided into multiple layers that support soil water processes including infiltration, evaporation, plant uptake, lateral flow, and percolation to lower layers. The soil percolation component of SWAT uses a water storage capacity technique to predict flow through each soil layer in the root zone. The soil type also plays a significant role for erosion depending upon its physical proper-ties and sensitivity to erosion.

Soil may be place in one of four groups, A, B, C, and D, or three dual classes, A/D, B/D, and C/D. Definitions of the classes

A. (Low runoff potential). The soils have a high infiltration rate even when thoroughly wetted. They chiefly consist of depth, well drained to excessively drained sands or gravels. They have a high rate of water transmission.
B. The soils have a moderate infiltration rate when thought wetted. They chiefly are moderately depth to deep, moderately well drain to well-drained soils that have moderately fine to moderately coarse textures. They have moderate rate of water transmission.
C. The soils have a slow infiltration rate when thoroughly wetted. They chiefly have a layer that impedes downward movement of water or have moderately fine the fine texture. They have a slow rate of water transmission.
D. (High runoff potential). The soils have a very slow infiltration rate when thoroughly wetted. They chiefly are of clay soils that have high swelling potential, soils that have a permanent water table, and soils that have a clay pan or clay layer at or near the surface and shallow soils over nearly impervious material. They have a slow rate of water transmission. Dual hydrologic group are given certain wet soils that can be adequately drained. The first letter applies to the drained condition, the second to the undrained condition. Only soils that are rated D in their natural condition are assigned to dual classes.

2.8.Soil Erosion and its Economic Impact in Ethiopia

Soil Erosion is one of the most important environmental problems among various forms of land degradation that poses serious challenge to the food security of the population and future development prospects of the country (Wagayehu and Lars, 2003). Yet, it is not a new phenomenon in the country (Hurni, 1989 cited by Tensay, 2011). It is a direct consequence of the past and the present agricultural practices in the highlands (Kassaye, 2004). Crop production system widely practiced in the highlands of the country such as cultivation of teff (*Eragrotis tef*) and wheat (Triticum Species) which require fine tilled seed bed and single cropping of fields encouraged soil loss via erosion (Belay, 2000; Kassaye, 2004). The ever-increasing population exacerbates this.

With the ever-increasing population, development of agricultural production increasingly became enhancing land degradation through deforestation and expansion of new land to fragile and erosion prone marginal lands (Wagayehu and Lars, 2003). Researches indicated that large proportion of soil erosion (almost half of soil losses) occurs from the cultivated fields that cover only 13% of the country and on average 42 tons of soil is being washed out from a hectare of cultivated fields (Hurni, 1990). The highest average soil loss occurs on currently productive land with less vegetation cover that was once under cultivation. It was estimated that every year Ethiopian highlands lose about 1.9 to 3.5 billion tons of topsoil (EFAP, 1994). This large amount of soil loss made the country to be described as one of the most serious erosion areas in Africa and in the world (Blaikie, 1985; Blaikie and Brookfield, 1987; El-sheaify and Hurni, 1996). Excessive soil loss with other factors led to reduced average crop yield per unit area.

2.9.Previous Application of Soil and Water Assessment Tool (SWAT)

2.9.1. Watershed Modeling

Watershed models are effective tools for investigating the complex nature of those processes that affect surface and subsurface hydrology, soil erosion and the transport and fate of chemical constituents in watersheds and can be used to achieve a better understanding of the impact of land use activities and different management practices on these hydrologic processes. Due to the increased spatial data availability, more and more distributed hydrological models are used. While linkages are being developed between the micro- and meso-scale (Shaman *et al.*, 2004), the lack of reliable field data limits testing to a few specific linkages such as stream chemistry or groundwater flow, but not the many other features which actually occur.

Watershed modeling provides insight into the field of hydrological sciences and actually represents the natural hydrological processes in a simplified way. According to Beven(2000) and Debary(2004) watershed is an extent or area of land where surface water from rain and melting snow or ice converges to a single point, usually the exit of the basin, where the waters join another water body, such as a river, lake, reservoir, estuary, wetland, sea, or ocean and watershed models are designed to understand the hydrological processes occurring in the watersheds and to investigate their interaction with each other and the Butcher(2008) indicates that the simulation of natural processes of the flow of water, sediment, chemicals, nutrients, and microbial organisms within watersheds, as well as quantify the impact of human activities on these processes by watershed modeling.

Watershed modeling is at the heart of modern hydrology, supplying rich information that is vital to addressing resource planning, environmental, and social problems. Models are an abstraction or simplification of complicated systems. The suitability of a model for particular application depends on the end user, the available data, time and resource available for the study and most importantly, the questions, which are being answered. Grayson and Bloschl, (2000) classify models in the three ways: 1. by their algorithmic approach 2.whether they are deterministic or stochastic 3. As being spatially lumped or distributed.

A model's algorithmic approach reflects how it is constructed. For example, physically based models use theory based processes or equation to describe different components; while empirically based models use past observation to characteristic the behavior.

Watershed models have been classified into three (Singh, 1995): (1) lumped model, (2) distributed model and (3) semi-distributed model.

In lumped models, the whole watershed is considered as a single unit (Beven, 2000). Hence, the watershed characteristics and input data are represented by averaging values for the entire catchment. Therefore, these models do not account for the spatial variations of the processes or the boundary conditions. For example (HEC-1(hydrological Engineering center, 1981)) and Hydrological model-HYMO (William and Hann, 1972). According to Putz et al., (2003), the act of averaging parameters and input data may lead to false representation of the hydrological processes. Lumped models consider a watershed catchment as one complete unit, characterized by a relative small number of parameters and variables (Shultz, 2007).

Contrary to the lumped model, distributed models take explicit account of spatial variations in the processes representation, input data and boundary conditions. SHE (System Hydrologique European) (Abbott et al., 1986) and IHDM model (Institute of Hydrological distributed model) (Calver and wood, 1995) are example of distributed model. In distributed model, watersheds are represented as a spatial grid or a pattern of elements (Chanasky et al., and William, 2003). Hence, in this type of model, it is required to input variables and physical characteristics to each grid point, which account for the spatial variation in the watershed representation. However, in many cases, detailed data on watershed characteristics and input parameter are not available, and may account for the spatial variability of the meteorological conditions of the drainage basin (Shultz, 2007). Therefore, it is required to interpolate or average some of parameters to assign values to each of the grid elements. This deficiency of distributed models has given rise to semi-distributed models, which are a gradation between lumped and distributed models. Distributed models

In semi-distributed models, watersheds are represented as a number of sub-catchments. The semi-distributed model can be created either from a lumped model, which can subdivided the watershed into different numbers of sub-catchments or from distributed model in which some processes, input and boundary conditions are lumped (Putz et al.,2003). SWAT model is an example of semi-distributed model (Arnold et al., 1998). According to Singh (1995) considering the spatial scale of the catchment, watershed are classified as: (1) small scale models (area ≤ 100 km^2), (2) medium scale models (100 km^2 ≤ area ≤ 1000 km^2); and (3) large scale models (area ≥ 1000 km^2). Watershed models are also categorized based upon the simulation period (continuous time series covering multiple events or single event based) and simulation time increment (hourly, daily, monthly and yearly increments) (Diskin and Simon, 1979).

Likewise, depending upon the description of the hydrological processes and the methods of solution used a model can be classified as deterministic, Stochastic or mixed model (Abbott and Refsgard, 1996). In deterministic model, the parameters are considered free from random variation while a stochastic model accounts for random variables in its modeling approach. A mixed model is the combination of deterministic and stochastic models. Hydrological models can also be further classified into empirical, physically based and conceptual (Abbott and Refsgarrd, 1996). An empirical model is a type of model that does not consider the physical processes occurring in a watershed in its modeling approach. However, a physically –based model uses a set of scientific principles and basic mathematical formulation to represent the natural system at an appropriate scale. According to Abbott and Refgarrd (1996), practically, a physically based model has to be fully distributed.

However, due to the complexity of this type of model, some of the processes descriptions of the natural system are simplified and often components are incorporated into it (Putz et al., 2003). A model including these types of simplifications and empirical components is called a called a conceptual model.

In a conceptual model, important hydrological processes such as evapotranspiration, surface storage, percolation, snowmelt, base flow and surface runoff are computed by using simple mathematical equations rather than solving governing partial differential equations. In order to replace the partial differential equations with simple statements, different model calibration parameters are incorporated into the model. Hence, the main advantage of this type of model is that it is much simpler than the mathematical point of view (e.g. Beven, 2000).

Singh (1988) determines further classify hydrological models as to whether they are continuous (long term) or even based (short term). Like spatial scale, identifying the time scale for which the simulation will be used is important to know before implementing a model. Hydrological processes occur at different time scale. For example, storm-generated floods occur over periods of hours or days, while aquifer recharge may occur over weeks or years. Knowledge of the end requirements will ensure that a model appropriate for the necessary time scale is chosen. In order to understand the long-term behavior of a water system continuous time models must be used. Event based models, which examine the result of single, transient occurrences are used for predicting such entities as expected peak flows but do not provide a long term view which is necessary for planning. It is necessary to use continuous models for water budget planning or the assessment of source protection measures.

Therefore, the Fincha Amarti Nashe (FAN) multipurpose project requires watershed modeling of hydrological, sediment yield, surface runoff for the estimation of water balance terms, water resource potential for current and future proper planning and managing the water resources based on physically semi-distributed model using Soil and Water Assessment Tool (SWAT).

2.9.2. Hydrological Modelling

Hydrology is the study of the movement, distribution and quality of water on the earth. It encompasses both the hydrological cycle and water resources. In choosing hydrological models as the vehicles for the relationship between water and agricultural land use, the focus is on water, the limiting factor for social, economic development and agricultural production (DAWC, 1991). Hydrological models have been created especially for the purpose of investigating the water cycle, as water interacts with soil, plants, atmosphere, chemical residues and physical elements. Hydrological studies do however require expert knowledge (Watson and Burnett, 1995) that should be conducted by specialist.

Hydrological models are useful tools for water resources assessment, understanding of hydrological processes and prediction of the impact of changes in land use and climate (Wagener, et al., 2003) and are developed to guide the formulation of water resource management strategies (Dingam,2002;Liden and Harlin,2000). The main hydrologic processes incorporated into the hydrologic model component are precipitation and interception, infiltration and transmission loss, surface storage, and overland and channel flow (Velleux, 2005). The hydrological simulation models have been developed as a tool for analysis of watershed processes and their interactions, and for development and assessment of watershed and assessment of watershed management scenarios (He C, 2003), and to anticipate their impact on associated water bodies.

Modeling of hydrology can then be used to generating decision support tools for policy makers, regulators and resource managers (Daniel, Camp et al., 2011). Besides establishing water balances, models can also be used to predict the impact of different management practices on rainfall-runoff response, sediment and contaminant transport (Elliott and Trowsdale, 2000) and are useful to solve practical problems of design and forecasting. A common challenges in modeling watershed hydrology is obtaining accurate weather input data (Mehta et al., 2004), often one of the most important drivers for watershed models (Ogden et al., 1994). Researchers and Engineers use model predictions to make decisions on Engineering projects such as flood control, wetland restoration, and dam operation (Yan W, 2011).

According to Wright (1988) defines that Modelling is the process of organizing, synthesizing, and integrating component parts into a realistic representation of the prototype. USDA (1980) lists the following benefits of modeling: Models help sharpen the definition of hypotheses, define and categorize the state of knowledge, provide an analytical mechanism for studying the system of interest, and can be used to simulate experiments instead of conducting the experiments on the watershed itself. Hydrological Models can be categorized into three classes: Empirical models, Conceptual models, and Physical models (Beven, 1985).

Empirical models or black box models: Contain non physically based transfer functions to transform input data to output data. These models are often referred to as cause and effect models where the physical processes taking place are not simulated. Black box models are divided generally, as linear and non-linear and in particular artificial neural network (ANN) method is used commonly in the modeling of non-linear system behavior (Cigizoglu and kisi, 2006).

Conceptual models: can be defined as semi-physical models since they simulate physical processes using major simplifications. Each physical component of the system or process is modeled in a simplified manner.

Physically based models: this type of models tries to simulate the internal mechanisms of the system using a theoretical approach without using major simplifications. These models use physical parameters that either can be measured or determined using appropriate equations. Hydrological assessment models further divided into lumped and distributed models. Physically based models are based on knowledge of fundamental processes and incorporate the law of conservation of mass and energy (Petter, 1992).

Lumped models: provide a unique output for the whole watershed. They do not provide any information regarding the spatial behavior of the outputs. The whole catchment is assumed homogeneous and all the potential variations are lumped (averaged) together. Thus, the degree of accuracy of the model is expected to vary with the degree of non-homogeneity of the catchment (Huggins and Monke, 1966).

Distributed models: this type of models takes into account the spatial variability of watershed characteristics. It divides the watershed into units, which are assumed homogeneous. All the hydrologic, climatic and management parameters are assumed homogeneous within each cell, but may vary from cell to cell. The dynamics of the simulated processes are then described at each point within the watershed, and the outputs from each cell are routed to the watershed outlet (Beven, 1985).

Physically based hydrological models are theoretically better process-based than conceptual models but require extensive data and need less tuning of parameters. Nonetheless, with their less data demanding character the principle on which conceptual rainfall-runoff models based is sufficient to produce reasonably accurate output. Especially in condition where there is scarce of data in the study area, which is a common situation in many developing countries (Lidén and Harlin, 2000), conceptual models are essential tools. Physically based models are based on the understanding of the physics associated with the hydrological processes, which control catchment response and utilize physically based equations to describe these processes (Grayson et al., 1992). The classification of Hydrological simulation models are summarized in the Figure 2.1.

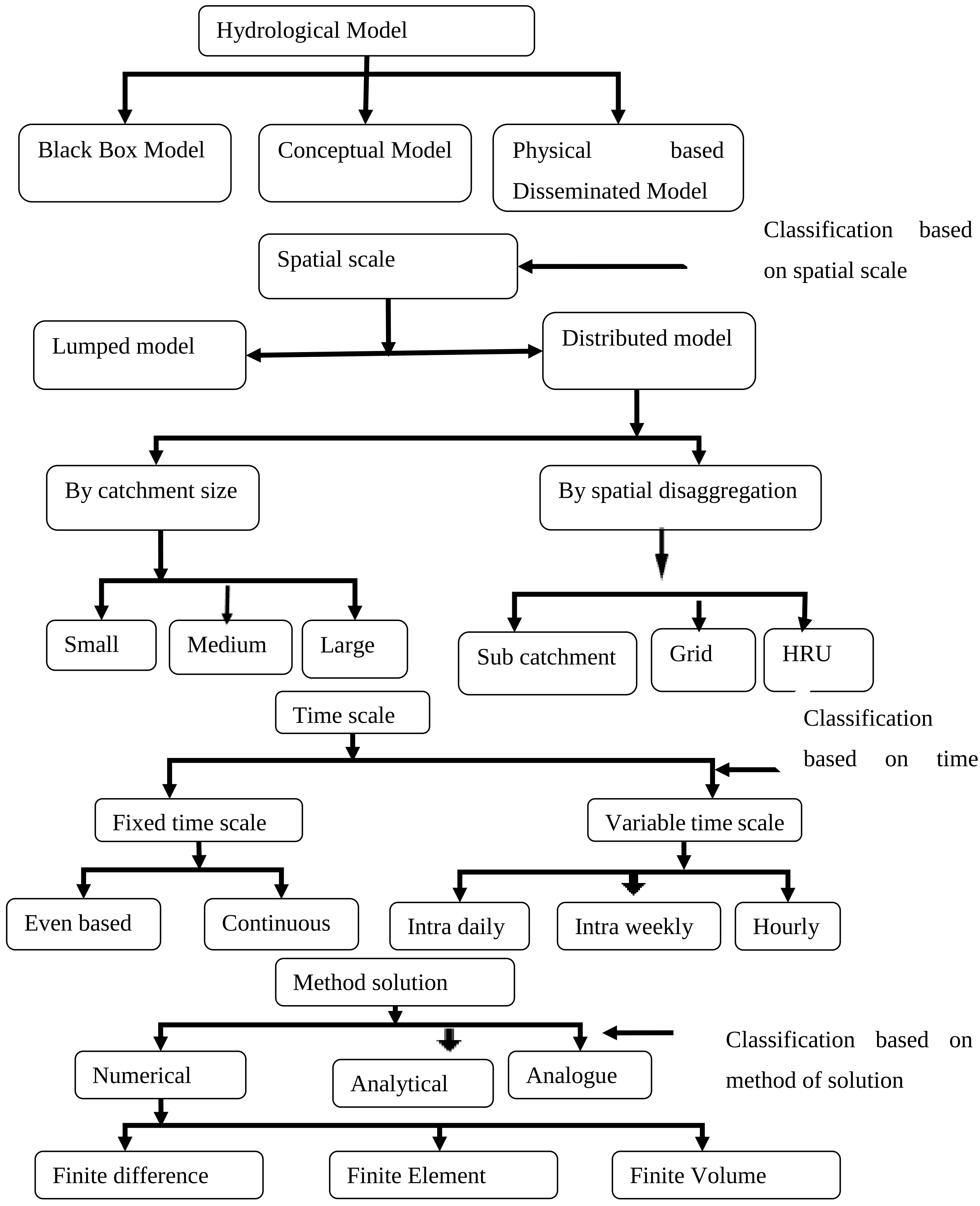

Figure 2. 1. Hydrological Model Classification (Semu, 2007)

2.10. Related Previous Works by SWAT in Ethiopia

Throughout Ethiopia, soil loss is a critical problem on agricultural land and without careful land management; erosion rates are likely to increase (Awulachew et al., 2008). A study conducted by (Kebede,2009), in Ethiopia's Gilgel Abbay catchment concerning hydrological response to land cover change, using integrated remote sensing data and GIS techniques, for year 1976-2001 showed that forest cover decreased from 51% to 17% and agriculture increased from 28 to 62%. Various reservoir sediment removal techniques have been adopted taking into consideration, the different climate, hydrological and geographic conditions (Liu et al., 2002).

Awulachew et al., (2008) stated that the maximization of sediment through flow (i.e., sluicing), diversion of heavy sediment flow (by passing) and dredging all help control sediment. Dredging, which most experts consider a costly operation, gathers bottom sediments and disposes of them at a different location, Amare (2005) suggested that the outlet sluice will play a great role in reducing deposited sediment from the Angereb reservoir. Increasing water discharge in high runoff period is an alternative method suggested to reduce sediment retention.

The study in Hare River basin concluded that the SWAT model satisfactorily predicted monthly and annual flows; and the model is useful to analyze the impacts of land use/land cover changes on stream flow even in basins with limited data (Tadele, and G.Forch,2007 cited by Abdi, 2012). Assessment of the spatial distribution of water resources and evaluation of the impacts of different land management practices on hydrologic response and soil erosion in the upper part of the Awash River basin in Ethiopia by Chekol *et al.*,(2007) was concluded that the SWAT model accurately tracked the measured flows and simulated well the monthly sediment yield and also the study of Andualem and Yonas(2008) shows that prediction of sediment inflow to Legadadi reservoir, the model performs well to predict the sediment inflow.

2.10.1. Application of SWAT Models

SWAT was developed for the USDA Agricultural Research Service (ARS). It is an extension of previously existing ARS models, the Simulator for Water Resources in Rural Basins (SWRRB) (Arnold et al., and Maidment, 1995 Cited by Tensay, 2011) and ROTO (Routing Outputs to the Outlet) (Arnold et al., 1995 cited by Setegn et al., 2008) and initially developed in the 1980 for managing water supplies and non-point source pollution in agricultural river basins (Arnold, Srinivasan et al.,1998; Daniel, Camp et al., 2011;Tuppad, Douglas-Mankin et al., 2011) is increasingly being applied to extended settings including urban watersheds (Easton, Fuka et al., 2008).

A physically based, non-proprietary, semi-distributed model, SWAT is computationally efficient and relies on readily available data to simulate upland and channel processes. The model can operate on a daily, monthly or annual time step and has historically been used to develop TDMLs. The model relies on governing equations to control the movement of water through surface, subsurface and lateral flow in each sub basin (E.g. Borah and Bera, 2003).

2.10.2. Comparisons Of SWAT With Others Models

Van Liew et al., (2003) compared the stream flow prediction of SWAT and Hydrological Simulation Program-Fortan model developed by the U.S.Environmental Protection Agency on eight-nested agricultural sub watershed within the Washita River Basin in southern Oklahoma. They found that differences in model consistent result than HSPF in estimating stream flow for agricultural watersheds under various climate conditions and thus, may be better suited for investigating the long-term effects of climate variability on surface-water resources.

Saleh and Du, (2004) indicated that the calibration, SWAT and HSPF with daily flow, sediment, and nutrients measured at the stream sites of the Upper North Bosque River watershed in central Texas. They concluded that the simulations of average daily flow and sediment and nutrient loading from SWAT were closer to measured values than were the corresponding simulated values from HSPF for the calibration and verification periods (Gassman et al., 2007).

Borah and Bera, (2004) Cited by Geleta, H. (2011) compiled 17 SWAT, 12 HSPF, and 18 Dynamic Watershed Simulation Model (DWSM) applications and concluded that both SWAT and HSPF were: (1) suitable for predicting yearly flow volumes, sediment loads, and nutrient losses; (2) adequate for monthly predictions, except for months with extreme storm events and hydrologic conditions; and (3) poor in simulating daily extreme-flow events. For Example Gasman et al., (2007) contrast that, developed by the Illinois State Water Survey reasonably predicted distributed flow hydrographs and concentration or discharge graphs of sediment, nutrients, and pesticides at small time intervals.

2.10.3. Benefits of SWAT Model Approach

- Watersheds with no monitoring data (e.g., stream gage or water quality data) can be modeled.

- The relative impact of alternative input data (e.g. changes in management practices, climate, vegetation, or land use) on water quality or another variable of interest can be quantified.
- Is successful in simulating soil water patterns in the watershed on daily time step (Gasman et al., 2007).
- SWAT is a deterministic, continuous watershed model that can operate on daily and hourly time steps (e.g. Daniel, Camp et al., 2011).
- The model uses readily available inputs. While SWAT can be used to study more specialized processes such as bacteria transport, the minimum data required to run the model are commonly available from government agencies.
- SWAT is computationally efficient. Simulation of very large basins or a variety of management strategies can be performed without excessive investment. The model enables users to study long-term impacts.
- It is continuous time or long-term yield model able to simulate long-term impacts of land use, land management practices and build-up of pollutant (Neitsch et al., 2002, 2005).
- SWAT has a weather simulation model that generates daily data for rainfall, solar radiation, relative humidity, wind speed and temperature from the average monthly variable for the data provides a useful tool to fill in gaps in daily data in the observed records.
- SWAT derives topography, contour and slope from a digital elevation model used to divide the basin into sub-watersheds (Zhou and Fulcher, 1997).
- SWAT explicitly incorporates routines for agricultural diversions and irrigation.
- SWAT includes routines designed to address the impacts on flow and pollutant loading of multiple small (or large) farm ponds within a basin.
- SWAT is designed to use either observed meteorological data or statistically generated meteorology, facilitating the development of long-term analyses.
- Can be used to simulate discharge and pollutant loading on this small scale, then the model outputs can be used to identify potential impacts of restoration efforts.

2.10.4. Limitation of SWAT Software

The following are some of the limitations using SWAT for hydrological modeling:

1. Due to the heterogeneity of the catchments, a number of meteorological observation stations are required to represent the spatial variation in the hydro meteorological characteristics in the area. The lack of adequate number of observation stations affects the model output.

2. In order to calibrate the model for the historic land use scenarios, the corresponding land use maps are needed. In order to get the real time picture of the land use pattern, this information can be extracted from the remote sensing satellite imageries by using digital image processing technique. However, acquisition of satellite imageries is expensive and the expertise required for the image interpretation is another major limitation.
3. Though SWAT is a free software tool, in order to represent the spatial variation in the catchments characteristics, GIS software is the prerequisite to run the model.
4. While SWAT is a process-based model, it intentionally incorporates simplified representations of most processes so that many parameters can be obtained from readily available geospatial coverage. For upland generation of flow and sediment, SWAT relies on the well-tested, semi empirical approaches of the SCS Curve Number and MUSLE. The basic time step of the model is one day (although hydrology can be simulated at a finer scale using Green-Ampt infiltration); so actual flow hydrographs are not represented.
5. The model also fares poorly at predicting individual flood events because it operates on a continuous daily time step instead of being event-based (Borah and Bera,2003)
6. The model's HRU units lack the ability to accurately represent parceled land units like riparian zones and wetlands or targeted management interventions (Gasman et al., 2007).
7. SWAT applications were less successful in simulating hydrological process. For example, Chu and Shirr Mohammad (2004) used 6 years of data to calibrate and validate SWAT's capability to calculate surface flow for a small watershed in Maryland, and found that SWAT was unable to simulate an extremely wet year within at that time period. (Spruill and Taraba, 2000) calibrated and validated a SWAT model to determine daily stream flow for small karst-influenced watershed in central Kentucky over a 2- year period, and found that the model poorly predicted peak flows and hydrograph recession rates.

2.10.5. SWAT CUP

SWAT CUP is an interface that was developed for SWAT and designed to integrate various sensitivity analysis, calibration, validation and uncertainty programs for SWAT using different interface. The main function of an interface is to provide a link between the input/output of a calibration program and the model. Using the generic interface, any calibration, and validation/uncertainty or sensitivity program can easily be linked to SWAT.

Various SWAT parameters for estimation discharge were estimated using the SUFI-2 program (Abbas pour et al., 2007). The SUFI-2 was the most suitable way to find the SWAT uncertainty under the condition that the parameter range. The Goodness of fit in SUFI-2 is expressed by the 95PPU band, it cannot be compared with observation signals using the traditional indices such as R^2, Nash-Sutcliffe (NS). For this reason two measures referred to as the p-factor and the R-factor (Abbas Pour et al., 2004, 2007) the P-factor is the percentage of the measured data bracketed by the 95PPU. The R-factor, on the other hand, is measure of the quality of the calibration and indicates the thickness of the 95PPU. As all forms of uncertainties are reflected in the measurements (e.g., discharge), the parameter uncertainties generating the 95PPU account for uncertainties.

2.11. Sensitivity Analysis

Sensitivity analysis is used to estimate the rate of change in model outputs in relation to changes in model inputs. If helps determine which parameters are important for accurate results. It facilitates understanding the behavior of the system being modeled, as well as evaluating the application of the model (Srinivasan and Van Griensven, 2007 Cited by Tensay, 2011 and Eyob, 2010).

Sensitivity analysis determines the sensitivity of the input parameters by comparing the output variance due to the variability. This is useful not only for model development, but also for model validation and reduction of uncertainty (Hamby, 1994). The sensitivity analysis was carried out to identify the sensitive parameters of the SWAT model.

2.12. Model Calibration and Validation

Since it is impossible to replicate watersheds and river basins, common practice in hydrologic studies is to divide the measured data either temporally or spatially for calibration and validation (Ingel et al., 2007). In hydrological simulation, two main exercises must be successful achieved before using a model. These are calibration and validation of the models (Gan et al., 1997).

2.12.1. Calibration

Model calibration is the process of selecting suitable values of model parameters such that the hydrological behavior of the catchment can be simulated closely (Wagener *et al*., 2004 cited by Abeyou W, 2008; Moore and Doherty, 2005). The exercise is vital because reliable values for some parameters can only be found by calibration (Beven, 1989). The calibration process can be either manual or automatic; however in practice is often a combination of the two. Manual calibration process that mainly depends on the modeler adjusting “by hand” model parameter values until the output of the model closely matches the observed data. In general, it is difficult to determine the “best fit” or to determine a clear point indicating the end of the calibration process, and hence different results will be obtained by different modeler’s (Wheatear, 2002).

2.12.2. Validation

Model validation is the process of representing that a given site specific model is capable of making sufficiently accurate simulation. The goal of validation is to assess whether the model is able to predict field observations for time periods different from the calibration period. This implies the application of the model without changing the parameter values that were set during calibration (Refsgaard et al., 1996). Physical parameters represent measurable properties of the basin such as surface area and slope of the basin. On the other hand, the process parameters represent watershed characteristic that are not directly measurable e.g. deep percolation.

Verification (also known as validation) takes place after calibration to test if the model performs well on a portion of data, which was not used in calibration. Model verification aims to validate the model’s robustness and ability to describe the catchment’s hydrological response, and further detect any biases in the calibrated parameters (Gupta *et al*., 2005).

2.13. Assessment of Model Performance

Model performance is usually better during calibration than verification period, a phenomenon called model divergence (Sorooshian and Gupta, 1995), and must be evaluated on the extent of its accuracy, consistency and adaptability (Go swami et al., 2005). During calibration and validation of a hydrological model, it is necessary to assess the performance of the model. These measures include the coefficient of determination, (R^2), Nash and Sutcliff (ENS) (1970), percent difference D, and root mean square error standard deviation ration (RSR) (Loage and Green, 1990). The range of values for $R^2$is 1.0 (best) to 0.0(poor).

The R^2 coefficient measures the fraction of the variation in the measured data that is replicated in the simulated model results. A value of 0.0 for R^2 means that none of the variance in the measured data is replicated by the model predictions. On the other hand, a value of 1.0 indicates that all of the variance in the measured data is replicated by the model predictions. Nash-Sutcliffe simulation efficiency (NSE) indicates the fitness degree of the observed and simulated plots with the 1:1 line. The statistical index of modeling Nash-Sutcliffe Efficiency (NSE) values range from 1.0(best) to negative infinity. NSE is a stricter test of performance than $R^2$and is never larger than R^2**.**

CHAPTER THREE

3. METHODOLOGY

3.1.General

This chapter describes the general, description of Fincha Amarti Nashe projects, location, socio economic and environmental setting of study area, Study area, location, the input data, their source and the methodology could be adopted for the modeling of Nashe watershed.
The main activities in the data collection phases are Literature review, site selection, and visual identification of land use/land cover around the study area made. During analysis phases, Geographic information systems (GIS) and the Soil and Water Assessment Tool (SWAT version 2012) technologies would be used to Model the Nashe watershed.

3.2.Description of Fincha Amarti Nashe Projects.

Ethiopia has been aware of using its water resources for development since the early 1920. Following the Blue Nile investigation of 1964 and the preliminary report of 1968, the imperial Regime planned and decided to construct dam on Fincha River for Hydroelectric power generation and irrigation in arid and semi-arid parts of Fincha valley. Fincha sub basin is a part of Blue Nile river basin, which contains three watersheds (Fincha, Amarti and Nashe) watershed.

However, the Fincha hydropower dam was constructed in 1973(Abdi,2012) as a strategy for fostering economic growth in the country through generation of hydroelectricity, irrigation, fishing and tourism (HARZA Engineering Company, 1965, 1966, 1975 cited by Bezuayehu T. and Geert S, 2008). Major infrastructural development of the area started in late 1960's, with the design and construction of the Fincha hydropower project. The Fincha dam formed the large Chomen Lake and provided water storage for development of 100-MW of the hydropower potential. In 1982, the former EELPA commissioned a power system planning study identifying the possibility of extending the generating potentials of the Fincha plant.

In light of this, the construction of Amarti Dam on Amarti river were takes place in mid-1980 and the flows diverted into the Fincha reservoir were expand the Fincha system and enters the Blue Nile. According to the study done by Bezuayehu T. (2006) cited by Abdi et al., and Ekaslt,(2012), the need to meet economic demands of the country and one of the way through which socio-economic and political developments of the country are realized is the generation of hydroelectric power and irrigation schemes from abundant water resources.

The newly multipurpose developed project on Nashe River called Fincha Amarti Nashe were accomplished in 2012, and for Hydropower and irrigation to raise the national economy, which originates in relatively long, broad valley top the Ethiopian Plateau at elevations above 2,200 m. The valley is surrounded by rolling topography and low ridges, which divide the Nashe River from adjacent drainage basins. Generally, Fincha, Amarti, Nashe dams plays a significant role in supporting the national economy through electrification, supplying water for sugar factory in downstream and introducing fisheries in the area and covers.

3.1.1. Location

The Fincha Amarti Nashe Multipurpose project situated (the project)is located about 364km North West of Addis Ababa from capital town of Ethiopia,50km from Zonal capital Shambu, in the Blue Nile river basin. The Blue Nile, also known as the Abbay, drains most of the North -central and North- Western part of Ethiopia. The area comprises highland plateaus elevated more than 2,000m above sea level and dramatic escarpments dropping over 600m to lowlands around the Abbay River. According to the Final Pre-Feasibility Report done by (Montgomery Watson Harza, Vol.1, Section.3, Main report) the project situated in the south central part of the Blue Nile (Abbay) River Basin, between the latitude 9°35' to 9°52'N and Longitudes 37°00' to 37°20'E.

The project area is North from the existing Amarti Reservoir and Fincha Reservoir (Lake Chomen), between the town of Shambu and Fincha, and to the West of Fincha Sugar Estate. The dam is likely to be located near or at the edge of escarpment, with the power plant located under the escarpment at approximately 1,600 masl. The proposed irrigation area would be located further downstream, near the confluence of Nedi and Fincha rivers, at the average of 1,300-1,500 masl.

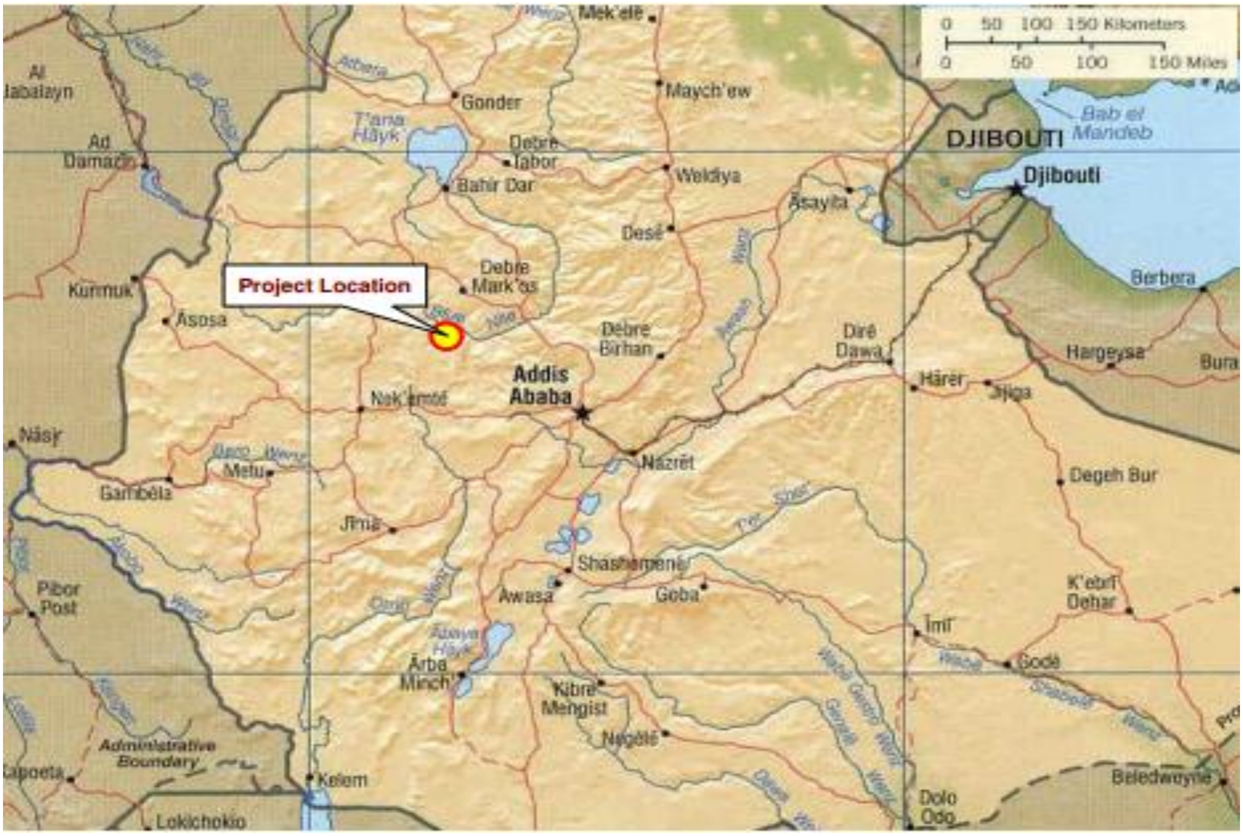

Figure 3.1. Project Location. (Source: MWH, 2004)

3.1.2. Socio-Economic and Environmental Setting of the Project.

The Project is located in the Oromia Region of Ethiopia and administratively is a part of the East Wollega Zone. The area potentially affected by the proposed project is located in two Districts: Abay Chomen District with the center in Fincha and Horo District based in Shambu.

3.1.3. Project Area

The area belongs to two District of the Horo Guduru Wollega Zone: Horo District based in Shambu and Abbay Chomen District with the seat in Fincha. The Nashe River Valley starts on the highland plateau Northeast of the town of Shambu and runs from West to east for about 10 km and then in a Northerly direction for further 7 km. The valley elevation is above 2,200 masl, with the surrounding ridges extending to over 2,500 masl. The proposed Nashe dam was being located close to the escarpment and the proposed reservoir was impounding most of the Nashe Valley.

At national level, the project produces more than 97 MW operating 6.5 hrs. Per day with two units and irrigates more than 6,000 hectares including the Community water supply and its construction was completed 2012 G.C. The proposed irrigation area was located downstream of the developed hydropower, on the Nedi river West bank and extending to the Nedi-Fincha confluence. One of the newly man made bodies of water in Ethiopia is Fincha Amarti Nashe multipurpose hydropower. With length and height of 1,000 meter and 35 meter respectively, and with total water storage capacity of 448 million cubic meters and help raise sugarcane development capacity of Fincha Sugar factory to 20,000 hectares from the existing 14,000 hectares.

As Final Pre-Feasibility Report done (MWH, 2004) Indicated that access to the project area is via the Addis Ababa – Gedo - Nekemte main road. At the town of Gedo, the road branches to the North towards Fincha. The road passes through the town of Fincha and 20 km further branches in three directions: eastwards, descending the escarpment to the Fincha Sugar Estate, Westwards to the town of Shambu passing between the Fincha and Amarti reservoirs, and Northwards to the Amarti Dam. Past the Amarti dam, the road becomes a track and continues across the range to the lower end of the Nashe Valley.

3.1.4. Topography

The Project area varies in elevation from 1,600 m in the lower plateau under the escarpment to hills and ridges of the highland climbing to over 2,500 m. The areas of the lower plateau, where the proposed irrigation area is located, are relatively flat and in sharp contrast with almost vertical cliffs of the escarpment that rise from around 1,600 to over 2,200 m above sea level. The escarpment is clearly visible on the satellite image shown in Figure (3.2). The highland area above the escarpment is characterized by relatively flat-bottomed valleys at about 2,200, continued by mild slopes up to EL 2,300 m and steep hills above.

The sources of the Nashe River are the creeks of Himane, Lege Ferso and Abuna that drain swampy areas in the region of Bone Muleta. These creeks form the Aserti River that flows North and then south into Nashe Valley. In the Nashe Swamp, the Aseti River meets Babo Creek, which flows from the West and downstream, the waters are referred to as the Nashe River. This upper area of the Nashe Valley is a relatively wide, swampy zone with a low gradient. Total catchment area of the Nashe River down to the Nashe Falls is estimated at between 322km^2- 338km^2, and the longitudinal slope of the Nashe River from its source to the Nashe Falls is about 4 ‰ and only 0.6 ‰ within the Nashe valley itself.

Figure 3. 2. FAN topography (Source, Google earth, MWH Main report, 2004).

The Fincha catchment area extends close to 1,400 km2 upstream of the Fincha Dam and is almost circular in shape. The reservoir represents about 25% of the catchment area, with a large area dominated by Chomen Swamp. Similar to Amarti and Nashe, the Fincha River plunges over the high escarpment, falling some 500 m over a 2 km stretch. The hydropower potential was developed in 1973's by the construction of the Fincha dam, about 5-km long tunnel and the penstock, leading to the 100-MW power plant located under the escarpment. The plant has since been a backbone of the Ethiopian electricity system and was recently extended by addition of a 4thunit, increasing the installed capacity to 134 MW. Downstream of the plant, the Fincha River flows in a Northerly direction, meets with the Nedi River, and then descends another 150 meters to meet the Abbay River at approximately 900 masl.

3.1.5. Geology

The Fincha Amarti Nashe (FAN) project area is located in West-central Ethiopia, approximately 364 km NorthWest of Addis Ababa, in the physiographic province of the Ethiopian Plateau. The plateau occupies nearly the entire Western half of Ethiopia and is fringed by the Sudan lowlands to the West and the Great Rift Valley to the east. The plateau is situated at elevations of 1,500 to 2,500m above sea level - with some areas reaching over 4,000m in elevation and is characterized by rolling topography interspersed with high mountain ranges, volcanic cones and deep gorges.

3.1.6. Geologic History

The Ethiopian Plateau is generally characterized by a thick sequence of Mesozoic sedimentary formations overlying the Precambrian basement complex and largely covered by Tertiary and Quaternary volcanic deposits.

The Precambrian basement complex underlies the entirety of Ethiopia and is comprised of intensely folded metamorphic rocks and igneous intrusions. Since the end of Precambrian time, the region has undergone massive continental uplift and subsidence. Uplift episodes, which occurred during the Paleozoic Era, resulted in a long period of erosion that lasted some 375 million years and eroded the landscape to a pen plane surface on the Precambrian basement rock. Subsequent episodes of subsidence occurred during the Mesozoic Era, allowing seas to transgress and regress, depositing sediments unconformable on the Precambrian basement complex.

Table 3. 1.General Chronology of major Geologic Events (MWH.Vol 1, 2004)

Era	Period	Event
Cenezoic	Quaternary 1.6 M yrs	Recent continental uplift
	Tertiary 1.6 M to 65 M yrs	Major rifting producing the East African Rift accompanied by volcanic episodes depositing Trap Series basalt - continuing into Quaternary.
Mesozoic	Cretaceous 65 M to 140 M yrs	Marine regression
	Jurrasic 140 M to 190 M yrs	Deposition of sedimentary formations (Adigrat Fmn)
Paleozoic and Precambrian	230 M to 600 M yrs	Uplift and erosion of metamorphic and igneous basement complex by late Triassic

3.1.7. Seismicity

Ethiopia is situated in a seismically active area where continental spreading has caused a rift structure to develop in a south-south West direction, extending through central Ethiopia and into Kenya. Several major seismic events have been recorded in recent history, some registering as high as 6.75 on the Richter scale.

It is generally interpreted that most of the recent seismic activity in central Ethiopia is related to movements along the Ethiopian Rift with epicenter locations in the rift valley and along the rift escarpments (i.e., plateau margins). Other regional seismic activity has been associated movements along tectonic plate boundaries in the Red Sea and Gulf of Aden. The FAN project is located more than 200 km from the Ethiopian Rift, the primary source of seismic activity in the region.

3.1.8. Climate

The Fincha Amarti reservoir system and the Developed Nashe reservoir are located on the highland plateau at an elevation of about 2,200 masl. The plateau is characterized by a subtropical climate, an average air temperature of 22°C and average annual rainfall of between 1,200 and 1,600mm. A temperate zone is located above 2,400 masl and it has an average temperature of 16˚C and the average annual rainfall of up to 2,000 mm. The temperatures decrease with altitude at about 0.7 °C per 100 m.

The area below the escarpment, where the developed powerhouse and the irrigation area will be located, descends from about 1,600 masl below the escarpment to about 900 masl at the Abbay River. Classified as "tropical climate II", the area is characterized by a higher average temperature (about 27˚C) and lower precipitation. The climatic conditions of the project site are generally suitable for growth of various crops, such as sugarcane, cereals, oil crops, pulses, vegetables and fruits. Luvisols are suitable for most of the crops, while more crops that are tolerant would need to be grown on Vertisols.

3.1.9. Temperature

Maximum temperatures are observed in March-April while the minimum is recorded in July-August. The relative humidity is highest in July-September with the minimum in February-April. The main wet season occurs between June and September, followed by a dry season that may be interrupted by a short rainy period between February and April (known as the Belg Season). Rainfall during the rainy season is in the order of 200 to 300 mm/month, with very little rainfall occurring during the rest of the year. Variation of the spatial and temporal precipitation distribution over Ethiopia is significant and the mean annual rainfall pattern points to four distinct rainfall regimes.

The Nashe project area belongs to the mono-modal rainfall pattern, characterized by a distinct wet period that lasts from about May until October, when about 90% of the annual rainfall occurs. The eastern part of the project area gets some influences of the bimodal rainfall type. Under the World Wildlife Fund (WWF) Global 200 Eco region classification, the project area is classified as Eco region 102 Ethiopian highlands, constituting part of the "Dry evergreen mountain forests and grasslands ecosystem".

3.1.10. Soil

Soil is defined as the top layer of the earth’s crust. It is formed by mineral particles, organic matter, water, air and living organisms. The soil profile is sub-divided into multiple layers that support soil water processes including infiltration, evaporation, plant uptakes, lateral flow, and percolation to lower layers. The soil percolation component of SWAT uses a water storage capacity technique to predict flow through each soil layer in the root zone. Soil nutrient status of the project site is generally low to medium.

To mitigate the poor drainage nature of the Vertisols, efficient and correct drainage and optimum water utilization system should be implemented. The Nashe catchment has a wide range of soil type mainly dominated by clay and loam soil. The largest portion of the watershed is characterized by red to reddish brown friable Luvisols and black heavy clay Vertisol. Most of the soil of the irrigated land is Luvisols and the rest Vertisols. The dominant soils in the basin are Cambisols and Nitisols, with occurrence of Arenosols, Luvisols, Vertisols and Regosols.

3.1.11. Land Use

The land use in Nashe watershed is dominated by cultivated and irrigated agriculture .Pastoral land is also practiced in Northern parts of watershed. The major portion of the watershed is under intensive cultivation and teff, maize, barley, and wheat are the major crops grown in the watershed. In addition to this, shrubs land, forest, woodland and wetland/swamp are also the land cover types in the study watershed.

3.1.12. Evaporation

The loss is an important consideration in determination of the water balance in the lake and it makes a significant part of the water balance.

3.3.Reservoir Area and Dam Volume

Nashe Reservoir is one of the biggest man made body of the water in Ethiopia, it is known as Fincha Amarti Nashe multi-purpose hydropower project, the reservoir area of above 322km^2, dam volume more than 448 million cubic meters(MWH,Main report, 2004).

3.4.Material and Methods

The necessary data that was collected and used for this study can be classified into spatial and time series data. Spatial data used are DEM, land use/cover and soil map of the study area and collected from MoWIE. The time series data are Meteorological and hydrological data and these data are collected from Ethiopian National Meteorological Agency and MoWIE respectively. The materials used in this study are:

- Data: Secondary hydrological, meteorological map and data were used for analysis.
- DEM; Digital elevation model of 30m x 30m was used to extract river networks and other Catchment indices.
- Software: Arc GIS 10.2
- Software: Arc SWAT
- PCP STAT
- Dew02.exe
- Microsoft Excel

Generally, the study involves for the application of the model calibration, validation, sensitivity analysis and uncertainty algorithms were used. The methodology of this work has the following components:

1. Data collection
2. Data processing
3. Running model
4. Sensitivity Analysis
5. Calibration and Validation of the model
6. Model result analysis

The overall methodology was analyzed using Geographic Information System (GIS) based on version of the Soil and Water Assessment Tool (SWAT). Generally, calibration, validation and evaluation by appropriate systems to check the performance of the model with observed data and the overall methodology of the study were presented in figure 3.3.

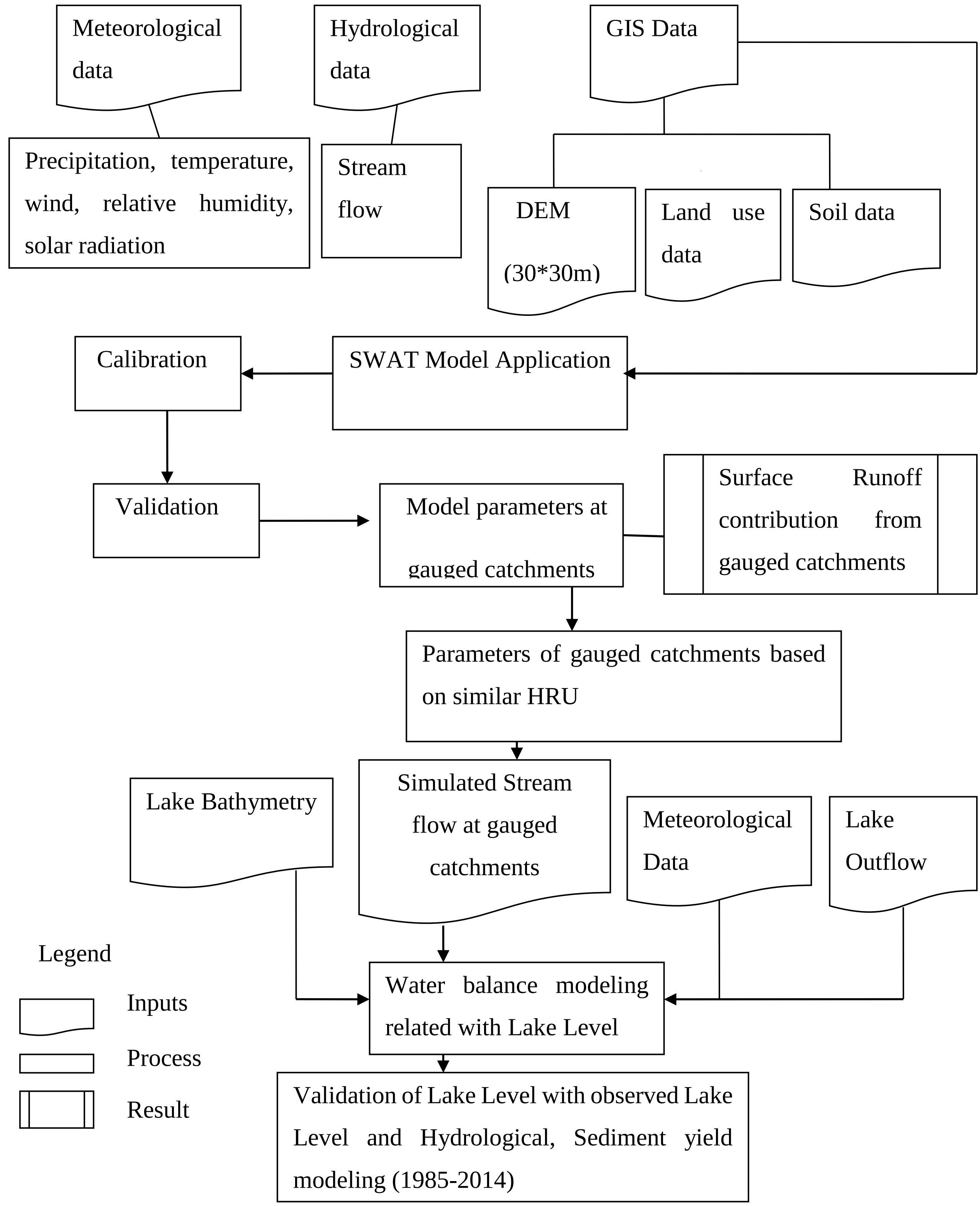

Figure 3. 3. Overall flow chart of the Methodology adopted in the research

3.5.Description of Soil and Water Assessment Tool Model

The Soil and Water Assessment Tool (SWAT)developed by the United States Department of Agriculture Research Service (Arnold et al.,1995), has been applied to watersheds throughout the world (Example: Arnold and Fohrer,2005) and is an example of a physically based, conceptual-time, long-term river basin simulation model that originated from agricultural models with spatially distributed parameters operating on a daily time step semi-distributed parameter model which simulates rainfall, infiltration, surface flow, groundwater flow, and transmission losses (Neistch et al., 2002), conceptual and computational efficiency model operates on daily time step at a basin ((Arnold et al., 1998, 2000; Neitsch et al., 2001), requires physically based data (Jacobs and Srinivasan, 2005).

It was being used on watershed as small as 0.15km^2 (chanasyk et al., 2003) and as large as 491,700km^2 (Arnold et al., 2000). The model is used to quantify the impact of land management practices on water, sediment and agricultural chemical yields (nutrient loss) in large and complex watersheds with varying soils, land uses and management conditions over a long period of time (Behera and Panda, 2006).

SWAT incorporates the effects of weather, surface runoff, evapotranspiration, irrigation, sediment transport, groundwater flow, crop growth, nutrient yielding, pesticide yielding and water routing, as well as the long-term effects of varying agricultural management practices (Neitsch *et al*., 2002, 2005). In the hydrological component, runoff is estimated separately for each sub basin of the total watershed area and routed to obtain the total runoff for the watershed. Runoff volume is estimated from daily rainfall using modified SCS-CN and Green Ampt methods. Sediment yield is estimated using a modified universal soil loss equation (MUSLE).

3.5.1. Hydrological Components of SWAT

Hydrological components (Surface runoff, ET, recharge, and stream flow) in SWAT have been developed and validated worldwide on a variety of watershed scales in an attempt to address different hydrological and environmental issues. Through the many application of SWAT, the model generally has proven to be an effective tool for assessing water resources. For example, Bingner (1996) simulated reasonable values of runoff for daily, monthly, and annual time steps for the Goodwin Creek watershed in the upper Mississippi Basin for a 10 year time period. Van Liew and Garbrecht (2003) evaluated the SWAT's ability to predict stream flow under varying climate for three-nested watershed in Oklahom.

They found that the model performed better in drier years than in wetter years. Sun and Cornish (2005) used SWAT to estimate recharge in the headwaters of the Liverpool Plains in Australia. The Study used water balance modeling at the catchment scale to drive parameters for long-term recharge estimation result showed that recharge occurs only in wet years and recharge primarily could be explained by the climatic factor rather than land use changes. Peterson and Hamlet (1998) found that SWAT was better suited for long periods of simulation and suggested that the snowmelt routine be improved (Gassman and others, 2007).

In recent years, SWAT, developed at USDA-ARS and Texac. A and M. A. grilife research in Texas, USA by Arnold *et al*.,(1998) has gained international acceptance as a robust interdisciplinary watershed modeling (Birhanu et al., 2005). It has proven to be an effective tool for assessing water resources and non-point source pollution problems for a wide range of scales and environmental conditions across the globe (e.g. Arnold et al., 1998; Arnold and Fohrer, 2005). According to (Neitsch et al., 2005) SWAT is a basin scale, continuous time model that operates on a daily time step and it is designed to predict the impact of management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions. The model is physically based, computationally efficient, uses readily available inputs and capable of continuous simulation over long –term impacts.

Major model components include weather, hydrology, soil temperature and properties, plant growth, Nutrient, Pesticides, and Bacteria and pathogens, and land management (Neitsch et al., 2002). SWAT is currently applied worldwide and considered as a versatile model that can be used to integrate multiple environmental processes, which support more effective watershed management and the development of better-informed policy decision (Gasman *et al*., 2005).

The SWAT system embedded within geographic information system (GIS) (Velleux et al., 2010) that can integrate various spatial environmental data including soil, land cove, climate and topographic features. Jacobs et al., (2005) Argues that SWAT is a physically based hydrologic model and requires physically based data. Neil H. (2007) indicates that SWAT is physically based and, for basic simulations, requires minimal input data and continuous time model. Currently SWAT is imbedded in an ArcGIS interface called Arc SWAT and is a version of SWAT integrated with a Geographic Information System (Winchell et al., 2007) allows the user to prepare SWAT input and run the model within the framework of ArcGIS.

The sub watershed discretization divides the watershed into sub basins based on topographic features of the watershed. This technique preserves the natural flow paths, boundaries, and channels required for realistic routing of water, sediment and chemicals. All of the GIS interfaces developed for SWAT use the sub watershed discretization to divide a watershed. The number of sub basins chosen to model the watershed depends on the size of the watershed, the spatial detail of available input data and the amount of detail required to meet the goals of the project. When subdividing the watershed, keep in mind that topographic attributes (slope, slope length, channel length, channel width, etc.) are calculated or summarized at the sub basin level.

The Sub basin delineation should be detailed enough to capture significant topographic variability within the watershed. Once the sub basin delineation has been completed, the user has the option of modeling a single soil land use management scheme for each sub basin or partitioning the sub basins into multiple hydrologic response units (HRU). HRU are used in most SWAT runs since they simplify a run by lumping all similar soil and land use areas into a single response unit. It is often not practical to simulate individual field (Neitsch et al., 2005), Soil and Water Assessment Tool input /output file documentation, version 2005.

3.5.1.1. Hydrological Processing in SWAT

In the SWAT model, the water balance is the backbone of the hydrologic simulation in a watershed; and the hydrology of a watershed can be separated into two major divisions, land phase and routing phase (Neitsch *et al.*, 2002). Hereafter the discussion is mainly focuses on main components of SWAT model and selected options (if option is required) for this study. For more explanation of each component and options, see SWAT 2005 model theoretical documentation (Neitsch et al., 2005). The SWAT model has difficulties reconciling both winter and summer seasons, for testing watersheds (ETIENNE et al., 2008).

SWAT simulates complete hydrological cycle of a watershed system. The Simulation of the hydrology of a watershed is done in two separate divisions. The first division is the land phase of the hydrological cycle that controls the amount of water, sediment .nutrient and pesticide loading to the main channel in each sub basin. Hydrological components simulated in the land phase of the hydrological cycle are canopy storage, infiltration, redistribution, evapotranspiration, lateral subsurface flow, surface runoff, ponds, tributary channels and return flow. The second division is routing phase of the hydrological cycle that can be defined as the movement of water, sediment, nutrient, and organic chemicals through the channel network of the watershed to the outlet (Neisch et al., 2000).

3.5.1.1.1. *Land Phase of the Hydrological Cycle.*

Water balance is the driving force behind everything that happens in the watershed. In SWAT, simulation of hydrology of the watershed can be separated in to two major divisions. The first division is the land phase of hydrologic cycle controls the amount of water, sediment, nutrient and pesticide loadings in to the main channel in each sub basin. In this hydrological cycle, SWAT simulates the hydrological cycle based on the water balance equation. The land phase of the hydrologic processes is simulated based on the water balance equation (Neitsch *et al.*, 2005) and computed by:

$$SW_t = SW_0 + \sum_{j=1}^{t} (R_{day} - Q_{surf} - E_a - \omega_{seep} - Q_{gw}) \quad (1)$$

Where, SW_t is the final soil water content (mm), SW_o is the initial soil water content on day i (mm), t is the time (days), R_{day} is the amount of precipitation on day i (mm H2O), Q_{surf} is the amount of surface runoff on day i (mm H2O), E_a is the amount of evapotranspiration on day i (mm H2O), ω_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm H2O), and Q_{gw} is the amount of return flow on day i (mm H2O).

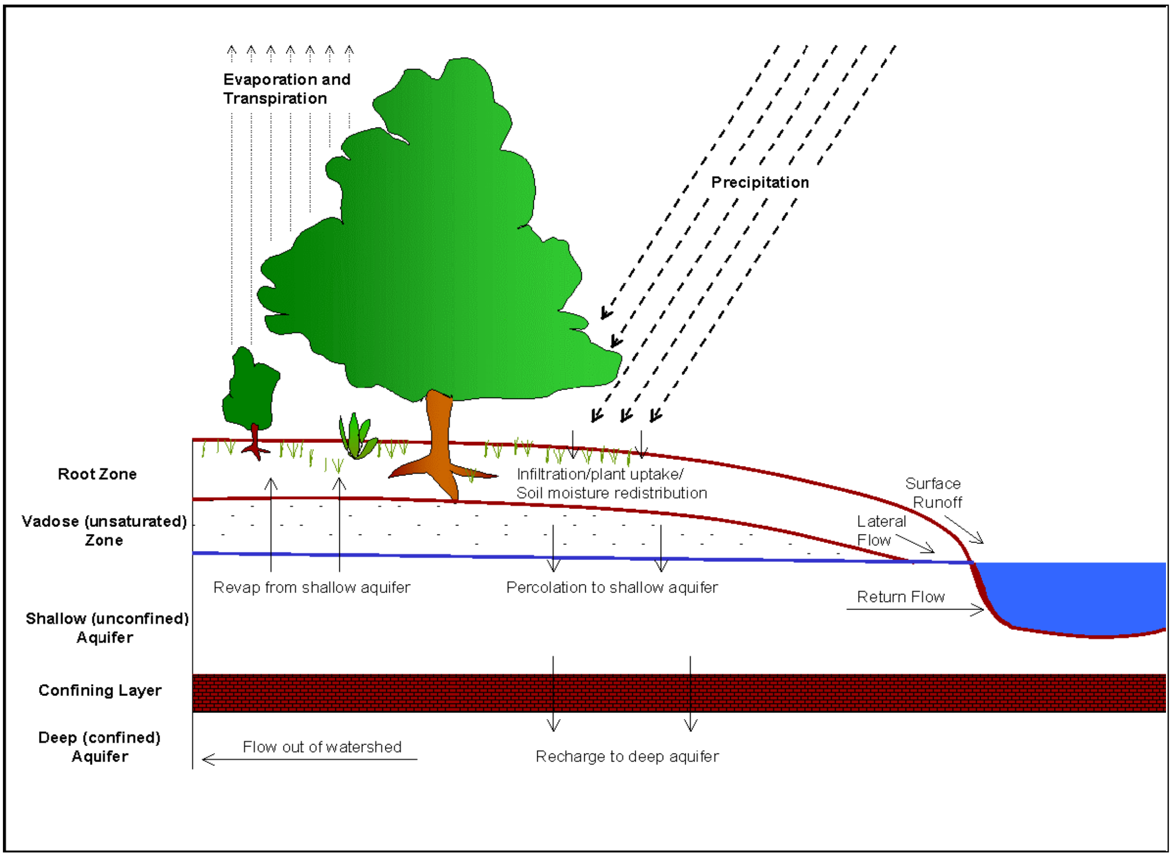

Figure 3. 4. Schematic representation of Hydrological Cycle used in SWAT Model

The Arch SWAT software requires variables among the most important variables required to model land phase of the hydrological cycle. The climatic required by the SWAT consist of daily precipitation, maximum/minimum daily air temperature, solar radiation, wind speed and relative humidity.

SWAT includes the WXGEN weather generator model (Sharpley and Williams, 1990) to generate climatic data or to fill in gaps in measured records. The occurrence of rain on a given day has a major impact on relative humidity, temperature and solar radiation for the day. Once the total amount of rainfall for the day is generated, the distribution of rainfall within the day is computed if the Green & Ampt method is used for infiltration, maximum temperature, minimum temperature, solar radiation and relative humidity are then generated based on the presence or absence of rain for the day.

Finally, wind speed is generated independently. To generate the data, weather parameters were developed by using the weather parameter calculated WXPARM (William, 1995) and dew point temperature calculator DEW02.exe (Liersch, 2003), which were downloaded from SWAT website (http://www.brc.tamus.edu/swat/soft_links.html).

The daily precipitation generator is a Markov Chain Skewed (Nicks, 1974) or Markov Chain Exponential model (Williams, 1995). A first-order Markov Chain is used to define the day as wet or dry. With the first-order Markov-chain model, the probability of rain on a given day is conditioned on the wet or dry status of the previous day. A wet day is defined as a day with 0.1 mm of rain or more. Wet-Dry probabilities and monthly statistics value of rainfall, Maximum, Minimum Temperature, Solar radiation, Wind speed and Relative humidity for principal stations.

The weather generator stochastically determines the occurrence of rainfall in a particular day. The probability of a wet day on day i given a wet day on day i – 1, Pi (W/W), and the probability of a wet day on day i given a dry day on day i – 1, Pi (W/D), for each month of the year. From these inputs, the remaining transition probabilities can be derived:

$$P_i(D/W) = 1 - Pi(W/W) \quad (2)$$

$$Pi(D/D) = 1 - Pi(W/D) \quad (3)$$

Where Pi (D/W) is probability of a dry day on a day given a wet day on day i-1 and Pi (D/D) is the probability of a dry day on I given a dry day on day i-1. To define a day as wet or dry, SWAT generates random number between 0.0 and 1.0. This random number is compared to the appropriate wet-dry probability, Pi (W/W) or Pi (W/D). If the random number is equal to or less than the wet-dry probability, the day is defined as wet. If the random number is greater than the wet-dry probability, the day is defined as dry. Skewed probability distributed function has been for the study area to describe the distribution of rainfall amount.

3.5.1.1.1.1.Surface Runoff

Using daily or sub-daily rainfall amounts, SWAT simulates surface runoff volume and peak runoff rates for each HRU, occurs whenever the rate of water application to the ground surface exceeds the rate of infiltration and provides two methods for estimating surface runoff volume: the SCS curve number procedure (USDA-SCS, 1972) and the Green-Ampt Mein-Larson infiltration method (Green and Ampt, 1911). Hence, the SCS curve number method was adopted; and the model was developed to provide a consistent basis for estimating the amounts of runoff under varying land use and soil types (Rallison and Miller, 1981). For these research work SCS curve number method has been used to estimate surface runoff because of the unavailability of sub daily data for Green and Ampt method. The SCS curve number used (USDA-SCS, 1972).

$$Q_{surf} = \frac{(Ra - Ia)^2}{(Rd - Ia + S)} \qquad (4)$$

Where; Qsurf is the accumulated runoff or rainfall excel (mm water),),Rday=is the rainfall depth for the for the day (mm water),Ia=is the initial abstraction which includes surface storage, interception and infiltration prior to runoff (mm water),S=is the retention parameter (mm water). Runoff will only occur when Rday > Ia. For the definition of the soil hydrologic groups, the model uses the U.S. Natural Resource Conservation Service (NRCS) classification, which classifies soils into four hydrologic groups (A, B, C, & D) based on infiltration characteristics of the soils. Group A, B, C and D soils have high, moderate, slow, and very low infiltration rates with low, moderate, high, and very high runoff potential, respectively. The retention parameter varies spatially due to changes in soils, land use, management, and slope and temporally due to changes in soil water content. The retention parameter is defined by equation (5):

$$S = 25.49\left(\frac{1000}{CN} - 10\right) \qquad (5)$$

Where CN is the curve number for the day and it is a function of land use, soil permeability and antecedent soil water condition. Commonly Ia, is approximated by 0.2S and equation (6) rewrite as follow:

$$Q_{surf} = \frac{(R_{day} - 0.2S)^2}{(R_{day} + 0.8S)} \tag{6}$$

SWAT includes two methods for calculating the retention parameter; the first one is retention parameter varies with the soil profile water content and the second method is the retention parameter varies with accumulated plant evapotranspiration. The soil moisture method equation (7) over-estimates runoff in the shallow soils. Nevertheless, calculating the daily CN as a function of plant evapotranspiration, the value is less dependent on soil storage and more dependent on antecedent climate.

$$S = S_{max}\left(1 - \frac{SW}{[SW + \exp(w_1 - w_2 SW)]}\right) \tag{7}$$

Where, S is the retention parameter for a given day (mm) Smax is the maximum value that the retention parameter can have on any given day (mm), SW is the soil water content of the entire profile excluding the amount of water held in the profile at wilting point (mm), and w1 and w2 are shape coefficients. The maximum retention parameter value, Smax is calculated by solving equation (8).using CN1.

$$S_{max} = 25.4\left(\frac{100}{CN_1} - 10\right) \tag{8}$$

When the retention parameter varies with plant evapotranspiration, the following equation is used to update the retention parameter at the end of every day:

$$S = S_{prev} + E_a * \exp\left(\frac{-cncoef - S_{prev}}{S_{max}}\right) - R_{day} - Q_{surf} \tag{9}$$

Where Sprev is the retention parameter for the previous day (mm water), Ea is the potential evapotranspiration for the day (mm/day), cn_{coef} is weighting coefficient used to calculate the retention coefficient for daily curve number calculations dependent on plant evapotranspiration, Smax is the maximum value of retention parameter can achieve on any given day (mm water), Rday is the rainfall depth for the day (mm water), and Qsurf is the surface runoff (mm water). The initial value of the retention parameter is defined as S=0.9*Smax.

The SCS defines three antecedent moisture conditions: AMC I-dry (wilting point), AMC II-average moisture, AMC III-wet (field capacity). The moisture condition I curve number can assume in dry conditions. The curve number for moisture conditions III and I are calculated with equation (10) and (11).

$$CN_1 = CN_2 - \frac{20.(100 - CN_2)}{\left(100 - CN_2 + \exp\left[2.533 - 0.0636.\left(100 - CN_2\right)\right]\right)} \quad (10)$$

$$CN_3 = CN_2.\exp\left[0.00673.\left(100 - CN_2\right)\right] \quad (11)$$

Typical curve numbers for moisture condition II are listed in various tables (Neitsch et al., 2005). The values are appropriate for a 5% slope. William, 1995 developed an equation to adjust the curve number to a different slope.

$$CN_{2S} = \frac{\left(CN_3 - CN_2\right)}{3}.\left[1 - 2\exp\left(-13.86.slp\right)\right] + CN_2 \quad (12)$$

Where CN1 is the moisture condition, I curve number; CN2 is the moisture condition II curve number for the default 5%slope. CN3 is the moisture condition III curve number for the default 5% slope. CN2 S is the moisture condition II curve number adjusted for slope and slp is the average percent slope of the sub basin. Initially CN is assigned for each specific land use/soil contribution in the watershed, and these values are read into the SWAT program. SWAT then calculates upper and lower limits for each CN following a probability function described by the NRCS to account for varying antecedent moisture conditions (CN-AMC)(USDA-NRCS,2004). SWAT determines an appropriate CN for each simulated day by using this CN-AMC distribution in conjunction with daily soil moisture values determined by the model.

SWAT calculates the peak runoff rate with a modified rational method for each HRU. In rational method it assumed that a rainfall of intensity i begins at time t = (0) and continues indefinitely, the rate of runoff will increase until the time of concentration, t = tconc. Arnold et al., (1994) presumed that the modified rational method can be expressed mathematically as:

$$q_{peak} = \frac{\alpha_{tc} * Q_{surf} * Area}{3.6 * t_{conc}} \quad (13)$$

Where: qpeak is the peak runoff rate (m3/s), αct is the fraction of daily rainfall that occurs during the time of concentration, Qsurf is the surface runoff (mm), A is the sub-basin area (km²), tconc is the time of concentration (hr), and 3.6 is a conversion factor.

SWAT estimates the value of α using the following equation:

$$\alpha_{tc} = 1 - \exp[2 * t_{conc} * \ln(1 - \alpha_{0.5})] \quad (14)$$

Where: t_{conc} is the time of concentration (hr), and α0.5 is the fraction of daily rain falling in the half-hour highest intensity rainfall.

The time of concentration, t_{conc} is a time with in which the entire sub basin area is discharging at the outlet point and can be calculated by summing up both the overland flow time of the furthers point in the sub basin to reach a channel(tov) and the upstream channel flow time needed to reach the outlet point(tch):

$$t_{conc} = t_{ov} + t_{ch} \quad (15)$$

The overland flow time (tov) is computed as:

$$t_{ov} = \frac{Lslp}{3600 * V_{ov}} \quad (16)$$

$$t_{ov} = \frac{Lslp}{3600 * V_{ov}} \quad (17)$$

Where Lslp is the average sub basin slope length (m),

Vov is the overland flow velocity (m/s) and 3600 is a unit conversion factor.

The overland flow velocity for a unit width along the slope is calculated by using the Manning 'equation:

$$V_{ov} = \frac{q_{ov}^{0.4} * Slp^{0.3}}{n^{0.6}} \quad (18)$$

Where: qov is the average overland flow rate (m3/s), Slp is the average slope of the sub basin (m/m), n is Manning's roughness coefficient of the sub basin. Assuming an average flow rate of 6.35 mm/hr and substituting the equation of Vov into tov, the simplified equation of the overland flow becomes:

$$t_{ov} = \frac{Lslp^{0.6} * n^{0.6}}{16 * slp^{0.3}} \quad (19)$$

Channel flow time is computed as:

$$t_{ch} = \frac{L_c}{3.6 * V_c} \quad (20)$$

Where Lc is the average flow channel length (km), Vc is the average flow velocity (m/s), and 3.6 is a unit conversion factor.

The average flow channel length is calculated as:

$$Lc = L * Lcen \quad (21)$$

Where: L is the channel length from the furthest point to the sub basin outlet (km), Lcen is the distance along the channel to the sub basin centroid (km). Assuming Lcen= 0.5L, and using the Manning's equation for Vc for a trapezoidal channel with side slope of 2:1 and bottom width to depth ratio of 10:1, channel flow time becomes:

$$t_{ch} = \frac{0.62 * L * n^{0.75}}{Area^{0.125} * Slp_{ch}^{0.375}} \quad (22)$$

Where: tch is the time of concentration for channel flow (hr), L is channel length from the most distant point to the sub basin outlet (km), n is Manning's roughness coefficient for the channel, Area is the sub basin area (km2), and Slpch is the channel slope (m/m).

In large sub basin Surface run off lag with a time of concentration greater than 1 day, only a partition of the surface runoff will reach the main channel on the day it is generated. SWAT incorporates a surface runoff storage feature to lag a part of the surface runoff release to the main channel. Once surface runoff is calculated, the amount of surface runoff released to the main channel is calculated as:

$$Q_{surf} = (Q'_{surf} + Q_{surf,i-1}) * (1 - EXP[\frac{-surlag}{t_{conc}}]) \quad (23)$$

Where: Qsurf is amount of surface runoff discharged to main channel in a day (mm), Q′surf is amount of surface runoff generated in a sub basin in a day (mm), Qstor, i-1 is the surface runoff stored or lagged from the previous day (mm), Surlag is the surface runoff lag coefficient, and tconc is the time of concentration for the sub basin (hrs).

The Soil Water Percolation, Bypass Flow and Lateral Flow of the Water may follow different paths of movement: vertically upward (plant uptake), vertically downward (percolation), or laterally contributing to stream flow. Water is allowed to percolate if only the water content exceeds the field capacity of that layer (Neitsch et al., 2002). Bypass flow is the vertical movement of free water along macro pores through unsaturated soil horizons. Cracks are filled in accordance with their presence in the consecutive layers: those at the bottom layers are filled first (Neitsch et al., 2002).

To replace the CN, a simple soil profile water balance was calculated for each day of simulation. While SWAT's soil moisture routine greatly simplifies processes that govern water movement through porous media (into particular, partly saturated regions), for a daily model, the approach can be shown to be acceptable (Guswa et al., 2002). This saturation-deficit (mm water) is termed the available soil storage, τ:

$$\tau = \mathrm{EDC}(\varepsilon - \theta) \tag{24}$$

Where EDC is the effective depth of the soil profile (unit less), ε is the total soil Porosity (mm) and θ is the volumetric soil moisture for each day (mm). The porosity is a constant value for each soil type, whereas θ varies by the day and is determined by SWAT's soil moisture routines. EDC will then be spatially varied in such a way that low values are assigned to areas with a high likelihood of saturation, and higher EDC will be used for areas where not much surface runoff is generated via saturation excess. This spatially adjusted available storage is then used to determine what portion of rainfall events will

Infiltrate and what portion will runoff:

$$Q = \begin{cases} 0, \mathrm{if} p \prec \tau \\ p - \tau, \mathrm{if} p \geq \tau \end{cases} \tag{25}$$

Where Q is surface runoff (mm) and P is precipitation (mm). The available storage, τ, is calculated each day prior to the start of any rain event. Once precipitation starts, a portion of the rain, equal in volume to τ, will infiltrate the soil. If the rain event is larger in volume than τ, the soil profile will be saturated and surface runoff will occur. If the rain event is less than τ, the soil will not be saturated and there will be no surface runoff.

3.5.1.1.2. Routing Phase of the Hydrological Cycle

The routing phase is the second division of hydrological cycle, which can be defined as the movement of water, sediment other constituents (e.g. nutrients, pesticides) in the stream network. The variable storage method uses a simple Continuity Equation in routing the storage volume, whereas the Muskingum routing method models the storage volume in a channel length as a combination of wedge and prism storages.

Once SWAT determines the loading of water, sediment, nutrient and pesticides to the main channel, the loading are routed through the stream network of the watershed using a command structure similar to that of HYMO (Williams and Hann, 1972). Water is routed through the channel network using the variable storage routing method or the Muskingum River routing method. For this study, the variable storage method was adopted. The method was developed by Williams (1969) and recommended Williams and Hann (1973) and Arnold et al., (1995).

For a given reach segment, storage routing is based on the continuity equation:

$$\Delta V_{stored} = V_{in} - V_{out} \qquad (26)$$

Where: Vin is the volume of inflow during the time step (m3 water), Vout is the volume of outflow during the time step (m3 water), and ΔVstorage is the change in volume of storage during the time step (m3 water).

The above equation (26) can also be rewritten in detailed as follows:

$$V_{storage,2} - V_{storage,1} = \Delta t * (\frac{q_{in,1} + q_{in,2}}{2}) - \Delta t * (\frac{q_{out,1} + q_{out,2}}{2}) \qquad (27)$$

Where: Δt is the length of the time step (s), qin, 1 is the inflow rate at the beginning of the time step (m3/s), qin, 2 is the inflow rate at the end of the time step (m3/s), qout, 1 is the outflow rate at the beginning of the time step (m3/s), qout, 2 is the outflow rate at the end of the time step (m3/s), Vstorage, 1 is the storage volume at the beginning of the time step (m3 water), and Vstorage, 2 is the storage volume at the end of the time step (m3 water).

Travel time is computed by dividing the volume of the water in the channel by the flow rate.

$$TT = \frac{V_{Storage}}{q_{out}} = \frac{V_{storage,1}}{q_{out,1}} = \frac{V_{storage,2}}{q_{out,2}} \qquad (28)$$

Where: TT is the travel time (s), Vstorage is the storage volume (m3 water), and qout is the discharge rate (m3/s).

3.5.1.1.2.1.Potential Evapotranspiration

Potential Evapotranspiration (PET) was concept originally introduced by Thornth waite (1948) as part of a climate classification. The evapotranspiration rate is strongly influenced by a number of vegetative surface characteristics, Penman (1956) redefined PET as "the amount of water transpired by a short green crop, completely shading the ground, of uniform height and never short of water". Penman used grass as his reference crop.

For the PET estimation, SWAT provides three numerous alternatives for its calculation: the Penman –Monteith method (Monteith, 1965; Allen et al., 1986), the Priestley-Taylor method (Piestley and Taylor, 1972) and the Hargreaves method (Hargreaves et al., 1985) methods. The percolation through the user defined soil profile. These methods have various needs for a number and type of climate variables: Penman-Monteith method requires solar radiation, air temperature, relative humidity and wind speed; Priestley-Taylor method requires solar radiation, air temperature and relative humidity; whereas Hargreaves method requires air temperature only.

In SWAT, the potential evapotranspiration was computed using Penman-Monteith (Monteith, 1965) Method equation combines components that account for energy needed to sustain evaporation, the strength of the mechanism required to move the water vapor and aerodynamic and surface resistance terms.

The penman-Monteith equation is:

$$\lambda E = \frac{\Delta.(H_{net} - G) + \rho_{air}.C_p.(e^0{}_z - e_z)/r_a}{\Delta + \gamma.(1 + r_c/r_a)} \quad (29)$$

Where λE is the latent heat flux density (MJ m-2 d-1), E is the depth rate evaporation (mm d-1), Δ is the slope of the saturation vapor pressure temperature curve, de/dT (kPa °C-1), Hnet is the net radiation (MJ m-2 d-1), G is the heat flux density to the ground (MJ m-2 d-1), ρair is the air density (kg m-3), cp is the specific heat at constant pressure (MJ kg-1 °C-1), is the saturation vapor pressure of air at height z (kPa), eozez is the water vapor pressure of air at height z (kPa), γ is the psychometric constant (kPa °C-1), rc is the plant canopy resistance (s m-1), and ra is the diffusion resistance of the air layer (aerodynamic resistance) (s m-1). For well-watered plants under neutral atmospheric stability and assuming logarithmic wind profiles, the Penman-Monteith equation may be written (Jensen et al., 1990).

$$\lambda E_t = \frac{\Delta.(H_{net} - G) + \gamma.k_1.(0.622\lambda(0_{air}/P).(e^0{}_z - e_z)/r_a}{\Delta + (1 + r_c/r_a)} \quad (30)$$

Where λ is the latent heat of vaporization (MJ kg-1), Et is the maximum transpiration rate (mm d-1), K1 is a dimension coefficient needed to ensure the two terms in the numerator have the same units (for uz in m s-1, K1= 8.64 x 104), and P is the atmospheric pressure (kPa).

3.5.1.1.2.2.Ground Water System

Groundwater flow contribution to total stream flow is simulated by creating shallow aquifer storage (Arnold et al., 1993). Percolate from the bottom of the root zone is recharge to the shallow aquifer. A recession constant, derived from daily stream flow records, is used to lag flow from the aquifer to the stream. Other components of groundwater system include evaporation, pumping withdrawals, and seepage to the deep aquifer. Hooghoudt (1940) estimates the steady-state response of ground water flow to recharge and calculated by:

$$Q_{gw} = \frac{800.K_{sat}}{L_{gw}}.h_{wtbl} \quad (31)$$

Where K_{sat} is the hydraulic conductivity of the aquifer (mm/day), L_{gw} is the distance from ridge or sub basin divide for the ground water system to the main channel (m), and h_{wtbl} the water table height (m). Smedema et al., (1983) Water table fluctuations due to non-steady state response of ground water flow to periodic recharge and can be calculated by:

$$\frac{dh_{wtbl}}{dt} = \frac{w_{rchrg.sh} - Q_{gw}}{800.\mu} \quad (32)$$

In which, dhwtbl is the charge in the water table height with time (mm/day), Wrchtg,sh is the amount of recharge entering the aquifer on day i (mm) and μ is the specific yield of the shallow aquifer (m/m). Assuming that variation in groundwater flow is the linearly related to the rate of change in the water table height. The combination of equations (n) and (m) can give:

$$\frac{dQ_{gw}}{dt} = 10.\frac{K_{sat}}{\mu..L^2{}_{gw}}\left(w_{rchrg.sh} - Q_{gw}\right) = \alpha_{gw}.\left(w_{rchrg.sh} - Q_{gw}\right) \quad (33)$$

In which, α_{gw} is the base flow recession constant or constant of proportionality. The base flow recession constant, α_{gw} is the direct index of groundwater flow response to changes in recharge

(Smedema et al., 1983), α_{gw} Varies from 0.1-0.3 for land with slow response to recharge to 0.9-1.0 for land with a rapid response. Groundwater balance in SWAT model is calculated by assuming two layers of aquifers. SWAT partitions groundwater into a shallow, unconfined aquifer and a deep-confined aquifer and it simulates two aquifers in each sub basin. The shallow aquifer is an unconfined aquifer that contributes to flow in the main channel or reach of the sub basin. The deep aquifer is a confined aquifer.

The shallow aquifer (unconfined aquifer) contributes to flow in the main channel or reach of the sub basin. The water balance for a shallow aquifer in SWAT is calculated with:

$$aq_{sh,i} = aq_{sh,i-1} + w_{rchrg} - Q_{gd} - w_{revap} - w_{deep} - w_{pump,sh} \quad (34)$$

Where, $aq_{sh,I}$ is the amount of water stored in the shallow aquifer on day i (mm), $aq_{sh,i-1}$ is the amount of water stored in the shallow aquifer on day i-1 (mm), w_{rchrg} is the amount of recharge entering the aquifer on day i (mm), Q_{gw} is the groundwater flow, or base flow, into the main channel on day i (mm), w_{revap} is the amount of water moving into the soil zone in response to water deficiencies on day i (mm), w_{deep} is the amount of water percolating from the shallow aquifer into the deep aquifer on day i (mm), and $w_{pump,sh}$ is the amount of water removed from the shallow aquifer by pumping on day i (mm).

The deep aquifer is assumed to contribute to stream flow somewhere outside of the watershed (Arnold et al., 1993). The water balance for the deep aquifer is:

$$aq_{dp,i} = aq_{dp.i-1} + w_{deep} - w_{pump,dp} \quad (35)$$

Where $aq_{dp,\ i}$ is the amount of water stored in the deep aquifer on day i (mm water), $aq_{dp,\ i-1}$ is the amount of water stored in the deep aquifer on day i-1 (mm water), w_{deep} is the amount of water percolating from the shallow aquifer into the deep aquifer on day i (mm water), and $w_{pump,dp}$ is the amount of water removed from the deep aquifer by pumping on day i(mm). If the deep aquifer is specified as the source of irrigation water or water removed for use outside the watershed, the model will allow an amount of water up to the total volume of the deep aquifer to be removed on any given day.

3.5.2. Sediment Component of SWAT

3.5.2.1.Introduction

The SWAT has been widely used for watershed scale hydrological simulation and for assessing the effect of land use changes on watershed scale hydrological and water quality. Sediment refers to the amount of sediment exported by a basin over a period of time, which is also the amount that will enter the reservoir located at the downstream limit of the basin (Morris and Fan, 1998). Besides, the SWAT model has particular advantages for the study of basin change impacts and applications to basins with limited records (Bathurst, 2002; Ndomba, 2007).

The SWAT model is a catchment –scale continuous time model that operates on a daily time step with up to monthly or annually output frequency. SWAT calculates the soil erosion and sediment yield for each HRU with the Modified Universal Soil Loss Equation (MUSLE) (Williams et al., 1977), which exhibits non-linear behavior with changes in area:

$$Sed = 11.8\left(Q_{surf} * q_{peak} * Area_{hru}\right)^{0.56} * K_{USLE} * C_{USLE} * P_{USLE} * LS_{USLE} * CFRG \qquad (36)$$

Where Sed is the sediment yield on a given day (metric tons), Q_{surf} is the surface runoff volume (mm /ha), q_{peak} is the peak runoff rate (m^3/s), $Area_{hru}$ is the area of the HRU (ha), K,C,P and LS are erodibility, cover, practice and topographical factors from the $_{USLE}$ equation and CFRG is the coarse fragment factor. The details of the USLE factors and the descriptions of the different model components can be found in (Neitsch et al., 2005). The sediment parameters in watershed are useful in predicting the hydrology or soil erosion, but are site specific and require long-term data (Elirehema, 2001). Physically based models are based on knowledge of the fundamental processes and incorporate the laws of conservation of mass and energy (Petter, 1992).

3.5.2.2.Sediment Routing

Sediment transport in the channel network is a function of two processes, deposition and degradation; in SWAT water is route through the channels network using either the variable storage routing or Muskingum River routing methods. The detail of the water routing methods are discussed in Neitsch et al., (2005). The sediment routing model Arnold et al., (1995) that simulates the sediment transport in the channel network, consists of two components operating simultaneously: deposition and degradation. To determine the deposition and degradation processes the maximum concentration of sediment calculated by equation (37) in the reach is compared to the concentration of sediment in the reach at the beginning of the time step. The maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity and is calculated by equation **(37)**

$$conc_{sed,\,ch,\,mx} = C_{sp} . V_{ch,\,pk}{}^{spexp} \tag{37}$$

Where $conc_{sed,ch,mx}$ is the maximum concentration of sediment that can be transported by water (ton/m^3 or kg/l) , C_{sp} is a coefficient defined by the user ,$V_{ch,pk}$ is the peak channel velocity (m/s), and spexp is exponent parameter for calculating sediment reeentrained in channel sediment routing that is defined by the user. It normally varies between 1.0 and 2.0. The maximum concentration of sediment calculated by equation (38) in the reach is compared to the concentration of sediment in the reach at the beginning of the time step, $Conc_{sed,ch,i}$. If $Conc_{sed,ch,i}$,$Conc_{sed,ch,mx}$ deposition is the dominant process in the reach segment and the net amount of sediment deposited is calculated by equation (38**)** ,whereas if the $Conc_{sed,ch,i} > Conc_{sed,ch,mx}$ degradation is the dominant process in the reach segment and the net amount of sediment reentrained is calculated by equation **(38).**

$$Sed_{dep} = (con_{sed,\,ch,\,i} - conc_{sed,\,ch,\,mx}).v_{ch.} \tag{38}$$

Where, Sed_{dep} is the amount of sediment re-entrained in the reach segment (metric tons), V_{ch} is the volume of water in the reach segment (m^3). On the other hand, if $conc_{sed,ch,i} < conc_{sed,ch,mx}$ degradation is the dominant process in the reach segment and the net amount of sediment re-entrained is calculated as in equation(39).

$$Sed_{deg} = (conc_{sed,\,ch,\,mx} = conc_{sed,\,ch,\,i}).V_{ch}.k_{CH}.C_{CH} \tag{39}$$

In which Sed_{dep} is the amount of sediment deposited in the reach segment (metric tons),sed_{deg} is the amount of sediment reentrained in the reach segment (metric tons),V_{ch} is the volume of water in the reach segment (m^3), K_{CH} is the channel erodibility factor (cm/hr/pa),and C_{CH} is the channel cover factor. The final amount of sediment in the reach is determined from equation (40).

$$Sed_{ch} = Sed_{ch,\,i} - Sed_{dep} + Sed_{deg} \tag{40}$$

In which Sed_{ch} is the amount of suspended sediment in which the reach (metric tons), $Sed_{ch,i}$ is the amount of suspended sediment in the reach at the beginning of the time period (metric tons).The amount of sediment transported out of the reach is calculated by equation (41)

$$Sed_{out} = Sed_{ch} \frac{V_{out}}{V_{ch}} \quad (41)$$

In which Sed_{out} is the amount of sediment transported out of the reach (metric tons), V_{out} is the volume of out flow during the time step (m^3).

3.5.2.3.Sediment Routing In Stream Channels

Sediment routing is the function of peak flow rate and mean daily flow. When the watershed was delineated into smaller sub basin, each sub basin has at least one routing reach. Therefore, the sediment from upward sub basins is routed through these reaches. To do this, SWAT uses the simplified version of Bagnold equation (Bagnold, 1977; Neitsch et al., 2011) indicated that the maximum amount of sediment that can be transported from a reach segment is a function of the peak channel velocity.

$$Conc_{sed,\,ch,\,mx} = Csp * V_{ch,\,pk}{}^{spexp} \quad (42)$$

Where, $conc_{sed,ch,mx}$ is the maximum concentration of sediment that can be transported by water(ton/m^3or kg/L), Csp and spexp are coefficient and exponent of the equation defined by the user, and $v_{ch,pk}$ is the peak channel velocity (m/s). The exponent spexp normally varies from 1.0 and 2.0 and was set at 1.5 in the original Bagnold stream power equation (Arnold et al., 1995).

$$Vch,\,pk = \frac{q_{ch,\,pk}}{A_{ch}} \quad (43)$$

Where, $q_{ch,pk}$ is the peak flow rate(m^3/s) and A_{ch} is the cross-sectional area of flow in the channel(m^2).

$$q_{ch,\,pk} = prf * q_{ch}\ 9) \quad (44)$$

Where, prf is the peak rate adjustment factor, and q_{ch} is the average rate of flow (m^3/s).

The routing in the river starts of by comparing the maximum concentration of sediment calculated with equation of ($2kx \prec \Delta t \prec 2k(1-x$) to the concentration of sediment in the reach at the beginning of the time step, $conc_{sed,ch,i}$.

3.6.SWAT Model Input Datum

The spatially distributed data (GIS) input needed for the Arc SWAT interface include Digital Elevation Model (DEM), land use/cover data, soil and the weather (climate) data, and AVSWAT Hydro meteorological and hydrological data.

3.6.1. Spatial Input Data

3.6.1.1.Digital Elevation Model (DEM) Data

DEM is one of the inputs of the main inputs of the SWAT model and which describes the elevation of any point in a given area at a specific spatial resolution as a digital file. The data were collected from Ministry of Water, Mineral and Electricity. From a digital elevation model (DEM), the watershed will be divided into sub basin that are assigned a stream channel, or reach in SWAT terminology. It was designed to predict the impact of watershed management practices on hydrology with varying soils, land use and management conditions (Neitsch et al. 2005). Different terrain characteristics like, slope, stream length, aspect, altitude, width of channel with the watershed, were derived from DEM and used for regionalization analysis. Topography is defined by a DEM that describes the elevation of any point in given area at a specific spatial resolution 30m by 30m. These data were obtained from Geographic Information System (GIS) department of Ministry of Water, Irrigation and Electricity, Ethiopia.

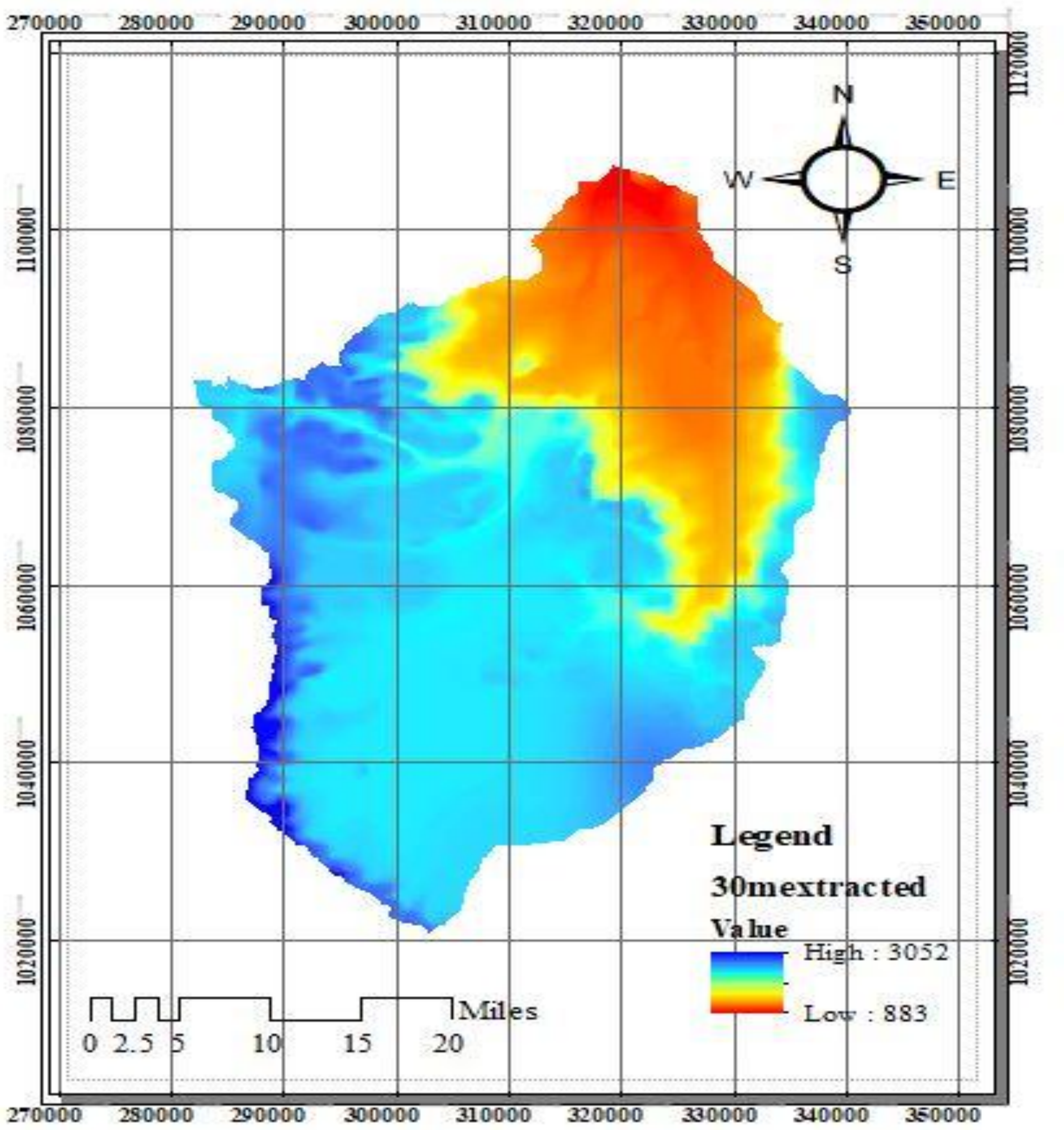

Figure 3. 5. Digital Elevation Model (meter +MSL) for Lake Fincha basin

3.6.1.2.Land Use/Land Cover Data

The land use of an area is one of the most important factors that affect surface erosion, runoff, and evapotranspiration in a watershed during simulation (Neitsch *et al*., 2005). The land use map of the study area was obtained from the Ministry of Water Resources of Ethiopia. According to (Di Luzio et al., 2002) look up table were used to link the LULC and soil data to the SWAT database and custom soil database respectively. The land use land cover classification are Water body, Grass land, and Irrigated land, Swamp, Wetland, Agricultural Land, Shrub land, Build up, Forestland.

3.6.1.3.Soil Map and Data

SWAT model requires different soil texture physical and chemical properties such as soil texture, available water content, hydraulic conductivity, bulk density, and organic carbon content for different layers of each soil type. Initially, these soil data were stored to the SWAT soil database through an editing interface and relevant information required for hydrological modeling and soil erosion modeling was provided to the mode. For this study, the soil map were defined manually and integrated by double clicking in the land use SWAT column in the SWAT land use classification. The data were obtained from Geographic Information System (GIS) department of Ministry of Water, Irrigation and Electricity, Ethiopia.

3.6.2. AVSWAT Model Input

3.6.2.1.Stream Flow Data

Daily river discharge values for Nashe Rivers were obtained from the Hydrology Department of the Ministry of Water Resources of Ethiopia and the period were 1985-2014 of the year.

3.6.2.2.Sediment Yield Data

There are no measured sediment data for the Nashe watershed; therefore, it is necessary to construct the sediment-rating curve to develop an equation between the relation of flow and sediment. The sediment yield data have been collected at Fincha station for Nashe River/stream for the year (1990-1996). The sediment-rating curve describes the average relation between discharge and suspended sediment concentration for a certain location (Asselman, 2000) and expressed as the power function of discharge.

$$Q_S = aQ^b \qquad (45)$$

Where Qs is the suspended sediment transport (M tons/day)

Q is the water discharge (m^3/s)

a and b regression coefficient and exponent respectively

The sediment rating curve was constructed using the linear least squares fit of the power and the figure (45) shows the sediment rating curve and the equation developed from the sediment rating curve described by equation (46).

$$Q_s = 22.105Q^{0.4377} \qquad (46)$$

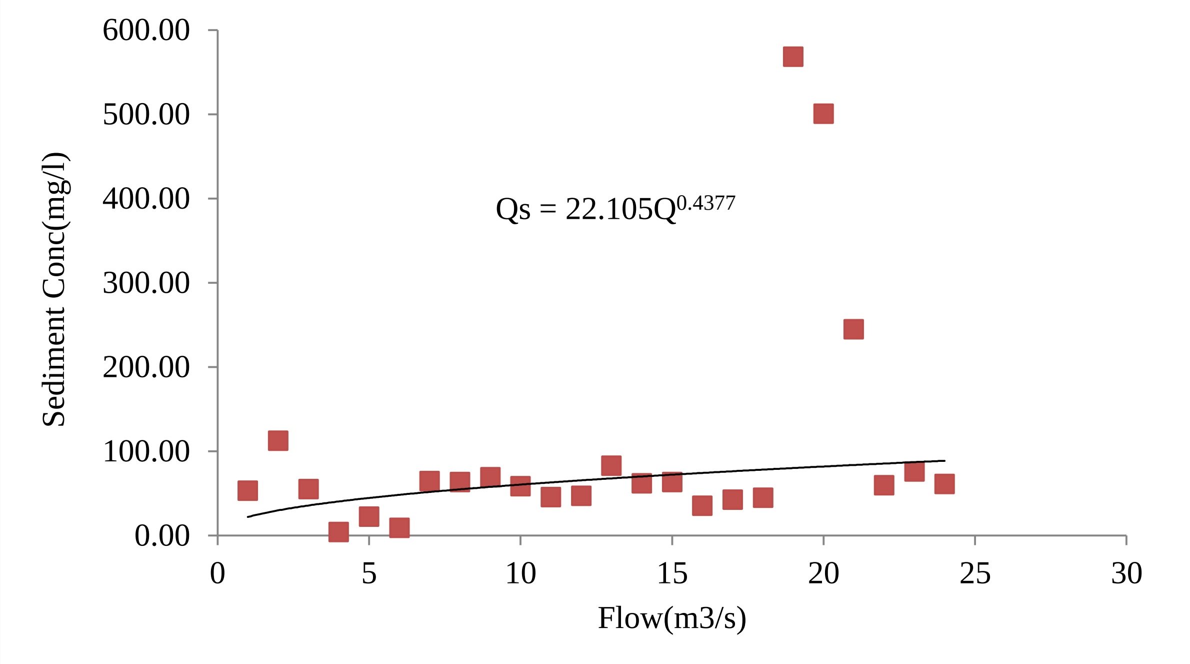

Figure 3. 6. Suspended Sediment concentration rating curve for Nashe station

3.6.2.3.Climate/Weather Data

The meteorological data elements such as daily precipitation, maximum and minimum temperature, daily wind speed, daily sunshine hours and daily relative humidity are basic climatic elements to set up the SWAT model. However, required data for this study was collected for five stations with around the study area: Nashe, Fincha, Alibo, Homi and Shambu. The SWAT requires daily precipitation, maximum, and minimum temperature, Solar radiation, wind speed, and relative humidity as input.

Anyhow, the only rainfall and temperature (maximum and minimum) data were available for all station. The other data such as relative humidity, wind speed, solar radiation were downloaded from Global weather data for Shambu. The downloaded ranges from 1985 to 2014 but for purpose of this study thirty year's data from 1985 to 2014 have been used for further analysis. The available weather data were obtained from Ethiopian National Meteorological Agency.

Table 3. 2. Location of meteorological station around watershed.

No	Station Name	Elevation (m)	Latitude	Longitude	Observation period					
					PCP	Temp	Rel.hum	Wind.sp	Solar	Flow
1	Nashe	2060	37.270	9.720	1985-2014	No data	No data	No data	No data	1963-2005
2	Alibo	2513	37.074	9.890	1985-2014	1985-2014	No data	No data	No data	No data
3	Fincha	2248	37.370	9.570	1985-2014	1985-2014	1985-2014	1985-2014	1985-2014	1985-2014
4	Shambu	2460	37.121	9.571	1985-2014	1985-2014	1985-2014	1985-2014	1985-2014	No data
5	Homi	2260	37.120	9.350	1985-2014	1985-2014	No data	No data	No data	No data

3.6.2.4.Rainfall Data

The only rainfall data were available for all station. The available data ranges from the year (1985 -2014). In general, rainfall is an observed parameter and is major hydrological input into the model. Obviously, the accuracy of the observation and computation of the areal values from the network of stations is a very important limiting and decisive factor on the reliability of the water balance computations. As discussed by Vandeweile and Elias (1995) cited by Abeyou(2008), both random and systematic errors in rainfall affect and have serious impact on the performance of water balance models.

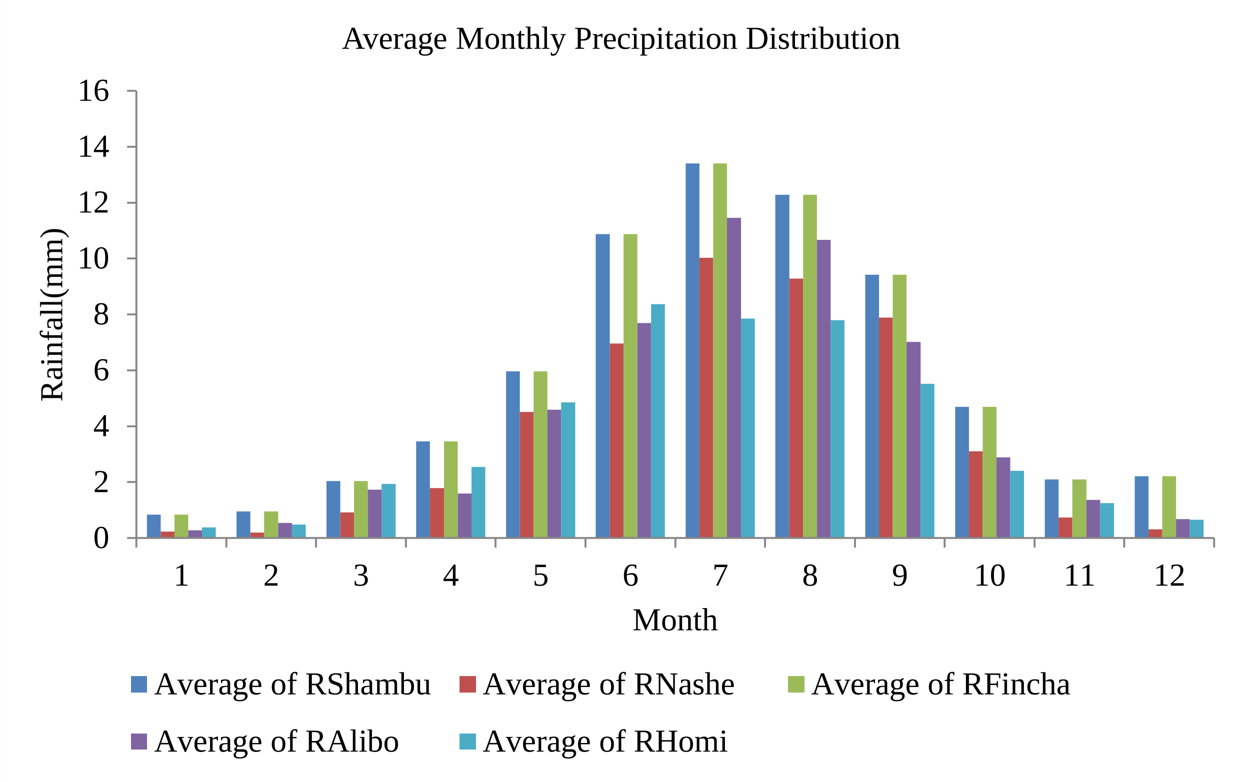

Figure 3. 7. Average monthly rainfall distribution by chart for different stations (1985-2014)

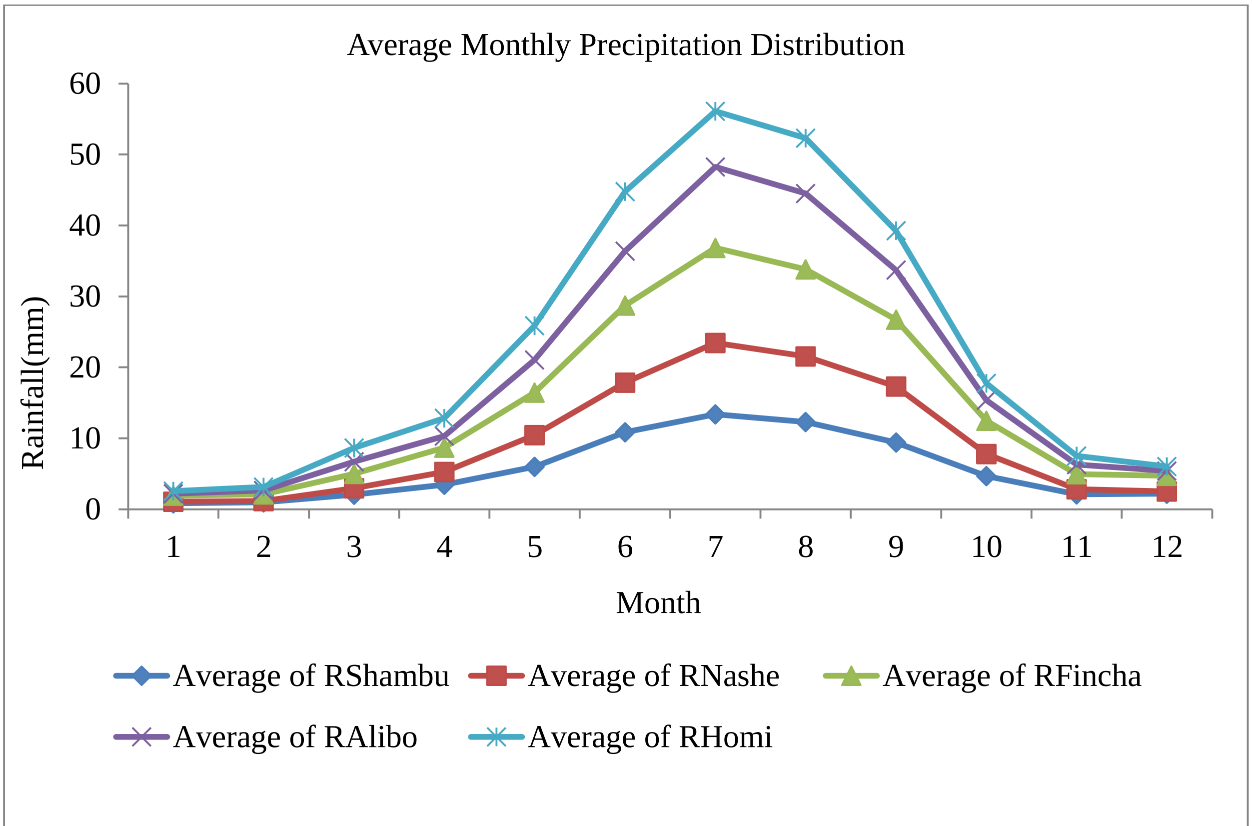

Figure 3. 8. Average monthly rainfall distribution by Graph for different stations (1985-2014)

3.6.2.5.Temperatures Data

The temperature (maximum and minimum) data were available for stations except for Nashe station. This data were ranges from 1985 to 2014 for the purpose of this research.

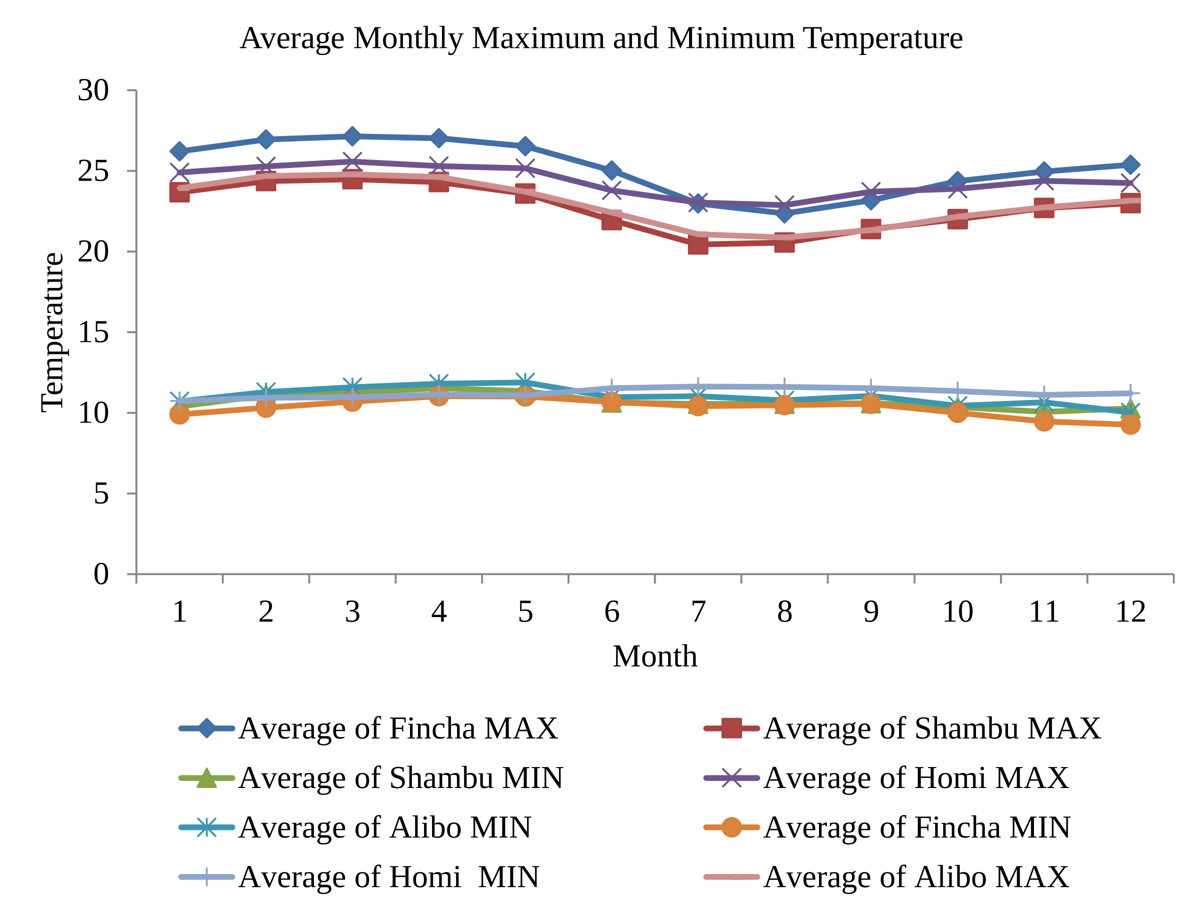

Figure 3. 9. Average monthly minimum and maximum temperature patterns of different stations (1985-2014).

The data of relative humidity were downloaded from Global weather data for Shambu. The downloaded ranges from 1985 to 2014 but for purpose of this study thirty year's data from 1985 to 2014 have been used for further analysis and the Solar Radiation data were downloaded from Global weather data for Shambu. The downloaded ranges from 1985 to 2014, but for purpose of this study thirty year's data from 1985 to 2014 have been used for further analysis.

Some of the Climate data required for this research study were collected from the National Meteorological Service Agency and the others such as wind speed were down loaded from Google internet ranges from 1985 to 2014 for Shambu station. At high elevation the temperature is the higher than the lower elevation area. Therefore, the evaporation is maximum at high elevation than lower elevation area. The Watson et al., (2008) indicates that the amount of incoming solar radiation can be heavily influenced by latitude and the orientation (slope and aspect) of the hill slopes. For this study, the used data were downloaded from Google internet were for Shambu station and ranges from 1985 to 2014 years, but for the purpose of this study thirty years data has been used for further analysis.

3.7.SWAT Input Data Preparation, Processing and Analysis.

3.7.1. General

To get a better result, it is critical to use all relevant and good quality data required. The outcome or result depends on the quality of data used. The Soil and Water Assessment Tool (SWAT) needs good quality of Digital Elevation Model (DEM), Soil, Land use and Land cover data above all other necessary data to simulate the discharge and sediment from a given watershed.

Van Liew et al., (2005) found that SWAT stream flow estimates were more accurate when using high-resolution topographic data land use/land cover data, and soil data. The required DEM data, soil data, land use /land cover data, flow data, climatic and sediment data was collected from different sources. For weather generator the necessary average precipitation value, maximum and minimum temperature, relative humidity were by dew point and average solar radiation, average wind speed, maximum half hour, and probability of wet and dry days, Skewness coefficient were determined by using PCP STAT,Dew02.exe and Pivot table. The weather generator is used either generate daily weather data or fill in missing value in the input data. The generator generates daily weather data based on monthly averages.

3.7.2. Missing Data Completion

The ability of SWAT to reproduce observed stream hydrographs is greatly improved by the use of measured precipitation data. For this study work, the weather information used was considered for a period of 1985-2014. However, the missing data is a common problem in hydrology and to perform hydrological analysis and simulation using data of long time series, by filling in missing data is very important. And, the Missing data can be completed by using linear regression method located in the nearby station, provided that the stations are located in the hydrological homogeneous regions.

Haan (2002) provided that the regression is the application of a statistical procedure for determining a relationship between variables. The same weather generator technique has been applied for filling in maximum, minimum temperature, wind speed, relative humidity and solar radiation. The variable to be determined is termed as the dependent variable while others are called the independent variables. Application of regression analysis made possible completing short and long period breaks in data series for given meteorological station.

3.7.3. Consistency of Recording Stations

Double mass curve is a simple, visual and practical method, and it is widely used in the in the study of the consistency and long-term trend test of hydro meteorological data. Before using the recorded data of station, it is necessary to first check the data for consistency. If the condition of relevant to the recording of the rain gauge station have undergone a significant change during the period of record, in consistency would arise in the rainfall data of that station. This inconsistency would be felt from the significant change took place. The checking for inconsistency of a record was done by double mass curve technique.

Double mass analysis used for checking consistency of hydrological and or meteorological record and is considered to be an essential tool before taking it for analysis purpose. The Double mass curve is a common used data analysis approach for investigating the behavior of records made of hydrological and or meteorological data at a number of locations. The accumulated totals of the gauge are compared with the corresponding totals for a representative group of nearby gauge. It is used to determine whether there is a need for corrections to the data to account for changes in data collection procedures or other local conditions.

Never the less, as all the selected stations in this study were consistent, there was no need of further correction. The graphs below Figure (3.10) shows all points set or from almost the straight lines, which was plotted for checking of consistency of rainfall, all stations were consistence to each other. Therefore, the stations did not need further adjustment. .

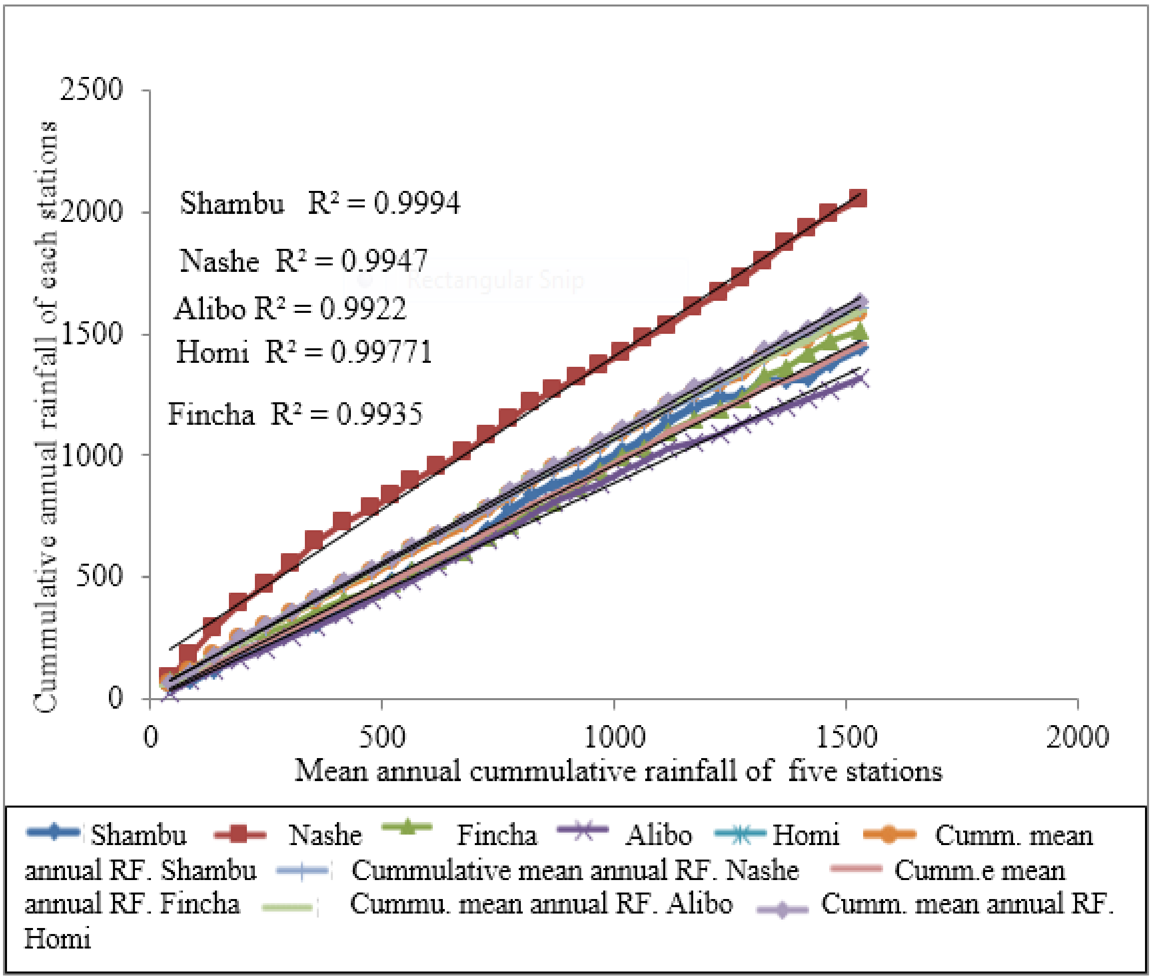

Figure 3. 10. Consistency Checking for the five rainfall stations within and around the catchment.

3.8. Model Setup

The required spatial data sets were projected to the same projection called Adindan UTM Zone 37 N, which is the transverse Mercator projection parameters for Ethiopia, using ArcGIS version 10.2.

The soil map was linked with the soil database which is a soil database designed to hold data for soils not included in the U.S. The watershed and sub watershed delineation was done using DEM data. The watershed delineation process include five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlets selection and definition and calculation of sub basin parameters. For the stream definition, the threshold based stream definition option was used to define the minimum size of the sub basin. The threshold area defines the minimum drainage area required to form the origin of a stream. Different scenarios were tested to study the effect of sub basin discretization on SWAT model performance on stream flow.

The parameter sensitivity analysis was done using the Arc SWAT interface Van Griens-ven et al., (2006) for the whole catchment. Twenty-seven hydrological parameters were tested for sensitivity analysis for the simulation of the stream flow in the study area. The details of all hydrological parameters are found in the Arc SWAT interface for SWAT user's manual (Winchell et al., 2007).

3.8.1. Watershed Delineation

After the setup of SWAT, the spatial data sets were projected Adindan UTM Zone 37N, and which the transverse Mercator projection parameter for Ethiopia is. This can be used by ArcGIS 10.2 software system which interface Arc SWAT was used for set up and parameterization of the model.

The DEM had a geographic coordination system, and converted into projected coordinate system by using Arc toolbox data box data management tool and imported in the SWAT project to start watershed delineation after sub setting of DEM. The procedure followed in the model set up were involved integrating DEM, Watershed delineation ,land use/land cover map and soil characterization, weather data to create sub basins and hydrological response unit and editing input information's and followed by creations of watersheds. The watershed delineation process consists of five major steps, DEM setup, stream definition, outlet and inlet definition, watershed outlet selection and definition and calculation of sub basin parameters.

3.8.1.1.Digital Elevation Model Set Up

Arc SWAT uses Digital Elevation Model (DEM) data to automatically delineate the watershed into several hydrological connected sub-watersheds. Burning in a stream network improves hydrological segmentation, and sub-watershed delineation. After the DEM grid was loaded and the stream networks superimposed, the DEM map grid was processed to remove the non-draining zones.

3.8.1.2.Stream Definition

The initial stream network and sub-basin outlets were defined based on drainage area threshold approach. The threshold area defines the minimum drainage area required to form the origin of a stream. The interface lists a minimum, maximum and suggested threshold area. The smaller the threshold area, the more detailed the drainage network delineated by the interface but the slower the processing time and the larger memory space required. In this study, defining of the threshold drainage area was done using the threshold value. Besides those sub-basin outlets created by the Interface, outlets were also manually added at the gauging stations where sensitivity analysis, calibration and validation tasks were later performed. Then watershed delineation activity was finalized by calculating the geomorphic sub-basin parameter.

3.8.1.3.Outlet and inlet Definition

In this study the outlet and inlet, defining was selected by using sub basin outlet and manually adding the outlet for the Nashe reservoir particularly at the dam site. The outlet of the sub basin can represents the monitoring data points and the reservoir whereas the inlets of draining watershed represent point source discharge, watershed not modeled in SWAT and the drainage inlets and sub basin watershed outlets may be added, deleted or redefined.

3.8.1.4.Watershed Outlets Selection and Definition

Is useful for comparison of measured and predicted flows and concentrations and convenient to select the downstream outlet of each target watershed to determine the whole basin. The last delineation of watershed process has been run, and when completed a message indicating successful completion displayed.

3.8.1.5.Calculation of Sub Basin Parameter

It is the final step in delineation of watershed and the calculation of sub basin parameter section contains function for calculating geomorphic characteristics of the sub basin and the step where the topography report was created, the longest path was added to the map which represent the longest flow path, and after this the reservoir along the main channel network was added by the reservoir symbol to monitoring point layer.

3.8.2. Hydraulically Response Unit (HRU) Analysis

Hydrologic response units (HRUs) are lumped land areas within the sub-basin that are comprised of unique land cover, soil, slope and management combinations. HRUs enable the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers and soils. The runoff is estimated separately for each HRU and routed to obtain the total runoff for the watershed. This increases the accuracy in flow prediction and provides a much better physical description of the water balance.

The last step in the HRU analysis was the HRU definition. The HRU distribution in this study was determined by assigning multiple HRU to each sub-watershed. In multiple HRU definition, a threshold level was used to eliminate minor land uses, soils or slope classes in each sub-basin. Land uses, soils or slope classes which cover less than the threshold level were eliminated and the area of the remaining land use, soil, or slope class was reapportioned so that 100% of the land Area in the sub-basin was modeled. The report was done and available various reports concerning the sub basin land use, soil, and slope distribution, topography and HRUs points. The watershed was divided into 17 sub basin which were further divided into hydrological response unit with the area of 168852(ha) were created within the Nashe watershed and sub basin HRU report has been generated composed of homogeneous land use, soil types and relevant hydrologic component.

3.8.2.1.Land Use /Land Cover

The land use and the soil data in a projected Grid file format were loaded into the Arc SWAT interface to determine the area and hydrologic parameters of each land-soil category simulated within each sub-watershed. The land cover classes were defined using the look up table. A look up table that identifies the letter SWAT code for the different categories of land cover/land use was prepared so as tolerate the grid values to SWAT land cover/land use classes. After the land use SWAT code assigned to all map categories, calculation of the area covered by each land use and reclassification were done.

Hence, taking the recommendations in to consideration, 5% threshold levels for the land use classes were applied, to encompass most of spatial details. Therefore, the default Land use land cover of the SWAT model was linked to land use land cover map through the look up table, which was again linked, to the land use land cover database.

The major land uses of the study area are described in shown on map figure 3.9.

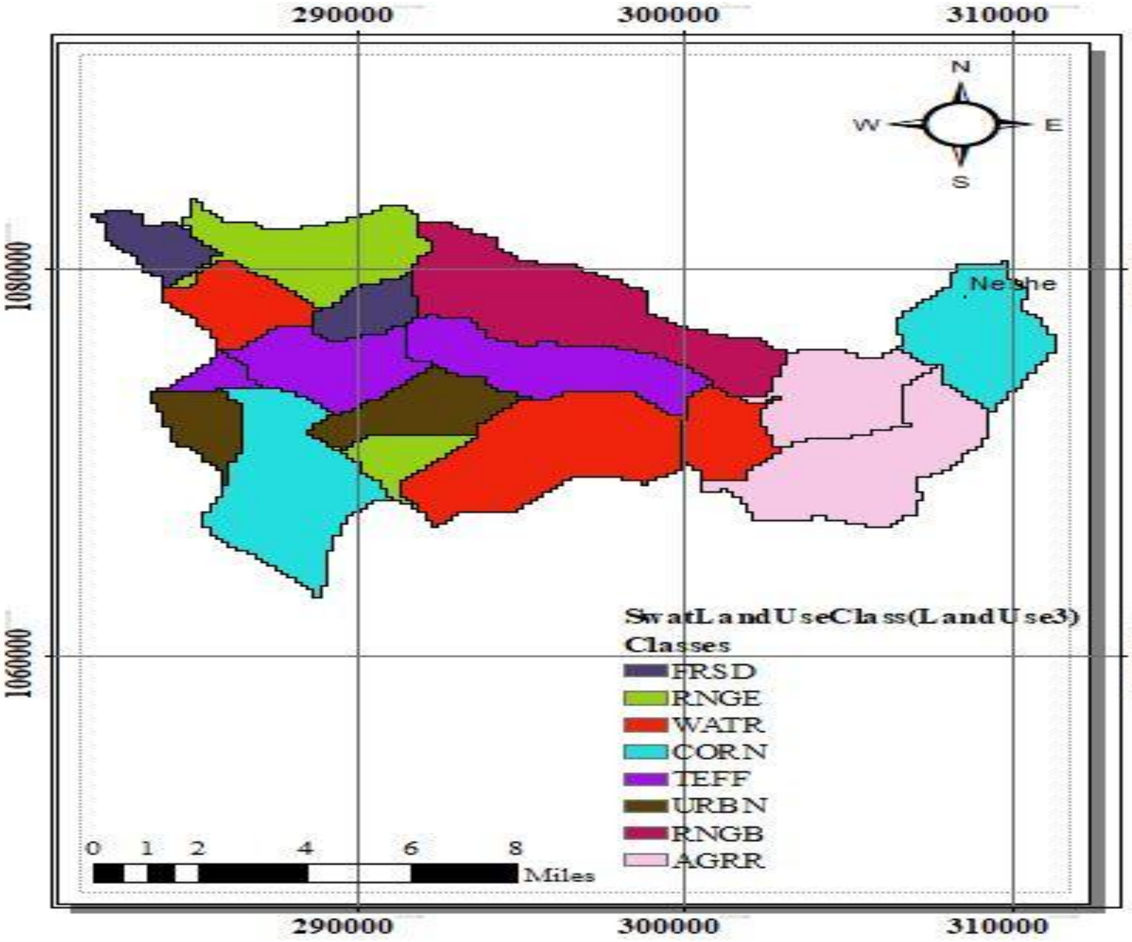

Figure 3. 11. Map of the major land use /land cover types of the Nashe Watershed.

Table 3. 3. Major land use/cover type of Nashe basin redefined according to SWAT code and aerial coverage.

Original land use	Redefined land use according to SWAT database	SWAT code	Area		
			Ha	Acres	%Watershed
Afro-alpine-Belt	Forest-Evergreen	FRSE	40672	100502.5456	24.09
Degraded savanna	Range-Grasses	RNGE	7140	17643.297	4.23
Water body	Water	WATR	13412	33141.7226	7.94
Moderately cultivated	Agricultural Land-Row Crops	AGRR	23072	57012.0656	13.66
open wood land	Forest-Mixed	FRST	30844	76217.0662	18.27
Built up-land	Residential	URBN	11708	28931.0534	6.93
Shrub land	Range-Brush	RNGB	42004	103793.9842	24.88
Total			168,852	417,241.73	100

3.8.2.2.Soil Data

As of the land use, the soil layer in the map was linked to the user soil data base information by loading the soil look-up table and reclassification applied. Hence, taking the recommendations in to consideration, 5% threshold levels for the land use, soil were applied to encompass most of spatial details. The major soil type and areal coverage of the soil types were presented in the Table 3.4 and Figure 3.12.

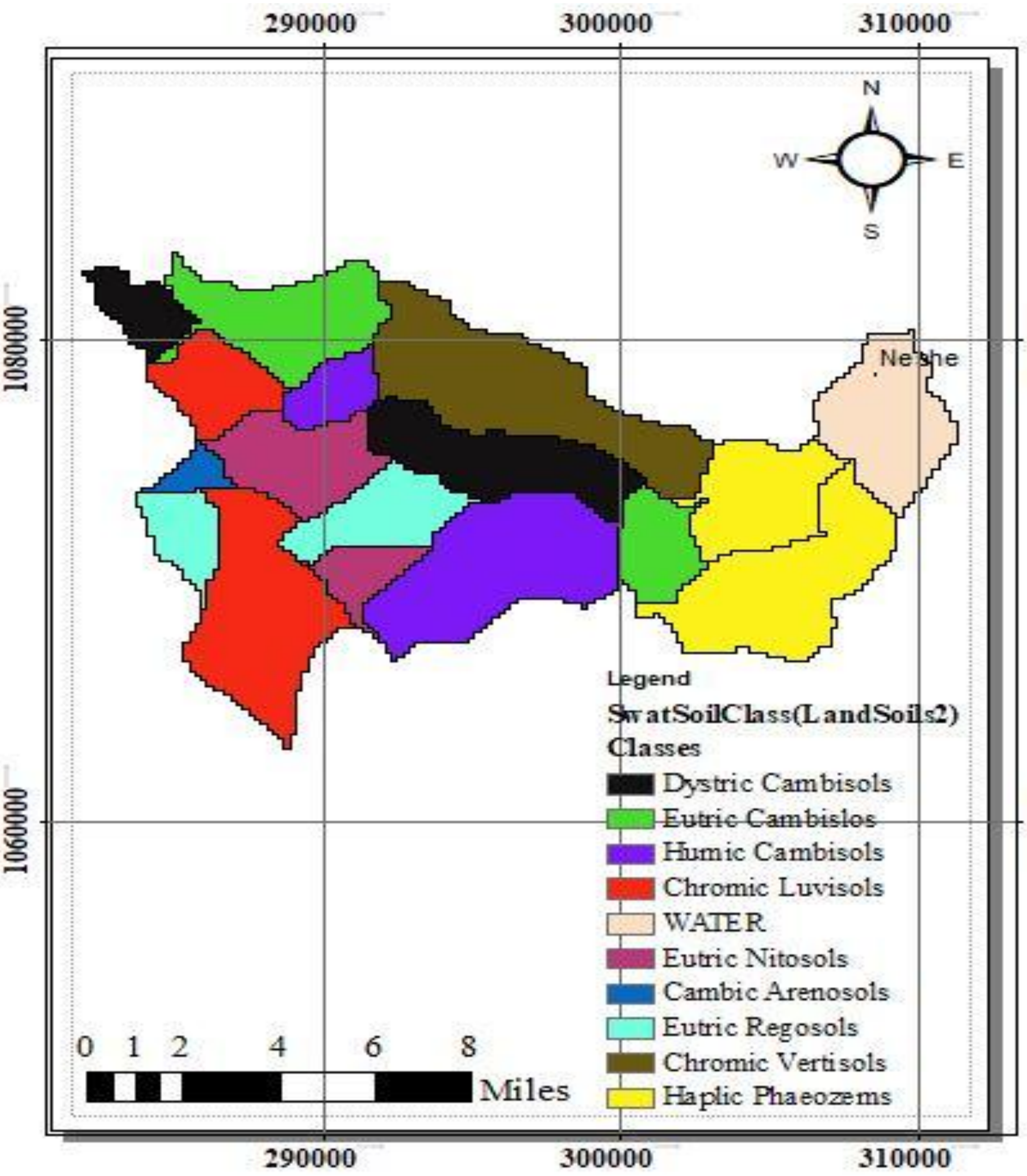

Figure 3. 12. Major soil type and coverage of Nashe Watershed.

Table 3. 4. The soil type of study area in Nashe Watershed area with their aerial coverage.

Soil types	Area		
	Ha	Acres	%Watershed
Cambic Arenosols	8720	21547.556	5.16
Chromic Luvisols	1572	3884.4906	0.93
Chromic Vertisols	28348	70049.3254	16.79
Dystric Cambisols	5980	14776.879	3.54
Eutric Cambislos	612	1512.2826	0.36
Eutric Nitosols	8900	21992.345	5.27
Eutric Regosols	23600	58316.78	13.98
Haplic Phaeozems	14632	36156.4036	8.67
Humic Cambisols	596	1472.7458	0.35
Water	75892	187532.9266	44.95
Total	168852	417241.7346	100

3.8.2.3.Slope

The DEM data used during the watershed delineation was also used for slope classification. The multiple slope discretization operation was preferred over the single slope discretization as the sub-basins have a wide range of slopes between them. Based on the suggested minimum, maximum, mean and median slope statistics of the watershed, three slope classes (0- 10, 10-20, and>20) were applied and slope grids reclassified. Then land use, Soil and slope grids were overlaid. Hence, considering the recommendations, 5% threshold levels for slope classes were applied, so as to encompass most of spatial details.

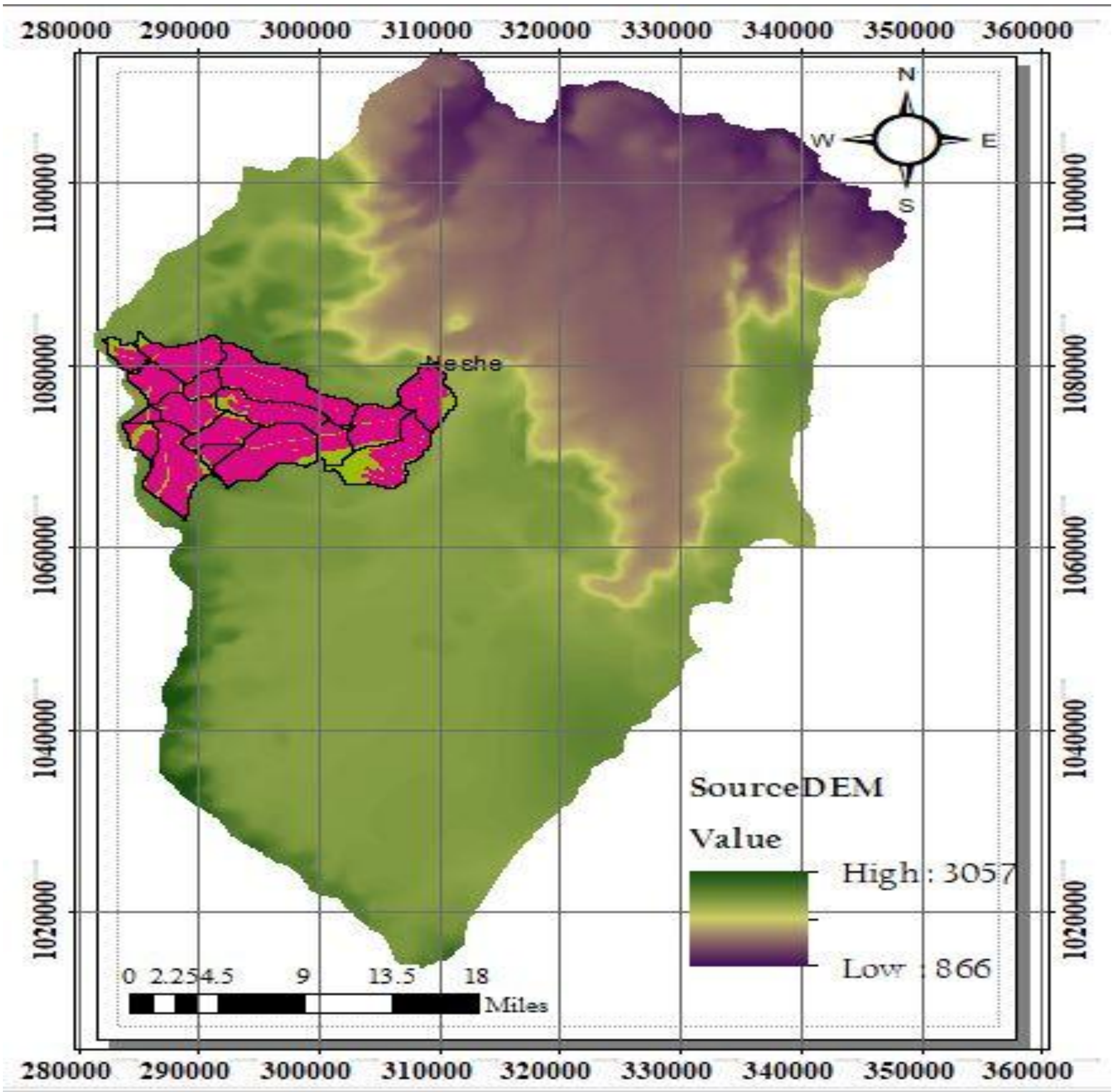

Figure 3. 13. Major slope type and coverage of Nashe Watershed.

Table 3. 5. Slope classes of the Nashe Watershed.

Classes	Slope	Land Form	Area		
			Ha	Acres	%Watershed
Classes 1	0-15	Flat or almost flat	147024	363303.66	87.07
Classes 2	15-30	Gently Sloping, Undulating plain.	16772	41444.451	9.93
Classes 3	30-9999	Steep hills, Very steep Slopes, Ridges, and Mountain.	5056	12493.629	2.99
Total			168852	417241.73	100

3.8.3. Weather Generator and Writing Input Tables

Weather generator is one of the steps used to full fill the data and realistic long period of climatic data by generating data having same statistical properties as the observed one, and

SWAT built in weather generator called WGEN that is used to fill the gaps for generating missing data. The weather data used in a watershed simulation was imported once the HRU distribution has been defined and loaded weather stations command in the write input tables menu item.

For this research file browser location was prepared in the text format, and all the weather station or weather data means weather generator data, rainfall data, temperature data, solar radiation data, wind speed data, and relative humidity data's are loaded in text format. The write command become enabled after weather data were successfully loaded and in sequence, processed only once for a project and again before the SWAT run, the initial watershed input values were defined, values were automatically based on the watershed delineation and land use, soil, slope characterization.

3.8.4. Edit Swat Inputs

The Edit SWAT input is one of the model setup steps that allows editing the SWAT model databases of the watershed, contains the files which current inputs to the SWAT model. In the watershed, if the parameters are not defined the dialog box notifies the warning.

3.8.5. SWAT Simulation

This is the final step menu allows to set up the input of model set up and the menu were running SWAT model, importing the files to the database to read the SWAT output, saving the output to the interest place. The SWAT simulations performed for the watershed were: output setups were monthly, Rainfall distribution were skewed normal, Simulation period were for thirty years (1985-2014), anyhow for the calibration and validation were separately.

3.9.Base Flow Separation.

Base flow is an important component of steam flow, which comes from ground water storage such as shallow subsurface storage, rivers, lakes, steam, etc. Base flow is ground water contribution to steam flow and during the storm even, that is not directly generated from excess rainfall. In Addition to the above, the determination of the base flow component of the stream is necessary to understand the hydrological budget of surface and ground water basins and the amount of base flow contribution to the total stream flow can be influenced by the catchment size, slope type, geology, land scape, vegetation caver, climate are the major catchment characteristic.

The automated base flow separation and recession analysis technique uses software called Base flow separation program found from the SWAT website.

3.10. Conceptual Basis of the SUFI-2 Uncertainty Analysis.

According to Abbas pour, 2007 indicated that the Sequential Uncertainty Fitting, version 2(SUFI-2) is one of the uncertainty analysis program that is incorporated in an independent program called SWAT calibration and uncertainty program. The development of SUFI-2 is developed for a combination of calibration and uncertainty analysis to find parameter uncertainty while calculating smallest possible prediction uncertainty band. Abbaspour et al., (2007) indicated that SUFI-2 parameter uncertainty accounts for all sources of uncertainty such as uncertainty in driving variables (e.g. Rainfall), parameter, conceptual model, measured data (e.g. observed flow, sediment).

The sequential uncertainty fittings are uncertainty of inputs parameters that depicted as uniform distribution and Abbas pour et al., 2007 indicates that the output model uncertainty is quantified by a p-factor which is the percentage of measured data bracketed the 95% prediction uncertainty (95PPU). The calculation at the 2.5% and 97.5% levels of the cumulative distribution of output variables obtained through Latin hypercube sampling. If the measurements are high quality data, then 80%-100% of the measured data could be bracketed by 95PPU, while a low quality data may contain outliers and it may sufficient to account only 50% of the data in the 95PPU.

The study of Abbas pour et al., 2007 indicates that the Goodness of fit and the degree to which the calibrated model accounts for the uncertainties area assessed by the above two measures.

3.11. Sensitivity Analysis

Sensitivity analysis determines the sensitivity of the input parameters by comparing the output variance due to the input variability. This is useful not only for model development, but also for model validation and reduction of uncertainty (Hamby, 1994). The sensitivity analysis is done by varying parameters value and checking how the model reacts. If small change on a given parameter value results on a remarkable change on the model output, the parameter is said to be sensitive to the model. Sensitivity analysis is the process of determining the rate of change in model output with respect to changes in model inputs parameters. It is necessary to identify key parameters and the parameter precision required for calibration (Ma et al., 2000).

According to Sorooshian *et al*., (1995) the sensitivity analysis evaluates the impact of changes in the model parameters, inputs or (initial) states on the model output of interest. It is the method of minimizing the number of parameters to be used in the Calibration step by making the use of most sensitive parameters largely controlling the behavior of the simulated process (Zeray, 2006). The background of the sensitivity analysis method is implemented in SWAT is called the Latin Hypercube One-factor-At-a-Time (LH-OAT). LH-OAT design is very useful method for SWAT modeling and Van-Griensven (2005) indicates that the Method in the Arc SWAT interface combines the Latin Hypercube (LH) and tor One-factor-at-a-time (OAT) sampling.

The local sensitivity analyses were by changing values one at a time and the global sensitivity analysis were by allowing all parameter values to change. Both analysis were may yield different results. The global sensitivity analysis is determined by calculating the multiple regression system, which regresses the Latin Hypercube generated parameters against the objective function values in the file. The disadvantage of the global sensitivity analysis is that it needs a large number of simulations. Both procedures, however, provide insight into the sensitivity of the parameters and are necessary steps in model calibration.

Table 3. 6. Sensitivity classes as per Lenhart et al., (2002)

Class	Index	Sensitivity
I	0.000<=/I<0.05	Small to negligible
II	0.05<=/I/0.2	Medium
III	0.2<=/I/<1	High
IV	/I>=1	Very high

3.12. Model Calibration and Validation

The ability of a watershed model is too accurately to predict stream flow and sediment yield is evaluated through sensitivity analysis, model calibration and model validation. The result from the simulation cannot be directly used for further analysis but instead the ability of the model to sufficiently predict the constituent stream flow and sediment yield should be evaluated through sensitivity analysis, model calibration and model validation (White and Chaubey, 2005). Ingel et al.,(2007) indicated that the impossibility to replicate watersheds and river basins, common practice in hydrological studies is to divide the measured data either temporary or spatially for calibration and validation and Gan et al.,(1997) determined that both wet and dry periods be included in both calibration and validation period.

The Setegn et al., (2010) indicates that there are several calibration and uncertainty analysis techniques common among researchers. The good calibration and validation should involve: observed data that include wet, average, dry years (Gan et al., 1997); multiple evaluation techniques (Legates and McCabe, 1999); calibrating all constituents to be evaluated; Verification that other important model outputs are reasonable.

3.12.1. Model Calibration

Model calibration is an effort to better parameterized a model to a given set of local conditions, thereby reducing the prediction of uncertainty. Van Liew et al., (2005) determines that the calibration can be accomplished by manually or using auto calibration tools in SWAT, and SWAT-CUP (Abbas pour et al., 2007). Based on the Refsgard and Storm, (1996) research, the model calibration divided in three types: the manual trial and error method, automatic or numerical parameter optimization method, and a combination of both methods. The manual calibration is the most common, time consuming, Very cumbersome; require experience, recommended in cases where good graphical representation is strongly demanded for the application of some more complicated models.

The other method of model calibration method is Automatic calibration. The automatic process can provide more objectivity and reduce the need for expertise with the particular model (Sorooshian and Gupta, 1995). However, automatic calibration methods have not yet matured to the point that they can entirely replace manual methods due to the difficulty of constructing objective functions and optimization algorithms and makes use of a numerical algorithm in the optimization of numerical objective functions. The third method makes use of combination the above two technique regardless of which comes first. Model performance is usually better during calibration than verification period, a phenomenon called model divergence (Sorooshian and Gupta, 1995) and since this default; parameters gave a good performance only manual calibration has been adopted in this research work.

In general, Abbas pour et al., (2004, 2007) indicated the Sequential Uncertainty Fitting Algorithm (SUFI-2) program were used. SWAT-CUP method was considered for calibration because in SUFI-2 both manual and automatic calibration incorporates sensitivity and uncertainty analysis. For this research 30 years historical data were used for Nashe watershed. However, the calibration was run for 17 years (1985-2001) where the first one-year 1985 is used to “Warm up” the model. Zhang et al., (2007) indicates that the importance of warm up is to simulation process that ensures the establishment of the basic flow conditions for the simulation to follow by bringing the hydrological processes to an equilibrium condition.

3.12.2. Model Validation

Validation is the other modeling method. Refsgard, (1997) indicates that, as model validation is capable of making sufficiently accurate simulation, sufficiently accurate vary based on the project goal. Once calibrations finished, Validation in SUFI-2 performed and the parameter ranges are used without further changes to simulate the validation period by editing the file observed_rch.txt, observed_hru.txt, observed_sub.txt, and observed.txt under objective function as necessary for the validation period.

In general, the measured data of stream flow of 13 years period of (2002-2014) were used for the model validation process. The graphical and statistical methods with some form of objective statistical criteria are used to determine when the model has been calibrated and validated. The flow data of Nashe with catchment area 1688.52km^2 has been selected from the period of (1985-2014).

3.13. Mode Efficiency (Performance)

The model performance must be evaluated on the extent of its accuracy, consistency, and adaptability (Goswami et al., 2005) and the simulation of stream flow, sediment yield evaluation will be using the software called SWAT-CUP. There are two types of model parameters in most models: physical parameters, and process parameters (Sorooshian and Gupta, 1995). Physical parameters represent the physical properties of the catchment and are usually measurable, such as the catchment area, surface slope etc. Process parameters represent catchment characteristics that cannot normally be measured such as the average depth of water storage capacity, coefficient of nonlinearity controlling discharge rates from component stores etc. (Sorooshian and Gupta, 1995).

The numerical model performance measures the fraction of the variation in the measured data that is replicated in the simulated model results are coefficient of regression (R^2) and Nash Sutcliffe simulation efficient (NS) (Nash and Sutcliffe, 1970). The other parameters used to evaluate the performance of the model are modified coefficient of determination %(bR^2) and percent bias PBIAS (%) which measure the average tendency of the simulated data to be larger or smaller than their observed counter parts.

The value, positive indicates a model bias toward underestimation, whereas a negative value indicates a bias toward overestimation (Gupta et al., 1999). Liew et al., (2007) indicates that, as BIAS $\prec \pm 25$ is satisfactory. The Legates and McCabe, (1999) evaluates that the R^2 ranges from 0.0 to 1.0 with higher values indicating better agreement and the values of NS ranges minus infinity to 1.0, with higher values indicating better agreement. The value of 0.0 for R^2 means that none of the variance in the measured data replicated by the model predictions and the value of 1.0 indicates that all of the variance in the measured data replicated by the model predictions.

In addition, the NS is more stringent test of performance than R^2 and is never larger than R^2. The value of 0.0 for NS means that the model predictions are just as accurate as using the measured data average to predict the measured data. The NS values less than 0.0 indicates the measured data average is better predictor of the measured data than the model predictions. The model simulation has been evaluated using efficiency criteria such as coefficient of determination, R^2 [Nash and Sutcliffe (NS), 1970], percent difference D, and root mean square error standard deviation ratio (RSR).The value R^2 calculated by the equation (47).

$$\mathbf{R2} = \frac{\sum[X_i - X_{av}]\,[Y_i - Y_{av}]}{\sqrt{\sum\,[X_i - X_{av}]^2}\ \sqrt{\sum\,[Y_i - Y_{av}]^2}} \tag{47}$$

Where, X_i – Simulated value (m^3/s),X_{av} – average measured value (m3/s),Y_i – simulated value (m^3/s) and,Y_{av} – average simulated value (m^3/s)

Nash-Sutcliffe simulation efficiency, NS, indicates the degree of fitness of the observed and simulated plots and the calculation will be as equation (48).

$$\mathbf{ENS} = \mathbf{1} - \frac{\sum(X_i - Y_i)^2}{\sum(X_i - X_{av})^2} \tag{48}$$

Where, X_i – measured value, Yi – simulated value and, X_{av} – average observed value.

The percent difference for a quantity (D) over a specified period with total day is calculated from measured and simulated values of the quantity in each model time step as shown in equation (49).

$$D = 100\left[\frac{\sum_{i=1}^{n} xav - \sum_{i=1}^{n} xi}{\sum_{i=1}^{n} xav}\right] \tag{49}$$

Where: Xi is the simulated value, Xav is measured value. A close to 0% is best for D.A negative value indicate model over estimation and a positive value indicate model under estimation. RMSE observation standard deviation ration (RSR) also another performance rating can described. The RSR standardizes RMSE using the observations standard deviation and it combines both an error index and the additional information recommended by Legates and McCabe (1999). RSR calculated as the ratio of the RMSE and standard deviation of measured data as shown in equation (50).

$$RSR = \frac{\sqrt{\left[\sum_{i=1}^{n}(Xobs - Xsim)^2\right]}}{\left[\sum_{i=1}^{n}\left(Xobs - \bar{X}obs\right)^2\right]^{1/2}} \quad (50)$$

Where: Xobs is the observed flow, Xsim is the simulated flow, $\bar{X}$ is the mean observed flow. The RSR varies from the optimal values of 0, which indicates zero RMSE or residual variation and therefore perfect model simulation, to a large positive value. The lower RSR the RMSE and the better the model simulation performance and as shown in equation (51).

Note: $NSE = 1 - (RSR)^2$ (51)

Table 3. 7. General performance rating recommended statistical for a monthly time step. (D.N.Morias et al., 2007).

Performance Rating	For the stream flow		
	RSR	NSE	%D
Very good	0<=RSR<=0.5	0.75<NSE<=1	D<=±10
Good	0.5<RSR<=0.6	0.65<=NSE<=0.75	±10<=D<±15
Satisfactory	0.6<RSR<=0.7	0.5<NSE<=0.65	±15<=D<±25
Unsatisfactory	RSR>=0.7	NSE<=0.5	D>=±25

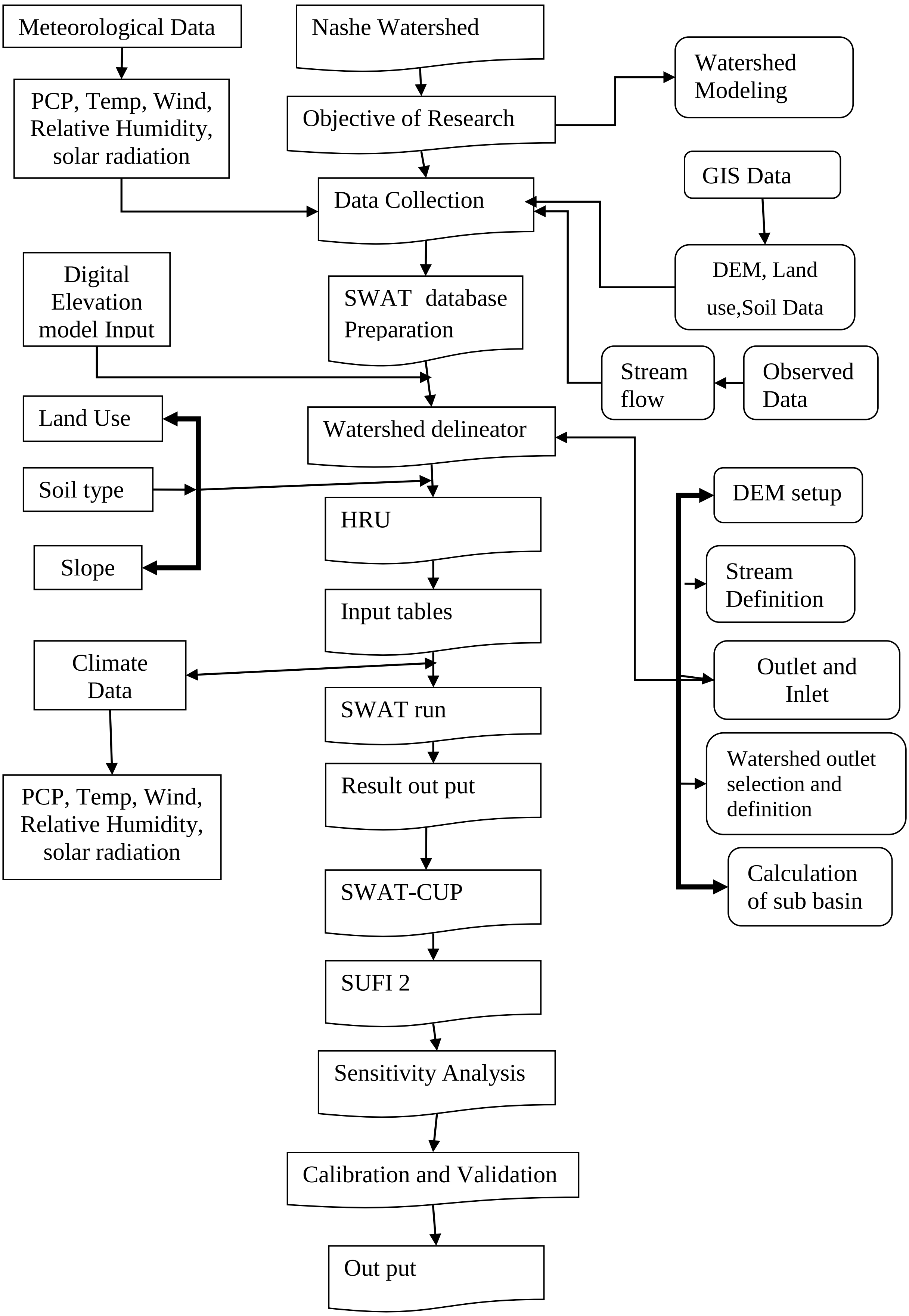

Figure 3. 14. Arch SWAT Processing steps and Data required for Water Modeling.

CHAPTER FOUR

4. RESULTS AND DISCUSSIONS

4.1. General

4.2. Sensitivity Analysis

A complex hydrological model is generally characterized by a multiple of parameter (Holvoet et al., 2005). Calibration of the most sensitivity parameters where selected before applying SUFI-2 by running the sensitivity analysis. By over parameterization (Van Griensven, et al., 2006) the identification of sensitivity parameters will avoid the problems and Latin hypercube simulation, the one at-a-time (LH-OAT) used to find sensitivity parameters. The total 27 parameters were considered for the model of parameterization sensitivity analysis; only ten of them were effective for monthly flow simulation analysis. The Nashe catchment have been considered for the model parameterization and calibration process used for the model were depicted in table 4.1 with their maximum, minimum and fitted value.

In general, the current version of SWAT model, SWAT 2012, provides the algorithmic techniques of for sensitivity analysis. Two types of sensitivity analysis are allowed when using SUFI2 (Sequential uncertainty fitting version 2). The Global Sensitivity and One-at-a time sensitivity analysis. The local and global sensitivity analysis were performed and the ranking of the parameters in both cases compared. These sensitivity parameters were mostly responsible for the model calibration and parameters change during model iteration model process.

4.2.1. Local (One –At-A-Time) Sensitivity Analysis.

The one-at-a-time (OAT) sensitivity analysis is performed for one parameter at a time only by keeping the value of other parameter constant. The OAT sensitivity analysis shows the sensitivity of a variable to change in a parameter if all parameters are kept constant at some reasonable value. The objective function used in the project for ranking of the parameters based on the OAT sensitivity analysis was the sum of the square of the difference of the simulated and measured value after ranking (SSQR). The SSQR method aims at the fitting of the frequency distribution of the observed and simulated series (Abbaspour, 2013). After independent ranking of the measured and simulated values, the new pairs are formed and the SSQR is calculated as:-

Minimize: $$SSQR = \frac{1}{n}\sum_{j=1}^{n}\left[Q_{j,m} - Q_{j,s}\right]^2 \quad (52)$$

Where, Q_m and Q_S are the measured and simulated value respectively.

Table 4. 1. The Best parameters of sensitivity analysis of flow Nashe Watershed (Result Maximum, Minimum and fitted value using SUFI-2).

No	Parameter Name	Fitted value	Minimum Value	Maximum Value
1	CN2	-0.03	-0.20	0.20
2	ALPHA_BF	0.10	0.000	1.00
3	GW_DELAY	36.30	30.00	450.00
4	GWQMN	1.13	0.00	2.00
5	GW_REVAP	0.20	0.00	0.20
6	ESCO	0.91	0.80	1.00
7	CH_K2	106.88	5.00	130.00
8	ALPHA_BNK	0.79	0.00	1.00
9	SOL_AWC	0.21	-0.20	0.40
10	SOL_K	0.20	-0.80	0.80

4.2.2. The Global Sensitivity Analysis

The Global sensitivity analysis performs the sensitivity of one parameters while the values of other related parameter are also changing. The Global Sensitivity analysis uses t-test and p-values to determine the sensitivity of each parameter. The t-stat provides a measure of the sensitivity (Large in absolute value are more sensitive) and p-value determine the significance of the sensitivity. A p-value close to zero has more significance. This type of sensitivity can be performed after iteration. The main problem related global sensitivity analysis is that it needs a large number of simulations (Abbaspour, 2013).

Table 4.2. Global sensitivity analysis performed after iteration.

No	Parameter Name	Parameter Description	t-stat	P-value	Rank
1	CN2	SCC runoff curve number	5.67	1.86	1
2	SOL_AWC	Available water content of soil	-0.36	0.712	7
3	SOL_K	Saturated hydraulic Conductivity	0.15	0.88	10
4	ALPHA_BF	Base flow alpha Factor	0.42	0.678	6
5	GW_DELAY	Ground water delay	-1.834	0.07	2
6	GWQMN	Threshold depth of water in the Shallow well aquifer for return flow to occur	0.54	0.59	5
7	GW_REVAP	Ground water revap coefficient	0.26	0.79	9
8	ESCO	Plant uptake compensation Factor	0.30	0.76	8
9	CH_K2	Effective hydraulic conductivity in the main channel alluvium	1.02	0.31	4
10	ALPHA_BNK	Base flow alpha factor for bank storage	1.18	0.24	3

In the table 4.2, the rank for each parameter is assigned depending on the p-value and t-stat. Here, stat provide a measure of sensitivity and hence larger in absolute values are more sensitive. On the other hand, the p-value indicates the significance of the sensitivity and hence a value close to zero has more significance. Therefore, ranking in both cases (t-stat and p-value) gives the same result i.e. Parameter will have the same rank whether it is ranked based on the t-stat and p-value.

4.3. Stream Flow Calibration and Validation in Nashe Catchments

4.3.1. Stream Flow Calibration

The stream flow comparison has been done between the observed and simulated discharge values for 17 years' time steps during (1985-2001) on the monthly basis. Initially one year of the flow during 1985 was taken as the warming period and the rest of the period was used for the model calibration. The model was calibrated using the ten of the parameters, which were recorded as the most sensitive parameter was used for the stream flow measurement.

The coefficient of determination R^2 and the Nash-Sutcliffe equation has been applied for model testing between simulated and observed flows and calculated on the monthly basis was 0.81 and 0.80 respectively. The degree to which all uncertainty are accounted for is qualified by a measure referred to as the p-factor, which is the percentage measured data bracketed by the 95% prediction uncertainty (95PPU) and uncertainty has been calculated as 0.87. Additionally, the strength of the model calibration and uncertainty procedure has been analyzed using the R-factor. The R-factor shows the average thicknesses of 95PPU band divided by the standard deviation of the observed data and have been calculated as 0.69.

The time series data of the observed and simulated flows on monthly basis were plotted for visual comparison to explore the similarity within the peak values resulting from the procedures of SUFI-2 and the scatter plot of monthly stream flow showing a well –fitting relationship of the observed and simulated values for calibration shown in figure 4.1.

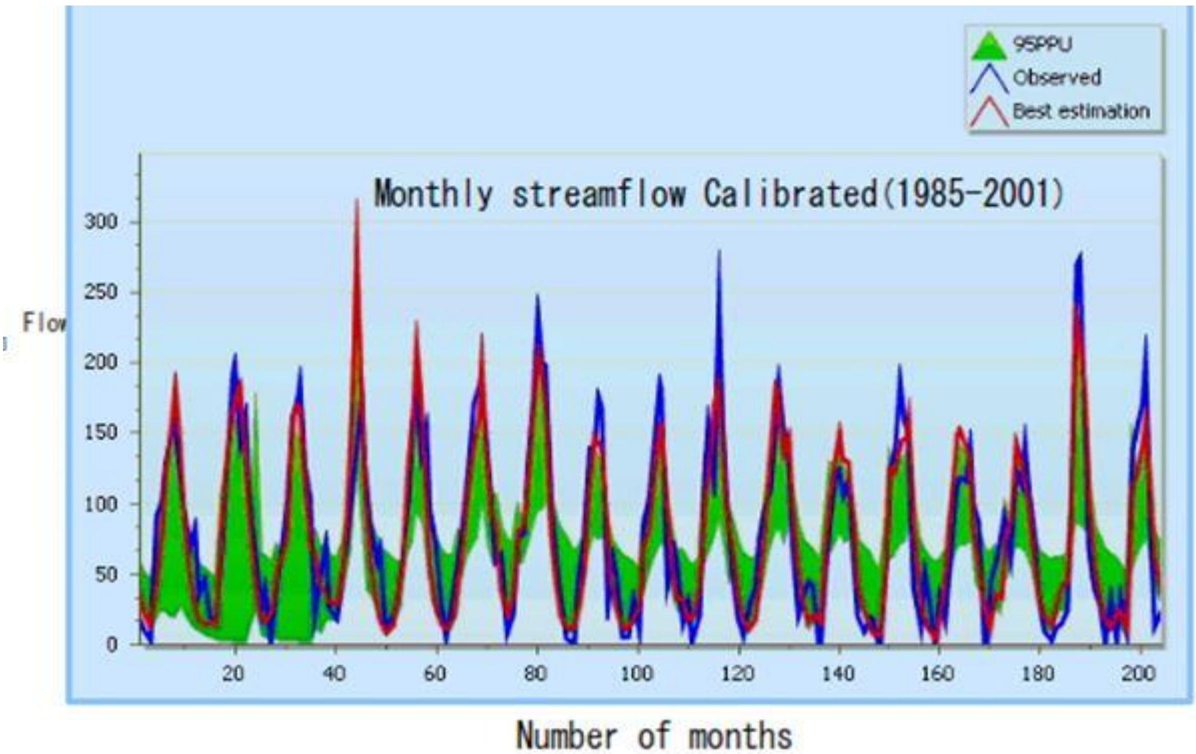

Figure 4.1. Monthly Stream flow Calibration result of Nashe using SUFI-2 Software for the period of (1985-2001).

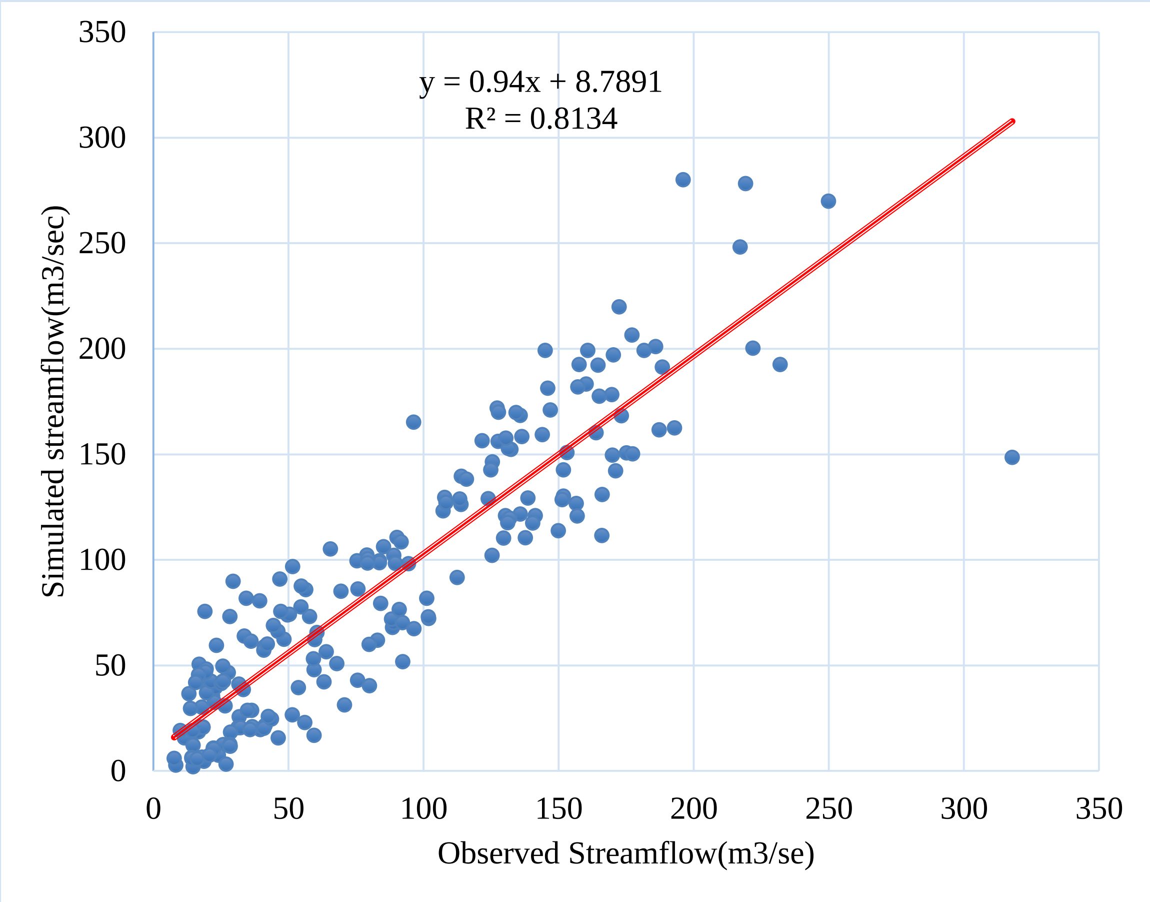

Figure 4.2. Scatter plot of Observed Stream flow during Calibration period (1985-2001).

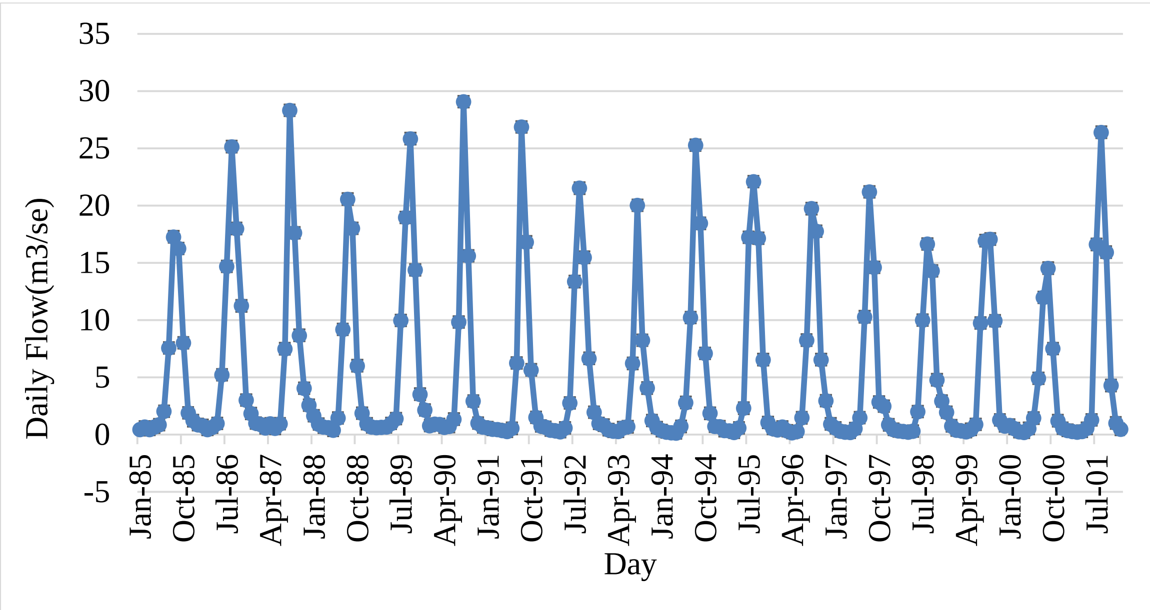

Figure 4.3. Daily Stream flow Calibration during period of (1985-2001).

4.3.2. Stream Flow Validation.

Calibration parameters were validated for the period of 13 years (2002-2014) from which one year was taken as warm up period. Validation proves the performance of the model for simulated lows in the periods different from the calibration periods, but without any further adjustment in the calibrated parameters. Validation was performed for 13 years from January 1, 2002 to December 2014.

The correlation coefficient ($R^2 = 0.84$) and the Nash-Sutcliffe ($NS = 0.74$) shows a good agreement between the observed and simulated values. The time series data of the observed and simulated flows on monthly basis were plotted for visual comparison to explore the similarity within the peak values resulting from the procedures of SUFI-2 (Figure 4.4) and the scatterplot showing the observed and simulated values for validation was shown in figure 4.5.

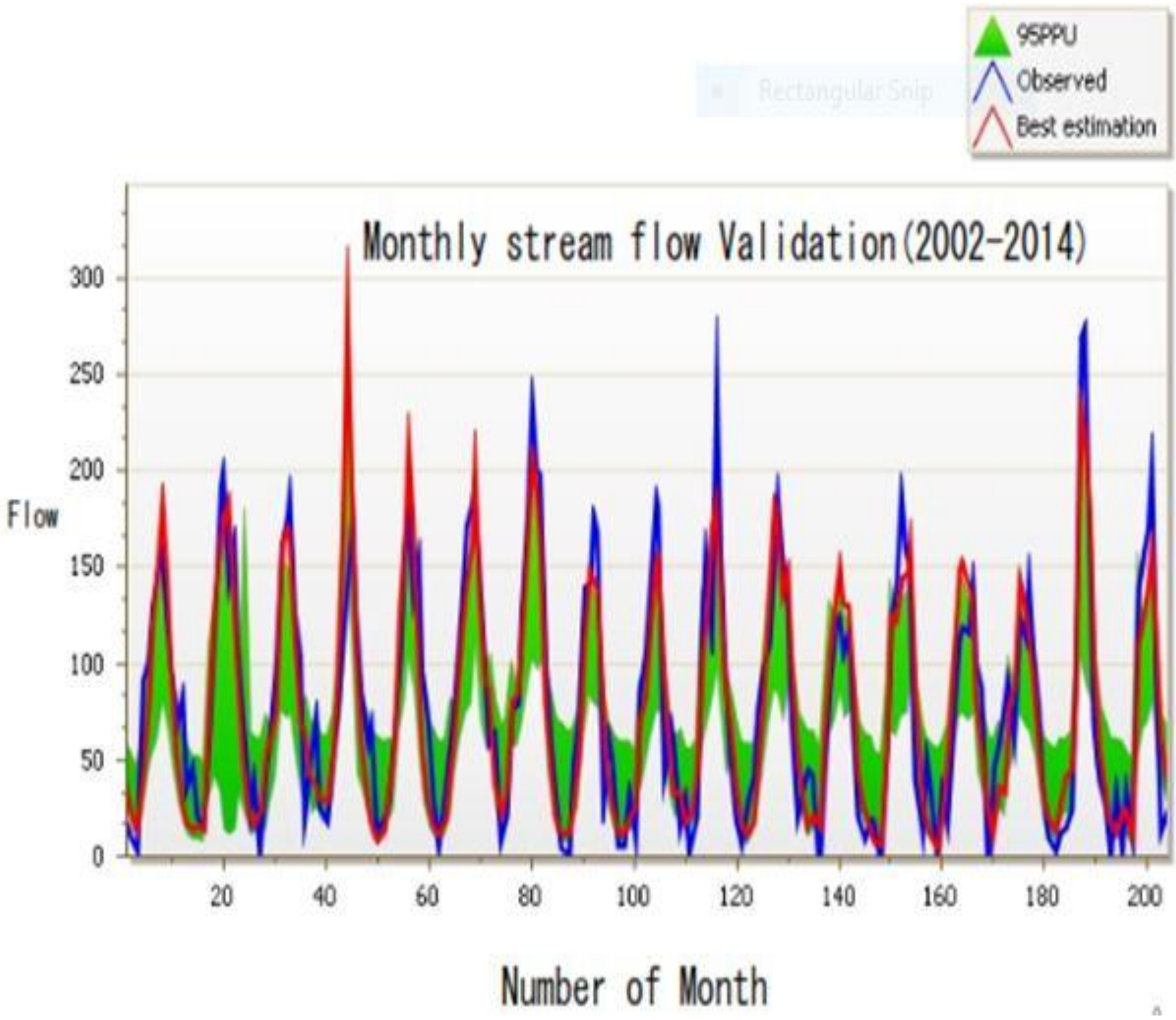

Figure 4.4. Monthly Stream flow Validation result of Nashe using SUFI-2 Software for the period of (2002-2014).

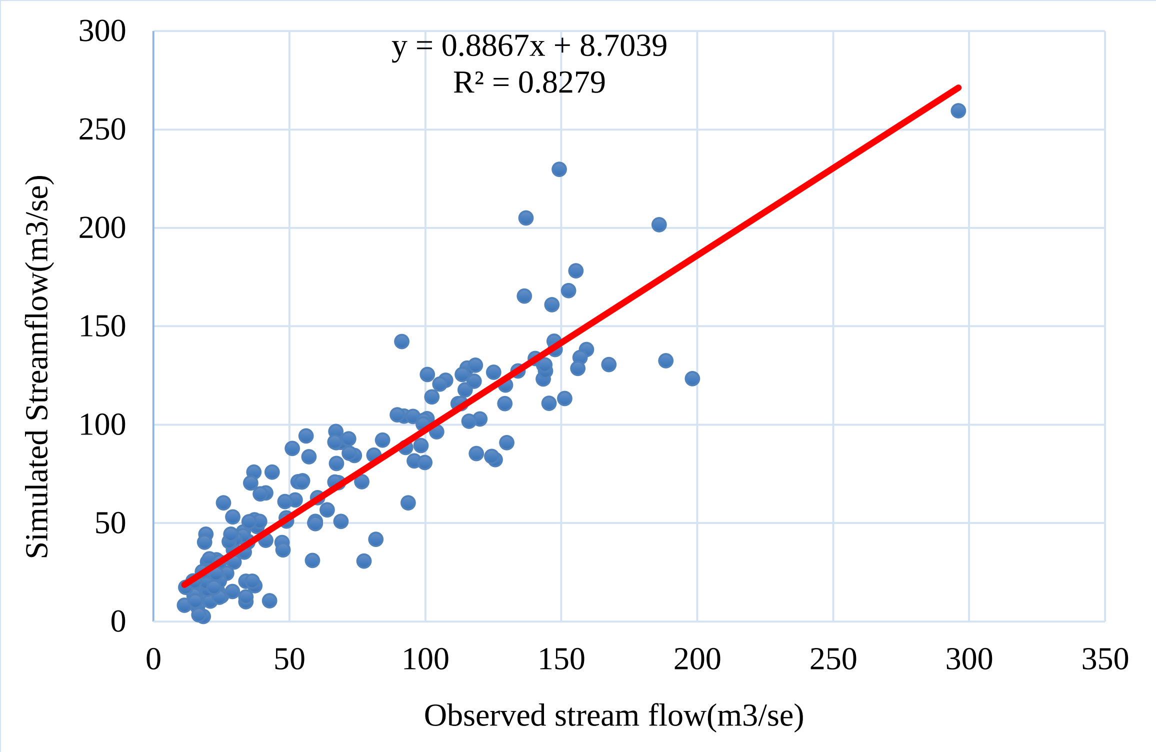

Figure 4.5. Scatter plot of Observed and Simulated Stream flow during Validation period (2002-2014).

However, the general result of flow calibration and Validation results on monthly basis obtained from SWAT-CUP, SUFI-2 were shown in table 4.3.

Table 4.3. The calibration and Validation of stream flow result on monthly basis (model evaluation performance results).

Variable		Calibration(1985-2001)	Validation(2002-2014)
p-factor		0.65	0.87
r-factor		0.94	1.15
R^2		0.81	0.84
NS		0.8	0.74
bR^2		0.71	0.75
PBIAS		4.3	3.8
Average monthly flow(m3/se)	Measured	12.44	11.08
	Simulated	14.96	12.85

4.4. Estimation of total inflow to Nashe

The hydrological model plays an important role in planning and management of water resources. In the lake Nashe basin, most of the river are flowing into lake are not gauged and the water yield from ungauged part of the basin has not quantified properly and not included in this research. In order to quantify the runoff contribution from gauged catchment, and to study hydrological process the SWAT hydrological model has been applied. Due to this research specific objective limitation the only gauged inflow were considered. Hence, as it was indicated in the description of the study area is of the total area is from gauged station only, and again the estimation of runoff from this huge percentage area is very crucial for current and future water resources development project.

4.5. Hydrological and Sediment Yield Modeling

4.5.1. Hydrological Modeling in Nashe Basin, Ethiopia Using SWAT Model

The analysis of HRU definition indicated that multiple scenarios that accounts for 10 % land use, 20 % soil and 10 % slope threshold combination give a better estimation of stream flow in the Nashe Basin. The watershed was divided into 17 sub basin which were further divided into hydrological response unit with the area overlaid of land use, Soil, Slope area were 168852(ha) were created within the Nashe watershed and sub basin HRU report has been generated composed of homogeneous land use, soil types and relevant hydrologic component.

The calibration process using SUFI 2 algorithm give the final fitted parameter. The final values for CN2, Soil_AWC include the amount adjusted during the manual calibration. These parameters were incorporated into the SWAT 2012 model for validation and further applications. The surface runoff estimated annual precipitation falling on the lake is 1578.8 mm, and the evapotranspiration loss from the Lake is about 376.0 mm, the potential Evapotranspiration 910.6mm, the Total water yield estimated 1173.26 mm, the total aquifer recharge 837.89 mm, percolation out of soil estimated were 848.43 mm, the Groundwater (Shallow aquifer) estimated 795.98 mm, the revap (shallow aquifer-soil/plants) 5.83mm, the estimated deep aquifer recharge 41.89mm.

The Calibration and Validation of the observed and simulated discharges for the station during the station during the period (1985-2001) and (2002-2014).respectively.

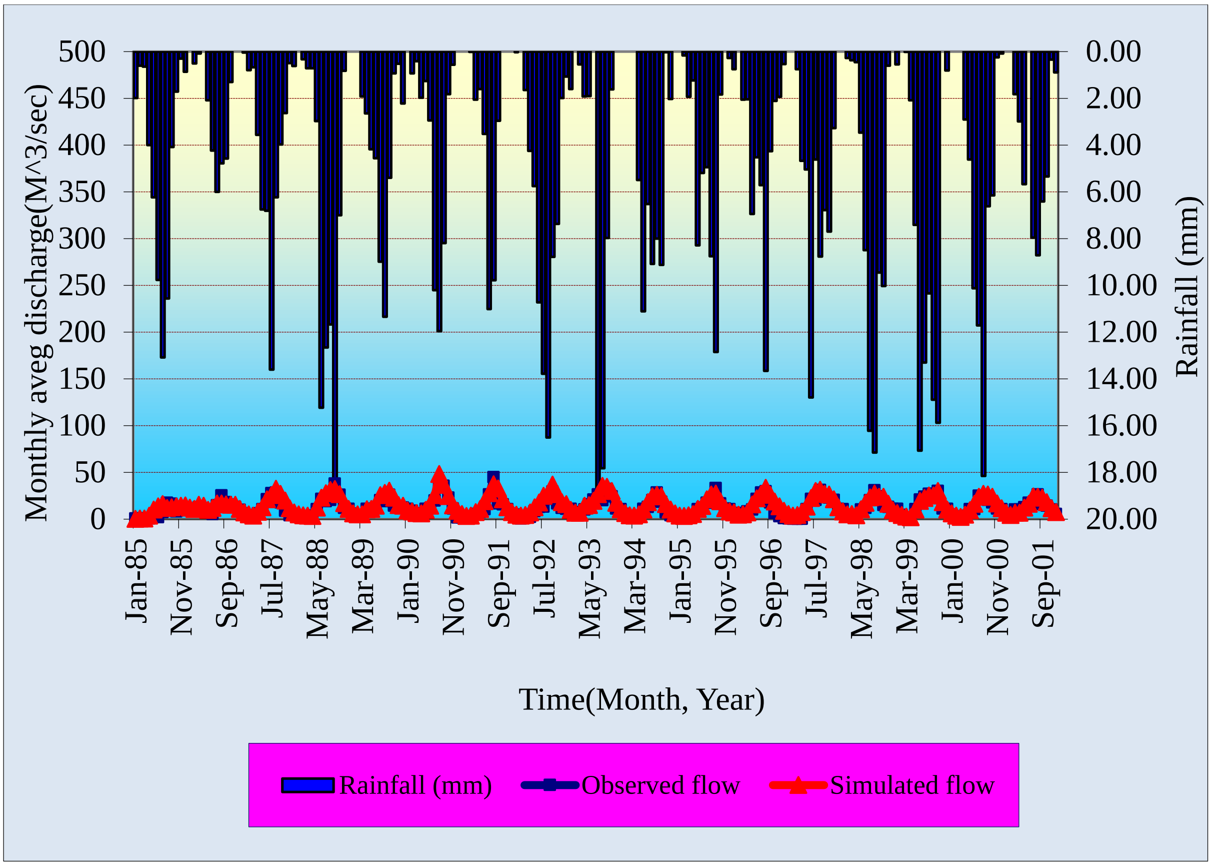

Figure 4.6. Calibration of Observed and Simulated Stream flow hydrograph of gauged Nashe River Period (1985-2001).

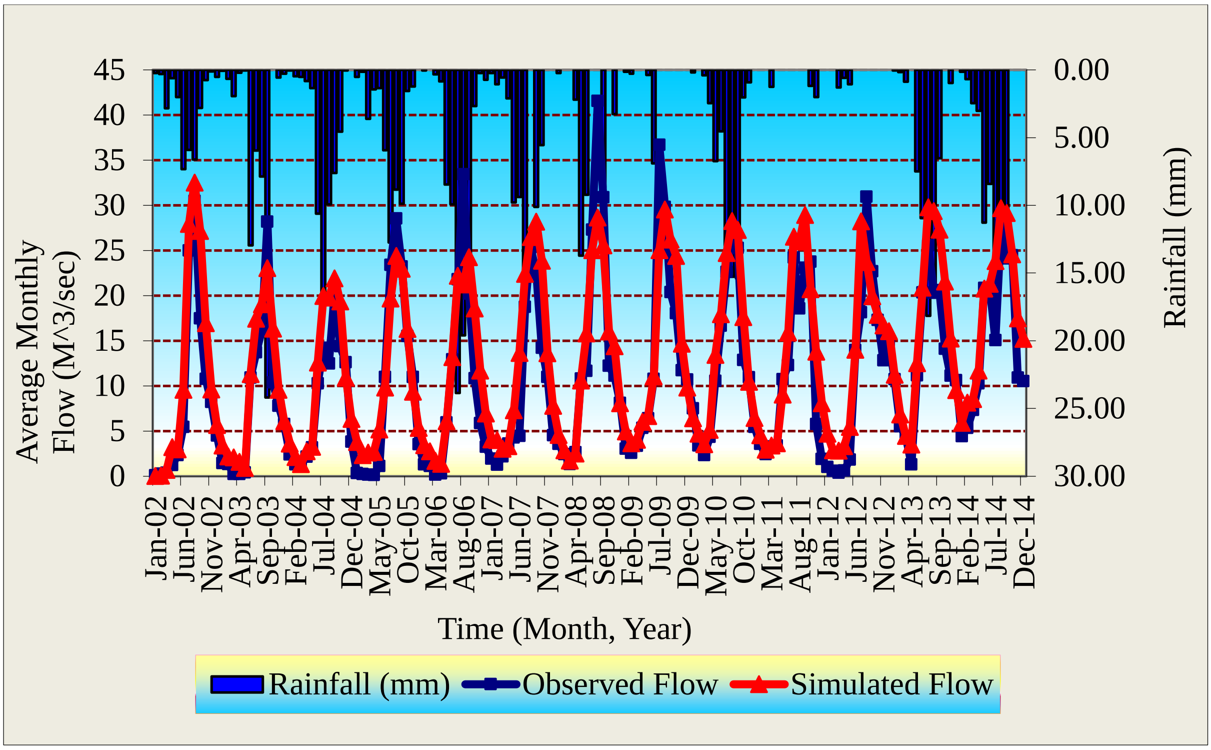

Figure 4.7. Validation of Observed and Simulated Stream flow hydrograph of gauged Nashe River Period (2002-2014).

4.5.2. Sediment Yield Modeling From Nashe Gauged Watershed, Using SWAT

There are limited sediment data in Ethiopia to do large scale calibration and validation of watershed models for sediment yield. The Average annual total sediment yield in the outlet of the watershed was 52.258 tons per hectare.

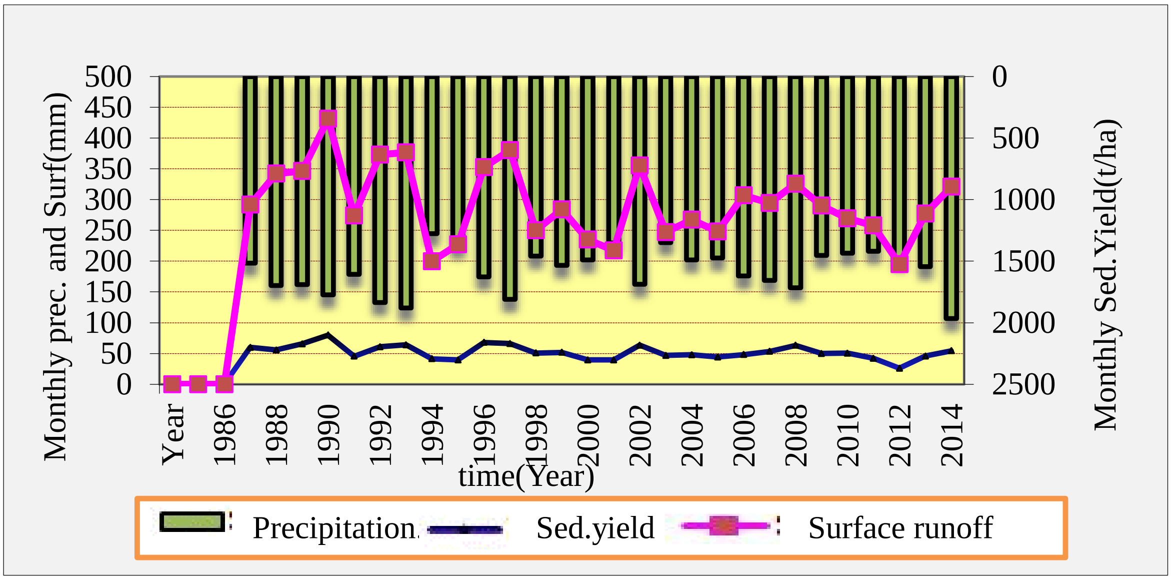

Figure 4.8. The yearly precipitation, surface runoff and sediment yield of the Nashe catchment.

The estimated sediment yield is a function of the surface runoff and peak rate of runoff. The sediment yield has direct relation with the rainfall and stream flow. Figure 4.9 shows mean yearly precipitation, catchment discharge and suspended sediment yield. Rainfall and runoff are responsible factors for the detachment, transport and deposition of sediment particles.

4.6. Water Balance Analysis of Nashe Watershed Components

The water balance component of the lake Nashe includes the direct rainfall over the lake surface(P), inflow from main rivers and streams(Q_{inflow}), surface runoff inflow from unmonitored sub-watershed(Q_{surq}), outflow from the lake (O_{utflow}), Lake evaporation(E_L),change in water balance (unidentified loss)(Δ S). We can assume the following water balance equation to the lake (Equation 53).

$$p + \sum Q_{\inf low} + Q_{surq} = \sum Qoutflow + E_L + \Delta S \qquad (53)$$

The prediction of lake water balance is based on the simulation result from 1985 to 2001. The estimated annual precipitation falling on the lake is 210.19 mm/year and the evaporation loss from the lake is 383.78 mm/year. The estimation of inflow 1239.07 mm/year and Outflow 1209.82mm/year water fluxes, in billion cubic meters and percentage with respect to the total water inputs to the lake, are indicated in table 4.4 Components such as ground water loss or recharge are difficult to estimate. The analysis of lake water balance has shown that there is annual surplus of -144.34 mm/year or -726.07MCM / year of water.

Based on the water balance components the change in storage is calculated by using an initial value of storage for the program. After that, the change in storage is converted to the lake level and the lake area. The lake area is used for computation of the volume of lake precipitation and lake evaporation for the next step using the daily-observed data. In such away, the lake level is computed with iteration for a series of time steps.

$$V_{lake(i)} = V_{lake(i-1)} + \Delta S_{(i)} \qquad (54)$$

Where: $V_{lake\ (i)}$, lake total volume at day i, $Vlake_{(i-1),}$ lake total volume at day i-1 and ΔS(i), change in storage at day i.

Water balance models are consistent with saturation excess runoff process because the runoff is related to the available watershed storage capacity and the amount of precipitation. The implementation of water balances into runoff calculations in the basin is not a novel concept and often performs better (as did our results) than more complicated models in Ethiopia type landscapes (Johnson and Curtis, 1994; Conway, 2000; Ayenew and Gebre egziabher, 2006; and Liu et al., 2007). The annual basin of Nashe water balance components for the period of 1985-2014 where shown on table 4.4. The total water yield value is the sum of (surface runoff, lateral flow, Ground water flow and subtraction of Transmission flow).

Table 4.4. The Annual Monthly water balance Values component of Nashe River.

Month	Rainfall(MM)	Surf Runoff (MM)	Lateral Flow (MM)	Water Yield(MM)	ET(MM)	PET(MM
1	12.25	1.17	0.34	69.23	17.93	73.22
2	17.88	1.07	0.45	56.84	18.49	74.32
3	52.19	5.06	1.17	61.85	26.17	83.25
4	79.86	12.23	1.8	64.61	31.26	82.08
5	180.34	34.5	4.17	91.85	41.36	85.7
6	254.58	46.4	6.47	110.55	40.83	71.84
7	323.53	71.82	8.47	153.32	32.99	54.18
8	295.05	61.46	7.99	154.44	41.27	70.32
9	216.06	37.98	6.03	133.41	47.27	86.27
10	86.59	15.62	2.67	109.76	33.87	84.8
11	34.08	4.01	1.03	86.59	23.71	72.88
12	26.23	2.9	0.76	80.31	20.82	71.12

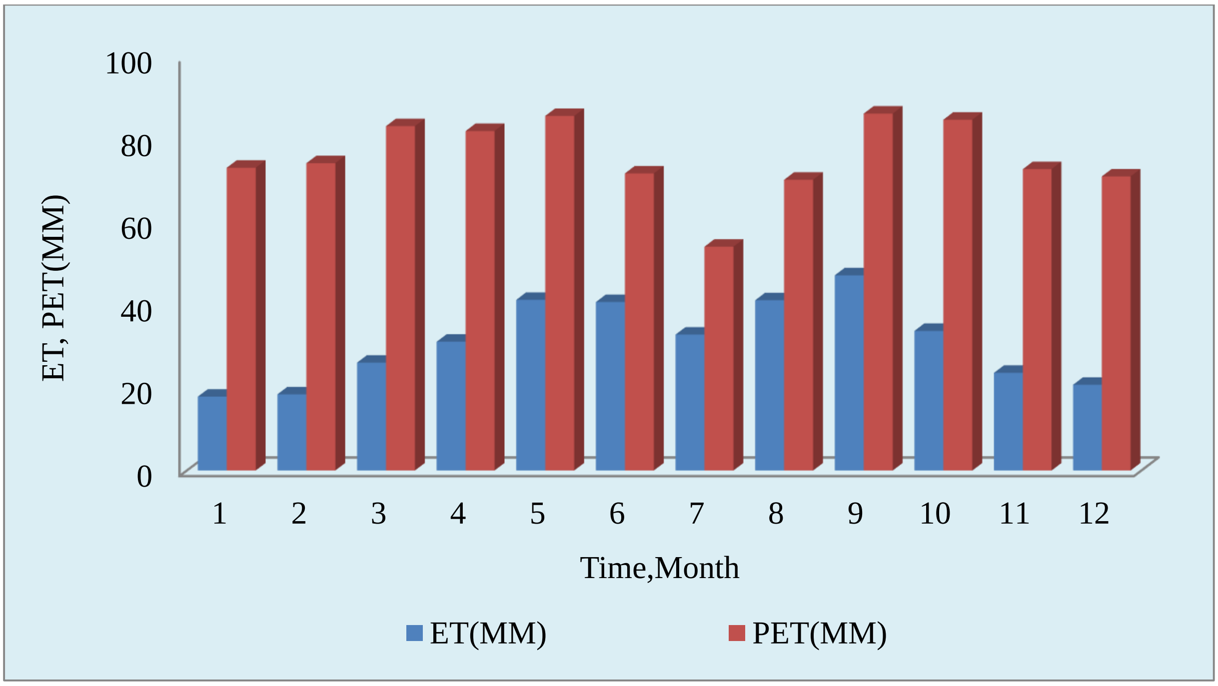

Figure 4.9. The Monthly average Evapotranspiration and Potential Evapotranspiration of Nashe gauged catchment period of (1985-2014).

4.6.1. *Inflow of Hydrograph*

Inflow series of gauged catchments were estimated during calibration in previous section. Once the model is calibrated and verified at the gauged location the model output during that period were quantified and taken as simulated inflow series. Later this inflow series will be used for water balance analysis.

Similarly, the inflow series for ungauged catchments can be transferred by calibrating parameters having the same HRUs as gauged catchments. The total inflow in to the Lake mouth was determined after having the inflow from gauged catchments and inflow from ungauged catchments separately and later the total inflow was taken as the aggregate of inflow series from gauged and ungauged catchments. However, the General and specific objective of this research were based on only gauged catchments. So, the detail inflow series of the model were only from Gauged catchment.

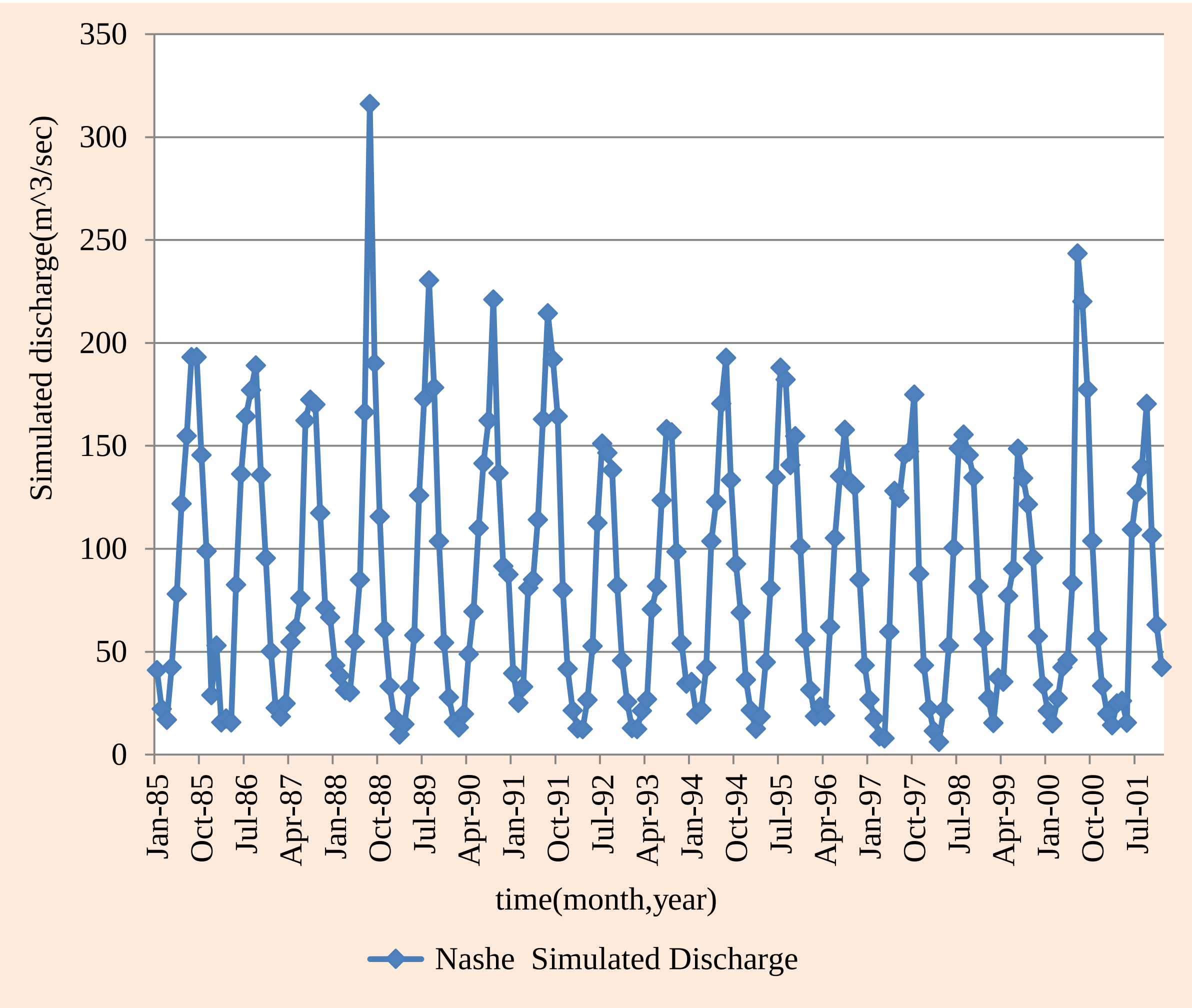

Figure 4.10. Inflow Hydrograph of Nashe Catchments.

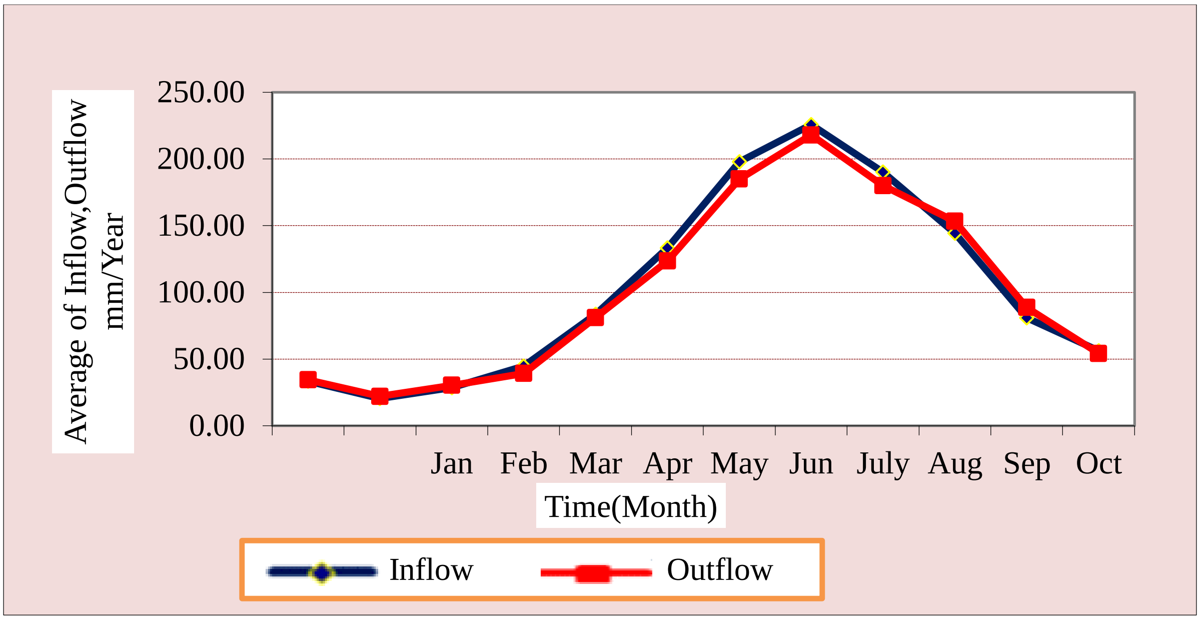

Figure 4.11. The Average Inflow and outflow of Nashe catchment.

The Figure 4.12 show that the yearly inflow and outflow hydrograph of Nashe watershed volume basis result in table Appendix 3 which is from the period of 1985-2001.

4.6.2. The Evaporation and Rainfall over the Lake

The monthly Evaporation and rainfall of Nashe watershed were shown in the water balance Volume basis result table Appendix table 19. From the period of 1985-2001 the average annual Evaporation from Simulation were 383.78 mm/year and the total in 812.23 mcm/year. The Annual Average areal rainfalls over the lake were 210.19mm/year and 111.25 mcm/year.

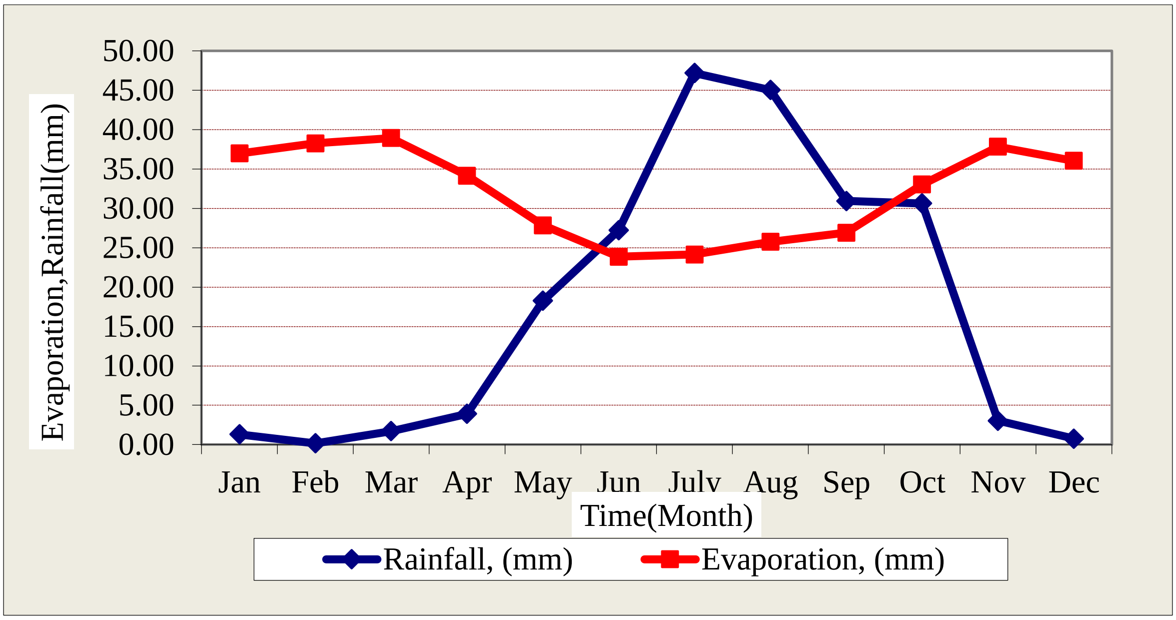

Figure 4.12. The Average Rainfall and Evaporation over the Nashe (1985-2001).

4.6.3. Physical Characteristic Data of the Lake

The polynomial of fitted bathymetry used in this research work is shown table 4.5 below.

Table 4.5. The Volume-Area-Elevation Relationship.

A=(0.87*10^-10*V^3-6.81*10^-6*V^2+1.89*10^-1*V+180.25)
E=(0.21*10^-14*V^2-2.02*10^-8*V^2+8.1*10^-4*V+2201.36)

Whereas E=Lake Level elevation, M+MSL

A=Surface area of the lake, km2

V=lake volume, mcm

The basic equation formula used in water balance is:

Change in Storage =Total inflow-total outflow-losses (55)

Never the less the equation (55) can be formulated as:

$$S_t = S_{t-1} + I(t) + P(t) - O(t) - E(t) + G_{in(t)} - G_{out(t)} - \text{otherlosses} \quad (56)$$

Whereas: St=Lake storage volume at the end of the current month,

St-1=lake storage volume at the end of previous month,

I(t)=Simulated inflow volume from gauged catchment at current month,

O(t)=Outflow volume at the lake outlet,

P(t)=Areal rainfall volume on the lake surface,

E(t)=Evaporation volume on the lake surface,

$G_{in(t)}$=Ground water inflow on the lake surface,

$G_{out(t)}$=Ground water outflow from the lake at the end of current month

Due to the lack of depth, volume information for inunded area, it was difficult to analyze in SWAT and Neglected in the water balance calculation. The water balance terms were computed using EXCEL spread sheet model and the monthly water balance result obtained.

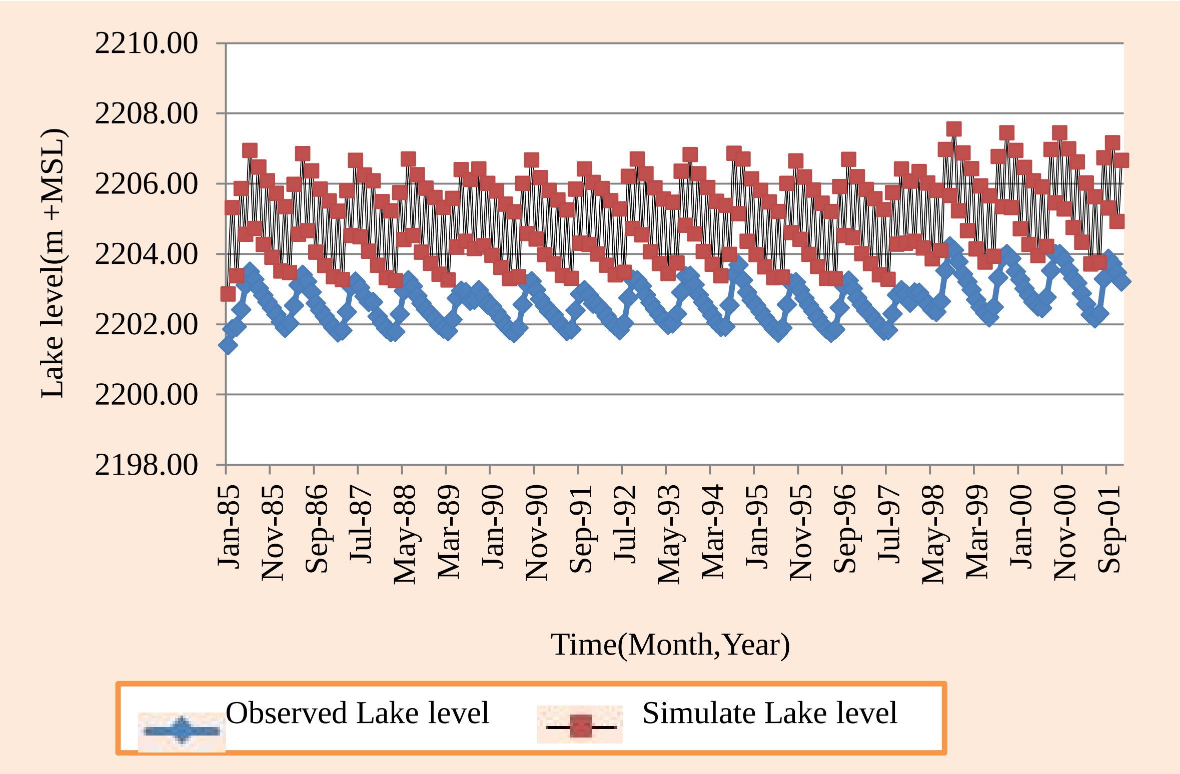

Figure 4.13. Observed and Simulated Nashe lake level from the period of (1985-2001).

The performance rate of lake level simulation for the period of 1985-2001 is the best fitted R^2 =0.25 and the Nash Sutcliff = -19.87 and, therefore the SWAT model output is applicable in simulating the lake level.

Table 4.6. The Lake Nashe Water balance component Gauged station simulated from (1985-2001).

Nashe water balance Component	mm/Year	MCM/Year
Lake areal rainfall	+210.19	+111.25
River inflow/Gauged	+1239.07	+2671.23
Lake Evaporation	-383.78	-812.23
River outflow	-1209.82	-2696.32
Change in Storage	-144.34	-726.07

From the period (1985-2001) on the review result of lake areal rain fall varies between 53.46 mm/year and 172.23 mm/year, Lake Inflow volume varies between 1023.18 mm/year to 1513.79mm/year, Lake Evaporation varies between 336.79 mm/year to 445.83 mm/year, and Outflow varies between 928.98 mm/year to 1414.42 mm/year. The annual inflow volume of BCM was obtained in this research.

CHAPTER FIVE

5. CONCLUSION AND RECOMMENDATION

5.1. CONCLUSION

During this study Meteorological data of Nashe catchment (Fincha Amarti Nashe Watershed) for the period of 30 years were used and the result of flow simulation were done by SWAT Model software. The SWAT model was setup from January 1985 – December 2014 in order to understand the hydrological processes in Nashe Watershed. SWAT model proved to be very well in simulating the stream flow in all majored modelled watershed. The present research is an attempt to obtain a scientific understanding of the basin as well as defining adequate tools for long term predictions of the basin characteristics. The model was successfully calibrated and validated for the Nashe gauged watershed using SUFI-2 algorithms. The model evaluation statistics for stream flows gave good results that was verified by NSE > 0.5 and $R^2 > 0.50$.

The performance rating criteria shows that model in all catchment were satisfactory and within an acceptance. The model output indicates that, the annual inflow volume estimated to be 2671.23 MCM/year from gauged watershed. The annual outflow Volume estimated to be 2696.32MCM/year. The lake areal rainfall, Evaporation for the simulation period (1985-2001) was found to be 111.25 MCM/year and 812.23 MCM/Year respectively. The Simulate Nashe Water balance components for gauged catchment, the balance component of change in storage is -726.07 MCM/year.

The result of sensitivity analysis also shows that CN is the most senility parameter in Lake Catchment. To accurately analysis the Sensitivity parameter in catchment the further study shall be Conduct by using different catchments to conclude the hydrological process in the basin from one catchment to another catchment and the paramount importance as it is new and original contribution using SWAT semi distribution modeling approach, to mainly estimate runoff from gauged and ungauged catchment and to study the lake water balance.

In general, the data created would enable for further research improvement or new research in monitoring lake water quality and sediment studies in the basin. The SWAT model is applicable in Lake Nashe basin and the result can be used for planning and management of water resources in the basin.

5.2. RECOMMENDATION

- The main study is to estimate the runoff contribution from gauged catchments based on the semi distributed modeling approach and in water balance component, the sub surface condition for the lake Nashe was not considered. The detail of research is which incorporates ground water is recommended to understand the interaction of surface as well as subsurface condition and lake water balance component.
- The database created in this research has paramount importance to conduct further research on water quality modeling and sediment study. Hence, it is recommended to use the database for further research work in the basin.
- Furthers researches to overcome the Water balance more, ungauged inflow from different catchment hydrological modeling best practice with the detail shall be done.
- SWAT model calibrated using observed flow data at gauging station. In order to improve the model performance, the Hydrological and Meteorological stations should be improved both in quality and quantity. Hence, it is highly recommended to establish a good network of both hydrometric and meteorological stations.
- The study has shown that the SWAT model can produce reliable estimates of Watershed modeling. The calibrated model can be used for further analysis of the effect of climate and land use change. The output of this study can help planners, decision makers and other different stakeholders to plan and implement appropriate soil and water conservation strategies.
- SWAT model calibrated using observed flow data at gauging station. In order to improve the model performance, the weather stations should be improved both in quality and quantity. Hence, it is highly recommended to establish a good network of both hydrometric and meteorological stations.
- Due to the lack of Enough Sediment Gaging station for Sediment data of Nashe catchment the Modeling of Sediment was not done. Therefore, Sediment modeling for catchment have to be done and full data have to be exist.
- Most of the stations in this catchment are located at the upper part of Watershed which is a challenge for calibration and Validation of hydrological characteristics of stream flow at the outlet of Lake Nashe. Therefore, more number of Meteorological and hydrological stations should have be installed at the downstream part of watershed.

- Generally, the rating curve shall be established to check the measurement, due to the flow measurement is likely affected by measurement error.

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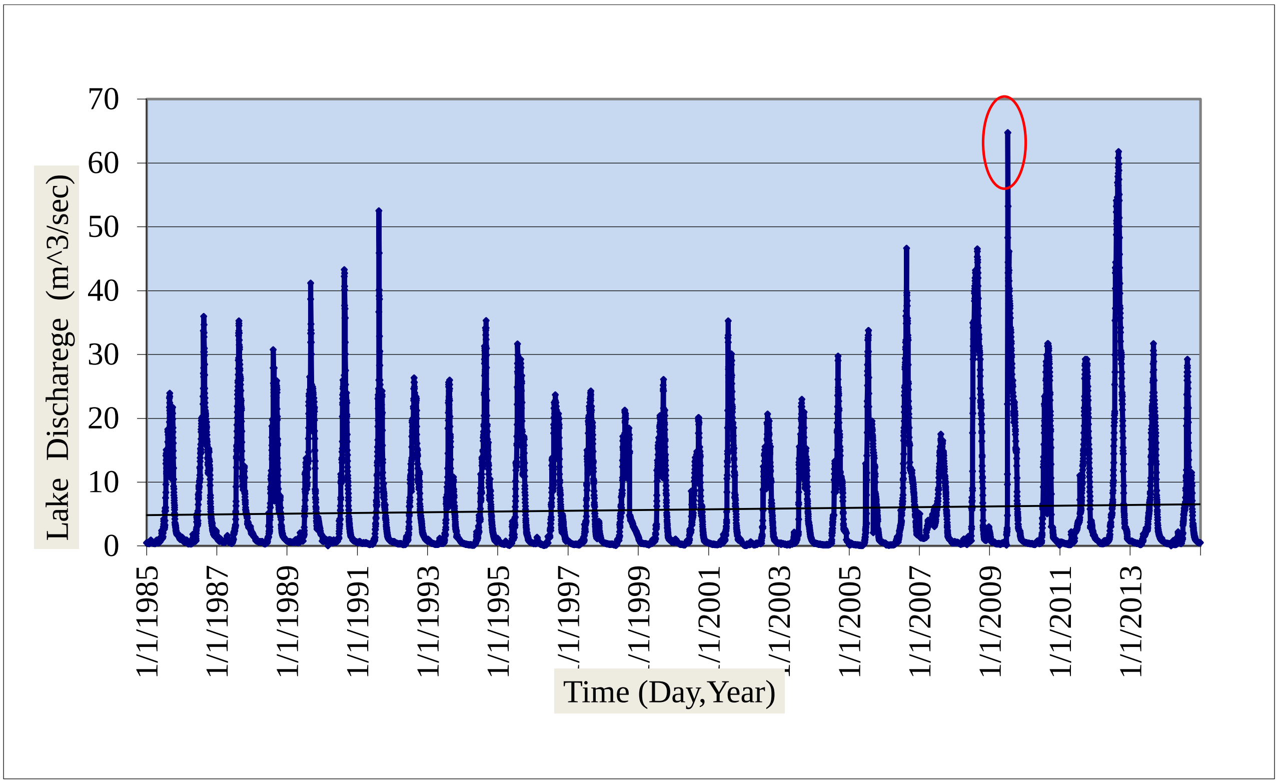
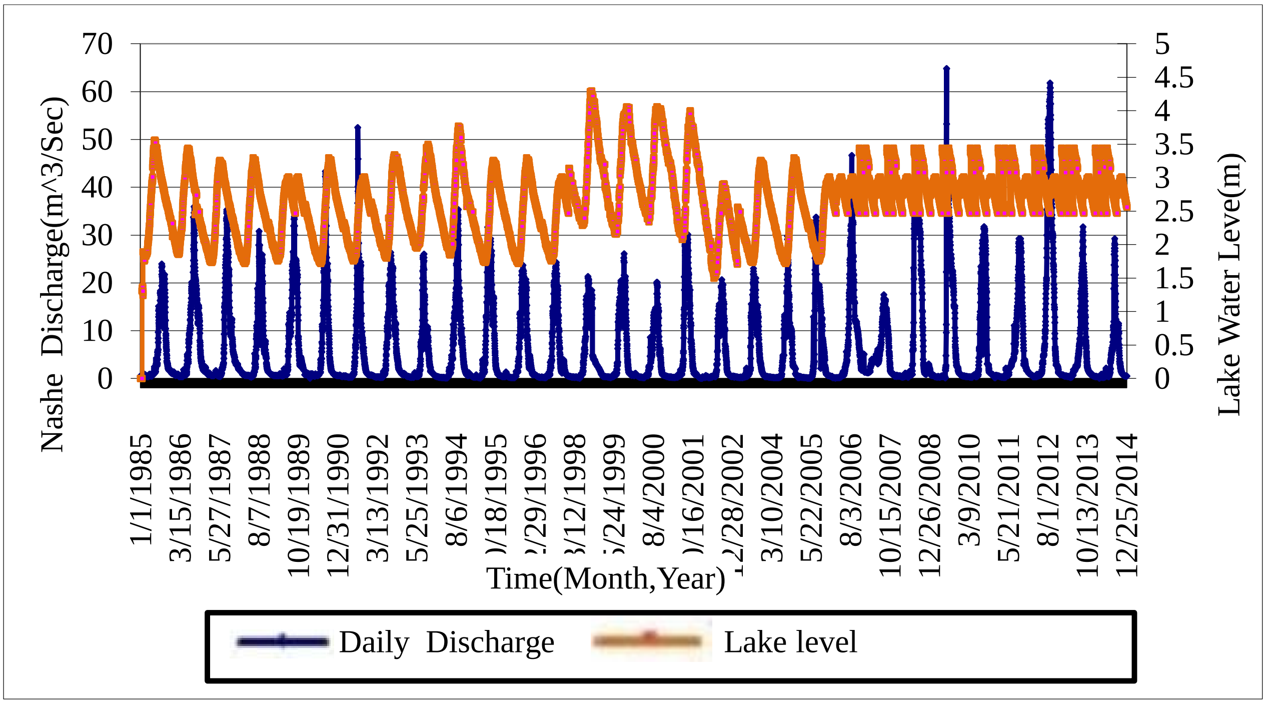
APPENDICES

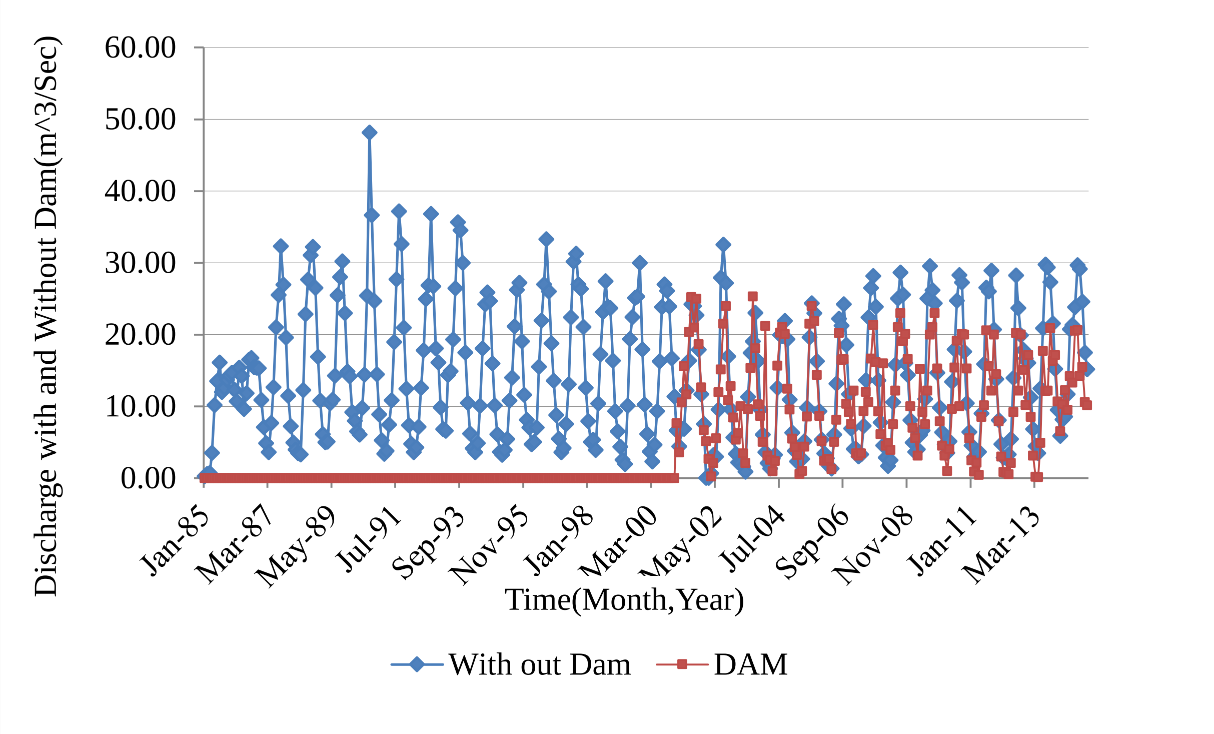
Appendix A Figures:-



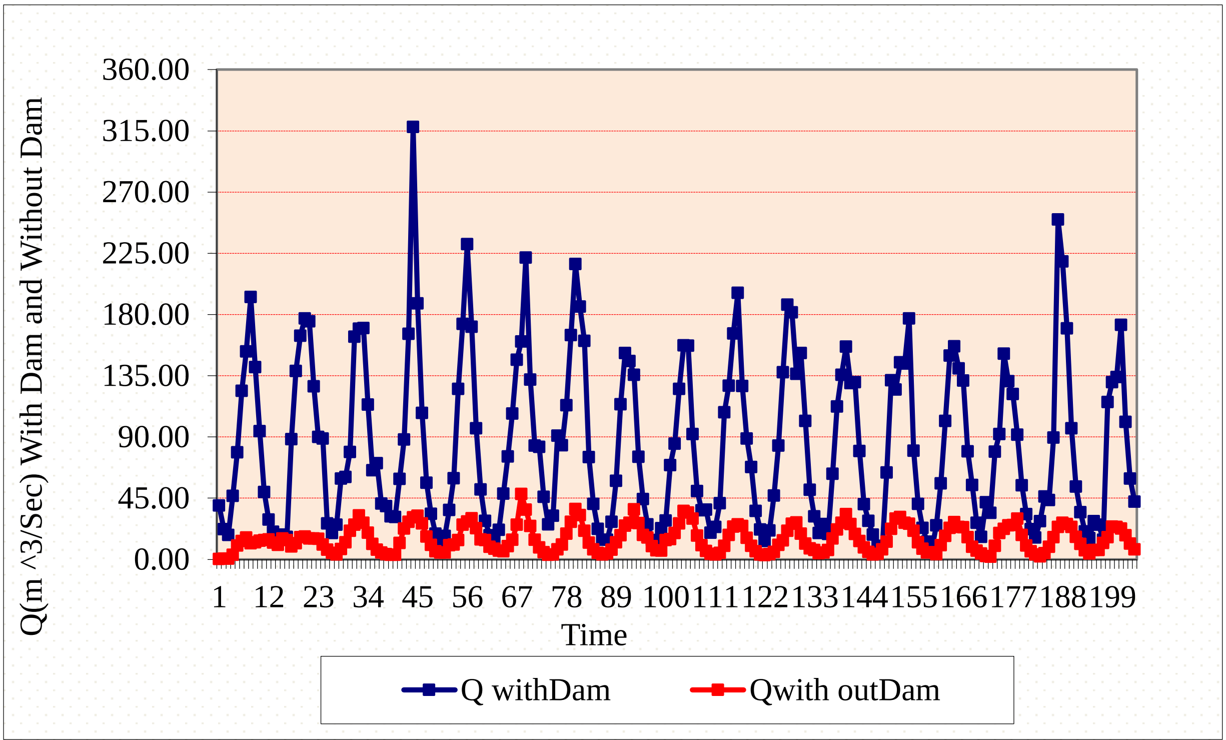
Appendix Figure 1. The Lake Nashe Flow Discharge for the period of (1985-2014).



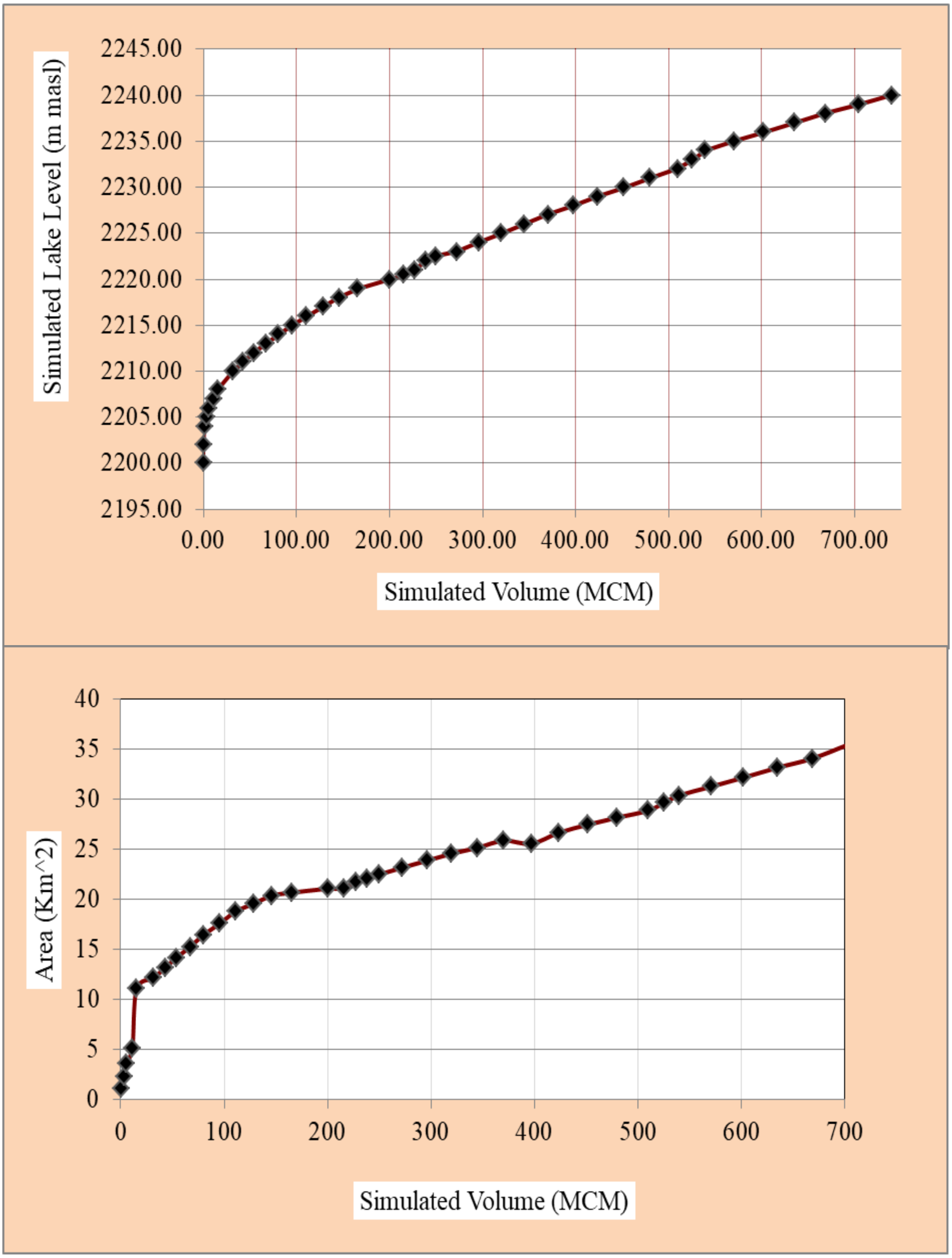
Appendix Figure 2. The Graph of Daily discharge and Nashe Lake Level for the period of (1985-2014)



Appendix Figure 3. The Graph of Daily Discharge with Dam and Without Development of Nashe Dam (1985-2014).



Appendix Figure 4. The Graph of Daily Gauged Discharge and the Dam project of Nashe Watershed



Appendix Figure 5. Area -Elevation-Volume Relationship of Lake Nashe Watershed.

Appendix B Tables

Appendix Table 1. List of Meteorological stations in the study area.

Station Name	X-co-ordination	Y-co-ordination	Elevation
Shambu	293788.960	1058565.770	2460.000
Fincha	321142.730	1058293.750	2248.000
Hareto	293528.88	1034097.79	2260.00
Nashe	310030.940	1075308.080	2060.000
Alibo	288808.270	1093417.610	2513.000

Appendix Table 2. Weather Generator parameters (WGEN) used by SWAT Model symbols and statistical analysis of daily precipitation and solar radiation data (1985-2014) input of Shambu where:-

PCPMM Average or mean total monthly precipitation in month (H2O)
PCPSTD Standard deviation for daily precipitation in month (mmH2O/day)
PCPSKW Skew coefficient for daily precipitation in month.
PR_1 Probability of wet day following a dry day in the month
PR_2 Probability of wet day following a wet day in the month
PCPD Average number of day of precipitation in month
SOLARAV Average daily solar radiation for month (MJ/m2/day)
Statistical analysis of daily precipitation data (1982-2014)

Input File name =Rshamb.txt

Number of years=30

Number of leap year=7

Number of records=10957

.

Month	PCP_MM	PCPSTD	PCPSKW	PR_W1	PR_W2	PCPD
Jan.	13.86	2.7839	11.027	0.074	0.2935	3.07
Feb.	22.02	3.3187	8.04	0.0852	0.4962	4.37
Mar.	54.62	4.8726	3.8778	0.1735	0.5641	9.1
Apr.	81.99	6.4125	3.9561	0.2195	0.6512	12.23
May.	175.58	8.7645	2.3653	0.3418	0.7726	19.2
Jun.	248.89	8.9879	1.7094	0.726	0.8249	25.13
Jul.	312.59	10.6159	1.7471	0.7534	0.9067	28.57
Aug.	282.25	10.7217	2.3793	0.6094	0.8691	26.73
Sep.	210.25	8.672	2.2847	0.6138	0.8464	25.17
Oct.	89.71	6.7852	4.1	0.1456	0.7302	12.23
Nov.	40.41	3.9849	5.9087	0.0877	0.6898	7.2
Dec.	28.92	3.7676	13.9219	0.056	0.7333	6

Appendix Figure 3. The average daily dew point temperature and humidity for period of (1985-2014) for Shambu Station.

This file has been generated by the program 'dew02.exe'

Input Filename =Dew02.txt

Number of Years=30

Number of Records =10957

Month	tmp_max	tmp_min	hmd	dewpt
Jan	23.66	10.38	43.15	4.99
Feb	24.36	11.08	39.39	4.11
Mar	24.47	11.25	45.32	6.17
Apr	24.3	11.52	49.19	7.49
May	23.59	11.34	64.65	11.02
Jun	21.94	10.63	85.75	14.7
Jul	20.44	10.53	91.88	14.84
Aug	20.54	10.55	91.41	14.83
Sep	21.39	10.58	82.85	13.7
Oct	21.99	10.33	66.13	10.36
Nov	22.68	10.03	55	7.94
Dec	22.99	10.26	47.88	6.08

TMPMX Average or mean daily maximum air temperature for month (°c)
TMPMN Average or mean daily maximum air temperature for month (°c)
TMPSTDMX Standard deviation for daily maximum air temperature in month (°c)
TMPSTDMN Standard deviation for daily minimum air temperature in month (°c)
DEWPT Average daily dew point temperature in month (°c)

Appendix Table 4. Average stream flow calibration (1985-2001) and Validation (2002-2014) of Fincha and Nashe stations.

Year	Flow Calibrated (m3/se)	Year	Flow Validated(m3/se)
1985	4.81	2002	0.05
1986	6.97	2003	0.09
1987	6.19	2004	1.30
1988	5.22	2005	2.49
1989	6.69	2006	2.58
1990	5.43	2007	3.03
1991	5.09	2008	12.05
1992	5.45	2009	10.50
1993	3.67	2010	9.58
1994	5.72	2011	8.03
1995	5.82	2012	7.83
1996	4.98	2013	6.84
1997	4.67	2014	3.62
1998	4.55		
1999	4.95		
2000	3.73		
2001	5.70		

Appendix Table 5. Sensitivity analysis Twenty Seven parameters of flow in Nashe Watershed.

No	Parameter Name	Parameter Description
1	CN2.mgt	SCC runoff curve number for moisture condition II
2	SOL_AWC.sol	Soil available water capacity (mm H2O/mm soil)
3	SOL_K.sol	Saturated hydraulic Conductivity(mm/hr)
4	SOL_BD.soil	Moist bulk density
5	SFTMP.	Snowfall Temperature(°c)
6	ALPHA_BF.gw	Base flow alpha Factor (days)
7	GW_DELAY	Ground water delay
8	GWQMN.gw	Threshold depth of water in the Shallow well aquifer for return flow to occur(mm)
9	GW_REVAP	Ground water revap coefficient
10	ESCO.hru	Soil evaporation compensation factor
11	CH_N2.rte	Manning's ''n'' value for the main channel
12	CH_K2.rte	Effective hydraulic conductivity in the main channel alluvium(mm/hr)

13	ALPHA_BNK	Baseflow alpha factor for bank storage
14	SLOPE.hru	Average slope steepness(m/m)
15	CANMX.hru	Maximum canopy storage(mm)
16	SURLAG.bsn	Surface runoff lag time (days)
17	TIMP.bsn	Snow pack temperature lag factor
18	BIOMIX.mgt	Biological mixing efficiency
19	BLAL.crop.dat	Sub-maximum potential leaf area index
20	TLAPS.sub	Temperature labse rate(ºc/km)
21	SLSUBBSN.hru	Average slope lIngth(m)
22	SMFMX.bsn	Melt factor for snow on June 21(mm H2O/ºC-day)
23	SMFMN.bsn	Melt factor for snow on December 21(mm H2O/ºC-day)
24	SMFMX.bsn	Snow melt base temperature(ºC)
25	SLOPE.hru	Average slope steepness(m/m)
26	REVAPMN.gw	Threshold water in the shallow aquifer for revap to occur(mm)
27	SOL_ALB.sol	Moist soil albedo

Appendix Table 6. The Average monthly sediment yield and surface flow basin value obtained From SWAT output Standard result.

Year	Sed. Yield(mm)	Surf(mm)	Prec(mm)	Year	Sed .Yield (mm)	Surf(mm)	Prec(mm)
1985	0	0	0	2000	39.57	234.88	1490.6
1986	0	0	0	2001	39.6	217.44	1350.8
1987	59.82	292.05	1516.2	2002	63.48	355.39	1686.4
1988	55.54	342.36	1698.6	2003	46.73	247.25	1349.3
1989	65.43	346.45	1688.9	2004	47.81	267.56	1489.3
1990	79.92	431.06	1772.3	2005	44.23	248.34	1475.2
1991	45.54	274.37	1605.6	2006	48.07	307.01	1620.1
1992	60.85	373.12	1834.8	2007	53.32	294.45	1656.3
1993	64.11	376.68	1880	2008	63.14	325.65	1715.7
1994	41.29	199.72	1275.8	2009	49.88	290.19	1452.9
1995	39.45	227.51	1376.2	2010	50.54	269.39	1434
1996	67.84	352.67	1629	2011	42.2	258.25	1419.6
1997	66.15	380.05	1809.3	2012	26.03	194.89	1476.4
1998	50.77	250	1458.6	2013	45.76	277.19	1543.4
1999	51.78	283.86	1534.7	2014	54.36	320.86	1966.4

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Appendix Table 7. The (Water Balance) Monthly Inflow, Outflow, Observed And Simulated Of Nashe Water Level From Period Of (1985-2001).

Month/ Date	Area(mm 2)	Inflow (mcm) (Gauged+un-gauged)	Rainfall (mm)	Out flow (mcm)	Evap.(m m) From the Lake	Simulated Vol.(mcm	Observed vol.(mcm)	Unaccounted loss(mcm)	Obs. Water level (m)	Simu. Water level (m)
							38200.26		2200.20	2200.20
1/1/1985	2.28	106.04	1.99	110.00	19.00	38149.07	38150.26	7.89	2201.41	2202.86
2/1/1985	2309.81	54.14	0.61	53.68	13.19	38120.47	38050.26	80.18	2201.86	2205.31
3/1/1985	2304.91	48.05	0.65	45.32	21.01	38076.27	37950.26	137.41	2201.93	2203.38
4/1/1985	2300.08	121.36	4.00	110.03	36.03	38013.93	37900.26	127.30	2202.41	2205.86
5/1/1985	2297.68	211.27	6.23	209.02	40.57	37937.27	37850.26	103.06	2203.11	2204.56
6/1/1985	2295.31	321.15	9.77	316.22	37.84	37877.77	37800.26	95.52	2203.50	2206.95
7/1/1985	2292.94	409.80	13.08	414.88	38.04	37815.45	37750.26	84.94	2203.28	2204.73
8/1/1985	2290.60	516.66	10.57	517.47	43.54	37739.12	37700.26	60.93	2203.03	2206.48
9/1/1985	2288.27	366.25	4.09	500.77	35.60	37532.50	37650.26	-93.50	2202.82	2204.27
10/1/1985	2285.95	252.73	1.71	389.98	16.50	37361.45	37600.26	-213.51	2202.63	2206.08
11/1/1985	2283.65	128.46	0.30	256.56	18.13	37192.63	37550.26	-331.08	2202.46	2203.91
12/1/1985	2281.36	78.85	0.87	77.54	17.34	37156.37	37500.26	-316.19	2202.28	2205.73
1/1/1986	2279.09	54.61	0.00	142.22	21.69	37019.33	37450.26	-401.71	2202.07	2203.52
2/1/1986	2276.83	40.86	0.51	37.86	22.01	36973.37	37400.26	-396.16	2201.90	2205.35
3/1/1986	2274.59	49.15	0.09	47.17	39.77	36885.10	37350.26	-431.66	2202.02	2203.47
4/1/1986	2272.36	43.13	0.00	40.56	40.34	36796.00	37300.26	-467.93	2202.54	2205.99
5/1/1986	2270.15	236.93	2.08	221.02	19.52	36772.32	37250.26	-440.39	2203.12	2204.57
6/1/1986	2267.95	359.25	4.23	353.55	37.66	36702.20	37200.26	-458.17	2203.41	2206.86
7/1/1986	2265.77	440.60	6.01	440.06	42.55	36619.95	37150.26	-487.87	2203.21	2204.66
8/1/1986	2263.60	474.34	4.79	474.61	34.40	36552.65	37100.26	-503.09	2202.92	2206.37

9/1/1986	2261.45	453.86	4.58	490.15	14.92	36492.98	37050.26	-512.03	2202.60	2204.05
10/1/1986	2259.31	340.69	1.31	363.99	19.28	36429.08	37000.26	-524.68	2202.40	2205.85
11/1/1986	2257.18	233.57	0.00	247.61	30.87	36345.35	36950.26	-556.25	2202.22	2203.67
12/1/1986	2255.07	238.06	0.00	134.67	34.01	36372.04	36900.26	-477.17	2202.06	2205.51
1/1/1987	2252.97	70.92	0.05	61.01	33.94	36305.60	36850.26	-491.24	2201.90	2203.35
2/1/1987	2250.89	47.20	0.80	44.66	38.07	36224.25	36800.26	-519.99	2201.77	2205.22
3/1/1987	2248.82	68.65	0.67	66.88	29.01	36162.29	36700.26	-479.97	2201.82	2203.27
4/1/1987	2244.72	154.12	3.57	142.12	41.60	36088.92	36650.26	-500.67	2202.35	2205.80
5/1/1987	2242.70	162.23	6.76	165.07	46.68	35996.55	36600.26	-540.24	2203.07	2204.52
6/1/1987	2240.68	204.82	6.81	197.17	29.55	35953.25	36550.26	-531.96	2203.22	2206.67
7/1/1987	2238.68	438.72	13.61	434.97	21.10	35940.23	36500.26	-494.45	2203.04	2204.49
8/1/1987	2236.70	454.26	6.24	461.76	33.59	35871.56	36450.26	-511.21	2202.80	2206.25
9/1/1987	2234.72	441.16	3.98	440.90	19.42	35837.31	36400.26	-494.37	2202.63	2204.08
10/1/1987	2232.77	304.80	2.63	314.44	23.93	35780.11	36350.26	-500.08	2202.63	2206.08
11/1/1987	2230.82	169.72	0.50	184.52	32.12	35694.77	36300.26	-533.21	2202.23	2203.68
12/1/1987	2228.89	189.44	0.62	178.89	30.57	35638.57	36250.26	-537.31	2202.04	2205.49
1/1/1988	2226.97	110.06	0.00	116.11	38.44	35546.91	36150.26	-526.28	2201.88	2203.33
2/1/1988	2223.17	94.98	0.33	93.07	39.23	35462.34	36100.26	-558.13	2201.78	2205.23
3/1/1988	2221.29	84.82	0.71	83.65	37.47	35381.86	36050.26	-586.03	2201.79	2203.24
4/1/1988	2219.42	80.87	0.71	78.64	42.88	35290.50	35950.26	-574.44	2202.29	2205.74
5/1/1988	2215.73	158.67	2.97	147.20	52.75	35191.67	35900.26	-619.79	2202.95	2204.40
6/1/1988	2213.90	228.51	15.24	220.24	27.13	35173.61	35850.26	-587.02	2203.25	2206.70
7/1/1988	2212.09	444.61	12.66	445.69	20.61	35154.95	35800.26	-555.12	2203.08	2204.53
8/1/1988	2210.29	851.46	11.67	846.91	17.32	35147.02	35750.26	-512.66	2202.81	2206.26
9/1/1988	2208.50	488.07	18.60	493.00	14.48	35151.19	35700.26	-458.77	2202.60	2204.05
10/1/1988	2206.72	288.73	7.01	309.89	11.84	35119.37	35650.26	-440.25	2202.43	2205.88
11/1/1988	2204.96	146.14	0.82	157.57	44.64	35011.32	35600.26	-495.24	2202.29	2203.74

12/1/1988	2203.20	90.18	0.00	89.08	49.36	34903.67	35550.26	-549.43	2202.16	2205.61
1/1/1989	2201.47	51.02	0.00	47.35	39.46	34820.47	35500.26	-579.87	2201.97	2203.42
2/1/1989	2199.74	27.84	0.00	23.81	35.60	34746.19	35450.26	-601.66	2201.88	2205.33
3/1/1989	2198.02	46.26	1.92	39.45	47.66	34652.46	35400.26	-642.19	2201.81	2203.26
4/1/1989	2196.32	94.17	2.65	83.95	48.90	34561.09	35350.26	-680.32	2202.13	2205.58
5/1/1989	2194.63	159.77	4.18	155.53	27.18	34514.85	35300.26	-674.95	2202.75	2204.20
6/1/1989	2192.95	324.78	4.57	326.33	19.28	34481.03	35250.26	-657.74	2202.95	2206.40
7/1/1989	2191.29	463.90	8.99	463.36	14.96	34468.49	35200.26	-619.87	2202.91	2204.36
8/1/1989	2189.63	621.12	11.35	617.37	18.63	34456.30	35150.26	-581.55	2202.67	2206.12
9/1/1989	2187.99	443.49	5.40	462.15	17.04	34412.16	35100.26	-574.86	2202.70	2204.15
10/1/1989	2186.36	258.04	0.93	278.02	30.81	34326.86	35050.26	-608.08	2202.97	2206.42
11/1/1989	2184.74	133.46	0.53	141.24	32.27	34249.74	35000.26	-632.98	2202.78	2204.23
12/1/1989	2183.13	75.91	2.22	74.73	41.34	34165.51	34950.26	-664.47	2202.56	2206.01
1/1/1990	2181.54	48.00	0.00	42.59	46.69	34069.06	34900.26	-707.64	2202.51	2203.96
2/1/1990	2179.95	35.56	0.94	31.89	34.95	33998.60	34850.26	-725.73	2202.34	2205.79
3/1/1990	2178.38	58.71	0.42	53.14	31.78	33935.86	34800.26	-736.27	2202.17	2203.62
4/1/1990	2176.82	125.30	1.98	126.44	47.34	33835.98	34750.26	-782.98	2201.97	2205.42
5/1/1990	2175.27	202.57	1.27	186.23	40.93	33766.04	34700.26	-800.14	2201.84	2203.29
6/1/1990	2173.73	277.86	2.95	285.38	28.41	33703.18	34650.26	-811.21	2201.75	2205.20
7/1/1990	2172.21	393.46	10.21	378.99	23.33	33689.15	34600.26	-774.33	2201.90	2203.35
8/1/1990	2170.69	429.08	11.96	434.97	21.89	33661.70	34550.26	-751.08	2202.56	2206.01
9/1/1990	2169.18	575.16	8.20	573.35	24.06	33629.11	34650.26	-882.56	2203.13	2204.58
10/1/1990	2172.21	354.35	1.83	366.41	30.27	33555.28	34600.26	-904.40	2203.22	2206.67
11/1/1990	2170.69	216.82	0.57	237.30	40.93	33447.20	34550.26	-959.66	2202.98	2204.43
12/1/1990	2169.18	221.91	0.00	234.52	42.31	33342.80	34500.26	-1011.09	2202.72	2206.17
1/1/1991	2167.69	123.26	0.00	105.88	44.72	33263.25	34450.26	-1037.52	2202.53	2203.98
2/1/1991	2166.21	62.44	0.00	61.16	32.26	33194.65	34400.26	-1053.86	2202.36	2205.81

3/1/1991	2164.74	86.19	0.01	88.33	41.48	33102.73	34350.26	-1092.87	2202.27	2203.72
4/1/1991	2163.27	235.72	2.06	209.90	48.56	33027.96	34300.26	-1114.39	2202.09	2205.54
5/1/1991	2161.82	225.09	1.60	227.74	37.45	32947.80	34250.26	-1142.04	2201.94	2203.39
6/1/1991	2160.38	293.93	3.52	296.01	24.20	32901.05	34200.26	-1137.34	2201.80	2205.25
7/1/1991	2158.96	441.94	11.02	436.58	17.64	32892.12	34150.26	-1095.81	2201.85	2203.30
8/1/1991	2157.54	581.48	9.79	574.25	17.83	32882.00	34100.26	-1055.36	2202.40	2205.85
9/1/1991	2156.13	481.85	2.96	497.92	14.56	32840.92	34050.26	-1045.63	2202.86	2204.31
10/1/1991	2154.73	430.69	0.00	440.06	30.93	32764.90	34000.26	-1069.49	2202.97	2206.42
11/1/1991	2153.35	195.26	0.00	207.33	48.24	32648.94	33950.26	-1132.07	2202.82	2204.27
12/1/1991	2151.97	109.55	0.00	111.80	36.17	32568.86	33900.26	-1159.62	2202.59	2206.04
1/1/1992	2150.60	60.53	0.03	57.59	23.52	32521.29	33850.26	-1155.55	2202.55	2204.00
2/1/1992	2149.25	35.05	0.00	30.92	36.37	32447.26	33800.26	-1177.04	2202.42	2205.87
3/1/1992	2147.90	39.16	1.64	33.29	48.19	32353.14	33750.26	-1217.90	2202.23	2203.68
4/1/1992	2146.56	71.67	4.25	69.02	23.09	35.34	33700.26	-1204.37	2202.07	2205.52
5/1/1992	2145.24	154.70	5.75	141.18	20.88	32296.41	33650.26	-1172.25	2201.95	2203.40
6/1/1992	2143.92	295.49	10.73	291.86	17.18	32286.21	33600.26	-1132.00	2201.83	2205.28
7/1/1992	2142.61	406.31	13.78	404.71	17.14	32280.62	33550.26	-1087.35	2202.03	2203.48
8/1/1992	2141.32	390.78	16.51	392.92	19.09	32272.95	33500.26	-1044.84	2202.76	2206.21
9/1/1992	2140.03	351.73	8.79	358.47	24.59	32232.40	33450.26	-1034.28	2203.27	2204.72
10/1/1992	2138.75	202.35	7.37	220.16	33.04	32159.68	33400.26	-1055.20	2203.25	2206.70
11/1/1992	2137.49	115.01	1.99	118.43	40.59	32073.76	33350.26	-1088.43	2203.09	2204.54
12/1/1992	2136.23	68.92	1.07	68.89	44.35	31981.33	33300.26	-1127.83	2202.84	2206.29
1/1/1993	2134.98	38.03	1.60	34.69	31.23	31921.41	33250.26	-1135.66	2202.61	2204.06
2/1/1993	2133.74	34.43	0.00	30.12	42.72	31834.57	33200.26	-1169.52	2202.43	2205.88
3/1/1993	2132.51	61.42	0.55	56.94	49.72	31734.18	33150.26	-1216.46	2202.27	2203.72
4/1/1993	2131.29	74.05	1.92	69.78	29.03	31680.68	33100.26	-1218.07	2202.12	2205.57
5/1/1993	2130.08	185.93	1.91	189.15	19.96	31639.02	33050.26	-1208.47	2201.99	2203.44

6/1/1993	2128.88	220.63	0.00	212.10	22.65	31599.33	33000.26	-1196.57	2202.02	2205.47
7/1/1993	2127.69	335.87	18.85	331.05	23.53	31594.19	32950.26	-1151.38	2202.29	2203.74
8/1/1993	2126.50	421.85	17.83	423.46	20.07	31587.82	32900.26	-1107.59	2202.90	2206.35
9/1/1993	2125.33	407.20	7.98	405.91	32.35	31537.32	32850.26	-1106.39	2203.37	2204.82
10/1/1993	2124.16	247.24	1.62	264.25	40.52	31437.69	32800.26	-1153.30	2203.38	2206.83
11/1/1993	2123.00	130.53	0.00	140.36	38.54	31346.04	32750.26	-1192.25	2203.12	2204.57
12/1/1993	2121.85	96.64	0.00	92.70	31.77	31282.57	32700.26	-1203.50	2202.84	2206.29
1/1/1994	2120.71	97.92	0.00	94.41	35.93	31209.88	32650.26	-1223.67	2202.63	2204.08
2/1/1994	2119.58	47.49	0.00	47.63	46.21	31111.79	32600.26	-1268.53	2202.44	2205.89
3/1/1994	2118.46	64.39	0.00	58.34	27.21	31060.20	32550.26	-1268.21	2202.25	2203.70
4/1/1994	2117.35	107.18	5.49	109.85	23.32	31019.78	32500.26	-1257.39	2202.05	2205.50
5/1/1994	2116.24	290.07	11.11	278.02	19.08	31014.96	32450.26	-1211.64	2201.93	2203.38
6/1/1994	2115.14	331.00	6.53	318.56	16.82	31005.64	32400.26	-1170.25	2201.93	2205.38
7/1/1994	2114.05	444.88	9.09	456.94	18.74	30973.19	32350.26	-1152.02	2202.54	2203.99
8/1/1994	2112.97	525.23	8.01	516.40	15.72	30965.73	32300.26	-1108.94	2203.42	2206.87
9/1/1994	2111.90	330.74	9.13	346.03	24.45	30918.09	32250.26	-1105.51	2203.69	2205.14
10/1/1994	2110.84	238.19	0.03	248.45	36.71	30830.40	32200.26	-1140.63	2203.25	2206.70
11/1/1994	2109.78	176.00	2.03	178.82	47.47	30731.71	32150.26	-1186.14	2202.91	2204.36
12/1/1994	2108.73	95.73	0.00	97.55	42.10	30641.11	32250.26	-1373.79	2202.69	2206.14
1/1/1995	2110.84	59.11	0.00	58.04	47.15	30542.66	32500.26	-1718.95	2202.53	2203.98
2/1/1995	2116.24	33.05	0.17	30.43	48.29	30443.43	32950.26	-2264.80	2202.36	2205.81
3/1/1995	2126.50	56.89	1.94	49.52	40.43	30368.95	32900.26	-2286.59	2202.19	2203.64
4/1/1995	2125.33	122.11	1.23	116.67	32.02	30308.96	32850.26	-2294.43	2202.03	2205.48
5/1/1995	2124.16	224.10	8.29	216.31	20.88	30290.01	32800.26	-2262.49	2201.88	2203.33
6/1/1995	2123.00	356.66	5.19	349.66	19.41	30266.82	32750.26	-2234.69	2201.76	2205.21
7/1/1995	2121.85	501.40	4.95	503.54	14.19	30245.07	32700.26	-2205.79	2201.90	2203.35
8/1/1995	2120.71	486.40	8.76	488.00	28.52	30201.55	32650.26	-2197.92	2202.56	2206.01

9/1/1995	2119.58	353.55	12.86	364.69	22.84	30169.26	32600.26	-2179.52	2203.16	2204.61
10/1/1995	2118.46	406.31	1.84	414.62	36.95	30086.57	32550.26	-2209.75	2203.20	2206.65
11/1/1995	2117.35	264.12	0.00	262.05	39.92	30004.12	32500.26	-2239.40	2202.97	2204.42
12/1/1995	2116.24	137.54	0.28	149.03	28.62	29932.66	32450.26	-2258.88	2202.74	2206.19
1/1/1996	2115.14	84.58	0.75	84.64	36.73	29856.50	32400.26	-2282.52	2202.54	2203.99
2/1/1996	2114.05	46.79	0.00	45.31	46.02	29760.69	32350.26	-2325.11	2202.37	2205.82
3/1/1996	2112.97	69.56	2.06	62.33	46.23	29674.59	32300.26	-2358.12	2202.19	2203.64
4/1/1996	2111.90	48.42	2.04	49.14	22.50	29630.66	32250.26	-2350.62	2202.00	2205.45
5/1/1996	2110.84	169.03	6.95	166.22	15.98	29614.41	32200.26	-6.24	2201.86	2203.31
6/1/1996	2109.78	291.34	4.52	272.94	21.98	29595.97	32150.26	-2283.45	2201.76	2205.21
7/1/1996	2108.73	363.46	5.71	362.39	15.37	29576.67	32100.26	-2252.07	2201.85	2203.30
8/1/1996	2107.69	419.17	13.66	422.92	16.92	29566.05	32050.26	-2212.47	2202.47	2205.92
9/1/1996	2106.66	335.92	4.26	343.70	20.44	29524.19	32000.26	-2203.19	2203.08	2204.53
10/1/1996	2105.63	349.00	2.11	349.00	51.20	29420.83	31950.26	-2253.12	2203.24	2206.69
11/1/1996	2104.61	206.87	1.93	220.37	44.39	29317.96	31900.26	-2303.02	2203.01	2204.46
12/1/1996	2103.60	108.80	0.54	116.46	34.82	29238.19	31850.26	-2330.39	2202.75	2206.20
1/1/1997	2102.60	76.04	0.00	71.54	41.76	29154.88	31800.26	-2360.77	2202.56	2204.01
2/1/1997	2101.61	44.22	0.00	42.65	50.01	29051.35	31750.26	-2410.80	2202.39	2205.84
3/1/1997	2100.62	26.73	0.75	24.00	42.75	28965.85	31700.26	-2443.36	2202.28	2203.73
4/1/1997	2099.64	21.47	4.67	20.45	19.75	28935.22	31650.26	-2422.94	2202.12	2205.57
5/1/1997	2098.67	171.36	5.05	159.82	16.18	28923.40	31600.26	-2383.98	2201.96	2203.41
6/1/1997	2097.70	341.63	14.80	332.29	13.85	28934.73	31550.26	-2322.72	2201.82	2205.27
7/1/1997	2096.74	334.53	4.62	334.00	17.32	28908.63	31500.26	-2297.92	2201.83	2203.28
8/1/1997	2095.79	388.37	8.77	389.98	31.93	28858.49	31450.26	-2296.45	2202.30	2205.75
9/1/1997	2094.85	372.99	6.78	381.54	49.00	28761.49	31400.26	-2340.49	2202.83	2204.28
10/1/1997	2093.91	474.88	7.70	468.72	47.46	28684.40	31350.26	-2364.80	2202.97	2206.42
11/1/1997	2092.98	207.10	3.28	227.84	45.76	28574.75	31300.26	-2421.47	2202.86	2204.31

12/1/1997	2092.06	109.31	0.00	116.38	48.84	28465.50	31250.26	-2477.30	2202.62	2206.07
1/1/1998	2091.14	62.46	0.00	60.02	42.18	28379.74	31200.26	-2510.12	2202.91	2204.36
2/1/1998	2090.23	31.74	0.27	27.87	30.02	28321.42	31150.26	-2516.35	2202.89	2206.34
3/1/1998	2089.33	20.49	0.37	16.58	22.78	28278.51	31200.26	-2607.69	2202.72	2204.17
4/1/1998	2090.23	65.01	0.45	56.56	16.44	28253.53	31250.26	-2681.55	2202.57	2206.02
5/1/1998	2091.14	150.04	3.47	142.22	18.20	28230.55	31200.26	-2653.50	2202.41	2203.86
6/1/1998	2090.23	263.87	8.50	260.24	27.97	28193.48	31150.26	-2639.20	2202.36	2205.81
7/1/1998	2089.33	401.22	16.23	398.55	65.28	28093.68	31100.26	-2685.57	2202.65	2204.10
8/1/1998	2088.43	419.97	17.15	416.49	48.06	28032.61	31050.26	-2694.48	2203.53	2206.98
9/1/1998	2087.54	363.92	9.45	377.14	49.09	27936.64	31400.26	-3137.67	2204.22	2205.67
10/1/1998	2093.91	351.94	10.03	360.51	45.09	27854.66	31350.26	-3167.20	2204.11	2207.56
11/1/1998	2092.98	205.75	0.61	211.58	44.66	27756.63	31600.26	-3512.15	2203.78	2205.23
12/1/1998	2097.70	146.48	0.00	150.53	36.06	27676.94	31550.26	-3539.31	2203.42	2206.87
1/1/1999	2096.74	72.10	0.55	73.71	45.06	27582.01	31500.26	-3581.13	2203.21	2204.66
2/1/1999	2095.79	40.42	0.00	37.30	49.53	27481.32	31450.26	-3628.35	2202.98	2206.43
3/1/1999	2094.85	112.76	0.01	100.15	39.58	27411.05	31400.26	-3645.85	2202.70	2204.15
4/1/1999	2093.91	89.09	2.09	91.94	39.19	27330.51	31350.26	-3673.79	2202.49	2205.94
5/1/1999	2092.98	212.21	7.42	206.80	27.45	27294.00	31300.26	-3658.90	2202.32	2203.77
6/1/1999	2092.06	238.88	17.07	233.85	18.79	27295.43	31250.26	-3607.35	2202.20	2205.65
7/1/1999	2091.14	405.24	13.30	398.28	21.96	27284.28	31200.26	-3567.89	2202.49	2203.94
8/1/1999	2090.23	351.14	10.35	359.98	17.96	27259.54	31150.26	-3542.10	2203.33	2206.78
9/1/1999	2089.33	315.45	14.90	315.19	18.39	27252.51	31100.26	-3498.89	2203.90	2205.35
10/1/1999	2088.43	245.61	15.88	256.24	32.15	27207.89	31050.26	-3492.37	2204.00	2207.45
11/1/1999	2087.54	141.37	0.00	149.30	36.98	27122.77	31300.26	-3824.91	2203.87	2205.32
12/1/1999	2092.06	89.00	0.81	91.01	32.31	27054.86	31250.26	-3840.61	2203.50	2206.95
1/1/2000	2091.14	59.70	0.00	57.13	49.04	26954.88	31200.26	-3887.15	2203.27	2204.72
2/1/2000	2090.23	39.24	0.00	36.92	43.99	26865.25	31450.26	-4223.70	2203.02	2206.47

3/1/2000	2094.85	75.61	0.00	73.31	46.81	26769.49	31400.26	-4266.18	2202.83	2204.28
4/1/2000	2093.91	119.70	2.91	110.00	44.53	26692.04	31350.26	-4290.72	2202.64	2206.09
5/1/2000	2092.98	117.02	4.62	123.26	27.33	26638.27	31300.26	-4292.91	2202.50	2203.95
6/1/2000	2092.06	232.04	10.13	216.07	19.54	26634.55	31250.26	-4245.97	2202.46	2205.91
7/1/2000	2091.14	669.33	11.72	652.19	18.01	26638.54	31200.26	-4191.54	2202.77	2204.22
8/1/2000	2090.23	586.84	18.15	589.78	19.42	26632.94	31350.26	-4347.05	2203.52	2206.97
9/1/2000	2092.98	440.38	6.62	459.82	35.23	26553.62	31300.26	-4374.37	2204.00	2205.45
10/1/2000	2092.06	258.22	6.16	278.29	24.67	26494.83	31250.26	-4381.86	2203.99	2207.44
11/1/2000	2091.14	139.03	0.25	146.14	20.33	26445.74	31200.26	-4379.54	2203.83	2205.28
12/1/2000	2090.23	93.18	0.08	89.62	41.48	26362.76	31150.26	-4409.62	2203.54	2206.99
1/1/2001	2089.33	55.34	0.00	53.19	32.15	26297.74	31100.26	-4422.40	2203.30	2204.75
2/1/2001	2088.43	37.69	0.00	34.74	41.96	26213.06	31150.26	-4554.14	2203.17	2206.62
3/1/2001	2089.33	75.29	1.83	66.85	50.14	26120.56	31400.26	-4893.26	2202.88	2204.33
4/1/2001	2093.91	66.46	2.99	67.57	25.08	26073.19	31350.26	-4889.08	2202.57	2206.02
5/1/2001	2092.98	39.00	5.67	41.65	22.43	26035.46	31300.26	-4875.64	2202.27	2203.72
6/1/2001	2092.06	300.15	0.00	283.56	23.38	26003.13	33250.26	-6856.32	2202.17	2205.62
7/1/2001	2133.74	349.26	7.96	340.16	20.59	25985.29	33190.26	-6813.28	2202.31	2203.76
8/1/2001	2132.27	359.44	8.71	374.17	32.78	25919.24	33550.26	-7237.65	2203.29	2206.74
9/1/2001	2141.32	446.86	6.42	441.94	41.15	25849.79	33350.26	-7104.66	2203.86	2205.31
10/1/2001	2136.23	271.05	5.35	285.25	50.24	25739.70	35310.26	-9171.61	2203.72	2207.17
11/1/2001	2193.29	154.02	0.35	163.79	37.50	25648.45	35210.26	-9160.26	2203.47	2204.92
12/1/2001	2189.96	113.83	0.89	114.02	21.35	25603.46	35110.26	-9103.83	2203.21	2206.66

Appendix Table 8. The Inflow with Dam and Without Dam of Nashe Watershed from (1985-2001)

Month/ Date	Nashe Simu. Flow (m^3/sec.)	Q with Dam	Q with Out Dam	Q Ungauged	Total Inflow Q Gauged+un gauged	No.Days	Inflow Vol.(mcm)	Outflow Vol.(mcm)	Inflow Dam Gauged (mcm)
Jan-85	39.59	39.59	0.27	0.00	39.59	31.00	106.04	110.00	106.04
Feb-85	22.38	22.38	0.58	0.00	22.38	28.00	54.14	53.68	54.14
Mar-85	17.94	17.94	0.70	0.00	17.94	31.00	48.05	45.32	48.05
Apr-85	46.82	46.82	3.53	0.00	46.82	30.00	121.36	110.03	121.36
May-85	78.88	78.88	10.17	0.00	78.88	31.00	211.27	209.02	211.27
Jun-85	123.90	123.90	13.52	0.00	123.90	30.00	321.15	316.22	321.15
Jul-85	153.00	153.00	16.11	0.00	153.00	31.00	409.80	414.88	409.80
Aug-85	192.90	192.90	11.99	0.00	192.90	31.00	516.66	517.47	516.66
Sep-85	141.30	141.30	12.59	0.00	141.30	30.00	366.25	500.77	366.25
Oct-85	94.36	94.36	13.70	0.00	94.36	31.00	252.73	389.98	252.73
Nov-85	49.56	49.56	14.33	0.00	49.56	30.00	128.46	256.56	128.46
Dec-85	29.44	29.44	14.69	0.00	29.44	31.00	78.85	77.54	78.85
Jan-86	20.39	20.39	12.30	0.00	20.39	31.00	54.61	142.22	54.61
Feb-86	16.89	16.89	10.71	0.00	16.89	28.00	40.86	37.86	40.86
Mar-86	18.35	18.35	15.38	0.00	18.35	31.00	49.15	47.17	49.15
Apr-86	16.64	16.64	14.25	0.00	16.64	30.00	43.13	40.56	43.13
May-86	88.46	88.46	9.64	0.00	88.46	31.00	236.93	221.02	236.93
Jun-86	138.60	138.60	11.85	0.00	138.60	30.00	359.25	353.55	359.25
Jul-86	164.50	164.50	16.50	0.00	164.50	31.00	440.60	440.06	440.60
Aug-86	177.10	177.10	16.75	0.00	177.10	31.00	474.34	474.61	474.34
Sep-86	175.10	175.10	15.50	0.00	175.10	30.00	453.86	490.15	453.86

Oct-86	127.20	127.20	15.38	0.00	127.20	31.00	340.69	363.99	340.69
Nov-86	90.11	90.11	15.30	0.00	90.11	30.00	233.57	247.61	233.57
Dec-86	88.88	88.88	10.91	0.00	88.88	31.00	238.06	134.67	238.06
Jan-87	26.48	26.48	7.10	0.00	26.48	31.00	70.92	61.01	70.92
Feb-87	19.51	19.51	4.88	0.00	19.51	28.00	47.20	44.66	47.20
Mar-87	25.63	25.63	3.64	0.00	25.63	31.00	68.65	66.88	68.65
Apr-87	59.46	59.46	7.66	0.00	59.46	30.00	154.12	142.12	154.12
May-87	60.57	60.57	12.67	0.00	60.57	31.00	162.23	165.07	162.23
Jun-87	79.02	79.02	21.01	0.00	79.02	30.00	204.82	197.17	204.82
Jul-87	163.80	163.80	25.51	0.00	163.80	31.00	438.72	434.97	438.72
Aug-87	169.60	169.60	32.32	0.00	169.60	31.00	454.26	461.76	454.26
Sep-87	170.20	170.20	26.97	0.00	170.20	30.00	441.16	440.90	441.16
Oct-87	113.80	113.80	19.61	0.00	113.80	31.00	304.80	314.44	304.80
Nov-87	65.48	65.48	11.49	0.00	65.48	30.00	169.72	184.52	169.72
Dec-87	70.73	70.73	7.23	0.00	70.73	31.00	189.44	178.89	189.44
Jan-88	41.09	41.09	4.98	0.00	41.09	31.00	110.06	116.11	110.06
Feb-88	39.26	39.26	3.96	0.00	39.26	28.00	94.98	93.07	94.98
Mar-88	31.67	31.67	3.50	0.00	31.67	31.00	84.82	83.65	84.82
Apr-88	31.20	31.20	3.33	0.00	31.20	30.00	80.87	78.64	80.87
May-88	59.24	59.24	12.27	0.00	59.24	31.00	158.67	147.20	158.67
Jun-88	88.16	88.16	22.85	0.00	88.16	30.00	228.51	220.24	228.51
Jul-88	166.00	166.00	27.67	0.00	166.00	31.00	444.61	445.69	444.61
Aug-88	317.90	317.90	31.04	0.00	317.90	31.00	851.46	846.91	851.46
Sep-88	188.30	188.30	32.24	0.00	188.30	30.00	488.07	493.00	488.07
Oct-88	107.80	107.80	26.51	0.00	107.80	31.00	288.73	309.89	288.73
Nov-88	56.38	56.38	16.92	0.00	56.38	30.00	146.14	157.57	146.14
Dec-88	33.67	33.67	10.82	0.00	33.67	31.00	90.18	89.08	90.18

Jan-89	19.05	19.05	6.12	0.00	19.05	31.00	51.02	47.35	51.02
Feb-89	11.51	11.51	5.01	0.00	11.51	28.00	27.84	23.81	27.84
Mar-89	17.27	17.27	5.10	0.00	17.27	31.00	46.26	39.45	46.26
Apr-89	36.33	36.33	10.43	0.00	36.33	30.00	94.17	83.95	94.17
May-89	59.65	59.65	10.93	0.00	59.65	31.00	159.77	155.53	159.77
Jun-89	125.30	125.30	14.28	0.00	125.30	30.00	324.78	326.33	324.78
Jul-89	173.20	173.20	25.49	0.00	173.20	31.00	463.90	463.36	463.90
Aug-89	.90	.90	28.04	0.00	.90	31.00	621.12	617.37	621.12
Sep-89	171.10	171.10	30.22	0.00	171.10	30.00	443.49	462.15	443.49
Oct-89	96.34	96.34	22.97	0.00	96.34	31.00	258.04	278.02	258.04
Nov-89	51.49	51.49	14.86	0.00	51.49	30.00	133.46	141.24	133.46
Dec-89	28.34	28.34	14.18	0.00	28.34	31.00	75.91	74.73	75.91
Jan-90	17.92	17.92	9.22	0.00	17.92	31.00	48.00	42.59	48.00
Feb-90	14.70	14.70	7.98	0.00	14.70	28.00	35.56	31.89	35.56
Mar-90	21.92	21.92	6.53	0.00	21.92	31.00	58.71	53.14	58.71
Apr-90	48.34	48.34	6.09	0.00	48.34	30.00	125.30	126.44	125.30
May-90	75.63	75.63	9.78	0.00	75.63	31.00	202.57	186.23	202.57
Jun-90	107.20	107.20	14.40	0.00	107.20	30.00	277.86	285.38	277.86
Jul-90	146.90	146.90	25.46	0.00	146.90	31.00	393.46	378.99	393.46
Aug-90	160.20	160.20	48.17	0.00	160.20	31.00	429.08	434.97	429.08
Sep-90	221.90	221.90	36.62	0.00	221.90	30.00	575.16	573.35	575.16
Oct-90	132.30	132.30	24.68	0.00	132.30	31.00	354.35	366.41	354.35
Nov-90	83.65	83.65	14.45	0.00	83.65	30.00	216.82	237.30	216.82
Dec-90	82.85	82.85	8.87	0.00	82.85	31.00	221.91	234.52	221.91
Jan-91	46.02	46.02	5.26	0.00	46.02	31.00	123.26	105.88	123.26
Feb-91	25.81	25.81	3.39	0.00	25.81	28.00	62.44	61.16	62.44
Mar-91	32.18	32.18	3.78	0.00	32.18	31.00	86.19	88.33	86.19

Apr-91	90.94	90.94	7.46	0.00	90.94	30.00	235.72	209.90	235.72
May-91	84.04	84.04	10.86	0.00	84.04	31.00	225.09	227.74	225.09
Jun-91	113.40	113.40	18.96	0.00	113.40	30.00	293.93	296.01	293.93
Jul-91	165.00	165.00	27.71	0.00	165.00	31.00	441.94	436.58	441.94
Aug-91	217.10	217.10	37.17	0.00	217.10	31.00	581.48	574.25	581.48
Sep-91	185.90	185.90	32.63	0.00	185.90	30.00	481.85	497.92	481.85
Oct-91	160.80	160.80	20.99	0.00	160.80	31.00	430.69	440.06	430.69
Nov-91	75.33	75.33	12.46	0.00	75.33	30.00	195.26	207.33	195.26
Dec-91	40.90	40.90	7.36	0.00	40.90	31.00	109.55	111.80	109.55
Jan-92	22.60	22.60	4.80	0.00	22.60	31.00	60.53	57.59	60.53
Feb-92	14.49	14.49	3.63	0.00	14.49	28.00	35.05	30.92	35.05
Mar-92	14.62	14.62	4.30	0.00	14.62	31.00	39.16	33.29	39.16
Apr-92	27.65	27.65	7.15	0.00	27.65	30.00	71.67	69.02	71.67
May-92	57.76	57.76	12.58	0.00	57.76	31.00	154.70	141.18	154.70
Jun-92	114.00	114.00	17.81	0.00	114.00	30.00	295.49	291.86	295.49
Jul-92	151.70	151.70	24.93	0.00	151.70	31.00	406.31	404.71	406.31
Aug-92	145.90	145.90	26.88	0.00	145.90	31.00	390.78	392.92	390.78
Sep-92	135.70	135.70	36.80	0.00	135.70	30.00	351.73	358.47	351.73
Oct-92	75.55	75.55	26.72	0.00	75.55	31.00	202.35	220.16	202.35
Nov-92	44.37	44.37	18.08	0.00	44.37	30.00	115.01	118.43	115.01
Dec-92	25.73	25.73	16.12	0.00	25.73	31.00	68.92	68.89	68.92
Jan-93	14.20	14.20	9.85	0.00	14.20	31.00	38.03	34.69	38.03
Feb-93	14.23	14.23	6.85	0.00	14.23	28.00	34.43	30.12	34.43
Mar-93	22.93	22.93	6.60	0.00	22.93	31.00	61.42	56.94	61.42
Apr-93	28.57	28.57	14.36	0.00	28.57	30.00	74.05	69.78	74.05
May-93	69.42	69.42	14.90	0.00	69.42	31.00	185.93	189.15	185.93
Jun-93	85.12	85.12	19.34	0.00	85.12	30.00	220.63	212.10	220.63

Jul-93	125.40	125.40	26.46	0.00	125.40	31.00	335.87	331.05	335.87
Aug-93	157.50	157.50	35.65	0.00	157.50	31.00	421.85	423.46	421.85
Sep-93	157.10	157.10	34.56	0.00	157.10	30.00	407.20	405.91	407.20
Oct-93	92.31	92.31	29.99	0.00	92.31	31.00	247.24	264.25	247.24
Nov-93	50.36	50.36	17.48	0.00	50.36	30.00	130.53	140.36	130.53
Dec-93	36.08	36.08	10.47	0.00	36.08	31.00	96.64	92.70	96.64
Jan-94	36.56	36.56	6.21	0.00	36.56	31.00	97.92	94.41	97.92
Feb-94	19.63	19.63	4.14	0.00	19.63	28.00	47.49	47.63	47.49
Mar-94	24.04	24.04	3.63	0.00	24.04	31.00	64.39	58.34	64.39
Apr-94	41.35	41.35	4.87	0.00	41.35	30.00	107.18	109.85	107.18
May-94	108.30	108.30	10.08	0.00	108.30	31.00	290.07	278.02	290.07
Jun-94	127.70	127.70	18.06	0.00	127.70	30.00	331.00	318.56	331.00
Jul-94	166.10	166.10	24.25	0.00	166.10	31.00	444.88	456.94	444.88
Aug-94	196.10	196.10	25.90	0.00	196.10	31.00	525.23	516.40	525.23
Sep-94	127.60	127.60	24.67	0.00	127.60	30.00	330.74	346.03	330.74
Oct-94	88.93	88.93	15.97	0.00	88.93	31.00	238.19	248.45	238.19
Nov-94	67.90	67.90	10.12	0.00	67.90	30.00	176.00	178.82	176.00
Dec-94	35.74	35.74	6.13	0.00	35.74	31.00	95.73	97.55	95.73
Jan-95	22.07	22.07	3.65	0.00	22.07	31.00	59.11	58.04	59.11
Feb-95	13.66	13.66	3.27	0.00	13.66	28.00	33.05	30.43	33.05
Mar-95	21.24	21.24	3.92	0.00	21.24	31.00	56.89	49.52	56.89
Apr-95	47.11	47.11	5.47	0.00	47.11	30.00	122.11	116.67	122.11
May-95	83.67	83.67	10.80	0.00	83.67	31.00	224.10	216.31	224.10
Jun-95	137.60	137.60	14.02	0.00	137.60	30.00	356.66	349.66	356.66
Jul-95	187.20	187.20	21.14	0.00	187.20	31.00	501.40	503.54	501.40
Aug-95	181.60	181.60	26.26	0.00	181.60	31.00	486.40	488.00	486.40
Sep-95	136.40	136.40	27.23	0.00	136.40	30.00	353.55	364.69	353.55

Oct-95	151.70	151.70	19.04	0.00	151.70	31.00	406.31	414.62	406.31
Nov-95	101.90	101.90	11.61	0.00	101.90	30.00	264.12	262.05	264.12
Dec-95	51.35	51.35	8.11	0.00	51.35	31.00	137.54	149.03	137.54
Jan-96	31.58	31.58	7.06	0.00	31.58	31.00	84.58	84.64	84.58
Feb-96	19.34	19.34	4.74	0.00	19.34	28.00	46.79	45.31	46.79
Mar-96	25.97	25.97	5.07	0.00	25.97	31.00	69.56	62.33	69.56
Apr-96	18.68	18.68	7.07	0.00	18.68	30.00	48.42	49.14	48.42
May-96	63.11	63.11	15.52	0.00	63.11	31.00	169.03	166.22	169.03
Jun-96	112.40	112.40	21.98	0.00	112.40	30.00	291.34	272.94	291.34
Jul-96	135.70	135.70	26.98	0.00	135.70	31.00	363.46	362.39	363.46
Aug-96	156.50	156.50	33.30	0.00	156.50	31.00	419.17	422.92	419.17
Sep-96	129.60	129.60	26.01	0.00	129.60	30.00	335.92	343.70	335.92
Oct-96	130.30	130.30	18.81	0.00	130.30	31.00	349.00	349.00	349.00
Nov-96	79.81	79.81	13.55	0.00	79.81	30.00	206.87	220.37	206.87
Dec-96	40.62	40.62	8.81	0.00	40.62	31.00	108.80	116.46	108.80
Jan-97	28.39	28.39	5.48	0.00	28.39	31.00	76.04	71.54	76.04
Feb-97	18.28	18.28	3.60	0.00	18.28	28.00	44.22	42.65	44.22
Mar-97	9.98	9.98	4.18	0.00	9.98	31.00	26.73	24.00	26.73
Apr-97	8.28	8.28	7.56	0.00	8.28	30.00	21.47	20.45	21.47
May-97	63.98	63.98	13.09	0.00	63.98	31.00	171.36	159.82	171.36
Jun-97	131.80	131.80	22.41	0.00	131.80	30.00	341.63	332.29	341.63
Jul-97	124.90	124.90	30.16	0.00	124.90	31.00	334.53	334.00	334.53
Aug-97	145.00	145.00	31.30	0.00	145.00	31.00	388.37	389.98	388.37
Sep-97	143.90	143.90	26.99	0.00	143.90	30.00	372.99	381.54	372.99
Oct-97	177.30	177.30	26.38	0.00	177.30	31.00	474.88	468.72	474.88
Nov-97	79.90	79.90	21.08	0.00	79.90	30.00	207.10	227.84	207.10
Dec-97	40.81	40.81	12.57	0.00	40.81	31.00	109.31	116.38	109.31

Jan-98	23.32	23.32	7.94	0.00	23.32	31.00	62.46	60.02	62.46
Feb-98	13.12	13.12	5.07	0.00	13.12	28.00	31.74	27.87	31.74
Mar-98	7.65	7.65	5.37	0.00	7.65	31.00	20.49	16.58	20.49
Apr-98	25.08	25.08	3.93	0.00	25.08	30.00	65.01	56.56	65.01
May-98	56.02	56.02	10.39	0.00	56.02	31.00	150.04	142.22	150.04
Jun-98	101.80	101.80	17.29	0.00	101.80	30.00	263.87	260.24	263.87
Jul-98	149.80	149.80	23.18	0.00	149.80	31.00	401.22	398.55	401.22
Aug-98	156.80	156.80	27.43	0.00	156.80	31.00	419.97	416.49	419.97
Sep-98	140.40	140.40	23.87	0.00	140.40	30.00	363.92	377.14	363.92
Oct-98	131.40	131.40	23.71	0.00	131.40	31.00	351.94	360.51	351.94
Nov-98	79.38	79.38	16.40	0.00	79.38	30.00	205.75	211.58	205.75
Dec-98	54.69	54.69	9.35	0.00	54.69	31.00	146.48	150.53	146.48
Jan-99	26.92	26.92	6.54	0.00	26.92	31.00	72.10	73.71	72.10
Feb-99	16.71	16.71	4.36	0.00	16.71	28.00	40.42	37.30	40.42
Mar-99	42.10	42.10	2.56	0.00	42.10	31.00	112.76	100.15	112.76
Apr-99	34.37	34.37	1.96	0.00	34.37	30.00	89.09	91.94	89.09
May-99	79.23	79.23	10.08	0.00	79.23	31.00	212.21	206.80	212.21
Jun-99	92.16	92.16	19.38	0.00	92.16	30.00	238.88	233.85	238.88
Jul-99	151.30	151.30	22.47	0.00	151.30	31.00	405.24	398.28	405.24
Aug-99	131.10	131.10	25.12	0.00	131.10	31.00	351.14	359.98	351.14
Sep-99	121.70	121.70	25.31	0.00	121.70	30.00	315.45	315.19	315.45
Oct-99	91.70	91.70	29.97	0.00	91.70	31.00	245.61	256.24	245.61
Nov-99	54.54	54.54	17.94	0.00	54.54	30.00	141.37	149.30	141.37
Dec-99	33.23	33.23	10.25	0.00	33.23	31.00	89.00	91.01	89.00
Jan-00	22.29	22.29	6.14	0.00	22.29	31.00	59.70	57.13	59.70
Feb-00	16.22	16.22	3.71	0.00	16.22	28.00	39.24	36.92	39.24
Mar-00	28.23	28.23	2.30	0.00	28.23	31.00	75.61	73.31	75.61

Apr-00	46.18	46.18	4.65	0.00	46.18	30.00	119.70	110.00	119.70
May-00	43.69	43.69	9.33	0.00	43.69	31.00	117.02	123.26	117.02
Jun-00	89.52	89.52	16.28	0.00	89.52	30.00	232.04	216.07	232.04
Jul-00	249.90	249.90	23.82	0.00	249.90	31.00	669.33	652.19	669.33
Aug-00	219.10	219.10	26.99	0.00	219.10	31.00	586.84	589.78	586.84
Sep-00	169.90	169.90	26.09	0.00	169.90	30.00	440.38	459.82	440.38
Oct-00	96.41	96.41	23.91	0.00	96.41	31.00	258.22	278.29	258.22
Nov-00	53.64	53.64	16.69	0.00	53.64	30.00	139.03	146.14	139.03
Dec-00	34.79	34.79	11.38	0.00	34.79	31.00	93.18	89.62	93.18
Jan-01	20.66	20.66	6.64	0.00	20.66	31.00	55.34	53.19	55.34
Feb-01	15.58	15.58	4.42	0.00	15.58	28.00	37.69	34.74	37.69
Mar-01	28.11	28.11	6.89	0.00	28.11	31.00	75.29	66.85	75.29
Apr-01	25.64	25.64	6.87	0.00	25.64	30.00	66.46	67.57	66.46
May-01	14.56	14.56	12.24	0.00	14.56	31.00	39.00	41.65	39.00
Jun-01	115.80	115.80	16.36	0.00	115.80	30.00	300.15	283.56	300.15
Jul-01	130.40	130.40	24.24	0.00	130.40	31.00	349.26	340.16	349.26
Aug-01	134.20	134.20	23.95	0.00	134.20	31.00	359.44	374.17	359.44
Sep-01	172.40	172.40	22.72	0.00	172.40	30.00	446.86	441.94	446.86
Oct-01	101.20	101.20	17.90	0.00	101.20	31.00	271.05	285.25	271.05
Nov-01	59.42	59.42	11.69	0.00	59.42	30.00	154.02	163.79	154.02
Dec-01	42.50	42.50	7.55	0.00	42.50	31.00	113.83	114.02	113.83

Appendix Table 9. Time Series of Observed and Simulated Discharge of Nashe Catchment.

Month/date	Obs.Discharge	Sim.Discharge	Month/Date	Obs.Calibrated	Simulated Discharge
Jan-85	19.58	41.07	Sep-93	181.98	156.6
Feb-85	10.89	22.19	Oct-93	51.8	98.66
Mar-85	6.56	16.92	Nov-93	74.21	54.15
Apr-85	90.89	42.45	Dec-93	61.51	34.61
May-85	101.895	78.04	Jan-94	20.96	35.25
Jun-85	129.005	122	Feb-94	37.034	19.69
Jul-85	150.896	154.9	Mar-94	7.453	21.78
Aug-85	162.58	193.2	Apr-94	21.56	42.38
Sep-85	120.986	193.2	May-94	127.24	103.8
Oct-85	98.256	145.6	Jun-94	169.96	122.9
Nov-85	73.987	98.98	Jul-94	130.94	170.6
Dec-85	89.896	28.95	Aug-94	280.1	192.8
Jan-86	39.895	53.1	Sep-94	156.2	133.5
Feb-86	50.586	15.65	Oct-94	102.21	92.76
Mar-86	20.865	17.61	Nov-94	50.89	68.99
Apr-86	18.526	15.65	Dec-94	19.56	36.42
May-86	68.023	82.52	Jan-95	10.9	21.67
Jun-86	129.3	136.4	Feb-95	29.6	12.58
Jul-86	192.32	164.3	Mar-95	42.46	18.49
Aug-86	206.58	177.2	Apr-95	75.56	45.01
Sep-86	150.68	189.1	May-95	98.68	80.76
Oct-86	171.89	135.9	Jun-95	110.47	134.9
Nov-86	110.58	95.53	Jul-95	161.58	188
Dec-86	70.25	50.28	Aug-95	199.2	182.2
Jan-87	30.89	22.78	Sep-95	158.45	140.7
Feb-87	48.256	18.46	Oct-95	130.23	154.8
Mar-87	12.358	24.97	Nov-95	72.3	101.1
Apr-87	48.02	54.83	Dec-95	26.56	55.64
May-87	65.568	61.63	Jan-96	41.15	31.6
Jun-87	102.23	76.07	Feb-96	46.98	18.73
Jul-87	160.21	162.4	Mar-96	42.56	23.27
Aug-87	178.23	172.4	Apr-96	4.54	18.96
Sep-87	197.03	170.1	May-96	42.245	62.06
Oct-87	126.26	117.4	Jun-96	91.65	105.3
Nov-87	105.23	71.19	Jul-96	121.68	135.3
Dec-87	31.25	66.79	Aug-96	126.65	157.9
Jan-88	58.89	43.35	Sep-96	110.36	132.6
Feb-88	80.56	38.47	Oct-96	120.98	130.3

Mar-88	25.69	31.23	Nov-96	59.98	85.02
Apr-88	20.56	30.34	Dec-96	20.54	43.48
May-88	53.2	54.96	Jan-97	11.78	26.71
Jun-88	71.89	84.97	Feb-97	20.63	17.63
Jul-88	111.56	166.4	Mar-97	19.23	8.962
Aug-88	148.58	316.2	Apr-97	2.789	7.888
Sep-88	191.31	190.2	May-97	56.45	59.67
Oct-88	129.56	115.7	Jun-97	119.78	128.2
Nov-88	85.987	60.79	Jul-97	142.6	124.7
Dec-88	63.86	33.26	Aug-97	199.2	145.6
Jan-89	75.67	17.68	Sep-97	159.3	147.2
Feb-89	15.67	9.843	Oct-97	150.2	175
Mar-89	20.87	14.73	Nov-97	40.36	87.9
Apr-89	28.75	32.39	Dec-97	20.23	43.45
May-89	62.23	58.07	Jan-98	59.56	22.41
Jun-89	102.2	125.9	Feb-98	36.65	11.52
Jul-89	168.23	173	Mar-98	5.96	6.191
Aug-89	192.56	230.5	Apr-98	41.4	21.82
Sep-89	142.25	178.3	May-98	22.98	53.1
Oct-89	165.28	103.8	Jun-98	72.98	100.4
Nov-89	96.87	54.49	Jul-98	113.8	148.8
Dec-89	73.22	27.9	Aug-98	120.8	155.5
Jan-90	30.23	15.9	Sep-98	117.5	145.5
Feb-90	12.25	13.18	Oct-98	152.8	134.6
Mar-90	35.56	19.84	Nov-98	100.5	81.63
Apr-90	62.35	48.78	Dec-98	87.6	56.2
May-90	86.2	69.53	Jan-99	3.23	27.52
Jun-90	123.23	110.1	Feb-99	45.5	15.42
Jul-90	170.98	141.5	Mar-99	60.1	37.39
Aug-90	183.23	162.4	Apr-99	81.89	35.47
Sep-90	200.23	221.2	May-99	98.48	77.21
Oct-90	152.3	136.8	Jun-99	70.23	90.22
Nov-90	99.5	91.55	Jul-99	128.6	148.7
Dec-90	61.9	87.56	Aug-99	117.56	134.4
Jan-91	66.26	39.53	Sep-99	156.5	121.6
Feb-91	12.56	25.28	Oct-99	108.5	95.67
Mar-91	20.56	32.98	Nov-99	77.698	57.6
Apr-91	76.58	80.98	Dec-99	38.56	33.98
May-91	79.36	85.03	Jan-00	10.589	21.33
Jun-91	128.78	114.2	Feb-00	5.65	15.26
Jul-91	177.56	163	Mar-00	12.68	27.37
Aug-91	248.23	214.4	Apr-00	15.68	42.44

Sep-91	201.1	192.1	May-00	24.68	46.02
Oct-91	199.3	164.3	Jun-00	98.31	83.36
Nov-91	99.55	79.99	Jul-00	269.89	243.5
Dec-91	57.23	41.74	Aug-00	278.23	220.2
Jan-92	32.5	21.5	Sep-00	149.58	177.4
Feb-92	5.56	12.78	Oct-00	67.36	103.9
Mar-92	2.02	12.43	Nov-00	39.48	56.38
Apr-92	46.69	26.63	Dec-00	28.78	33.46
May-92	73.23	52.71	Jan-01	7.56	19.86
Jun-92	139.69	112.6	Feb-01	41.89	14.36
Jul-92	142.6	151.1	Mar-01	11.88	24.96
Aug-92	181.35	146.7	Apr-01	42.56	26.07
Sep-92	168.5	138.3	May-01	19.15	15.55
Oct-92	42.99	82.2	Jun-01	138.25	109.4
Nov-92	68.96	45.69	Jul-01	157.69	127
Dec-92	49.68	25.72	Aug-01	169.87	139.7
Jan-93	6.5	12.95	Sep-01	219.89	170.5
Feb-93	5.98	12.45	Oct-01	81.8	106.5
Mar-93	39.63	21.26	Nov-01	16.96	63.19
Apr-93	18.41	26.92	Dec-01	25.8	42.57
May-93	85.2	70.62			
Jun-93	106.3	81.83			
Jul-93	146.5	123.6			
Aug-93	192.51	158.1			

Appendix Table 10. Hydrological Component of Nashe Watershed.

Year	Prec.(mm)	Surf(mm)	Lateral Q(mm)	GWQ(mm)	Perc. Late(mm)	SW(mm)	ET(mm)	PET(mm)	Water Yield(mm)	Sed Yield(mm)
1985	0	0	0	0	0	0	0	0	0	0
1986	0	0	0	0	0	0	0	0	0	0
1987	1516.2	292.05	39.46	720.87	814.88	42.66	357.96	870.86	1088.11	59.82
1988	1698.6	342.36	44.44	799.4	943.84	41.53	329.94	799.19	1226.54	55.54
1989	1688.9	346.45	42.57	827.97	880.94	55.64	369.15	836.14	1261	65.43
1990	1772.3	431.06	43.83	859.45	897.34	39.88	381.89	904.51	1378.74	79.92
1991	1605.6	274.37	42.97	868.34	887.73	39.67	380.53	907.1	1.51	45.54
1992	1834.8	373.12	46.73	842.71	960.78	60.51	390.51	879.38	1306.12	60.85
1993	1880	376.68	49.45	954.87	1022.66	43.82	405.76	915.05	1430.55	64.11
1994	1275.8	199.72	34.76	833.05	711.68	38.52	339.71	894.34	1114.23	41.29
1995	1376.2	227.51	36.15	704.95	725.55	53.51	369.5	906.89	1006.92	39.45
1996	1629	352.67	40.94	758.97	839.19	50.79	372.04	874.9	1191.57	67.84
1997	1809.3	380.05	45.86	811.52	939.06	47.78	413.39	943	1278.94	66.15
1998	1458.6	250	39.16	810.37	807.09	40.25	357.91	887.6	1142.74	50.77
1999	1534.7	283.86	40.25	778.56	826.29	42.15	375.23	980.45	1143.78	51.78
2000	1490.6	234.88	39.77	771.95	797.68	50.8	408.02	997.97	1087.54	39.57
2001	1350.8	217.44	35.36	746.78	702.79	48.68	400.9	936.6	1039.9	39.6
2002	1686.4	355.39	43.05	760.17	879.44	46.88	391.19	961.71	1197.28	63.48
2003	1349.3	247.25	35.47	730.03	717.18	46.72	354.29	932.67	1052.33	46.73
2004	1489.3	267.56	39.15	729.82	794.86	46.13	382.59	947.61	1074.56	47.81
2005	1475.2	248.34	39.49	761.83	802.46	40.52	387.61	961.91	1089.4	44.23
2006	1620.1	307.01	41.96	776.74	850.69	48.26	395.91	945.48	1166.22	48.07

2007	1656.3	294.45	44.36	845.65	917.69	38.63	387.54	920.18	1227.97	53.32
2008	1715.7	325.65	45.62	868.73	949.7	45.37	362.88	937.61	1285.27	63.14
2009	1452.9	290.19	36.86	788.59	736.38	46.01	386.68	955.4	1159	49.88
2010	1434	269.39	37.1	757.95	759.94	43.91	360.05	886.79	1104.72	50.54
2011	1419.6	258.25	38.06	724.8	787.97	39.48	328.95	893.95	1059.2	42.2
2012	1476.4	194.89	39.37	696.54	800.33	60.75	410.4	942.44	968.04	26.03
2013	1543.4	277.19	42.3	833.96	880.11	44.15	340.16	896.39	1195.29	45.76
2014	1966.4	320.86	53.36	922.73	1121.8	60.45	386.75	781.52	1343.95	54.36

Appendix Table 11. The Average maximum and Minimum Temperature of 5 Stations.

Station Name	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Nashe Max.Temp	25.32	25.96	26.18	26.09	25.93	24.43	22.45	22.4	22.74	23.29	23.94	24.11
Shambu Max.Temp	12.04	13.06	13.11	13.33	13.63	12.62	11.89	11.79	11.83	11.55	11.36	11.63
Homi Max.Temp	26.77	27.15	27.4	27.18	27.46	26.51	25.78	25.77	26.32	26.61	26.38	25.97
Alibo Max.Temp	26.19	26.64	26.98	26.91	26.22	25.2	23.72	23.61	23.4	24.12	24.45	25.38
Nashe Min.Temp	8.22	8.97	9.16	9.25	8.86	8.83	8.98	9.05	9.19	8.95	8.28	8.95
Shambu Min.Temp	21.45	22	21.98	21.55	21.11	19.22	17.54	17.87	19.44	20.31	20.8	21.58
Homi Min.Temp	9.21	9	8.97	8.99	8.68	10.05	10.3	10.21	10.11	10.05	9.75	9.53
Alibo Min.Temp	8.6	9.45	9.94	10.12	10.26	9.04	9.4	9.09	9.25	8.67	8.9	7.96

DECLARATION

This thesis entitled “Watershed Modeling SWAT: A case study of Nashe Watershed” is submitted to Department of Hydraulic and Environmental Engineering at the School of Graduate Studies of Jimma University as partial fulfillment of the requirement of the Master of Science in Hydraulic Engineering.

The study of this was carried out from February 2016 G.C up to December 2019 G.C at Jimma University under the supervision of Dr.Tamene Adugna (PhD) a main supervisor and Mr. Megersa Kebede (MSc) as a co- supervisor.

I, Abdena Yadessa, hereby declare the work presented in this thesis is my own work and significant outside input is acknowledge properly.

Where I have consulted the published work of others, this is always clearly attributed. Where I have quoted from the work of others, the source is always given. With the exception of such quotations, this is entirely my own work. I have acknowledged all main sources of help.

Abdena Yadessa Keno

Sept, 2019

Jimma University, Ethiopia