SIMULATING THE IMPACT OF CHECK DAMS ON RIVER FLOW- A CASE STUDY IN BHARATHAPUZHA RIVER BASIN

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PROJECT REPORT

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DECLARATION

We hereby declare that this project entitled "**SIMULATING THE IMPACT OF CHECK DAMS ON RIVER FLOW- A CASE STUDY IN BHARATHAPUZHA RIVER BASIN**" is a bonafide record of project work done by us during the course of project and the report has not previously formed the basis for the award to us for any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Place: Tavanur
Date : - 12 – 2010

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Certified that this project report entitled "**SIMULATING THE IMPACT OF CHECK DAMS ON RIVER FLOW- A CASE STUDY IN BHARATHAPUZHA RIVER BASIN**" is a record of project work done independently by Arshana, V.K, Haritha, A, Hredhya Haridas, Jyothish, V. and Rashida Rajuva, T.A. under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to them.

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Dedicated to

The Almighty,

Loving parents

& Teachers

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SYMBOLS AND ABBREVIATIONS

ASCII	American Standard Code for Information Interchange
AISLUS	All India Soil and Land Use Survey
Apr	April
Aug	August
AV	Arc View
cm	centimeter(s)
CN	Curve Number
COD	Coefficient Of Determination
dBASE	Data base
Dec	December
DEM	Digital Elevation Model
D_RECH	Deep recharge
EIMU	Erosion Intensity Mapping Units
et.al	and others
ET	Evapotranspiration
EVAP	Evaporation
FAO	Food and Agricultural Organisation
FCC	False Colour Composite
Feb	February
GIS	Geographic Information System
GIUH	Geomorphologic Instantaneous Unit Hydrograph
GPS	Global Positioning System
GWQ	Ground Water Runoff
GWDelay	Ground Water Delay(days)
ha	hectare
ha m	hectare metre(s)
h	hour
HRUs	Hydrologic Response Units
IARI	Indian Agricultural Research Institute
ILWIS	Integrated Land and Water Information System
IRS	Indian Remote Sensing
Jan	January
Jul	July
Jun	June
KAU	Kerala Agricultural University
KCAET	Kelappaji College Agricultural Engineering & Technology
Kg	Kilogram(s)
km	Kilometre(s)
km^2	Square Kilometer(s)
kPa	kiloPascal
Lat	Lateral Flow
LISS	Linear Imaging and Self Scanning
LWRCE	Land and Water Resources and Conservation Engineering
m	metre(s)

M ha m	million hectare metre(s)
M km^3	million cubic kilometre(s)
Mar	March
MAX	Maximum
MIN	Minimum
mm	millimeter
MSL	Mean Sea Level
NBSS & LUP	National Bureau of Soil Survey and Land Use Planning
Nov	November
NRSA	National Remote Sensing Agency
NSE	Nash–Sutcliffe Simulation model Efficiency
Oct	October
PAN	Panchromatic
PET	Potential Evapotranspiration
PREC	Precipitation
res	reservoir
s	second
SCS	Soil Conservation Service
SD	Standard Deviation
Sep	September
SOI	Survey of India
SOL_AWC	Soil Available water capacity
Sur_Q	Surface Runoff
SWAT	Soil and Water Assessment Tool
t	tonnes
TEMP	Temperature
TM	Thematic map
USDA	United State Department of Agriculture
VOL	Volume
VOL_IMPND	Volume of water impounded
WEPP	Water Erosion Prediction Project
WRD	Water Resource Department
&	and
α_BF	Baseflow Recession Coefficient

Introduction

Chapter 1

INTRODUCTION

Water appears to be so common that it is hard to understand that its availability is limited. It is a very scarce commodity which one cannot afford to waste. We have to constantly remind ourselves that it is water which makes the earth so green and full of life, and thereby different from any other known planet in the universe. Hence, we have to make sure that we do not fritter away a single drop of this immeasurable wealth, and use it for the best developmental purposes, for sustaining human life and culture.

Out of the world's total available water of 1400 Mkm^3, about 95% is contained in oceans as saline water and 4% in the form of snow and ice. Thus, the fresh and unfrozen water is only 1% of total availability, of which 99% is ground water and only 1% is present as surface water in lakes, rivers, soil and atmosphere.

However, the State of Kerala is located at the extreme southern tip of the Indian subcontinent, blocked between the Arabian Sea to the west and the Western Ghats to the east. It has a vast stretch of coast that extends to a length of 580 km. Width of the state varies between 35 and 120 km. The state receives about 300 cm of average annual rainfall and blessed with 40 minor rivers and 4 medium rivers, chain of backwater bodies, tanks, ponds, springs and wells. Hence, Kerala is often considered as a land of water.

Kerala has been experiencing increasing incidents of drought in the recent past, due to the weather anomalies and developmental pressures resulting from the changes in landuse, traditional practices and life style of people. The state experiences severe shortage of water during the summer months. Compared to Indian national average, Kerala receives 2.78 times more rainfall, but due to the steep slopes and undulating topography, much of the rain water is not retained on land. The increase in population and subsequent expansion in irrigated agriculture and industrial growth necessitated the exploitation of more water resources. In addition to these, spatial and temporal variations in rainfall, high population density has aggravated the water scarcity. Thus, appropriate management of water resources of Kerala is essential.

It is felt that to solve the water scarcity of the State of Kerala, scientific water conservation measures have to be adopted on each river basin. A thorough water balance study is the first and foremost prerequisite for this task. This work envisages carrying out such a study in one of the important river basins of Kerala viz. Bharathapuzha.

Bharathapuzha, the second longest river of Kerala takes its origin at an elevation of +1964 m above M.S.L from Anamalai hills and flows through the districts of Coimbatore, Palakkad, Malappuram and Thrissur and joins Arabian Sea near the Ponnani town, where it is known as Ponnanipuzha. This river is the major water source for meeting drinking and irrigation demands of about 175 villages on either side of the river course.

The length of the river is 209 km with a catchment area of 6186 km^2. Its catchment area is spread over 11 taluks from the Western Ghats to the Arabian Sea. About 2/3rd of the drainage area of the basin, i.e. 4400 km^2, lies in Kerala state and the balance is in Tamil Nadu. Its major tributaries are Gayatripuzha, Chitturpuzha, Kalpathypuzha and Thuthapuzha.

Till a quarter century back, Bharathapuzha was perennial carrying significant amount of flow during summer seasons also. But, today the unscientific human activities have exploited the river and it has lost its capability to maintain flow in summer season and faces severe water stress. The major reasons for the depletion of the river include destruction of rainforest in its catchments, conversion of paddy fields into dwelling and commercial purposes, indiscriminate sand mining and sediment depositions due to cultivation along slopes of stream bank. Absence of sand in the riverbed affects the velocity of flow making it turbulent during the summer.

Depletion of summer flow and lowering of water table in the river basin have accelerated the intrusion of sea water into the main stream up to a distance of 10 to 12 km inland. Wells dug for water supply schemes on the river bank are not functional during lean seasons due to salinity.

Preliminary investigations into the hydrologic scenario of the river basin suggest that construction of a series of check dams at appropriate sites can improve the summer flow regime of the river. Construction of water retaining structures like check dams can be used to restrict the natural flow of water in the stream which in turn will raise the ground water levels of the regions at the downstream side of it. This will reduce the available gradient of flow of ground water in the surrounding area and will help to reduce the baseflow discharge into the stream. However, such an exercise requires a micro-scale water balance of the basin coupled with water demand analysis.

A detailed water balance analysis of a river basin is not practical by conventional means. One has to take the help of a distributed watershed model by incorporating the sciences of Remote Sensing (RS) and Geographic Information System (GIS). Hence, this study proposes to utilize the physically based distributed watershed model, Soil and Water Assessment Tool (SWAT).

SWAT is a watershed scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS). SWAT was developed to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time.

The model is physically based, computationally efficient and capable of continuous simulation over long time periods. Major model components include weather, hydrology, sediments and nutrients. In SWAT, a watershed is divided into multiple sub watersheds. These are further sub divided into Hydrologic Response Units (HRUs) that consist of homogeneous land use, management and soil characteristics.

In addition to predict the natural hydrologic components in a spatially distributed manner, the model can also predict the impact of the presence of on stream and off stream check dams and other water impoundments. This study envisages exploiting this capability of the model to analyze the impact of low height check dams in the river basin drainage network.

The specific objectives of the study are given as:

1. To study the interrelationship between morphological & hydrological characteristics of watershed using GIS & RS.
2. To study the impact of check dams on various hydrological processes such as surface runoff, lateral flow, baseflow and total water yield.
3. To suggest suitable sites and optimum number of check dams for augmenting river flow in summer.

Review of Literature

Chapter 2

REVIEW OF LITERATURE

2.1 Watershed and its characteristics using RS and GIS

Watershed is an area drained by river or a stream system. It is a natural unit in which hydrologic processes are taking place. Accordingly, all water conservation and management programs should be planned on a watershed basis. The major phases of hydrology which influences watershed characteristics are rainfall, infiltration, transpiration, evaporation, surface runoff and groundwater flow.

Runoff is the draining or flowing off of water, resulting from precipitation from a catchment area. Surface runoff consists of a fraction of precipitation that neither evaporates, transpires nor penetrates the surface to become groundwater. It represents the output from the catchment in a given unit of time. Surface runoff occurs when rainfall exceeds a soil's infiltration rate or maximum saturation level and all surface depression storage is filled to capacity. The rate of runoff flow depends on the ratio of rain intensity to the infiltration rate

Ravinder *et al.* (2002) made a study on GIS based digital delineation of watershed and its advantage over conventional manual method in Hazaribagh and Bankura district of Jharkhand and West Bengal. Besides, benefits of digital delineation procedure over convention (AISLUS) manual method have also been highlighted. The study indicated that the traditional manual delineation of watershed involves subjectivity in locating the ridge lines, which often leads to a slight change in actual watershed shape and thus area. Digital delineation of watershed boundaries avoids this subjectivity and thus gives more accurate shape and size of the delineated watershed

Upadhye *et al.* (2005) used remote sensing and GIS technique for prioritization of watershed for development and management in India. Remote sensing and GIS technique can be effectively used for priority delineation of sub-watershed. Initially polarization of watershed was mainly done with the help of aerial photographs and FCC. Then with progress in remote sensing and availability of data, work was carried out with visual interpretation techniques on LISS II and LISS III, PAN data as well as GIS techniques for overlapping maps. The maps were in 1:100000 scale. The satellite remote sensing technique provides data on land slope, land use and land cover which can be integrated with data on rainfall, erosivity and GIS to arrive quantitative estimation of soil loss.

Selvi *et al.* (2006) studied about utilities and limitations of remote sensing and GIS applications in micro-watershed planning with an experience through the image map obtained on 1:12,500 scale of Kuruthukuli watershed in Kundah basin of the Nilgiris district, Tamil Nadu. The geocoded image was subjected to visual interpretation. Slope map was generated from SOI toposheets (1:50,000) in GIS environment (ARC/INFO) and other thematic maps on land use, soils and cropping patterns were prepared in GIS after field verification. On the basis of these thematic maps together with information obtained from field visits and Participatory Rural Appraisal (PRA) exercises, watershed management plan was prepared for KG-4-1 watershed. Crucial factors apart from land use categories, which are needed for land use planning, like irrigation status, cropping status and land management conditions could not be obtained from the image map of KG-4-1 watershed processed at 1:12,500 scale. It was concluded that, GIS was an ideal system to support watershed planning which is an integrated process, especially with the help of topological overlays of different thematic layers.

Selvi *et al.* (2007) studied about digital micro watershed atlas which is a tool for watershed development planning. The soil survey and land use survey of India (SLUSI) prepared digital data base through rapid reconnaissance survey on watershed prioritization using GIS and updated certain data set with remotely sensed data. They developed digital layers of drainage, micro watershed and EIMU (Erosion Intensity Mapping Units) and integration of these layers were done with the help of GIS. Finally they made spatial distribution of different priority and categories of micro watershed using sediment yield index model developed.

2.2 Application of watershed models in predicting hydrologic processes

Sharma *et al.* (2000) studied about the application of SCS model with GIS data base for estimation of runoff in arid watershed. Soil Conservation Service model (SCS) has been applied in the estimation of runoff from a 509 ha watershed which is a part of upper Jojri in Nagaur district of Rajasthan. This method involves various types of information related to topography and soil. The thematic map of soil, land use, etc, are prepared from satellite and topographic map from survey of India. And all this information was converted into raster format at scale 1:50000 and used as an input to derive SCS runoff curve number. The SCS model was then applied to estimate the runoff for daily storm and was validated comparing it with the measured runoff of five events of present monsoon period.

Sarangi *et al.* (2000) studied about the use of GIS in assessing the erosion statistics of watersheds. In this study two watersheds, Banha watershed at upper Damodar valley, Jharkhand and IARI watershed at Delhi are considered. These watersheds are digitalized along the contour lines using the GIS tool. The hypsometric analysis performed on these watersheds revealed that the Banha watershed is less susceptible to erosion whereas IARI watershed is at stabilized state. Hypsometric analysis aims at developing relationship between horizontal cross sectional area of the watershed and its elevation in a dimensionless form. They concluded that conservation measures are needed in Banha watershed whereas no activity is needed in IARI.

Kumar *et al.* (2006) estimated direct runoff based on geomorphologic characteristics of a hilly watershed. A Geomorphologic Instantaneous Unit Hydrograph based on two parameter gamma type conceptual model was developed for estimation of direct runoff from a hilly sub watershed of Ramganga river catchment in Uttaranchal, India. The instantaneous unit hydrograph developed after determining both the parameters n and k, i.e. the shape and scale parameters, from the measured hydrologic data, geomorphic parameters and characteristics of the watershed, is called the GIUH for the given watershed, the performance of the developed GIUH model was evaluated by visual observation of the shape of the predicted and observed direct runoff hydrograph for different storm event.

Kamble *et al.* (2006) estimated the surface runoff from micro watershed using Soil and Water Assessment Tool (SWAT) model and was tested on daily and monthly basis for estimating the runoff from a micro watershed in Chhattisgarh, India. The model was calibrated and validated for the monsoon season of the years 1994 and 1995 using observed daily rainfall and temperature data for the respective years. The major components of SWAT model include hydrology, weather, sedimentation, soil temperature, crop growth, nutrients, groundwater and lateral flow and agricultural management. The model uses SCS curve method for estimation of runoff volume and adjusts curve number based on Antecedent Moisture Conditions (AMC). On the basis of results obtained through this study, it can be concluded that SWAT model can simulate daily and monthly surface runoff satisfactorily from a micro watershed.

Omani *et al.* (2007) conducted study on Gharasu watershed to develop its hydrologic model and to simulate the effect of management practices on water and sediment yielding using SWAT 2000. The SWAT 2000 interfaced with Arc View GIS data layers including DEM, land cover and soil map by AVSWAT 2000 software. The model was calibrated from 1991 to 1996 and validated from 1997 to 2000. The model was used to assess suspended sediment load.

Stehr *et al.* (2007) studied the impact of climate and anthropogenic factors on the hydrology of the Vergara basin, a sub basin of Biobio. SWAT was used to develop the hydrology model of the basin. The model was calibrated from 2000 to 2002 and validated using monthly output data for the periods between 1994 to 1999 and 1992 to 1997 which represent current and historic land use conditions respectively. The result showed that the model performance can be considered as satisfactory for most part of the basin during calibration and validation period.

Somura (2007) studied about the Hii river basin using SWAT model from 1986 to 2005 on a daily time step. The parameters of SWAT were calibrated from 1993 to 1996 and validated from 1986 to 1992 and from 1997 to 2005. The river discharge was frequently monitored from the discharge observation station located at the outlet of the basin. Both the calibration and validation results represented fluctuations of discharge relatively well, though some peaks were overestimated. During the calibration period, R^2 varied from 0.65 to 0.77 & NSE did from 0.64 to 0.76. During the validation period from 1986 to1992, R^2 varied from 0.58 to 0.74 & NSE did from 0.53 to 0.74 & from 1997 to 2005 R^2 varied from 0.51 to 0.71 and NSE did from 0.38 to 0.68.

Gebriye (2007) conducted studies to assess the impact of land management practices on the surface runoff in Anjeni gauged watershed using SWAT 2005. A 2m by 2m DEM, land use, and soil layers, 10 years climatic and stream flow data were used for the delineation and simulation of hydrology. The model was calibrated using 8 years hydrometric measurements from 1984 to 1991. The validation was also done with independent measured stream flow data from 1992 to 1993. The model performance evaluation statistics such as NSE > 0.91 and R^2 > 0.92 showed that the model can produce reasonable estimates of monthly discharge. The study showed that the SWAT model is a useful modeling tool for analyzing the hydrological processes and to design appropriate land and water resources conservation strategies.

Sathian and Syamala (2009) studied about the calibration and validation of a distributed watershed hydraulic model. In this study, the SWAT model, developed by USDA, has been used to analyze and quantify the water balance of a river basin namely, Kunthipuzha in Kerala. DEM, land use, soil and digitized stream network were prepared in ILWIS GIS package developed by ITC, Netherlands. Land use of the area has been prepared from LISS-III imagery of IRS 1C. Climatic data has been collected from two meteorological observatories at Pattambi and Mannarkkad. Water balance components of the basin have been simulated and it is found that the baseflow contribution is the maximum in the river flow followed by lateral flow and surface runoff. Predicted water balance components were also been compared with their measured or alternately computed counterparts and has shown good agreement. The study makes the recommendation that SWAT model can be effectively used for assessing the water balance components of a river basin. The model has been calibrated and validated for seven years period from 1996 to 2002 using the daily rainfall and observed river flow data. The results indicate that the predictive power of the model for both flow and sediment is very high as shown by the time series and NSE and COD.

2.3 Impact of check dams on river flow

Ramakrishnan *et al.* (2005) studied about the Kali sub-watershed, situated in the semi-arid region of Gujarat, India and forms a part of the Mahi River Watershed. This watershed receives an average annual rainfall of 900mm mainly between July and September. Due to high runoff potential, evapo-transpiration and poor infiltration, drought like situation prevails in this area from December to June almost every year. In this paper, augmentation of water resource is proposed by construction of runoff harvesting structures like check dam, percolation pond, farm pond, well and subsurface dyke. The site suitability for different water harvesting structures is determined by considering spatially varying parameters like runoff potential, slope, fracture pattern and micro-watershed area. GIS is utilized as a tool to store, analyze and integrate spatial and attribute information pertaining to runoff, slope, drainage and fracture. The runoff derived by SCS-Curve Number method is a function of runoff potential which can be expressed in terms of runoff coefficient (ratio between the runoff and rainfall) which can be classified into three classes, viz., high (>40%), moderate (20–40%)

and low (<20%). In addition to IMSD, FAO specifications for water harvesting/recharging structures, parameters such as effective storage, rock mass permeability are herein considered to augment effective storage. Using the overlay and decision tree concepts in GIS, potential water harvesting sites are identified. The derived sites are field investigated for suitability and implementation. In all, the accuracy of the site selection at implementation level varies from 80–100%.

Fei (2006) studied about the Zhengshui River basin which is one of the most important commodity grain production bases, which is located in the mid-south of Hunan Province in China. Due to uneven distribution of rainfall, the frequent flood has caused enormous losses and threatened the sustainable development of agricultural economy in this basin. This paper aims to study on effect of reservoir operation on hydrological processes. The SWAT (Soil and Water Assessment Tool) model, a distributed hydrology model, was applied to this catchment to study the impacts of reservoir operation on runoff. Choosing six medium scale check dams, all related hydrology processes and water resource was simulated with different scenarios from 1980 to 2000 using SWAT. Based on the simulation results, the authors compared the simulation results in different reservoir scenarios. Through analysis of the relationship between the reservoir and differentia of runoff, the effect of reservoir on runoff was stated. The check dams can obviously reduce the runoff and the effect is different in different years or different seasons. The results also show that the SWAT model is an efficient tool for simulating hydrology process and water resource.

Ravinder *et al.* (2006) studied the potential of a Spatial Decision Support System (SDSS) for estimating water and sediment yield in a large (92.46 km²) experimental catchment in the Damodar Barakar basin. The SDSS is based on a SWAT model and was operated under prevailing resource management conditions. Application of the proposed SDSS predicted average water and sediment yields of 383.37mm.year^{-1} & 21.28ha^{-1}year^{-1} were predicted as against actual observations of 390.69 mm.year^{-1} & 25.35 t.ha^{-1}year^{-1} for the validation periods 1981-83; 1985-89 and 1991. Simulations of the annual dynamics of total water and sediment yields showed good to moderately good correlation coefficients of 0.83 & 0.65; model efficiency coefficients of 0.54 & 0.70 mean relative errors of -4.28% & -17.97% and root mean square prediction errors of 71.8mm & 9.63t.ha^{-1} respectively. The study demonstrated that the proposed SDSS could also be used to identify priority areas having high water and soil losses within the test catchment. The presence of large areas under long duration paddy rice and maize crops or low forest cover appeared to be the major reasons for the high water and soil losses from some experimental areas.

Koskiaho ***et al.*** **(2007)** studied the effect of alternative management options in varying environmental conditions and assessing their effects on loading from agricultural sources to water bodies using SWAT. In this study, the parameters of SWAT have been developed in terms of dynamics and sediment fluxes and a sensitivity analysis was made. In this project the land was divided into 5 classes. The SWAT modelling was done for a second order catchment, Ylaneenjoki (233 km^2) of the Eurajoki river basin in south western Finland. This catchment was intensively monitored during more than 10 years. This data was used for parameter setup and calibration of SWAT.

2.4 Case Studies Conducted at K C A E T

Premraj (1999) has conducted a study of Bharathapuzha basin with special reference to check dams. The study includes general study of river basin monitoring of existing and post structure ground water profile, drill holes to find the depth of clay levels, laboratory investigation, water requirement details, and construction details of sub surface dam. The study reports that this type of check dams is cheap, economical, eco-friendly and fast method of construction.

Arun ***et al.*** **(2007)** carried out the assessment of runoff and erosion using GIS. The study has been carried out on Gayathri sub basin of Bharathapuzha river basin, with focus on runoff and erosion generating process of the watershed. The specific objective of the study included characterization of watershed from the stand point of runoff and erosion process and quantification of these physical processes. Surface runoff has been computed by SCS curve number method and the result indicate that 38% of annual runoff flows out as surface runoff.

Divya ***et al.*** **(2008)** studied about the watershed simulation using GIS integrated physically based model. They selected Kadalundi river basin of Kerala state to study the hydrologic behavior of the basin. Widely recommended SWAT model has been used for the study. Study gave emphasis for calibration and simulation of watershed processes. GIS techniques are made use of to incorporate spatial variability more thoroughly and efficiently. This study revealed that the model predicts the low flow of the river with very good accuracy. Contribution of different sub watersheds towards the total stream flow has been quantified.

Hence, recommendations to alleviate the water scarcity and development of micro watersheds can be given more specifically and effectively.

Aiswarya *et al.* (2009) studied about the measures for rejuvenating river Bharathapuzha and sustaining this water source round the year with specific objectives of modeling the topography of the river using simulation model. They studied about the hydrologic behavior of the river basin at micro level to suggest sustainable interventions to improve summer flow regimes of the river. For the quick and efficient delineation of micro watersheds, GIS and SWAT were made use of.

2.5 Current Issues related to rivers of Kerala

Prabhakaran (2001) reporter of "**The Hindu**" reported that, the first biodiversity study on the Bharathapuzha conducted by the University Grants Commission has found indiscriminate sand-mining from the river bed as the main reason for its destruction. The study on the environmental issues of the river said that as the sand layers holding considerable quantity of water in the spaces between them are disturbed, the water flow through the river gets reduced considerably. Also, the percolation of water through the river bed and its subsequent recharge into the groundwater supply also declines. The villagers along the river basin now face the severe problem of drinking water shortage because of the lowering of the water table. The report said that `pollution (mainly agricultural waste), sand and clay mining, destruction of natural pools and riparian vegetation and unscientific fishing methods are the major threats to fish fauna in the river'. Bharathapuzha has 10 dams (six in Kerala and four in Tamil Nadu) besides a large number of weirs and check-dams. The study suggested a holistic approach for the restoration and conservation of the river. The Government is spending several crores of rupees every year for providing drinking water to the riparian people and for constructing check- dams in the river basin.

Staff reporter of "**The Hindu**" reported on 30th May 2004 that, the project for water conservation and recharging should be based on the principle of "making running water walk". This would increase the scope of water retention in the soil and the scale of water recharging. This was the bottom line of the message for the people, the farmers in particular, that evolved at a one-day media workshop on water conservation held under the joint auspices of the State Planning Board and the `Jalanidhi', a State Government institution exclusively for water conservation and sanitation projects, at the Kerala Institute for Local

Administration in Thrissur recently. According to S. Sankar, scientist, Kerala Forest Research Institute, the absence of a rational mechanism to check the free flow of rainwater into the sea is the main reason for the droughts and floods being experienced by the State quite often. In view of the slanting topography of the state, within a length of 600 km and a width of just 60 km, it takes less than six hours for the rainwater to flow into the sea. But an effective and Nature-friendly mechanism, suiting the topography of the State, would help reduce the speed of rainwater flow, thereby increasing the "residence time" of rainwater to percolate down through the soil.

Staff reporter of "**The Hindu**" reported on 29th April 2009 about The `Action Plan' of the report describes about the arrangements, to provide water-locks with regulating arrangements, check dams along all the rivers and streams, river-side afforestation, river-bank protection, solid waste treatment, catchment area treatment, basin water management and the augmentation of existing irrigation projects. But none of these schemes have been taken up by the State Government except the construction of just one check dam that began in Parali recently. The idea of construction of check dams for water conservation was first mooted under the Rajiv Gandhi Mission in the 1990s. But only three of the 14 identified sites for check dams and sub surface dams have been constructed so far. Check dam construction is the cheapest and most effective way for water conservation.

Staff Reporter of **"The Hindu"** reported on 18th April 2009 about the government sanction for a check-dam at Ampalappra in the Bharathapuzha between Parali and Chammravattom has come as a relief for the people who depend on the river for drinking and irrigation water. The sixth check-dam in the river is being constructed connecting Ampalappara in Palakkad district and Thiruvilwamala in Thrissur district at a cost of Rs.4.5 crore. The cost of the check-dam is met from the river management fund of the district. The government had recently sanctioned a check-dam at Kuttilakkadavu near Ottappalam where the Gayathripuzha joins the Bharathapuzha. The Kuttilakkadavu check dam will be the source of drinking water for Ottappalam municipality and Ampalappara panchayat in Palakkad district and the Thiruvilawamala and Kondazhi panchayats in Thrissur. "Check-dam is the cheapest, effective and ideal way of water conservation and beneficial usage," he said. Check-dams were earlier constructed at Njavalin Kadavu, Lakkidi, Parali Old Railway Station and Parali Old Bridge in the river.

Staff Reporter of "**The Hindu**" reported on 28th January 2009 that more check dams are going to be constructed in Bharathapuzha soon. A couple of temporary check dams will be constructed in the Bharathapuzha with people's participation to solve the drinking water problem in the river basin. The work on the dam at Ottapalam will start in the first week of February. A committee with the Sub-Collector of Ottapalam, Dinesh Arora, as its chairman and T.N.N. Bhattathiripad, former Chief Engineer of the Kerala Water Authority, as member secretary, has been formed to undertake the various development activities in the Ottapalam Sub-Division on the waterfront. Mr. Arora has said that the construction of a permanent check dam in Ottapalam will cost Rs.2 crores. Since it is difficult to mobilise the funds at the fag end of the financial year, a temporary check dam is being constructed as a contingency measure. A permanent check dam at Mundai will be constructed at a cost of Rs.74 lakhs. Work on a temporary check dam near the Shoranur old bridge will begin shortly. Mr. Bhattathiripad has said that work on a temporary check dam at Koottakadavil, near Anakkara, will begin soon. A number of check dams are urgently required to conserve water in the Bharathapuzha. Though the State received normal rainfall in 2004, already drinking water shortage is felt in many rural and urban areas.

Materials & Methods

Chapter 3

MATERIALS AND METHODS

3.1 Study area

Kunthipuzha, one of the major tributaries of Bharathapuzha is taken as the study area. The remarkable feature of this river is its crystal clear water in all seasons. It originates from the north eastern side of the Silent Valley National Park. Kunthipuzha subbasin lies in the north east part of the Bharathapuzha basin and has a total catchment of 940 km^2. River flow and sediment data has been collected from Pulamanthole river gauging station ($10^0$53'50''N, $76^0$11'50''E) manned by Central Water Commission, India. Catchment area corresponding to the gauging station is 822 km^2. The river side is enriched with flora and fauna. After passing through the valley Kunthipuzha river joins with Bharathapuzha. Bharathapuzha river basin, the largest of Kerala, originates from the Western Ghats and has a total catchment area of 6400km^2 spread in Kerala and Tamilnadu. Bharathapuzha flows westward through Palakkad Gap, across Palakkad, Thrissur and Malappuram districts of Kerala, with many tributaries joining it, including the Tirur River. It discharges into the Arabian Sea at Ponnani.

3.2 Basic maps and softwares used

1. Toposheets from SOI bearing numbers 49N/13, 58A/8, 58A/12, 58B/1, 58B/2, 58B/5, 58B/6, 58B/7, 58B/9, 58B/10, 58B/11, 58B/13 and 58B/14 prepared in 1:50000 scale.
2. Soil map from National Bureau of Soil Survey and Land Use Planning (NBSS and LUP) prepared in 1:500000 scale.
3. Satellite imagery of LISS III of IRS P6 having four bands from NRSA, Hyderabad.
4. Daily rainfall and temperature data from various meteorological observatories controlled by Water resource Department (WRD), Kerala and Kerala Agricultural University.
   - ILWIS 3.3 developed by ITC, Netherlands for the generation of GIS maps and attribute data.
   - SWAT developed by United State Department of Agriculture ARS.

3.2.1 ILWIS

ILWIS is an acronym for the Integrated Land and Water Information System. It is a Geographic Information System (GIS) software with Image Processing capabilities. ILWIS has been developed by the International Institute for Aerospace Survey and Earth Sciences (ITC), Enschede, The Netherlands.

As a GIS and Remote Sensing package, ILWIS allows to input, manage, analyze and present geo-graphical data. From the data one can generate information on the spatial and temporal patterns and processes on the earth surface. Geographic Information Systems are nowadays indispensable in applications related to spatial analysis.

3.2.2 SWAT

SWAT is the acronym for Soil and Water Assessment Tool. It is a river basin, or watershed, scale model developed by Dr. Jeff Arnold for the USDA Agricultural Research Service (ARS) to predict the impact of land management practices on water, sediment and agricultural chemical yields in large complex watersheds with varying soils, land use and management conditions over long periods of time. The model is physically based. No matter what type of problem studied with SWAT, water balance is the driving force behind everything that happens in the watershed. Simulation of the hydrology of a watershed can be separated into two major divisions. The first division is the land phase of the hydrologic cycle which controls the amount of water, sediment loadings, etc to the main channel in each sub basin. The second division is the water or routing phase of the hydrologic cycle which can be defined as the movement of water, sediments, etc. through the channel network of the watershed to the outlet.

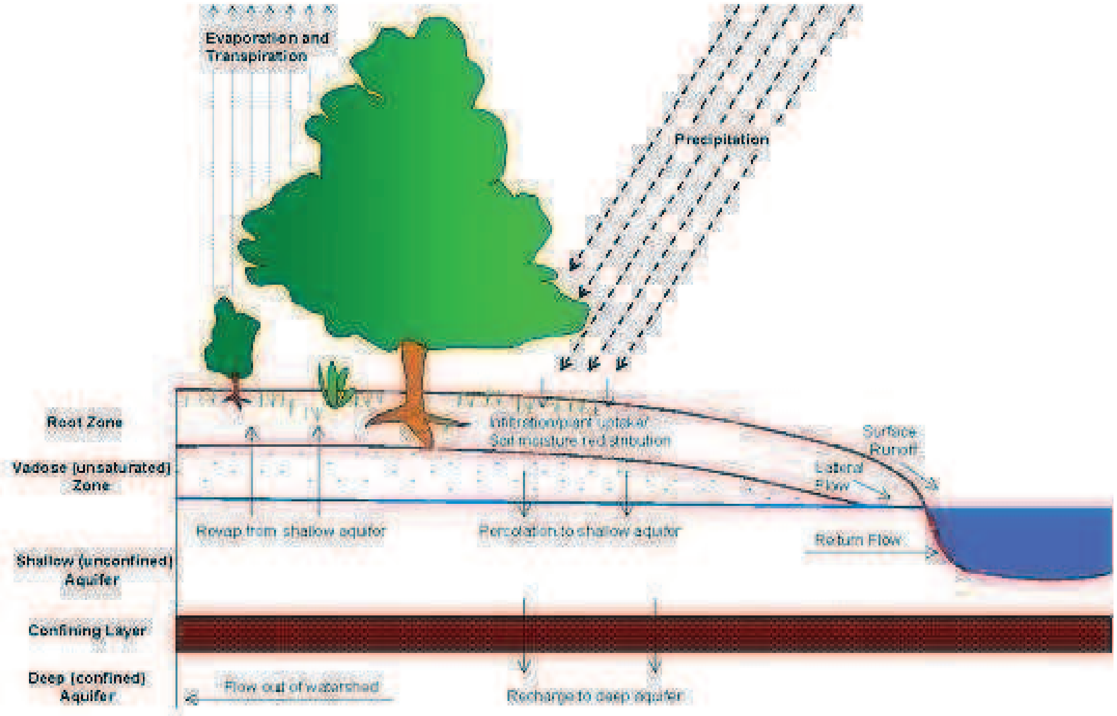

Fig. 3.1 Schematic representation of the hydrologic cycle

3.2.2.1 Land Phase of the Hydrologic Cycle

The different inputs and processes involved in this phase of the hydrologic cycle are climate, hydrology, land cover/plant growth, erosion, nutrients, pesticides, management.

3.2.2.2 Routing phase of the Hydrologic Cycle

Routing in the main channel or reach: Routing in the main channel can be divided into four components: water, sediment, nutrients and organic chemicals.

Flood routing: As water flows downstream, a portion may be lost due to evaporation and transmission through the bed of the channel. Another potential loss is removal of water from the channel for agricultural or human use. Flow may be supplemented by the fall of rain directly on the channel and/or addition of water from point source discharges. Flow is routed through the channel using a variable storage coefficient method developed by Williams (1969) or the Muskingum routing method.

Routing in the reservoir: The water balance for reservoirs include, inflow, outflow, rainfall on the surface, evaporation, seepage from the reservoir bottom and diversions.

Reservoir outflow: A reservoir is an impoundment located on the main channel network of a watershed. No distinction is made between naturally-occurring and man-made structures. The features of an impoundment are shown in Fig. 3.2.

The model offers three alternatives for estimating outflow from the reservoir. The first option allows the user to input measured outflow. The second option, designed for small, uncontrolled check dams, requires the user to specify a water release rate. When the reservoir volume exceeds the principle storage, the extra water is released at the specified rate. Volume exceeding the emergency spillway is released within one day. The third option, designed for larger, managed reservoirs, has the user specified monthly target volumes for the reservoir.

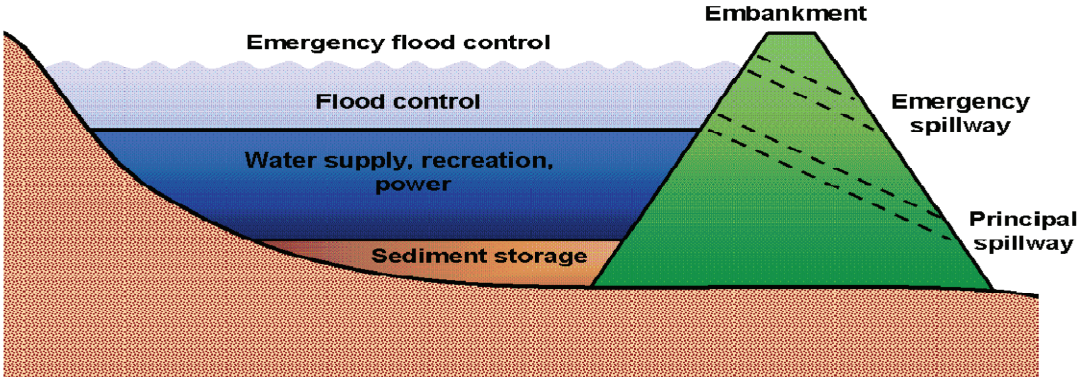

Fig. 3.2 Components of a reservoir with flood water detention features

3.3 Important hydrologic equations used in SWAT

The hydrologic cycle as simulated by SWAT is based on the water balance equation:

$$SW_t = SW_O + \sum (R_{day} - Q_{surf} - E_a - W_{seep} - Q_{gw}) \qquad 3.3.1$$

Where SW_t is the final soil water content (mm H_2O), 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), Q_{surf} is the amount of surface runoff on day i (mm), E_a is the amount of evapotranspiration on day i (mm), W_{seep} is the amount of water entering the vadose zone from the soil profile on day i (mm H_2O), and Q_{gw} is the amount of return flow on day i (mm).

Surface runoff is predicted by:

$$Q_{surf} = \frac{(R_{day} - I_a)^2}{(R_{day} - I_a + S)} \qquad 3.3.2$$

Where Q_{surf} is the accumulated runoff or rainfall excess (mm), R_{day} is the rainfall depth for the day (mm), I_a is the initial abstractions which includes surface storage, interception and infiltration prior to runoff (mm), and S is the retention parameter (mm).

Baseflow is predicted by:

$$Q_{gw,i} = Q_{gw,i-1} \cdot exp[-\alpha_{gw} \cdot \Delta t] + w_{rchrg,sh} \cdot (1 - exp[-\alpha_{gw} \cdot \Delta t]) \qquad 3.3.3$$

Where, $Q_{gw,}$ is the groundwater flow into the main channel on day i (mm), $Q_{gw,i-1}$1 is the groundwater flow into the main channel on day i-1 (mm), α_{gw} is the baseflow recession constant, Δt is the time step (1 day), and $w_{rchrg,sh}$ is the amount of recharge entering the aquifer on day i (mm).

Lateral flow is predicted by:

$$Q_{lat} = 0.024 \cdot \left(\frac{2 \cdot SW_{ly,excess} \cdot K_{sat} \cdot slp}{\emptyset_d \cdot L_{hill}}\right) \qquad 3.3.4$$

Where, Q_{lat} is the lateral flow (mm/ day), $SW_{ly,excess}$ is the drainable volume of soil water per unit area of saturated thickness (mm/day), K_{sat} is the saturated hydraulic conductivity (mm/h), slp is the increase in elevation per unit length, L_{hill} is the hillslope length (m), and $\emptyset_d$ is the drainable porosity.

Evapotranspiration is estimated by Penman-Montieth equation:

$$\lambda E = \frac{\Delta \cdot (H_{net} - G) + \rho_{air} \cdot c_p \cdot [e_z^o - e_z] / r_a}{\Delta + \gamma \cdot (1 + r_c / r_a)} \qquad 3.3.5$$

Where λE is the latent heat flux density (MJ/ m^2d), E is the depth rate evaporation (mm/d), Λ is the slope of the saturation vapour pressure-temperature curve, de/dT(kPa/^{o}C) H_{net} is the net radiation (MJ/m^2d), G is the heat flux density to the ground (MJ/m^2d), ρ_{air} is the air density (kg/m^3), c_p is the specific heat at constant pressure (MJ/kg^{o}C), e_z^o is the saturation vapour pressure of air at height z (kPa), e_z is the water vapour pressure of air at height z (kPa), γ is the psychrometric constant (kPa/^{o}C), r_c is the plant canopy resistance (s/m), and r_a is the diffusion resistance of the air layer(s/m).

Flow is routed through the channel using the Muskingum routing method:

$$V_{stored} = K \cdot [q_{out} + X \cdot (q_{in} - q_{out})] \tag{3.3.6}$$

Where, V_{stored} is the storage volume (m^3), q_{in} is the inflow rate (m^3/s), q_{out} is the discharge rate (m^3/s), *K* is the storage time constant for the reach (s), and *X* is the weighting factor.

The water balance for a reservoir is:

$$V = V_{stored} + V_{flow\ in} - V_{flow\ out} + V_{pcp} - V_{evap} - V_{seep} \tag{3.3.7}$$

Where, *V* is the volume of water in the impoundment at the end of the day (m^3), V_{stored} is the volume of water stored in the water body at the beginning of the day (m^3), $V_{flow\ in}$ is the volume of water entering the water body during the day (m^3), $V_{flow\ out}$ is the volume of water flowing out of the water body during the day (m^3), V_{pcp} is the volume of precipitation falling on the water body during the day (m^3), V_{evap} is the volume of water removed from the water body by evaporation during the day (m^3), V_{seep} is the volume of water lost from the water body by seepage (m^3).

The surface area is updated daily using the equation:

$$SA = \beta_{sa} \cdot V^{expsa} \tag{3.3.8}$$

Where, *SA* is the surface area of the water body (ha), β_{sa} is a coefficient, *V* is the volume of water in the impoundment (m^3), and *expsa* is an exponent. The coefficient, β_{sa}, and exponent, are calculated by solving equation using two known points. The two known points are surface area and volume information provided for the principal and emergency spillways

$$expsa = \frac{log_{10}(SA_{em}) - log_{10}(SA_{pr})}{log_{10}(V_{em}) - log_{10}(V_{pr})} \tag{3.3.8.1}$$

$$\beta_{sa} = \frac{[SA_{em}]^{expsa}}{V_{em}} \tag{3.3.8.2}$$

Where, SA_{em} is the surface area of the reservoir when filled to the emergency spillway (ha), SA_{pr} is the surface area of the reservoir when filled to the principal spillway (ha), V_{em} is the volume of water held in the reservoir when filled to the emergency spillway (m^3), and V_{pr} is the volume of water held in the reservoir when filled to the principal spillway (m^3).

The volume of precipitation falling on the reservoir during a given day is calculated:

$$V_{pcp} = 10 \cdot R_{day} \cdot SA \qquad 3.3.9$$

Where, V_{pcp} is the volume of water added to the water body by precipitation during the day (m^3), R_{day} is the amount of precipitation falling on a given day (mm), and *SA* is the surface area of the water body (ha).

The volume of water lost to evaporation on a given day is calculated:

$$V_{evap} = 10 \cdot \eta \cdot E_o \cdot SA \qquad 3.3.10$$

Where, V_{evap} is the volume of water removed from the water body by evaporation during the day (m^3), η is an evaporation coefficient (0.6), E_o is the potential evapotranspiration for a given day (mm), and *SA* is the surface area of the water body (ha).

The volume of water lost by seepage through the bottom of the reservoir on a given day is calculated:

$$V_{seep} = 240 \cdot K_{sat} \cdot SA \qquad 3.3.11$$

Where, V_{seep} is the volume of water lost from the water body by seepage (m^3), K_{sat} is the effective saturated hydraulic conductivity of the reservoir bottom (mm/hr), and *SA* is the surface area of the water body (ha).

The volume of outflow may be calculated using one of four different methods: measured daily outflow, measured monthly outflow, average annual release rate for uncontrolled reservoir, controlled outflow with target release.

When measured daily outflow (IRESCO = 3) is chosen as the method to calculate reservoir outflow, the user must provide a file with the outflow rate for every day the reservoir is simulated in the watershed. The volume of outflow from the reservoir is then calculated:

$$V_{flow\,out} = 86400 \cdot q_{out} \qquad 3.3.12$$

Where, $V_{flow\,out}$ is the volume of water flowing out of the water body during the day (m^3), and q_{out} is the outflow rate (m^3/s).

When measured monthly outflow (IRESCO = 1) is chosen as the method to calculate reservoir outflow, the user must provide a file with the average daily outflow rate for every month the reservoir is simulated in the watershed.

When the average annual release rate (IRESCO = 0) is chosen as the method to calculate reservoir outflow, the reservoir releases water whenever the reservoir volume exceeds the principal spillway volume, V_{pr}. If the reservoir volume is greater than the principal spillway volume but less than the emergency spillway volume, the amount of reservoir outflow is calculated:

$$V_{flow\,out} = V_p - V_{pr} \quad ; \text{ if } V - V_{pr} < q_{rel} \cdot 86400 \qquad 3.3.13$$

$$V_{flow\,out} = q_{rel} \cdot 86400; \text{ if } V - V_{pr} > q_{rel} \cdot 86400$$

If the reservoir volume exceeds the emergency spillway volume, the amount of outflow is calculated:

$$V_{flow\,out} = (V - V_{em}) + \left(V_{em} - V_{pr}\right) ; \text{ if } V_{em} - V_{pr} < q_{rel} \cdot 86400 \qquad 3.3.14$$

$$V_{flow\,out} = (V - V_{em}) + q_{rel} \cdot 86400; \text{ if } V_{em} - V_{pr} > q_{rel} \cdot 86400$$

Where, $V_{flow\,out}$ is the volume of water flowing out of the water body during the day (m^3), V is the volume of water stored in the reservoir (m^3), V_{pr} is the volume of water held in the reservoir when filled to the principal spillway (m^3), V_{em} is the volume of water held in the reservoir when filled to the emergency spillway (m^3), and q_{rel} is the average daily principal spillway release rate (m^3/s).

When target release (IRESCO = 2) is chosen as the method to calculate reservoir outflow, the reservoir releases water as a function of the desired target storage. The target release approach tries to mimic general release rules that may be used by reservoir operators. Although the method is simplistic and cannot account for all decision criteria, it can realistically simulate major outflow and low flow periods. For the target release approach, the principal spillway volume corresponds to maximum flood control reservation while the emergency spillway volume corresponds to no flood control reservation. The model requires the beginning and ending month of the flood season. In the non-flood season, no flood control reservation is required, and the target storage is set at the emergency spillway volume. During the flood season, the flood control reservation is a function of soil water content. The flood control reservation for wet ground conditions is set at the maximum. For dry ground conditions, the flood control reservation is set at 50% of the maximum. The target storage may be specified by the user on a monthly basis or it can be calculated as a function of flood season and soil water content.

If the target storage is specified:

$$V_{targ} = starg \tag{3.3.15}$$

Where, V_{targ} is the target reservoir volume for a given day (m^3), and $starg$ is the target reservoir volume specified for a given month (m^3).

If the target storage is not specified, the target reservoir volume is calculated:

$$V_{targ} = V_{em} \quad \text{if} \quad mon_{fld,beg} < mon < mon_{fld,end} \tag{3.3.16}$$

$$V_{targ} = V_{pr} + \frac{\left[1 - min\left(\frac{SW}{FC}, 1\right)\right]}{2} \cdot \left(V_{em} - V_{pr}\right);$$

If $\quad mon \leq mon_{fld,beg}$ or $\quad mon \geq mon_{fld,end}$

Where, V_{targ} is the target reservoir volume for a given day (m^3), V_{em} is the volume of water held in the reservoir when filled to the emergency spillway (m^3), V_{pr} is the volume of water held in the reservoir when filled to the principal spillway (m^3), SW is the average soil water content in the sub basin (mm), FC is the water content of the Sub basin soil at field capacity (mm), mon is the month of the year, $mon_{fld,beg}$ is the beginning month of the flood season, and $mon_{fld,end}$ is the ending month of the flood season.

Once the target storage is defined, the outflow is calculated:

$$V_{flow\ out} = \frac{(V - V_{targ})}{ND_{targ}} \tag{3.3.17}$$

Where, $V_{flow\ out}$ is the volume of water flowing out of the water body during the day (m^3), V is the volume of water stored in the reservoir (m^3), V_{targ} is the target reservoir volume for a given day (m^3), and ND_{targ} is the number of days required for the reservoir to reach target storage. Once outflow is determined using one of the preceding four methods, the user may specify maximum and minimum amounts of discharge that the initial outflow estimate is checked against. If the outflow doesn't meet the minimum discharge or exceeds the maximum specified discharge, the amount of outflow is altered to meet the defined criteria.

$$V_{flow\ out} = V'_{flow\ out} \text{ if } q_{rel,mn} \cdot 86400 \leq V'_{flow\ out} \leq q_{rel,mx} \cdot 86400 \tag{3.3.18}$$

$$V_{flow\ out} = q_{rel,mn} \cdot 86400 \;\; ; \quad \text{if} \quad V'_{flow\ out} < q_{rel,mn} \cdot 86400$$

$$V_{flow\ out} = q_{rel,mx} \cdot 86400 \;\; ; \quad \text{if} \quad V'_{flow\ out} > q_{rel,mx} \cdot 86400$$

Where, $V_{flow\ out}$ is the volume of water flowing out of the water body during the day (m^3), $V'_{flow\ out}$ is the initial estimate of the volume of water flowing out of the water body during the day (m^3), $q_{rel,mn}$ is the minimum average daily outflow for the month (m^3/s), and $q_{rel,mx}$ is the maximum average daily outflow for the month (m^3/s).

3.4 Digital thematic maps required by SWAT & their preparation

3.4.1 Drainage map

Drainage network of the study area are digitized from the topographic map mentioned in section 3.2 using on-screen digitization capability of ILWIS software. Thus segment map of drainage network was prepared. Universal Transverse Mercator (UTM) projections corresponding to zone 43 was used as the co-ordinate system for all the thematic maps.

3.4.2 Digital Elevation Model (DEM)

Digital Elevation Model can store continuously varying variables such as elevation, groundwater depth or soil thickness. The accuracy of a DEM depends very much on the detail of the contour lines and the scale of the original topographic map from which the contour lines were digitized. The larger the scale of map, smaller the contour interval, the more accurate the DEM will be. Contour lines given in the toposheets were digitized to get the contour map for the study area. While digitizing the contours, the contour lines lying at the outer premises of the river basin boundary were also included to make the interpolation of the contour values possible at the time of DEM generation. Corrections were applied to remove the errors caused due to surface overlaps, dead end and intersections. After the error corrections, the segment contour map was rasterised using the segment to raster feature of ILWIS. Then a point elevation map was prepared for the entire study area using the point elevation data given in the toposheet. Point map was then rasterised to get a raster point map. Using the raster contour segment map and raster point map DEM was prepared.

3.4.3 Soil map

An analog soil map has been collected from NBSS & LUP containing the details of different soil classes and their aerial coverage. The map is scanned and imported to ILWIS environment using the “File-import” option of the software. Then boundaries of the different soil groups were digitized and segment soil map was generated. A point map was then prepared giving labels to individual soil types. Using this segment soil map and the label points the polygon map of the soil was prepared.

3.4.4 Land use map

Land use details like agriculture, non-agriculture, plantation, forest, grasslands, with demarcation of its boundaries are represented in the land use map. The landuse map of Bharathapuzha river basin was prepared from the satellite imagery of IRS P6, LISS-III using the spectral bands of I (0.52-0.59µm), II (0.62-0.68µm) and III (0.77-0.876 µm) using ILWIS as described in the following procedure:

- Prepare the FCC of the imagery and georeference the same.
- Create the sample set for the georeferenced map.
- Create a class domain for the land use classes to be sampled and enter the various land use classes.
- After having entered all classes, create a representation for the domain and choose a colour from the colour list or define your own colour for each class.
- Select pixels representing water from the map and this selection is added to the class water in the domain.
- Repeat the sampling procedure for a number of clusters of pixel representing water. Then continue the sampling procedure for other land cover classes also.
- Once sampling is over, classify the FCC using an appropriate classifying scheme. A box classifier is used in this study.
- Filter the classified output map to eliminate the undefined pixels. A majority filter is used in the study.

The land use map is thus created.

All the above said thematic layers in digital format and the corresponding attribute data were given as input to the SWAT and the modelling of the physical characteristics and simulations of the hydrological processes of the watershed were carried out. The basic map inputs required for the AVSWAT include digital elevation model, soil maps, land use/cover, hydrography (stream lines). In addition, the interface requires the designation of land use, soil, weather, as well as the simulation period, to ensure a successful simulation. The physical processes associated with water movement, sediment movement, crop growth, nutrient cycling etc are directly modeled by SWAT using this input data.

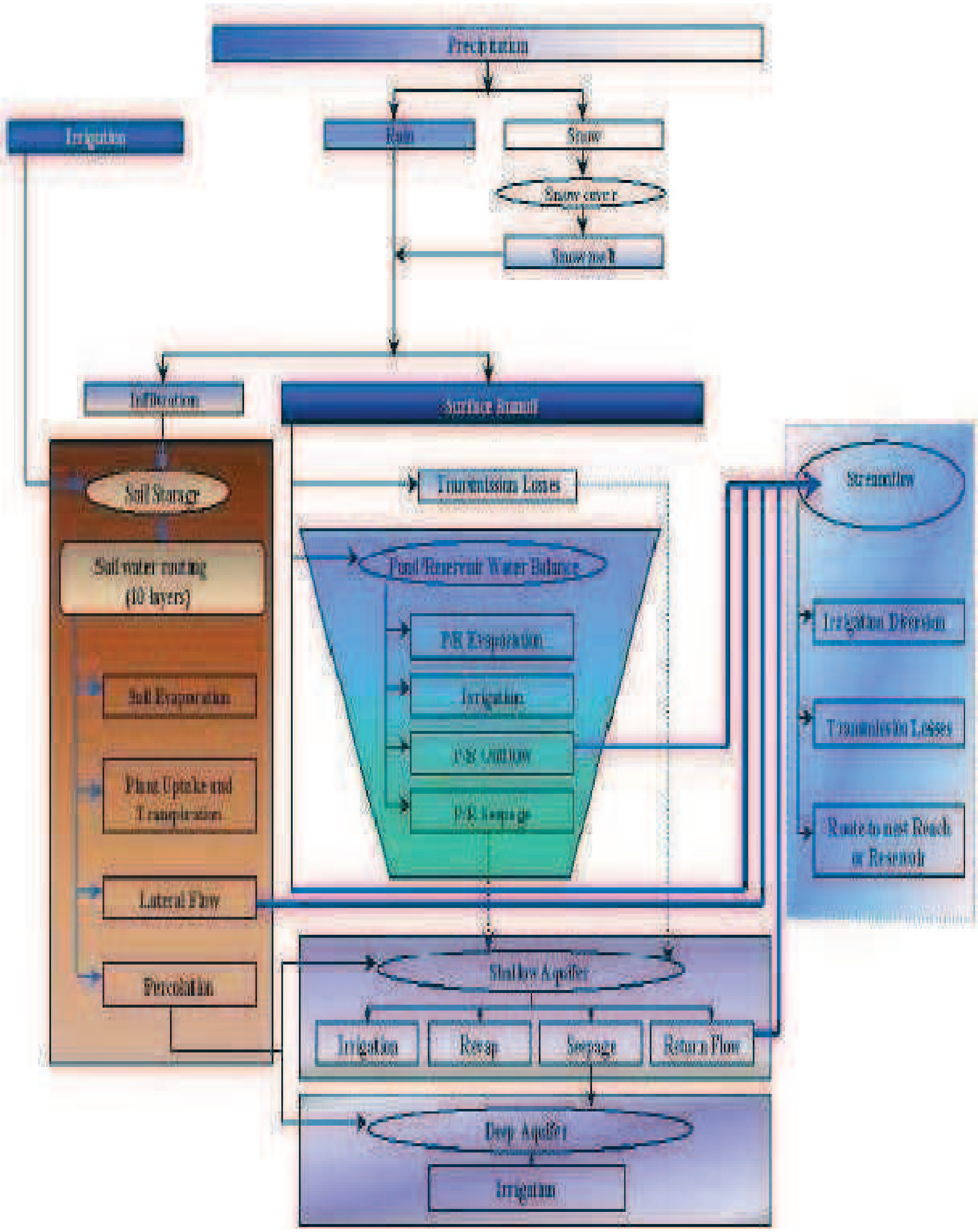

Fig. 3.3 Flow chart showing the pathway available for water movement in SWAT

3.5 Attribute information required by SWAT & their preparation

SWAT can be used to simulate a single watershed or a system of multiple hydrologically connected watersheds. Each watershed is first divided into sub basins and then into hydrologic response units (HRUs) based on the land use and soil distributions.

3.5.1 Precipitation Gauge Location Table. (dBASE)

The precipitation gauge location Table. is used to specify the location of rain gauges. The format of the data is given in the Table. 3.1.

Table. 3.1 Precipitation Gauge Location Table.

Field name	Field format	Definition
ID	Integer	Gauge identification number
NAME	String max 8 char	Corresponding Table. name string
XPR	Floating point	X coordinate in the defined projection
YPR	Floating point	Y coordinate in the defined projection
ELEVATION	Integer	Elevation of rain gauge (m)

3.5.2 Precipitation Data Table. (dBASE)

The precipitation data table is used to store the daily precipitation for an individual rain gauge. This table is required if the rain gauge option is chosen for rainfall in the weather data dialog box. There will be one precipitation data table for every location listed in the rain gauge location Table.. The name of the precipitation data table is "named" or “name.txt” where name is the character string entered for NAME in the rain gauge location Table.. This table is formatted as a dBase Table..

Table. 3.2 Precipitation Data Table.

Field name	Field format	Definition
DATE	Date(yyyymmdd)	Day of precipitation
PCP	Floating point(f5.1)	Amount of precipitation(mm)

3.5.3 Temperature Data Table. (dBASE)

The temperature data table is used to store the daily maximum and minimum temperatures for a weather station. This table is required if the climate station option is chosen for temperature in the weather data dialog box. The name of the temperature data table is "name.dbf" or “name.txt” where name is the character string entered for NAME in the temperature gauge location table. This table is formatted as a dBase table.

Table. 3.3 Temperature Data Table.

Field name	Field format	Definition
DATE	Date(yyyymmdd)	Day of measure
MAX	Floating point(f5.1)	Daily maximum temperature(^{0}C)
MIN	Floating point(f5.1)	Daily minimum temperature (^{0}C)

3.6 Setting up of swat model

Key Procedures involved in the setting up of the model is given below:

- Load or select the AVSWAT 2005 extension
- Delineate the watershed and define the HRUs
- (Optional) Edit SWAT databases
- Define the weather data
- Apply the default input files writer
- (Optional) Edit the default input files
- Set up (requires specification of simulation period, PET calculation method, etc.) and run SWAT
- (Optional) Apply a calibration tool
- (Optional) Analyze, plot and graph SWAT output.

3.6.1 Watershed Delineation

The Watershed Delineation carries out advanced GIS functions to aid in segmenting watersheds into several hydrologically connected sub-watersheds for use in watershed modeling. The delineation process requires a Digital Elevation Model (DEM) in Arc Info grid format. Key Procedures involved are:

1. The DEM is first loaded to the Arc-VIEW - SWAT interface.
2. The digitized stream network is then loaded for the delineation to be accurate.
3. Preprocessing of the DEM is then done.
4. The minimum sub-watershed area (critical source area) is then specified.

5. The outlet for the main watershed is defined and selected.
6. The calculation of the sub basin parameters are then done in SWAT.
7. Once the delineation is complete, the check dams are located along the main channel network.

3.6.2 Land Use/Soil Characterization

Land Use and Soil Characterization for a watershed are performed using two commands in the AVSWAT menu of the Watershed View. This tool allows loading land use and soil themes into the current project and determines the land use/soil class combinations and distributions for the delineated watershed and each respective sub watershed. The themes can be either grid or shape format.

Once the land use and soil themes have been imported and linked to the SWAT databases, the criteria are specified which are used in determining the HRU distribution.

Key Procedures involved for land use/ soil overlay are:

1. The land use theme is defined.
2. The land use theme is then reclassified.
3. Similarly, the soil theme is also defined and reclassified.
4. The land use and soil themes are then overlaid.

3.6.3 HRU Distribution

Once the land use and soil data layers have been imported, the distribution of hydrologic response units (HRUs) within the watershed is determined. One or more unique land use/soil combinations (HRUs) can be created for each sub basin. Subdividing the watershed into areas having unique land use and soil combinations enables the model to reflect differences in evapotranspiration and other hydrologic conditions for different land covers/crops and soils. Runoff is predicted separately for each HRU and routed to obtain the total runoff for the watershed. This increases the accuracy of load predictions and provides a much better physical description of the water balance. HRU distributions involve selecting multiple HRUs or dominant HRU for each sub watershed. Then for these multiple HRUs, the land use and soil threshold levels are defined. In case multiple HRUs are to be delineated, the threshold levels of landuse and soil are defined.

3.6.4 Weather Data Import

Weather data to be used in the watershed simulation is imported once the HRU distribution has been defined. Weather station locations are loaded into the current project and weather data namely, rainfall and temperature data of the sub watersheds are assigned. A

-99.0 value is given to fill in skipped daily data and to fill in measured climate records so that all records have the same starting and ending date. The starting date used for measured climate data is the earliest starting date listed in the record while the ending date is the latest ending date listed in the record. The –99.0 value is used to call the weather generator to generate a value to replace the missing data during run time. Other data like wind speed, solar radiation and relative humidity data are successfully simulated accordingly.

3.6.5 Creation of Input

The items contained in the Input menu allow to build database files containing the information needed to generate default input for SWAT. Several commands are listed on the Input menu. These commands are enabled in sequence (the next command is enabled only after the steps associated with the previous command are completed) and need to be processed only once for a project. When all of the default inputs have been generated, the SWAT can be simulated and is made to run.

3.6.6 Reservoir Data Input

The dimensions of various check dams are calculated based on the channel slope obtained from the input file. The various parameters of check dams like volume at emergency spillway, volume at principal spillway, surface area at emergency spillway, surface area at principal spillway, hydraulic conductivity of reservoir bottom are given as reservoir input in the SWAT interface.

3.7 SWAT Output

The Simulation menu allows finalizing the set up of input for the SWAT model and run the SWAT model; it reads the results of the simulation and builds dBASE tables and applies a calibration tool and performs load calculations. Only the ASCII output files in spreadsheet format are loaded into dBASE tables. Some of the SWAT output files viewed in the study include Standard Output File (.std), Reservoir Output File (.rsv), Sub basin Output File (.sub) and Main Channel Output File (.rch).

3.8 Model calibration and validation

Calibration is a process of model testing with known input and output used to adjust and estimate factors and validation is a process of comparison of model results with an independent data set without further adjustments. Some of the calibration issues include individual landuse parameter determination, location of gauging station data, available information on stream systems etc. Physically based distributed watershed models should be calibrated before they are made use of in the simulation of hydrologic processes. This is to reduce the uncertainty associated with the model prediction. Hence, before going for the determination of the hydrologic components, a thorough attempt has been made to tune the parameters of the model so that the predicted values are in very close agreement with available measured data. The key considerations of the hydrologic calibration includes water balance and storm sequence. The calibration statistics include the mean and standard deviation of the simulated and measured data, Nash-Sutcliffe Efficiency (NSE) and coefficient of determination (R^2). The model was calibrated by changing the parameters α_BF (baseflow recession coefficient), GW_DELAY (ground water delay in days), GWQMN {Threshold depth of water in the shallow aquifer required for return flow to occur (mm)} and SURLAG (surface lag time) sequentially for obtaining values of river flow which are closely matching with the observed values. Since daily rainfall data for the basin was available for seven years only, from 1996 to 2002, the calibration and validation exercise had to be confined to this period. Out of this, two years data (from 1998 to 1999) has been used for calibration and the period 2001 and 2002 was considered for validation. First, the calibration has been done for annual output values and then it was extended to monthly basis and daily basis. The mathematical form of Nash-Sutcliffe Efficiency is given as:

$$NSE = 1 - \{\sum(Y_O - Y_S)^2 / \sum(Y_O - Y)^2\} \qquad 3.8.1$$

Where, Y_O is the observed value, Y_S is the simulated value, Y is the mean of observed values.

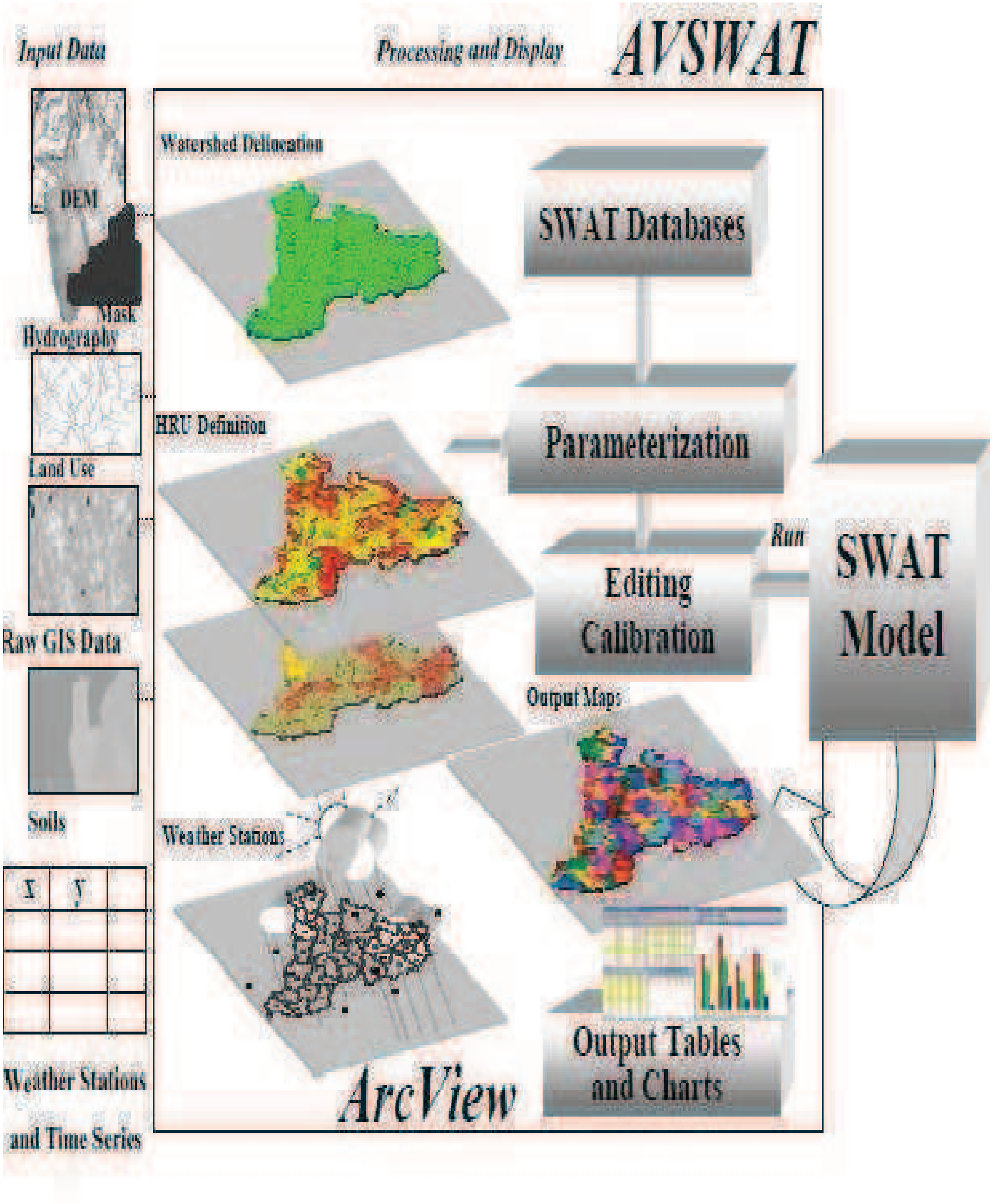

Fig.3.4 Schematic diagram of setting up of SWAT model.

3.9 Site selection of check dams

A **check dam** is a small dam, which can be either temporary or permanent, built across a minor channel, swale, or drainage ditch. Similar to drop structures in purpose, they reduce erosion and gullying in the channel and allow sediments and pollutants to settle. They also lower the speed of water flow during storm events. The most important decision to be taken when building such a dam is its location.

The advantages of check dams are that they store surface water for use both during and after the monsoon. They help in ground water recharge of the area. Recharge of water helps in raising the water table in the area. Availability of water ensure increase in agricultural yield by multi-cropping. Check dams can also be used for pisciculture.

The process of selecting the site for the construction of check dams requires detailed analysis of different aspects.

- The total water available for impoundment without affecting the natural flow of the river.
- Total amount of water need in the riparian region of the check dam.
- Geological properties of the area like soil stability, porosity, etc.
- Site selected should be such that length of dam is minimized and amount of water which can be impounded is maximized.
- Economical aspects.
- The structure should be able to store a high volume of rain-water over a long duration of time. It should provide a long length of stored water.
- There should be a high percentage of cropped area on either side of the length of stored water.
- Minimizes risk of submergence of cropped lands during flash floods. It should have a high benefit-cost ratio.

In this study, we examine the long-term impact of check dams on stream channels. The results are used to evaluate the effectiveness of check dams.

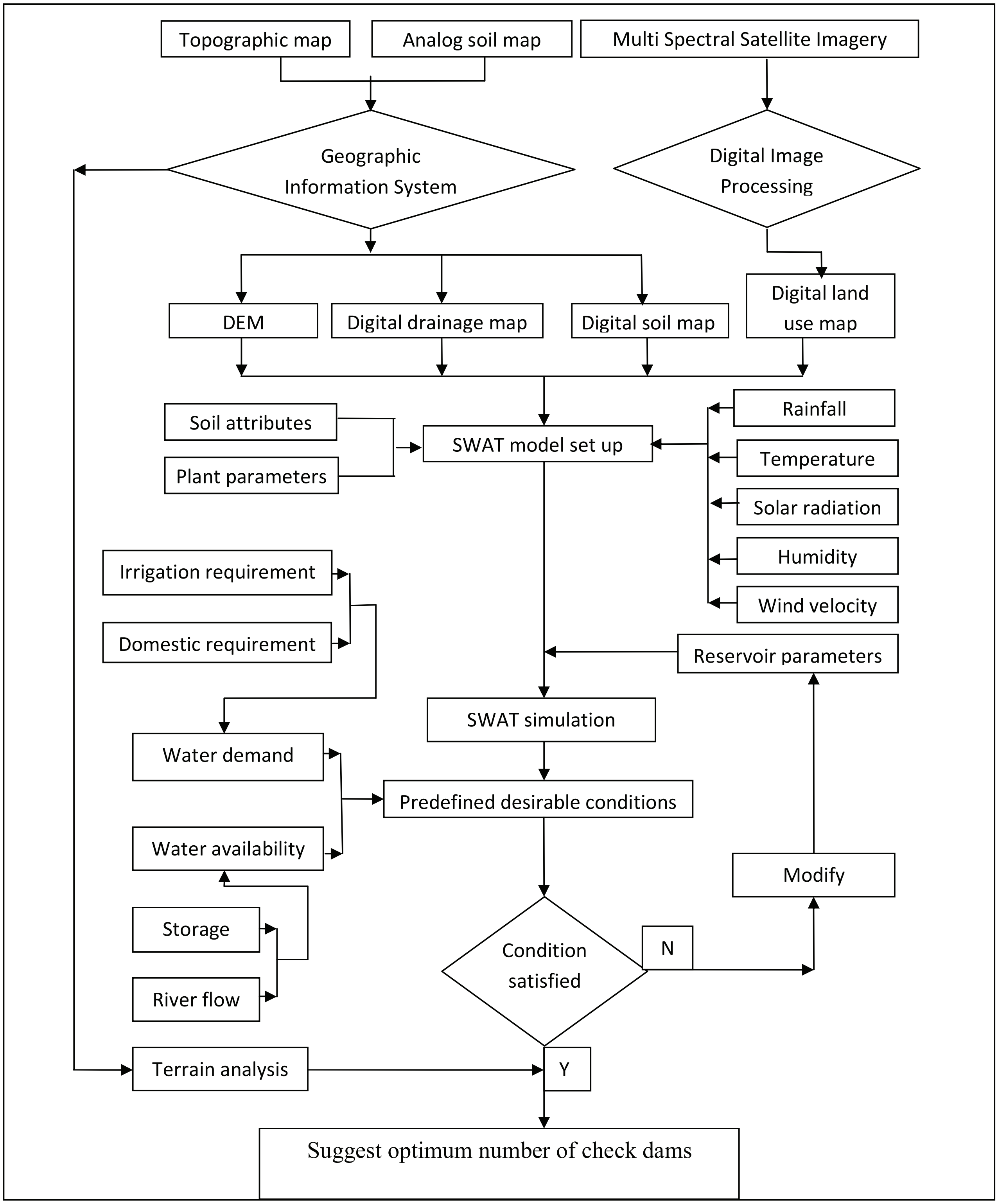

Fig.3.5 Flow chart showing operation of SWAT

Results & Discussions

Chapter 4

Results and Discussions

4.1 Physiographic description of the catchment

The geographical area of the Kunthipuzha basin corresponding to the Pulamanthole gauging station, which is about 5 km upstream of the confluence of this tributary with the main stream Bharathapuzha, is 822.2 km^2. The salient findings of the detailed spatial analysis of the basin using remote sensing and GIS are given below. Study area is shown in Fig 4.1.

Fig.4.1 Kunthipuzha catchment

4.2 Digital Elevation Model (DEM)

The DEM of Kunthipuzha sub basin was prepared with a grid resolution of 50m x 50m. The DEM was classified for different elevation bands and the classified map showing different elevation ranges are shown in Fig 4.2. It was found that the elevation varies from 20m to 2300m. The mean elevation was found to be 303.71m. About 9.46% area of the watershed was within the bounds of 20 to 50 m, 19.54% between 50 to 75 m, 32.51% between 75 to 100 m, 17.82% between 100 to 500 m, 11.17% between 500 to 1000 m and the remaining 9.5% lies between 1000 to 2300 m.

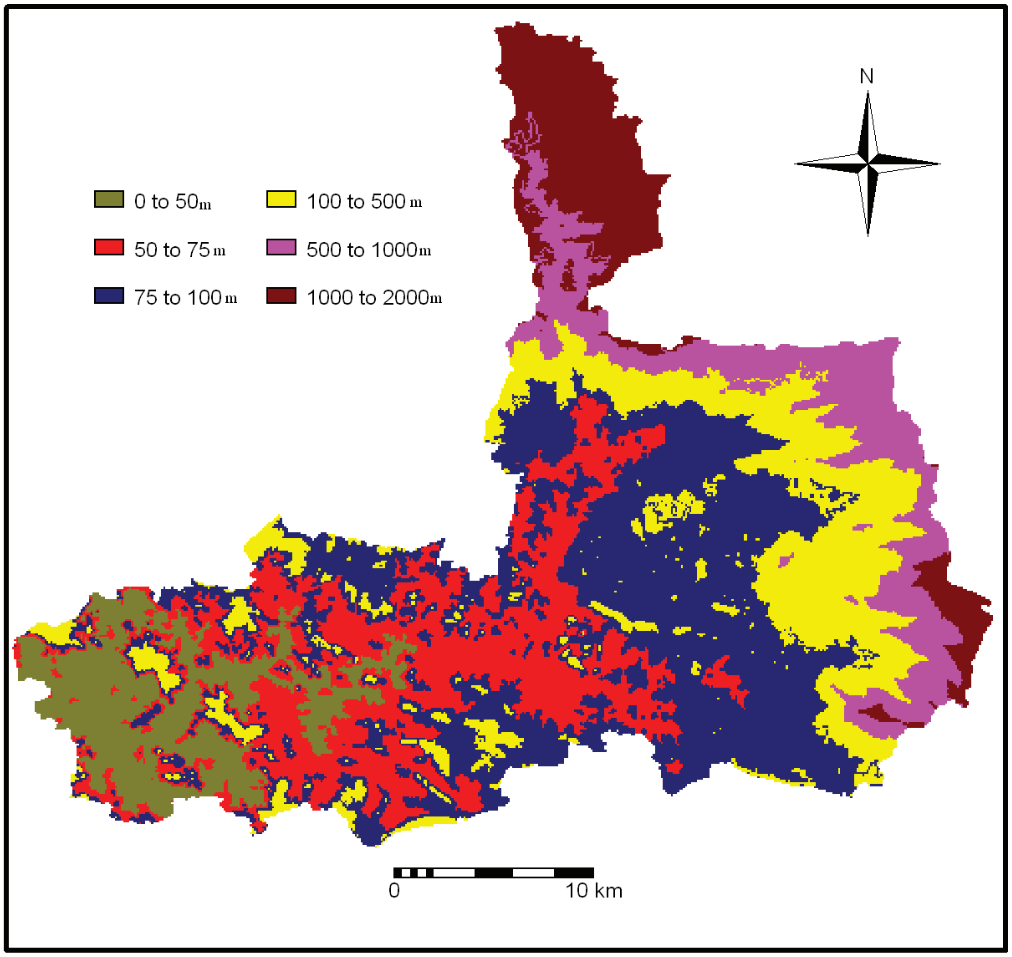

Fig.4.2 Digital Elevation Model of Kunthipuzha watershed

4.3 Hypsometric curve

The hypsometric curve of the watershed which shows the area elevation relationship is presented in Fig 4.3. The curve indicates that about 20% of the catchment has very high slope, 50% of the area has moderate to high slope and 30% of the area has low land slope.

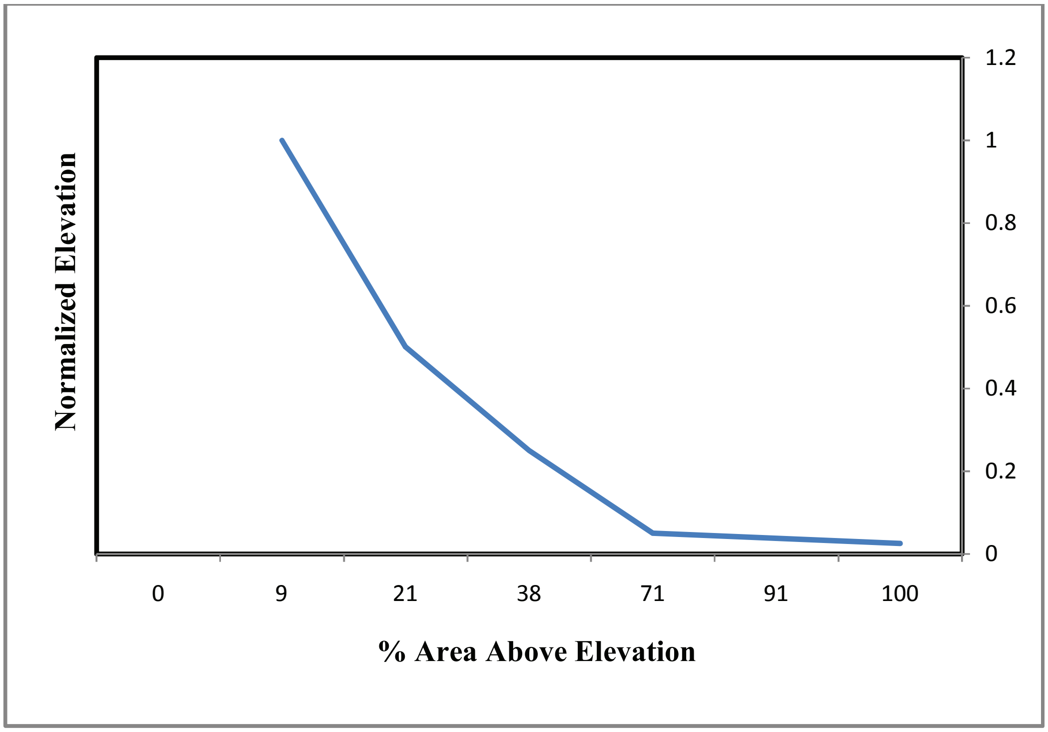

Fig.4.3 Hypsometric curve of Kunthipuzha Basin

4.4 Soil map

The soil map of the river Kunthipuzha with 10 soil classes was developed. The digital soil map showing different soil series are shown in the Fig 4.4. About 44.89% of the total area of the watershed is composed of Pallippadi soil series. The other soil series of the watershed include Chelikkuzhi, Kanchirappuzha, Kongad, Manimala, Manjallor, Kalladikkode, Perambra, Kottappadi and Ithux.

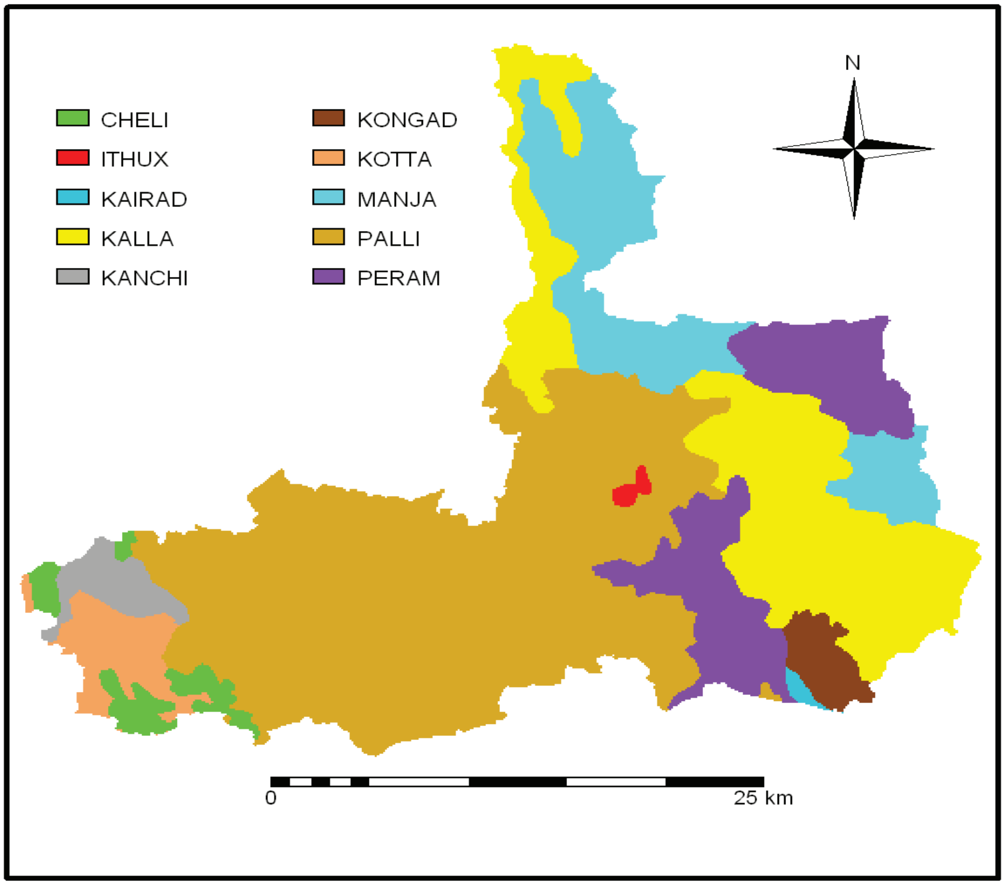

Fig.4.4 Soil map of Kunthipuzha catchment

4.5 Land use map

The land use map developed through supervised classification of the satellite imagery shows that there are 12 different land use classes as shown in Fig 4.5. Major land use types of the watershed are Garden land (37.37%) and Evergreen forest (18.51%). The rest of the landuse classes delineated in the watershed include Dense Mixed Crop, Mixed forest, Rubber Plantation, Paddy dry, Paddy, Barren land, Open scrubs, River bed and Water.

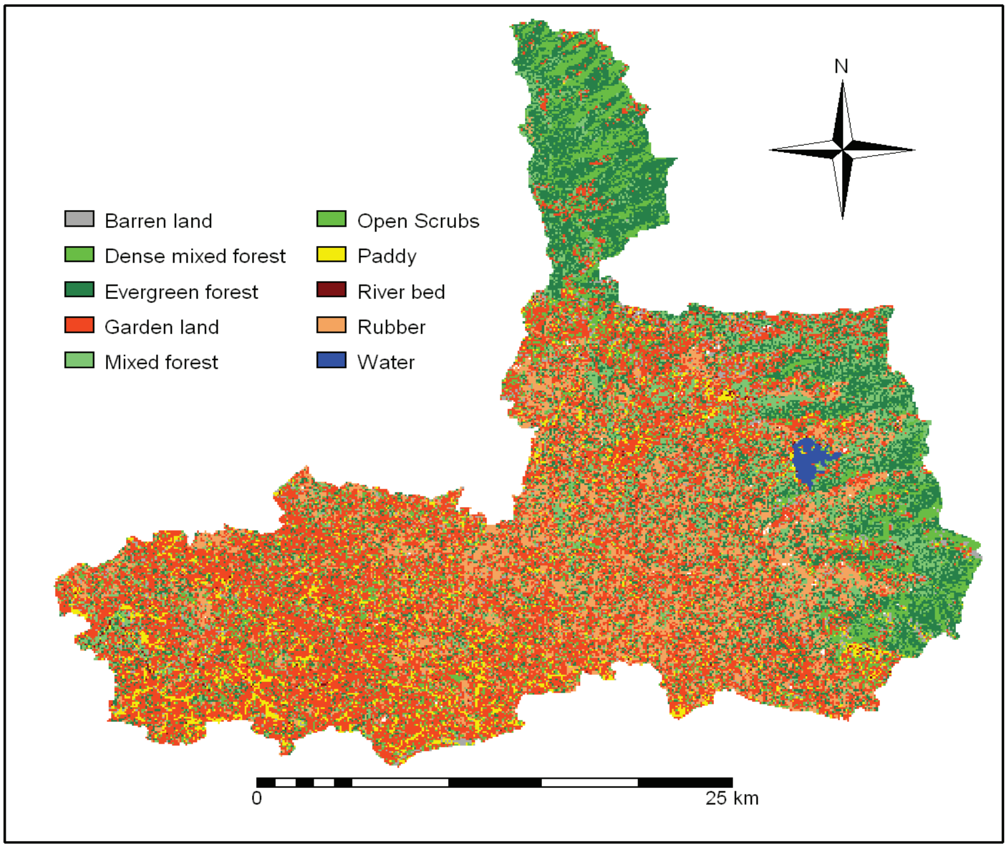

Fig.4.5 Landuse map of Kunthipuzha watershed

Table.4.1 Soil types in Kunthipuzha watershed and their area coverage.

Series	**Area(km^2)**	**% Area of watershed**
Chelikkuzhi	20.3	2.46
Ithux	2.41	0.29
Kairad	1.93	0.23
Kalladikkode	168.34	20.47
Kanchirappuzha	17.53	2.13
Kongad	15.7	1.9
Kottappadi	28.33	3.44
Manjallor	104.11	12.66
Pallippadi	369.15	44.89
Perambra	91.01	11.06
Total	**822.22**	**100**

Table.4.2 Landuse within Kunthipuzha watershed and their area coverage.

Class	Area(km^2)	% Area of watershed
Barren land	24.06	2.92
Dense mixed crop	42.72	5.19
Evergreen forest	152.24	18.51
Garden land	307.27	37.37
Mixed forest	90.88	11.05
Open scrub	53.74	6.53
Paddy	41.75	5.07
River bed	2.26	0.27
Rubber	99.65	12.11
Water	3.4	0.41
Total	**822.22**	**100**

4.6 Mean monthly rainfall and temperature.

Mean monthly rainfall distribution for the study period is shown in Fig 4.6 and it indicates that temporal variation of rainfall is very significant. The month of June receives the maximum rainfall of about 537.82 mm out of the annual total of 2269.57 mm and it is followed by August, October and July, (519.73mm, 323.01mm & 293.23 mm respectively). Practically there is no rainfall from the month of December to February. The monthly temperature variation shows that maximum temperature is received in the months of March (30^0C), followed by May (29.9^0C) and April (29.4^0C). Lowest temperature is experienced during November (23.6^0C) and February (24.6^0C).

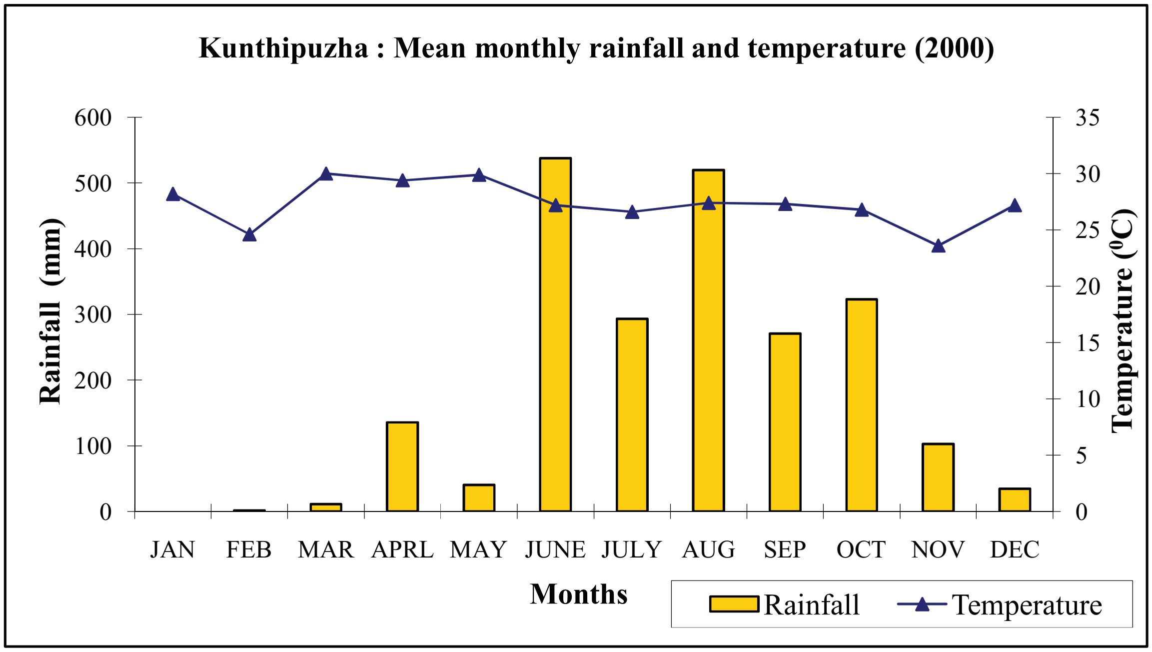

Fig. 4.6 Mean monthly rainfall and temperature of Kunthipuzha

4.7 Mean monthly river flow

It can be observed from Fig 4.7 that 25% of annual river discharge is taking place during August followed by October (20.7%), September (16%) and July 15%. River flow of Kunthipuzha is almost nil during February to May.

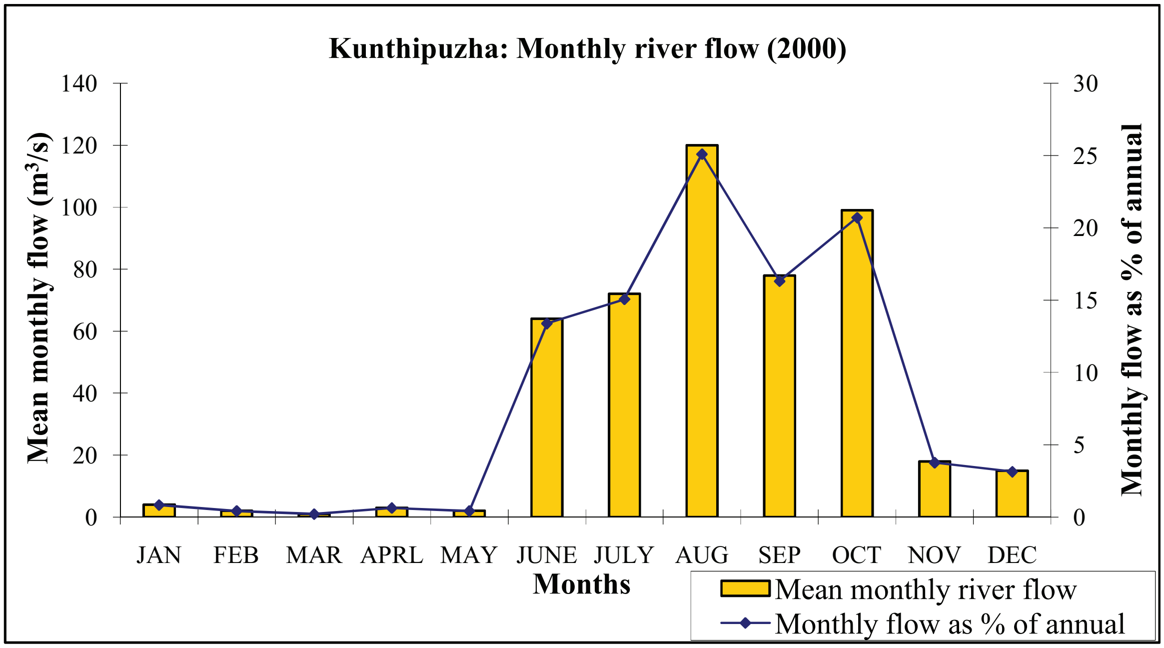

Fig. 4.7 Mean monthly river flow of Kunthipuzha

The observed and simulated values of average annual river flow for calibrated model without check dams are shown in Fig.4.8. NSE of the simulation is 92%.

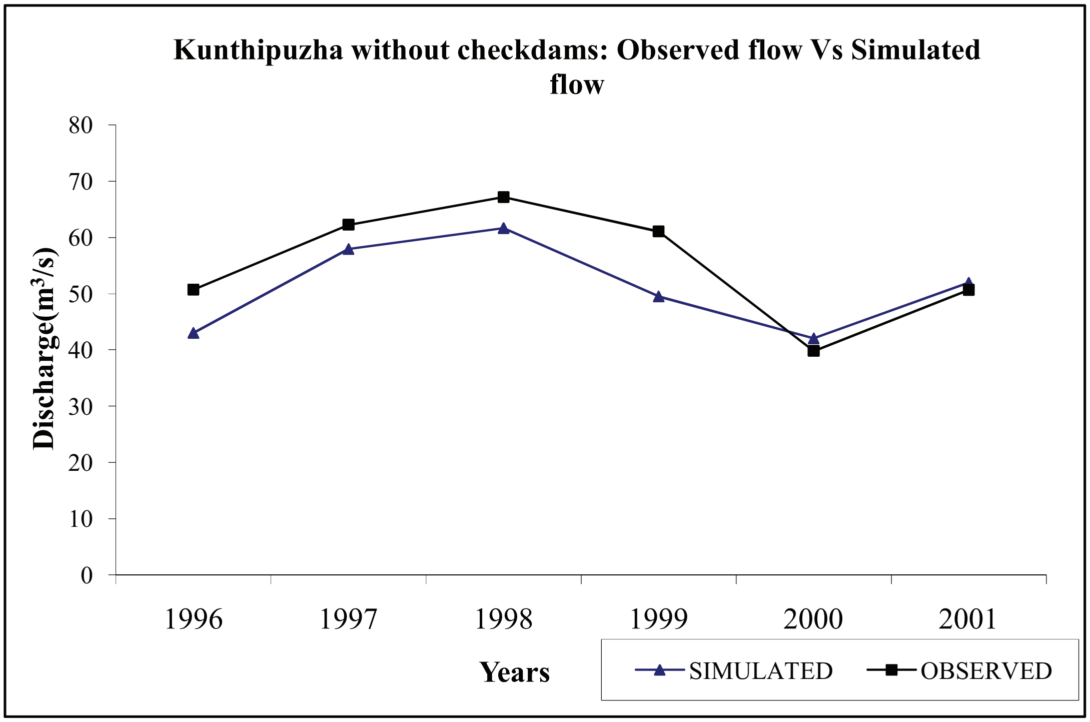

Fig.4.8 Average annual river flow without check dams

4.8. Sub watersheds of Kunthipuzha

The Kunthipuzha basin corresponding to Pulamanthole outlet was divided into 53 sub watersheds. Along the drainage networks 50 check dams were added, one each to the outlets of the 50 sub basins. Fig.4.9 shows the watershed with sub watershed boundaries and the locations of check dams.

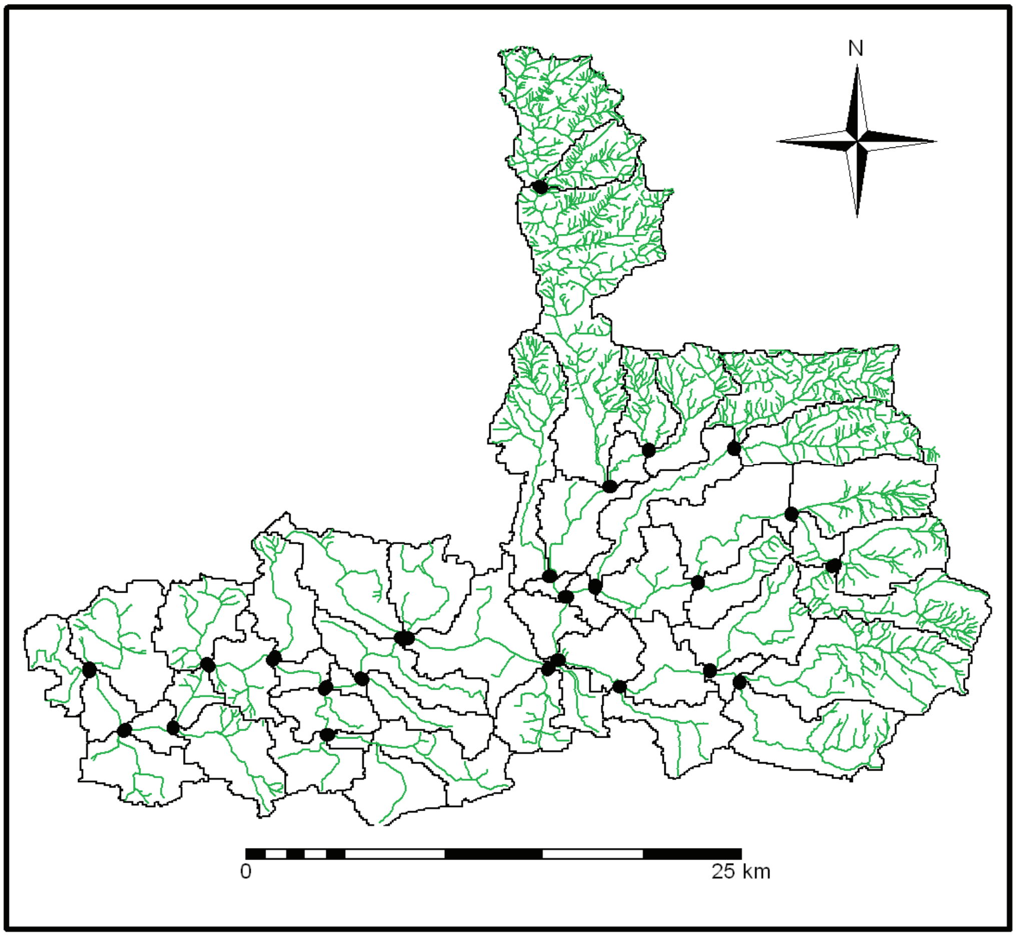

Fig.4.9 Kunthipuzha watershed with sub basins and locations of check dams

4.9 Description of Sub watersheds

The detailed physical descriptions of the sub watersheds are shown in the Table. 4.3.

Table.4.3 Physical characteristics of the sub watersheds of Kunthipuzha River basin

Sub watershed No	Area (km^2)	Mean elevation(m)	Mean slope (m/m)	Channel length(km)	Channel slope(m/m)
1	26.77	1500	0.421	4.756	0.03
2	12.08	1400	0.390	1.322	0.097
3	27.99	420	0.272	4.825	0.046
4	10.35	233	0.255	0.292	0.069
5	24.62	600	0.339	4.283	0.025
6	17.37	80	0.248	3.144	0.01
7	66.12	1030	0.284	20.361	0.045
8	4.50	70	0.045	3.456	0.006
9	23.7	120	0.314	3.906	0.005
10	5.41	200	0.208	3.905	0.015

Sub watershed No	Area (km^2)	Mean elevation(m)	Mean slope (m/m)	Channel length(km)	Channel slope(m/m)
11	18.66	400	0.450	1.716	0.012
12	22.54	600	0.462	8.208	0.068
13	28.37	80	0.162	9.565	0.002
14	15.98	82	0.030	6.694	0.002
15	25.18	83	0.062	8.536	0.002
16	12.47	80	0.130	1.174	0.007
17	18.98	80	0.049	11.571	0.002
18	15.51	100	0.055	6.36	0.003
19	2.26	62	0.042	1.473	0.002
20	3.78	120	0.068	1.607	0.018
21	21.74	120	0.085	5.531	0.008
22	0.12	40	0.046	0.341	0.001
23	16.38	61	0.062	3.309	0.008
24	25.56	60	0.041	8.177	0.004
25	17.02	56	0.100	3.006	0.002
26	4.92	40	0.067	3.514	0.005
27	8.11	62	0.057	3.756	0.003
28	11.23	60	0.064	3.739	0.007
29	17.24	60	0.091	1.840	0.001
30	13.31	40	0.083	3.880	0.002
31	23.32	35	0.079	3.281	0.005
32	7.07	70	0.033	0.624	0.003
33	12.02	81	0.045	1.278	0.002
34	20.55	90	0.109	3.026	0.007
35	7.02	25	0.040	3.904	0.002
36	3.05	60	0.038	1.89	0.001
37	18.26	40	0.068	3.656	0.004
38	11.04	80	0.067	1.095	0.001
39	39.04	250	0.332	9.859	0.007
40	28.07	85	0.149	7.103	0.003
41	2.25	48	0.046	1.966	0.005
42	15.38	80	0.037	3.988	0.003
43	13.64	80	0.046	5.729	0.005
44	10.41	60	0.038	3.014	0.003
45	57.90	41	0.082	4.046	0.001
46	4.70	43	0.070	2.566	0.01
47	18.19	38	0.089	3.426	0.005
48	15.10	40	0.056	1.599	0.013
49	11.82	60	0.075	1.016	0.017
50	1.88	58	0.050	2.449	0.008
51	15.57	80	0.081	3.485	0.003
52	13.31	60	0.084	1.174	0.002
53	9.56	33	0.066	3.226	0.003

4.10. Model calibration and validation

Seven years (1996-2002) of daily rainfall data is used for the model simulation. The period of 1998 to 1999 is taken as calibration period and the period of 2001 to 2002 is taken as the validation period. Nash Sutcliffe Efficiency and Coefficient of Determination for calibrated and validated models during these periods are shown in Table.4.4. Time series curve shown in Fig 4.10 and Fig 4.11 for calibration and validation periods have close resemblance for the observed and simulated river flow. The results suggest that the model can be used to predict the average monthly discharge values.

Table.4.4.Descriptive statistics of mean monthly river flow

Statistics	Calibration period (1998 -1999)		Validation period (2001-2002)	
	Observed Flow (m^3/s)	Simulated Flow (m^3/s)	Observed Flow (m^3/s)	Simulated Flow (m^3/s)
MEAN	66.3	65.9	36.5	54
SD	69.42	65.85	40.75	47.86
NSE		0.92		0.47
COD		0.99		0.98

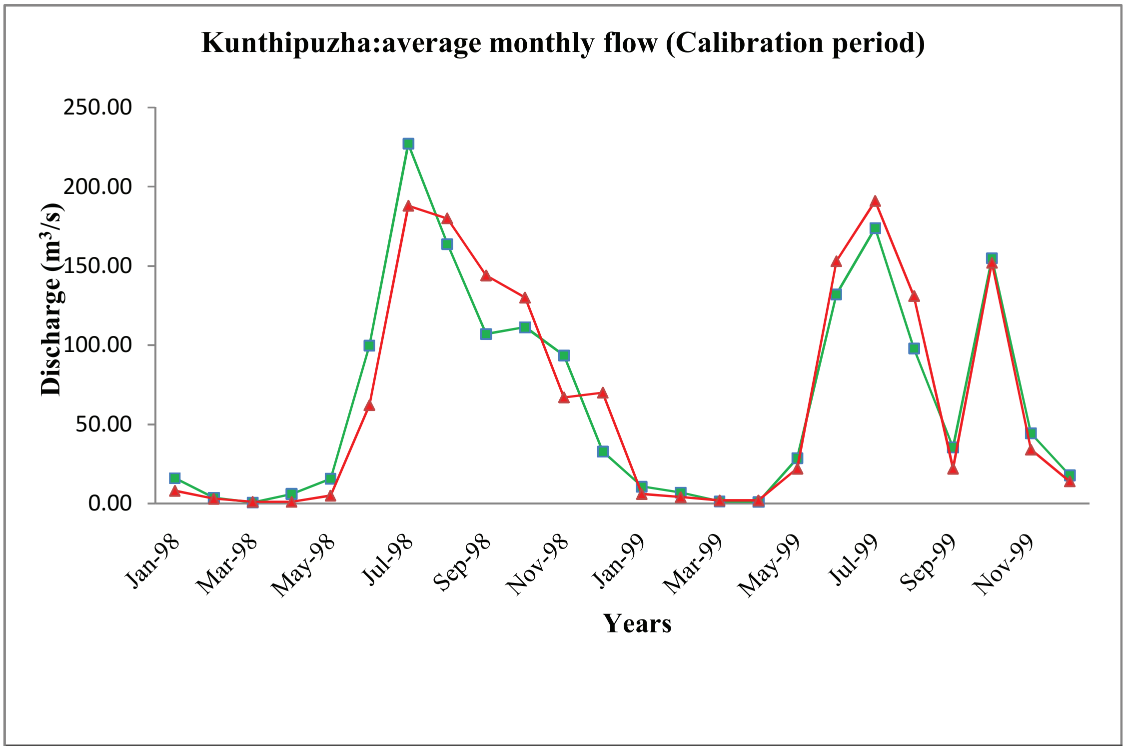

Fig. 4.10 Monthly average river flow - calibration period

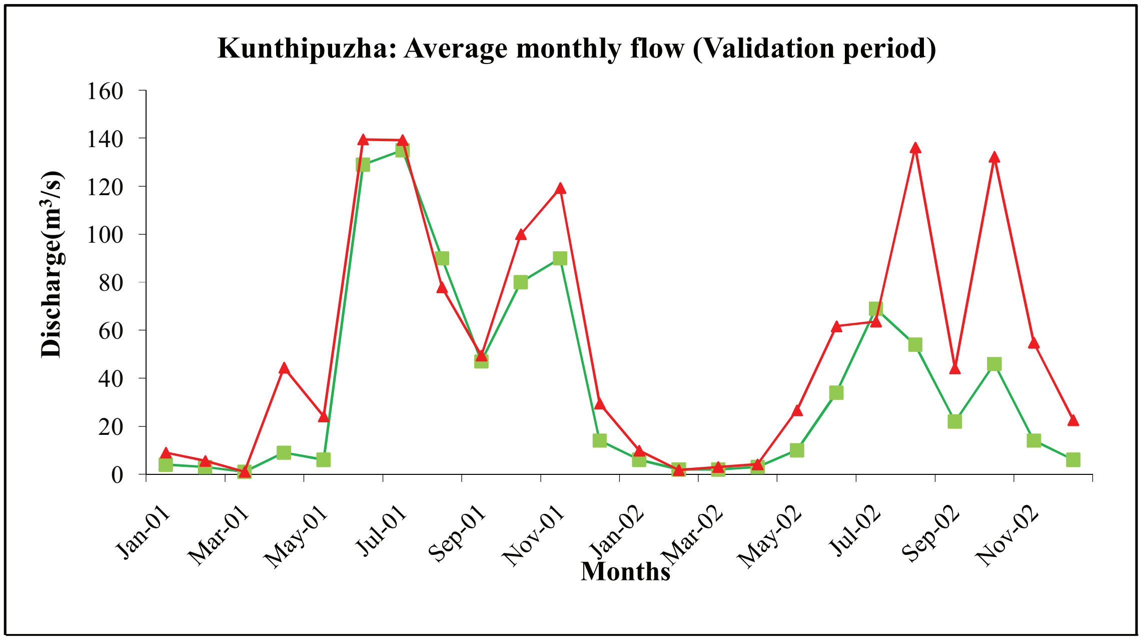

Fig.4.11 Monthly average river flow - validation period

4.11. Impact of check dams on various hydrologic processes

The calibrated model was used for simulation of hydrologic processes of the basin without check dams, with 23 check dams and with 50 check dams to analyse the impact of check dams on riverflow. The various hydrologic components obtained from the standard output files were compared**.** It is seen that increase in the number of check dams has a positive impact on the baseflow and yield during the summer months.

Table.4.5 Comparison of basin yield and base flow for the year 1999

Months	**Monthly Yield (mm)**			**Monthly Base Flow(mm)**		
	No checkdams	**24 check dams**	**50 check dams**	**No checkdams**	**24 check dams**	**50 check dams**
January	28.78	30.43	31.48	28.10	29.75	30.80
February	18.46	19.58	20.28	7.64	8.76	9.47
March	3.6	4.75	5.46	3.26	4.41	5.13
April	2.53	3.09	3.43	0.38	0.94	1.28
May	77.33	77.85	78.12	0.20	0.7	0.97
June	356.98	358.94	360.20	30.13	32.09	33.35
July	469.83	469.96	469.98	105.01	105.11	105.13
August	264.39	264.38	264.40	149.20	149.18	149.20
September	95.78	97.29	98.29	84.74	86.24	87.24
October	418.48	419.3	419.77	51.80	52.54	53.01
November	119.77	120.06	120.21	90.63	90.92	91.07
December	48.09	50.21	51.55	47.32	49.43	50.78
	1904.01	**1915.82**	**1923.17**	**598.40**	**610.08**	**617.43**

Table.4.6 Comparison of basin yield and base flow for the year 2000

Months	Monthly Yield (mm)			Monthly Base Flow(mm)		
	No checkdams	24 check dams	50 check dams	No check dams	24 check dams	50 check dams
January	11.71	13.09	13.96	11.28	12.66	13.53
February	1.73	2.58	3.09	1.45	2.30	2.81
March	2.04	2.37	2.53	0.25	0.59	0.74
April	29.92	30.17	30.29	0.06	0.31	0.43
May	6.27	6.59	6.94	0.08	0.40	0.75
June	198.46	201.12	202.84	10.82	13.44	15.17
July	284.02	285.62	286.43	88.71	90.29	91.10
August	351.41	351.46	351.50	97.16	97.18	97.22
September	266.09	266.2	266.21	112.84	112.92	112.94
October	289.39	285.80	286.06	112.01	112.39	112.64
November	108.14	110.22	111.56	81.29	83.36	84.70
December	71.75	73.12	73.99	45.69	47.05	47.92
	1616.93	**1628.34**	**1635.40**	**561.63**	**572.90**	**579.95**

Comparison of baseflow and yield without check dams, with 24 and 50 check dams

Daily yield of Kunthipuzha basin and base flow is analyzed for the summer period and is presented in Fig. 4.12. The results show that there is tremendous increase in both yield and base flow for the scenario with check dams.

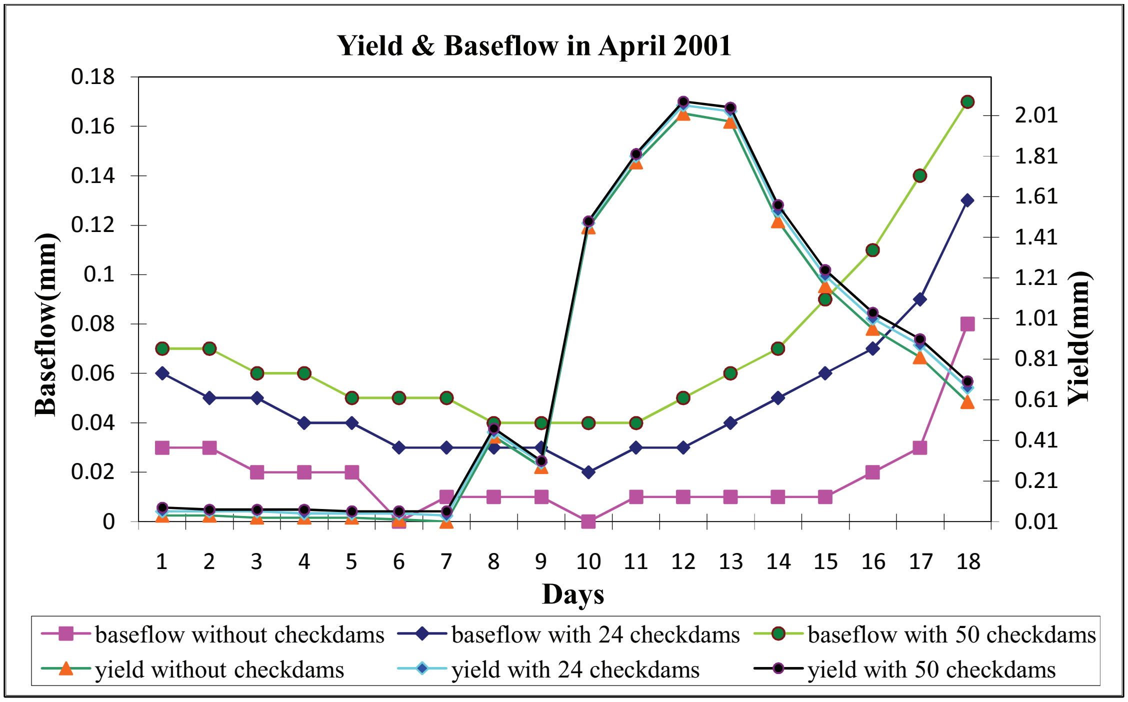

Fig.4.12 Yield and Baseflow (April 2001)

It can be seen from Fig. 4.15 that the baseflow has increased considerably by the addition of check dams. Improvement in summer flows underlines the effectiveness of check dams in the river network to augment the lean flow.

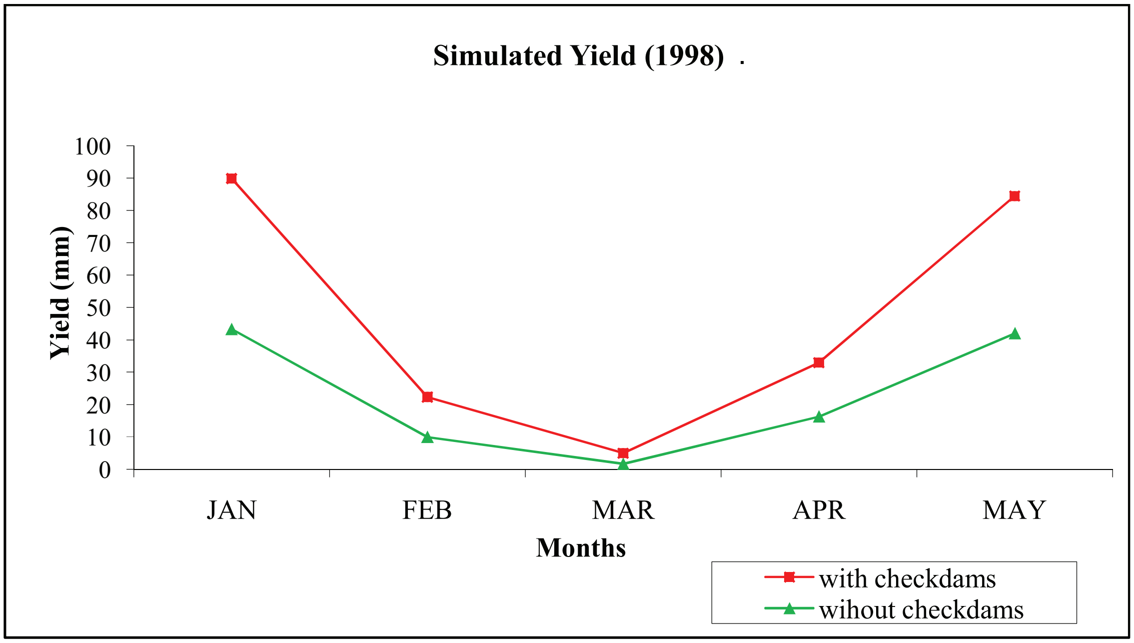

Fig. 4.13 Comparison of yield of the summer months in 1998

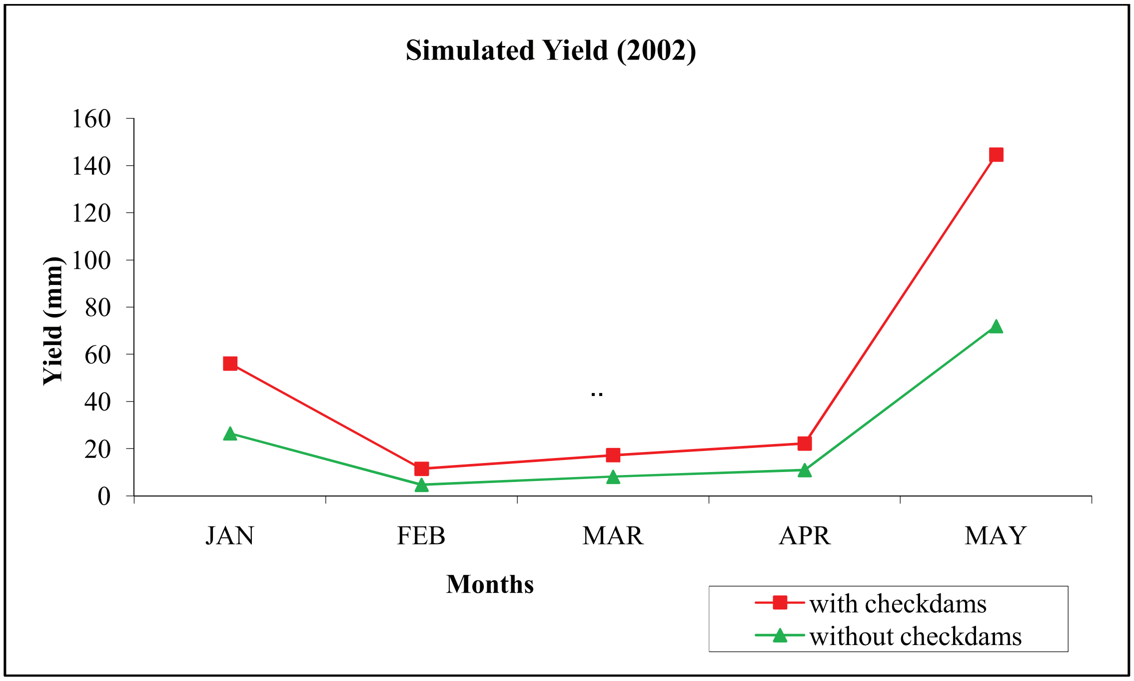

Fig. 4.14 Comparison of yield of the summer months in 2002

Similarly, the contribution of checkdams in supplementing baseflow can be understood from the result presented in Fig. 4.15. Increase in the baseflow will directly augment the river flow and helps in maintaining the flow in the river channels during water scarce periods.

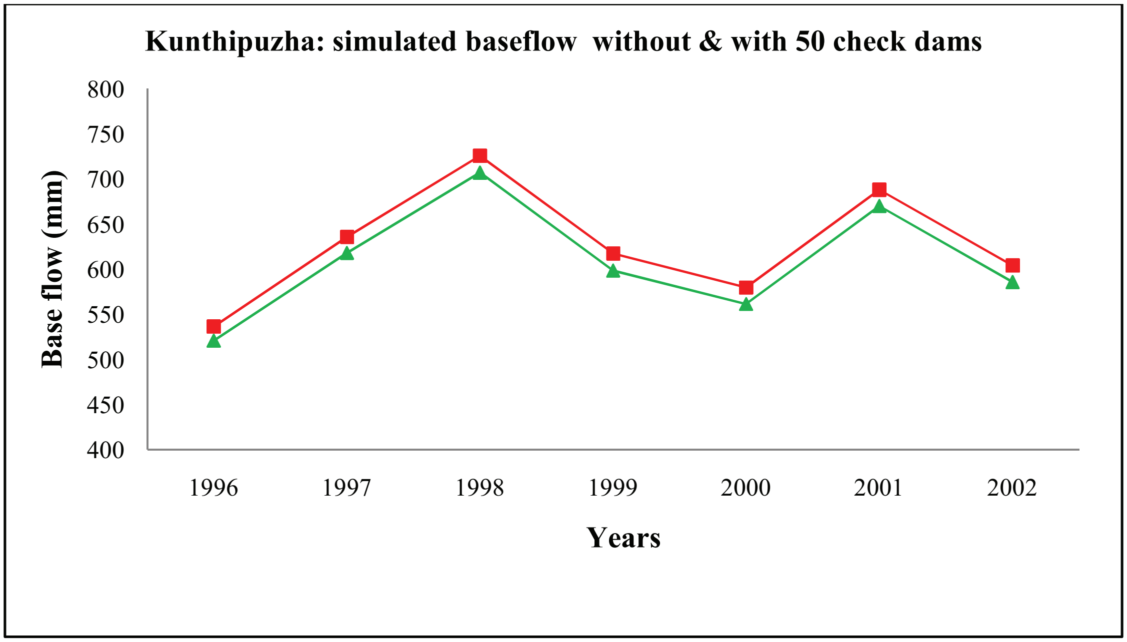

Fig.4.15 Yearly baseflow comparison

Approximately an increase in discharge of 0.32m^3/s during summer months was obtained when a total of 50 check dams were added.

4.12. Water balance of the basin

From the point of view of water conservation, one must consider the individual hydrologic components rather than the total river flow. Water balance components such as surface runoff, lateral flow, baseflow, evapotranspiration and deep percolation have also been simulated. Thus the study revealed that a properly calibrated watershed model could be of great help in predicting the basin level water balance. The predicted values of the water balance components for model with check dams and without check dams as a percentage of mean annual rainfall for the years 2000-2002 are shown in Fig. 4.16. It can be observed that the check dams have an influence on groundwater recharge and for the year 2002, the groundwater flow has increased from 27.55 % to 28.41 %.

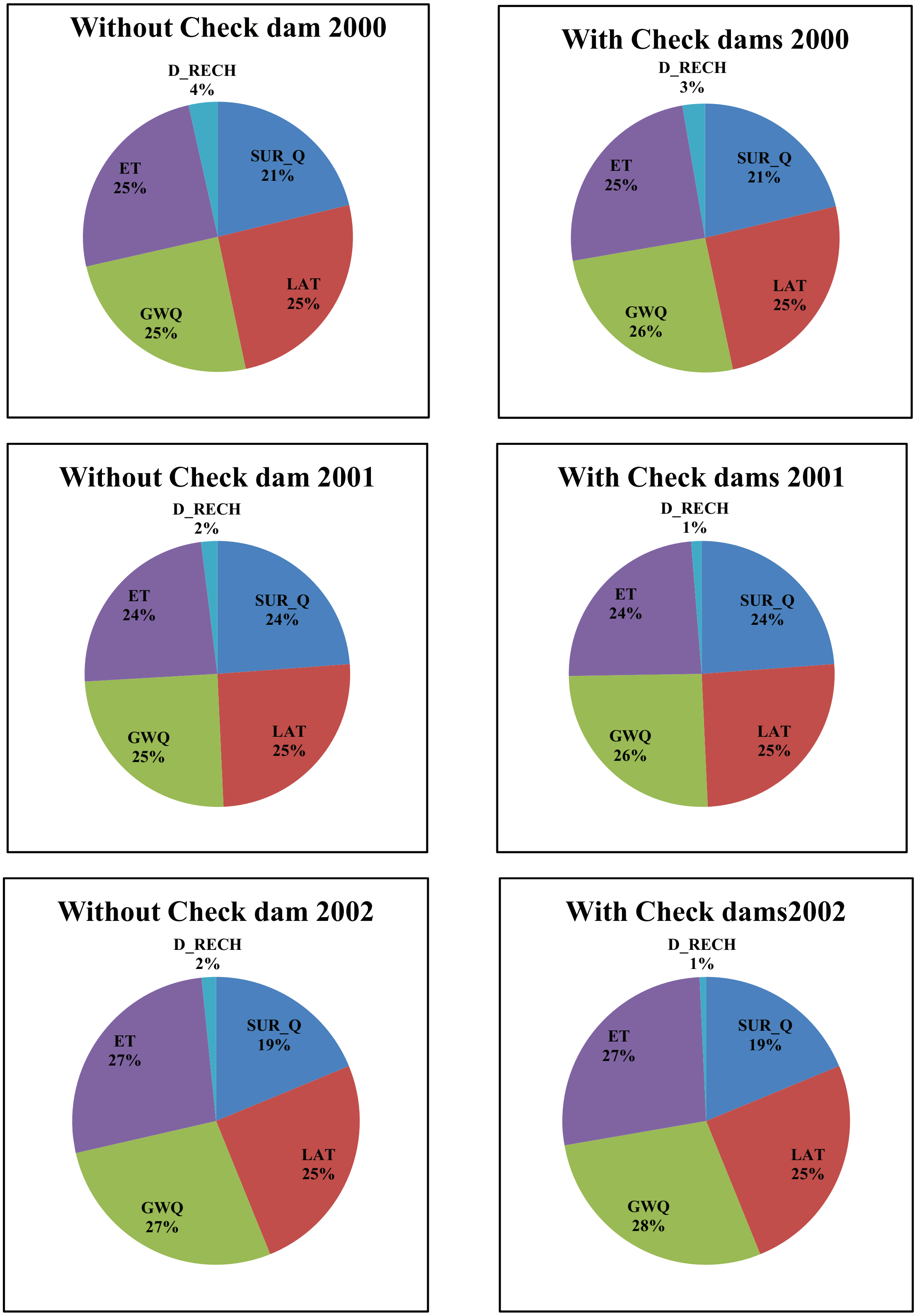

Fig.4.16 Percentage values of water balance components

4.13. Water balance of Check dams

The water balance of some of the check dams incorporated into the river network is presented in Table. 4.7.

Table.4.7 Check dam water balance for March (1999)

Check dam	Flow in during month (m^3)	Precipitation during month (m^3)	Vol. Stored at beginning of month (m^3)	Flow out during month (m^3)	Seepage During month (m^3)	Evaporation during month (m^3)	Vol. impound ment (m^3)
1	151918.8	36	1795	134375.3	14380	848.5	4146.02
6	92619.07	540	23310	20074.61	75140	4300	16954.46
8	290874.2	0	53370	151061.8	133900	6642	52640.48
37	318729.6	0	72690	117126.4	200000	9913	64380.17

4.14 Benefits of river flow augmentation

The state of Kerala has been facing increasing incidents of water shortage in the summer months for the past few years. This problem can be solved to a great extent by augmenting the river flow during summer months.

The increase of 1mm of basin yield per month will result in an increase of flow of 0.32 m^3/s in the Kunthipuzha and when it is extrapolated for the entire Bharathapuzha basin will result in an increase in flow of about $2.5m^3/s$ for every month. This extra amount of water is sufficient for meeting the daily domestic requirements (100 l per head) of nearly 20 lakh people throughout the year. Considering the fact that water scarcity is faced only during 3 to 4 summer months this figure can very well go up to about 4 times.

Nowadays, one of the reasons for the paddy fields being left fallow during summer months is due to the lack of irrigation water. Nearly 5000ha of paddy fields can be irrigated using this water by considering the average daily evapotranspiration from the field as 4.15 mm.

Additional utilities like pisciculture and recreational activities can be carried out in the reservoirs formed by these check dams. Indirectly, the impoundment of excess rainfall will reduce the erosion of top soil from the catchment. The increase in the residence time of water will facilitate enhanced groundwater recharge. The reservoirs will further create a cushioning effect for the flood wave by reducing its intensity to the lower reaches.

Summary & Conclusion

Chapter 5

SUMMARY AND CONCLUSION

Hydrologic simulation studies were conducted on Kunthipuzha subbasin of Bharathapuzha river in Kerala State of India using GIS integrated physically based distributed model. The geographical location of the watershed is between $10^0$53’40” and $11^0$15’59” North latitude and between $76^0$11’3” and $76^0$37’51” East longitudes respectively. The total area of the watershed is 822.22 km^2. The main objectives of the project work include studying the interrelationship between morphological & hydrological characteristics of watershed using GIS & RS, the impact of check dams on various hydrological processes such as surface runoff, lateral flow, base flow, etc. and to suggest suitable sites and optimum number of check dams to achieve augmented and sustainable river flow for the lean season.

Geographical area of Kunthipuzha comprises about 14% of the Bharathapuzha river basin. The elevation of Kunthipuzha watershed varies from 20m to 2300m as revealed by the DEM. And the average elevation was found to be 303.71 m. The soil map of the river basin with 10 soil classes was developed. About 44.89% of the total area of the watershed consists of Pallipady soil series. The other soil series of the watershed include Chelikkuzhi, Kalladikkode, Kanchirappuzha, Kongad, Kottappadi, Manimala, Manjallor, Pallippadi, and Perambra. Land use map for the study area was prepared from LISS Ш imagery of IRS P6 by supervised classification. The land use map thus developed shows that there are 11 different land use classes within the Kunthipuzha watershed. Major land use types identified in the watershed are Garden land (37.37%) and Evergreen forest (18.51%). The rest of the landuse classes delineated in the watershed include Dense Mixed Crop, Mixed forest, Rubber Plantation, Paddy, Barren land, Open scrubs, River bed and Water.

SWAT model was set up for Kunthipuzha, river basin by inputting all thematic and attribute data. The entire watershed was divided into 53 sub basins and 327 HRUs by selecting the basin outlet at Pulamanthole (10°53' 50" N, 76°11 '50"E). Simulations were carried out for the model with check dams and without check dams, by manually changing the parameters and comparing their output files. Simulations were done on annual, monthly and daily basis for both calibration and validation period. The statistical methods of NSE and COD were used to evaluate the model’s predictive capability. The model showed an NSE of 92% and COD of 99% for the monthly simulation in the calibration period and NSE of 47%

and COD of 97 % in the validation period. The low NSE value for the validation period may be due to the discrepancy in the observed data of June to September for the year 2002.

The base flow contribution showed an increase during summer months when a number of check dams were incorporated and this in turn resulted in the enhanced basin yield. The graphs showing the comparison of simulations for no checkdam, with 24 & 50 checkdams were plotted on daily, monthly and annual basis for different years. Approximately an increase in discharge of $0.32m^3/s$ per month was obtained when a total of 50 check dams were added. If we extrapolate this result for the entire Bharathapuzha basin a corresponding increase in flow of about $2.5m^3/s$ will be resulted. The benefits of augmentation are also discussed in brief in this report.

There is scope for further research to optimize the number and location of check dams. Similar studies can be extended to other riverbasins of Kerala.

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SIMULATING THE IMPACT OF CHECK DAMS ON RIVER FLOW- A CASE STUDY IN BHARATHAPUZHA RIVER BASIN

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PROJECT REPORT

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ABSTRACT

The state of Kerala faces severe water stress during summer months. One of the most feasible solutions to this problem is the livening of the rivers of Kerala. Hence, a pilot study has been carried out on Bharathapuzha, which is the lifeline of several millions of people in the state. This study focused on implementation of check dams for improving summer flow regimes of the river. The project is aimed to improve the yield of Kunthipuzha, one of the tributaries of Bharathapuzha. It has a catchment area of 822.22 km^2. Micro watershed delineations and their topographic analysis were carried out with the help of ILWIS and SWAT. Digital Elevation Model (DEM), drainage network, soil map and land use map for the catchment were prepared by utilizing the integrated GIS and image processing capability of ILWIS. SWAT was set up and calibrated for the basin with good simulation efficiency and the calibrated model was used to analyze the water balance of the whole basin and that of the individual subbasins. The statistical measures of NSE and COD were used to evaluate the model's predictive capability. The model showed an NSE of 92 % and COD of 99 % for the monthly simulation in the calibration period and NSE of 47 % and COD of 97 % in the validation period. The base flow contribution showed a significant increase during summer months when a number of check dams were incorporated and this in turn resulted in considerable enhanced yield of the basin. The graphs showing the comparison of simulations without, with 24 & 50 checkdams was plotted on daily, monthly and annual basis for different years. Approximately an increase in discharge of 0.32m^3/s during summer months was obtained when a total of 50 check dams were added.

There is scope for further research to optimize the number and location of check dams. Similar studies can be extended to other river basins of Kerala.