

STUDIES RESEARCH PROGRAMMES AND PROGRESS



March 1987

**NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE- 247667 (U.P.)**

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FOREWORD

Water as the medium of life, has been a well recognised fact since time immemorial. Increasing demand on its usage due to growth in population, general living standards, industrialisation, urbanisation, use of modern agricultural practices, pollution control, demand on energy and recreation has given rise to its harnessing, control and allocation for the benefit and use of mankind. A large number of projects, therefore, have been undertaken world over to develop the water resources.

National Institute of Hydrology, the premier research institution of India in the field of hydrology has been engaged in undertaking, assisting, promoting and co-ordinating systematic scientific studies through theoretical and applied researches for bringing about improvements in the present practices in planning, designing, operation and management of water resources projects of the country. From its inception in 1979 till the end of Sixth Five-Year Plan, the emphasis of research has been on selected areas including computer oriented studies. During Seventh Five-Year Plan (1985-90) the scope of research has been broadened through the inclusion of field, laboratory and multi-disciplinary studies with the help of fourteen scientific divisions :

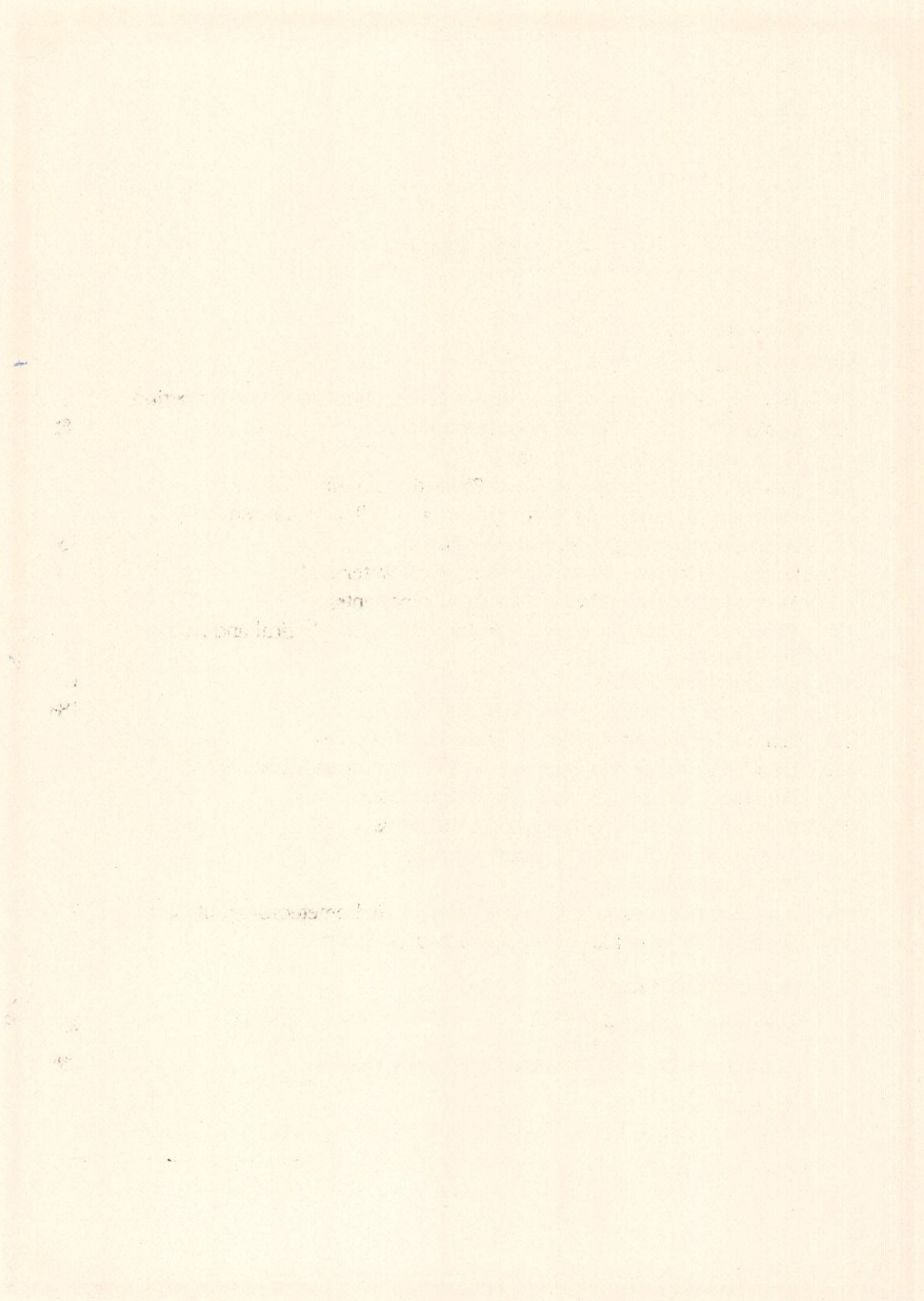
- (i) Hydrologic Design
- (ii) Surface Water Analysis and Modelling
- (iii) Flood Studies
- (iv) Mountain Hydrology
- (v) Groundwater Assessment
- (vi) Conjunctive Use
- (vii) Drainage
- (viii) Water Resources System
- (ix) Man's Influence
- (x) Drought Studies
- (xi) Information Systems and Data Management
- (xii) Remote Sensing
- (xiii) Hydrological Investigation
- (xiv) Hydrological Applications of Climate Information

Alongwith its research programmes, the Institute provides services in form of consultancy projects, technology transfer workshops etc. to various organisations of the country. As such besides others, nineteen research projects have been undertaken for extensive study under various divisions of this Institute. In order to bring out their broad objectives, status till 1986-87 as well as further works to be undertaken, a summary of each project has been brought out through this brochure.

SATISH CHANDRA
DIRECTOR

CONTENTS

	Page
Foreword	3
PROJECT TITLES	
1. Techniques for Capacity Computation and Optimal Reservoir Operation	7
2. Conjunctive Use of Surface and Groundwater	8
3. Hydrological Aspects of Droughts	9
4. Use of Unit Hydrograph in Flood Estimation for Small Basins	10
5. Mathematical Models for Water Quality and Pollution Assessment	11
6. Statistical Modelling of Annual Peak Floods	13
7. Design of Drainage System for Agricultural Watersheds	14
8. Assessment of Groundwater Balance Components	15
9. Measurement of Hydrological Variables Using Geophysical and Nuclear Techniques	16
10. Flood Routing Studies	17
11. Hydrological Studies in Forested Catchments	18
12. Remote Sensing Application to Hydrological Studies	19
13. Dam Break Studies for Planning of Flood Protection Measures	20
14. Data Base Management and Information System	21
15. Stochastic Modelling of Hydrologic Variables	23
16. Analysis of Hydro-meteorological Variables	23
17. Watershed Modelling	25
18. Automated Collection and Transmission of Hydrometeorological Data	25
19. Sediment Yield and Reservoir Sedimentation Studies	27
Organisational Chart	28
Institute's Capabilities	29
Consultancy Projects Completed and Under Progress	29
Appendices	31



TECHNIQUES FOR CAPACITY COMPUTATION AND OPTIMAL RESERVOIR OPERATION

Reservoir capacity computation based on various demand patterns, yields and releases is primary to design of any storage structure. In order to allocate the available resources as envisaged in the demand pattern to the various users particularly with stochastic inputs and to safeguard the structure as well as the surroundings, an optimal reservoir operation policy is essential. Setting up of an optimal operation policy is further complicated while dealing with a system comprising of many multipurpose reservoirs.

The project envisages to assist the planners in arriving at economic reservoir capacity together with optimal management policies for single or multiple reservoirs. As a first step towards the accomplishment of the objectives as outlined above, various methods of reservoir capacity computation have been reviewed, taking into account aspects such as, effect of stochasticity on inflows, storage requirements for specified yields and optimal management of single or multiple reservoirs. Based on the performances of various techniques the simulation technique has been found to be suitable and hence has been recommended.

Taking into account the inflows, outflows and change in storages, besides others, water balance analysis of reservoir has been carried out. A review of various optimization techniques as applicable to reservoir operation has also been carried out and discrete differential dynamic programming technique implemented for determination of optimal operation policy of a reservoir. In order to overcome and set priority over two conflicting purposes such as conservation and flood control, methodology for preparation of spillway regulating curves during floods have also been identified and adopted. Several simulation models have also been studied and implemented at this Institute and a case study on Bhakra-Beas system has been carried out.

The above aspects of studies carried out at the Institute have been brought out through review notes, technical note, user manuals and manuals on reservoir operation and management techniques including a case study of the Bhakra Beas Reservoir operation system.

Studies on storage computation for single purpose reservoirs is in progress and further studies on storage computation and setting up of operation policies for a multi-purpose reservoir and studies for real time operation of reservoirs are proposed to be taken up.

CONJUNCTIVE USE OF SURFACE AND GROUNDWATER

With the increasing demand placed on the groundwater as a source of supply for irrigation, industry and municipal use, the need for a rational management of groundwater has become evident. Groundwater systems are often connected with surface waters and the possibility for their exploitation in many cases depends on the conjunctive management of both surface and groundwater. The aim of this research project is to develop a sound conjunctive use model coupling the physical simulation model and alternate operational policies so that optimal use of water resource is achieved in a river basin.

In order to achieve the objectives envisaged in this project, different methods of assessment of rainfall recharge and irrigation return flow have been reviewed. Analytical methods to quantify seepage from water bodies such as depression storage and canals, when water table is at shallow depth have been developed. A methodology for determining storage in confined aquifer with flowing artesian well has been developed. Evaporation when water table is at shallow depth has been studied. Analytical solution has been obtained for unsteady flow to well that may tap any number of aquifers which are separated by aquicludes and which may have different initial hydraulic heads. Base flow computation has been made for varying river stages and groundwater levels.

Review of the graphical and empirical techniques for estimation of transmissivity, storage coefficient, specific yield and hydraulic conductivity has been done. Variation of specific capacity of large diameter well with time for different well storage has been studied. The relationships between transmissivity and specific capacity at various time after the onset of continuous pumping have been presented for different values of well storage and specific yield which can be used for quick estimation of aquifer transmissivity. An attempt has been made to establish guidelines to decide the minimum and maximum durations of the pumping test.

The above studies have been documented in form of review notes, technical reports and technical notes on various aspects of groundwater development, their assessment as well as techniques for their effective use in conjunction with surface water.

The future research programme envisaged under the project is to undertake detailed studies on :

- (i) Augmentation tubewell
- (ii) Assessment of groundwater recharge from surface water bodies
- (iii) Stream, multiaquifer, and well interaction.

After studying the different process level models, it is proposed to develop an aquifer management oriented conjunctive use model which will address to the withdrawal of water from groundwater reserve keeping in view the availability of surface water so as to get maximum benefit from the land resources without causing harmful effects such as water-logging, excessive drawdown and deterioration of water quality. The crop planning will be the outcome of the optimization model which is also envisaged to take into account the uncertainty of availability of surface water. The study will be undertaken for some of the river basins in hard rock areas and in alluvial plains.

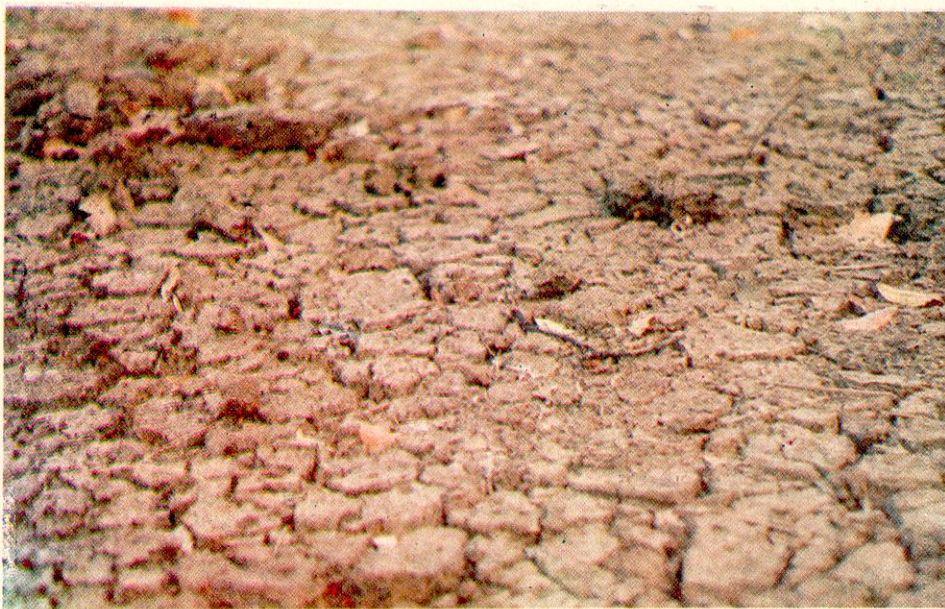
HYDROLOGICAL ASPECTS OF DROUGHTS

Hydrological uncertainties together with extreme manifestation of some of the related phenomena are main reasons for droughts, necessitating thereby formulation of policies for multi-objective integrated water resources planning and management and other strategies. Thus, this project has been envisaged with the following objectives:

- (i) carrying out analysis of hydrological aspects of drought in terms of deficits in surface water, soil moisture and ground water.
- (ii) assessment of drought impact on water supply, fodder and agricultural production, and
- (iii) development of integrated drought indices which could be of help in planning and development of water oriented drought management strategies including preparedness measures.

In order to accomplish these objectives, review of the status of various drought studies carried out at the national level and elsewhere has been done as an initial step. Thereafter review of the impact of droughts on various sectors viz, agricultural production, morphology, ground water and socioeconomic conditions have been made. A comprehensive review of important drought indices has also been carried out to assess their applicability as well as limitations while selecting a particular criteria for drought quantification. Attempt has also been made to develop a simple approach of soil water budgeting for simulating daily soil moisture in dry lands in order to study the incidence, severity, duration and frequency of drought. A study on the hydrological aspects of drought in 1985-86 in drought prone areas of the States of Andhra Pradesh, Gujarat, Karnataka, Madhya Pradesh, Maharashtra and Rajasthan has been carried out based on limited amount of available hydrological and allied data and an interim report has been brought out.

To plan drought management measures based on low flow characteristics, studies have been carried out to review the various deterministic, statistical and stochastic approaches for use in determination of magnitude, frequency and duration of low flows. Efforts have also been made to study the impact of droughts on groundwater through construction of well hydrograph superimposed with rainfall hyetographs.



Various studies carried out under this project have been documented in the review notes, technical reports and status report on drought studies based on various hydrological parameters and their management (estimation and control).

Further efforts are in progress to collect more field data to study the hydrological aspects of drought in details and prepare a final report therefrom. Further analyses of impact of drought on ground water are envisaged and will be taken up after sufficient data have been collected in this respect. Analysis of low flow characteristics as well as multiyear hydrological droughts are also envisaged for study under this project.

USE OF UNIT HYDROGRAPH IN FLOOD ESTIMATION FOR SMALL BASINS

Unit hydrograph representing the system response function of any basin has been well accepted for its use in rainfall-runoff modelling. But, many, a times, designers are faced with the problem of derivation of a proper unit graph form out of the available inadequate records as well as for ungauged basin, hence misled with unrealistic flood estimates.

In order to overcome such practical difficulties, this project aims at bringing out an appropriate technique for derivation of event based unit graph from amongst the several available ones, for the gauged basins and to extend it for regional study such that unit graph parameters can be evaluated for estimation of floods from ungauged basins of a particular region. To broaden the scope further, it is also aimed at derivation of geomorphologic unit hydrographs which not only would attach more physical sense to the unit graph but also be useful for estimation on floods from any ungauged basin.

For accomplishing these objectives, a comparative study of various unit hydrograph methods available in literature had been carried out and assessed for their applicability along with their limitations. Two different approaches viz, parametric system synthesis and non-parametric analysis have been adopted for derivation of unit hydrographs. Based on the consistency in physically realizable and non-oscillating ordinates, use of the former approach had been recommended. Simulation studies carried out using the unit hydrograph derived by the parametric system synthesis have yielded satisfactory results.

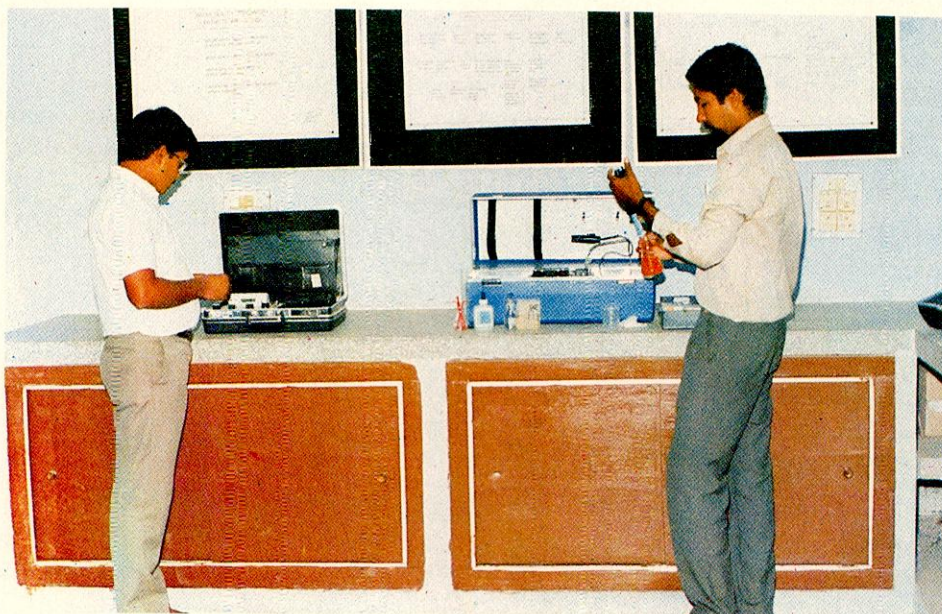
For computation of regional unit hydrographs, a detailed review of the regional studies have been made and attempts in terms of quantification of the regional parameters for typical Indian regions are in progress.

Several documents in form of review notes, case studies and user manuals on derivation techniques of unit hydrograph for gauged as well as ungauged catchments have been brought out.

In order to cover all the objectives of this project, it is envisaged to carry out regional studies covering a large number of hydrologic similar regions of the country for which collection of data is in progress. Further attempts to derive geomorphologic unit hydrographs for Indian basins are also envisaged.

MATHEMATICAL MODELS FOR WATER QUALITY AND POLLUTION ASSESSMENT

The use, development and management of water resources is one of the most important factors affecting the socioeconomic structure of any community. The greatest threat to this are the pollution problems and thus need a proper combination study while planning any river basin development. This will help the hydrologist in not only assessment of the water quality but also its monitoring as well as management. This project has therefore been undertaken with the objectives of carrying out various water quality modelling studies and therefrom adapt suitable models that can critically assess some of the river water quality variables under varied flows, climatic conditions and waste loads for Indian rivers, developing appropriate models for bio-degradable wastes eutrophication and conservative constituent and studying various water resources problems arising due to thermal discharges.



In order to accomplish these objectives, mathematical models accounting for different water quality variables have been studied and implemented at the Institute. Simulation experiments using these models have been carried out for variables like dissolved oxygen and phosphorous under changing physical and biological conditions such as flows, wasteloads as well as varied climatic conditions. Based on the performance of simulation, a suitable model has been recommended for adaption.

Realising the need of a strong database for further validation of the model identified, a water quality laboratory equipped with some of the latest and sophisticated equipments has been established at the Institute for carrying out regular tests on samples to obtain the input variables.

In order to model the biodegradable wastes, eutrophication and conservative constituent, a conceptual model has been developed and sensitivity of the parameters with respect to some important variables such as dissolved oxygen, temperature, etc. brought out.

Studies carried out so far have been documented in form of status reports and technical report on modelling studies based on several pollution aspects including a case study related to dissolved oxygen modelling in rivers.

For reinforcing the objectives envisaged in the project, further modelling studies with other important variables such as Nitrogen content, Algal content, etc. are proposed

to be taken up. Case studies on some Indian rivers are also proposed under this project for which collection of data is in progress.

STATISTICAL MODELLING OF ANNUAL PEAK FLOODS

Estimation of design flood based on annual peak discharges is one of the primary tasks engaging the attention of the hydrologists all over the world. Such hydrologic events being random, need use of frequency analysis through which it is possible to predict the design flood at specified probability and significance levels. This project therefore, has been aimed at studying some of the extensively used statistical models which can explain the varying magnitude of events and the varying time that has elapsed between them. It is also aimed at studying the usefulness of transformation techniques in flood frequency analysis for gauged catchments and in carrying out regional flood frequency analysis for design flood estimation for ungauged catchments. Further, it is aimed to develop a uniform guideline for carrying out flood frequency analysis in the country.

In order to accomplish the objectives mentioned above, two categories of model, i.e., annual flood series model and partial duration series model have been reviewed. Case study using partial duration series model for design flood estimation at Narmada Sagar Dam has been taken up with postulated Poisson and Exponential distributions. Efficiency of this model against the annual flood series model has been compared and brought out.

Use of power transformation techniques for transformation of annual peak flow have been brought out which can be used with normal distribution to estimate design floods. Studies have also been carried out for extending this technique for use with EV-1 distribution. Inadequacy of data forms a major limitation in reliable computation of plotting position. As an outcome of a study, the Gringorten plotting position formula has been recommended for use in EV-1 distribution on the basis of its fit in uppertail region. Further, regional frequency analysis has been carried out as a case study for the sub zone 3-D region of Mahanadi basin taking into consideration 18 stations with varying records. Three methods, viz, the Index Flood Method, the method based on normalisation of peak flood data and method based on Wakeby regional parameters with James Stein corrected means have been brought out in the study which have shown comparable performance.

Documents based on the above studies carried out at this Institute have been brought out, in the form of review note, technical note and user manual on several flood frequency analysis techniques for gauged and ungauged catchments including a case study for design flood estimation of Narmada Sagar Dam.

It is further envisaged to carry out flood frequency analysis for other regions of the

country, with inadequate data and also to develop a uniform guideline for carrying out flood frequency analysis.

DESIGN OF DRAINAGE SYSTEM FOR AGRICULTURAL WATERSHEDS

Improper agricultural drainage has been found to create water logging and conditions of salinity in the agricultural watersheds, thereby resulting in loss of crop yield. In order to overcome such difficulties identification and proper design of surface and subsurface drainage system is essential. The aim of this project is to come out with necessary guidelines for overcoming problems encountered in agricultural drainage in varying field conditions.

To accomplish this objective a detailed review identifying several hydrological parameters used in design of surface and subsurface drainage systems has been done. Runoff coefficients to be used in design of surface drainage system has been highlighted and daily runoff from agricultural watersheds, using SCS method with soil moisture accounting quantified.



For subsurface drainage system, irrigation return flow and drainage coefficients adopted in practice for various land uses have also been reviewed. Study on the leaching requirement for salinity removal has been undertaken and such requirements quantified. Solute movement from 1st layer to 2nd layer and so on has been determined and its variation with time and depth have been estimated and presented. Based on various physical meteorologic and hydrologic variables, a drainage manual has been prepared for design of subsurface drainage system.

Guidelines for design in saline soils have also been prepared and other appropriate techniques such as plantation and layout of intercepting drains suggested.

Documents based on the above studies have been brought out through review notes, technical notes and case study dealing with aspects related with drainage problems and their remedial measures for agricultural watersheds.

Works on drainage in heavy soils, salt balance in rootzone, control of waterlogging by vertical drainage are proposed to be taken up in the subsequent study.

ASSESSMENT OF GROUNDWATER BALANCE COMPONENTS

Increasing demand on water together with uncertainties of nature has necessitated exploitation and management of ground water. In order to make optimal utilisation of ground water resources of a particular basin; it is essential to assess the various components that influence ground water reserve. This project, therefore, aims at identifying and modelling such components for evaluation of ground water potential of a basin.

In order to achieve these objectives, factors responsible for framing ground water budget, viz, the recharge into the basin and discharge out of the basin have been identified and processes contributing to these have been brought out. Existing methodologies for evaluation of various recharge components and the aquifer-yield have been reviewed.

Case study for assessment of recharge to aquifer and yield out of it in the alluvial plains of north India has been carried out. Another case study for evaluation of seasonal water balance components in the Upper Ganga Canal Command area has been carried out. Computation of draft from ground water which is another important aspect has been identified and procedure laid out for collection of such information for possible inclusion in the modelling studies.

Studies carried out so far have been documented in form of technical report and technical note on the assessment of recharge as well as yield of an aquifer including a case study on Upper Ganga Canal Command Area relating to various ground water balance components.

In order to carry out studies for assessment of ground water balance for individual years, data collection for Upper Ganga Canal Command is in progress. Besides, it is envisaged to take up further studies on the following themes to obtain a complete scenario of ground water balance assessment project.

Interaction of large water bodies with aquifer; Analysis of flow to a dug well in hard rock areas in an unconfined aquifer; Protection zone for drinking water supply from dug wells; Conservation of energy-well storage relationship and Assessment of ground water potential in hard rock areas.

MEASUREMENT OF HYDROLOGICAL VARIABLES USING GEOPHYSICAL AND NUCLEAR TECHNIQUES

Measurement of sub-surface hydrological variables and determination of geologic and hydraulic parameters need the help of exploratory techniques such as geophysical and nuclear techniques. This project has therefore, being aimed at carrying out various hydrological studies using the above techniques.

In order to accomplish the objectives, various available geophysical and nuclear methods for carrying out studies like ground water exploration, assessment of water balance components, ground water pollution, geothermal exploration, seepage losses from reservoirs and canals, soil moisture variation and movement, permeability, transmissivity and lithology of soils have been reviewed.

Use of environmental isotopes for study of ground water recharge and interconnection between surface and subsurface waters have also been reviewed.



In-situ studies for soil moisture content in top soil layer using nuclear and resistivity techniques have been carried out. Field measurements of soil moisture movement in artificial ponding conditions have also been carried out using Neutron Probe. In order to establish the effect of variation of degree of saturation, conductivity of electrolyte saturating the soil and porosity, a theoretical study has been done.

The findings of various studies carried out at the Institute have been documented in form of review notes and technical reports on use of geophysical and nuclear techniques for investigation of soil moisture variations.

Experimental studies on temporal and spatial variation of soil moisture using resistivity, S.P. and nuclear techniques are in progress. Use of electromagnetic method for similar studies is also envisaged with an aim to develop comprehensive nomograms between soil-moisture and soil-resistivity. Field investigations utilizing resistivity, S.P. and nuclear techniques for studying groundwater pollution are also proposed.

FLOOD ROUTING STUDIES

Simulation of flood wave propagation, resulting due to reservoir releases or outflow from a watershed, along the channel is essential for issue of flood warnings and taking up emergency measures in the downstream reaches. Use of an appropriate flood routing technique enables the water engineer to judiciously perform the above tasks. Therefore, this project envisages study of various flood routing techniques available in literature, bring out their usefulness, short comings, applicability to complex channel processes, compound channels and theoretical basis for development and evolve therefrom a simplified technique for use in the field.

In order to accomplish this task, various hydrologic flood routing methods viz. Muskingum, Kalinin-Milyukov, Lag and Route, Modified Puls, Working R & D, Multiple reach Muskingum, Two and Three Parameter Gamma Distribution, Linearised St. Venant's Equations, Multiple Linearization and Simple nonlinear models have been reviewed and their data requirements, and usefulness brought out. Also various hydraulic routing models based on St. Venant's Equations have been studied and their advantages and disadvantages have been compared with the hydrologic flood routing methods.

In view of easy applicability and advantages of simple models such as Muskingum, Multiple reach Muskingum, Muskingum-Cunge, Kalinin-Milyukov, and two and three parameters Gamma distribution, generalised softwares with options to use some of them have been developed and documented.

Case studies carried out for reach between Mortakka and Garudeswar of river Narmada and between Dharoi and Ellis-bridge of river Sabarmati using Muskingum Cunge and Kalinin-Milyukov methods respectively have yielded good results. Further review to study the complexities arising due to flood plains and channel processes on flood routing have been carried out.

In order to model the non-linearity of the routing process, a simplified model, which uses the concept of varying the parameters for achieving linearised solution at each time level, has been developed. This model has further been found to bring out explanations as well as justifications for the causes of reduced outflow at the start of the Muskingum method and its negative weighing parameters.

The above studies carried out under this project have been documented and brought out in form of review notes, technical reports, case studies and user manuals on various hydrologic and hydraulic flood routing techniques including development of a simplified flood routing model.

It is further envisaged to study the routing of floods in prismatic channels using simplified models developed at NIH taking into account the presence of lateral flows. It is also proposed to study the effect of channel modification due to construction of flood levees on the routing characteristics. The applicability of the simplified model developed at NIH will be tested for several practical flood routing programs.

HYDROLOGICAL STUDIES IN FORESTED CATCHMENTS

Forests, major component of the ecological cycle, influence certain hydrological variables. Their growth, partial removal, drastic removal or even replacement with another type or species of vegetation can effect the water yield from a watershed besides other hydrological variables. It is, therefore, of interest to the hydrologist to evaluate their influence in terms of biological and physical growth as well as their management practices on the hydrological behaviour of watersheds. This project has aimed to assess the influence of forests on various hydrological processes viz; rainfall, interception, infiltration, evapotranspiration, groundwater recharge, floods, water quality etc. and as well as certain the effect of their management on water yield from watersheds.

In order to achieve these objectives, review of studies that have already been carried out in the country and elsewhere to assess the forest influence on various component processes as well as hydrological variables have been done and their status brought out. In addition to this the effects of forests as they influence the hydrologic regime of a watershed have also been spelt out. Since most of the studies are related to small experimental watersheds and their results can not be extrapolated to larger watersheds, need for systematic study on large representative watersheds have been identified.

Vegetation management practices in upland watersheds for augmentation of water yield have also been reviewed and found to possess great potentiality for improvement of water yield, because of the variation in evapotranspiration rates, from the watersheds. Studies done to this effect have been summarised and best management practices

leading to increased water yield without causing appreciable soil loss and at the same time maintaining substantial yields of forests products have been outlined.

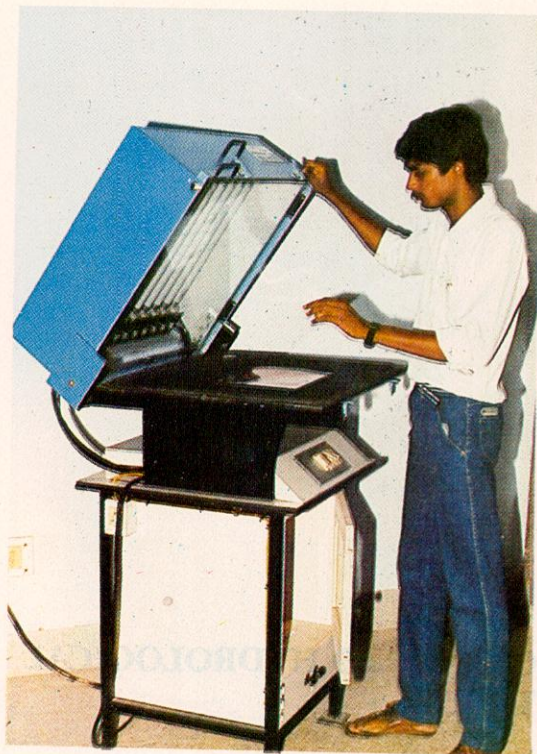
Studies carried out under this project have been documented and brought out in form of review notes and status reports on forest influences on hydrological parameters and their management for increased water yield.

To accomplish the objectives of this project, it is envisaged to carry out studies using mathematical models for evaluating the effects of forests on streamflow. For estimation of effect of land use changes on stream flow development of appropriate watershed model have also been envisaged under this project for which collection of data for the identified watershed as well as development of suitable computer programs are in progress. Another study to prepare a comprehensive note of influence of forests on ground water is under progress. More studies on computation of forest evapotranspiration, setting up representative basin, effects of social and cultural practices on hydrological regime of a forested catchment, and in general role of forests in water resources planning are scheduled to be taken up in future.

REMOTE SENSING APPLICATION TO HYDROLOGICAL STUDIES

Success of any hydrologic study/analysis primarily depends upon the available informations and exhaustive data base. Remote sensing technique in conjunction with conventional methods is useful in creating an exhaustive data base of the space and time variant hydrologic phenomena/characteristics by use of imageries taken through repetitive and synoptic coverage of the satellite. This project is envisaged to take up case studies using remote sensing applications for snowline and snow cover mapping, land use/vegetal coverage mapping, flood inundation studies, reservoir sedimentation studies, watershed characterisation and its mapping and monitoring of drought prone areas.

In order to accomplish the aforesaid objectives, review of works already undertaken in the areas of various hydrological applications have been made and the status of the technology brought out. Case study in respect of land use mapping of Upper Yamuna Catchment have been carried out and six land use categories of hydrologic



importance viz. thick forest, thin forest, barren and built-up area cultivated area, snow bound area and rivers demarcated. Land use classification of two test sites using digital image processing and visual interpretation have been carried out and found comparable. Another case study on Mahanadi basin has been taken up for preparation of a detailed flood plain map in 1 : 250000 scale.

The studies carried out on this project have been documented in form of review notes on various applications of remote sensing techniques such as snow cover mapping, land use mapping, flood inundation and sedimentation etc, in hydrological studies.

Further works in respect of delineation of river course, river levees, inundated areas and sediment deposits for the river Mahanadi are in progress. It is proposed to carry out digital

analysis using image processing software, visual analysis and analysis using maximum likelihood classifier approach in respect of the flood plain mapping. It is further proposed to take up case studies in respect of snowline and snow cover mapping of Beas-Sutlej basin as well as sedimentation studies of Tungabhadra reservoir for which digital image processing software development, collection of imageries and data are in progress.

DAM BREAK STUDIES FOR PLANNING OF FLOOD PROTECTION MEASURES

Multi-objective water resources planning and development has given rise to construction of many dams across streams. Since failure of any such dam can be catastrophic due to inundation of adjoining areas besides the flood plains, it is essential to study and plan necessary preventive measures so that in such an eventuality the disaster could be minimum. This project, therefore, has been aimed at studying the

various hypothetical dam-break situations and pre-determining the warning time at specific downstream locations for planning necessary safety measures.

In order to accomplish the objectives of this project, study of one of the well known dam break models has been carried out and data requirements identified. A case study of Machhu Dam-II, which had failed on Aug. 11, 1979, have been carried out at this Institute by routing the inflow hydrograph across the reservoir and routing the resulting outflow hydrograph along the channel reaches by sub-critical dynamic flood routing method. The simulated results and the observed highest flood elevations/discharges have been found to be comparable to the extent needed for practical purposes.

Further study for quick estimation of the characteristics of dam break flood, viz : peak discharges, peak stages and their time to peak, at the dam site and at specified locations have been carried out.

A methodology for developing dimensionless hydrographs based on dam break flood waves computed from different breach areas using the dam break model and thereafter developing relationship such as area of breach vs peak flow and peak flow vs the time to peak flow, has been adopted which can be used in the eventuality of dam break to quickly estimate the peak flow and time to peak flow knowing the area of breach.

The above studies carried out under this project have been documented and brought out in form of technical note on requirement and preparation of data for dam break analysis including a case study on Machhu Dam-II.

It is further envisaged to carry out case studies based on hypothetical dam failure scenarios for some of the major dams of our country for which collection of data are in progress.

DATA BASE MANAGEMENT AND INFORMATION SYSTEM

In recent times, advent of sophisticated water resources and hydrological studies have necessitated the development of hydrologic information system which can provide information for decision making and hence help in successful and efficient implementation of these studies through execution of a set of organised procedures.

Informations which are outcome of data processing primarily depend upon an exhaustive data base. Computer oriented data management techniques assist in rapid, easy and economic handling of these data. The objectives of this project are to carry out studies on data base management techniques, develop information systems for various user oriented as well as hydrologic applications, and thereafter extend these studies to micro-computer based applications.



In order to accomplish these objectives, status of data systems have been reviewed. Based on which a Library Retrieval System has been developed using an appropriate input, output and process design. Further studies on data base management techniques have been carried out and a management information system for computerised accounting has been developed.

With a view to implementing proper storage and retrieval of hydro-meteorological data, a data storage and retrieval system has been developed using which data can be stored and retrieved from the data base through a common and controlled approach. This system has been kept flexible in such a way that the data stored are independent of the program which uses them and their structure can conveniently be modified.

Documents based on the above studies have been brought out through technical notes and status reports on management information system, data system and library.

Further improvements on the data storage and retrieval system are in progress which will make the package more general and be able to account for all sorts of hydrometeorological data alongwith physical characteristics of any basin. Specific extension of this system for ground water data storage and retrieval system is also under

progress. It is further aimed to develop a decision support system using the developed data storage and retrieval system. Implementation of various developed systems at this Institute on the micro-computer in future is also envisaged.

STOCHASTIC MODELLING OF HYDROLOGIC VARIABLES

Hydrologic variables which show significant serial dependence are stochastic in nature. Modelling these variable is essential for forecasting as well as synthetic data generation in order that planning, designing, management and operation of water resources projects, can be achieved properly and optimally. It is, therefore, envisaged in this project to carry out a detailed study of various models available in literature explaining the stochastic realisations, and chose from them suitable ones that could be used for forecasting and synthetic generation based on short length of the variables at single or multiple sites.

In order to achieve these objectives, models such as Autoregressive (AR), Moving average (MA), Auto regressive moving average (ARMA), Auto regressive integrated moving average (ARIMA), Fast fractional Gaussian noise, Filtered fractional Gaussian noise and broken line model have been reviewed and a state-of-art report prepared.

In the area of forecasting, various flow forecasting models related to short term as well as long term forecasting have been reviewed and a methodology for forecasting of runoff from monsoon rainfall has been developed. In the area of synthetic data generation, case studies have been carried out for monthly stream flow generation for Chaliyar river basin using univariate Thomas Fiering model and for Mahanadi basin using bivariate Thomas Fiering models.

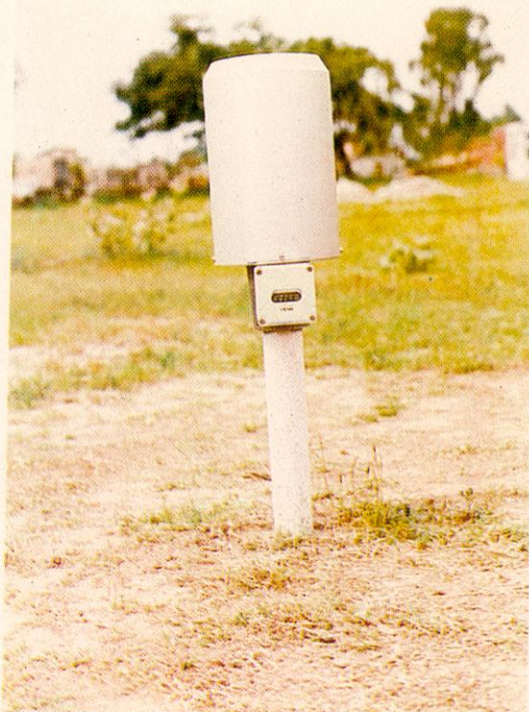
Studies carried out so far have been brought out through review notes, technical report, state-of-the-art report on use of time series models in forecasting including a case study on stream flow data generation for Mahanadi river basin.

It is envisaged to take up further case studies in the above two areas and adopt as well as implement programs for multisite generation of data. It is also proposed to carry out studies on disaggregation and aggregation models and apply them to some of the Indian catchments.

ANALYSIS OF HYDRO-METEOROLOGICAL VARIABLES

Meteorological variables form essential input to most of the hydrologic studies and hence need proper analysis as well as accounting. Besides, they also need careful considerations because of the fact that they can bring in catastrophies due to their severe combinations resulting in failure of water resources structures and damages. It is,

therefore, envisaged in this project to study and carry out various hydro-meteorological analyses such as climatological study, processing and analysis of precipitation data, network design of raingauges for average rainfall analysis; depth-duration and depth-area-duration analysis; intensity-duration-frequency analysis; modelling of moving storms and estimation of design storms for direct application in hydrologic studies.



In order to accomplish these objectives, study for processing of precipitation data have been carried out and procedure for quality control of these data suggested. Steps of rain data analysis have been brought out through a manual and software for computation of hourly values from daily values and estimation of areal average rainfalls, have been developed. Network design of raingauges have been carried out for the state of Rajasthan through a case study. Characteristics of some of the severe storms of Rajasthan and Saurashtra region have been studied and necessary depth-duration and depth area-duration relationships brought out. Also, hydro-meteorological study of storms in Narmada basin have been carried out and attempt to mathematically model the movement of storm along the Narmada basin using hourly self-recorded raingauge data

at several locations have been carried out. Analysis for trend and periodicity in the rainfall data of different talukas of Belgaum district have been carried out.

The studies carried out so far have been documented in form of review note, technical reports, technical notes, user manuals on various analyses on various techniques in analysing meteorological data including case studies on hydrometeorological aspects of Narmada basin and network design of raingauge in Rajasthan.

Statistical analysis of rainfall data for Rajasthan State is in progress and it is further envisaged to take up various hydro-meteorological studies as outlined earlier for other states and major basins of this country.

WATERSHED MODELLING

Precipitation over a watershed undergoes a number of transformations and abstraction through various component processes to merge as run-off at the outlet. Since such runoff is of interest to the hydrologist associated with planning and designing of various water resources structures, water yield estimation, simulation of flows for reservoir operation and flood forecasting besides others, it is necessary to establish the precipitation-runoff relationship for the watershed for future use. This relationship being complex in nature, needs study of each component process which is governed by physical phenomena which may vary in space and time.

The objective of this project, is to study the various watershed models developed world over and compare their structure with respect to various component processes and ascertain there from a suitable model structure which can model component processes typical to Indian conditions.

As such modelling of various hydrologic component processes viz., interception, evapotranspiration, overland flow, infiltration, percolation, interflow and base flow have been reviewed in eleven watershed models and different simplified techniques and typical model structures for component processes have been identified for considering development of rainfall-runoff model suited to Indian conditions.

Simulation exercises as part of case studies on Kasurnala basin, and Jamtara and Ginnore sub-basins of Narmada basin have also been carried out at this Institute, using various watershed models and their limitations as well as usefulness brought out.

The above studies have been brought out in form of review note, and user manuals for selection of a proper watershed model including case studies on flow simulation in Narmada Basin.

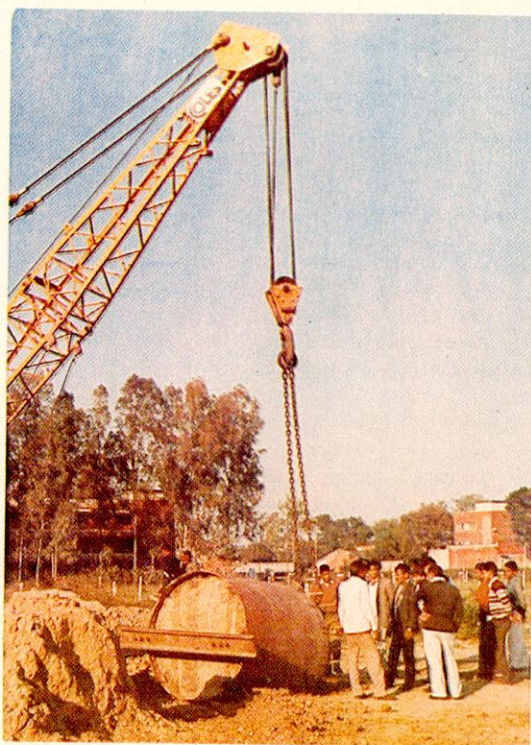
It is further envisaged to develop a suitable model through hybrid of various simplified component process identified from different watershed models that could be useful for Indian conditions. It is also envisaged to bring out users manuals on other watershed models for easy operation on computer.

AUTOMATED COLLECTION AND TRANSMISSION OF HYDROMETEOROLOGICAL DATA

Most of the hydrological research studies being data based necessitate collection and transmission of relevant data for further analysis and use. Advent of sophisticated sensors, microprocessors and microcomputers have made it possible to accomplish these tasks on-line and with high degree of reliability. It is, therefore, envisaged in this project to study in details the use of computers in collection and transmission of hydro-

meteorological data based on which develop a suitable data acquisition system for future use.

In order to accomplish these objectives, various schemes of data collection and transmission systems in hydrology and hydrometeorology, use of microprocessors and microcomputers in modern data acquisition system and use of some of hydro-meteorological sensors based on microprocessors have been reviewed.



Various pre-processing operations viz; amplification, filtering, trend-removal, decimation and calibration needed for the input signal to be compatible with the recording system have also been reviewed. Studies on two types of data acquisition systems, i.e., central data acquisition system and remote data acquisition system have been carried out and their configurations brought out. Operational details of automatic hydrologic station, to be installed at the Institute, have been studied and outlined.

In order to evolve a suitable configuration for the type of data acquisition system being developed at the Institute, various telemetry systems for transmitting data from remote data collection sites have been reviewed.

The above studies have been documented and brought out in form of review notes on data collection and transmission system (telemetry system) and use of microprocessors in hydrological studies.

It is further envisaged to develop a suitable data acquisition system using the latest technology and connect it to a telemetric device for remote data collection and transmission.

SEDIMENT YIELD AND RESERVOIR SEDIMENTATION STUDIES

The process of sedimentation is of great concern to water resources engineers as they affect the flow measurements, carrying capacity of streams, reservoir capacity, stability of channels etc. This process, complimented with the process of erosion, i.e., soil loss or silt production in a watershed is primarily dependent on the land-use pattern or land management practices. Therefore this project has been undertaken to study the various phenomena processes involved with the process of sedimentation and use them for estimation of sediment yield/soil loss under different land use conditions.

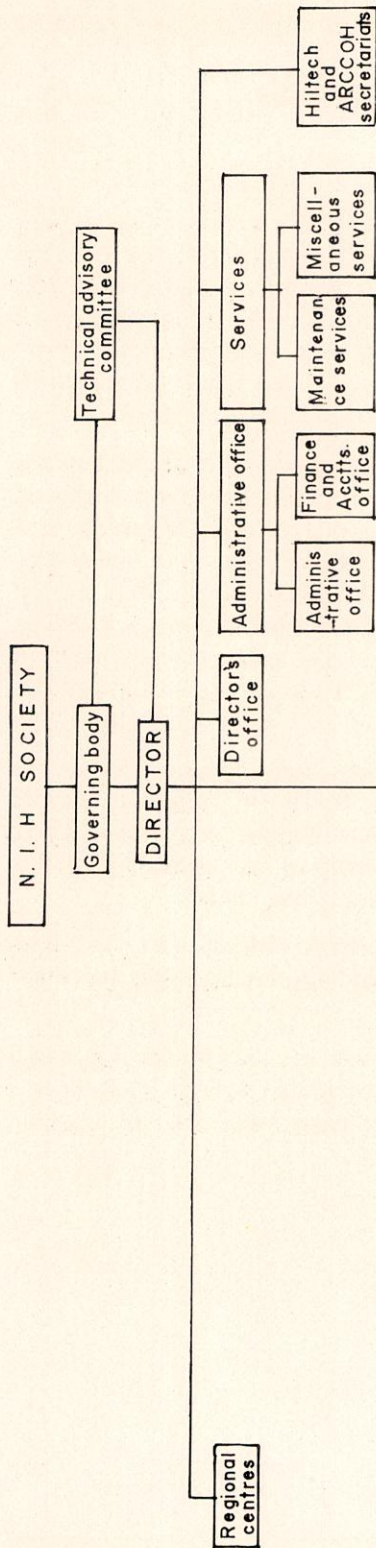
To achieve these objectives, review of sedimentation processes and modelling has been carried out and the status of reservoir sedimentation in India has been brought out. Various empirical, analytical/mathematical and experimental methods for forecasting of reservoir sedimentation, have also been discussed. Impacts of reservoir sedimentation and methods to control reservoir sedimentation have been brought out and the procedures for field surveys and results for various Indian reservoirs given. Knowledge gaps in respect of physical phenomena including physics of sedimentation, quality of deposits etc., lacuna in measurement techniques, surveying and prediction methods have been also brought out.

Based on experimental results of sediment yield from different land uses, a summary status has been prepared for specific ranges of sediment yield from different land use pattern. Various techniques for soil loss computation have been reviewed and a specific widely used technique studied for varied land use and management. This technique for soil loss estimation has been adopted for a case study.

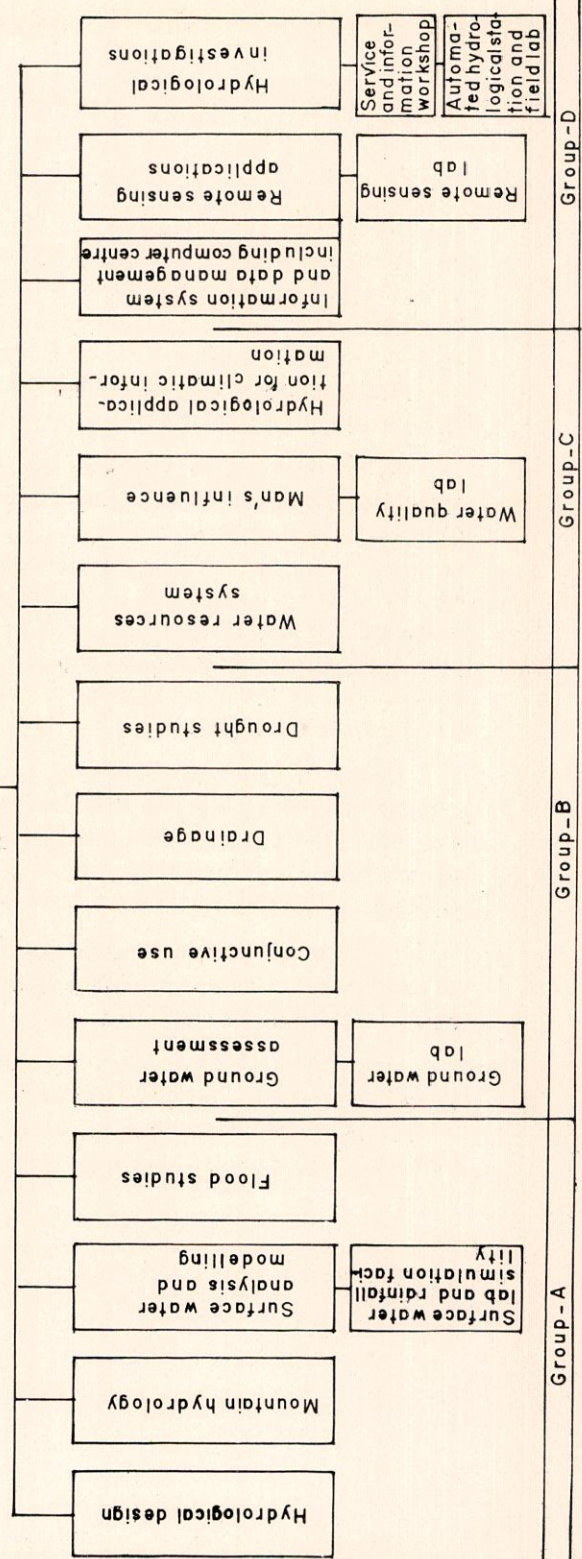
The studies carried out so far have been documented in form of a review note, technical reports and status report on various aspects leading to sediment yield and their effect on reservoir management.

It is further envisaged to carry out reservoir sedimentation studies adapting a suitable mathematical model. Case studies are also proposed to be taken up. Review of project hydrology pertaining to reservoir sedimentation with aims of possible improvement are further envisaged under this project.

National Institute of Hydrology, Roorkee Organisational Structure



SCIENTIFIC DIVISIONS



INSTITUTE'S CAPABILITIES

With the expertise available and developed over the years at the Institute, the studies and projects in the following areas can readily be undertaken :

1. Water Yield Studies
2. Flood Routing and Forecasting
3. Hydrologic Water Balance Computation
4. Design Storm and Design Flood Estimation
5. Watershed Modelling and Simulation
6. Water Quality Modelling
7. Reservoir Operation and Integrated Planning
8. Ground Water Balance and Assessment of Aquifer Yield
9. Synthetic Data Generation
10. Ground Water Modelling and Aquifer Response Studies
11. Conjunctive Use of Surface and Ground Water
12. Applications of Computer in Hydrology
13. Remote Sensing Applications.

CONSULTANCY PROJECTS COMPLETED AND UNDER PROGRESS

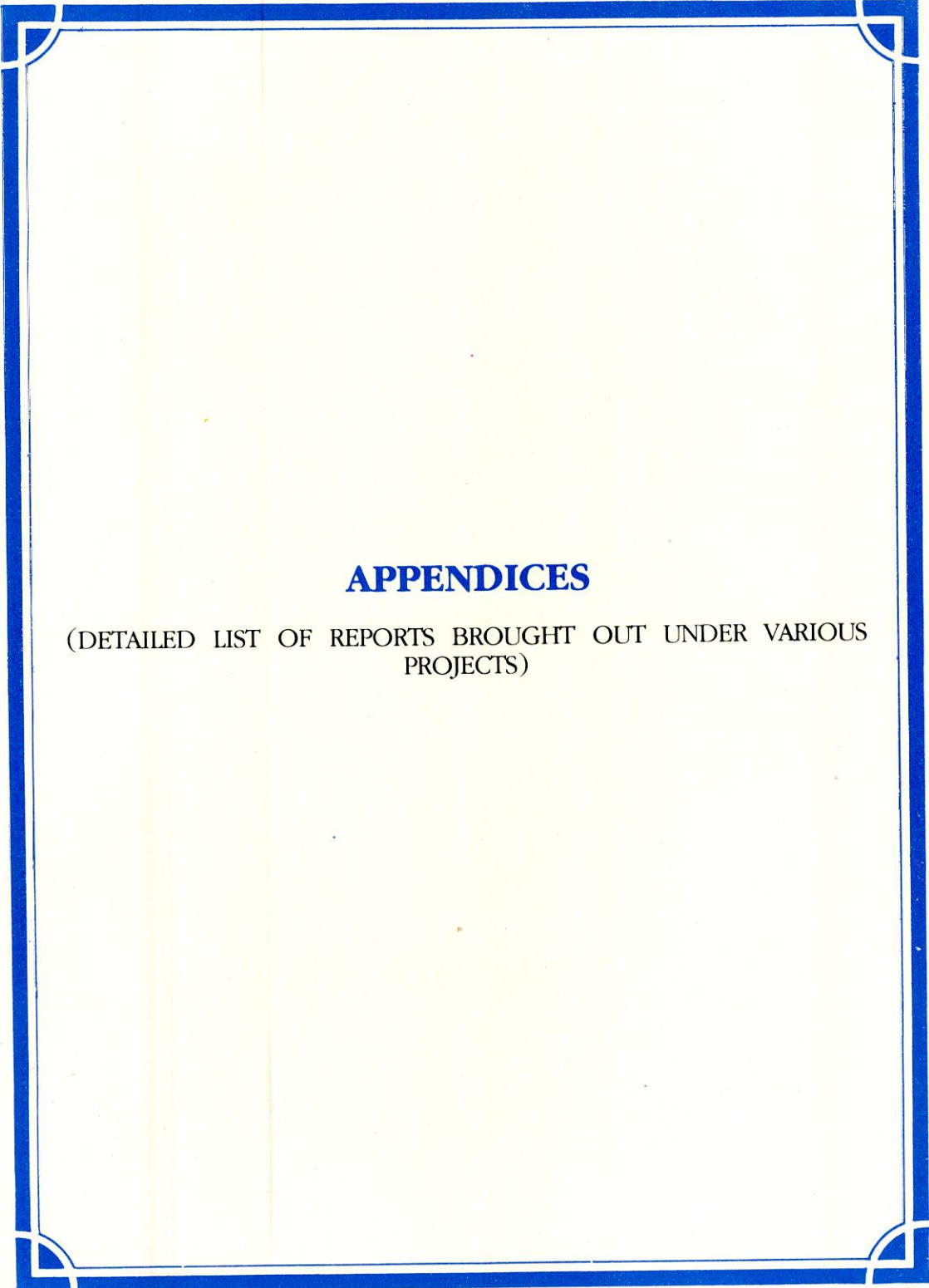
Till March, 1987 the Institute has undertaken and completed several consultancy projects to advise various state and central organisations as listed below :

1. 'Groundwater Modelling in Upper Ganga Canal Command Area' sponsored by Water and Power Consultancy Services (WAPCOS), Delhi.
2. 'Design Flood Studies for Narmada Project' sponsored by Narmada P & P Cell, Ministry of Water Resources, Govt. of India, Delhi.
3. 'Water Availability Studies of Mahanadi Basin' sponsored by National Water Development Agency, Delhi.

Some of the projects currently under progress as well as under consideration are :

1. 'Preparation of a Reservoir Operation manual for Dharoi Reservoir' sponsored by Gujarat Irrigation Department.
2. 'Hydrological Studies of Kishau Dam' sponsored by U.P. Irrigation Department.
3. 'Preparation of a Reservoir Operation Manual for Machhu Reservoir' sponsored by Gujarat Irrigation Department.
4. 'Generalised Computer-based Groundwater Data Storage and Retrieval System' sponsored by Ground Water Investigation Organisation, U.P.

5. 'Hydrological Studies of Lower Indravati Project' sponsored by Orissa Irrigation Department.
6. 'Hydrological Studies of Barak Basin', sponsored by Brahmaputra Board.
7. 'Flash Flood Studies of Punjab' sponsored by Punjab Irrigation Department.
8. 'Waterlogging Problem of Sarju Nahar Pariyojna' sponsored by U.P. Irrigation Department.
9. 'Design of Well Point System for Dewatering Solani Aqueduct, Upper Ganga Canal Modernisation' sponsored by U.P. Irrigation Department.
10. 'Software Development for Ground Water Balance' sponsored by Ground Water Investigation Organisation, U.P.



APPENDICES

(DETAILED LIST OF REPORTS BROUGHT OUT UNDER VARIOUS
PROJECTS)



TECHNIQUES FOR CAPACITY COMPUTATION AND OPTIMAL RESERVOIR OPERATION

Review Notes :

- Range analysis for storage
- Optimisation and programming techniques for reservoir operation

Technical Report :

- Water balance of a reservoir

Case Study :

- Reservoir operation study for Bhakra Beas System

User Manuals :

- Optimum reservoir operation using dynamic programming
- A flood control operation of a reservoir

Manual :

- Reservoir capacity computation.

CONJUNCTIVE USE OF SURFACE AND GROUNDWATER

Review Notes :

- Hydrogeological parameters in hard rock areas
- Hydrological parameters in drainage studies
- Study of hydrogeological parameters
- Irrigation return flow

Technical Notes :

- Unsteady flow to a large diameter well influenced by a river and a no flow boundary
- Estimation of Seepage from canal using tracer technique
- Study reach transmissibility for stream aquifer interaction
- Unsteady flow to a multiaquifer flowing well
- Drought analysis using soil moisture simulation approach
- Parametrisation of hydrological factors in ground-water study
- Duration of test pumping
- Design and performance of large diameter wells in hard rock areas
- Seepage from water bodies
- Seepage from parallel canals

Technical Reports :

Storage in confined aquifer with flow artisan well
Study of parameters affecting base flow
Determination of reach transmissivity under various hydrologic boundary conditions.

HYDROLOGICAL ASPECTS OF DROUGHTS**Review Notes :**

Hydrological aspects of droughts
Analysis of low flow to investigate drought characteristics and plan water use management
Comprehensive review of drought indices
Rainwater harvesting and conservation for drought management

Technical Note :

Soil moisture simulation for drought studies

Technical Report :

Estimating evaporation losses from lakes and reservoirs

Status Report :

Drought estimation and control

Interim Report :

Hydrological aspects of drought in 1985-86

USE OF UNIT HYDROGRAPH IN FLOOD ESTIMATION FOR SMALL BASINS**Review Notes :**

Use of catchment characteristics for Unit Hydrograph
Derivation
Regional Unit Hydrograph

Case Study :

Comparative study of Unit Hydrograph Methods

User Manuals :

Unit Hydrograph Derivation
Model parameter evaluation using catchment characteristics

**MATHEMATICAL MODELS FOR WATER QUALITY AND POLLUTION
ASSESSMENT****Technical Report :**

Water quality modelling in rivers

Case Study :

Dissolved oxygen modelling in rivers

Status Reports :

Water quality and sediment modelling in surface waters
Thermal pollution in water bodies

Training Report :

Water quality modelling and sedimentation—Training Report

STATISTICAL MODELLING OF ANNUAL PEAK FLOODS**Review Note :**

Partial duration series models

Technical Reports :

Suitability of power transformation based gumbel EV—L distribution
for flood frequency analysis
Some studies for plotting position formulae for
Gumbel EV-1 distribution

Case Study :

Partial duration series models
Regional frequency analysis

User Manual :

Frequency analysis.

Documentation of Program :

Flood frequency analysis using power transformation
Best fit distribution

DESIGN OF DRAINAGE SYSTEM FOR AGRICULTURAL WATERSHEDS**Review Notes :**

Hydrological parameters in drainage studies
Hydrological soil classification
Irrigation return flow
Estimation of ET for variable water table situation

Technical Note :

Estimate of ET under variable soil moisture situation

Technical Report :

Leaching requirement of agricultural land and study of movement of salts

Case Study :

Soil water accounting using SCS hydrologic soil classification

ASSESSMENT OF GROUNDWATER BALANCE COMPONENTS**Technical Notes :**

Guidelines for sample survey for minor irrigation works
Assessment of recharge from various sources to an aquifer and assessment of aquifer yield

Case Studies :

Mean year seasonal groundwater balance for Upper Ganga Canal Command area.

MEASUREMENT OF HYDROLOGICAL VARIABLES USING GEOPHYSICAL AND NUCLEAR TECHNIQUES**Review Notes :**

Environmental isotopes for hydrological investigation
Geophysical investigation for hydrological studies
Study of soil moisture using neutron probe
Estimation of ET under variable soil moisture situation

Technical Note :

Application of resistivity method for moisture estimation in top soil layer

Technical Reports :

Field measurement of soil moisture movement in ponding conditions
Estimation of soil moisture variation using resistivity technique

FLOOD ROUTING STUDIES**Review Notes :**

Hydrologic flood routing including data requirements
Hydraulic routing techniques
Effect of flood plain on flood routing
Effect of channel processes on flood routing

Technical Reports :

Cause of negative outflow in Muskingum method
Development of a simplified hydraulic flood routing model for rectangular channels
Development of simplified hydraulic flood routing model for trapezoidal channels
Comparison of some variable parameter simplified hydraulic flood routing models

Case study :

Application of Muskingum cunge method

User Manuals :

Muskingum cunge routing procedures
Hydrologic flood routing
Kalinin-Milyukov method of flood routing

Documentation of Program :

Flood routing (Muskingum cunge procedure)

HYDROLOGICAL STUDIES IN FORESTED CATCHMENTS**Review Notes :**

Vegetation management for increased water yield
Effects of type and density of forests and their management practices on hydrological regime of a forested watershed

Status Reports :

Forest influence on hydrological parameters
Hydrological studies in forested catchments

REMOTE SENSING APPLICATION TO HYDROLOGICAL STUDIES**Review Notes :**

Snowline and snowcover mapping by remote sensing techniques
Land Use/Vegetal cover mapping using satellite data
Remote sensing application for flood inundation studies
Remote sensing application to sedimentation studies.

DAM BREAK STUDIES FOR PLANNING OF FLOOD PROTECTION MEASURES**Technical Note :**

Data requirement and data preparation for dam break analysis

Case Study :

Dam Break analysis for Machhu Dam-II

DATA BASE MANAGEMENT AND INFORMATION SYSTEM**Technical Notes :**

System specific program inputs for documented programs
Management information system

Status Report :

Data systems and Library

STOCHASTIC MODELLING OF HYDROLOGIC VARIABLES**Review Notes :**

Time series analysis model
Forecasting models

Technical Report :

Forecasting of monsoon rainfall and runoff

Case Studies :

Monthly streamflow generation
Application of bivariate Thomas Fiering model for monthly stream flow generation in Mahanadi River Basin

Status Report :

Time Series modelling-an overview.

ANALYSIS OF HYDRO-METEOROLOGICAL VARIABLES

Review Notes :

Atmospheric general circulation model

Technical Notes :

Study of depth area duration and depth duration characteristics
Methodology for estimation of design storm

Technical Reports :

Statistical analysis of rainfall in Belgaum district,
Karnataka
Mathematical modelling of moving storms

Case Studies :

Study of hydrometeorological aspects of Narmada basin
Network design of rain gauge in Rajasthan State

Manual :

Processing of Precipitation data

WATERSHED MODELLING

Review Note :

Comparative study of components of watershed models

Case Studies :

Modelling of daily runoff for Kasurnala basin using
Betson and USGS models
Simulation of daily runoff of two sub basins of river
Narmada using tank model

User Manuals :

Application of tank model for daily runoff analysis
Application of tank model for flood analysis.

AUTOMATED COLLECTION AND TRANSMISSION OF HYDRO-METEOROLOGICAL DATA

Review Notes :

Data collection and transmission system
Hydrological applications of microprocessors
Telemetry systems and signal analysers for data transmission

Technical Note :

Data acquisition system

SEDIMENT YIELD AND RESERVOIR SEDIMENTATION STUDIES

Review Note :

Sedimentation in reservoir

Technical Report :

Study of soil erosion for different land uses and vegetal covers using universal soil loss equation

Status Reports :

Water quality and sediment modelling in surface waters
Sediment yield from different land uses

Training Report :

Water quality modelling and sedimentation

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