Volume 10 (1984)

HYDROLOGY REVIEW

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PROLOGUE

The 'Hydrology Review' was brought out as a quarterly journal by erstwhile Indian National Committee for the International Hydrological programme (IHP). During August 1982 a High Level Technical Committee on Hydrology (HILTECH) has been constituted to continue the work being carried out by the Indian National Committee and to provide advice to Central and State Government agencies on the problems referred to the Committee. The membership is drawn from various Central and State water resources organisations, academic institutions and experts. The Secretariate of this committee has been functioning as a part of National Institute of Hydrology. During the first meeting of the HILTECH held on 22nd February 1983 it was decided that the publication of 'Hydrology Review' would be continued as part of HILTECH activities by National Institute of Hydrology. Accordingly, an Editorial Advisory Board has been constituted and its membership approved at the second meeting of HILTECH held on 26 February 1984. In view of these and due to other unavoidable circumstances the 1984 issue of 'Hydrology Review' could not be brought out in time. Though some of the events might have lost their newsworthiness, it is felt that the technical activities of the various Central and State Government Water Resources Organisations and Irrigation Departments and Academic Institutions during this period have made valuable contribution to the water resources develoment and utilisation in general and hydrology in particular. It has, therefore, been decided to report important technical activities in the field of hydrology and water resources during 1984 in this issue which is being brought out for limited circulation within the country.

2. NATIONAL ACTIVITIES

2.1 High Level Technical Committee on Hydrology (HILTECH)

1. The Second meeting of the High Level Technical Committee on Hydrology was held on 16th Feb, 1984. The third and fourth meetings of HILTECH were held on 12th November and 20th December, 1984 respectively. The committee took important decisions for an effective functioning of HILTECH. The committee has constituted a number of sub-committees and panels to carry out specific functions. They are : (i) Sub Committee on Technician Training, (ii) Sub-Committee/panel on Education & Training, (iii) Editorial Advisory Board of Hydrology Review, (iv) Expert Review Group for IHP Phase III Plan, (v) Sub-Committee for constitution of Hydrology Panels, (vi) Steering Committee, (vii) group on interaction between Research organisation (viii) Sub-Committee on Manpower Requirement, (ix) Sub-Committee on Draft Country Plan (x) Sub-Committee for P.G. Level Courses.

2. The Second meeting of the ARCCOH Committee was organised in Kathmandu, Nepal from 4th to 6th March, 1984. The meeting was attended by representatives from India, Japan, Malaysia, Nepal and UNESCO. The Committee essentially concentrated on participation of ARCCOH countries in the IHP Phase III (1984-89) projects and preparatory work plan for launching Major Regional Projects. Actions were also initiated to prepare a hydrogeological map of Asia. It was also decided at the 2nd meeting of ARCCOH to prepare a directory indicating education, training and research facilities and expertise concerning hydrology in Asian regions. The Directory is being compiled based on the questionnaires received from ARCCOH countries, and Directory would be published soon. The ARCCOH Secretariate will be bringing out a Newsletter soon. This would be a quarterly publication. Action on other resolutions of the ARCCOH are in progress.

3. The first meeting of the Editorial Advisory Board for Hydrology Review was held in August 1984 at which it was decided that the Hydrology Review which has been published up to 1980 only, be brought up to date. It is proposed to bring out two issues per year of Hydrology Review from 1986.

4. The meeting of the sub-Committee on Hydrology Panels held its meeting and suggested panels to be constituted and their terms of reference. The Committee considered the recommendations of the sub-committee and has constituted six panels on the various aspects of hydrology. The names and composition of the panels are given herein.

(i) Panel on Surface Water

1. Dr. Subhash Chander, Professor of Civil Engineering, IIT, Delhi.
2. Representative of CWC.
3. Dr. GP Malhotra, Chief Engineer, Haryana State Minor Irrigation (Tubewell) Corpn. Ltd, Chandigarh.
4. Representative of National Institute of Hydrology, Roorkee.
5. Representative of Maharashtra Irrigation Department.
6. Representative of India Meteorological Department.
7. Sri D.C. Das, Joint Commissioner (Soil Cons.) Ministry of Agriculture, New Delhi.

(ii) **Panel on Ground Water**

1. Representative of National Institute of Hydrology, Roorkee.
2. Representative of Central Ground Water Board.
3. Dr. B B.S. Singhal, Professor, University of Roorkee, Roorkee
4. Dr. P.C. Chatterjee, Central Arid Zone Research Institute, Jodhpur.
5. Prof. V.V.J. Sarma, University of Andhra, Waltair.
6. Representative of Ground water Development Agency, Karnataka.

(iii) **Panel on Hydrometeorology**

1. Representative of India Meteorological Department.
2. Representative of Indian Institute of Tropical Meteorology, Pune.
3. Representative of Central Water Commission.
4. Representative of National Institute of Hydrology, Roorkee.
5. Dr. A.R. Subramaniam, Professor, Andhra University, Waltair.

(iv) **Panel on Snow and ICE**

1. Representative of S.A.S.E., Manali
2. Representative of National Institute of Hydrology, Roorkee.
3. Representative of Geological Survey of India.
4. Representative of Department of Science and Technology.
5. Representative of Bhakra Beas Management Board.
6. Representative of India Meteorological Department.
7. Representative of Central Water Commission (Flood Wing).

(v) **Panel on Water Resources Systems**

1. Prof. Hari Krishna, Consultant, New Delhi.
2. Dr. S. Ramaseshan, Professor, Indian Institute of Technology, Kanpur.
3. Dr. P.S. Rao, Professor, Indian Institute of Management, Bangalore.
4. Dr. G.N Yoganarasimhan, Professor, W.R.D. T.C., University of Roorkee, Roorkee.
5. Representative of Central Water Commission.
6. Representative of National Institute of Hydrology, Roorkee.
7. Representative of Narmada Design Unit, Gujarat.

(vi) **Panel on water Quality, Erosion and Sedimentation**

1. Dr. V.V. Dhruvanarayan, Director, Central Soil and Water Conservation Research and Training Institute, Dehradun.
2. Dr. R.J. Garde, Professor, University of Roorkee, Roorkee.
3. Representative of Central Board for Prevention and Control of Water Pollution, Delhi.
4. Representative of National Environmental Engineering Research Institute, Nagpur.
5. Representative of D.V.C.
6. Representative of Central water Commission (Reservoir Sedimentation Wing)
7. Representative of Bihar Irrigation Department
8. Representative of Deptt. of Envirnoment, New Delhi.
9. Representative of National Institute of Hydrology, Roorkee.

5. Shri K. K. Framji, Secretary-General I.C.I.D. was nominated as a member of the Committee. He attended the third and fourth meeting of the Committee during November and December 1984. Dr. Satish Chandra who was a member

of the Committe joined as Director, NIH and is a member of the Committee in that capacity.

Shri Pritam Singh, Chairman, Central Water Commission and Chairman, HILTECH retired on December 31, 1984.

2.2 National Institute of Hydrology, Roorkee

1. The fourth Annual General Meeting of the National Institute of Hydrology was held on 3rd January, 1984. The President of the Society Suggested that the information and methodologies developed at the Institute should be disseminated at the earliest. It was also decided to publish Newsletter from the Institute and these are being published regularly with effect from January, 1984.

2. Six Scientists have completed training under UNDP Project Fellowship in the areas of time series analysis, irrigation and water use management, hydrologic forecasting, geohydrology, reservoir operation, and irrigation planning.

3. The studies and research activities of Institute encompass the component processes of the hydrologic cycle, their interaction and the influence of human activities on the quantity and quality of water resources. These studies are important for the assessment, planning and utilisation of surface and ground water resources. The Institute has following six scientific divisions to deal with these activities.

(a) Hydrologic Analysis (Surface Water)
(b) Hydrologic Analysis (Ground Water)
(c) Hydrologic Synthesis (Surface Water)
(d) Hydrologic Synthesis (Ground Water)
(e) Integrated Planning
(f) Information System

The studies and research carried out in these divisions include the following :

(a) Research involving development of systematic procedures including computer oriented procedures for use by field agencies,

(b) Theoretical and basic studies in hydrology for understanding the component processes of hydrologic cycle and their interactions,

(c) Studies involving measuring techniques, as well as data collection and processing procedures,

(d) Development of standardised and systematic procedures for hydrologic analysis and synthesis and their documentation, and

(e) Assistance and advice to field organisations in the application of procedures through sponsored consultancy research projects.

4. The progress of research works in the six divisions is briefly given herein.

(i) Hydrologic Analysis (Surface Water)

The research activities in this division were carried out mainly in the area of hydrometeorology, hydrologic routing and stochastic hydrology. The methods for estimation of design storm were reviewed and a technical note has been prepared. A Manual giving guidelines for processing of precipitation data both for climatological purposes and real time use, has been prepared. This review notes for different methods of regional flood frequency analysis and partial duration series models have been completed. Users Manuals have been prepared for frequency analysis, multiple linear regression analysis and polynomial regression analysis and a case study on application of Thomas Fiering model has been completed. Different techniques on hydrologic routing have been reviewed and Users' Manuals for rating curve analysis and Muskingum Cunge rating Procedure have been prepared. A case study for rating curve development for gauging sites at Narmada river has also been completed.

New problems in the areas of Atmospheric land surface modelling, hydrometeorology of hydrological droughts, effects of flood plain and channel processes on flood routing, stochastic data processing and forecasting models have been taken up.

(ii) Hydrologic Synthesis (Surface Water)

The activities in this division mainly deal with three aspects viz., (i) Unit hydrograph studies (ii) Hydrologic routing and (iii) watershed modelling. Comparative study of unit hydrograph procedures including a case study and Users' Manual on Unit hydrograph deviation and Users' Manual on model parameter evaluation using catchment characteristics have been completed. In the area of hydrologic routing, a review note and Users' Manual on hydrologic flood routing have been completed. In the area of watershed modelling, a case study has been done & a review note has been prepared on comparative study of components of watershed models. Besides these, a Manual on hydrologic water balance and review note on overland flow have also been completed. Study on dam break problem including case study using computer programme has been taken up and is in progress. New problems In the areas of regional unit hyrograph studies, comparative performance of watershed model components, flash flood studies, hydrologic water balance and urban watershed modelling have been taken up.

(iii) Hydrologic Analysis (Ground Water)

A basic study has been carried out to analyse unsteady flow to a multiaquifer flowing well using discrete kernel approach. A critical review of seepage studies by tracer technique has been carried out for assessing seepage losses from Deoband Canal. Using analytical method, interference of parallel canals has been studied. Emphasis has been given on the existing parallel canals of Lower Ganga Canal (LGC) system. Study has been initiated to assess recharge to ground water due to rainfall and different methods available for estimation of recharge have been reviewed. A review has been conducted for the study of hydrogelogical parameters in alluvial and hard rock areas. Suitability of existing methods of evaluation of hydrogeological parameters from pump test data have also been studied. A study to find a suitable diameter and depth of large-diameter well in hard rock area is under progress. Analysis of flow to large diameter well tapping multiple aquifers has been carried out. A review of hydrological soil classification based on effective soil depth, soil texture of surface and subsurface layer, clay content, infiltration rate, soil permeability and soil drainability has been done. A Manual for agricultural drainage is being prepared.

(iv) Hydrologic Synthesis (Ground Water)

In the area of ground water studies, a basic study of ground water balance as a lumped system has to be conducted before taking up a study on distributed simulation of ground water system. A Manual for ground water balance has been prepared for the purpose. A technical note on regional Aquifer Simulation studies has been prepared. This is based on AQUIFEM-I, a Finite Element Aquifer Model developed at MIT and implemented on VAX-II/780 computer system. In was adopted with suitable modifications to a typical study area treating the aquifer as a single layer system. Earlier, Tyson Weber Model was used for this study. Users Manuals for Tyson Weber Model as well as AQUIFEM (modified verslon) have been prepared. Technical notes on artificial recharge to groundwater and estimation of cropwater requirement have also been completed. A status report on Hydrological studies carried out in India is being prepared.

(v) Intergrated Planning

CREAMS and DOSAG models developed in USA for Water Quality Modelling have been

implemented on VAX-II/780 computer systems. Testing with Indian data will be carried out soon. The testing of SIMYLD II (with modifications) was carried out using data of Bhakra Beas System and an operation study for this system has been completed. A review note has been prepared on optimization and programming techniques as applied to reservoir operation study. Users Manuals for preparation of Routing Curve/Working Tables for reservoir operation and a Manual on computation of reservoir capacity have been completed. Case studies using HEC-5 and SIMYLD II are being taken up for DVC Reservoir System and Reservoir System in Chambal basin. Manual for yield analysis will also be taken up.

(vi) Information System

The management of computer centre with VAX-II/780 computer system and its peripherals form one of the main activities of this division. Efforts have been made to obtain hydrologic data and computer programmes on magnetic tapes from different organisations in the country and abroad.

2.3 Central Water Commission, New Delhi

2.3.1 Water Resources Directorate

This Directorate is entrusted with surface water resources study for all the rivers of country except Ganga, Brahmaputra and Indus. The water resources study of Tambraparni and the Periyar Basins are at various stages of progress.

2.3.2 Hydrology Directorate-I

This Directorate is mainly entrusted with technical examination of hydrological aspects of various projects. During the year, about 16 number of new projects were examined on hydrological aspects like water availability, design flood, reservoir sedimentation, evaporation etc. Further comments on replies of 48 number of projects were offered on hydrological aspects. Special assistance and consultancy were provided to 28 nos. of projects. The tripartite meeting/discussions were held between Hydrology-Dte-I and World Bank experts and projects authorities on six projects. Technical advice was provided to sort out the questions which arose due to seven storms in Saurashtra region during 1983 and taking into account the technical modenisation, the matter of fixation of spillway was examined. Technical collaboration with Indian and outside agencies, the work relating to W.M.O. projects, HILTECH, CBIP, NIH etc. were carried out. With a view to updating the knowledge, various Seminars, Technical Courses, and workshops were attended by the officers of the Unit.

2.3.3 Hydrology-II Directorate

1. The Hydrology-II Directorate participated in the 3rd annual convention of Association of Hydrologists of India at Pune & chaired the technical sessions. A paper entitled "Estimation of Design floods in a basin with two distinct flood causing Zone" was presented at the 25th International Geophysical Congress in Freiburg (F.R.G.). Contributed technical paper on "Flood Forecasting Criteria for Appraisal" in the National Seminar on Real time Hydrological Forecasting" sponsored by C.W.C. & CBI & P. Worked as Hydrology Member of Panel of Experts on World Bank aided "Kandi watershed and Area Development project (Punjab)" and tendered advice on hydrological aspects on various Dam projects. A second order network of linear reservoirs models to account for uneven distribution of rainfall in space and time was developed using equivalent reservoir concept and also developed regional curves for arriving at monthly water availability of snowfed streams for planning Mini/Micro hydel schemes in J & K.

2. Co-ordination and collaboration on development activities in Hydrology were carried out with N.I.H. on research activites; with I.S.I. on evolution of draft standards on Hydrology aspects; with W.M.O., UNESCO

(through HYDCOM); etc. on operation hydrology. Review of design criteria manuals and technical papers, preparation of schemes for external technical assistance like UNDP, USAID, Indo-U.K. technical aid programme, review & examination of research project of CBIP and other agencies were undertaken. Apart from this, participated in the training courses for in-service engineers organised by CBI P and other institutions. Provided technical support to various committees, working groups set up by Central/State Govts. and also provided consultancy on project Hydrology connected with planning, design and operation of water resources projects referred by other agencies. Special studies carried out on design flood aspects of Dihang Dam, Lohand Khed, S.Y.L. projects and Gambit Water Supply schemes.

3. Simulation model studies and a status reports on hydrological study carried out for Dihang Zone-I Catchment. Dependable flow and water availability studies at Tejewala and Okhla on sharing of Yamuna Water between U.P. and Haryana; study on Water resources for Tuivai H.E project (Mizoram); study on monthly and annual weighted catchment rainfall & yield of Chambal basin; Hydrological studies on Khowai Dam project (Tripura) & Ganga Barrage at Kanpur were also carried out. Studies on relations for estimating monsoon floods for 15 sites of Brahmaputra Basin were carried out.

4. Carried out Technical examination on hydrological aspects of projects in Brahmaputra, Indus and Ganga Basin and connected studies on water availabilities of River Systems of N.E. States. 36 New projects were technically examined on hydrological aspects like water avilability, design flood, reservoir sedimentation and evaporation etc. Special assistance was provided in case of 28 new projects. A tripartite meeting/discussions was arranged between C.W.C., World Bank experts and project authorities on 6 projects & technical advice provided.

2.3.4 Reservoir Sedimentation Directorate

The Directorate made studies of Malampuzha and Iduki reservoirs of Kerala and the views of C.W.C. communicated to the State Government. Sediment load data of Krishna and Godavari basins transferred to magnetic tape. An H.E.C. IV—Programme has been tested using Upper Indravati project data and a revised capacity curve developed by running a computer programmme. Comments were offered on sediment studies in reservoirs of Kerala regarding "New approach on mobile bed mechanics". Suggestions on reservoir surveys were given to Meghalaya State Electricity Board.

2.3.5 Hydrological Observations

Gauge and discharge observations at more than 400 key hydrological stations covering various river basins of the country were continued. Besides, collection of sediment and water quality data was also continued. Observations was continued at 45 road bridge sites in small and medium catchments on behalf of the Ministry of Shipping and Transport. Sanction of the Ministry of Irrigation and Power was obtained for establishment of 163 additional observation stations in order to strengthen the hydrological network as per WMO norms.

2. Under the NCST programme "A study of flow of pollution loads in the Ganga river system" was continued by strengthening water quality laboratories at Varanasi and Agra. Water samples from 42 selected sites of the Ganga River System were analysed for 38 water quality parameters comprising of metallic, non-metallic, organic and inorganic constitutents. Micro-biological and bacteriological studies were also undertaken as a part of the programme. A proposal for extending

similar level of water quality investigation to other river basins of the country as a part of the regular hydrological observations during the VIIth plan period is under prepatation.

3. Two CBI&P Research Schemes entitled "Development of mathematical models for flood forecasting in the Gomti Basin" and "A study of the scour characteristics of some rivers in the Ganga basin" are under execution by the WR & FCC, Varanasi.

4. Storage of hydrological data on magnetic tapes and preparation of water Year Books are continued. Verification, analysis and authentication of hydrological data of Joint discharge Observation Stations at Farakka (India) ond Hardinge Bridge (Bangladesh) in connection with JRC Work was coordinated.

2.3.6 Flood Forecasting Organisation

1. Flood forecasting organisation issued 5825 forecasts including DVRR forecasts during the monsoon of 1984 to prevent loss of Human/Cattle lives, movable properties and also to protect engineering works.

2. To improve accuracy of forecasts and to improve warning time, modern techniques in the communication System have been adopted by installation of Telemetry system upto Delhi on river Yamuna and a computer to computerise the hydrological forecasting models.

Computerised mathematical models VIZ, SSARR, HEC-IF, NLC have been calibrated for testing.

3. As part of UNDP Pilot Project on Yamuna, an experimental watershed was established ou Sundlinala in H.P. in the Upper reaches of Yamuna Basin for study of Snow Hydrology & very useful data was collected from this study. 16 Snow Courses were selected for measurement of "Snow Water Equivalents" by Snow Surveys. Measurement of river flow were carried out at 'V' Notch weir on Sundlinala for developing correlation between Snow accumulation and snow melt run-off.

2.3.7. P&D Unit

Computerised and published water year book for Ganga Basin for 1982-83, and stored the hydrological data on magnetic tapes. Prepared draft formats for collection of hydrological data. Information on upstream and downstream slopes of 33 old and new Barrages supplied to I.S.I. for I.S.O. meetings. Hydrological data of River Ganga was supplied to various agencies for planning the water resources projects. Carried out flow monitoring from Patna to Farakka and other reaches in Ganga Basin for water balance studies.

2.3.8 Statistics Directorate

Statistics Directorate deals with hydrological data of all non-classified river basins in India. Daily G.D. data are received from Central and State Agencies. After necessary cleaning, the data are stored on magnetic tapes. During the year the work on Krishna, Godavari, Cauvery, and Sabarmati basins, was taken up. An inventory of hydrological sites in non-classified river basins as on 1.1.79 was brought out and up-dating of the same as on 1.1.84 is in progress. Computerised Water Year Books were supplied to various agencies during 1984 for about 2000 site years. Computerisation of sediment load data for Krishha basin was completed. Apart from G-D data and Sediment data, rainfall data as procured from India Meteorological Department, are being stored on magnetic tapes. A Data Base Management system is under development for G-D data in collaboration with National Informatics Centre. During the year, studies on rating curves for two sites in Mahanadi basin and estimation of daily discharge from hourly gauge values were completed. At the request of Central Electricity Authority,

dependable yield studies were undertaken for selected sites of Narmada, Mahanadi and Tapi basins.

2.3.9 Remote Sensing Directorate

This Directorate has built up a small photo-interpretation cell and is envisaging to equip the cell with more optical and digital systems for the analysis of remotely sensed data. The Directorate has completed aerial photo interpretation of the Hasdeo catchment of Mahanadi basin for broad land use classification, for assisting the systems studies of the Mahanadi basin. In addition to this, flood inundation study of Sahibi river; drought area studies of three districts of Karnataka have been completed by using satellite data in Collaboration with NRSA, Hyderabad. The Directorate is also involved in the activities of NNRMS by participating actively in the Task Force on Water Resources, Standing Committee on Water Resources etc.

2.3.10 Sytem Engineering Unit

1. A Project titled 'Systems Engineering for Integrated Development of Water Resources in India' became operative in the CWC, with UNDP assistance, in May, 1982. The project has the important objectives of training a cadre of engineers in water resources systems engineering and detailed study of a typical river basin (Mahanadi) to apply the systems techniques for planning and operation of a system of reservoirs. After some initial work on planning of reservoirs, the Project is now concentrating its activities on development and adaptation of models for operation of reservoirs.

2. Hydrology forms an important input to the systems studies as simulation study of a historical flow series or a generated flow series at Projects is an inherent aspect of all systems models. The accuracy of the model results depends to a very large extent on the accuracy of the hydrological inputs. Due to paucity of observed flow data in the Mahanadi basin, it has become necessary to work out the flows using the long term rainfall data avilable in the basin. The hydrological studies are being undertaken under the consultancy guidance of Dr. N.T. Kottegoda of Birmingham University. The studies so far done have concentrated in the following areas.

(a) In-filling of missing rainfall data before development of rainfall series.

(b) rainfall-runoff regression modelling.

(c) stochastic generation of hydrological data.

(d) Conceptual modelling.

(i) In-filling of Missing Rainfall data

The following methods of infilling were tested

(a) HEC—4 program of US Army Corps of Engineers.

(b) FILLIN—I Program of Texas Water Development Board.

(c) MOSS—III Program of Texas Water Development Board.

(d) Weighted average method based on the distances of the raingauge stations.

(e) modified weighted average method which preserves the statistical parameters and is based on the distance between the raingauge stations. A programme MODWTAV was developed for this.

For the Mahanadi basin, FILLIN-I Weighted average and modified weighted average methods are considered.

(ii) Rainfall-Run off Regression

Monthly rainfall-runoff regressions have been developed at a number of gauging sites in Mahanadi. Simple and multiple, linear and non-linear type of regression models have been

attempted and suitable models adopted for extending observed runoff series.

The disaggregation of monthly flow series into 10—daily flows, which is required in many types of simulation studies, is done based on the observed ratios of 10-daily to monthly flows by a suitable methodology. The programmes MULREG and DISAGR were developed in the Project for the regression modelling and disaggregation respectively.

(iii) Stochastic Generation

Both single site and multisite models are being attempted for stochastic generation of flow data in the Project. The IDARMA and GENSEA, single site stochastic modelling programmes developed in CSU, have been tested for Mahanadi conditions. IDARMA identifies the type of ARMA model suitable for the data on hand. The GENSEA programme generates synthetic data of a seasonal hydrologic series at a single site for any type of ARMA model. LAST (Lane's Applied Stochastic Technique) developed by USBR, which is a package programme for multi site data generation, has also been obtained and is under testing.

(iv) Conceptual Modelling

Unlike statistical and stochastic models for rainfall-runoff analysis, which are 'black box' type of models conceptual rainfall-runoff models simulate the phase of the total response of the entire surface phase of the hydrological cycle taking into account the various processes such as evapotranspiration, infiltration, soil moisture, channel storage, ground water and runoff for any given watershed. Work in this area has covered evaluation of models like SSARR and development of a new Water Yield Model (WYM). The WYM is essentially a lumped parameter, continuous model for simulating monthly water yields from the entire catchment. This is particularly useful where continuous data on evaporation and rainfall is not available. The WYM has been calibrated for the Hasdo and Seonath sub basins of Mahanadi and further work on optimisation of parameters is in progress.

2.4 Central Ground Water Board

1. The regional hydrological surveys aim at bringing out generalised picture of status of ground water utilisation and demarcating areas suitable for ground water exploration/development. These surveys were carried out in the States of Uttar Pradesh, Gujarat, Maharashtra, Assam, Jammu & Kashmir, Himachal Pradesh, Madhya Pradesh, Karnataka, Kerala, Tripura Mizoram, Andaman & Nicobar Islands.

An area of 147, 194 sq. km. was covered by systematic hydrogeological surveys in various parts of the country. Under these surveys data on geology, hydrogeology and nature of aquifers etc. were collected. Reappraisal hydrogeological survey were carried out in an area of 83,944 sq. km. in various parts of the country with a view to monitoring changes in groundwater situation on subjection to large scale ground water development.

2. Water supply investigations were taken up for augmentation of water supply for various agencies. In all 160 investigations were carried out in various parts of the country and recommendation for development of water supply by wells and tubwells were made.

3. Exploratory drilling was carried out for estimation of ground water resources. Under this programme, wells were constructed and aquifer parameters determined by conducting pumping test. In all 129 exploratory, 95 observatiod wells, 63 piezometers and 4 slimholes were drilled. Besides 63 deposits wells also constructed.

4. A total of 5357 of hydrograph network stations were monitored for water levels. Water samples were also collected in the month of April for complete chemcial analysis. This

data is being analysed for use in groundwater resources evaluation.

5. Surface Geophysical surveys were carried out in parts of Andhra Pradesh, Kerala, Rajasthan, Goa, Maharashtra Uttar Pradesh & Punjab States. Under bore hole geophysical work, 188 boreholes were electrically logged for precise delineation of water bearing zones for making recommendations on Well Assemblies.

6. The water samples collected by field officers for partial and complete chemical work subjected to study in the chemical laboratories in the C.G.W.B. A total of 12,843 water samples were analysed for partial/complete chemical analysis for making studies of chemical quality of ground water and preparation of chemical quality maps.

7. Photogeological and Remote Sensing studies were carried out as support studies for organising geophysical surveys and to give boost to exploratory drilling programme in selection of areas of exploration and siting of well sites.

8. Under ground water exploratory drilling programme one exploratory well, 4 observations wells and one piezometer were constructed as a part of the Mehsana Project activities. The work on development of mathematical modelling is nearing completion. The data collected during the project period is being analysed for preparation of the final report of the Project as per its objectives. The terminal report of the project giving salient findings has been prepared and is being examined for issuance by UNDP.

Nine exploratory wells and 3 observation wells were constructed under SIDA Project. Besides regular monitoring of Regional Water levels being carried out periodically, the existing Hydrological and Hydrometeorological data has since been collected and systematised for analysis and interpretation. Photogeological and remote sensing studies have been carried out in priority study basins such as Kole lands and Pamba river basin. Electric resistivity as V L F soundings were carriad out to identify occurrence of potential areas for location of exploratory well sites. Seismic surveys have also been planned to be carried out in the project area.

The Kasai - Subarnarekha project was recently put on ground. The existing Hydrometeorological data is being collected and analysed. Observation net work stations are being set up for periodic monitoring of water level data. The areas are being cleared and sites being selected for carrying out detail exploratory drilling programme. The work is in progress as per plan of operation.

9. A revised hydrogeological map of India (1:5,000,000) incorporating the latest data collected by C.G.W.B. was prepared. The same is under process of printing by Geological survey of India, Hyderabad. Besides 1:2,000,000 scale hydrogeological map of India was taken up for compilation. Ground water atlas of Haryana has been prepared, and the ground water atlases of Andhra Pradesh and Tamil Nadu are under printing.

2.5. National Water Development Agency

1. For optimal utilisation of available water resources of the country by storage and inter-basin transfer from surplus to deficit & drought prone areas of the country, the Government of India in the Department of Irrigation have formulated the National Perspective for water resources development. This scheme consists of two components :—

(a) Peninsular Rivers Development; and

(b) Himayan Rivers Development.

The scheme when completed will create an additional irrigation potential of 35 million hectares-25 million hectares by surface waters and 10 million hectares by ground waters.

This will be, over and above the present assessed ultimate potential of 113 million hectares. Initially, it has been decided to undertake surveys & investigations for the Peninsular Rivers Development compoment of the National Perspective. The Agency has been collecting relevant hydrological, hydrometeorological, geohydrological, land-use and Soil data. It is also collecting the information on completed, ongoing and contemplated projects. The master Plans of various basin States are also being collected. During the current year good progress has been achieved in respect of collectlon of data and information on the irrigation projects. The above data and the Master Plans are being used in conducting hydrological studies, land use studies, technical studies and toposheet studies.

2. The programme of hydrological studies and assessment of water resources at three sites on the Mahanadi and its tributaries, and 6 sites on Godavari have been entrusted to NIH Roorkee, and CWPRS, Pune respectively.

The studies for some of the west flowing rivers of Kerala for possible storage sites on them are in progress and some basin studies in this connection have also been made. The studies for the location of the storage sites in Maharashtra and Gujrat are also in progress.

The National Remote Sensing Agency, Hyderabad had agreed to take up the work of remote sensing of Shivnath sub-basin area and area below Hirakud dam upto Naraj (Delta Head) in Mahanadi basin for land use and land irrigability studies using landsat data.

But of the field surveys for reservoir capacity completed so far, two have been completed on the west flowing rivers (Bhugad on Damanaganga and Khargi Hill on Wagh), while two each have been completed in the basins of southern tributaries of Yamuna (Kundaliya and Siameri) and Mahanadi (Lemdora and Bheden).

Water balance studies for six-sub-basins and topo-sheet studies for seven basins have been completed.

2.6 International Commission on Irrigation and Drainage

1. Transactions of Twelfth Congress on Irrigation and Drainage, Fort Collins (USA), 1984 Vol, I (A), I (B), I (C), and; Price per set US $ 225 (National Committee), US $ 250 (Booksellers) US $ 300 (Individuals).

The Transaction of ICID Congresses (held triennially) present the latest technological advance and experiences in the fields of Irrigations drainage, flood control and river engineering.

Vol. I (A) of the Twelfth Congress Transactions Contains 77 reports dealing 'Water management factor'; Vol, I (B) 54 reports on 'Irrigation and drainage of problem soils'; and Vol. I (C) 7 reports on 'New developments in the protection of irrigation, drainage and flood control structures on rivers' and 11 reports on the 'Impact of the energy crisis on irrigation and drainage' and two communication reports. Vol. II contains, among others, the discussions held on these subjects at the various Technical Sessions of the Congress.

2. Design Practices of Open Drainage Channels in an Agricultural Land Drainage System—A World wide Survey, 1984; Price per copy US $ 25 (National Committees) US $ 28 (Booksellers), US $ 34 (Individuals).

The publication contains useful information for irrigation and drainage engineers and scientists the world over about the practices being followed in various countries for the layout and design of drainage channels in agricultural lands. It comprises two parts: Part I is general review of the various engineering aspects (Including design aspects) of an open channel drainage system as relevant to an agricultural land/area: Part II includes 22 country reports.

3. State-of-the-art: Irrigation, Drainage and Flood Control, No. 3, 1984 : Price Us $ 29 (National Committees), US $ 32 (Booksellers), Us $ 39 (Individuals).

Third in the State-of-the-art series on 'Irrigation, Drainage and Flood Control' (the first two numbers were issued in 1978 and 1981), the Publication is focused on 'Irrigation by low quality waters', containing 15 papers on the subject in Part I. Part II of the publication on 'Status of irrigation, drainage and flood control techniques' deals with (i) weed and silt control and cleaning of open canals and drainage systems. and (ii) construction problems in difficult soils.

2.7 India Meteorological Department

1. Rainfall studies were carried out for the evaluation of the standard project storm for different projects in the country at the request of the state Governments/Project Authorities. Time distribution of storm rainfall was also carried out for these projects on the basis of 24 hours/hourly rainfall data. Short Duration rainfall studies of (a) sub-zone 2 (b) Brahmputra South were completed and its report was submitted to the Planning and coordination committee. Studies regarding Middle Gangetic Plain sub zone 1 (f) continued. A note on estimation of probable maximum precipitation for Dehang catchment was sent to the Chairman, Brahmaputra Board, Gauhati. Crop yield forecast for Rabi wheat based on weather data upto the end of December, 1983 for 15 Meteorological sub-divisions was supplied to Ministry of Agriculture. A coloured met. subdivisionwise map of SW monsoon' 83 for the period from 1.6.83 to 30.9.83 was supplied for coordinated Improvement Project, to ICAR New Delhi. Districtwise rainfall statistics, charts of SW monsoon 1984 as well as comparative rainfall information for the last four years was supplied to parliamentary consultative committee meeting of Ministry of Tourism & Civil Aviation.

2.8 Indian Institute of Tropical Meteorology, Pune

1. An up-to-date generalized one-day probable maximum precipitation (PMP) map of the north Indian plains north of Lat. 20°N was prepared by updating the maximum point rainfall data of about 1000 long-period rainfall stations. It was found that the one-day PMP over this region ranges from about 45 cm to 110 cm. Greater magnitudes of PMP were found to occur over Gujarat and Orissa coast.

The magnitudes of maximum point rainfall for 1 to 10 day durations for about 100 stations in Kerala State were determined. The maximum rainfall varied from 21-53 cm for 1-day, 31-85 cm for 2 day, 33-117 cm for 3-day, 31-143 cm for 4-day, 40-170 cm for 5-day, 44-194 cm for 6-day, 48-214 cm for 7-day, 56-222 cm for 8-day, 61-230 cm for 9-day and 62-243 for 10-day durations. These estimates are useful for various hydrological applications.

The long period daily rainfall data of about 100 stations in and around the Narmada basin were analysed to determine the estimates of maximum rainfall for the return periods of 10, 50 and 100 years for durations of 1 to 7 days. 21 generalized maps for 10, 50 and 100 years return periods for rainfall durations of 1 to 7 days were prepared. It was found that the maximum one-day rainfall for 10, 50 and 100 year return periods over this basin vary from 14-28 cm, 19-40 cm and 21-45 cm respectively. However, for 7-day duration, these estimates vary from 26-66 cm, 35-83 cm and 39-91 cm respectively.

2. The available water potential of six major catchments of India was assessed in terms of annual rainfall using the rainfall data of 83-year period 1891 to 1970. It was revealed that the rainfall of Brahmapntra catchment showed no relationship with the rainfall of other catchments. Using a first order Markov model the likely future annval rainfall sequences

were generated. The statistical properties of the historical data and those of the generated data were compared. It was seen that the model preserves the statistical properties of the historical data.

Maps showing the probability (between 10 to 90%) of receiving an annual rainfall of 50 cm, 100 cm, 150 cm and 200 cm over different parts of India were prepared, using annual rain fall data of about 460 stations uniformiy distributed over the country.

3. The space time distribution of monthly evaporation over the country was studied by means of harmonic analysis. It was seen that the first two harmonics permit almost a complete characterization of the space-time variations of evaporation. The largest amplitude of 4.5 mm per day in the annual wave occurs cver an area extending from east to west between lat. 20°N to 25°N. The lowest amplitude of the order of 1 mm per day occurs over northeast India, southern peninsula and along the west coast.

The normal monthly potential evapo-transpiration values of 240 stations distributed uniformly over India were subjected to harmonic analysis. It was revealed that the largest amplitude of the annual wave or the first harmonic varies from 20 mm in the southernmost parts of the peninsula to more than 100 mm over west Rajasthan. The date of occurence of maximum amplitude annual waves was around 1 March over the west coast of South India and around 4 July over the southernmost parts of the peninsula.

The precipitation data collected during the six snow-survey expeditions conducted during 1947-49 in the eastern Himalayas were examined. The precipitation during the winter season was found to be too meagre to build up the seasonal snow cover. Observations revealed that up to an altitude of 17000 ft asl, whatever snowfall occurs in winter season, it melts away rapidly.

Rainfall characteristics of Nepal Himalayas bounded between Long. 80°E to 88°E and Lat. 28° 30'N to 30° 15'N were analysed. The analysis showed that the eastern half of Nepal receives heavy rainfall as compared to the western half. It was further revealed that the mean annual rainfall along the foothills and Terai region is about 150 mm, increasing to about 300 cm in the central parts and then decreasing continuously until the Great Himalayan range is reached. It was also observed that two stations viz. Lamachaurs and Luma to the north of Pokhara valley receive annual rainfall of more than 500 cm.

The spatial variation in rainfall during winter and summer monsoon months over the Garhwal-Kumaon region was studied. The analysis revealed that the winter and the summer monsoon months contribute about 10 to 40 cm and 50 to 200 cm of rainfall respectively. One-day PMP estimates over this region was found to vary from about 32 to 78 cm. Estimates of 100-year 1-day rainfall over this region ranged from 15 to 48 cm.

Correlation analysis between the southwest (SW) and northeast (NE) monsoon rainfall over 24 stations the two series were found to be negative correlated. However, the southwest monsoon rainfall was found to be uniformly distributed throughout the state as compared to that of the northeast monsoon season. It was further observed that the inter-station correlations were independent of the distance between the stations.

The characteristics of rainfall over the Saurashtra-Kutch region were studied using 90 year's rainfall data. The analysis revealed that there were no increasing or decreasing long-term trends in the occurrence of excess ($\geqslant +20\%$) or deficit ($\leqslant -20\%$) rainfall over this region. However, two periods between

1909 to 1918 and 1966 to 1975 were found to be worst regarding the incidence of excess and dificit rainfall.

Investigation of severe floods during the monsoon season of 1982 revealed that despite large deficiency in rainfall over different sub-divisions, the country recorded 12 highest floods which had exceeded their previous records. Uttar Pradesh region alone experienced 7 out of these 12 floods.

4. The severemost rainstorm of 1 to 5 July 1941 which caused exceptionally heavy rains over north Konkan and Gujarat coasts was analysed. The average areal raindepths for 1 to 3 day durations that were yielded from this rainstorm exceeded the depths for same durations which occurred over other tropical regions of USA and Australia. The efficiency of this record storm was also found to be the highest among the world's severemost rainstorms.

2.9 Hydraulic Data Division, Damodar Valley Corporation

1. Systematic collection and compilation of Hydrologic data in Damodar Valley was continued.
2. Systematic study of river cross sections was conducted upto 150 Km below Maithon and Panchet Hill dams to study the change in river regime below the dams.
3. Capacity survey of Panchet Hill Reservoir (5th Resurvey) was completed.
4. Design of hydraulic model for Panchet Hill reversible turbine scheme and Hydraulic design of components of the tail pool dam were completed.

2.10 Hydraulic Study Department, Calcutta Port Trust.

1. Calcutta Port along with Haldia Dock Complex is riverine. The port complex is situated on the left and on the right bank of the alluvial tidal river Hooghly respectively. The distance of Haldia Dock Complex is about 164 k.m. from the sandheads in the Bay of Bengal. The navigational route leading to these ports through meandering channels, is interspersed with bars and crossings in the Hooghly Estuary. The presence of several bars on the way has imposed serious limitations on the draft of the plying vessel. Modern shipping trend indicates that the draft of vessel is gradually increasing and the ports are required to cater for greater drafts. Calcutta Port Trust is faced with great challenge of improving the draft of the navigational channel against the natural tendency of decaying estuary.

2. To understand the navigational waterway to improve the regime of the esturary and also to initially investigate the site for a deep dock so essential to handle larger and deeper vessels, the department came into existence in 1962 with world Bank loan. The Deptt. is organised into several sections trying to keep pace with the everchanging modern technology applicable to the science of river mechanics. Broadly, the different sections under the Hydraulic study Department Study which have been functioning are as follow:—

1. Analytical Section,
2. Computer Section,
3. Simulation and Instrument Department Section,
4. River Research section,
5. Dredging Research section,
6. Hydraulic Study Field Organisation at Berhampore in the district of Murshidabad,
7. Navigational Aid and maintenance section,
8. Laboratory section,
9. Hydraulic Model section, and

10. River Training Wing.

3. The programme of studies and observation of the Hydraulic Study Department during the year 1984 as prepared and executed is given below:—

(i) Behaviourial assessment of critical bars at Moyapur, Balari, Haldia area, Jellingham, Auckland and Middleton.

(ii) Study of scour in front of existing Oil Jetty at Haldia,

(iii) Simulation of Analogue model of Brahmani River System for its Flood Control Master Plan,

(iv) Hydraulic Model experiments on the 1/80, 1/160 model of the river Hooghly at Calcutta,

(v) 1-D & 2-D Mathematical Model between Bansberia and Sagor of the river Hooghly,

(vi) Movement of sediment by Radioactive tracers,

(vii) Scour study of the Second Hooghly Bridge,

(viii) Behaviour of automatic tide recorder,

(ix) Study of ship-borne Data Logger,

(x) Appraisal of shore disposal scheme at Jellingham,

(xi) Surveys of Balari area, Nayachara Island bank, Kulpi spur, Sagor Foreshore, Secondary channel closure, Sankrail spur, Khijri spur and other areas in the estuary,

(xii) Observations of velocities at different positions in the estuary.

2.11 Soil Conservation Division, Deptt. of Agriculture and Cooperation, Ministry of Agriculture, Government of India.

The Soil Conservation Division, Department of Agriculture & Cooperation, Ministry of Agriculture, had brought out a publication 'Guidelines and Status of Hydrologic and Sediment Monitoring of Watersheds in Selected River Valley Catchments'. The guideline covers the methodology for collecting data on rainfall runoff and sediment yield including instrumentation in small watersheds.

The Hydrologic and sediment data for the selected watersheds of the catchments of Damodar, Barakar, Chambal and Mayurakshi had been published. The results of various type of analysis carried out by the Soil Consercation Division had been given which provide insight on the methodology and possible techniques of analysis. The information published would be very useful for the personnels having interest in the soil conservation programmes within the country and also abroad.

2.12 All India Soil and Land use Survey Organisation.

The All India Soil and Land Use Survey Organisation of the Department of Agriculture & Cooperation, Ministry of Agriculture has compiled the information on "Hydrologic Soil Groups" from information collected by their regional centres covering 445 soil series. This compilation is an updated version of its previous compilation in February, 1972. The compilation is quite useful for estimating the peak run off rate of the area using the Hydrologic Cover Complex Method particularly of small watersheds in the River Valley Projects of the Country. The information could be effectively used by the organisations, namuly, Soil & Water Conservation, Flood Control Management, Forest Department and any other organisation responsible for developing the catchment areas.

2.13 Central Arid Zone Research Institute, Jodhpur

1. Geological and hydrogelogical survey of Barmer district

140 query points were studied for hydrogeological parameters and quality of groundwater within the area of 5000 sq. km of Barmer tehsil. Predominantly the aquifer are: calcereous blown sand, younger alluvium and older alluvium, weathered rhyolite and granite. In the calcereous blownsand, younger alluvium and older alluvium, SWL varies from 8.40-63 00, 4.9-10.5 and 18.40-77.00 m whereas the T.S S. varies from 2490-9920, 1472-5760, 1408-10240 ppm respectively. In younger alluvium the yield of wells varies from 5 lps to 12 lps. In some villages only small "barries" at the base of the dune, having depth to water ranging from 1 to 3 m b g.l. are the main source of drinking water. The granite aquifer is formed due to well developed on structurally weak zones. In this aquifer the SWL varies from 35.5 to 60.00 m. Whereas in rhyolite aquifer SWL varies from 19.0 to 46.0 m b g.l. Based on twelve geo-electrical investigations good quality water zones and saline zones have been demarcated.

2. Studies in groundwater hydrology using isotopic tracers

Analysis to tritium and 60 Co measurements indicate that there is very meagre vertical reacharge due to rainfall in Siwana, Raital and Bhadrajun areas of Barmer and Jalore districts. The studies on soil moisture distribution-laterally and vertically indicate that the tritium tracer is evenly distributed in all directions and upward soil moisture is found to be absent. In south of Siwana region, on account of clay particles encountered at Shallow depth, the recharge to the groundwater is very slow.

3. Geological and hydrogeological survey of Jaisalmer district

The studies on Hydrogeological parameters and groundwater quality of 40 sampled wells were carried out. The principal aquifers are; calcareous blown sand, older alluvium and medium to coarse grained sandstone. Depth to water in calcareous blown sand aquifer was 57.30 m b.g.l. whereas the same in older alluvium and sandstone it varies from 28.7-65.0 m and 14.0 to 73.6 m b.g.l. respectively.

The total soluble salts content in calcareous blown sand, older alluvium and sandstone was 1600 ppm, 1408-5120 ppm and 1024-9600 ppm respectively.

4. Resistivity depth sounding in Luni basin

Geo-electrical investigations of entire Luni basin were completed. The interpretation of resistivity values along the seven traverses was carried out to determine the sub-surface conditions and also iso-resistivity maps at the depth of 1.5,10,40 and 60 m were prepared.

5. Surface water resources survey of Barmer and Jaisalmer distt. The districts Barmer and Jaisalmer are mostly covered with the blanket of sand. Due to such terrain conditions and rainfall pattern the runoff to the village tank is very meagre and surface water is available for 1-6 months of the year. Moreover groundwater is also brakish. Owing to such water problem in the villages, the villagers are migrating to their fields, where they have own underground water storage tanks (masonry structure) to meet the drinking water requirement. Most of the underground storage tanks are covered with thorns and water is contaminated. Properly designed covered underground takns is the solution for drinking water problem. Such structures will eliminate the seepage and evaporation losses and will store water free from health hazards. In this region the Khadin cultivation is most dominant. Sixteen new sites were identified for promoting this old practice.

6. Environmental pollution and their impact on biota

The influence of industrial and municipal effluent waters on natural water resources was observed around Jodhpur, Pali and Balotra. Most of the industrial effluent is being drifted in river (River Jajri, Bandi and Luni) sections without pre-treatment, Along both the banks of ephemeral river sections, effluent water has accumulated and has become the main source of recharge to ground water, and converting the irrigation wells and lands of no use. Ec of water of such wells have increased from 970 to 2014 micromhos/cm as compared to the year 1983. The chilly crop was highly affected.

7. Water balance study of Luni basin.

(a) Raingauging net work and variation in static water level

The average annual rainfall of the basin during monsoon period was 285.00 mm, which can be characterised as below the normal. The average number of rainy days were 15.4 days but their distribution are erratic with low intensity due to which no appreciable runoff was generated. 218 well hydrographs were plotted for calculating the amount of recharge received by different aquifers. In general, it is seen that the recharge to groundwater occurs only during the above normal rainfall years.

(b) Stream gauging and sediment studies in Luni basin

Last five years' observations reveal that during the normal flow geometrical dimensions of different river sections does not change, except in flood years. During 1984, out of 31 stream gauging stations, at seven stations flow did not occur. At remaining gauging stations the H.F.L. varied from 0.10 to 2.00 m and flow was confied to river sections. The peak discharge varied from 0.48 to 790 cumecs. The maximum average suspended load in runoff was 7.29 g/lit whereas the minimum was 0.21 g/lit.

Based on the size of bed materials and avarage depth of flow, the Manning's roughness coeffjcient for differnt river of the basin was determined. The mean diameter of bed materials varied from 0.16 to 1.68 mm and the average value of Manning's roughness coefficient varied from 0.0197 to 0.0321.

2.14 ICAR Research Complex for NEH Region, Shillong.

1. Data regarding Rainfall, Runoff, Soil loss, harvesting of surface flow and sub-surface flow through dug out cum embankment type of ponds in eight micro-watersheds (0.5 to 3.9 ha) under various land use such as live-stock based farming, forestry, Agro-forestry, Agriculture, Agri-horti-silvipastoral, Horticulture, Natural fallow and traditional, agricultural system of food production (shifting cultivation are being collected and inter-relationships of various hydrological parameters are being worked out. The study is one aspect of a multi-disciplinary project. Treatments were applied only in 1984. First year observations indicate that under this high rainfall area (2148 mm in 1984) it was possible to retain over 98% rainfall in the hill slopes of the watersheds and the runoff water yield from the area was mostly in the form of baseflow. The soil erosion losses were also of minor nature.

2. Under water resources development study two watersheds of 3.21 and 11.0 hectares catchment are under observation from the point of view of water yield and water harvesting. Besides 6 natural springs are under monitoring for water yield. Inter-relationships of various hydrological parameters are being worked out.

3. Based on soil and water loss data available from various hill slopes (0—100%) under rice

crop the analysis indicates sinusoidal relationship in between soil loss/runoff and slope. The equation was of the following type.

$$P_f = 201 - 78.0 \sin\left(\frac{S-64.9}{20.66}\right) \quad \ldots\ldots(1)$$

$$S_l = 34.97 + 10.03 \sin\left(\frac{S-35.1}{20.66}\right) \quad \ldots\ldots(2)$$

Where R_f = Runoff (mm),

S_l = Soil loss (t/ha), and

S = percent Slope

2.15 Water Technology Centre, New Delhi

1. Surface Drainage Design in Irrigaiion Command Areas

Rainfall, water table, irrigation water releases, cropping pattern and other hydrometeorological information were collected for a 1200 ha area under the Mahi Right Bank Canal Command Area in Gujarat. The data were analysed and a computer water balance model was developed. The model was tested against the observed water table fluctuation data for the area. It was then used to estimate the drainage coefficient for surface drainage design. The drainage coefficient was determined on the basis of one to five consecutive dry rainfall magnitudes corresponding to a recurrence interval of one year. This was done due to the fact that only 5 years of recorded information on most of the components in the water balance mode was available. Determination of drainage coefficient for higher recurrence intervals from a short period data of 5 years, therefore, would be in error. After the water balance model was verified, and the expected runoff as a percentage of rainfall was worked out, long term rainfall data were analysed to obtain the rainfalls of 1-5 consecutive days corresponding to recurrence intervals of 5,10 and 15 years. Modified surface drainage coefficients were then computed based on these values. The main work in validating the water balance model was to select the appropriate "Curve number" in the hydrologic soil cover complex method of runoff estimation, so that the observed and predicted ground water storage (hence the water table rise) as a result of rainfall, match with each other. Appropriate stalistical test was performed to find if any significant difference existed between the observed and predicted water rable depths.

2. Management of windmill based Irrigation System

An analysis was made to estimate the cost of windmill pumping system corresponding to five assumed daily irrigation demands of 10, 25, 40, 55 and 70 m^3 of water and at each of 50, 70 and 90% levels of probability of failure (i.e. risk levels) of supplying the required discharge by the windmill. The analysis was done for the Apoly-12 PU 500 type windmill with threshold and cutoff wind speeds of 9 and 36 km/hr respectively. The estimates of daily water pumped py the windmill was done on the basis of daily average wind energy. The wind energy was calculated from the basic wind velocity data. The hourly wind velocity data of Delhi fcr 5 years were collected for this purpose from the India Meteorological Department. Budgeting computations were done between the assumed daily water demand and the estimated water pumped by the windmill for each of the 15 combinations of daily demand (5 levels) and risks (3 levels). The purpose of the budgeting calculation was to find the size of the resorvoir required to supply assured quantity of water at the chosen risk levels. Thd cost of the system was calculated on the basis of the costs of windmill and its transport and installation, cost of reservoir and the cost of a polythene lined channel. The annual cost of the system was found out by assuming appropriate values of amortization period and interest rate. Subsequent to this optimal crop plan was found out corresponding to each of the combinations of daily demand and risk level.

3. Resources Analysis and plan for Efficient Land Use and Water Management in Mahi Right Bank Canal Command Area, Gujarat

The study was taken up to analyse in detail the availability of water Resources in the Mahi Right Bank Canal Command Area in relation to the water requirements and to suggest appropriate policy measures for irrigation management in the command area. A detailed groundwater model study of the groundwater basin in the Mahi Right Bank Canal Command Area was also undertaken. Available data on Rainfall, groundwater, wells, irrigation system, water use etc was collected and analysed. A preliminary water balance study of the basin was done to estimate the net groundwater recharge. It was observed that the annual rate of groundwater table rise has increased substantially over the years and has reached the alarming rate of about 1m per year during 1976-79. To develop a suitable operational policy for groundwater extraction and utilization it is proposed now to construct a detailed groundwater model for the basin. Preliminary tests on the computer programme needed for this have been completed and detailed testing and application are in progress.

4. Evaluation of water-crop Distribution and Management

A new study involving largescale observation management of water-crop distribution was planned in Mathura district of U.P. The study area spans over 20,000 hectraes along with associated canals and tubewells.

The following important results were obtained pending detailed data scrutiny.

(a) A hydrological cum population sampling method has been developed for evaluating large-scale water distribution and crop production system performance without interrupting these processes.

(b) A clarification has emerged that the canals have been provided as the main tool of social justice in farm economy. For this reason, whereever feasible, the groundwater development has to be widely spread over the entire political area rather than concentrated in a smaller part.

(c) About 30% of lawful canal beneficieries particularly at tail ends, have remained deprived of their share of water for various reasons, widening the gap in farm economy. The present canal water distribution practice is not crop productivity oriented and hence needs revision.

(d) Inadequate drain capacities and scanty field drains constrain kharif productivity. Development programmes of water course lining without simultaneous construction of field drains in water logged area are questionable.

(e) Improper kharif crop selection practices on poorly drained lands has been identified as an important cause of low crop production on an annual basis. Thus change of conventional Bajra with paddy production on poorly drained lands is called for in areas where such change has not already occured.

5. Analysis, Synthesis and Design of Irrigated Farming System with Special Reference to Canal Water.

The objective of this project is to generate canal water engineering management technology by application of water-soilplant relationship. The following analytical study were carried out.

(a) Crop change Planning Study.

An analysis of existing data was done to conclude that there is no conflict in the crop change planning policies when irrigation is supplied from canal sources vis a vis tubewell sources. Under both sources of irrigation the order of priority of crop changes was deduced to be in the following order : (i) Mustrad (ii) Gram

(iii) Lentil (iv) Pea or Wheat (v) Barley (v) Sugarcane.

(b) The study reviews canal irrigation system parameters and analyzes their shortcoming. It concludes that the current basis for estimating basic design parameters of canal irrigation system ignores water-fertilizer interaction, climatic and soil type influences, imput-output considerations and time variability of estimates. An analytical system model for design parameter estimation was developed.

(c) Study of On-Farm Development Policy and Impact Assessment

System analysis has been applied to develop a rationable and method of impact assessment on-farm development programmes. It shows that under an optimal policy of on-farm development, the impact of investment is essentially that of any linear dynamic system. An optional policy rule also has been derived that the proportional past investments in each component of development should be equal.

6. Collaborative Studies

Water management problems in Mahi Right Bank Canal Command Area, Gujrat were studied in collaboration with the soil survey and irrigation departments of the state. An inventory of resources and a plan for its efficient water management was also prepared and published by the centre.

Studies on water requirement of citrus (Kinhow) were conducted in collaboration with the Division of Horticulture, I.A.R.I. Scheduling of irrigation at IW/CPE ratio of 0.6 with 10 cm of irrigation water was found beneficial in retention of flowers and fruits.

Experiments on ET pattern on wheat and maize in lysimeter are being undertaken at this centre in collaboration with the India Meteorological Department, Pune

Water quality of irrigation tubewell and open wells along with the salinity/sodicity developed in irrigated soils of Delhi territory was determined in collaboration with the Department of Agriculture, Delhi Administration.

Onfarm water management including adoption of precast channels for lining and monitoring the flows below an outlet are being carried at Barabanki in the Sarda Sahayak Command Area, U.P.

2.16 Central Board for the Prevention and Control of Water Pollution, New Delhi.

1. Prevention of pollution rather than the control has been taken in principle as one of the major thrust areas. Action in this direction requires the interaction with different ministries and agencies. The Planning Services Cell of the Board is shaping up well to implement action in this preventive area specially with regard to proper storage of Molasses and Chlor-Alkali industries. The programme of preparation of a Comprehensive Industry Document for each specific group of industries is continuing to evolve industry-specific Minimal National Standrads (MINAS) as well as policies to control water pollution from the industrial sources. The industries contemplated for such nation-wide implementation during the Seventh Five Year Plan period (1985-90) are : (1) Pulp and Paper, (2) Thermal Power, (3) Pesticide, (4) Petrochemical, (5) Pharamaceutical, (6) Dairy, (7) Inorganic Chemicals (8) Non-Ferrous Metals (9) Dye Manufacturing, (10) Tannery, and (11) General Engineering industry including Electroplating units.

The preparation of comprehensive industry documents for : (1) Pulp and Paper industry, (2) Thermal power plant, (3) Integrated Iron & Steel industry, and (4) Pesticide industry is at fairly advanced stage.

2. The implementation of industry-specific

Minimal National Standrads (MINAS) is under progress for the following industries : (i) Chlor-Alkali, (ii) Sugar, (iii) Man-made fibre, (iv) oil refineries, (v) Distilleries, (vi) Fertilizer, and (vii) Textile mills.

3. Studies on systematic comprehensive survey of pollution potential and status of the entire Ganga River Basin excluding the Yamuna sub-basin is completed in co-operation with the State Pollution Control Boards of Bihar, Madhya, Pradesh, Uttar Pradesh and West Begal. The report is published as 'Basin Sub-basin Inventory of Water pollution—The Gange Basin, Part II.' The report contains 7 maps of the Ganga basin projecting the follawiag aspects.

* Physiography, Ground Water and Stream Flow Characteristics.
* Soil Types and Climate (rainfall, temperature, and evaporation)
* Land Use (Cultivable to total area and gross sown to cultivable area), and Fertilizer Consumption N.P.K. separately)
* Land Use (net irrigated to net sown area, canal to net irrigatad area), and Pesticide Consumption (organo-chlorine, organo-phosphorus and others)
* Pollution Generating Potentials, Generated Load and Discharge
* Abstraction and Stream classification (use based)
* Pollution Discharge Locations and Quantification, Stream Classification (quality based)

The Central Board has taken up the work of preparation of an atlas of maps of 14 major river basins to provide a scheme of zoning and classification of these rivers on the basis of designated best use concept and to identify the reaches where the gap between desired and present water quality is significant enough warranting pollution control measures. The atlas preparation is at an advanced stage.

4. As usual data from 33 monitoring stations located in 7 states continued to flow during the year. The water quality data for four Inter-State rivers of Gujarat viz. the Mahi, the Sabarmati, the Narmada and the Tapti, are brought out in a publication titled, 'Quality of Major Rivers-Gujarat State (The Biennium 1979 & 1980 Survey)'. The Sabarmati being the most polluted among the 4 rivers, specially downstream of the city of Ahmedabad, 5 continuous stream water quality monitoring stations are envisaged under an Indo-French joint programme.

The river water quality monitoring under Monitoring of India's National Aquatic Resources MINARS is continuing. Data analysis and interpretation for the rivers Yamuna and Ganga are completed. The updated water quality data of the Yamuna is published in a report titled, 'Quality and Trend of River Yamuna (1977-1982)'. The inter-State Yamuna monitoring programme was undertaken by Central Board s team from July, 1983. The monitoring is being done every three months at 13 stations. Biological monitoring is included in the above programme. Diversity index of planktonic organisms is being determined at each stations.

With a view to collecting baseline information under pristine conditions, monitoring of the rivers Sutlej, Beas and Ravi within the State of Himachal Pradesh was carried out, A total of 19 samples were collected from 19 stations and were analysed for 20 parameters. The results have shown that there is little effect of man-made pollution in these stretches. To collect further data it has been proposed to the Himachal Pradesh State Board to continue monitoring of these rivers at every three months interval. The finally selected monitoring stations are four in the Sutlej, nine in the Beas, and two in the Ravi.

In addition to the water quality analysis, information was also collected on various uses

of these river stretches such as for fisheries, irrigation, wildlife, water supply and direct discharges, for preparation of designated best use map.

5. As a follow up of the preliminary survey of coastal stretch from Ennore, North of Madras to Kanyakumari, covering the entire State of Tamil Nadu and the Union Territory of Pondicherry, the Central Board has awarded the job of carrying out the monitoring of two ecologically sensitive areas, namely Pitchavaram and Vedaranniyam to the Centre of Advanced Studies in Marine Biology, Porto Novo. Four stations have been selected in each area for chemical and biological monitoring. The preliminary results show that these areas are at present relatively free from pollution but require protection from pollution inducive activity in future. The Sectional Office of the Central Board located at Pondicherry has also initiated coastal monitoriug of the Pondicherry-Cuddalore stretch.

As a part of the Central Board's plan to prepare designated best use map and a water quality map for the entire cost line of the country, the Central Board has conducted a rapid inventory of the Thane to Alibagh stretch in Bombay region, The Stretch falls in the State of Maharashtra. The survey was conducted during March, 1984. The map are under preparation for this part of the stretch.

6. The river Damodar flows through the States of Bihar and West Bengal to meet the complex tidal Hooghly estuary. In its course the river water is subjected to use and abuse by several industries locatad particularly in the Bokaro-Dhanbad and Asansol-Durgapur regions of Bihar and West Bengal respectively. There are about 42 large industries (23 in the Bihar and 19 in the West Bengal regions) which may be classified broadly into the following categories: (a) Coal washeries and Coal coking plants, (b) Coal-based thermal power plants, (c) Intergrated iron and steel mills (including special steel). (d) Chemicals and Fertilizer plants, and (e) others (like distillery, paper mill etc).

A 2-year programme is initiated in July 1983 by the Central Board in collaboration with the State Pollution Control Boards of Bihar and West Bengal. The programme was envisaged (a) to ensure control of pollution at sources through installation of appropriate pollution control systems within a definite time-frame by the industries responsible for the pollution of the Damodar river : (b) to conduct a systematic monitoring of the river water quality, and (c) to assess, by dry-study, the total pollution potential of the whole river basin.

To monitor improvement of the river water quality 17 monitoring stations in the Bihar stretch of the river and 17 in West Bengal stretch are identified.

2.17 Research Designs and Standards Organisation, Ministry of Railways

1. Hydrometeorological studies are being carried out by Indian Railways Bridges & Floods Wing of R.D.S.O., with a view to rationalise, improve, refine and simplify the approaches for estimation of flood peak values of different return periods for design of water ways for bridges. In this context and pursuant to the accepted recommendations of the Khosla Committee of Engineers, work on the collection of hydrometeorological data from representative catchments throughout the country, was continued during the year,

During the monsoon period of 1984 observations of stage, discharge and rainfall at required short intervals of time were made in 44 catchments for unit hydrograph studies and daily peak stage of flood frequency studies were observed at 281 railway bridges spread throughout the country. For collection of rainfall data, 146 ordinary rain gauge stations and 73 self-recording rain gauge stations were

set up in 44 catchments. Plans have also been drawn up for setting up a few automatic water level recorders on the Eastern and Western Railways.

2. Since the subject of hydrometeorological studies and estimation of peak floods and their return periods is of common interest to Central and several State Flood Departments, a Central committee known as the Planning & Coordination Committe, with members drawn from the Railways, Central Water Commission, India Meteorological Department and Ministry of Transport, created in pursuance of Khosla Committee's recommendation, directs the policies, coordinates, guides and monitors the works of the four Ministries. This Committee met twice during the year, under the chairmanship of the Joint Director Research (Bridges & Floods) from RDSO and guided the participating departments in respect of work to be done after monitoring the work donem the past.

3. Under the longterm plan as per accepted recommendations of Khosla Committee, the Country was to be divided into a number of zones and sub-zones based on their hydrometeorological character and flood estimation reports prepared for each sub-zone using the latest techniques and data collected.

During the year, long term plan reports for South Brahmaputra Basin under sub-zone 2 (b) and Upper Indo-Gangetic Plain 1 (e`, were finalised and brought out under the auspices of Khosla Committee. Bridges & Floods Wing of RDSO, has brought out and circulated a report on simplified approach for Mahanadi Basin-subzone 3 (d). Suitability of various probability distribution function for flood frequency study was tested using data collected for Mahanadi Basin covering a large part of South Eastern Railway.

4. With a view to facilitate up-dating/ validation of reports and monitoring of artificial and natural changes in the hydrometeorological characteristics, about 177 key gauging observation stations were indentified for collection of data over a long period. Work at 160 (Railway and Central Water Commission sites) stations is in progress.

2.18 Isotope Division, Bhabha Atomic Research Centre, Bombay

1. Salinization of Coastal Minjur aquifer near Madras

Environmental isotopes Deuterium, Oxygen-18, Tritium along with major and trace chemical species have been used to study the salinization of coastal Minjur aquifer. The results obtained show that the salinity of groundwater in the area is largely due to sea water ingress. Some hypersaline groundwaters encountered in certain packets in the salt pan area in this region could have derived their salinity by leaking of salts from the salt pans and do not appear to be connate.

2. Seepage study in Salal Hydroelectric Project, Jyotipuram (J&K)

Measurement of environmental isotopes ^{18}O and Tritium was used to investigate the source of seepage waters in the tail race tunnel of the salal Hydroelectric Project, Jyotipuram (J&K). It was found that the seepages were due to rain water stored in the dolomite rock and the age of water ranges upto 10 years and can be correlated with the thickness of dolomite above the tunnel.

3. Groundwater recharge studies in Western Rajasthan

The source of chronology of recharge to the deep wells in Jalore district in Western Rajasthan was studied using environmental isotopes (D, ^{18}O, ^{3}H and ^{14}C). The data show that deep waters are probably recharged druing a more moist and ancient cooler period than

the present. The distant outcrop areas are the possible recharge zones.

In an injected tracer study carried out separately it was shown that direct recharge of local precipitation in these arid areas is generally very small or non-existant.

4. Direction of flow of deep geothermal waters in Manikaran, H.P.

A radiotracer study was carried out in collaboration with NGRI, Hyderabad for detection of flow of deep geothermal water in Manikaran. It was shown that the direction of flow is north to south across the Parbati river at Manikaran village.

2.19 Department of Space

1. NRSA undertook resources survey projects on behalf of several users Study of pre and postmonsoon conditions of river basins in Punjab for hydrological characteristics and survey of Madras and its environs for groundwater potential and land-use were completed using satellite imagery. Projects for mapping of salinity, alkalinity and river water quality, and environmental studies of Nilgiris bio-sphere comprising Silent Valley and its environs were completed using aerial and satellite data. Aerial remote sensing projects that were completed include: town planning survey over seven towns of Andhra Pradesh, scanner (thermal) survey in Bastar District of MP for mineral exploration, monitoring of changes due to natural and developmental activities in Sriharikota, photographic survey over Kerala and survey for road bridge near Tejpur. Consultancy projects completed using aerial photo-interpretation include a geological survey in Uttar Pradesh, groundwater surveys near Dehradun and a semi-detailed soil survey of Maheshwar Project area in MP. About 40 projects involving different resources and regions are underway.

2. Imageries from cameras aboard Salyut-7 obtained as part of the 'Terra' experiment in the Joint Indo-Soviet manned mission, are under analysis. Preliminary results of the analysis of 'Terra' imagery were presented and discussed at a seminar with scientists from various user organisations in February 1985. 'Terra' imagery of the Gulf of Cambay revealed some megalineaments (For the first time) and circular features of importance to oil exploration in the area. New geological lineaments, circular features and anomalies were detected in the Western and Northern regions. A very detailed map of forests in Gujarat was generated. In the Western ghat forests of Karnataka, increase in forest clearance over the past nine years was delineated. Consequential increased silting by river Aghanshini into the Arabian sea was prominently shown.

A new mangrove island of 8km × 3km was detected off the Orissa coast. Extensive studies of the entire Indian coast were conducted yielding valuable information on geology, sand dunes, salt pans, mud flats, mangroves, turbidity, silting pattern as well as simultaneous ground-truth surveys, selected forests were mapped giving details of significance to Project Tiger.

3. Study of monsoon heat flow structure was initiated, Theoretical studies commenced on micro-wave backscatter from windroughened ocean surface and a novel algorithm was developed for retrieval of wind-vector from scatterometer data. A study on the impact of satellite data on short-term monsoon prediction was initiated jointly with IIT, Delhi. Radiometers and line-of sight systems were set up at Kozhikode, Ahmedabad, Delhi, Ranchi, Madras and Gulmarg for collection of monsoon data.

2.20 National Remote Sensing Agency, Hyderabad

1. An aerial Photographic survey of Brahmaputra river was carried out for Brahmaputra Board and Brahmaputra Flood Control Commission so as to enable the user Agency to plan

for anti-erosion/flood protection works and also to study the efficiency of the existing flood control works.

Satellite remote sensing survey has been taken up to map the channel configuration of the vulnerable reaches of Brahmaputra river (viz., Moriahota, Mulkalmna Gurni and Fakirgunj-South Salmara); changes of channel configuration will be mapped initially at three year intervals. As an output product, satellite interpreted channel configuration maps for each of the scenes analysed showing position of the channels together with the geometry, location and character.

2. The Aerial Remote sensing survey of irrigation command area of Narmada Project was done for the Irrigation Dept, Govt. of Gujarat. The aerial photo mosaics prepared were interpreted for information on the existing hydrologically significant land cover/landuse features of the command area.

3. The behaviour of Sutlej and Beas rivers downsteam of Bhakra and Pong dams respectively has been mapped using pre and post monsoon landsat data. Computer classified photo outputs showing hydrologic landuse/landcover types in the area were also prepared.

4. The Indian Remote Sensing Satellite Programme is a major step forward in the overall programme for using space technology for defined applications in India. For the utilisation of data received from Indian Remote Sensing Satellite (IRS) a set of sixteen application projects in the fields of Agriculture, Geology, Hydrology, and the Environment have been selected on the basis of priority areas jointly identified with user agencies and configured so as to transfer the technology of applications to the user agencies in a phased manner. Eight of the projects are to be carried out by NRSA, in collaboration with the user agencies. In the field of Hydrology, Flood Mapping, Snow Mapping and Drought Monitoring Projects have been taken up under the IRS Utilisation Programme.

2.21 Centre for Water Resources Development and Management, Kerala.

5. The Centre for Water Resources Development and Management (CWRDM) is an autonomous research organisation established by the Government of Kerala in 1978, under its science and technology programme. The main objective of CWRDM is to conduct research and studies on assessment, conservation, development and utilisation of water resources. It is envisaged to function as a Centre of excellence for advanced research, training and extension on all aspects of water resources. CWRDM will also act as an advisory and functional institution in the Planning and execution of national projects of water use.

CWRDM is organised into eight Divisions; of which five are scientific, two technical and one administrative. The scientific Divisions are, Surface water, Groundwater, water Quality and Environment, Water Management (Agriculture), and Education and Extension. The technical Divisions are Library Documentation and Information and Engineering and Construction. The Administration Division looks after both administrative and financial matters.

CWRDM is having two campuses. The main campus where the laboratories, technical and scientific Divisions, library and administrative buildings are located at Kottamparamba situated 13 km. east of Calicut city. The second campus intented for the field experimental station is located near Kuttiyadi Dam at Peruvannamuzhi, about 53 km. north of calicut.

1. Surface Water Division

The methematical model developed for river discharge will help in estimating flow at ungauged river stations.

The results of the estuarine studies can be used for predicting salinity at different cross sections of estuaries of Malabar Coast.

A method has been evolved for the designs of raingauge network which will be useful for scientifically locating raingauges in regions where hydrologic studies are to be made.

A regional flood-frequency study has been completed for the Malabar Coast which will be of much help for various government agencies to estimate peak flood discharges in ungauged streams.

Relationships have been evolved between various geomorphologic parameters and with river discharge which will assist in the estimation of river flows for the region.

The availability of water and the feasibility of its use for eight water supply schemes in the State, for proposed World Bank funding, was studied and reported to the Kerala Water and Waste Water Authority.

Technical assistance was given to agencies as the State PWD (Irrigation), Cardamom Board, Oil Palm India, etc. on various water resources aspects.

Five post-graduate students from Karnataka Regional Engineering College have been trained in different areas of water resources as a part of their project work.

2. Groundwater Division

The ground water availability and its quality as well as extent of utilisation of the present resources have been found out for the coastal tracts of Kasargod, Cannanore, Kozhikode, Ma'appuram and Trivandrum districts.

The Talukwise inventory of existing water resources along with analysis of future water requirements upto 2050 A.D. have been made for the districts of Kasargod, Cannanore, Wynad and Kozhikode.

Through geophysical survey and hydrogeological investigations sites have been located for groundwater development in the entire Kozhikode district and part of Malappuram district. Remote sensing technique employing aerial photographs and satellite images have been applied to targat water potential zones with specific reference to groundwater sources in the greater Chaliyar River Basin.

A detailed investigation of the landslide problem in the Wynad Region of Kerala State has been made with particular reference to the largest landslide in the State which occured at Mundakkay (near Meppadi) in July 1984. The causative factors for this landslide have been found out and the preventive and remedial measures to control future recurrence have been suggested.

3. Water Quality end Environment Division

The results of studies to find out viable uses of the perniceous weed, **Salvinia** for biogas production and waste water treatment and of those to evolve guidelines for the safe management of industrial effluents, are of immense value for economic exploitation.

The Centre for advancement for Rural Technology of the Government of India and the State Government of Jammu and Kashmir are making use of the know-how developed at CWRDM for the bioconversion of aquatic weeds. The University of Florida has shown interest in the technology for waste water treatment using aquatic plants.

4. Water Management (Agriculture) Division

The water Management (Agriculture) Division developed a technology (CST) involving spraying of reflectants such as lime, china clay etc. to reduce photoinjury in shade-loving crops. Basic data on climate and soil in relation to water management practices have been collected and analysed.

Instrumented watersheds have been established for plantation crops like coffee, tea, rubber, cardamom, cashed and multistoryed cropping system for the study of land use effects in the Western Ghats Region of Kerala on the soil, climatic, and hydrological parameters in comparison with the natural forest and reforested Eucalyptus plantations.

Developed efficient low-cost micro irrigation and fertilization systems suitable for plantation crops of the humid tropics.

Field studies were conducted on fertilizer management especially for nitrogenous fertilizers under wetland and upland ecosystems and new methods to quantify the volatalization losses under field conditions were developed.

Water quality studies of the Kuttanad region have been undertaken. Quality of water and sediments from the reservoirs of major irrigation projects of Kerala have been studied.

Drainage type lysimeters have been designed, fabricated and installed in the field for studies on water and fertilizer use efficiency under coconut-based cropping systems.

2.22 Maharashtra Engineering Research Institute, Nasik

1. The set up of Maharashtra Engineering Research Institute, established in April 1959 (M.E.R.I.) comprises of fifteen research Divisions and one Mechanical Division. The Research problems and testing work carried out in MERI is mainly referred to by Field Officers/C D.O. in the Department. There are also some "Self sponsored" problems and a number of research projects, which are entrusted to the institute by the Government of India through Central Board of Irrigation & Power and Ministry of Transport under different Research Schemes. Problems and testing work of Semi-Government and private bodies are also taken up in M.E.R.I. as far as possible.

2. Some of the important works completed/undertaken during the year by different divisions of the Institute are described briefly.

(a) Koyna Hydro Electric Project Stage-III Monsoon-Intake.

To evolve an arrangement for diverting a constant boulder free discharge for Konya Stage-III, power house by the model studies. When river discharge was $17m^3$/sec all the discharge was diverted. When river discharge was $545m^3$/Sec., a discharge about $30m^3$/Sec., was diverted. Slit of size 50mm coming in the chamber was sweeping out automaticaly.

(b) Vaitarna Dam Bye-pass outlet : Model studies of stilling basin.

The existing stilling basin of the bye-pass outlet is designed for discharge of 350 cusecs. As the discharge is to be augmented to 600 cusecs the object of the problem is to observe the adequacy of the stilling basin or to modify the stilling basin for the augmented discharge.

During conducting experiment, it was observed that for the discharge of 6000 cusecs, the performance of stilling basin was not satisfactory; hence it become essential to increase the length and width of stilling basin. Most of the energy (about 80%) is dissipated in stilling basin when two rows of friction blocks were provided. It was observed that the water was splashing occasionally over the guide-walls on either side of E.D.A. Hence the guide-wall height is to be increased so that the stilling basin walls will not be overtopped by surges, splash, spray and wave-action set up by the turbulence of the jump.

(c) Remote Sensing–The work of assessment water resources of Tultuli Irrigation Project, Tal, & District Gadchiroli.

(i) The area of the catchment measured from aerial photo map is 2.42% less to the value reported as having been obtained from the ground based methods namely, 769.23 sq. km.

In the case of visually interpreted map from imagery, (Landsat MSS) it is 7.02% less and from digital method of analysis it is obtained as 4.46% more.

(ii) The number of land cover features identified on the aerial photographs are 10. On Landsat imagery it is 6 from both visual and digital methods. The results show that the total forest covered area constitute the single largest land feature in the catchment area. Cultivated land constitute the second largest feature and the villages and open areas the third.

(iii) The validity of the run-off estimate can be conclusively proved only when data of the river gauge station is available for a number of years.

(iv) A detailed analysis of the drainage, geomorphology & geology of the area suggest that the proposed site for the dam will enable retention of water for long periods.

(v) Good quality materials for construction works namely, sand aggregates are readily available around the region within normal lead.

(d) Development of Electronic current meter.

Current meter is used for velocity measurement of water flowing through canals. Manufacturing of various parts of current meter is completed. Study of appropriate electronic circuit suitable for current meter is in progress. The problem will be continued in the year 1985-86.

(e) Development of vibrating wire type tiltmeter

Tiltmeters are used to measure deflection of Dam (namely plumb line). Design work of tiltmeter is completed. Material required for fabrication have been procured. Fabrication testing and calibration will be completed during the year 1985-86.

(f) Installation of photovoltaic water pumping system

Study of available literature on solar energy, photovoltaic effect and application etc. is completed. Procurement of various instruments pumping system have been completed. Installation of the photovoltaic pumping system in the institute premises is completed. Feasibility study will be carried out during the year 1985-86.

(g) Detection of waterlogged and saline lands in Purna command area in Parbhani and Nanded districts.

The aerial photographs of the two periods enabled to detect the deteriorated lands. These lands generally appeared in light tones; they were devoid of crop cover as they had become infertile. The CCT analysis showed more classes of land cover than the visual interpretation.

2.23 Groundwater Surveys and Development Agency, Pune

1. The hydrogeologists carry out surveys by collecting the data in the field by way of well inventory of the representative wells in the village including various information pertaining to depth, diameter of well, static water levels in winter and summer, geologicai information of the rock formation and connecting the surveyed wells with reference to the mean sea level. The hydrogeological maps are prepared on the basis of various scientific data collected in the field indicating the ground water conditions, groundwater flow lines. The worthy and nonworthy areas for groundwater development are also indicated in these maps. Pumping tests are conducted on representative well to understand the characteristics of aquifer and groundwater hydraulics. These basic maps are immensely useful in recommending the sites for

well sinking programme and planning groundwater development projects. Under this scheme, 1075 villages were surveyed covering an area of 7508 Sq. Kms; in all 21058 wells were examined and 330 aquifer performance tests were conducted.

2. The percolation tanks are constructed for artificial recharge to groundwater. The sites for construction of percolation tank are recommended by the Agency. Under this scheme in all 211 cases were surveyed in 190 villages, for which 687 supporting wells were examined. In all 165 cases were recommended.

3. This Agency has set up a Geophysical Division under Centrally Sponsored Scheme for strengthening of Groundwater organisatlon of the state. At present there are about eight geophysical survey units. They are carrying out the electrical resistivity surveys for the selection of bore well sites for drinking water. In addition they are taking the surveys for delineating the saline zones and other problems regarding groundwater conditions occurring in the various districts of the state. Under this scheme in all 313 cases were surveyed in 230 villages for which 1063 VES were taken. On the basis of these surveys 223 cases were recommended.

In order to assess the ground water recharge by rainfall infiltration, seven hydrometeorological stations in different agrocliamatic and geological condition were established in the State. In addition, study of percolation tanks, estimation of seepage losses, projects for artificial recharge to groundwater are being undertaken.

2.24 Irrigation Department, Madhya Pradesh

1. Madhya Pradesh occupies central position in the county and constitutes northern part of Peninsular Plateau. The plateau comprising of Vindhyan and Satpura ranges, acts as origin of major rivers which flow in all directions viz. Narmada and Tapti to west, Sone to the east, Pench, Wainganga, Wardha to the south, Chambal, Betwa, Ken and Tons to the north. The Mahanadi and Indravati rise in Bastar-Jaypur Plateau, the former flow directiy into Bay of Bengal and the latter joins Godavari. There is vast potential for irrigation and hydel power generation from these rivers and their tributaries in M.P. Most of these water resources are still unharnessed.

Survey and Investigation formation of Irrigation Department, M.P. is investigating major irrigation, hydel and multipurpose projects in a phased manner to harness these water resources for the maximum benefit of the State.

2. Hydrometeorological Network in the State

This formation is assisting basin Chief Engineers in establishing and maintenance of hydrometeorological net work in the state which is World Bank aided. It is also coordinating and compiling the various data collected from basin Chief Engineers. It is also entrusted with procurement of hydrometeorological equipment.

3. Inter-State Projects and National Bodies

This formation is assisting Irrigation Department in dealing with the various inter-state projects (with neighbouring states like Uttar Pradesh and Orissa). It is also assisting Engineer-in-Chief in maintaining liason with national bodies like National Water Development Agency, Ganga Flood Control Board, Sone River Commission, Inland Water Transport Board etc.

2.25 Irrigation and Flood Control Department, Manipur.

1. The State, although small in geographical area (22,327 sq. km.) has been gifted with rich water resources especially for surface

water. The total surface water resources of the 2 major river basins of the State viz. Barak and Imphal, has been broadly estimated to be 1.8487 million hectare-metres in the form of average annual yield, against the requirement of 1.1121 million hectare-metres for irrigation, water supply and power generation upto 2000 AD.

2. The State, in consultation with the Govt. of India, has taken up many important projects. The Loktak Hydro Electric Project, having an installed capacity of 105 MW is one of the biggest hydroelectric projects taken up in the North Eastern Region and is also the first project taken up in Manipur. Projects for irrigation water however, taken up at a later stage. It was only in the Year 1973-74 that the State Government had started its first Major Irrigation project viz. the Loktak Lift Irrigation Project which is one of the biggest in the country and the first of its kind in the North Eastern Region. Within a short period of a decade 7 projects under Major & Medium Irrigation Programme, most of which are in the advanced stage of construction were taken up. Besides, there are other 17 projects under investigation. By 2000 AD it is possible to cover an area upto 1,00,600 Hectares and provide irrigation benefit to the extent of 1,59,000 Hectares under Major & Medium Irrigation programme. Over and above this, the water supply system will be augmented to the extent to 45.5 million gallons per day and also provide power for an installed capacity of 87 MW under programme. By season ending 1984-85 cumulative annual irrigation potential to the extent of 40,000 Hectares has been created from the onging projects and partial storage created in Singda Dam for supplying water to the extent of 1 million gallons per day,

3. Singda Dam multipurpose project comprising the construction of an earthdam having a height of 60 M and length of 516 M across Singda river, which is a tributary of Nambul river. The reservoir will have a gross storage capacity of 7880 acre feet, live storage capacity of 6900 acre feet. The Project, on completion, will provide an annual irrigation benefit of 4000 Hectares and addition to this, Imphal water will be augmented by 4 million gallons per day. A scheme for generating mini-hydro power is also under considration. 50% of the dam fill and 50% of the main canal has been completed. Partial storage has also been created for 7.74 lakhs cubic metres of water, capable of supplying 1 million gallons per day of water from the storage so created by pumping arrangement, as a temporary measure before completion of the dam. Development of fishery, tourism are other objectives of the Project.

4. The Thoubal Multipurpose project consists of (i) construction of an Earthdam of a maximum height of 66 m and crest length of 1074 m. with an R.C.C. Chute of Spillway on the right flank with the discharging capacity of 2240 cumecs, (ii) construction of a Barrage at Keithelmanbi, (iii) construction of Left and Right Canal with distrlbution system and (iv) Water Supply and Power generation arrangements. The project, on its completion, will be able to create an annual irrigation potential of 22,542 Hectares, augmentation of water supply by 10 million gallons per day for Imphal town and neighbouring villages and generate power for 7.5 MW (installed capacity). Besides this, development of fishery, tourism are other purposes of the project. The Barrage at Keithelmanbi, 17 Km. downstream of the dam site, is now in the advanced stage of construction, together with the canal system at the head reaches for providing an annual irrigation benefit of 4000 Hectares by 1986-87. The Right and Left Abutments of the Barrage has come to the completion stage. Central Raft and upstream protection are progressing satisfactorily. The canal at the head reaches are also in progress.

(5) The Khuga Multipurpose project envisages construction of an earthdam of height 38

m, provided with chute gated spillway across Khuga river at Mata in Churachandpur District, about 70 Km. from Imphal. The project, on completion, will be able to provide an annual irrigation benefit of 15,000 Hectares, augment water supply system of Churachandpur town by 5 million gallons per day. The projects also having a hydro power component with an installed capacity of 1.5 MW. Construction of the dam is in progress. Colony buildings with approach roads, diversion of Tiddim Road and machinery planning had almost been completed. Construction of dam has also been started and progressing well.

6. The Loktak lift irrigation project has a culturable command of 24,000 Hectares. This on completion, will provide an annual irrigation benefit of 40,000 Hectares, covering a large portion of cultivable area in Imphal West-II Sub-Divn. of the Imphal District and Bishenpur and Moirang Sub-Divns. of Bishenpur District. The source of water is the Loktak lake. The Project has a first stage pumping station located at Ningthoukhong for drawing 600 cusecs of water from the open power channel of Loktak hydroelectric project, sending 450 cusecs towards Imphal side for feeding Imphal Main Canal, Imphal Low Level Canal and Imphal High Level Canal. The remaining 150 cusecs are sent to Moirang side for Moirang Low Level Canal and Moirang High Level Canal. There are two more Pumping stations for 2nd stage lifting at Bishenpur and Ningthoukhong for pumping water into Imphal High Level Canal and Moirang High Level Canal respectively. The project is in the advanced stage of construction and expected to be completed in all respects in the first part of 1986. Arrangement has been completed by year 1984-85 for creating annual irrigation potential upto 28,000 Hectares.

7. The Khoupum dam project envisages construction of an earthdam of height of 17.11 m. having a length of 530 m. across Manchandui river which is a tributary of Barak river in Tamenglong District of Manipur, with an ultimate annual irrigation potential of 1,000 Hectares which had already been created. The gross and live storage capacities or the reservoir are 22,500 acre ft. and 20,000 acre ft. respectively. The project is at the completion stage except for some finishing work which is expected to be completed, in all respects by 1985-86. Arrangement has also been made to supply irrigation water through sluices to the paddy fields lying on both sides of the Imphal River and Turel Ahanbi, up-stream of the Barrage and Cross Regulator respectively for giving an additional annual irrigation benefit to the extent of 1000 Hectares, over and above the targetted ultimate potential of the Project.

8. The Sekmai Barrage project envisages the construction of an R.C.C. Barrage across Sekmai river at Keirak having 4 bays of 9 m. each. The ultimate annual irrigation benefit will be 8,500 Hectares. The main Barrage has been completed and the canal system is also nearing completion. The project is expected to be completed by 1985-86. Annual irrigation potential to the extent of 5000 Hectares has been created upto 1984-85.

9. The State has formulated a Master Plan on Flood Control, which is now under scrutiny. Within the framework of this Master Plan, works have been started for major Flood Control Project riverwise. The Merakhong Flood Control Project having an estimated cost of Rs. 1.16 crores is one of such projects sanctioned by Planning Commission. The project is now under execution. Other projects for Imphal river, Wangjing river etc. have also been formulated and are under scrutiny.

2.26 Madras Metropolition Water Supply and Sewerage Board, Madras

1. The pre investment studies conducted by a UNDP Project in 1978 recommended a

detailed study of the Araniar, Kortaliyar and Palar basins with a veiw to assessing the surface water flows and the ground water potentials for augmenting city's water supply. Arising from this, Hydrogeological aud Artificial Recharge study was taken up with U.N. assistance in the middle of 1982 and is in its final phase of study. The study and its achievements are as follows.

(a) To correctly assess the rainfall and run-off in the three river courses over a period (20 years) from the various flow data collected across anicuts. These were evaluated and the reliable quantity of flow available as surplus was established.

(b) The study on climatology under the project has also led to correctly assess the storage losses in the three reservoirs (viz. Poondi, Red Hills and Cholavaram, the city's three storage systems) like evaporation, seepage etc. It has made to realise the need for a better water management to minimise these losses for optimum utilisation of the stored water for not only city's water supply but also for irrigation and industry, conjunctively, with surface and groundwater.

(c) The hydrogeological study was consisted of geological and Geophysical surveys followed by intensive study of the Alluvial regime by putting number of exploratory, and observation cum production wells to assess the extent of ground water storage, its transmisivity and other characteristics and ultimately the safe yield and extraction potential of the various aquifers in the above basin area.

(d) Reclamation and use of sewage effluent by soil aquifer treatment by converting the otherwise wasteful sewage effluent generated from the city into a useful resource for use in Industry in exchange of ground water hitherto being used by them, is another important study under the project. Also using the above renovated water along the coastal belt of North Madras and particularly in the coastal regions of the Araniar and Kortaliyar rivers to check and arrest further sea water advancement inland as also to retract the sea water back to coastal area is a part of the study undertaken. This will also help in protecting the Minjur coastal aquifer, which has been polluted with salt water intrusion, in restoring the aquifer back to its original condition.

2. The outcome of the study has resulted in

(a) quantifying the surplus waters in the Araniar river that can be effectively diverted to the city's storages through linking by a canal between Araniar and Kortaliyar for supplementing the city water supply,

(b) recommending construction of check dams across Kortaliyar river in the flood plains to enable interception and impoundment of flood waters for rechange and build-up of ground water,

(c) recommending practise of conjunctive use of surface and ground water to help in minimising storage losses besides improvement in ground water storages for the optimum benefit of all users (Irrigation Industry and city water supply),

(d) recommending a new and perennial source of industrial quality water from treated sewage effluent through S.A.T. (Soil Aquifer Treatment), and

(e) recommending a check on further advancement of sea water intrusion in the coastal bed and from polluting the otherwise good aquifer in the coastal region through artificial recharge.

2.27 Indian Institute of Technology, Bombay

1. 'Optimum operation of Multiple reservior system' M. Tech Thesis of Mr. K.C. Tayade (Supervisor Dr. B.V. Rao, Civil Engineering Department, I.I.T. Bombay) 1984.

The study reported herein deals with the optimal operation of multiple reservoir system with six reservoirs both series and parallel which are the sources for water supply to Bombay Metropolitan region. Future inflow values were generated using Fiering model. Benefits were calculated for 120 future seasons with proper discounting factors. The optimal solution corresponds to that demand for which benefits are maximum. Simulation approach which gives better information is adopted to find the optimal solution.

2. 'Multiobjective Analysis to Water Resources Planning' M. Tech Thesis of Mr. K.L. Prasad, (Supervisor Prof. C. Natarajan, Civil Engg. Dept.) 1984.

The problem elucidates the optimal operational strategies regarding monthly releases from a storage reservoir to cater to irrigation and power demand. Linear programming model is used to optimise the releases. Historical data of sixteen years of inflow data is analysed to generate a further 10 years flow pattern. Three distinct inflows viz. minimum, mean and maximum of inflow data are considered and the optimal strategies are evolved. Although the conflicting objectives have considered in this report, the scope may be extended by incorporating objectives like flood control, water supply etc.

2.28 Indian Institute of Technology, Delhi

The Water Resources Group at IIT, Delhi has been engaged in water resources research through M.Tech. dissortation, Ph.D. thesis, sponsored research projects and R&D work on problems referred for consultancy. During 1984, seventeen M. Tech. dissertations were completed,and twelve students have been working on research for their Ph.D. degree. An IHP project on Newer Techniques in High Flow Forecasting was completed and the reports were submitted to the High Level Technical Committee on Hydrology. The water Resources Group is also engaged in a joint R & D work with the G.B. Pant University of Agriculture & Technology, Pantnager. The project has been sponsored by Ganga-Brahmaputra water Studies unit of the Central Water Commission. The research results on the completed project on High Flow Forecasting were presented in September 1984 in a National workshop which was sponsored by the High Level Technical Committee on Hydrology. The Water Resources Group at IIT (Delhi) also organised a winter school on Prediction and Forecasting of Floods under Quality Improvement Program of the Ministry of Education during January 1984 for engineering teachers. Three field organisations also sponsored their officers for the course. The Group has been experimenting on the Newer Techniques on teaching and learning in water resources engineering through the Curriculm Development Cell. During February 1984 a national workshop on Computer Aided Instruction for teaching and learning of Hydrology was held at IIT (Dehli) under the auspices of the above cell.

2.29 Indian Institute of Technology, Kharagpur

1. Reservoir operation and management

The operation of multiple reservoir system has been studied in view of the DVC reservoir network. Each of the four reservoirs is a multipurpose one. The optimal operating rule was sought for monthwise release from each reservoir subjected to deterministic as well as chance constraints. Linear Decision Rule was employed and several objective functions were sought to be optimised (e.g. max flood free board, maximisation of net storage, etc.)

2. Investigation of Operation Hydrology models with regard to their applicablity to West Bengal streams

The investigation was carried out wherein streamflows of West Bengal streams were studied (eight streams at nine sites) in order to

indentify the operational model for synthetic generation of streamflows for each. For monthly flows the Thomas-Fiering, ARIMA and seasonal regression models were used in which natural data as well as their log and square root transformation were considered. For annual flows AR processes upto fourth order with and without log transformation and the Fast Fractional Gaussiun model were employed. The criteria for appropriateness of the model was preservation of certain selected features of the historial data. The results showed that for monthly flows for most of the streams the Thomas-Fiering model was most suitable whereas AR models of different orders suited annual flows most.

2.30 Mahatma Phule Agricultural University, Rahuri, Maharashtra

The University has two faculties : Agriculture and Agricultural Engineering. The department of Soil and Water Conservation Engineering in the Faculty of Agricultural Engineering, carries out teaching and research on surface water hydrology, soil conservation structures, soil mechanics, recycling of runoff water and soil erosion process. The dryland agricultural research centre at Solapur carried out research on methods of soil moisture conservation, intercropping for retardation of runoff and erosion, and crop management to control erosion. The operation Research scheme in the Department of Agronomy has taken up work on Watershed Management on farmers' fields.

2.31 Earth Science Department, University of Roorkee, Roorkee

1. Hydrological aspects of waste disposal in the upper parts of Hindon Basin, District Saharanpur, U.P.

Hydrogeomorphic survey and drainage basin analysis have been done. Geophysical resistivity survey has also been carried out in a part of the area with a view to mapping the various aquifer horizons as well as to determine the applicability of electrical resistivity methods in monitoring the movement of pollutants in ground water. Periodic analysis of chemical characteristics of surface water and ground water is in progress. Five years Ganga-Canal data were used to study the influence of canal on the ground water regime. For this study, flow nets of ground water regime for maximum and minimum spring levels were drawn. Seepage losses and dominant directions of ground water flows were established for identified sections/areas.

Hydrological analysis through synthetic approaches were carried out. Soil samples were analysed to determine the roughness of river bed material. Gross slope and average statistic slopes of river bed were estimated, and using Manning's equation the velocities were computed for different heads of water in the river at the road bridge site. The synthetic gauge-discharge curve was established Also, using basin physiography the synthetic unit hydrographs were developed. For adopted rainfall patterns and using the unit hydrographs, the floods flows were computed.

2. Approximation-theoretic finite difference schemes for ground water studies.

Conventional finite difference schemes to solve partial differential equations such as those involved in the groundwater simulation and pump-test analysis use Taylor's series as the starting point. But Taylor's series is known for its bad convergence properties and hence suitable superior alternatives to it from approximation theory should be investigated to provide more accurate finite difference approximation for the derivatives. Some techniques based on the expansions of exponential functions in terms of the Chebyshev, shifted Chebyshev and Bernstein polynomials have been investigated. Stability of the resultant finite

difference scheme is an important topic for further study. Approximation-theoretic schemes seem to have superior convergence properties.

3. Terrain evaluation and mapping using remote sensing data

The project is aimed to investigate the feasibility of using satellite data for automatic terrain evaluation and classification. Under this project, a part of Sangrur district in Punjab was chosen as a test area. Aerial-photointerpretation and ground checks have been made and a land use map of the area has been prepared. The remote sensing data have been also used in the monitoring of water bodies with respect to their depth and size etc.

4. Geohydrological studies of the piedmont zone at the foot hills of the Himalaya

Sedimentological and hydrogeomorphic studies of the Kosi alluvial cone has been carried out. Similar studies for the piedmont zone west of the Gola river fan are underway using remote sensing techniques like analysis of digital data from CCT'S,

2.32 Water Resources Development Training Centre, University of Roorkee

1. Ford Foundation Research Project

The following field studies were continued in Salawa Command of Upper Ganga Canal System in Meerut district, U.P.

(i) Critical Study of Ground Water Model Calibration with Special Reference to Salawa Command.

(ii) Evaluation of Conveyance and Field Efficiency in Salawa Command.

2. Other Research Studies (in progress)

(i) Analysis of Riverflow and Power Potential in Sapt-Kosi Basin (Nepal)

(ii) Hydrologic Data Analysis–A Case Study of Indonesia

(iii) An appraisal of Water Resources Development in Medium Upper Solo Basin of Indonesia

(iv) Assessment of Environmental Impact of Some Irrigation Projects

2.33 School of Hydrology, University of Roorkee, Roorkee

1. A separate course in Snow Glaciers and Avalanche Studies leading to Masters degree is expected to start soon in the School.

2. Laboratories of Remote Sensing Hydrology, R.C. Analog, Water Quality and Computational Workshop have been established. A 3.6 m × 3.6 m rainfall simulator is being fabricated. A data acquisition system with a computer facility procured under UNDP project is in the process of installation.

3. Under UNDP project, faculity is being trained in the areas of Watershed Hydrology, Hydrologic Systems, Snow Hydrology, Remote Sensing Hydrology, Operational Hydrology and Water Quality Modelling.

4. Following Research/Consultancy projects were completed :

a. Groundwater Studies in Yamuna Basin.

b. Tritium Tracer Studies in Sarda Sahayak Command Area.

c. Effect of Pollution of surface and Groundwater in respect of Industries of North-western Regions.

d. Application of Remote Sensing Methods to Hydrology Watershed Studies Using Simulation Models for Upper Yamuna Catchment.

e. Hydrological Studies of Ram Ganga Dam Project.

f. Design Flood Studies of Rajghat Dam on River Betwa.

g. Assessment of Silting of Jamrani Dam Reservoir.

h. R.C. Analog Studies in Agra and Varanasi Districts.

i. Mathematical Model Studies for Ganga Basin.

j. Hydrological Investigations of Machhu Dam II-1980.

k. Special Studies on Sub-surface Drainage in Command Area of Narmada Sagar Project.

5. The ongoing research/consultancy projects are :

a. Assessment and Utilization of Himalayan Water Resources for Regional Cooperation and National Development

b. Conjuctive Use Modelling for Ground and surface Water in Eastern Yamuna Canal Command Area

c. Study of Sone River Hydrology.

d. Generation of Stream Flow Data Using Generated Multistation Daily Rainfall Runoff Deterministic Models.

e. Water Quality and its Modelling for Hindon River Basin.

2.34 Centre for Water Resources, Anna University, Madras.

1. The Centre for Water Resources has a wide range of academic and training programmes supported by a highly competent teaching faculty. Over the last 28 years, the courses offered in the centre have been restructured and updated from time to time to be in line with the development of the country. The centre presently offers the following courses, viz, (i) M E. in Hydraulics and Water Resources, (ii) P.G. Degree in Irrigation Water Management and (iii) P.G. Diploma in Hydrology and Water Resources. Besides these, the Centre handles many research projects including collaborative projects with foreign countries, universities, the Ford Foundation etc. Some important projects are briefly mentioned herein.

2. Systems Planning Study for the Parambikulam-Aliyar Project.

An operating policy for the chain of reservoirs has been developed which ensures approximately 10 percent more of water utilization than what has been hitherto achieved with the present practice of operation.

3. Analysis and Interpretation of Electrical Resistivity Data for Siting Water Wells in Hard Rock Areas.

A new methodology has been developed to site a water well in hard rock area. This method ensures a success of 85 to 90 percent as against 70 to 75 percent in the conventional methods.

4. Collaboration with Utah State University

A Water Resources Systems Planning and Management Institute with USAID assistance is being planned for India. The Utah State University and Harza Engineering Consultants would like to bid the contact to run the Institute in India. They have sought the assistance from the Centre for Water Resources, Anna University (i) to design the program of instruction (ii) to provide case studies and (iii) to provide course work instruction. The detailed work plan is being finalised in the Government of India and USAID

5. Modernisation of Tank Irrigation System-A Pilot Project Study

With a view to improving the efficiency, a pilot study has been taken up by the Anna University to investigate the present status of tank irrigation system, examine the deficiencies, design measures for improving the system, have the measures carried out by co-ordinating

Government Departments of Public Works & Agricultural Engineering, evaluate the results and evolve general policy guidelines for efficient management. This study is funded by the Ford Foundation, New Delhi to the tune of $ 25,000 and is being implemented by the Anna University since July 1981. After due investigations and surveys, the physical improvements to the tank system, comprising strengthening of the tank bund and appurtenant structures, restructuring of water courses and on-farm development works have been executed. As a result, there has been a substantial increase in the water yield to the tank over a longer storage period than before. The farmer beneficiaries have become quite conscious of the conservation of tank water for utilisation for a second irrigated crop and of the conjuctive use of ground and surface water. A rotational irrigation schedule has been planned for implementation during the current second crop season which when undertaken will prove to be a boon for the equitable distribution of water to the farmers of head, middle and tail end reaches. It is now programmed to take up 150 tanks for modernisation in the districts of Chengalpattu, North Arcot, South Arcot, Pudukkottai and Ramanathapuram with financial assistance from the European Economic Community.

Besides, a team of Irrigation Water Management Scientists from various countries have visited the pilot project and have subsequently had deliberation at the International Irrigation Management Institute, Sri Lanka to assign research priorities in this area of growing interest. The utilisation of experience of the Anna University in Irrigation Management Research is under active consideration of the International Irrigation Management Institute for collaboration with them in a Regional Network Research Study.

6. Digital Modelling of Regional Groundwater Flow

Digital modelling of regional ground water flow is one of the few field problems the centre has taken for research work. The centre has taken an alluvial aquifer in Araniar-Kortaliar basin, known as Madras Aquifer situated north-west of the city of Madras for modelling regional groundwater flow. The areal extent of the aquifer considered for study is about 500 sq. km and its thickness varies from 5m to 20m. The aquifer is underlain by aquiclude and overlain by silt and clay deposits which form an aquitard. It is bounded on the East by the Bay of Bengal.

The aquifer is being utilised to supply water for irrigation, in addition to providing water supply for industries located in and around the city of Madras and supplementing the city water supply. It is likely to be polluted by sea-water intrusion and it is imperative to understand the response of the aquifer system to different volumes of pumping.

7. Systems Studies for Planning of Narmada Sagar Complex

The planning of the Narmadasagar Complex of Narmada sagar, Omkareshwar and Maheshwar projects is being carried out by the Government of Madhya Pradesh and World Bank assistance is sought for the construction of the complex. In order to generate information and useful analysis for the appraisal, the Government of Madhya Pradesh, among other studies, has commissioned the present study. The objectives of this are i) to help assess, with reasonable assumptions, the economics of the Narmadasagar Complex for projected upstream development scenarios and ii) to prepare an optimal plan for phasing the development of the Narmadasagar Complex, given the flow of funds. The stream of physical outputs of irrigation and power from the complex for the scenarios of development upstream of the complex given by the Government of Madhya Pradesh for the years 1991-92, 2003-04, 2013-14, 2023-24 has been determined for Central

Water Commission wetted series of 29 years (1949-50 to 1978-79) and for the variable irrigation demands computed on the basis of climatological data. These outputs have been determined for proposed live storages with different carry over storages and installed capacities for power generation at Narmadasagar, Omkareshwar and Maheshwar. Based on the releases at Maheshwar, inflows into Sardarsarovar are obtained. An optimal operating policy for the complex to maximise the power output, meeting irrigation demands, has been obtained.

Further, the effects of variation of minimum draw down level (MDDL) & full reservoir level (FRL) at Narmadasagar on power generation, irrigation demands & the total utilisable flow have been studied.

Presently, the performance of the Narmadasagar Complex for the generated hydrological series is being studied and the economic analysis to choose the optimal among various alternatives is being made.

2.35 Address by Shri Ram Niwas Mirdha, Hon'ble Union Minister For Irrigation at the Fourth Annual General Meeting of National Institute of Hydrology Society, New Delhi, 3rd January, 1984.

I am indeed happy to welcome you all to the Fourth Annual General Meeting of the National Institute of Hydrology Society. Until recent years, the area of water resources development and management in India, has been characterised by two special features which made it particularly difficult for an integrated hydrologic approach to be adopted in the solution of water resources problems. The first feature is the fragmentation of water administration leading a large number of agencies, which are dealing with one or the other aspect of water resources development. The second feature is the constitutional position where the primary responsibility for the development of the water resources lies with State Governments. Realising this, Government of India has decided to constitute a National Water Resources Council in March, 1983, with Prime Minister as its Chairman. The Government has also set up a National Water Development Agency to take up investigations and detailed studies for the development of our water resources in the larger national interest. With the growth of our economy and with the increase in our population, the demand for water is increasing rapidly for catering to the needs for domestic water supply, irrigation, Hydro-power, industrial uses etc. The Government has, therefore, laid great importance on the development of water resources.

The rainfall in our country is erratic and is subject to fluctuations in space and time. Floods as well as droughts result from distortion of normal patterns of rainfall and lead to vast damages and sufferings to human and animal population. The surface water resources of our country are estimated at 178 million hectare metres of which about 70 million hectare me res can be utilized and the utilisable groundwater is estimated to be about 35 million hectare metres.

India is a very vast country with a large population of 684 million (1981 Census) which is estimated to reach 1,000 million 2000 A.D. The food production required for feeding this large population is estimated to be around 230 million tonnes which is nearly twice the present level of production. The total culturable area of the nation is around 189 million hectares and since nearly the entire area is being cultivated, the area under agricultural production can be marginally increased. As such the increase in agricultural production will have to come from improvement in the agricultural technology, extensive and intensive irrigation practices and efficient water use.

The ultimate irrigation potential with integrated optimal utilisation of surface and ground water resources is of the order of 150 million hectares. The total hydro-power potential of the country is estimated to be 75,000 megawatts at 60 per cent load factor. The domestic water supply requirements may reach to about 25 million acre feet and the industrial water requirements may increase to 45 million acre feet by the year 2000 A.D. It has been estimated that in next two decades there will be almost doubling up of the different uses of water.

The harnessing of available water resources for the development of irrigation potential has received added attention of the Government since independence. At the time of Independence, the country had irrigation potential of 22.6 million hectares, the potential rose to 44.2 million hectares by 1973-74 with the corresponding growth rate being one million hectares per yeer. During the period of 7 years (1974-80) additional potential of 12.41 million hectares has been added. The activity under irrigation sector has been further accelerated during the period after 1979-80 with a target of creation of potential of about 14 million hectares during the Sixth Five Year Plan. In the future perspective, the rate of development of irrigation is planned at 3 million hectares per year so that hopefully by the turn of the century the country will be able to achieve the presently assessed potential of 113 million hectares, of which 40 million hectares will be from ground water exploitation. The next 15 years would therefore be crucial and efforts of all concerned at Central Government level as well as State Government level and also academic, research and field personnel will have to be mobilized to achieve these targets.

In addition to large increase in demands for water, the seasonality of rainfall leading to reservoirs for irrigation, flood control, power generation etc. as well as for carrying over water from monsoon season to non-monsoon season. There are also other problems dealing with drainage of water logged areas, management of watersheds for controlling erosion, irrigation in desert areas etc.

In order that the availability and variability of water resources and the problems like floods and droughts are evaluated quantitatively and for planning, development and operation of water resources systems, it has become imperative to use modern methods of hydrological analysis and design. The International Hydrological Decade Program of UNESCO launched in 1965 and then continued as a long term program since 1975 emphasised the need for (i) scientific assessment of water resources, (ii) study of hydrological processes and interaction as well as the influence of human activities on these processes, and (iii) the creation of adequate educational and research base for water resources development and management.

It is very important to recognize that though water is a renewable resource, there are several natural constraints for conservation and utilization of water. The science of Hydrology is an interdisciplinary science which is linked by common content to other areas of science including Environmental Sciences such as Geomorphology, Climatology, Hydrometeorology and Ecology. Besides the problems like floods, droughts, erosion etc. it also necessitates study of environmental impact of water resources development, problems of water quaiity etc. Development strategy of water resources is to be directed to basin-wise planning for integrated development and management and conjunctive utilisation of surface and groundwater resources with adequate provision both for storage and transfer of any surplus water to control the negative effects from floods and droughts. Adequate care has also to be exercised for the protection of environment for maintaining the ecological balance.

I am glad to inform that the above mentioned

important aspects and other related aspects of water resources development form an integral part of the work plan of National Institute of Hydrology. The Institute has completed nearly five years since its inception. With the grant-in-aid funds provided by Govt. of India and with the assistance available under UNDP project, the Institute has been able to grow at a satisfactory pace. Scientists of the Institute have undergone training abroad in the areas of groundwater, hydrometeorology, watershed modelling, reservoir operation, remote sensing in hydrology, stochastic hydrology etc. A sophisticated computer system VAX-11/780 has been operational since Oct. 1982 and action has been initiated for procurement of an automatic hydrologic station which would be used for intensive short period measurements of various components of hydrological cycle, so as to provide better understanding of processes like evapotranspiration, rainfall, groundwater recharge etc. in Indian conditions.

I am happy to note that the research activities of the Institute, in priority areas of research, have already gained momentum and reports have been prepared of the research work in the fields of flood frequency analysis, surface water groundwater interaction, rainfall-runoff models, flood routing, hydrometry, water balance studies, hydrogeological studies, seapage studies, hydrometeorology etc. Besides carrying out research in priority areas, the Institute is also actively involved in field problems referred to it as sponsored research projects. I am glad that the Institute has already completed a project sponsored by WAPCOS on 'Groundwater Modelling Studies in Upper Ganges Canal Command Area' and it is presently involved in two sponsored research projects dealing respectively with 'Design Flood Studies of Narmada Projects' sponsored by Narmada Cell and 'Water Availability Studies of Mahanadi Basin' sponsored by NWDA.

In order to achieve greater coordination in the field of hydrology and water resources, High Level Technical Committee on Hydrology was formed by the Government of India. It is also the successor body of the Indian National Committee of International Hydrological Program. The Secretariat of this committee is attached to NIH. It is heartening to note that India is actively participating in International Hydrological Program through this Secretariat.

I understand that the Institute is planning to strengthen and diversify its research activities by including some of the important areas such as subsurface water quality, remote sensing application in hydrology, aerial photo and satellite application to hydrology, snow and glacial hydrology, use of nuclear techniques in hydrology etc, which were not included in the present phase, but which are necessary for a balanced structure for an institute of hydrology at national level.

It is gratifying to note that the Institute is also working on the recommendations made by National Flood Commission for setting up of regional centres of NIH and also working on the idea of setting up representative basins studies for providing better understanding of hydrological processes in Indian conditions. In pursuance of the primary objectives of disseminating technology and methodologies developed by the Institute, the Institute is proposing to organise short-term courses, seminars etc. in near future and a Trainee's Hostel is proposed to be constructed to provide facilities for organisation of such activities.

I am happy that the Institute is working in close cooperation and is interacting with Central Water Commission, Central Ground Water Board, National Water Development Agncy, India Meteorological Depertment, University of Roorkee and various other Central and State Govt. agencies and academic and research

institutions. Under your advice and active assistance, I have no doubt that the Institute will be able to contribute significantly to the hydrological research at national and international levels and for the optimal development of water resources of the nation.

Jai Hind.

2.36 Inaugural Address by Shri P.C. Sethi, Hon'ble Union Minister For Planning and Irrigation at the 54th Session of Central Board of Irrigation and Power, New Delhi, 27th August, 1984

I am extremely happy to be with you all today to inaugurate this 54th Session of the Central Board of Irrigation and Power. This gives me the opportunity soon after I assumed charge of the Ministry of Irrigation to meet you all and to share some of my thoughts with you, at this critical juncture when we are finalising our plans and programmes for the VII Plan to be launched shortly.

The VII Plan will have as its main thrust increase in Food Production, Employment and Productivity. It is our duty to ensure that the Irrigation and Power Sectors, with which you are directly concerned, make the maximum contribution to the realisation of these objectives of the VII Plan.

As all of you are aware, food production in the country increased from 52.8 million tonnes in 1951 to 150.6 million tonnes in 1983-84. Keeping in view the anticipated increase in population, a 20 to 25 percent increase in food production will be required to be achieved by the end of the VII Plan. It is here that Irrigation can make its important contribution. Accordingly, we have to accelerate our Irrigation programme and make every effort to achieve our targets fully. Out of the total irrigation potential of the country which has been assessed as 113 million hectares, we expect to achieve a potential of 68 million ha. by the end of the Sixth Plan. During the Sixth Plan, we have been able to create a potential of 2.3 million ha. per annum on an average and it is necessary to step up this effort in the Seventh Plan. It is envisaged that during the VI Plan a target of 15 million hectares can be achieved.

A muiti-pronged strategy is being evolved to make the Irrigation programme cost effective and yield benefits as quickly as possible. Many of the earlier major and medium projects have been lingering on for a number of years while a large number have been taken up in recent years. We expect projects with spill over cost of over Rs. 22,500 crores to spill over in the Seventh Plan. Constraints of financial resources require that the available resources should be carefully deployed in the Seventh Plan. Therefore, irrigation development will have to be based on quick completion of on-going schemes, rapid utilisation of potential and better water management. There is hardly any room for taking up new projects in the next Plan, except irrigation projects in drought prone tribal and backward areas and minor irrigation schemes. This will require the States to adopt rigorous financial discipline.

A lot of attention is being paid to increasing the productivity of Irrigation projects. Present estimates indicate that the gap between creation and utilisation of irrigation potential will be about 5 million ha. at the end of the Sixth Plan. One of the remedial measures proposed for reducing this gap is the construction of field channels upto 5-8 ha. blocks. This work has been taken up on a large scale under the Command Area Development Programme in 102 major projects. A special effort is to be made during the Seventh Plan to undertake this task even in the major projects not so far covered under the CAD Programme and in the medium projects. I am happy to say that the target of 4 million hectares fixed for the construction of field channels for the Sixth Plan has already been exceeded and the achievement

by the end of the Plan is expected to be 5.7 million hectares. The general low productivity of irrigated agriculture is attributed to poor water management and inefficient use of water apart from the low level of other inputs and extension services. I am sure your deliberations in the Central Board of Irrigation and Power would throw up many new ideas which can be tried and experimented in the field so as to improve upon our irrigation efficiencies. I would also like to stress that the Board's research programmes should progressively lay greater emphasis on the issues connected with Water Management.

In recent years it has been recognised that in a number of existing irrigation systems, there is scope for improvement in the efficient and economical utilisation of the water resources harnessed by the projects. Lining of the canal system, provision of adequate drainage as well as conjunctive use of surface and sub-soil water-logging and arrest the decline in yields are some of the measures called for to stabilise the irrigated agriculture. The Modernisation concept has to be taken up and implemented in a big way so as to consolidate the gains already achieved and improve productivity. In this context, a suggestion has been made for mobilisation of resources from beneficiaries who are already in receipt of benefits from the old works and would receive further benefits for modernisation. This requires serious consideration.

India is chronically short of power and irrigation canal networks are theoretically a potential source of substantial amount of energy. Such micro hydel power stations can provide a captive source of power for operating canal control structures or for operating tube-wells in the canal commands either for augmentation or for conjunctive use. There is considerable scope for introducing such new concepts in the management of our canal systems. I am sure your deliberations in the CBI & P would generate the necessary enthusiasm for undertaking such innovative experiments in an extensive manner.

A related aspect to which I wish to refer is the environmental impact of Water Resources Development Projects. That construction of large reservoirs and expansion of irrigation to new areas, lead to many changes in the environment is well recognised and accepted. Many of these adverse impacts can be controlled by suitable remedial measures. It is, however, a matter of regret that there is often ill-informed comment regarding only the adverse impact of Water Resources Development Projects based on the little or inadequate data and the beneficial impacts are often ignored. The critics should bear in mind that only irrigation offers the most promising technological solution to the growing food needs of the country. The benefits accruing from Irrigation projects and the adverse impacts should not be viewed in isolation. What is to be considered is whether the gains outweigh adverse environmental impact and whether the environment would be able to absorb this impact without progressive deterioration. I would, therefore, plead for a quantitative measurement of the various environmental impacts both positive and negative of a few selected projects. Our research stations should take up these studies and come up with quantitative data.

On the Power side, my colleague, the Hon'ble Minister of State for Power, has drawn attention to various issues facing the country. For my part, I wish to stress that attempts should be directed to see that this sector also makes the maximum contribution to the Plan. All of us are aware of the contribution Rural Electrification and Energisation of Tubewells and Pump-sets has been making to increase food production. It has, however, been noticed that the pump-sets acquired by the farmers often do not come up to the desired level of fuel efficiency. Towards this end, the Ministry of Irrigation is taking steps so that all the pump-sets for

which loans are made available by the banks should be ISI marked in the interest of energy conservation.

I am very happy to note that you are holding two Symposia to discuss 'Modern Management Techniques in Irrigation Projects' and 'Power System Management' during the course of this Board Session. The need for introduction of Modern Management Culture in the Construction and Operation of the Irrigation Projects is now-a-days well appreciated. Our engineers should not only be competent in their technical fields, they should also be good managers, as they have to get the maximum out of the men, machines and other resources at their command so as to ensure that the projects are completed with the least time and cost over-runs. In this context the Symposia should help to discuss all relevant issues and lead to a better understanding of the problems involved and methods for their solution.

In conclusion, I wish to say that the rapid progress of the country is entirely dependent on the good work of the engineers, technicians and all the workers who are contributing their mite for the rapid harnessing of the Water and Power Resources of the country. May I wish you all success in your efforts.

I have now great pleasure inaugurating this 54th Annual Board Session of the Central Board of Irrigation and Power and the Symposia arranged on this occasion.

Jai Hind.

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