PN-ABK-307

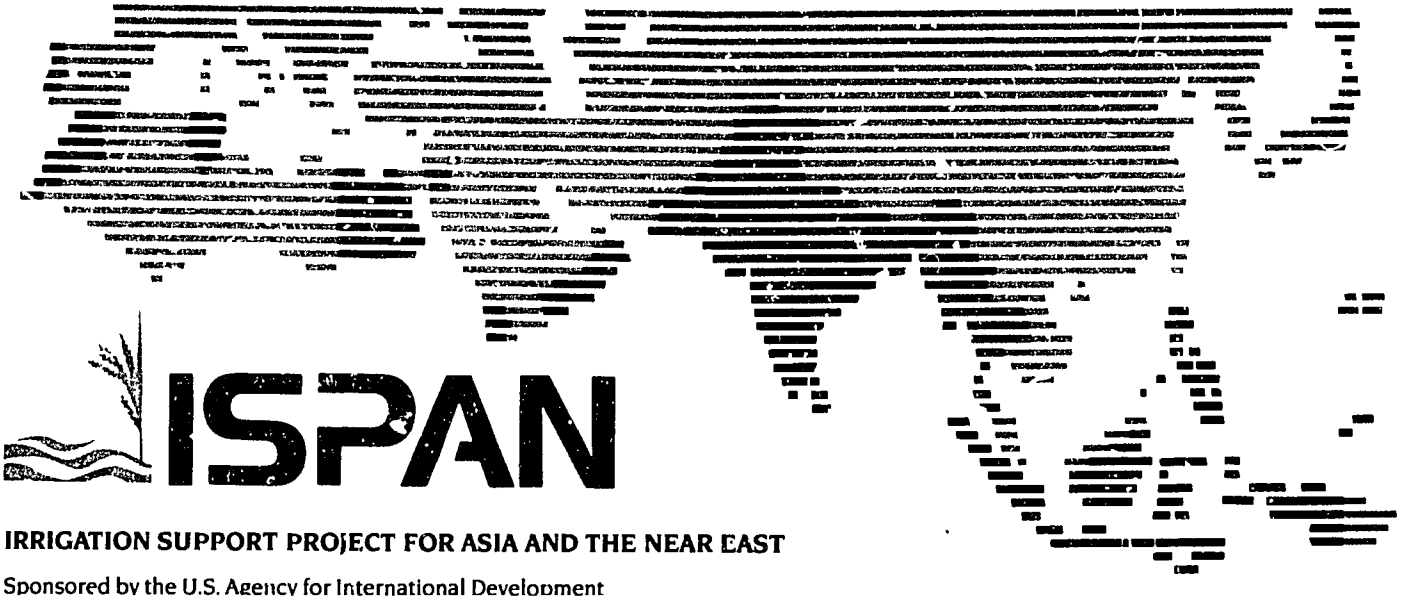
75[illegible]

Madhya Pradesh Minor Irrigation Project
Bureau of Design for Hydroelectric and
Irrigation Projects (BODHI)

STRENGTHENING HYDROLOGIC STUDY CAPABILITIES

ISPAN Activity No. 622A

ISPAN Report No. 32



ISPAN

IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST

Sponsored by the U.S. Agency for International Development

IRRIGATION SUPPORT PROJECT FOR ASIA AND THE NEAR EAST

ISPAN Technical Support Center
Room 1001
1611 North Kent Street
Arlington, Virginia 22209-2111
U.S.A.
Phone: (703) 243-7911
FAX: (703) 525-9137
TELEX: 276532 ISPAN UR

INTEGRATED IRRIGATION MANAGEMENT RESOURCES

Camp Dresser & McKee International Inc. (Prime Contractor)
CARE
Cornell University
Development Alternatives, Inc.
Harza Engineering Company
International Science and Technology Institute, Inc.
Training Resources Group
The University of Arizona

ISPAN Report No. 32

Madhya Pradesh Minor Irrigation Project
Bureau of Design for Hydroelectric and
Irrigation Projects (BODHI)

STRENGTHENING HYDROLOGIC STUDY CAPABILITIES

Prepared for the USAID Mission to India,
under ISPAN Activity No. 622A

by

T. Kumara Das
and
B.K. Lee

February 1990

Irrigation Support Project for Asia and the Near East
Contract No. ANE-0289-C-00-7044-0, Project No. 3-7631510
is sponsored by the Asia/Near East Bureau
U.S. Agency for International Development
Washington, D.C. 20523

TABLE OF CONTENTS

ACRONYMS iii

ACKNOWLEDGEMENTS v

EXECUTIVE SUMMARY vii

1. INTRODUCTION 1

2. IRRIGATION DEPARTMENT, BODHI AND HYDROLOGY DIRECTORATE 3

2.1 Irrigation Department 3
2.2 BODHI 4
2.3 Hydrology Directorate 5

3. APPROACH 7

3.1 Discussion Meetings 7
3.2 Review of Project Reports 8
3.3 Field Visits to Projects 8

4. ASSESSMENT OF BODHI'S CAPABILITIES OF HYDROLOGIC STUDIES 9

4.1 Existing Capabilities 9
4.2 Additional Assessments 10

5. REQUIREMENTS FOR STRENGTHENING BODHI'S CAPABILITIES IN HYDROLOGIC STUDIES 13

5.1 Two-Phase Improvements 13
5.2 First Phase Requirements 14
5.2.1 Anticipated Workload 14
5.2.2 Staff Strength 15
5.2.3 Computation Records and Files 16
5.2.4 Hydrology Library 16
5.2.5 Computer Requirements 17
5.2.6 Training Requirements 18
5.3 Second Phase Requirements 20
5.3.1 Environmental and Social Impact 20

TABLE OF CONTENTS
(continued)

6. CONCLUSIONS AND RECOMMENDATIONS 23

6.1 Conclusions 23
6.2 Recommendations 25

APPENDICES

A. Daily Activities of the Team 29

B. Organization Chart of Irrigation Department 33

C. Organization Chart of BODHI 35

D. Reports, Guidelines and Memoranda Reviewed by Team 37

E. Hydrology Directorate Staff (Qualifications and Training) 39

F. Capability of Hydrology Directorates Staff for Assessing Training Requirements 41

G. Anticipated Future Workload of Hydrology Directorate 43

H. Hydrologic Computer Programs Available at BODHI 45

ACRONYMS

ASCE	American Society of Civil Engineers
BODHI	Bureau of Design for Hydroelectric and Irrigation Projects
CCA	Culturable Command Area
CTU	Central Training Unit, Pune
CWC	Central Water Commission
GOMP	Government of Madhya Pradesh
ISPAN	Irrigation Support Project for Asia and the Near East
NVDA	Narmada Valley Development Authority
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
USAID	U.S. Agency for International Development
S&I	Survey & Investigation
SPF	Standard Project Flood

CURRENCY EQUIVALENCIES

U.S. $1 = Rs. 15.25 (as of June 1990)

Rs. 1 crore = Rs. 100

Rs. 1 lakh = Rs. 100,000

ACKNOWLEDGEMENTS

A number of individuals and organizations helped the team complete its assignment. W.A. Garvey of Irrigation Support Project for Asia and the Near East (ISPAN) arranged for the participation of B.K. Lee, and Thaper Hydroconsult made available the services of T. Kumara Das.

John Grayzel, Chief of the Office of Natural Resources Management, USAID, New Delhi, and J.R. Khanna, Project Officer, gave an effective orientation to the team.

At Bhopal, where the team performed its assignment, excellent arrangements for daily transportation, typing and reproduction of documents, and other required logistic supports were made by H.N. Gandhi, Head of Thapar Hydroconsult's Liaison & Coordination Unit, K.P. Bargye, S.S. Misra and other staff.

Special mention must be made in regard to the help received from Kundan Singh Manral, office secretary, in processing the report; from A.K. Ghosh and Sangeeta Srivastava in preparing charts and in photocopying documents; and from Miss Omana who did the typing. Their ready and willing efforts were largely responsible for the timely completion of the team's report.

O.N. Thapar, Chief Engineer, BODHI, participated in the discussions and gave us excellent co-operation. He arranged for meetings with J.R. Malhotra, Irrigation Secretary to Government of Madhya Pradesh, and P.C. Agarwal, Engineer-in-Chief, Irrigation Department. T.W. Hingankar, Director of Hydrology, and his officers readily provided the team with details of their respective works. M.S. Sohoni, Chief Engineer, Survey and Investigation, and officers of the Hydrometeorology Directorate, provided the team with information about their work relating to hydrology.

O.P. Malga, Superintending Engineer, and his staff hosted the team on the visit to the Kolar Project and briefed the team, as did V.K. Mathur, Executive Engineer at Halali Project, K.L Gupta, Superintending Engineer at Ghora Pachhar, and G.S. Arora at the Hydraulic Research Station.

EXECUTIVE SUMMARY

T. Kumara Das and B.K. Lee were retained by the United States Agency for International Development (USAID) to critically examine the current capabilities of the Bureau of Design for Hydroelectric and Irrigation (BODHI), Irrigation Department, Government of Madhya Pradesh, India. They were asked to assess the needs for improvement and recommend measures to strengthen the area of hydrology within the organization.

The team held discussions with the senior officers of Irrigation Department and BODHI, and examined the hydrology portion of reports representative of major and medium projects. The team then had detailed discussions with officers of the Hydrology Directorate to assess their capabilities. The team also visited typical irrigation projects to evaluate their size relative to hydrologic study requirements.

A training program for the Hydrology Directorate of BODHI was prepared under a two-phase scenario, taking into consideration BODHI's future role and workload.

- First Phase: Bring BODHI up to the standard necessary to perform the hydrologic studies assigned to it for the next five years (1990-1995).

- Second Phase: Upgrade BODHI's hydrologic expertise to a par with any specialized hydrologic organization, such as the Hydrology Directorate of the Central Water Commission, for 1995-2005 period.

As BODHI's future functions and workloads beyond the Eighth Five-Year Plan period (1990-1995) are not totally clear at this time, the training program should be reviewed in 1992 based on the situation at that time. A revised program should be prepared if appropriate.

The existing staff strength of BODHI's Hydrology Directorate is adequate to carry out the current workload. However, it is estimated that four additional engineers will be required for dam-break simulation analyses when BODHI is ready for such analyses. The team found that the engineers of Hydrology Directorate are well qualified and dedicated. However, in certain areas of hydrology, especially in computer applications, their capabilities are limited and further training is required.

It is recommended that BODHI should train the officers of Hydrology Directorate in much wider disciplines of hydrology. BODHI should make every effort to ensure that the trained officers are placed in positions where they can utilize their knowledge/skill in actual practice.

Two PC/AT micro-computers should be made available to the Hydrology Directorate. BODHI's library should be equipped with up-to-date reference materials in the areas of hydrology.

Chapter 1

INTRODUCTION

In February 1989, at the initiative of USAID, a two-member team comprised of H. Walter Anderson of the Harza Engineering Company, U.S.A., and Pritam Singh, former Chairman of Central Water Commission (CWC), performed an organizational review of the Bureau of Design for Hydroelectric and Irrigation Projects in the Irrigation Department of the Government of Madhya Pradesh, India, and made recommendations for its improvement.

One important recommendation was that three expert teams, each consisting of one specialist from the U.S. and one from India, should further look into the specific needs for strengthening BODHI in the fields of Geotechnical Engineering, Hydrology, and Hydraulic modeling.

Accordingly, a team consisting of T. Kumara Das, former Chief Engineer, CWC, India and B.K. Lee, Chief Hydrologist, Harza Engineering Company, U.S.A., has evaluated BODHI's capabilities in hydrologic investigation and has made recommendations for improvement. This report presents findings and recommendations of that team.

Mr. Das and Dr. Lee were in Bhopal, the capital of Madhya Pradesh, from February 8 through 26, 1990. They had extensive discussions with officers of Hydrology Directorate of BODHI, reviewed their facilities, and visited irrigation projects that represent typical major, medium and minor projects. Discussions were also held with other officers of the Irrigation Department including Chief Engineer, Survey and Investigation. Their daily activities are summarized in Appendix A. The team's draft report was presented to the Chief Engineer, BODHI, on February 22, 1990. Thereafter, discussions with the Chief Engineer and other officers were held, and the report was finalized.

Chapter 2

IRRIGATION DEPARTMENT, BODHI AND HYDROLOGY DIRECTORATE

2.1 Irrigation Department

The bulk of the irrigation work in Madhya Pradesh is under the authority of the Irrigation Department of the Government of Madhya Pradesh (GOMP), except for the large projects on the Narmada River for which the Narmada Valley Development Authority (NVDA) has been established. The responsibility for irrigation at the farm level for major projects is with the Command Area Development or "Ayacut" Department. An organization chart of the Irrigation Department is shown in Appendix B.

The head of the Department of Irrigation is the Engineer-in-Chief. Reporting to him are 16 chief engineers who supervise various projects, zones, and activities. Four chief engineers have statewide responsibilities:

1) Bureau of Design for Hydroelectric and Irrigation Projects (BODHI)
2) Survey and Investigation
3) Tubewell and Lift Irrigation
4) Electrical and Mechanical

There are seven zonal or basin chief engineers who are located in various parts of Madhya Pradesh. These chief engineers have total responsibility for investigations, planning and design, supervision of construction, and operation and maintenance of medium and minor irrigation projects within their respective territories. In addition, construction, operation and maintenance of a few major projects are supervised by some of the chief engineers.

In the past, designs for dams for certain medium and all major projects were prepared by the Central Water Commission. It is anticipated that in the future, BODHI will perform the design function presently performed by CWC. The design work for major structures of the NVDA has also been entrusted to CWC. The detailed technical examination of major projects and summary examination of medium projects, prior to their inclusion in the five-year plans, will continue to remain with CWC.

The Engineer-in-Chief has supervisory responsibility for approximately 29,792 individuals, 13,635 of whom are engineers. The cadre management of engineering personnel under the NVDA is also performed by the Engineer-in-Chief.

The civil works of the hydroelectric projects in close proximity to the dams or irrigation canal structures are generally constructed by the Irrigation Department, although the overall responsibility for power development lies with the Madhya Pradesh Electricity Board (a public sector undertaking).

The responsibility for water utilization in major projects is with the Ayacut Department which is under another ministry. The work involved in the improvement of irrigation practices at the farm level in 50 minor irrigation projects under USAID-Madhya Pradesh Minor Irrigation Scheme is monitored by Engineer-in-Chief, with the assistance of two superintending engineers heading the Special Appraisal and Supervision Cell and Special Coordination Cell respectively. BODHI is not entrusted with any role connected with water utilization, nor is such a role envisaged in the near future by the senior officers of the Irrigation Department.

2.2 BODHI

The BODHI organization was created in 1985. The primary functions are preparation of design and specification for dams, spillways, tunnels, canals and appurtenant works of major and medium irrigation projects, and some hydropower projects. In addition, BODHI is to update and circulate technical circulars and specifications throughout the department, and examine project reports for medium and major irrigation projects. BODHI also processes cases of revised administrative approval of all major projects and medium projects as are referred by GOMP.

Because BODHI has not built up adequate expertise in design of large river projects, its design works for some major and medium irrigation projects are prepared by CWC. The CWC is the specialized body in India having the best expertise and know-how in respect to all activities connected with planning and design of water resources development projects.

A major project is one having a culturable command area (CCA) of more than 10,000 hectares (25,000 acres) and a medium project is one between 2,000 and 10,000 hectares (5,000 and 25,000 acres). Projects having CCA of less than 2,000 hectares (5,000 acres) are defined as minor projects.

If the necessary capability and expertise are achieved, it is envisaged that BODHI itself will gradually be in a position to perform these design functions in the near future. Nevertheless, technical examination of major projects and performance examination of medium projects by the specialized Directorates of CWC, as required under the current regulations, will continue.

The BODHI organization is headed by a Chief Engineer who reports to the Engineer-in-Chief of the Irrigation Department. The organization is divided into eight directorates, including the Hydrology Directorate, and two cells, as shown in Appendix C.

There are approximately 101 engineers in the BODHI organization. Its total strength at the present time is 209. There are 132 vacancies from the sanctioned strength in the organization, mainly in the technician and clerical positions.

The Government of Madhya Pradesh has granted various incentives to personnel engaged in design and research work in order to attract and retain competent workers. Continuity of personnel and a sufficient workload in diversified fields will encourage the specialization required to achieve technical excellence in a design organization like BODHI.

2.3 Hydrology Directorate

The Hydrology Directorate consists of 12 officers: one director, three deputy directors, and eight assistant directors (including two vacant posts). The Director of Hydrology reports to the Chief Engineer of BODHI. Organization of Hydrology Directorate is shown in Appendix C. The current duties of the Hydrology Directorate are detailed in Chapter 5. It is anticipated that these duties will be continued in the Eighth Five-Year Plan.

Chapter 3

APPROACH

As mentioned earlier, the objective of the team's mission is to evaluate BODHI's capabilities in hydrologic studies and analysis, and to make recommendations for improvement and/or strengthening its capabilities.

The team's approach to the assignment is based on:

1) Meetings with various levels of officers of BODHI and other organizations in the Irrigation Department.

2) Review of selected project reports and memoranda representative of medium and major projects.

3) Visits to selected projects near Bhopal which are representative of the minor, medium, and major projects.

3.1 Discussion Meetings

A series of discussions were held with O.N. Thapar, Chief Engineer, BODHI, to obtain first-hand information on the present and anticipated future role of BODHI, in particular the role of Hydrology Directorate.

Extensive meetings with all the officers of the Hydrology Directorate were then conducted to assess their academic background, their experience, and capabilities for analyzing different disciplines involved in hydrology projects. This information enabled the team to assess the officers' experience and capabilities and to determine the improvements necessary to develop a more competent and efficient group.

Discussions were also held with M.S. Sohoni, Chief Engineer, Survey & Investigation (S&I), in order to assess S&I capabilities for hydrologic analyses other than hydrologic data collection and compilation activities. Discussions included the two engineers of S&I to assess their capabilities in hydrologic analysis, particularly in the area of water uses and return flow analysis.

The team visited J.R. Malhotra, Secretary to GOMP, Irrigation Department, and P.C. Agarwal, Engineer-in-Chief, Irrigation Department, for their input to the team's mission.

3.2 Review of Project Reports

The team reviewed the hydrologic portions of selected reports, guidelines and memoranda for typical major and medium projects to evaluate:

1) Scope of hydrologic studies
2) Data base for hydrologic studies
3) Methodologies used

A list of these reports is provided in Appendix D.

3.3 Field Visit to Projects

The team visited three selected projects near Bhopal in order to obtain a clear concept of the project components and the magnitude of typical major, medium and minor projects. Discussions were also held with the project engineers regarding applications of hydrologic criteria to design and construction. The projects visited and the engineers in charge of the project office were:

1) Kolar Project (major project) on February 9, 1990; O.P. Malga, Superintending Engineer, Kolar Project Circle, Bhopal.

2) Halali Project (medium project) on February 10, 1990; V.K. Mathur, Executive Engineer, Irrigation Division, Vidhisa.

3) Ghora Pachhar Project (minor project) on February 12, 1990; K.L. Gupta, Superintending Engineer, Betwa Circle, Bhopal.

The team also visited the Hydraulic Research Station of the Irrigation Department at Hathaikheda, Bhopal, on February 12, 1990. Here the team observed the on-going physical model studies carried out for some of the major irrigation and hydroelectric projects of the state, such as Rani Awanti Bai Sagar Dam (Bargi dam), a major hydroelectric scheme to generate nearly 1,000 MW, and the Narmadasagar Dam. G.S. Arora is Research Officer in charge of the station.

The team's findings and evaluation based on the approach described above are presented in the following two chapters.

Chapter 4

ASSESSMENT OF BODHI'S CAPABILITIES FOR HYDROLOGIC STUDIES

4.1 Existing Capabilities

Based on the approach described in the previous chapter, the team evaluated BODHI's existing capabilities of hydrologic studies in the following study areas that are important to planning (feasibility studies) and design of irrigation and hydroelectric projects:

1) Surface Water Availability Studies

   (a) Rainfall analysis
   (b) Streamflow analysis
   (c) Water-use and return flow analysis
   (d) Computer application and modeling

2) Flood Studies

   (a) Flood frequency analysis
   (b) Standard project flood (SPF) studies
   (c) Probable maximum precipitation (PMP) study
   (d) Probable maximum flood (PMF) study
   (e) Computer application and modeling

3) River-Reservoir Sedimentation Studies

   (a) Reservoir sedimentation study
   (b) River sedimentation study
   (c) Computer application and modeling

4) Tailwater Studies

   (a) Backwater computation
   (b) Water surface simulation

5) Water Quality Investigation

   (a) Basic concept
   (b) Computer modeling

6) Dam Safety Hydrology

   (a) Dam-break simulation

7) Field Investigation

   (a) Discharge and sediment measurement
   (b) Field estimation of river roughness

Water quality and river-reservoir sediment studies are highly important for environmental impact studies for the irrigation and hydropower projects. Familiarization with field measurement and observation procedures is essential for hydrologists in making sound judgement of data quality and in interpretation of field data.

4.2 Additional Assessments

In addition to the above study areas, the team also made assessment on the following areas:

1) Hydrology computation records and files
2) Computer facilities and programs
3) Hydrology library

General assessment by the team of BODHI's capabilities on hydrologic studies are:

1) Academic background of Hydrologic Directorate staff is appropriate, as shown in Appendix E.

2) While BODHI's existing capabilities are adequate in surface water availability and flood studies, their capabilities are somewhat limited in other study areas listed above. Overall, the existing capabilities are probably adequate to handle BODHI's current functions.

3) Substantial improvements are needed in the area of river-reservoir sediment studies, tailwater studies, water quality investigation, dam-break analysis and field investigation.

4) BODHI's capabilities in computer application and modeling are extremely limited as shown in Appendix F. This is mainly due to lack of computer facilities at BODHI and lack of opportunities for computer usage.

5) Hydrologic computation records and files need to be improved.

6) Hydrology library needs to be upgraded.

Requirements for strengthening BODHI's capabilities in hydrologic studies are presented in the following chapter. Two probable scenarios of BODHI's role in the future are considered.

Chapter 5

REQUIREMENTS FOR STRENGTHENING CAPABILITIES IN HYDROLOGIC STUDIES

The existing capabilities of the staff of Hydrology Directorate of BODHI are limited, and improvement is essential in order to upgrade the standards and bring them to a level capable of undertaking all required hydrologic studies. The CWC guidelines published in 1980 (listed in Appendix D) provide information on the level of hydrologic analysis required for different types of projects.

5.1 Two-Phase Improvements

Improvements projected for the Hydrology Directorate of BODHI have been examined under a two-phase scenario in consideration of BODHI's future role and workload.

1) First Phase: Bring BODHI up to the standard necessary to perform the hydrologic studies assigned to it for the immediate future.

2) Second Phase: Upgrade BODHI's hydrologic expertise to a par with any specialized hydrologic organization, such as the Hydrology Directorate of CWC.

To effectively fulfill its functions under either of the two scenarios, BODHI should develop the capability to perform hydrologic analyses using appropriate methodologies and updated techniques, with particular emphasis on computer-aided analyses.

Effectiveness of its capabilities greatly depend on the following two factors:

1) Continuous services of trained officers for Hydrology Directorate This requirement will establish a favorable climate for developing officers into specialists in various areas of hydrology.

2) Opportunities to apply hydrologic analysis techniques acquired in training to actual project hydrology Such opportunities almost entirely depend on BODHI's future function and workload, which are highly affected by the five-year plans and by high-level policy decisions.

Because BODHI's future functions and workload are not totally clear at this time, the requirements for strengthening BODHI should be reviewed periodically and revised accordingly. The team recommends the first follow-up review be within two years (or year 1992).

5.2 First Phase Requirements

The first phase is to strengthen the Hydrology Directorate as required to do current functions and the workload envisaged by BODHI in the Eighth Five-Year Plan summarized in Appendix G.

5.2.1 Anticipated Workload

The Engineer-in-Chief, Irrigation Department, and Chief Engineer, BODHI, indicated that their present intention is to confine hydrology work to the current functions entrusted to BODHI, as listed below:

1) Review and/or perform hydrologic studies required for the medium projects and prepare related reports.

2) Carry out any specific hydrologic assignments that are referred to BODHI by the other Chief Engineers.

3) Carry out special studies on hydrologic problems such as watershed yield methodology.

4) Perform hydrologic studies of schemes referred to BODHI by other agencies outside of the Irrigation Department.

5) Update technical circulars and prepare manuals on hydrologic aspects.

6) Review and/or perform dam safety hydrology for 752 large dams over a period of 10 years (75 dams per year or about 375 dams in a five-year period). This work would include dam-break simulation studies for about 75 dams and checking adequacy of spillway-design floods for all 375 dams by the Hydrology Directorate in the next five years (1990-1995). This is a recent addition of work and is yet to commence.

5.2.2 Staff Strength

As mentioned previously, the existing staff of the Hydrology Directorate consists of one director, three deputy directors and eight assistant directors (inclusive of the two vacant posts). The director performs mainly a supervisory role.

Five engineers are required to carry out tasks one through five listed above. Seven engineers are required to perform part of task six, review of adequacy of spillway design flood for the 752 large dams over a period of 10 years starting from 1990 (i.e. 75 dams per year) assuming one man-month per dam. The present strength is, therefore, adequate for these tasks.

When the work of dam-break simulation studies are undertaken by BODHI, after acquiring the capability for it, improvement will be necessary. It is expected that BODHI will be able to initiate these studies in 1992. An experienced engineer may take about two months to analyze one dam. Considering this is a new field for BODHI, they may need more time in the beginning. Allowing six man-months per dam, the Hydrology Directorate may need four more engineers for these studies to cover 75 dams in 10 years. One deputy director and three assistant directors would be suitable. The deputy director should be an engineer with a master's degree in engineering and have about five year's experience in hydrology; and the assistant director should have a master's degree in hydrology or two years' experience in hydrology beyond a bachelor's degree. However, the requirement of additional staff can be looked into sometime in 1992 in the context of the improvements achieved by then.

The engineers of the Directorate are well qualified and dedicated. Their primary handicap is limited actual experience in carrying out detailed analyses in some areas of hydrology, including computer modeling as shown in Appendix F. Some practical training is required in hydrologic computations and analyses of actual projects. This experience is necessary if the Directorate is to effectively perform or review the hydrology work of any projects, whether major or medium projects.

More specifically, the entire staff is familiar with derivation of regression equations for rainfall-runoff correlation. Improvements are needed in the areas of evaluation of upstream water uses, assessment of data base, and computer-simulation study, all of which are essential to integrated development of river basins.

Computation of design flood by frequency analyses and application of unit hydrograph methods for probable maximum flood (PMF) are well understood. However, they still require more detailed knowledge of storm transportation and maximization techniques so that they can determine probable maximum precipitation (PMP) for the areas where no PMP values are published. Currently, the PMP values are taken from the atlas prepared by Indian Institute of Tropical Meteorology or those provided BODHI by the Indian Meteorological Department or CWC.

There is only limited experience in river-reservoir sedimentation studies, including determination of sediment inflow to reservoir, distribution of sediment within the reservoir, and river sedimentation analysis, including river bed aggradation and degradation, and use of computer models in the analyses.

5.2.3 Computation Records and Files

Documentation of the calculation records and files needs improvements; otherwise it becomes very difficult to locate the computation sheets and relate the study details at a later date. Introduction of standardized computation sheets is extremely desirable. The calculation sheets must include:

1) Statements on purposes of calculation
2) Dates of initial and revised (if any) calculations
3) Names of officers who performed the calculations
4) Names of officers who made calculation checks

5.2.4 Hydrology Library

Reference material on hydrology which is currently available in BODHI's library is very limited and mostly outdated. The hydrology library of BODHI needs to be upgraded to the level of CWC.

Additional reference material that will help improve performance of the Hydrology Directorate are standard text books, journals, and handbooks in the following areas:

1) Applied hydrology
2) Computational hydraulics and hydrology
3) Water quality hydrology
4) Stochastic hydrology

Some references that will be useful for the Hydrology Directorate are:

<u>Books</u>

1) <u>Sediment Engineering</u> by American Society of Civil Engineers (ASCE)

Journals

2) Waterway, Port, Coastal and Ocean Engineering, ASCE

3) Water Resources Research, American Geophysical Union

Technical Manuals and Guides

4) Complete sets of U.S. Geological Survey's publication series on Techniques of Water Resources Investigation

5) World Meteorological Organization publications on "Probable Maximum Precipitation" and "Operational Hydrology"

6) Indian codes of practice on hydrology

In addition, a photocopy machine will be essential for BODHI to reproduce selected pages of references and computation sheets. An overhead projector will also be very useful for BODHI's engineers in order to pass on technologies they learn from training courses to their fellow associates.

5.2.5 Computer Requirements

BODHI has only one Apple Mackintosh PC at present. This is totally inadequate for the Hydrology Directorate for future workload. It is understood that the computer requirements of BODHI have been examined in detail and that BODHI will be equipped with two IBM PC/AT and one mini-computer in the near future. Two PC/AT computers should be at the disposal of the Hydrology Directorate.

Hydrologic computer programs available at BODHI are listed in Appendix H. Although these are sufficient for the simpler types of analyses done in the past, it will be necessary to obtain other advanced and newer programs capable of performing the additional work envisaged by BODHI, such as dam-break analysis and more elaborate computations for the current studies. Software packages such as those of U.S. Army Corps of Engineers Hydraulic Engineering Center's programs (HEC-1, HEC-2, HEC-4, HEC-5, HEC-6 and U.S. National Weather Service's DAMBRK) will be highly useful.

5.2.6 Training Requirements

Officers of the Hydrology Directorate should be sent to various short-term and long-term training courses available at Central Training Unit (CTU) in Pune, Water Resources

5.2.6 Training Requirements

Officers of the Hydrology Directorate should be sent to various short-term and long-term training courses available at Central Training Unit (CTU) in Pune, Water Resources Development Training Centre in Roorkee, CWC in Delhi, and other institutes, including those abroad. This should be a continuing program, so that the officers will be in close contact with up-to-date developments in the field of hydrology.

Although BODHI is not directly involved in stream gauging and data collection, the staff of the Hydrology Directorate should be conversant with the different stream-gauging methods, their uses and limitations, field procedures, and computational details for river flow, as well as sediment and water quality. Good knowledge of these factors will be invaluable to enable an hydrologist to judge the quality of data received from the field agencies, their possible inconsistencies, and the extent of accuracy of the data. The entire staff of the Directorate should be familiar with these aspects. It might be a good idea to make arrangements with the CWC for practical training of the staff in convenient CWC gauging stations in Madhya Pradesh.

The team's proposals for training requirements are shown in Table 1. The requirements in the table give only a broad indication of the training needs. Details of when training courses are offered by the different organizations should be ascertained by BODHI periodically and arrangements should be programmed accordingly. BODHI may also have to find out to what extent training facilities are available in India and consider training the officers abroad only in the disciplines where adequate arrangements are not possible within the country. The schedule should not cause difficulty, because there are five years in the Eighth Plan in which to cover it.

To ensure continuity of trained engineers in the Hydrology Directorate, it may be necessary to give them suitable incentives. BODHI should formulate incentives in this regard. Some suggestions are:

1) Grant of design allowance, currently granted to BODHI officers, that would increase with length of service, instead of a fixed amount.

2) Longer compulsory service for officers who are given foreign training, such as advanced degree programs.

Table 1

Proposal for Training Requirements

Areas of Training[1]	First phase Requirements[2] Approximate[4] Training Duration (Weeks)	First phase Requirements[2] Number of Officers	Second phase Requirement[3] Approximate[4] Training Duration (Weeks)	Second phase Requirement[3] Number of Officers
1. Dam Safety Hydrology				
- Dam Break Simulation	4	3	4	4
2. Field Investigation				
- Discharge, Sediment, Rainfall Mesurement	2	10	2	10
3. Flood Hydrology				
- Flood Frequency and PMF	2	2	2	2
- Flood Hydrograph Simulation	4	2	4	4
4. Surface Water Hydrology				
- Water Use & Water balance	4	1	4	4
- Rainfall-Runoff Simulation	4	1	4	2
5. River-Reservoir Sedimentation				
- General Sediment Transport Analyses	1	2	2	2
- Computer Simulation	-	-	4	4
6. Tailwater Analyses				
- Backwater Calculation	2	2	-	-
- Water Surface Simulation	3	2	3	4
7. Water Quality Hydrology				
- Basic Concept	2	2	2	4
- Computer Simulation	-	-	4	4

1 Listed in the order of priority for First phase Requirements
2 Five-year period from 1990 to 1995
3. Ten-year period from 1995 to 2005
4. Training Duration per each officer

It is important that after return from training, officers are placed in positions where they can apply their training in actual practice. This must be done within a short period of their return, say about one year, so that they are able to apply their knowledge while it is still fresh. Otherwise, the purpose of the training might be defeated and the expenses largely wasted. If the nature and quantity of work in BODHI become inadequate to create such opportunities, the training program should be modified from time to time. A mid-plan review is therefore appropriate.

5.3 Second Phase Requirements

The need for sound training in certain fields of hydrology has already been described earlier under first phase requirements. This need will be equally relevant to the second phase requirement, because training is a continuing process. Hydrology Directorate staff must continuously upgrade their capabilities in step with various advancements in hydrology. As mentioned earlier, the Hydrology Directorate staff should be sent for training in batches, to minimize disruption to on-going work. They should, in turn, train other engineers in the BODHI and Irrigation Department so that the department will have larger numbers of qualified engineers. Long-term requirements for training are provided in Table 1.

BODHI should eventually develop a complete set of capabilities and expertise, based on up-to-date methodologies, to handle a wide range of hydrologic assignments. It is desirable that the Hydrology Directorate of BODHI should be comparable, in capability and efficiency, to Hydrology Directorate of CWC. Even though all major projects are examined in CWC for clearance, reports prepared by an organization with an established reputation will be looked on by CWC with great confidence. This will, in turn, facilitate minimal scrutiny by CWC.

5.3.1 Environmental and Social Impact

Because of growing concern on environmental and social impact by the water resource projects in India, it is highly desirable for BODHI to train their hydrologists to perform and/or review the hydrologic studies needed for environmental and social impact analyses. Such hydrologic studies would include:

1) Water Quality modeling studies
2) River-Reservoir Sedimentation modeling study
3) Basin-Wide Water Balance modeling study

Water quality studies normally involve analyses of change in key water quality parameters, including water temperature, dissolved oxygen level, and P.H. level. These analyses are best handled by computer modeling techniques. Prediction of change in riverbed material, and/or river alignment, and/or river cross-sections as a result of dam construction is highly important because they would change riverine ecology. This, again, can best be handled by computer simulation techniques.

Determination of seasonal and special variation of future streamflows in a large basin must take into account upstream and downstream water uses, return flows, and future water resource development projects in the basin. As the future water quality and sediment greatly depend on future streamflow, streamflow studies are also important to environmental impact studies. Basin-wide streamflow can be best analyzed by using water balance modeling techniques.

As stated earlier in the assessment of first phase improvements, realistic requirements for the second phase improvements are difficult to make, because BODHI's future functions and workload are not totally known. A further review toward the middle of the Eighth Five-Year Plan (or in the year 1992) would be desirable, by which time a clearer picture may become available.

Chapter 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

1. The staff strength of the Hydrology Directorate is adequate to handle the anticipated workload in the Eighth Five-Year Period (1990-1995). However, four additional hydrologists will be needed for dam-break simulation studies. It is anticipated that computer facility and trained engineers for the dam-break simulation studies will be available by about 1992. Academic background of the staff is, in general, appropriate to current functions.

2. BODHI's capabilities are adequate in surface water availability and flood analyses areas of hydrology. The engineers of the Hydrology Directorate are well qualified and dedicated. However, in certain other areas of project hydrology, their capabilities are somewhat limited. On the whole, the existing capabilities are sufficient to manage the present activities of BODHI, but may be inadequate for dam-break simulation studies and BODHI's anticipated future assignments.

3. The entire Hydrology Directorate staff is familiar with application of regression equations for rainfall-runoff relationship. Improvements are needed in the areas of evaluation of upstream water uses, assessment of representativeness of data base, and computer simulation study.

4. Computation of design flood by frequency analyses and application of unit hydrograph methods for probable maximum flood (PMF) determination have been well understood. However, they still require more detailed knowledge of storm transportation and maximization techniques in order to use them to determine probable maximum precipitation (PMP) for the areas where no PMP values are published.

5. The Hydrology Directorate staff has only limited experience in river-reservoir sedimentation studies, including determination of sediment inflow to reservoir, distribution of sediment within the reservoir, river sedimentation analysis, including riverbed aggradation and degradation, and use of computer models in the analyses.

6. BODHI's capabilities in computer application and hydrologic modeling are very limited. This is from lack of opportunities for computer-aided analysis and from inadequate computer facilities. A large number of computer programs for hydrologic studies are available in BODHI which are sufficient for the simpler types of analysis done in the past. But it is necessary to procure advanced and new software packages

to efficiently perform the additional studies envisaged for BODHI, such as dam safety hydrology, including dam-break simulation.

7. Library facilities of BODHI need to be improved. Reference material on hydrology currently available are limited and out-dated. BODHI is handicapped by lack of photocopy machines which are essential for reproduction of important pages of reference materials and computation sheets.

8. Computational records of hydrologic studies and related material are not satisfactorily documented and maintained. Their documentation should be standardized and improved.

9. Training requirements and other improvements could be planned in two phases; the first aimed at bringing the Hydrology Directorate up to standards required for the immediate future, and the second to further upgrade expertise to that of a specialized unit in the area.

10. Officers of the Hydrology Directorate should be abreast of the latest developments in hydrology. In order to achieve this, they should attend various short-duration and long-duration training/refresher courses available at different centers in the country from time to time. This should be a continuous program.

11. Practical experience for about two weeks in actual field works of discharge measurements will be advantageous to the staff for a proper appreciation of the quality and limitations of the data they use for analyses.

12. To effectively utilize training, the trained officers must continue to be available in the Hydrology Directorate for a reasonable length of time, and they must also have enough opportunities to apply their knowledge in actual practices. The availability of such opportunities largely depends upon BODHI's future functions and workload. These, in turn, will be affected by policy decisions at higher levels and the number and types of projects executed by BODHI in future five-year plans. In this light, a further review by an expert team is recommended toward the middle of the Eighth-Five-Year Plan (in 1992), when the position will perhaps be clearer and a more realistic assessment will be possible.

13. BODHI should create suitable incentives in order to attract and retain experienced hands in the Hydrology Directorate.

6.2 Recommendations

The recommendations one through six listed below are common to both first and second phase improvement, seven through nine are for the first phase improvement; and 10 through 12 are during the second phase.

1. BODHI should train the officers of Hydrology Directorate in the following areas of hydrology.

   (a) Dam Safety Hydrology
   (b) Field Investigation
   (c) Flood Hydrology
   (d) Surface Water Hydrology
   (e) River-Reservoir Sedimentation
   (f) Tailwater Analyses
   (g) Water Quality Hydrology

2. The training program should be implemented in two phases. The first phase involves about 68 man-weeks of training for the five-year period (1990-1995). The second phase involves about 140 man-weeks of training for the 10-year period (1996-2005). Details are presented in Table 1, Chapter 5.

3. BODHI should ensure that trained officers are placed in positions where they have an opportunity to use their knowledge/skill in actual practice. This must be done within a short period of their return, say about one year, so that they are able to apply their knowledge while memory is still fresh.

4. To ensure continuity of trained engineers in the Hydrology Directorate, it may be necessary for BODHI to provide them suitable incentives. Some suggestions for consideration are:

   (a) Increase in the design allowance currently granted to BODHI officers according to length of services instead of a fixed amount.

   (b) Foreign training, including advance degree programs, with stipulation for a longer period of compulsory service.

5. Officers of the Hydrology Directorate should be sent to various short-term and long-term training courses available at Central Training Unit (CTU) in Pune, CWC in Delhi, Water Resources Development Training Center in Roorkee, and other institutes including those of foreign countries.

6. The strength of the Hydrology Directorate should be augmented by four additional hydrologists, consisting of one deputy director and three assistant directors for dam-break simulation studies. Computer facilities and trained engineers are expected to be available for these studies by about 1992.

7. Two PC/AT micro-computers should be made available to the Hydrology Directorate for their own use. Every engineer in the Hydrology Directorate should be able to use computers in the analysis of hydrologic problems.

8. The library should be well equipped with up-to-date standard books, reference materials, Indian codes of practice, and journals on hydrology. A photo copy machine in or near the library is essential in order to reproduce selected reference pages and computation sheets. An air-conditioned reading room in the library should be considered.

9. All computational records and files should be improved by adopting standardized forms and office procedures.

10. In the light of growing public concern about environmental and social impact by the water resource projects in India, BODHI should train hydrologists to perform and/or review the hydrologic studies needed for environmental and social impact analyses. Such hydrologic studies should include:

    (a) Water Quality modeling studies
    (b) River-Reservoir Sedimentation modeling study
    (c) Basin-Wide Water Balance modeling study

11. In order for the Hydrology Directorate to functioned like CWC in the future, the Hydrology Directorate staff must continuously upgrade their capabilities in accord with various advancements in hydrology. The trained Hydrology Directorate staff should in turn train other engineers in the BODHI and Irrigation Department.

12. As BODHI's future functions and workloads beyond the Eighth Five-Year plan period (1990-1995) are not clear at this time, the training programs should be reviewed in 1992 and a revised program should be prepared if appropriate. A one

-week assignment by a team consisting of one Indian and one U.S. hydrologist is recommended. Their qualifications are:

(a) Advanced degree in civil engineering with specialization in hydrology

(b) Fifteen years of professional experience in hydrologic studies related to water resources development including hydroelectric and irrigation projects in tropical/subtropical countries preferably in India

(c) Professional communication skill

APPENDIX A

Daily Activities of the Team for Strengthening BODHI in the Field of Hydrology

1.	Feb 5 (Mon)	-	B.K. Lee arrived New Delhi
		-	Met J.R. Khanna, USAID
2.	Feb 6 (Tue)	-	B.K. Lee & J. Borg had an orientation meeting with J.R. Khanna
3.	Feb 7 (Wed)	-	T. Kumara Das arrived New Delhi. Discussion meeting among J.R. Khanna, S.V. Chitale, T. Kumara Das, J. Borg and B.K. Lee. Met John Grayzel, Chief, Office of Natural Resources Management
4.	Fen 8 (Thur)	-	Travel to Bhopal
		-	Met O.N. Thapar, Chief Engineer, BODHI
		-	Visit BODHI Library
		-	Reviewed hydrology portions of selected project reports
5.	Feb 9 (Fri)	-	Visit Kolar Project
		-	Reviewed hydrology portions of selected project reports
6.	Feb 10 (Sat)	-	Visit Halali Project
		-	Reviewed hydrologic portions of selected project reports
7.	Feb 11 (Sun)	-	Rest
8.	Feb 12 (Mon)	-	Visit Ghora Pachhar Tank Project
		-	Begun discussion meeting with Hydrology Directorate staff
		-	Visit BODHI Hydraulic Laboratory
9.	Feb 13 (Tue)	-	Continued discussion meeting with Hydrology Directorate staff
		-	Visit Secretary to Government of Madhya Pradesh, Irrigation Department, Mr. J.R. Malhotra
		-	Discussion meeting with Director of Irrigation Research, Mr. R.D. Ektare
		-	Continued to review hydrology portions of selected project reports

APPENDIX A

Daily Activities - Contd.

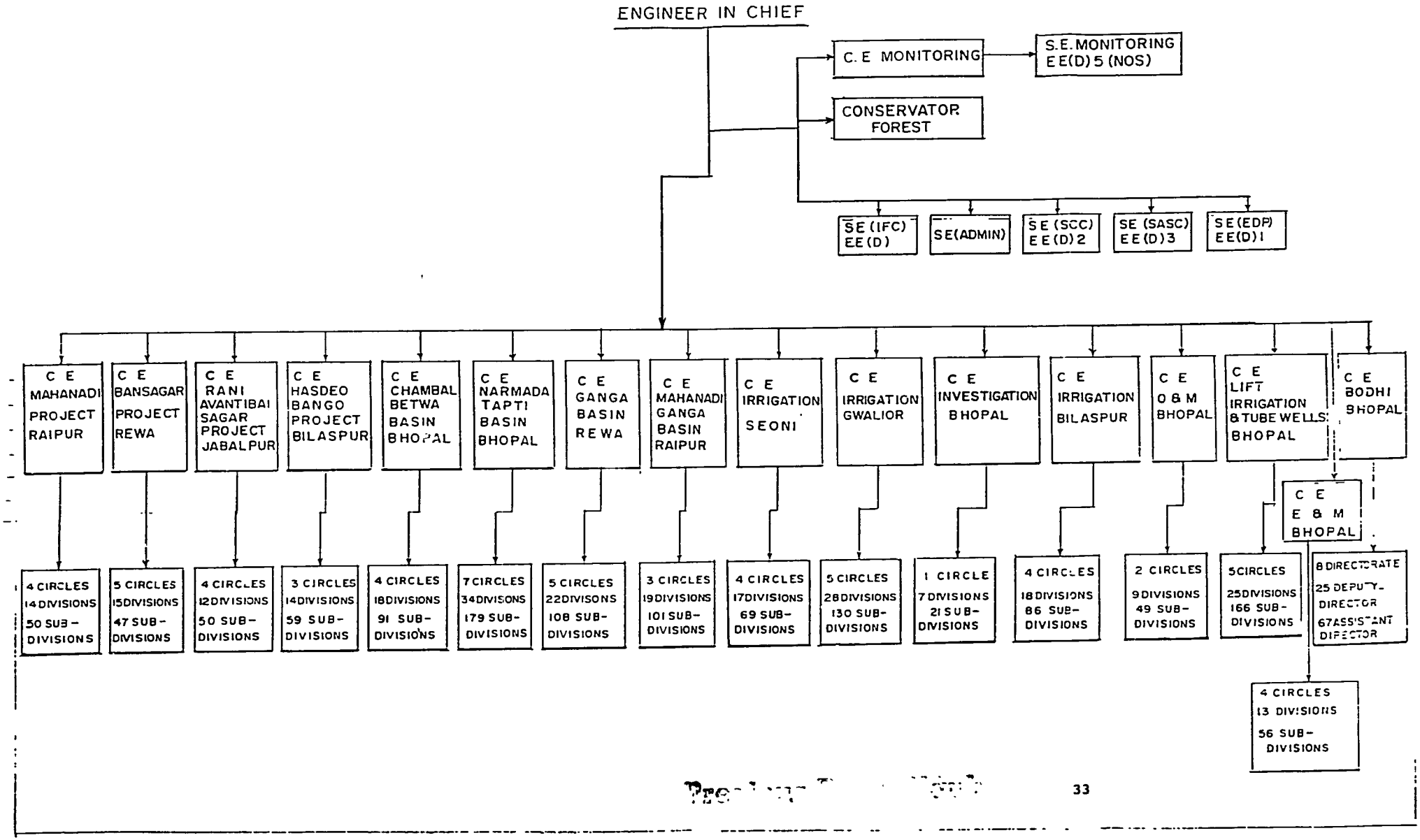
10.	Feb 14 (Wed)	-	Visit Chief Engineer, Survey and Investigation and Director, Hydro-meteorology Directorate
		-	Continued discussion meeting with Hydrology Directorate staff
		-	Prepared Report Outline
11.	Feb 15 (Thur)	-	Continued to review hydrology portions of selected project reports
		-	Begun to prepare Report
		-	Discussion meeting with Engineer-in-Chief, Irrigation Department and Chief Engineer, BODHI
		-	Initial discussions meeting with J.R. Khanna, USAID
12.	Feb 16 (Fri)	-	Met with J.R. Khanna for progress briefing
		-	Continued to prepare Report
13.	Feb 17 (Sat) (Local Holiday)	-	Continued to prepare Report
14.	Feb 18 (Sun)	-	Continued report preparation
15.	Feb 19 (Mon)	-	Continued to prepare report
		-	Completed to review hydrology portions of selected project reports
16.	Feb 20 (Tue)	-	Continued to prepare report
17.	Feb 21 (Wed)	-	Completed Draft Report
18.	Feb 22 (Thur)	-	Copies of Draft provided to Chief Engineer and Hydrology Director for review comments
		-	Begun typing the report
19.	Feb 23 (Fri) (Local Holiday)	-	Begun improving the draft report
20.	Feb 24 (Sat)	-	Begun incorporating review comments of Chief Engineer and Hydrology Director
		-	Discussion meeting with Chief Engineer and Hydrology Director on their review comments on the draft report

APPENDIX A

Daily Activities - Contd.

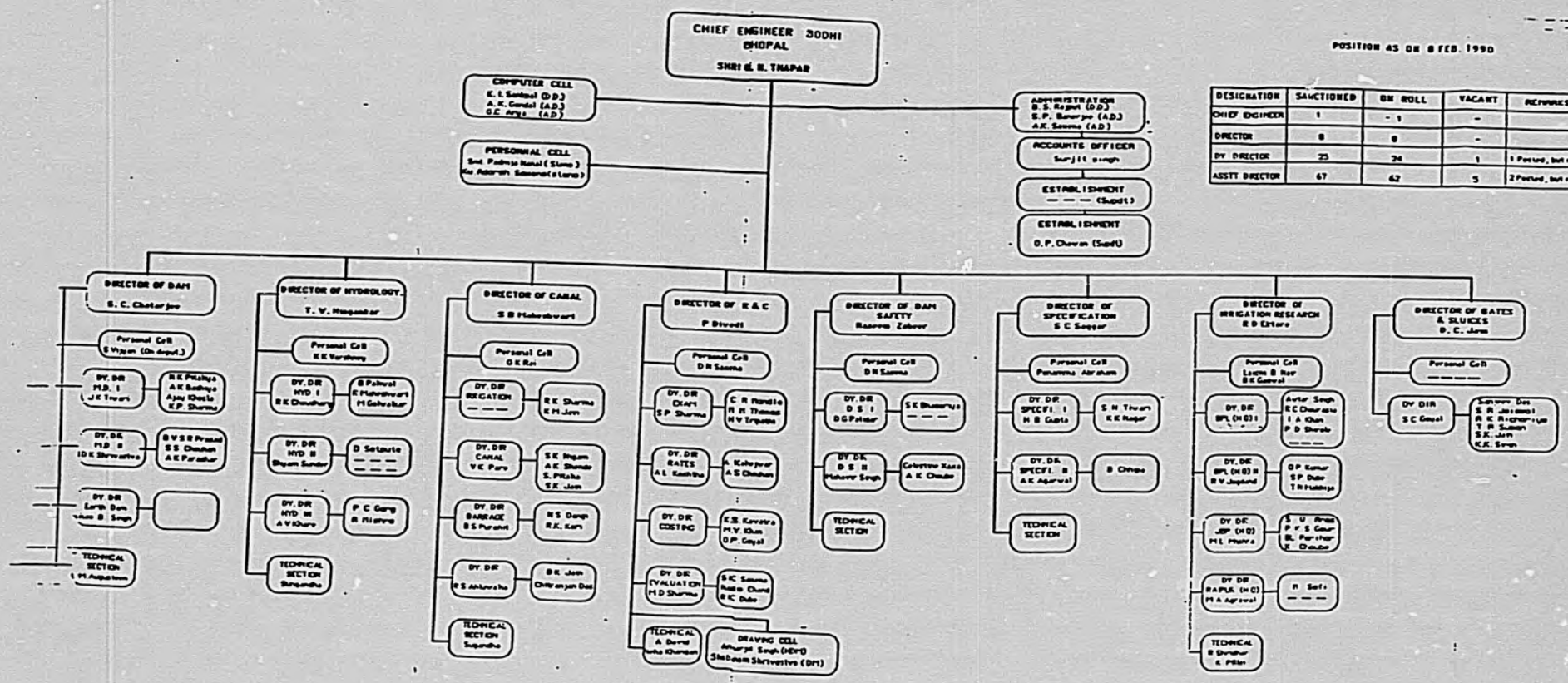
21.	Feb 25 (Sun)	-	Continued finalizing the report
22.	Feb 26 (Mon)	-	Scheduled to brief Secretary and Engineer-in-Chief, Irrigation Department with team's findings
		-	Revised the report as needed
		-	Prepared photo copies of the report
23.	Feb 27 (Tue)	-	Scheduled to leave Bhopal for New Delhi
		-	Scheduled to discuss the report with USAID staff
24.	Feb 28 (Wed)	-	Scheduled to complete discussion of the report with USAID staff
		-	Scheduled to prepare Contract Performance Evaluation Form
25.	Mar 1 (Thur)	-	Scheduled to leave New Delhi for USA

Organization Chart of Irrigation Department
Government of Madhya Pradesh



APPENDIX C

Organisation Chart of BODHI



POSITION AS ON 8 FEB. 1990

DESIGNATION	SANCTIONED	ON ROLL	VACANT	REMARKS
CHIEF ENGINEER	1	1	-	
DIRECTOR	8	8	-	
DY DIRECTOR	25	24	1	1 Posted, but not joined
ASSTT DIRECTOR	67	62	5	2 Posted, but not joined

Previous Page Blank

APPENDIX D

Reports Guidelines & Memoranda Reviewed by Team For Evaluating BODHI's Capabilities On Hydrologic Study

1. A note on Activities of Directorate of Hydrology, Directorate of Hydrology, BODHI, Government of Madhya Pradesh, February 8, 1990.

2. Research Facilities in Irrigation Depatment, Madhya Pradesh, Directorate of Irrigation Research, BODHI, Government of Madhya Pradesh, February, 1990.

3. Note on Ghora Pachhar Tank, Executive Engineer, Irrigation Division, Bhopal, February, 1990.

4. Design Memorandum for Rainfall-Runoff Studies of Kolar Project, Superintending Engineer, Kolar Project Circle, Bhopal March, 1989.

5. Technical Memorandum on Flood Studies of Kotwal, Pillowa and Pagara Dams (M.P. Chambal Phase II), Chief Engineer, BODHI, Bhopal Government of Madhya Pradesh, Irrigation Department, January, 1988.

6. Uri Bagh Project, Volume II, Annexures, Chief Engineer, Narmada Tapti Basin, Bhopal, Irrigation Department, Government of Madhya Pradesh, 1988 (Estimated, Report Preparation Date not Specified).

7. Design Memorandum for Flood Studies and Dam Safety Aspects of Kolar Dam, Superintending Engineer, Kolár Project Circle, Bhopal, November, 1987.

8. Uri Bagh Project, Volume I, Report Estimates and Fiancial Statements, Chief Engineer, Narmada Tapti Basin, Bhopal, Irrigation Department, Government of Madhya Pradesh, 1985 (Estimated, Report Preparation Date not Specified).

9. Detailed Project Report of Arpa Project, Volume V, Appendix 4, Hydrology & Water Planning, Chief Engineer, Hasdeo Bango Project, Bilaspur, August, 1985.

10. Bargi Multipurpose Project, Headworks, Volume I(A), Project at a Glance and What is Where, Irrigation Department, Government of Madhya Pradesh, January, 1983.

APPENDIX D - cont.

11. Bargi Multipurpose Project, Headworks, Volume III, Appendices, Irrigation Department, Government of Madhya Pradesh, January, 1983.

12. Guidelines for preparation of Detailed Project Reports of Irrigation and Multipurpose Projects, Working Group Report, Annexure 4, Volume II, Guidelines for preparation of Hydrology, Volume of Detailed project report, Ministry of Irrigation, Government of India, PP 87-99, 1980.

APPENDIX E

Hydrology Directorate Staff and their Qualification and Training

Officers	Academic Degrees and Year	Number of Years of Experience in Hydrology	Number of Years of Experience in other other Civil Engg.
1. T.W. Hingankar (D)	B.E, 1961	2	27
2. R.K. Choudhary (DD)	M.E, 1977	6	21
3. Shyam Sunder (DD)	M.E, 1989	6	21
4. A.V. Khare (DD)	M.E, 1978	8	12
5. B. Poliwal (AD)	M.E, 1989	3	10
6. R.C. Maheshwari (AD)	M.E, 1984	6	8
7. M. Golwalker (AD)	B.E, 1981	2	7
8. D. Satpute (AD)	P.G. Dip, 1984	5	2
9. P.C. Garg (AD)	M.E, 1979	7	11
10. A. Mishra (AD)	B.E, 1979	1	9

Abbreviation

D = Director
DD = Deputy Director
AD = Assistant Director

APPENDIX F

CAPABILITY OF HYDROLOGY DIRECTORATE STAFF

BODHI

(AS OF FEBRUARY, 1990)

FOR ASSESSING TRAINING REQUIREMENTS

S. No	Name of Officer	Surface Water Availability Studies				Flood Studies				Sedimentation Studies			Tailwater Studies		Water Quality Investigation		Dam Safety Hydrology	Field Investigation	
		Rainfall	Stream flow	Water use & Return Flow	Computer Application & Modelling	Flood Frequency	PMP	PMF	Computer Application & Modelling	Reservoir Sedimentation	River Sedimentation	Computer Application & Modelling	Backwater computations	Computer Simulation	Basic concept	Computer Modelling	Dam Break Simulation	Discharge & sediment measurements	Field Estimation of River Roughness
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
1.	T.W. HINGANKAR	A	A	VL	L	A	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
2.	R.K. CHAUDHARY	A	A	VL	L	A	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
3.	SHYAM SUNDER	A	A	VL	L	A	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
4.	A.V. KHARE	A	A	VL	L	A	L	A	VL	L	VL	VL	A	VL	VL	N	VL	L	L
5.	B. PALIWAL	L	A	VL	L	A	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
6.	R.C. MAHESWARI	L	A	VL	L	A	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
7.	M. GOLWALKAR	L	A	VL	L	L	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
8.	D. SATPUTE	L	A	VL	L	A	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
9.	P.C. GARG	L	E	VL	L	A	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L
10.	A. MISHRA	L	L	VL	L	L	L	A	VL	L	VL	VL	L	VL	VL	N	VL	L	L

ABBREVIATIONS

E = Extensive

A = Adequate

L = Training Required in Selected Areas

VL = Extensive Training Required

N = None.

Note : 1. Officer at serial No.1 is the Director of Hydrology, Serial Nos. 2,3 & 4 are Deputy Directors, and Serial Nos. 5 to 10 are Assistant Directors

2. In addition to the above ten officers of the Hydrology Directorate, about eight officers in other Directorates of BODHI have received limited training in Hydrology during the period 1984-1989.

APPENDIX G

ANTICIPATED WORKLOAD OF HYDROLOGY DIRECTORATE AS ENVISAGED BY BODHI

Major Projects	Medium Projects	Other Works
(a) Eighth Five-Year Plan :		
Four New Projects :	One New Project	
Any specific hydrologic studies that may be referred to BODHI by the territorial Chief Engineers on the four new projects included in Eighth Five-Year Plan, viz. Pench Diversion, Kelo, Mongro and Arpa.	One (Sank Swarnaratla line Project) complete analysis of hydrologic aspects and preparation of hydrology report and 9 more yet to be identified	Preparation of guidelines, technical circulars, manuals, etc. relating to work of hydrology from time to time.
No on-going Projects :	Eleven on-going projects	Carry out special studies on hydrological problems, e.g. watershed yield methodology .
Hydrological studies of the other continuing projects have already been completed, and no work on these is anticiaated.	Hydrological Studies might probably be reviewed for 10 medium Projects.	Perform studies of schemes referred to BODHI by other agencies.
Dam Safety Review :		
Review of the adequacy of spillway capacity of 752 existing/on-going large dam over a period of 10 years i.e.about 75 dams per year. This would include Dam break analysis for 75 dam over the ten-year period. Preparation of inundation maps will be done by the zonal Chief Engineer, are not by BODHI.		

(b) Ninth Five-Year Plan :

Project proposals for ninth plan have not been formulated. It was indicated during discussions with BODHI that tentatively we may assume two major projects ten medium projects for the ninth plan period.

Dam safety review will be continued for an equal number of large dams in the ninth plan period also.

APPENDIX H

List of Hydrologic Computer Programs Available at BODHI (Fortran)

	Source	Program Code	Title
1.	NIH	FLD FREQ ANA	Flood Frequancy Analysis of annual maximum series using Log Transformation and Power Transformation assuming transformed series follows the normal distribution
2.	NIH	ARAINFALL.INT	Interpolation of rainfall by Distance Power & Ratio Method
3.	NIH	*WTD.AV.RAIN	Computation of Waited average rainfall
4.	NIH	*CATCH RAIN	Estimation of mean areal precipitation (Theisen polygon)
5.	BODHI	*SY.UNIT	Synthetic Unit Hydrograph based on Flood Estimation Report of CWC
6.	NIH	*MISSING FLOW	Estimation of Sample Mean, Standard Deviation, Coefficient of Skewness with missing records
7.	NIH	*POLY.REGRE	Polynomial Regression
8.	NIH	*MULTI.REGRE	Multiple Linear Regression
9.	CWC	*FLOOD ROUTING,2	Reservoir Flood Routing by Modified Pulse Method
10.	NIH	*EFF.FOR	Computation of Effective Rainfall from discharge hydrograph after separating base flows
11.	NIH	*UNIT.FOR	Computation of Unit Hydrograph of a specified duration from the direct surface runoff hydrograph after separating base flows
12.	NIH	*UHISO.FOR	Estimation of the Unit Hydrograph from the direct surface runoff of an isolated storm event

---

Note: Symbol * designates the computer programms used by Hydrology Directorate as of February 14, 1990.

APPENDIX H - cont.

	Source	Program Code	Title
13.	NIH	*CLARK.FOR	Unit Hydrograph derivation using Clark's Model
14.	NIH	SCURVE.FOR	Development of S-Curve hydrograph from T-hour unit Hydrograph
15.	NIH	SUPERIM.FOR	Changing the duration of Unit Hydrograph by Superimposing method
16.	FAO.24	CROP WATER	Estimation of Reference crop Evapotranspiration (ETo) by Modified Panman, Blanny-Criddle and Pan Evaporation methods
17.	NIH	LOSS.FOR	Separation of Uniform loss from rainfall hyetograph and base flow from Discharge hydrograph
18.	NIH	COLUH FOR	Derives the Unit hydrograph from multi period Strom using collin's method
19.	NIH	NEWD.FOR	Computes the Unit hydrograph ordinate of new duration using S-Curve
20.	NIH	REFROD.FOR	Used for reproduction the observed direct surface runoff hydrograph and computes the various error functions based on observed and computed direct surface runoff hydrograph
21.	NIH	SYNTH.FOR	Used for computing the direct surface runoff hydrograph from the excess rainfall of the multiple period storm and unti hydrograph
22.	NIH	*GAPF.FOR	Used for estimating the missing station rainfall data using Normal Ratio method
23.	NIH	*DOUBLE.FOR	Checks the consistency of a particular record using double mass curve analysis

---

Note: Symbol * designates the computer programs used by Hydrology Directorate as of February 14, 1990

APPENDIX H - cont.

	Source	Program Code	Title
24.	NIH	*THIES.FOR	Used for computing the areal average rainfall due to a storm event in the catchment using the Thiessen Polygon method
25.	NIH	ISO.FOR	Computes the variation of depth with area over the catchment using Isohyetal method
26.	NIH	DAILY.FOR	Distributes the daily rainfall into hourly rainfall as per the choice of the SRRG and computes the average hourly rainfall
27.	NIH	VEL.FOR	Calculates the discharge from velocity measurements
28.	NIH	*RATING.FOR	Used for developing the rating curve in the form of Q=a(G-e)b
29.	NIH	*GAUGE.FOR	Used for converting the given stage values into corresponding discharge values using a given rating curve in the form: Q=a(H-Ho)b
30.	NIH	NASHF.FOR	Used for derivation of unit hydrograph using conventional Nash Model from the Direct Surface Runoff Hydrograph an Excess Rainfall Hyetograph of an event
31.	NIH	INTNAS.FOR	Used for derivation of unit hydrograph using integer Nash Model
32.	IS.5477 (Part iv)	PK.FL	Peak flood estimation by maximum likelyhood method (100 yr, 500 yr, 1000 yr return flood)
		(Basic)	
33.	Basic.hyd	DOUBLEMASS	Checking of consistency of rainfall records

---

Note: Symbol * designates the computer programs used by Hydrology Directorate as of February 14, 1990

APPENDIX H - cont.

	Source	Program Code	Title
34.	Basic.hyd	FOURQUAD	Estimation of missing rainfall record by four quadrant method
35.	Basic.hyd	INTENDUR	Depth-Intensity-Duration analysis
36.	Basic.hyd	DEPAREA	Computation of depth with area over the catchment
37.	Basic.hyd	UGRAPH	Computation of ordinate of unit hydrograph
38.	Bssic.hyd	SCURVE	Development of S curve
39.	WALMI (Aurangabad)	BACK-WATER	Computation of back-water profile