REPORT OF THE EXPERT GROUP

ON

WATER QUALITY MONITORING SYSTEMS FOR PROTECTING THE NATIONAL WATER RESOURCES

APRIL, 2002

ACKNOWLEDGEMENT

The members of the Expert Group express their sincere thanks to the Ministry of Environment and Forests as well as the Ministry of Water Resources, Government of India, for providing the opportunity to the Group to complete the task assigned to it. The Group also acknowledges with thanks the assistance provided by the Central Pollution Control Board, the Central Water Commission and the Central Ground Water Board for preparing the report.

Special thanks are also due to the Hydrology Project, and the Government of The Netherlands for freely using their publications in preparing the report.

FOREWORD

The Ministry of Environment and Forests, Government of India, vide Office Order No. J-15011/8/2000-NRCD, dated 28.11.2001 (copy of the order enclosed), constituted the Expert Group on Water Quality Monitoring Systems, with a view to unifying and streamlining the widely varying water quality monitoring systems being followed at present by various Central and State agencies viz. the Central Water Commission, the Central Ground Water Board, the State Surface Water and Groundwater Departments as well as the Central and State Pollution Control Boards, making it difficult to have a concerted action programme for protecting the quality of the national water resources. On behalf of the Expert Group, I would like to record here its sincere appreciation of the decision, taken by the Water Quality Assessment Authority (WQAA) of the Government of India, to constitute the Expert Group to systematize the water quality monitoring systems for the national water resources in the country.

2. In the six meetings during December 2001 - April 2002 by the Group, the present status of surface water and groundwater quality monitoring programmes of the concerned central and state agencies were reviewed to help develop a unified procedure, so that the water quality data generated by any agency can be shared by others in drawing up their respective Action Plans for implementation in an integrated manner without any undue overlapping as well.

3. The Expert Group reviewed the method of designing the water quality monitoring network, sampling procedures, on-site analysis of certain parameters, preservation and transportation of samples to laboratories for detailed analysis of physico-chemical and bacteriological parameters including pollution related parameters, toxic heavy metals and pesticides, adopting standard procedures, frequency of sampling and parameters for various categories of monitoring stations, data entry system and validation of results, analytical quality control, data analysis and interpretation – in fact, every aspect of the monitoring system.

4. Based on its findings after the review, as aforesaid, the Group has evolved and recommended a ‘Protocol for Water Quality Monitoring’ for uniform application by all the monitoring agencies. Various levels of laboratories optimally required for monitoring selective parameters have also been mentioned in the report. The minimal requirement of personnel (chemists and biologists), based on number of samples to be analyzed and the number of parameters to be analyzed for each sample, has been estimated. Lack of such manpower is considered to be a major risk in the development of infrastructure in operationalisation of the laboratories. The protocol encompasses only the groundwater and inland freshwater. This leaves the estuarine and the coastal waters, which are of more importance now than ever before for the country. The Group, therefore, recommends that a separate study be made for evolving monitoring systems for such water resources as well.

5, The Expert Group has recommended institution of a quality assurance programme including ‘within-laboratory’ and ‘inter-laboratory’ analytical quality control (AQC) exercises, to be performed by the laboratories to ensure reliability in data generation.

The CPCB is acting as a ‘referral laboratory’ for organizing inter-laboratory AQC exercise among the laboratories participating in their water quality monitoring programme since 1991. Presently it is conducting the exercise for 130 laboratories of the State Pollution Control Boards/Committees, six zonal offices of CPCB, laboratories recognized under the Environment (Protection) Act, 1986 and some other agencies. Likewise, there is an urgent need for developing two ‘referral laboratories’ – one with the Central Water Commission and the other with the Central Ground Water Board – for providing expert guidance to the surface water and groundwater laboratories, respectively and for conducting ‘Inter-laboratory AQC’ exercise at least once a year among the laboratories. The two referral laboratories should be equipped with state-of-the-art instruments and adequate qualified and trained scientists/chemists. The Central Pollution Control Board (CPCB) shall include these two laboratories in its ‘Inter-laboratory AQC’ programme.

6, The Expert Group has also suggested the computerized method of recording, storage and analysis of data using software, and dissemination of data to user agencies. This will *inter alia* help in the generation of a database for both water resources management and pollution abatement.

7. It has been the considered view of the Group that there is a need for establishing a Central Training Institute for water quality monitoring, assessment and management, preferably located in the CPCB Office Complex for better coordination.

8. It need be highlighted here that the most vulnerable aspect in water quality monitoring programme is the lack of qualified and trained manpower. The Group has studied the manpower requirement based on the experience of the CPCB and other agencies. To estimate the manpower requirement, a relationship could be established based on the number of samples and the parameters to be analyzed, as stated in the concluding part of this report.

9. This report could be prepared within a rather short span of time primarily because of the very devoted and hard work put in by my colleagues in the Expert Group. I must record here my thankful appreciation of their valued contribution.

10. I believe, the Report would meet the requirements of the WQAA and the National River Conservation Directorate of the Ministry of Environment and Forests, Government of India.

New Delhi
April 29, 2002

Arunoday Bhattacharjya
Chairman, Expert Group

No. J-15011/8/2000-NRCD
Government of India
Ministry of Environment & Forests
National River Conservation Directorate

Paryavaran Bhawan
CGO Complex
Lodhi Road
New Delhi-110 003

28 November, 2001

OFFICE ORDER

It has been felt that the water quality monitoring programmes of the concerned central and state agencies need to be reviewed for uniformity in the monitoring systems being followed by them and for the generation of reliable and reproducible data, based on which coordinated Action Plans could be drawn for protecting the quality of the national water resources.

2. Accordingly, the Government has decided to constitute an Expert Group with the following members:

1. Shri Arunoday Bhattacharjya — Chairman
Former Chairman
Central Pollution Control Board
E-006, Purvasha
Mayur Vihar, Phase I
Delhi-110 091, Tel. 275 3513 (R)

2. Dr. R. H. Siddiqi — Member
Former Professor
Aligarh Muslim University
Dar-e-Hasan
Dodhpur
Aligarh-202 001, Tel. 0571-702918, Fax 702758

3. Dr. R. Dalwani — Member
Additional Director
National River Conservation Directorate
Ministry of Environment and Forests
Paryavaran Bhawan
CGO Complex
Lodhi Road
New Delhi-110 003, Tel. 436 4789

4. Dr. S. D. Makhijani — Member
Additional Director
Central Pollution Control Board
Parivesh Bhavan
East Arjun Nagar
Delhi-110 032, Tel. 222 0844

5. Shri N. K. Verma — Member
Additional Director
Central Pollution Control Board
Parivesh Bhavan
East Arjun Nagar
Delhi-110 032, Tel. 222 6122

6. Dr. S. P. Chakrabarti — Member
Water Quality Expert
Hydrology Project
4th Floor, CSMRS-Building
Olof Palme Marg
Hauz Khas
New Delhi-110 016, Tel. 686 1681-84
Fax 686 1685

7. V. N. Wakpanjar — Member Convener
Sr. Jt. Commossioner (WM)
Ministry of Water Resources
B-Wing,2nd Floor
Lok Nayak Bhawan
Khan Market
New Delhi-110 003, Tel. 464 3918

3. The terms of reference of the Expert Group shall be as follows:

(i) Review the present status of the surface water and groundwater quality monitoring programmes of the concerned central and state agencies against the minimum basic need and identify the agencies falling short of the requirements.

(ii) Review the method of designing the monitoring network and recommend improvement, if needed.

(iii) Review the water sampling procedures in vogue and suggest modifications for representative sampling, field analysis of important parameters, sample preservation and transportation for detailed analysis in the chemical laboratory, and standardize analytical procedures.

(iv) Review the procedure of selection of parameters for examining the quality of water to meet the normal requirements of monitoring for Baseline, Trend and Flux or Surveillance stations.

(v) Review the requirements for different levels of laboratories for monitoring selective parameters

(vi) Suggest measures for quality assurance and quality control for the water quality monitoring laboratories.

(vii) Suggest a unified system of recording water quality data through a computerized method to facilitate data analysis and interpretation for dissemination of information.

4. The Expert Group shall be entitled to travelling and daily allowance as per the Government of India rules.

5. The Expert Group shall finalize their recommendations on or before 31 March 2002.

Sd/-
A. M. Gokhale
Addl. Secretary, MoEF &
Project Director, NRCD

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REPORT OF THE EXPERT GROUP ON MONITORING SYSTEMS FOR PROTECTING THE QUALITY OFTHE NATIONAL WATER RESOURCES

1 INTRODUCTION

1.1 Background

It needs no emphasis that our country's fresh water wealth is under serious threat from contamination due to discharge of untreated/partially treated municipal sewage and industrial trade effluents into rivers and lakes. The groundwater is also not being spared from this havoc. Indiscriminate disposal of municipal garbage and hazardous solid wastes in low-lying areas, without any protection against percolation of leachates to groundwater reserves, is a perpetual threat to the groundwater aquifer. There are many a legislation to prevent and control water pollution. But the infrastructure support available with the Central Pollution Control Board (CPCB) and the State Pollution Control Boards (SPCBs), for extensive monitoring of the quality of the natural water bodies for effective planning, is seldom adequate to implement the provisions embodied under various rules.

The resources of the pollution control agencies are apparently exhausted in containment of pollution generated from major industrial sources in view of the dimension of the problem. The mushrooming growth of small-scale polluting industrial sector adds to the problem as they still play truant to treat their effluents before discharge, obviously for lack of cleaner technological advancement and economic reasons. The scenario is going to persist, and the pollution level in natural water bodies is also not going to recede over-night. However, effective monitoring of water quality can influence containment of pollution through better understanding of the problem and devising appropriate solutions for better management.

The Central Pollution Control Board along with its counterpart Boards in the States is presently monitoring mainly the surface water quality in the main stems of the 14 major river basins at about 500 locations, while 44 medium rivers and 55 minor rivers are yet to be extensively monitored for quality of water. The groundwater quality is monitored by them only at limited locations.

The Central Water Commission (CWC) and the Central Ground Water Board (CGWB) / Central Ground Water Authority (CGWA) of the Ministry of Water Resources (MoWR) at the Centre, and the State Surface Water (SSW) and the State Groundwater (SGW) agencies, namely, the State Irrigation Departments / State Surface Water Development Agencies and the State Groundwater Resource Development Agencies, are responsible for the development of water resources in the Country. However, their main concern till the mid-nineteen nineties as to determine river flow / groundwater potential that could be harnessed with little emphasis on monitoring the quality of water to find the suitability of the water resources developed for irrigation and drinking. Pollution related parameters were not being monitored by these agencies. Moreover, these agencies had no legal mandate in clear terms to monitor the quality of water under any legislation. There is, therefore, an urgent need for extensive and intensive monitoring of surface water and groundwater quality to monitor suitability of our water resources to meet the quality requirements for various designated-best-uses of the resources as defined by the Central Pollution Control Board (CPCB).

1.2 Need for Co-ordination among the Monitoring Agencies for Water Quality Management

Water quality is being monitored by several agencies in the country. The CWC and the SSW agencies in respective States, while developing water resources through various projects are mainly concerned with the requirements for irrigation and drinking water in terms of quantity and quality (to some extent). The CGWB and the respective SGW agencies develop groundwater resources depending upon the recharge potential with the similar objective. The CPCB and the SPCBs are mainly concerned with the monitoring of water quality deterioration due to discharge of wastes and find ways and means for the prevention and control of pollution. The monitoring programmes seldom match among these agencies. The objectives of water quality monitoring being none too similar, the data so generated are not complimentary for the common cause of interpretation. Some sort of databases is maintained in each of these agencies, which stockpile and gather dust for the lack of computerisation with modern management systems. Thus, there is a strong need for the development of a unified water quality monitoring procedure and storage of data at the district level, state level and also at the national level, so that the water resources development agencies make use of the data for their individual programmes without duplication of effort in generating data and avoiding wasteful expenditure.

1.3 Constitution of the Water Quality Assessment Authority

In view of the multiplicity of agencies involved in water management in the country with no virtual co-ordination among them, the problem of pollution of national water resources has become a matter of serious concern. To circumvent the situation, the Ministry of Environment and Forests (MoEF), Government of India, has issued an *Extraordinary notification,* vide Notification No. S.O. 583(E), in the "The Gazette of India", dated 22 June 2001, constituting the "Water Quality Assessment Authority (WQAA)" with effect from 29 May 2001, Annexure I.

1.3.1 Functions of the WQAA

The Government of India, through the afore-mentioned Gazette notification on the constitution of WQAA, *inter alia* recognises the need for constitution of state level "Water Quality Review Committees", and the importance of water quality monitoring through an extensive network at national and state levels in the country. It further authorises the WQAA in standardising and unifying the process of monitoring. The notification also empowers the Authority to impose necessary action through issuance of direction to defaulting agencies for the protection of the quality of the water resources and maintaining discipline in water abstraction from and discharge into water bodies for sustenance of aquatic life forms, so essential for the natural process of self-purification.

The hydrological information including water quality data are envisaged to identify hot spots requiring immediate actions at several places in the country. The pollution control agencies will be assisted by the central and state water monitoring agencies in identifying such areas for priority actions in management of water quality and also in having a close watch.

1.4 Constitution of the State-level Water Quality Review Committees

In exercise of the powers conferred under sub-clause (m), Para-II of clause-2 of the above-mentioned notification, the Authority (WQAA), resolved in its first meeting held on 26 September 2002, for the constitution of the state-level Water Quality Review Committee (WQRC). Based on the recommendations of the WQAA, the National River Conservation Directorate (NRCD), Ministry of Environment and Forests, Government of India requested the State Governments for constitution of the Water Quality Review Committees (WQRC) in the respective states consisting of the following members with immediate effect until further orders:

1.	Secretary, Water Resources Department	Chairperson
2.	Chief Engineer, State Public Health Engineering Department	Member
3.	Director, State Agriculture Department	Member
4.	Member Secretary, State Pollution Control Board	Member
5.	Representative of the state agencies in-charge of the Data Processing Centre for surface water	Member
6.	Representative of the state agencies in-charge of the Data Processing Centre for groundwater	Member
7	Regional Director, Central Ground Water Board	Member
8.	Additional Director (D), National River Conservation Directorate, Ministry of Env. and Forests, New Delhi	Member
9.	Representative of an educational / research institution in the state or any other water quality data user agency	Member
10.	Senior Joint Commissioner-II, Ministry of Water Resources, New Delhi	Member
11.	Chief Engineer / Superintending Engineer, CWC (in the State)	Member Secretary

II. The scope of the State WQRC, whose role is mainly for co-ordination among the central and state agencies in the concerned state, will be as follows:

~ To review the WQ monitoring network in the respective region for optimisation in terms of location of stations, frequency of monitoring and choice of parameters;
~ To review the water quality data analysis and interpretation to identify problem areas, and developing Action Plan for improving quality on a sustainable basis.
~ To review / assess schemes launched/to be launched to improve quality of the water resources;
~ To identify hot-spots for surveillance monitoring
~ To promote R & D activities;
~ To share WQ data and provide assistance to member agencies in the management of the quality of the national water resources; and
~ Any other responsibility, as may be assigned to the WQRC by the Authority/ State Govt., in the context of quality of the national water resources

III. The Committee may examine and discuss specific WQ related tasks to be carried out and recommend the mode of executing such tasks (e.g. by constituting small task groups, using State or Central agency resources or by hiring WQ domain experts).

IV. The Committees shall submit Quarterly Reports every three months to the WQAA commencing from April 2002, so that the same may be reflected in the Annual Report of the Authority.

V. The WQRC may evolve its own procedures for carrying out the above.

1.5 Constitution of the Expert Group on Water Quality Monitoring

Based on the recommendations of the Water Quality Assessment Authority, in its first meeting, held on 26 September 2001, the Central Government decided that the water quality monitoring programme of the concerned Central and State agencies need to be reviewed for uniformity in the monitoring systems for the generation of reliable and reproducible data, based on which co-ordinated Action Plans could be drawn for protecting the quality of the national water resources. Accordingly, the Government decided to constitute an Expert Group with the following as members:

Shri Arunoday Bhattacharjya Former Chairman Central Pollution Control Board E-006, Purvasha Mayur Vihar, Phase I Delhi-110 091 Tel.: 275 3513 (R)	Chairman
Dr. R. H. Siddiqi Former Professor Aligarh Muslim University Dar-e-Hasan, Dodhpur Aligarh-202 001 Tel.: 0571-702918 Fax: 702758	Member
Dr. R. Dalwani Additional Director National River Conservation Directorate Ministry of Environment and Forests Paryavaran Bhawan CGO Complex Lodhi Road New Delhi-110 003 Tel.: 436 4789	Member
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Shri N. K. Verma — Member
Additional Director
Central Pollution Control Board
Parivesh Bhavan
East Arjun Nagar
Delhi-110 032
Tel.: 222 6122

Dr. S. P. Chakrabarti — Member
Water Quality Expert
Hydrology Project
4th Floor, CSMRS-Building
Olof Palme Marg
Hauz Khas
New Delhi-110 016
Tel.: 686 1681-84 (4 lines)
Fax: 686 1685

V. N. Wakpanjar — Member Convener
Senior Joint Commossioner (WM)
Ministry of Water Resources
B-Wing, 2nd Floor
Lok Nayak Bhawan
Khan Market
New Delhi-110 003
Tel.: 464 3918
Fax: 4652459, 469 4752

2 TERMS OF REFERENCE OF THE EXPERT GROUP

The terms of reference of the Expert Group as assigned by the National River Conservation Directorate, Ministry of Environment and Forests, Government of India are as follows:

(i) Review the present status of the surface water and groundwater quality monitoring programmes of the concerned central and state agencies against the minimum basic need and identify the agencies falling short of the requirements.

(ii) Review the method of designing the monitoring network and recommend improvement, if needed.

(iii) Review the water sampling procedures in vogue and suggest modifications for representative sampling, field analysis of important parameters, sample preservation and transportation for detailed analysis in the chemical laboratory, and standardise analytical procedures.

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(vi) Suggest measures for quality assurance and quality control for the water quality monitoring laboratories.

(vii) Suggest a unified system of recording water quality data through a computerised method to facilitate data analysis and interpretation for dissemination of information.

The Expert Group shall finalize their recommendations on or before 31 March 2002.

3 REVIEW OF PRESENT STATUS OF WATER QUALITY MONITORING IN INDIA

In India, water quality monitoring is being carried out historically for a number of reasons. Different organizations have been and are currently operating networks to satisfy their own particular objectives:

- Central & State Pollution Control Boards (CPCB, SPCBs)
- Central Water Commission & State Surface Water departments (CWC, SSWD)
- Central Ground Water Board & State Ground Water departments (CGWB, SGWD)
- National River Conservation Directorate (NRCD)
- Research Institutions (e.g., NEERI)
- Others (Academic Institutions, State Public Health and Environmental Departments (PHED), Water Supply and Sewerage Boards (WSSB) etc.

Mandates and objectives of the water quality monitoring activities of these organisations are summarised in Tables 3.1 and 3.2. Information regarding programmes of water quality monitoring of these agencies are given in various sections below.

Table 3.1 Mandates of various organisations involved in water quality monitoring

Mandates	CWC & SSWD	NRCD	CGWB & SGWD	Central & State PCB	WSSB
Monitoring (directly or through sponsored studies) of water quality and subsequent assessment	✓ assessment of water re-sources, implying quality	✓	✓	✓	✓
Storage and processing of water quality data	✓	✓	✓	✓	✓
Management / control of pollution		✓		✓	
Dissemination of water quality information /mass awareness	✓ upon request , official use	✓ restricted	✓ upon request, official use	✓	✓
Imparting training in water quality management to target groups				✓	✓

Table 3.2 Monitoring Objectives of various organisations involved in water quality monitoring

Objectives	CWC & SSWD	NRCD	CPCB & SPCBs	CGWB & SGWD	WSSB
Estimation of natural background or baseline concentrations	✓	✓	✓	✓	✓
Estimation of trends in quality changes due to anthropogenic or other influences	✓	✓	✓	✓	✓
Routine evaluation of fitness of water for its designated use (specify the uses addressed)	✓ irriga-tion	✓ various	✓ various	✓ irrigation, drinking	✓ drinking
Provide warnings of potentially deleterious changes for specific use			✓	✓	✓
Check effects of effluent discharges for compliance or charging			✓		
Characterisation/ Classification of water bodies			✓	✓	
Specific investigations and corrective measures		✓	✓	✓	✓

Prior to the Hydrology Project (see chapter 3.6), State Surface Water Departments in many states were not involved in routine water quality monitoring. Under the Hydrology Project, these state departments have started water quality monitoring activities.

3.1 CENTRAL POLLUTION CONTROL BOARD[1]

The Water (Prevention and Control of Pollution) Act, 1974, was passed for restoration and maintenance of wholesomeness and cleanliness of national aquatic resources. The Central Pollution Control Board (CPCB) was constituted in September 1974 as part of the Ministry of Environment an Forests. Since the parliament has no powers to make laws for the states, all the Houses of Legislature of 25 states of the Union of India adopted the Act and respective State Pollution Control Boards (SPCBs) were formed. For Union Territories (UT), the Central Board initially exercised the powers and performed the functions of pollution control. Later, for each UT, pollution control committees were formed and the functions and powers of the Central Board were delegated to the respective committee.

In order to have stringent environmental policies and new laws, the Environment (Protection) Act, 1986, was enacted. The Act empowered the Central Government to take all necessary measures to protect and improve the environment. Under this Act, the 'environment' is defined to include air, water and land, and the inter-relationship, which exists among and

[1] Extracted from ' Water Quality Monitoring, the Indian Experience' Assessment and Development Studies of River Basins Series: ADSORBS/12/1984-85, CPCB and 'Pollution Control Acts, Rules and Notifications Issued Thereunder', September 1997, CPCB

between the biotic and abiotic components. Its functions, in relation to objective of prevention and control of pollution of water environment and to maintain and restore wholesomeness of water, can be summarized as:

- Advise Central and State governments with respect to location of any industry, which is likely to pollute a stream or ground water.
- Advise Central Government on restriction of areas in which certain types of activity shall not be carried out or shall be carried out subject to prescribed safeguards.
- Lay down standards for treatment of municipal and industrial wastewaters and the treated effluents.
- Co-ordinate activities of State Pollution Control Boards and provide technical assistance where necessary.
- Sponsor investigation and research.
- Organise training and awareness programmes.
- Plan and cause to be executed nation-wide programmes on pollution control.

3.1.1 Water quality monitoring network

Water quality monitoring is one of the important activities of CPCB. It helps in the identification of water bodies, which are in need of quality improvement. It also helps in formulation of national pollution control programmes.

National water quality monitoring programme was initiated by CPCB in 1977, when under 'Global Environmental Monitoring System (GEMS)', 24 surface water and 11 groundwater stations were selected for monitoring.

Parallel to GEMS, a national programme of Monitoring of Indian National Aquatic Resources (MINARS), was started in 1984; with a total of 113 stations spread over 10 river basins.

The CPCB is monitoring the water quality of the river Yamuna, a tributary to the Ganga, under the Yamuna Action Plan (YAP) of the NRCD to observe the effectiveness of the various action programmes launched for improving the quality.

Presently the inland water quality monitoring network is operated under a three-tier programme:

Monitoring Programme	Number of Stations
GEMS	50
MINARS	430
YAP	27
Total	507

Out of these 507 stations, 444 are on rivers and canals, 38 on lakes and creeks, and 25 are groundwater stations. Samples are analysed for 24 parameters on monthly to quarterly basis.

The stations operated by the respective State Pollution Control Boards (SPCBs) are mostly to monitor the effect of specific waste discharges and to evaluate the impact of water pollution control programmes. The water quality data are reported in Water Quality Statistics yearbooks.

3.1.2 Approach to Pollution Control

The basic objective of Environment Protection Act is to maintain and restore the wholesomeness of water by prevention and control of water pollution. The act does not define 'wholesomeness'. Taking a pragmatic approach, the Board has identified predominant uses, calling them designated best use, of different water bodies or stretches of river and also defined water quality criteria for different uses of water. These criteria are given in Table 3.3. Based on the monitoring data, the existing water quality is compared with the water quality objective defined by criteria for the designated-best-uses. Where the designated-best-use requires better quality water than what exists, an Action Plan is prepared for maintenance of the use. The Ganga Action Plan was the first such plan. Now the NRCD, Ministry of Environment & Forests, has prepared other National River Action Plans also.

Table 3.3 Primary water quality criteria for various uses of fresh water

Designated-best-use	**Class**	**Criteria**
Drinking water source without conventional treatment but after disinfection	A	Total coliform organisms (MPN/100mL) shall be 50 or less, pH between 6.5 and 8.5, Dissolved oxygen 6 mg/L or more, and Biochemical oxygen demand 2 mg/L or less
Outdoor bathing (organised)	B	Total coliform organisms (MPN/100mL) shall be 500 or less, pH between 6.5 and 8.5, Dissolved oxygen 5 mg/L or more, and 4. Biochemical oxygen demand 3 mg/L or less
Drinking water source with conventional treatment followed by disinfection	C	Total coliform organisms (MPN/100mL) shall be 5000 or less, pH between 6 and 9, Dissolved oxygen 4 mg/L or more, and Biochemical oxygen demand 3 mg/L or less
Propagation of wild life, fisheries	D	pH between 6.5 and 8.5, Dissolved oxygen 4 mg/L or more, and Free ammonia (as N) 1.2 mg/L or less
Irrigation, industrial cooling, controlled waste disposal	E	pH between 6.0 and 8.5, Electrical conductivity less than 2250 micro mhos/cm, Sodium absorption ratio less than 26, and Boron less than 2mg/L

3.2 National River Conservation Directorate[2]

Surveys carried out by the Central Pollution Control Board indicated that large stretches of many of the Indian rivers were grossly polluted, particularly from municipal wastewaters. While the rules and regulations under the Environment (Protection) Act, 1986 could be applied to industrial establishments, their enforcement for the municipal discharges was not feasible, as the municipalities do not have sufficient resources to undertake large scale sewerage and sewage treatment works.

The Ganga Action Plan (GAP) was started in 1985 as a 100% centrally funded scheme to restore the water quality of River Ganga to the bathing class. To accomplish this task, pollution abatement works related to 29 Class I towns in Uttar Pradesh, Bihar and West Bengal, located on the riverbanks, were undertaken. Later in 1991, important tributaries of River Ganga were also included in the Action Plan. In 1994 the GAP model with suitable modifications was extended to the national level through a National River Conservation Plan (NRCP) and the Ganga Project Directorate was renamed as the National River Conservation Directorate (NRCD).

3.2.1 Water quality monitoring

NRCD is contracting with various organisations in the country such as CPCB, SPCBs and academic institutions to measure water quality of river stretches where it has taken up pollution abatement schemes. So far the major monitoring thrust has been in the Gangetic basin. With schemes being taken up on other rivers, the monitoring programme of the Directorate is also extending.

The objective of the monitoring programme is to establish the water quality in the rivers before the schemes are taken up and then compare it with the quality as the implementation of scheme progresses in order to check the efficacy of the actions taken. The stations are usually closely spaced downstream of cities and wastewater out falls. The stations may be classified as surveillance type for pollution monitoring. The water is analyzed mainly for pollution related parameters, BOD, DO and coliforms. At some places analysis for heavy metals is also included.

3.3 Central Water Commission

Being the apex national body for development of water resources in the country, its mandate is assessment of water resources in general. This would include the following objectives in regard to water quality monitoring:

- Establishment of baseline water quality
- Assessment of suitability of water for various uses, particularly for irrigation
- Detection of trends in water quality changes.
- Dissemination of water quality information upon request.

[2]Extracted from 'National River Action Plan' 1994 and 'Status Paper on River Action Plans' 1998 Ministry of Environment & Forests, GOI, New Delhi

CWC has, however, no mandate with respect to managerial measures, like informing the public, checking discharges for compliance with regulations or corrective measures. quality data collected are not used for data analysis and presentation other than tabular listings in the yearbooks.

3.3.1 Water quality monitoring network

The CWC has a national network of hydrological observations in all the major river basins of the country. It is operating 570 gauge discharge observation stations in the 12 basins or zones. Table 3.4 lists numbers of the stations on the peninsular rivers. It is seen that out of 295 stations, water quality measurements are carried out at 146 stations.

Table 3.4 CWC operated hydrological observation stations[3]

S. No.	State	GD	GDS	Total	WQ
1	Andhra Pradesh	26	14	40	19
2	Bihar	1	3	4	3
3	Daman	1	-	1	1
4	Gujarat	12	10	22	11
5	Goa	2	-	2	2
6	Karnataka	22	15	37	19
7	Kerala	6	13	19	13
8	Maharashtra	45	22	67	24
9	Madhya Pradesh & Chhattisgarh	27	24	51	24
10	Orissa	8	12	20	12
11	Rajasthan	9	2	11	2
12	Tamil Nadu	13	8	21	16
	Total	172	123	295	146

GD – gauge discharge
GDS – gauge discharge & silt
WQ – water quality (including gauge discharge)

3.3.1 Water Quality Monitoring Network

The CWC has been involved in surface water quality monitoring since 1972. It operates level I, II and III laboratories in the country. The samples are collected from rivers and adjacent groundwater wells through the level I site-laboratories (located at a limited number of gauging sites), where *in situ* parameters (T, pH, EC and DO) are determined. Remaining parameters are determined in the level II and II$^+$ laboratories. At a few locations pollution related parameters, like BOD and coliforms, are also measured.

[3] source: GOI, Central Water Commission, River Data Directorate, New Delhi, April 1992

CWC has established 23 level II laboratories in the country, which monitor 25 parameters, and 4 level III laboratories, which are to monitor 45 parameters. However, the infrastructure facilities are not adequate to analyze all the parameters.

Sampling frequency ranges from once to three times a month. So far surface water pollution with respect to toxic metals and organic micro pollutants has not received attention.

The results of the monitoring programme are computerised in the regional offices in different packages (spreadsheet or word processor). Annual reports (in tabular form only) are produced and contain monthly averaged data, not the original measurements.

3.4 Central Ground Water Board and State Ground Water Departments

Development of groundwater is the major task of the CGWB and SSW Departments. To keep a watch on the groundwater quality situation in different parts of the country, the CGWB, the national apex organization, has set up a national network of observation wells, and is monitoring water level and water quality of these observation wells. Recently the CGWB is also given the responsibility of controlling pollution and over-exploitation of groundwater in the country under the provision of the Environment (Protection) Act, 1986 notified by the Ministry of Environment and Forests, Govt. of India.

The basic objectives of CGWB for groundwater quality monitoring can be listed as follows:

- Provide background data against which future changes can be assessed
- To trace the slow and rapid water quality degradation processes
- To check compliance with the standards for designated best use" under EPA, 1986
- To re-construct water and solute development history
- To identify anomalous concentrations of natural and man-made pollutants
- To characterise aquifer including tracing of flow direction and mixing process

3.4.1 Water Quality Monitoring Network

At national level, the Ground Water Division of the Geological Survey of India established a network of observation wells and commenced monitoring water level and water quality in 1969. As originally established the number of wells stood at 410, the criteria being one well for every degree sheet, covering about 11,600 sq km. The CGWB was created in 1972 and the task of water level recording was transferred to it. Over the years the network has been extended greatly. Presently the CGWB has about 14,965 wells spread all over the country. The state-wise distribution of these wells is given in Table 3.5. The SGW departments have mandates similar to those of the CGWB. The State agencies have their own water level and quality monitoring network. There are about 32,826 hydro-graph network stations in 28 states of the country.

Table 3.5 CGWB Network of Observation Wells

S. No.	State	No. of Observation / WQ Wells	No. of Observation / WQ wells of State agencies
1	Andhra Pradesh	1,042	3,118
2	Arunachal Pradesh	17	-
3	Assam	371	170
4	Bihar and Jharkhand	599	586
5	Gujarat	974	2,480
6	Goa	53	-
7	Haryana	521	2,282
8	Himachal Pradesh	78	750
9	Jammu & Kashmir	162	-
10	Karnataka	1,349	1,539
11	Kerala	651	206
12	Madhya Pradesh & Chhattisgarh	1,350	4,450
13	Maharastra	1,409	3,217
14	Manipur	25	-
15	Meghalaya	37	-
16	Mizorum	-	-
17	Nagaland	8	-
18	Orissa	1,122	105
19	Punjab	497	361
20	Rajasthan	1,414	6,248
21	Sikkim	-	-
22	Tamil Nadu	766	2,500
23	Tripura	37	-
24	Uttar Pradesh & Uttaranchal	1,514	3,600
25	West Bengal	836	1,214
Total		14,965	32,826

Presently the water quality data are collected mostly with respect to major ions and salinity. The main water quality issues are not addressed adequately in the programme.

The frequency of sampling of these stations is generally once/twice a year (pre-monsoon / pre- and post-monsoon). The data generated are being used for groundwater resource quality evaluation and to show the changes in ground water level.

3.5 Other Organisations

Other organisations, which are interested in water quality measurements, include:

- Academic Institutions
- National and State Research Organisations
- Central Public Health and Environmental Engineering Organisation (CPHEEO)
- State Health Departments
- State Public Health Engineering Departments
- Municipalities

¤ Water Supply and Sewerage Boards (WSSB)

The above-named first two organisations usually do not conduct long term monitoring. They take up surveys for research studies or investigation of water quality management problems. The remaining organisations carry out water quality surveillance on a regular basis, usually with use related objectives. Monitoring of raw and treated water for drinking water supply is the major reason.

3.6 Recent Developments in Water Quality Monitoring under the Hydrology Project

3.6.1 General

The Ministry of Water Resources, Government of India, has recently initiated development of a Hydrological Information System (HIS) for the peninsular part of India to start with, deriving financial assistance from the World Bank and the technical assistance from the Government of The Netherlands under the Hydrology Project (HP). The HIS includes collection, collation and interpretation of hydro-meteorological, hydro-geological and hydrological data (both quantity and quality) through state-of-the-art technology. Developmental features of the programme are described in the following paragraphs and also in the HP publications listed under Bibliography.

3.6.2 Improved Water Quality Monitoring Network

Under the HP, upgradation of existing Water Quality Monitoring Systems (WQMS) of the Central and the State agencies have been taken up. In States, which did not have such programmes earlier, water quality monitoring networks have been designed and data collection has been initiated.

In the nine peninsular States, 675 surface water and 29,036 groundwater monitoring locations have been finalised under the Central and State agencies. The stations are categorised as *Baseline*, *Trend* and *Flux/Surveillance* stations based on the guidelines of the World Health Organisation. Location maps for each surface water station have been prepared to pin-point representative sampling sites. Frequency of sampling and water quality parameters to be analysed for each categories of stations have been defined and documented as a "*Protocol for Water Quality Monitoring*", to unify the monitoring procedure of all the participating agencies for reliable/comparable results.

3.6.3 Laboratory development

A three-tier system of 291 laboratories has been established. 217 Level I laboratories monitor six field parameters at the site of sampling. For analyses of remaining parameters, samples are sent to 53 level II or 21 Level II+ laboratories with the addition of preservatives and proper storage. Level II laboratories analyse physico-chemical and microbiological parameters, while the level II+ laboratories additionally analyse heavy metals and pesticides.

3.6.4 Instrumentation in water quality analysis

Technical assistance has been provided in evolving specifications for the state-of-the-art instruments necessary for water quality analyses to facilitate the user agencies in procurement of the instruments. This would reduce variability in analytical observations in terms of sensitivity and accuracy. Advanced level instruments, like UV-visible spectrophotometer, Atomic absorption spectrophotometer (AAS) and Gas chromatographs (GC) have been provided in the level II and level II^+ laboratories to facilitate analysis of pollution related parameters including toxicants, like trace metals and pesticides.

3.6.5 Analytical Procedure

Out of the methods available, the most preferred procedure for analyses of various identified parameters have been identified and documented as "*Guidelines on Standard Analytical Procedures for Water Analysis*", May 1999 with illustrations/examples and sample calculations as guidelines for the reference of the laboratory chemists as a ready-reckoner.

3.6.6 Analytical Quality Control

In view of the multiplicity of the water quality monitoring agencies and the large number of analytical laboratories participating in the pregramme of sampling and analysis, it is imperative to conduct Analytical Quality Control (AQC) exercises for reliability and reproducibility of data. Technical assistance has been provided through conducting a two-tier system of AQC viz. "Within-laboratory" and "Inter-laboratory" exercises. While the first exercise is a routine exercise of the laboratory to be conducted regularly to check precision and to gain confidence in analysis, the latter provides the opportunity to test the analytical skills of the chemists and the method of accuracy in comparison to other participating laboratories. Two control laboratories (level II^+) from within the HP laboratories, namely the CWC laboratory, Hyderabad, and the CGWB laboratory, Bhopal, have been identified for conducting the inter-laboratory AQC for the surface water and the groundwater laboratories respectively. A software has been developed for the data analysis of the Inter-laboratory AQC-exercises to evaluate performances of the participating laboratories

Two-rounds of "Within Laboratory" AQC and three annual rounds of "Inter-laboratory" AQC exercises conducted among the participating laboratories showed marked improvement in the generation of quality data.

3.6.7 Software Development for Water Quality Data Entry System

Software has been developed for water quality data entry system (WQDES) as a part of SWDES/GWDES. The software also validates the data and provides the facility for graphical presentation of data with inter-parametric correlationships in a user-friendly manner. The software is being used by the participating agencies and also can be made available to other user agencies

3.6.8 Human Resource Development through "Training of Trainers"

Since the number of laboratory chemists are too large to be trained, the concept of "Training of Trainers (ToT)" has been introduced to train a nucleus of well-qualified chemists who will act as Trainers to train their fellow colleagues. Hands-on training has been imparted to the 'ToT's, with particular reference to analyses of pollution related parameters.

Hands-on training of laboratory chemists have been held to promote use of modern instruments in water quality analysis. Self-coaching documents for use of AAS and GC by the laboratory personnel have also been brought out and published.

Fifty Training Modules have been developed for the training of Trainers, covering theoretical and practical aspects of sampling, chemical analysis, instrumentation, good laboratory management practices including analytical quality control, data analysis and interpretation techniques etc. These modules also contain overhead transparency material for projection during training programmes, so that the programme is uniformly delivered among all the monitoring agencies. The lists of the training modules and other publications of the HP are enclosed.

Hands-on training of Trainers have been held on the use of WQDES with real world field data to familiarise them with the various graphic applications it could provide to facilitate interpretation of data.

3.6.9 Requirement of a Sustainable Water Quality Monitoring and Assessment Programme

The Hydrology Project of the Ministry of Water Resources is being executed in eight states viz. Andhra Pradesh, Chattishgarh, Gujarat, Karnataka, Kerala, Madhya Pradesh, Maharashtra, Orissa and Tamil Nadu . The project duration is six years, ending in 2002 with possible extension for a year. Benefits of such an extensive programme need to be utilised for other states of the country to unify the process of water quality monitoring.

4 WATER QUALITY AND MONITORING

4.1 General

The term 'water quality' is generally used to express the physical, chemical or biological state of water. This, in turn, may be related to the suitability of water for a particular use or purpose.

The quality of water is characterized by a range of physical, chemical and biological parameters, which may change due to a variety of natural and human influences. The International Standards Organisation (ISO) defines monitoring as follows:

'The programmed process of sampling, measurement and subsequent recording or signalling, or both, of various water characteristics, often with the aim of assessing conformity to specified objectives.'

A systematic plan for conducting water quality monitoring is called a 'monitoring programme' for which a manual is necessary for observance of the procedure. This manual supplies the technical aspects of the design of a monitoring programme that aims at generating water quality data that is justified, complete and accurate. Figure 4.1 shows the relevant components of a water quality monitoring programme and the division into

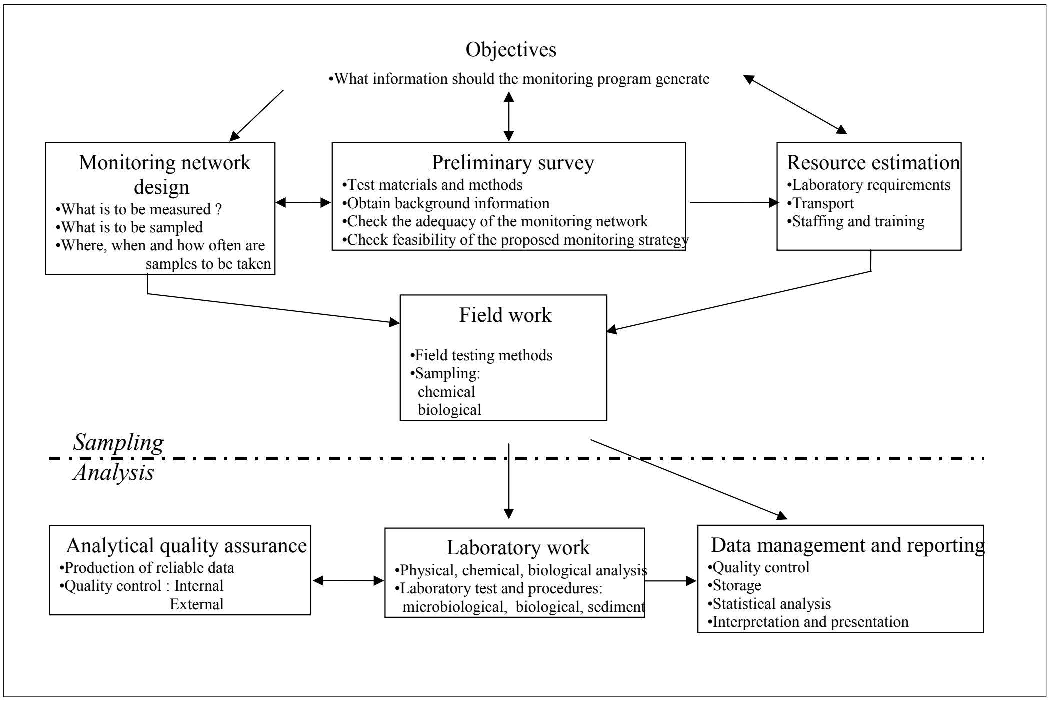

Figure 4.1 Elements of a water quality monitoring programme

4.2 The Monitoring Cycle

The process of water quality monitoring should principally be seen as a sequence of related activities that starts with the definition of information needs, and ends with the use of the information product. This sequence of activities is linked in a cycle, which is called the 'monitoring cycle', as shown in Figure 4.2. In developing water quality monitoring programmes, all stages of the monitoring process should be considered. Each of the above-mentioned steps is briefly described below:

1. **Water management:** The need for information should be based on the main issues or problems in management of water, and the active use of information in the decision-making process. Water management should consider the functions/use of a water system, the problems and threats to the water system and the possible measures that can be taken to manage the water system.

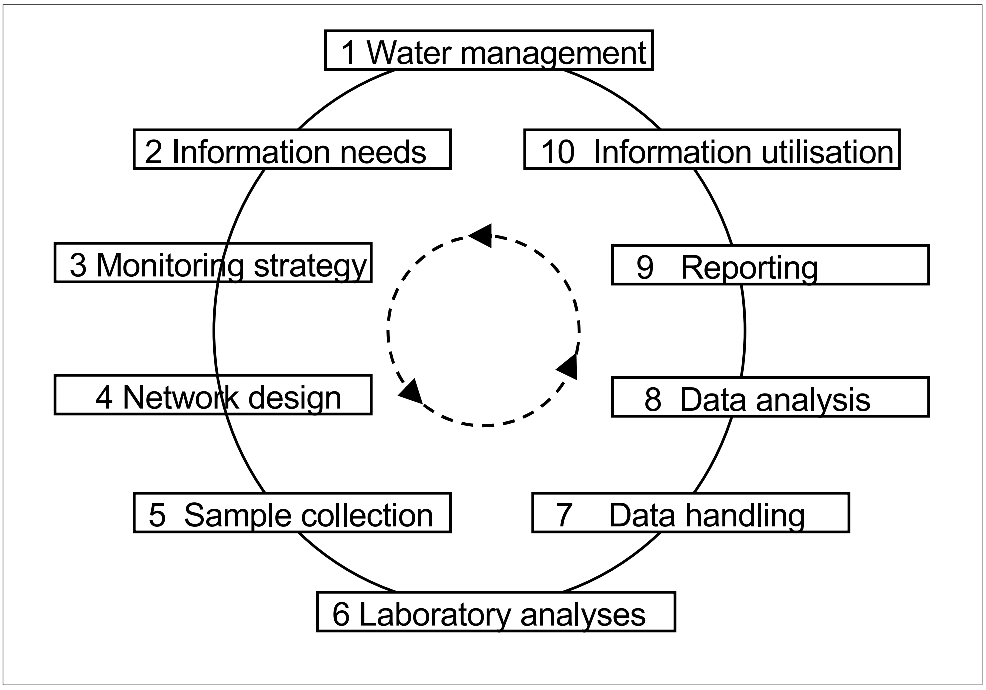

Figure 4.2 The Monitoring Cycle[4]

2. **Information needs:** *The most critical step* in having a successful water quality monitoring programme is to have a clear definition and specification of the monitoring objectives and information needs for water management. Information needs and monitoring objectives need to be specified so that the following steps in the monitoring cycle can logically follow.
3. **Monitoring strategy:** After the specification of the information needs, a monitoring strategy is required to design and operate the monitoring programme in such a way

[4] from UN/ECE Task Force on Monitoring and Assessment: Guidelines on Water-Quality Monitoring and Assessment of Transboundary Rivers

that the desired information is obtained. The strategy defines the approach and the criteria needed for a proper design of the monitoring programme.

4. **Network Design:** The design of the monitoring network includes the selection of sampling locations, parameters, and sampling frequency.
5. **Sample Collection:** Sample collection refers to going to the field and collecting the water samples to be analysed for water quality parameters. Samples are collected at the sampling locations and with the sampling frequency as specified in the network design. Some simple 'field analyses' are conducted at the time of sample collection.
6. **Laboratory Analysis:** The majority of samples collected in the field are brought to a chemical laboratory for analysis of various water quality parameters. The parameters to be analysed are according to the specifications in the network design.
7. **Data Handling:** The results of the field and laboratory analyses are entered into a data handling system.
8. **Data Analysis:** In this step, the collected data have to be analysed, keeping in mind the information needs and objectives of the monitoring programme (as defined in step 2). Data analysis should provide information (i.e. transform data to information) which is relevant to the water managers who need the information.
9. **Reporting:** In this step, the results of the data analysis are reported to the water managers and other who want and need the water quality information. Reporting is typically done via a written report, but can also presented by a newsletter, or electronically (with internet), or as a presentation.
10. **Information Utilisation:** The water managers who receive the information from the monitoring programme via the report(s) can then act upon this information. For example, measures could be taken to address identified problems.

4.3 Management Issues for Water Quality Monitoring

Using the monitoring cycle as the basis for water quality monitoring, the first step is the identification of the water quality management issues (Figure 4.2).
Contamination of water is certainly one of the key issues, as it can prevent water for being used for its intended purpose. Contamination can enter the water bodies through one or more of the following ways:

- Direct point sources: Transfer of pollutants from municipal - industrial liquid waste disposal sites and from municipal and household hazardous waste and refuse disposal sites.
- Diffused agricultural sources: Wash off and soil erosion from agricultural lands carrying materials applied during agricultural use, mainly fertilisers, herbicides and pesticides.
- Diffused urban sources: Run off from city streets, from horticultural, gardening and commercial activities in the urban environment and from industrial sites and storage areas.
- Change in the hydraulic regime of a water system due to excessive water abstraction, construction of developmental works etc.

Contamination by faecal and organic matter

In India, faecal contamination is still the primary water quality issue for both surface and ground waters. Although this applies to both rural and urban areas, the situation is probably more critical in fast-growing cities. Faecal contamination is a source of pathogenic organisms responsible for water borne diseases. It affects the use of water for drinking water source or bathing water, as well as ecological health of the river.

The release of untreated domestic or industrial wastes high in organic mater into rivers results in a marked decline in oxygen concentration (sometimes resulting in anaerobic conditions) and a rise in ammonia and nitrogen concentrations downstream of the effluent input. The most obvious effect of the release of organic matter along the length of the river is the depletion of oxygen downstream of the discharge. Industrial activities, which discharge large organic loads, include pulp and paper production and food processing.

Toxic pollutants: Organics and Heavy Metals

Organic pollutants (mostly chemicals manufactured artificially by man) are also becoming an important water quality issue. They enter water bodies through:

- Point-sources directly from sewers and effluent discharges (domestic, urban and industrial sources)
- Diffused-sources from the leaching of solid and liquid waste dumps or agricultural land run-off
- Indirect-sources in the form of long-range atmospheric transport and deposition

Uncontrolled discharge of industrial wastewaters often causes pollution due to toxic metals. Other sources of metal pollution are leachates from urban solid waste landfills and mining waste dumps.

The processes of bioaccumulation and bio-magnification are extremely important in the distribution of toxic substances (discharged in waste effluents) in fresh water ecosystems. The concentration of pollutants within the organism due to bio-accumulation and bio-magnification depends on the duration of exposure of the organism to the contaminated environment and its trophic level in the food chain. Several fold increases in trace contaminant concentrations have been commonly observed in lakes and estuarine environments.

Salinisation

Increased mineral salts in rivers may arise from several sources:

- pollution by mining wastewaters
- pollution by certain industrial wastewaters
- increased evaporation in the river basin (mainly in arid and semi-arid regions)
- surface wash-off/irrigation run-off

Industrial and mining waste pollution results in increase in specific ions. Evaporation, however, increases the concentration of all ions.

Contamination from Agrochemicals

Agricultural land use and cultivation practices have been shown to exert major influences on both surface water and groundwater quality. Of particular concern, in India, is the leaching of fertilizer chemicals (e.g., nitrate) and pesticides from regular, intensive cultivation of crops. These cultivation practices affect surface waters and relatively shallow unconfined aquifers, both of which are used for potable supply.

Little attention has been given in this country to the leaching of pesticides from agricultural land in spite of the dramatic increase in the use of pesticide formulations over the last years. There are currently few laboratories with the capability of analysing pesticides.

Mining Activities

A range of surface water and groundwater pollution problems can be associated with mining activities. The nature of the pollution depends on the materials being excavated and extracted. Both surface and underground mines usually extend below the water table and often de-watering is required to allow mining to proceed. The water pumped, either directly from the mine or from specially constructed bore holes, may be highly mineralised and its usual characteristics include low pH (down to pH 3) and high levels of iron, aluminium and sulphate. Disposal of this mine drainage effluent to surface water or groundwater can cause serious impacts on water quality for all uses. Pollution of surface and groundwater can also result from the leaching of mine tailings and from settling ponds and can, therefore, be associated with both present and past mining activity.

Eutrophication

Simply speaking, eutrophication is the biological response to excess nutrient input to surface water bodies. The production of bio-mass and its death and decay results in a number of effects, which individually and collectively result in impaired water use. The most important of these effects are decreased dissolved oxygen levels, release of odorous gas (e.g. H_2S) and siltation. These factors individually and also collectively have an adverse effect on the aquatic life.

5 MONITORING OBJECTIVES

The most *critical* step after identification of the water quality management issues is the definition of monitoring objectives and specific of information needs:

- o what is the purpose or objective of the water quality monitoring programme?
- o what water quality information do the water managers want and need to have?

The above questions are fundamental - there is no point in monitoring surface water or effluent quality unless the objectives of the programme and, hence, what will be done with the resulting data, are clearly defined. Definition of the programme's objectives, and providing answers to the above questions, prior to planning the sampling exercises will ensure that the correct conclusions regarding sampling locations, number of samples, selection of analytical parameters and sampling frequency are reached.

Normally samples of effluents and water bodies are taken with one or more of the following 'global objectives' in mind:

a) to build up an overall picture of the aquatic environment thus enabling pollution cause and effect to be judged
b) to provide long-term background data against which future changes can be assessed
c) to detect trends
d) to provide warnings of potentially deleterious changes
e) to check for compliance of permitsor for charging purposes
f) to precisely characterise an effluent or a water body (possibly to enable classification to be carried out)
g) to investigate pollution
h) to collect sufficient data to perform in-depth analysis (e. g. mathematical modelling) or to allow research to be carried out

These global objectives can also be considered under the following three separate categories of sampling:

- ¤ **Monitoring:** long-term standardised measurements in order to define status or trends (i.e. a, b and c above)

- ¤ **Surveillance:** continuous specific measurements for the purpose of water quality management and operational activities (i.e. d and e above)

- ¤ **Survey:** a finite duration, intensive programme to measure for a specific purpose (i.e. f, g and h above)

These three basic sampling categories can be further split into a number of sample types, each of which has a specific objective. The sample categories, types and their associated objectives are described in Table 5.1.

Table 5.1 Water Quality Monitoring Objectives for different monitoring categories

Category	Type	Objectives
Monitoring	Baseline	- Natural Background Concentrations
	Trend	- Detection of changes over time due to anthropogenic influences
	Flux	- Calculation of load
Surveillance	Water Use	- Check that water is fit for use
	Pollution Control	- Check effects of discharges - Check water quality standards
Survey	Classification	- Classification of reach
	Management and Research	- Investigation of pollution and need for corrective measures - Special Interest - Filling in knowledge gaps

6 NETWORK DESIGN

This chapter briefly describes the three important aspects of a water quality monitoring network design, namely location and density of monitoring stations, frequency of monitoring and parameters of water quality. Complementing details are available in the Chapter titled 'Recommended Protocol for Water Quality Monitoring'.

6.1 Surface Water Network

Tables 6.1 to 6.4 summarise the design information for streams. Where the flow in ariver changes significantly in different seasons, the sampling frequency given in Table 6.1 should be modified. For example, for seasonal rivers the sampling frequency may be atleast once a month for baseline stations.

It may be noted that ideally a sampling location should be located at a river gauging site, but this is not necessarily always so. The sampling locations or the stations, as referred in this chapter, indicate the approximate vicinity where a sample is to be collected, the exact position is referred to as 'site' and is further discussed in Chapter 7.

It is important to remember that the parameters suggested in Tables 6.2 and 6.3 represent a minimum suite of parameters for each sample type. This is to maintain a sensible balance between the desire for more information and analytical costs. It should be noted, however, that some potentially important parameters may not have been included in the programme (e.g., certain heavy metals). Some research effort should be directed towards ascertaining whether or not certain pollutants, which are not routinely covered by the programme, are present in unacceptable concentrations. Pollutants, which could usefully be subjected to this type of investigation, are:

¤ heavy metals, such as lead, copper, nickel, arsenic, chromium
¤ organic pollutants such as polychlorinated biphenyls (PCBs) and certain types of pesticide (e.g., DDT)
¤ certain organic solvents
¤ oils and hydrocarbons

If any of the above, or other parameters are discovered in unacceptable concentrations at a sampling location, then the concerned pollutant(s) should be added to the parameter list for that sampling point. Frequency of the parameters analytical determination will then depend on the polluting nature of the substance and its concentration in the river.

Monitoring

Baseline: This type, 'baseline' monitoring, is designed to build up a picture of the 'natural' (i.e., before the influence of pollution by man) background conditions of a particular watercourse or river basin.

Table 6.1 Water Quality Monitoring Objectives, Network Densities and Sampling Frequencies

Category	Type	Objective	Network Density	Sampling Frequency (per year)	Parameters
Monitoring[5]	Baseline	Natural Background Concentrations	One for each mainstream stem and one for each major tributary (>20% of flow at confluence)	Initially 6 X , then repeat every 2 - 3 years	see Table 6.2
	Trend	Detection of changes over time due to anthropogenic influences	Mainstream:: After each1½ days travel time or after each major infiltration (whichever is sooner) Tributary: Before confluence if >20% of mainstream flow	12 X (if river catchment area > 100,000 km^2) 24 X (if river catchment area < 100,000 km^2)	
	Flux	Calculation of load or mass flux	State or border crossings Outflows into lakes and seas	Simultaneously with flow measurement 24 X	
Surveillance[6]	Water Use	Check that water is fit for use	At all points of use or intake	see chapter 6.1.4, 'Water Use' Surveillance	see Table 6.3
	Pollution Control	Check effects of discharges Check water quality standards	Upstream and downstream of discharge point In river after mixing	For discharges with significant effects: 12 X (or 52 X for high significance). Annually for others. For river waters: 12 X	
Survey[7]	Classification	Classification of reach	Same as trend	12 X to 24 X for two years	see Table 6.4
	Management and Research	Investigation of pollution and need for corrective measures Special Interest Filling in knowledge gaps	Dependent upon scale of survey required	Sufficient to characterise problem and likely solution	

[5] Monitoring: Long-term, standardised measurement in order to define status and trends
[6] Surveillance: Continuous, specific measurement for the purpose of water quality management and operational activities
[7] Survey: A finite duration, intensive programme to measure for a specific purpose

Table 6.2 Water Quality Parameters (Monitoring Category)

Parameter Group	Parameter	Baseline	Trend	Flux
General	Temperature	✓	✓	
	Suspended Solids	✓	✓	✓
	Conductivity	✓	✓	
	PH	✓	✓	
	Dissolved Oxygen	✓	✓	
	Total Dissolved Solids	✓	✓	
Nutrients	Ammoniacal Nitrogen	✓	✓	✓
	Total Oxidised Nitrogen	✓	✓	✓
	Total Phosphorus	✓	✓	✓
Organic Matter	Chemical Oxygen Demand		✓	
	Biochemical Oxygen Demand		✓	✓
Major Ions	Sodium	✓		
	Potassium	✓		
	Calcium	✓		
	Magnesium	✓		
	Carbonates and Bicarbonates	✓		
	Chloride	✓	✓	✓
	Sulphate	✓		
Other Inorganics	Silica	✓		
	Fluoride			
	Boron			
Metals	Cadmium		✓	✓
	Mercury		✓	✓
	Zinc		✓	✓
Organics	Pesticide (Indicator)	✓	✓	✓
	Surfactants		✓	
	Mineral oil & petroleum			
	Phenols			
Microbiological	Total coliforms	✓	✓	
Biological	Chlorophyll ‘a’	✓	✓	

Table 6.3 Water Quality Parameters (Surveillance Category)

Parameter	Parameter	Water Use[8]					Pollution[9]
		D	I	B	L	F	
General	Temperature	✓	✓			✓	✓
	Suspended Solids	✓				✓	✓
	Conductivity	✓	✓		✓	✓	✓
	pH	✓	✓	✓	✓	✓	✓
	Dissolved Oxygen			✓		✓	✓
	Total Dissolved Solids		✓				
Nutrients	Ammoniacal Nitrogen	✓				✓	✓
	Total Oxidised Nitrogen				✓		
	Total Phosphorus						
Organic Matter	Chemical Oxygen Demand						✓
	Biochemical Oxygen Demand	✓		✓		✓	✓
Major Ions	Sodium		✓				
	Potassium						
	Calcium		✓				
	Magnesium		✓				
	Carbonates and Bicarbonates						
	Chloride	✓	✓				✓
	Sulphate						
Other Inorganics	Silica						
	Fluoride	✓					
	Boron		✓				
Metals	Cadmium					✓	
	Mercury					✓	
	Zinc						
Organics	Pesticide (Indicator)	✓				✓	
	Surfactants						
	Mineral oil & petroleum product	✓					
	Phenols	✓					
Microbiological	Total coliforms	✓	✓[1010]	✓	✓[10]	✓	✓
Biological	Chlorophyll ‘a’	✓				✓	

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[8] D = Water Abstracted for Treatment as Drinking Water, I = Water for Irrigation, B = Waters Used for Human Bathing, L = Water for Livestock Watering, F = Waters Capable of Supporting Fish and Other Aquatic Life

[9] Suggested suite of parameters to test for organic pollution. For guidance only, specific parameters sampled will depend upon the discharge being monitored.

[10] Extracted from ‘Optimisation of Monitoring Programme for River Cauvery’, Monitoring of Indian National Aquatic Resources Series, MINARS/11/1995-96, CPCB, Delhi

Table 6.4 Water Quality Parameters (Survey Category)

Parameter Group	Parameter	Water quality criteria requirements
General	Temperature	
	Suspended Solids	
	Conductivity	✓
	pH	✓
	Dissolved Oxygen	✓
	Total Dissolved Solids	
Nutrients	Ammoniacal Nitrogen	✓
	Total Oxidised Nitrogen	
	Total Phosphorus	
Organic Matter	Chemical Oxygen Demand	
	Biochemical Oxygen Demand	✓
Major Ions	Sodium	✓
	Potassium	
	Calcium	✓
	Magnesium	✓
	Carbonates and Bicarbonates	
	Chloride	
	Sulphate	
Other Inorganics	Silica	
	Fluoride	
	Boron	✓
Metals	Cadmium	
	Mercury	
	Zinc	
Organics	Pesticide (Indicator)	
	Surfactants	
	Mineral oil & petroleum	
	Phenols	
Microbiological	Total coliforms	✓
Biological	Chlorophyll 'a'	

To adequately cover a river catchment whilst limiting cost, it is proposed that only the major tributaries within a basin are sampled. This could be achieved by sampling on the main river stem and on any tributaries, which contribute more than 20% of the volume of the main river as measured at the confluence point.

In order to ensure that the data obtained reflect the natural condition of each tributary it will be necessary to site each baseline sampling station at a convenient point upstream of any man made pollution. Practically, this may prove difficult but if this is the case the best possible point should be chosen with, if necessary, some notes describing how this point may deviate from the 'ideal' baseline monitoring station.

A further important consideration when planning sites for baseline monitoring stations is the geology of each river catchment and how this might vary over the basin area. The underlying rocks in a river basin influence the chemical quality of the water and so, if the geology of the catchment is known to vary, it is worth considering obtaining a baseline sample from each distinct geological area. This will aid understanding of the basic water chemistry of the river system and how this varies over the catchment area.

Sufficient samples need to be taken to characterise the water including, if applicable, describing the influence of natural changes in the system (e.g., seasonal effects). Initially, therefore, it is sensible to take three to four samples at each point spread throughout the year to account for seasonal effects.

As baseline monitoring is concerned with the natural and unpolluted state of the river basin it would seem that a reasonably wide range of parameters should be chosen so that the catchment can be adequately characterised. However, the range can be narrowed down somewhat because, as these samples should be unpolluted, there is little point looking for parameters which do not occur naturally in the area. Thus, many anthropogenic chemical species can be excluded including man-made organic materials, heavy metals and other organic polluting matter. The analysis of major ions is important, however, as these species help to show the natural chemical make-up of the river basin.

It is important to note that some chemical species, which would normally be derived from human activities, are present in the list of baseline monitoring parameters. Such species include ammoniacal nitrogen, total oxidised nitrogen, total phosphorus and an indicator pesticide. These parameters have been included as they can reach otherwise unpolluted watercourses through diffuse inputs such as run-off from land - for example excess fertiliser, which often contains nitrogen and phosphorus compounds, can pollute rivers after it has been applied to agricultural land. Total coliforms have also been included in the baseline list as these species can be present in water following contamination by animal faece.

Trend: Trend monitoring stations are designed to show how a particular point on a watercourse varies over time due, normally, to the influence of man's activities. By regularly sampling such stations it is possible to build up a picture of how the point is changing either gradually or as a result of a particular upstream event (e.g., a new source of pollution being discharged to the river).

Ideally, this type of sample needs to be obtained at regularly spaced points throughout the river basin in order to completely characterise the catchment. However, in order to limit the number of samples to a reasonable level, it is suggested that this sampling is initially carried out only along the main river stem and on 'major' tributaries (> 20% of the mainstream flow at the confluence point).

Similarly, main river samples should be taken at sites where the river flow has increased by approximately 20% from the flow, which existed at the previous station. Thus, the first such sampling station would be at a site where the flow is 20% greater than that which applied at the baseline station (see above). The exception to this rule would be if a major tributary joined the main river before the next '120% flow' point. In this case a sample station should be sited on both the main river and the tributary at points just upstream of the confluence. Sampling station sites would then continue to be distributed downstream on the main river as before (i.e., a new sampling station to be located whenever the main river flow increased by 20% as compared to the flow at the previous station). It should be noted that in this scheme the only 'Trend' sampling stations not located on the main river stem are those sited on major tributaries and then only at points just upstream of the confluence with the main river. This type of sample needs to be taken between 12 and 24 times per year. This ensures that these important points are sampled regularly enough to provide sufficient data for trend analysis to be carried out and to ensure that seasonal effects within the data can be identified. In order to limit sample numbers whilst retaining data quality it is suggested that on large river catchments (>100,000 km^2) twelve 'Trend' samples should be obtained per year at each station. On smaller river catchments (<100,000 km^2) twenty-four samples should be obtained at each station annually.

Trend monitoring is chiefly concerned with cataloguing the variation in pollution concentration at a sampling point. Traditional anthropogenic pollutants, such as organic matter, metals, nutrients and microbiological parameters, need to be determined. In addition, a number of general parameters are also important, as they are also good pollution indicators.

Flux: Flux samples are taken so that the mass of particular pollutants can be calculated at important points on the river system. Measurement of the flow of the river is also normally carried out at the same time so that the mass flux (load per unit time) of pollutants can be calculated.

Samples are normally taken at points in the river system where it is deemed necessary or useful to know the flux of one or more pollutants. Such points are immediately upstream of where a major river crosses a state or national border (often for political reasons) or before river discharges into a lake, sea or ocean (to enable the pollutant load being discharged by the river to be judged).

Within this programme, therefore, flux sampling stations should be located on all main river stems and major tributaries at sites immediately upstream of the points where these watercourses discharge into lakes, seas or oceans or cross state or national borders. It should be noted that when flux samples need to be obtained upstream of lakes, seas or oceans, care must be taken to choose the sampling station site such that the influence of the receiving water body is excluded from the samples obtained.

Flux samples should be collected at the same time as water flow measurement is carried out at these points. Flux samples should be obtained at least twenty-four times per year. With flux monitoring the aim is to gauge the quantity (load) of anthropogenic pollutants passing a sampling point. Thus the parameters measured are similar to those measured in trend monitoring, except that it is not necessary to measure most general parameters.

Surveillance

Water Use: As the name implies, these samples are taken to ensure that the water is fit for its intended use. Possible uses of river water for which such sampling may be undertaken are: drinking water, irrigation, cooling, industrial processes, human bathing, livestock watering, support of fish life and support of other aquatic life.

If the water to be used is abstracted from the river the sample is taken at the abstraction point. If the water is to be sampled for an in-river use (e.g., bathing), sampling is carried out at or very near to the point of use.

Sampling stations should be positioned at all points of use, wherever practical and without unnecessary duplication. That is to say, if there is an 'irrigation' sampling station on a particular river reach there is no need for another one at a nearby abstraction point unless significant changes are thought to have taken place in the river between these two points. Sampling frequency will depend on the use to which the water is being subjected. The following is a rough guide to the frequency of sampling which would be appropriate for each designated use:

- drinking water - one sample per day (minimum)
- irrigation - one sample per week when irrigation is being carried out. More frequently during times of change in the river regime or if pollution is suspected
- bathing - depends upon number of bathers but daily in the bathing season if numbers bathing are high, weekly if less people are bathing
- livestock watering - monthly (minimum) but more frequently during times of change in the river regime or if pollution is suspected
- waters supporting fish and other aquatic life - monthly minimum but more frequently if pollution is present or suspected or if the river flow is particularly low.

As it is impossible to generate a generic list of parameters for this type of monitoring, Table 3.3 splits water use into five distinct categories. Parameter selection has then been carried out so that pollutants particularly important to each use are screened. For example, certain crops are sensitive to high boron concentrations so this chemical is included in samples to be taken from water used for irrigation.

It should be noted that no attempt has been made to sample river water, which is to be abstracted for industrial process and cooling water use. This is because the water quality required for this type of use is variable, depending on the particular process employed by the abstracting organisation.

Pollution control: This sampling is undertaken for particular pollutants to check the effect that discharges are having on the receiving watercourse or to ensure that watercourses are within their designated quality standard limits.

Samples to measure the effects of discharges are normally taken upstream and downstream of the outfall. When water quality of a reach is monitored, samples are taken from one or more points within the reach. A sampling station should be located in the most polluted part of the reach.

With regard to discharges, the number of samples taken per year may vary from 12 to 48, depending on the importance of the discharge in terms of its effect on the receiving water and its pollution load. If the discharge has little or no noticeable effect on the quality of the river then annual sampling of the watercourse is adequate. River water samples for checking water quality standards should be taken monthly within each designated reach.

As noted in Table 6.3, analytical parameters in samples taken to check discharge permits or river water quality standards will generally reflect the permit or set of standards against which the sample is being compared. Thus, if a particular discharge only has a permit to discharge zinc and cadmium, the sample may be analysed for these parameters only. The parameters in Table 6.3 represent the type of analysis, which might be undertaken to check a river or a discharge for organic pollution (e.g., to monitor effluent from a sewage treatment works).

Survey

Classification: These samples are taken to classify a river reach in accordance with Inland River Water Quality Standards into different reaches (Table 3.3). Location of sampling stations may follow the criteria given for monitoring category in Table 6.1. The stations should also be located in reaches, which have a distinct designated use. The sampling frequency should be 12 to 24 times per year. The programme may be discontinued after sufficient data are collected to classify the stream into different reaches.

The parameters for the sampling type are taken from the classification scheme.

Management and research: Samples taken for special purposes, such as investigating and tracing pollution episodes, instigating anti-pollution measures or gathering information for research purposes.

Samples will normally form part of a discrete survey, which has been dedicated to gathering the information required to address a particular problem. As such, no guidance is possible on the location of sampling points and frequency of sampling, as each survey must be planned individually.

6.2 Groundwater Network

A groundwater quality monitoring network should take into account the features of the area or region, which are likely to have an impact on the water quality. Some of these features are:

- Aquifer geology
- Type of aquifer
- Land use pattern
- Climatic zones
- Soil types
- Drainage basin

A simple approach to locating the monitoring stations would be to mark the boundaries of the relevant features on a map and locating at least one station in each intersection. For example, if in an area there are two aquifer geological formations, gravel (G) and limestone (L), Figure 6.3 (a), and two types of land uses agricultural (A) and fallow (F), Figure 6.3 (b), then their intersection would yield three unique possibilities as shown in Figure 6.3 (c). The network should have at least three stations, one in each of the intersections. Depending on the extent of each intersection and resources, the number of stations in each of the intersections may be increased. The density of the network may also be increased by including more influencing features or sub-features, as in the case of agriculture, canal command area and non-command area could also be considered as different features.

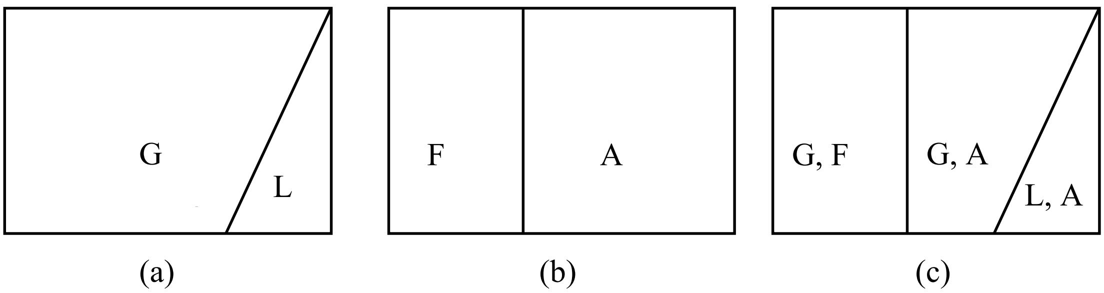

Figure 6.3 Intersections of features influencing groundwater quality

Often the water quality monitoring network is clubbed with the groundwater level monitoring network, which comprises mostly open dug wells. Some of these wells may not be in use as a source of water. For water quality monitoring stations, it is essential that the well is a production well, so that the water in the well represents the aquifer water and not the stagnant water. Therefore, only production wells should be designated as the water quality monitoring stations. Where purpose-built piezometers are installed for water level measurements, arrangement should be made for purging the stagnant water before sampling for water quality measurement, if such wells are included in the network.

The classification of the groundwater monitoring stations should be on similar lines as that for surface water stations. Stations, where there is no or little possibility of anthropogenic influence on aquifer water quality, should be classified as *baseline* stations. A few of these baseline stations may also be called trend stations. The baseline stations may be monitored only once a year, since the groundwater quality does not change rapidly. The sampling may be done during the pre-monsoon season, when the water quality is most critical. The *trend* stations on the other hand may be monitored four times a year to facilitate drawing statistically reliable conclusions in 2 to 3 years.

Stations, where there is a threat to water quality, may be classified as *Surveillance* or *trend-cum-surveillance* stations. These stations should also be monitored four times a year or more frequently, if the water use involves greater risks.

Surveys may also be taken up in the groundwater quality monitoring programme, with specific objectives, such as to find if the groundwater in an area contains naturally occurring fluoride, or pesticides as a result of contamination from agricultural applications. Such surveys may be carried out for at least two years. The frequency of sampling may 3 to 4 times a year. At the end of the survey, depending upon the results, a few survey stations may be retained in the network as baseline, trend or trend-cum-surveillance stations

The water quality parameters for which the water samples should be analysed are similar to those discussed for surface waters, except dissolved oxygen, which has no relevance in routine monitoring of groundwater. Further, samples may not be analysed for BOD (Biochemical oxygen demand) unless recent contamination is suspected.

7 RECOMMENDED PROTOCOL FOR WATER QUALITY MONITORING

The Expert Group reviewed the water quality monitoring programmes followed by various agencies and the methodology developed under the Hydrology Project. This Chapter suggests a protocol for the monitoring programmes for natural water resources in the country.

The main objectives for water quality monitoring for Surface and Groundwater Agencies have been identified as follows:

- monitoring for establishing baseline water quality
- observing trend in water quality changes
- calculation of flux of water constituents of interest
- surveillance for irrigation use
- control and management of water pollution (for groundwater only)

The objective of control and management of water pollution comes under the preview of the Central and State Pollution Control Boards and the Central Ground Water Authority.

The networks of monitoring stations have to designed/upgraded accordingly with the above objectives in mind.

7.1 Frequency and Parameters

7.1.1 Surface water

- Initially when not much is known about the present water quality status at various stations, to start with, all stations will be a combination of *baseline* and *trend* stations.

- Samples will be collected once every two months: May/June, August, October, December, February, and April. This will generate six samples from perennial rivers and 3-4 samples from seasonal rivers, every year. In case the number of samples from the seasonal rivers is likely to be lesser, the frequency may be once every month.

- After data are collected for three years, the stations will be classified either as *baseline, trend* or *flux* station.

- Those stations, where there is no influence of human activity on water quality, will be reclassified as *baseline* stations. Others will remain as *trend* stations.

- If a station is classified as a *baseline* station, it will be monitored, after every alternate year, for one year every two months.

- If a station is classified as *trend* station, it will continue to be monitored but with an increased frequency of once every month.

- Stations will be classified as *flux* stations where it is considered necessary to measure the mass of any substance carried by the flow. The frequency of sampling at such stations and analyses of constituents of interest may be increased to 12 or 36 times per year. Measurement of discharge at such stations is necessary.

- The recommended parameters for analysis are given in Table 7.1.

- Other inorganics, metals, organics and biological parameters will be determined as part of special *survey* programmes.

- The *survey* programmes may include some of the trend stations where there is a need for determination of any of these groups of parameters.

- The *survey* programmes will ordinarily be of one year duration. The sampling frequency may be the same as that for trend stations.

- Special arrangements for sampling and transport of the samples would be necessary for the *survey* programmes and microbiological samples.

7.1.2 Groundwater

- Initially all stations, for which water quality data are not available or sketchy, may be classified as the *baseline* stations.

- About 20 to 25% of the baseline stations may be classified as *trend* or as *trend-cum-surveillance* stations, where there is a perceived problem.

- Table 7.2 gives the frequency of sampling and parameters for various types of stations.
- After data are collected for three years, the stations may be reclassified. Some *baseline* stations may be discontinued or monitored once every alternate year, and some *baseline* stations may be operated only as *trend* stations. Suspect wells may be operated as *trend-cum-surveillance* stations.

7.2 Sample Collection

7.2.1 General

- At least one day before sampling, make sure that all the arrangements are made as per the check list given in Annexure I (of Chapter 7).

- Make sure that you know how to reach sampling site(s). Take help of location map for the site, which shows the sample collection point with respect to prominent landmarks in the area. In case there is any deviation in the collection point, record it on the sample identification form giving reason.

- Rinse the sample container three times with the sample before it is filled.

- Leave a small air space in the bottle to allow mixing of sample at the time of analysis.

- Label the sample container properly, preferably by attaching an appropriately inscribed tag or label. The sample code and the sampling date should be clearly marked on the sample container or the tag.

Table7.1 Parameters of analysis for surface water samples

Type of station	Frequency	Parameter
Baseline:	**Perennial rivers :** Six times a year **Seasonal rivers :** 3-4 times (at equal spacing) a year	**Pre-monsoon: Once a year** Analyse 25 parameters as listed below : General : Colour, odour, temp., pH, EC, DO, turbidity, TDS Nutrients : NH_3-N, NO_2^- + NO_3^-, total P Organic matter : BOD, COD Major ions : K^+, Na^+, Ca^{++}, Mg^{++}, CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--} Other inorganics : F^-, B^{3+} and other location-specific parameter, if any Microbiological : Total and faecal coliforms **Rest of the year (after the pre-monsoon sampling)** at **every two months**' interval : Analyse 12 parameters: Colour, odour, temp., pH, EC, DO, TDS, NO_2^- + NO_3^-, BOD, COD, total and faecal coliforms
Trend:	Once every month starting April-May (pre-monsoon), i.e. 12 times a year	**Pre-monsoon:** Analyse 25 parameters as listed for baseline monitoring. **Other months :** Analyse 15 parameters as listed below General : Colour, odour, temp, EC, pH, turbidity, DO Nutrients : NH_3-N, NO_2^- + NO_3^-, total P Organic matter : BOD, COD Major ions : Cl^- Microbiological : Total & faecal coliforms
Trend-cum-surveillance / impact: (for areas having problems of the following nature due to geologic features or human interference) ~ Industrial, mining, specific local problems ~ Agricultural run-off ~ Salinity due to irrigation, natural contribution or seawater intrusion ~ Urban *pollution*	Monthly/fortnightly depending on pollution potential / importance of water use (12-24 times a year)	**Pre-monsoon:** Analyse 25 parameters as listed for baseline monitoring **Other months : A**nalyse 15 parameters as mentioned for Trend stations and **additional parameters as follows** according to the problem under surveillance (e.g. Heavy metals in mining areas)**:** As, Cd, Hg, Zn, Cr, Pb, Ni, Fe, F^-, phenols, cyanide, sulphide etc. (according to local situations) Pesticides in most prevalent use in the area : BHC (total), DDT(total), endosulphan, aldrin, dieldrin, carbamate, 2,4-D, monocrotophos, malathion, methyl parathion etc. Na^+, K^+, Ca^{++}, Mg^{++}, CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--} Total & faecal coliforms (already included under 15 parameters for Trend monitoring)

Note : The parameters to be analysed as mentioned above are the minimal requirement. This does not, however, restrict analysis of more parameters depending upon specific requirements of the analysing agency and its manpower availability.

For lakes/reservoirs, monitoring of additional parameters, like Total Kjeldahl Nitrogen, Chlorophyll and total plankton count, are to be included in the list of parameters.

If bio-monitoring is done in rivers/lakes/reservoirs, additional parameters, like Photosynthesis-Respiration (P/R) ratio, saprobity index and diversity index are to be included.

Table 7.2 Parameters of analysis for groundwater samples

Type of station	Frequency	Parameter
Baseline:	**New stations :** Once every year (pre-monsoon,April-May) for 3 years, thereafter every alternate year if there is no perceptible deterioration in quality. Otherwise, re-categorise as trend/surveillance station. **Existing stations:** If no perceptible change is observed in previous 5 years' data indicating no deterioration in quality, sample once every alternate year (pre-monsoon, April-May)	**Analyse 20 parameters as listed below:** General : Colour, odour, temp, pH, EC, TDS Nutrients : $NO_2^- + NO_3^-$, ortho-phosphate Organic matter : COD * Major ions : K^+, Na^+, Ca^{++}, Mg^{++}, CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--} Other inorganics : SiO_2 , F^-, B^{3+} and other location-specific parameters, if any
Trend:	Four times every year (once in pre-monsoon, April-May, and thereafter at intervals of 3 months).	**April-May :** Analyse 20 parameters as listed for Baseline monitoring **Other times :** Analyse 14 parameters as listed below: General : Colour, odour, temp, EC, pH, TDS Nutrients : $NO_2^- + NO_3^-$, ortho-phosphate Organic matter : COD* Major ions : Cl^- Other inorganics : F^-, B^{3+} Microbiological : T otal & faecal coliforms
Trend-cum-surveillance /impact: (For areas having problems of the following nature due to geologic features or human interference)	Minimum four times a year (as in trend stations); higher frequency, if dictated by importance of water use	**April-May :** Analyse 20 parameters as listed for Baseline monitoring **Other times:** Analyse14 parameters as mentioned for Trend stations and additional parameters as follows according to the problem under surveillance (e.g. Heavy metals in mining areas) :
– Fluoride		F^-
– Iron		Fe
– Industrial/mining/ geological features		As, Cd, Hg, Zn, Cr, Pb, Ni, Fe, phenols, cyanide, sulphide etc. (according to local situations)
– Agricultural		Pesticides in most prevalent use in the area : BHC (total), DDT(total), endosulphan, aldrin, dieldrin, carbamate, 2,4-D, monocrotophos, malathion, methyl parathion etc.
– Salinity due to irrigation, natural contribution, or seawater intrusion		Na^+, K^+, Ca^{++}, Mg^{++}, CO_3^{--}, HCO_3^-, Cl^-, SO_4^{--}
– Urban *pollution*		Total and faecal coliforms (already included under 16 parameters for Trend monitoring).

Note : The parameters to be analysed as mentioned above are the minimal requirement. This does not, however, restrict analysis of more parameters depending upon specific requirements of the analysing agency and its manpower availability.

* If COD value exceeds 20 mg/L, the sample is to be analysed for BOD also.

- Complete the sample identification forms for each sample, Figures 7.1 and 7.2 for surface water and groundwater, respectively.

- The sample identification form should be filled for each sampling occasion at a monitoring station. Note that if more than one bottle is filled at a site, this is to be registered on the same form.

- Sample identification forms should all be kept in a master file at the level II or II^+ laboratory where the sample is analysed.

7.2.2 Surface Water

- Samples will be collected from well-mixed section of the river (main stream) 30 cm below the water surface using a weighted bottle or DO sampler.

- Surveillance samples will be collected from the point of interest, such as bathing ghat, water supply in-take etc.

- Samples from reservoir sites will be collected from the outgoing canal, power channel or water intake structure, in case water is pumped. When there is no discharge in the canal, sample will be collected from the upstream side of the regulator structure, directly from the reservoir.

- DO is determined in a sample collected in a DO bottle using a DO sampler. The DO in the sample must be fixed immediately after collection, using chemical reagents. DO concentration can then be determined either in the field or later, in a level I or level II laboratory.

7.2.3 Groundwater

- Samples for groundwater quality monitoring would be collected from one of the following three types of wells:

  ~ *Open dug wells* in use for domestic or irrigation water supply,
  ~ *Tube wells* fitted with a hand pump or a power-driven pump for domestic water supply or irrigation
  ~ *Piezometers*, purpose-built for recording of water level, only if the arrangement is provided for purging

- Open dug wells, which are not in use or have been abandoned, will not be considered as water quality monitoring station. However, such wells could be considered for water level monitoring.

- Use a weighted sample bottle to collect sample from an open well about 30 cm below the surface of the water. Do not use a plastic bucket, which is likely to skim the surface layer only.

- Samples from the production tube wells will be collected after running the well for about 5 minutes.

- Non-production piezometers should be purged using a submersible pump. The purged water volume should equal 4 to 5 times the standing water volume, before sample is collected.

- For bacteriological samples, when collected from tube wells/hand pump, the spout/outlet of the pump should be sterilised under flame by spirit lamp before collection of sample in container.

7.3 Sample containers, preservation and transport

- The following type of containers and preservation shall be adopted:

Analysis	Container	Preservation
General	Glass, PE	None
COD, NH_3, NO_2^-, NO_3^-	Glass, PE	H_2SO_4, pH<2
P	Glass	None
DO	BOD bottle	DO fixing chemicals
BOD	Glass, PE	4 ^oC, dark
Coliform	Glass, PE, Sterilised	4 ^oC, dark
Heavy metals	Glass, PE	HNO_3, pH<2
Pesticides	Glass, Teflon	4 ^oC, dark

- Samples should be transported to concerned laboratory (level II or II+) as soon as possible, preferably within 48 hours.

- Analysis for coliforms should be started within 24 h of collection of sample. If time is exceeded, it should be recorded with the result.

- Samples containing microgram/L metal level, should be stored at 4^{o}C and analysed as soon as possible. If the concentration is of mg/L level, it can be stored for up to 6 months, except mercury, for which the limit is 5 weeks.

- Discard samples only after primary validation of data.

<table>
<tr><th colspan="14">Sample code</th></tr>
<tr><td colspan="5">Observer</td><td colspan="5">Agency</td><td colspan="4">Project</td></tr>
<tr><td colspan="5">Date Time</td><td colspan="9">Station code</td></tr>
<tr><th rowspan="2">Parameter code</th><th colspan="4">Container</th><th colspan="4">Preservation</th><th colspan="3">Treatment</th></tr>
<tr><th>Glass</th><th>PVC</th><th>PE</th><th>Teflon</th><th>None</th><th>Cool</th><th>Acid</th><th>Other</th><th>None</th><th>Decant</th><th>Filter</th></tr>
<tr><td>(1) Gen</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>(2) Bact</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>(3) BOD</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>(4) COD, NH_3,NO_3^-</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>(5) H. Metals</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>(6)Tr. Organics</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

<table>
<tr><th colspan="5">Source of sample</th></tr>
<tr><th>Waterbody</th><th>Point</th><th>Approach</th><th>Medium</th><th>Matrix</th></tr>
<tr><td>o River
o Drain
o Canal
o Reservoir</td><td>o Main current
o Right bank
o Left bank</td><td>o Bridge
o Boat
o Wading</td><td>o Water
o Susp matter
o Biota
o Sediment</td><td>o Fresh
o Brackish
o Salt
o Effluent</td></tr>
<tr><th>Sample type</th><td colspan="4">o Grab o Time-comp o Flow-comp o Depth-integ o Width-integ</td></tr>
<tr><th>Sample device</th><td colspan="4">o Weighted bottle o Pump o Depth sampler</td></tr>
</table>

<table>
<tr><th colspan="4">Field determinations</th></tr>
<tr><th>Temp °C</th><th>pH</th><th>EC µmho/cm</th><th>DO mg/L</th></tr>
<tr><th>Odour Code</th><td>(1) Odour free
(2) Rotten eggs
(3) Burnt sugar
(4) Soapy
(5) Fishy
(6) Septic
(7) Aromatic
(8) Chlorinous
(9) Alcoholic
(10) Unpleasant</td><th>Colour code</th><td>(1) Light brown
(2) Brown
(3) Dark brown
(4) Light green
(5) Green
(6) Dark green
(7) Clear
(8) Other (specify)</td></tr>
</table>

<table>
<tr><th colspan="2">Remarks</th></tr>
<tr><th>Weather</th><td>o Sunny o Cloudy o Rainy o Windy</td></tr>
<tr><th>Water vel. m/s</th><td>o High (> 0.5) o Medium (0.1-0.5) o Low (< 0.1) o Standing</td></tr>
<tr><th>Water use</th><td>o None o Cultivation o Bathing & washing o Cattle washing
o Melon/vegetable farming in river bed</td></tr>
</table>

Figure 7.1 Sample identification form for surface water samples analysis and record

Sample code		
Observer	Agency	Project
Date	Time	Station code
Source of sample: o Open dug well	o Hand pump	o Tube well o Piezometer

Parameter code	Container				Preservation				Treatment		
	Glass	PVC	PE	Teflon	None	Cool	Acid	Other	None	Decant	Filter
(1) Gen											
(2) Bact											
(3) BOD											
(4) COD, NH_3, TO_xN											
(5) H Metals											
(6)Tr Organics											

Field determinations			
Temp °C	pH	EC μmho/cm	DO mg/L

Odour code		Colour code	
	(1) Odour free (2) Rotten eggs (3) Burnt sugar (4) Soapy (5) Fishy (6) Septic (7) Aromatic (8) Chlorinous (9) Alcoholic (10) Unpleasant		(1) Light brown (2) Brown (3) Dark brown (4) Light green (5) Green (6) Dark green (7) Clear (8) Other (specify)

IF WELL IS PURGED, COMPLETE BELOW:

Office Well Data			
Diameter	φ		cm
Depth	D		m
Static water level (avg)	SWL		m
Water column (D-SWL)	H		m
Initial volume well	V		L
Projected pump discharge	PQ		L/s
Projected time of purging (V/PQ)	PT		min
Field Flow Measurements			
Static water level on arrival	SWL		m
Actual pump setting			m
Purging duration			min
Pump Discharge before sampling	Q		L/min
Pump Discharge after sampling	Q		L/min
Volume purged	V		L
Dynamic water level	DWL		m
Field Chemical measurement			
Time at start of sampling started	T (°C)	EC(μmho/cm)	pH
+10 min			
+20 min			
+30 min			
+40 min			

Figure 7.2 Sample identification form for groundwater samples

7.4 Analysis and Record

7.4.1 Sample receipt register

Each laboratory should have a bound register, which is used for registering samples as they are received. An example of headings and information for such a register is given in Figure7.3.

Date/Time received at lab.	Date/Time collected	Station code	Project	Collecting agency/collector	Preservation	Parameter code	Lab. Sample No.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
02.07.99/1400	01.07.99/1100	M 22	WQ monitoring	SW Div II/ Singh	No	1	28-1
02.07.99/1400	01.07.99/1700	M 24	WQ monitoring	SW Div II/ Singh	No	1	29-1
02.07.99/1400	01.07.99/1700	M 24	WQ monitoring	SW Div II/ Singh	Yes	4	29-4
05.07.99/1100	02.07.99/1300	S 44	Survey A	SPCB/ Bhat	Yes	5	30-5

Figure 7.3 Sample receipt register

Note:

- Column 3 gives the station code conventionally followed by the monitoring agency.
- Column (4) gives the project under which the sample is collected.
- Column (7) corresponds to the parameter(s) code given in the sample identification form.
- Column (8) gives the laboratory sample number assigned to the sample as it is received in the laboratory. Note that the numbering has two parts separated by a hyphen. The first part is assigned in a sequential manner as samples are received from various stations. If two samples are collected at the same time from a station for different sets of analysis, the first part of the number is the same. The second part corresponds to the parameter code as given in the sample.
- The results of the analyses of all the samples having the same first part of the code would be entered in the data entry system as one sample having the same station code and time of sample collection.

7.4.2 Work assignment and personal registers

- The laboratory in-charge should maintain a bound register for assignment of work. This register would link the lab. sample number to the analyst who makes specific analyses, such as pH, EC, BOD etc.

- An estimate of time needed for performing the analyses may also be entered in the register.

- Each laboratory analyst should have his/her own bound register, where all laboratory readings and calculations are to be entered.

- When analysis and calculations are completed, the results must be recorded in a register containing data record sheets described in the next section.

7.4.3 Analysis record and data validation

- A recommended format for recording data is given in Figure 7.4. It includes all parameters, except heavy metals and trace organics, that may be analysed in the water quality monitoring programme currently envisaged. Note that ordinarily a sample would NOT be analysed for all the listed parameters.
- Record of analyses for heavy metals and trace organics, which would be performed on a limited number of samples, would be kept separately in a similar format.
- Columns (2) – (3) are filled from the entries in the Sample Receipt Register.
- Columns (4) – (9) pertain to the field measurements. This information would be available from the Sample Identification Forms.
- Columns (10) – (36) would be filled in by the analyst(s) whom the work has been assigned (see Work Assignment Register).
- The format also includes primary data validation requirements, columns (37) – (53). The laboratory incharge should perform these validation checks as the analysis of a sample is completed. In case the analysis results do not meet any one of the validation checks, whenever possible, the analysis should be repeated. She/he would also fill in Columns (54) – (55).
- The results of the laboratory analyses would be entered from these records in the data entry system format provided in Figure 7.4.

Data record *Laboratory / organisation* *Laboratory code*

			Field determinations						General				Nutrients			Org matter		Alkalinity		Hardness		Major ions								Other inorganics			Coliforms		Biol
		Date of collection	pH	EC, µmho/cm	DO, mg/L	Temp, °C	Colour, code	Odour, code	pH	EC, µmho/cm	TDS, mg/L	TSS, mg/L	NH_3, mg N/L	$NO_2^-+NO_3^-$, mg N/L	Total P, mg/L	BOD, mg/L	COD, mg/L	Phen, mg $CaCO_3$/L	Total, mg $CaCO_3$/L	Total, mg $CaCO_3$/L	Ca^{++}, mg $CaCO_3$/L	Ca^{++}, mg/L	Mg^{++}, mg/L	Na^+, mg/L	K^+, mg/L	Cl^-, mg/L	SO_4^{--}, mg/L	CO_3^{--}, mg/L	HCO_3^-, mg/L	Si, mg/L	F^-, mg/L	B, mg/L	Total, MPN/100 mL	Faecal, MPN/100mL	Chlorophyll-A,
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)

Data validation

		Cations					Anions						Ion balance		EC bal	Carbon bal	CO_3^{--} bal	Verification criteria	Checked by	Remarks
Lab sample No	Station code	Ca^{++}, meq/L	Mg^{++}, meq/L	Na^+, meq/L	K^+, meq/L	Total cations	Cl^-, meq/L	SO_4^{--}, meq/L	CO_3^{--}, meq/L,	HCO_3^-, meq/L	$NO_2^-+NO_3^-$, meq/L	Total anions	{(41)-(47)} / {(41)+(47)}	(39) / (42)	(12) / (11)	(18) / (17)	If (10) < 8.3, is (19)=0 ?			
(1)	(2)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)
																		(48) < 0.1 (49) = 0.8-1.2 (50) = 0.55-0.9 (51) > 1 (52) = yes		

Figure7.4 Data record and validation register

7.5 Manpower Requirement in Laboratories

7.5.1 Surface water sample analysis

a. Two instrumentation specialists are required in a level II^+ laboratory since two types of advanced instruments, viz. Atomic Absorption Spectrophotometer and Gas Chromatograph, need to be operated under supervision of trained, skilled and dedicated staff only.

b. Special parameters, such as trace pollutants (heavy metals, pesticides or other organics) are analysed in Level II^+ laboratories by the two specialists associated with the instruments involved in trace analyses. The trace pollutants are analysed in selected samples as part of special survey programme. It is assumed that the two specialists can perform analysis of 500 samples in a year for selected trace pollutants (average 5 pesticides and 5 heavy metals) including treatment of samples. Planning of survey programme needs to be done accordingly.

c. One chemist and one assistant chemist may perform 35 analyses[11] per day. During 200 working days, the number of analyses adds up to 7,000 per year.

d. The workload is evenly distributed over the different laboratories of an agency.

e. To the total number of analyses, 10% is added for validation, AQC and future needs.

f. A minimum of one chemist and one assistant chemist is required to staff any non-field laboratory.

g. Each agency needs at least one "water quality expert' for analysis and interpretation of data and the necessary interaction with the data centre. This function may be combined with the role of laboratory supervisor. For central agencies, one expert is to be assigned tentatively for each region.

h. For state agencies, the total number of river stations (S) identified for water quality monitoring is to be treated initially, for three years, as a combination of "baseline" and "trend" stations, (performing 20 analyses);

i. For the state agencies, the prescribed frequency of sampling varies from 6 times per year for perennial rivers to 4 times a year for seasonal rivers (Ref. Recommended Protocol for Water Quality Monitoring, Chapter7 of the report). To be on the safe side, the overall frequency is assumed to be 6 times per year.

j. For CWC, the total number of river stations (C) identified for water quality monitoring is to be treated as per network design consisting of baseline, trend and flux stations. For this estimate, we assume an overall sampling frequency of 24 per year and 20 analyses per sample.

[11] An analysis is defined as the determination of one parameter in one sample. The required time for analysis strongly depends on the type of analysis, e.g. determination of pH is a matter of minutes, whereas heavy metal analysis including preparation may take hours.

Based on these assumptions, relationships between the number of river stations and the number of analysis per year are derived (See Table 7.5 below for details):

No. of analyses/ year = 130 x no. of state river stations (for States in Level II & II$^+$ labs, S)
No. of analyses/ year = 530 x no. of CWC stations (for Level II & II+ labs, C)
No. of trace analysis per Level II+ lab for both state and central is assumed as 5000 each

Table 7.5 Estimate of the number of analyses required for SWQ stations

Type		Total Stations (S: State) (C : CWC)	Frequency (per year)	No. of Samples (per year)	No. of Analyses per Sample	No. of Analyses (per year)
States	Baseline and trend (Level II and II+ labs) samples	S	6	6 S	20	120 S
	Additional analyses for validation, AQC and future needs (Level II and II+ labs)	approximately 10 % of 120 S				10 S (say)
	Total					**130 S**
	Special survey programme where trace pollutants are to be analysed in each Level II+ lab	Depends on requirement and available facilities	Depends on requirement and available facilities	Maximum 500	10	**5000**
CWC	Baseline/trend/flux (Level II and II+ labs) samples	C	24	24 C	20	480 C
	Additional analyses for validation, AQC and future needs (Level II and II+ labs)	Approximately 10 % of 480 C = 48 C				50 C (say)
	Total					**530 C**
	Special survey programme where trace pollutants are to be analysed in each Level II+ lab	Depends on requirement and available facilities	Depends on requirement and available facilities	Maximum 500	10	**5000**

7.5.2 Groundwater sample analysis

The assumptions (a) to (g) in Section 7.4.1and the following are also valid for GW analysis:

k. The total number of wells (W) identified for water quality monitoring are all to be treated initially as “baseline” (sampling frequency once a year, 20 analyses per sample)

l. 20% of the total number of wells is to be considered under ‘trend’ or ‘trend-cum-surveillance’ (sampling frequency 4 times a year) for additional sampling three times a year .

m. For “trend-cum-surveillance” samples, on an average 14 analyses are assumed; 8 parameters are prescribed to be analysed for ‘trend’ wells, while for ‘trend-cum-surveillance’ wells, the number of parameters to be analysed depends on the nature of prevailing water quality problem, assuming 5 problem-related parameters to be analysed additionally.

Based on these assumptions, relationships between the number of river stations and the number of analysis per year are derived (See Table 7.6 below for details):

Groundwater sample analysis:

Number of analysis per year = 36 x number of wells (W)
Number of trace analysis per Level II^{+} lab for both state and central is assumed as 5000

Table 7.6 Estimate of the number of analyses required for GWQ stations

Types of Monitoring	Fraction of Total Wells,W	Frequency (per year)	No. of Samples (per year)	No. of Analyses / Sample	No. of Analyses (per year)
Baseline (Level II & II+labs)	W	1	W	20	20.0 W
Trend (level II and II+ labs)	0.2 W	3	0.6 W	14	8.4 W
Trend-cum-surveillance (level II and II+ labs)	0.2 W	4	0.8 W	5	4.0 W
Sub-total					**32.4 W**
Additional analyses for validation, AQC and future needs (level II and II+ labs)		10% of 32.4 W			3.2 W
Total					**36 W (Say)**
Special survey program where trace pollutants are to be analysed in each level II+ lab	As per requirement	As per requirement	500	10	**5000**

7.5.3 Manpower requirement

Three categories of staff, as per their origin of need, are defined:

- staff for operating the monitoring network
- staff to man the advanced instruments in level II+ laboratories
- staff to analyse and report data

Based on the assumption made at paragraph 7.4.1(c) and the formulae established above, the required number of staff (chemical analyst) can be calculated for each agency agency as follows:

No. of teams (comprising one chemist + one assistant chemist)

$$= \frac{\text{Total no. of analysis to be performed}}{\text{No. of analysis / day (i.e. 35) x No. of working days/year (i.e. 200)}}$$

The number of 'Instrumental Specialists' required to operate sophisticated instruments is, however, not separately estimated in the above calculation, which may be derived from the number of level II^+ laboratories. The number of "Water Quality Experts" is one per agency per State and one per region for the central agencies.

7.5.4 Staggering of sampling programme to ease workload

It is observed in most of the groundwater laboratories that the manpower shortage is often coupled with the receipt of a large bulk of samples during a short period. This seriously affects the quality of analysis results in two ways:

i) overloading of the staff / infrastructure leading to poor quality of performance; and
ii) prolonged storage of samples affecting its composition, which introduces systematic measurement errors

To avoid large peaks in the receipt of samples, it is recommended that the sampling is done in a staggered manner. This implies that the collection of (in particular) baseline samples needs to be staggered over a longer period. Since the largest peak originates from the yearly pre-monsoon sampling, especially this collection period needs to be extended over a period of 3-4 months (March-June). To form a scientific basis for this approach, it was suggested to investigate the seasonal variations in some selected existing wells. If the variation turns out to be low (e.g. in deep wells), the one-year sampling should be spread out over a longer (pre-monsoon) period. The investigation can also reveal for which parameters the sampling can better be done post-monsoon! Additional motivation for development of an "around the year programme" and judicious planning of the sampling programme to stagger the sampling originates from the facts that:

8 QUALITY ASSURANCE AND QUALITY CONTROL

8.1 Need for Quality Assurance

Many studies have shown that analytical results are often subject to serious errors, particularly at the low concentrations encountered in the analysis of environmental water samples. In fact the errors may be so large that the validity of actions taken regarding management of water quality may become questionable.

Nutrients, N and P, in very small concentrations can cause eutrophication of waterbodies. An analytical quality control (AQC) exercise conducted by United States Environmental Protection Agency (US-EPA) (Table 8.1) showed a wide variation in results when identical samples were analysed in 22 laboratories.

Nutrient	Concentration, mg/L	Range of results, mg/L
Ammonia	0.26	0.09 - 0.39
Nitrate	0.19	0.08 - 0.41
Total phosphorus	0.882	0.642 - 1.407

Table 8.1 Results of analytical quality control exercise, 22 laboratories

It is seen that the range of values reported are significantly large, ±50% for ammonia and ±100% for nitrates, compared to the actual concentrations. Therefore, the need for nutrient control programme and its results become difficult to assess.

Many laboratories under Hydrology Project (HP) report total dissolved salts (TDS) calculated from the electrical conductivity (EC) value:

$$\text{TDS, mg/L} = A \times \text{EC, } \mu\text{mho/cm}$$

Where, A is a constant ranging between 0.55 and 0.9 depending on the ionic composition of salts dissolved in the water.

An inter-laboratory AQC exercise conducted by Central Pollution Control Board (CPCB) showed that for measurement of EC of a standard solution, out of 44 participating laboratories only 34% reported values in the acceptable range.

8.2 Quality Assurance Programme

The QA programme for a laboratory or a group of laboratories should contain a set of operating principles, written down and agreed upon by the organisation, delineating specific functions and responsibilities of each person involved and the chain of command. The following sections describe various aspects of the programmes:

Sample control and documentation: Procedures regarding sample collection, labelling, preservation, transport, preparation of its derivatives, where required, and the chain-of-custody.

Standard analytical procedures: Procedures giving detailed analytical method for the analysis of each parameter giving results of acceptable accuracy.

Analyst qualifications: Qualifications and training requirements of the analysts must be specified. The number of repetitive analyses required to obtain result of acceptable accuracy also depends on the experience of the analyst.

Equipment maintenance: For each instrument, a strict preventive maintenance programme should be followed. It will reduce instrument malfunctions, maintain calibration and reduce downtime. Corrective actions to be taken in case of malfunctions should be specified.

Calibration procedures: In analyses where an instrument has to be calibrated, the procedure for preparing a standard curve must be specified, e.g., the minimum number of different dilutions of a standard to be used, method detection limit (MDL), range of calibration, verification of the standard curve during routine analyses etc.

Analytical quality control: This includes 'within-laboratory' AQC and 'inter-laboratory' AQC.

Under the 'within-laboratory' AQC programme, studies may include: recovery of known additions to evaluate matrix effect and suitability of analytical method; analysis of reagent blanks to monitor purity of chemicals and reagent water; analysis of sample blanks to evaluate sample preservation, storage and transportation; analysis of duplicates to asses method precision; and analysis of individual samples or sets of samples (to obtain mean values) from same control standard to check random error. It is obligatory that all the level II and II^+ laboratories perform 'within-laboratory' AQC exercise as a routine programme to improve precision in analysis of water quality.

Inter-laboratory programmes: These are designed to evaluate laboratory bias.

It may be added that for various determinands all of the AQC actions listed may not be necessary. Further, these are not one-time exercises but rather internal mechanisms for checking performance and protecting laboratory work from errors that may creep in.

8.3 Need for Referral Laboratory to Perform Inter-laboratory AQC Exercise among the Laboratories

The Ministry of Water Resources, Government of India, has identified the CWC laboratory at Hyderabad, and the CGWB laboratory at Bhopal (both are level II^+ laboratories) for conducting the Inter-laboratory AQC once a year among the SW and GW laboratories respectively. These two laboratories are required to participate in the similar AQC programme conducted separately by the CPCB.

However, there is an urgent need for developing two 'Referral Laboratories' – one with the Central Water Commission and the other with the Central Ground Water Board – for providing expert guidance to the surface water and groundwater laboratories respectively and for conducting 'Inter-laboratory AQC' exercise once a year among the laboratories. The two Referral Laboratories should be equipped with state-of-the-art instruments and adequate qualified and trained scientists/chemists. The Central Pollution Control Board (CPCB) shall include these two laboratories in its 'Inter-laboratory AQC' exercise, which is conducted for the laboratories recognised under the provisions of the Environment (Protection) Act, 1986

8.4 Need for Central Training Institute on Water Quality Monitoring, Assessment and Management

With the constitution of the Water Quality Assessment Authority at the centre and the State level Water Quality Review Committees, it is imperative that the central and the state agencies concerned with water quality management develop co-ordination among them to function in a holistic manner. In consequence these agencies have to be trained in various aspects of water quality monitoring, assessment and management, so as to strengthen the pollution control programmes of the central and state pollution control Boards through complementary functions. While it is deemed that the water quality monitoring programmes of the national resources are seriously taken up by the central and state surface water and groundwater agencies, the pollution control boards take cognisance of the data so generated to plan action programmes without undue overlapping of activities.

It is, therefore, essential that the scientists/chemists/engineers of these agencies are trained in a manner that their services become subservient for the cause of protecting the quality of our national water resources.

It has been the considered view of the Group that there is a need for establishing a Central Training Institute for water quality monitoring, assessment and management, preferably located in the CPCB Office Complex for better and effective co-ordination among the agencies.

8.5 Accreditation of Laboratories

8.5.1 What is Laboratory Accreditation?

Laboratory accreditation is the formal recognition, authorization and registration of a laboratory that has demonstrated its capability, competence and credibility to carry out specific test or types of tests claimed by the laboratory. Accreditation of laboratories creates a transparent situation in the world of quality assurance and a powerful tool in developing and establishing confidence and credibility between parties in the market. The accredited laboratory is authorised to issue calibration/test reports and reports of chemical analysis which are recognised and accepted internationally.

8.5.2 Why Laboratory Accreditation?

There are many reasons for laboratories to opt for accreditation as follows:

- Provides recognition of technical competence including quality system management of the laboratories based on external (third party) assessment.

- Helps external verification of efficiency, correctness and accuracy of the processes in the laboratory.

- Improves (international) acceptance of test reports issued by the accredited laboratories.

- Builds up improved customer confidence in the test reports issued by the accredited laboratories.

- Develops potential for increased business through greater user confidence.
- Saves time and money through elimination of multiple assessment.
- Increases confidence of personnel in their work.
- Improves protection against liability.
- Helps clients to locate and identify the laboratories, appropriate to their need from compendium of Accredited Laboratories.

8.5.3 Recognition of laboratories under the Environment (Protection) Act, 1986

The Ministry of Environment and Forests (MoEF) has the system of recognising environmental laboratories under Section 12 of the Environment (Protection) Act, 1986. There is a specific format for application seeking recognition. After submission of the filled-in application, a team of Scientists constituted by MoEF inspects the laboratory. Recognition under such a system has many advantages as follows:

- The laboratory management gets systematised.
- Analytical quality control exercises, within laboratory and inter-laboratory, become obligatory to improve the performance in quality data generation.
- The name(s) of the Scientist / Chemist in the laboratory having requisite educational qualification and experience is notified as the Government Analyst in the official Gazette of the Govt. of India.
- The laboratory so recognised will have the authority to analyse environmental samples brought by industries/individuals/NGOs on payment basis. The analysis report submitted by the recognised laboratory is acceptable to the pollution control boards at the time of granting of “Consent” to industries before their establishment (one time) and also before discharge of effluent into environment (initially once and subsequently at the time of consent renewals at frequencies to be decided by the PCBs).
- The revenue so earned from analyses of water samples may off-set the cost of operation & maintenance of the laboratory besides bringing credibility to the laboratory.

8.5.4 Accreditation under NABL Programme of the Ministry of Science and Technology

- A laboratory seeking accreditation under the Ministry of Science and Technology, Government of India, must be able to demonstrate that it is meeting all the requirements of the National Accreditation Board for Testing and Calibration Laboratories (NABL) accreditation criteria Doc. 101 (1994). NABL-Doc. 101 is consistent with the provisions of ISO/IEC - Guide 25 and European Standards EN 45001.

- The criteria set out in the NABL-Doc. 101 covers all the aspects of a laboratory's activities and include its legal identity, organization and management, quality system, personnel, accommodation and environment, facilities and equipment, measurement traceability, calibration, test procedures, sample handling and identification and the recording and reporting of results. It also include quality system audit, review and quality control which ensures that quality system is fully implemented and in practice.

- A laboratory applying for accreditation should prepare a Quality Manual which documents the quality system (the operating procedures, standard test methods and work instructions, training records etc.) adopted by it for assuring compliance with the NABL criteria.

8.5.5 Preparation for Laboratory Accreditation

Internal Preparation Needed

(i) There must be a commitment from the top management to establish a quality assurance system which is real and visible.
(ii) Obtain all relevant NABL documents and get fully acquainted with requirements of NABL criteria at all levels.
(iii) Make a definite plan of action for obtaining accreditation.
(iv) Establish a core group to review the progress of preparedness of accreditation.
(v) Nominate a Technical Manager and a Quality Manager to co-ordinate all activities related to seeking accreditation. Such persons should be familiar with laboratory's existing quality system.
(vi) Define and declare the laboratory Quality Policy which must be communicated and understood at all levels.
(vii) Assess existing quality system and technical competence (documented procedures, records etc.) and identify gap/weak areas and make action plan to fill up the gaps.
(viii) Define the scope for accreditation i.e. the range of sample types to be tested or analyzed and types of tests (parameters).
(ix) Prepare a Quality Manual.
(x) Develop next level documents like Quality Procedures, Test Procedures & Quality Record formats.
(xi) Implement Quality Manual, Operational Procedures, Test Methods and prepare/maintain records.
(xii) Train laboratory staff at all levels specifically those who perform functions which may affect the quality of output.
(xiii) Arrange internal quality audit training for selected staff to be used for internal audit of laboratory.
(xiv) Establish/conduct internal quality audit using the trained staff and repeat few cycles.
(xv) Conduct management review to assess the effectiveness of the quality system implemented and take corrective actions.
(xvi) Prepare the accreditation application in prescribed proforma enlisting tests (parameters) conducted with detection limits and accuracy and also test methods being followed.

(xvii) Laboratories are required to submit ten sets of applications in appropriate application form for each field alongwith two copies of the Quality Manual.

External Preparation Needed

(i) On receipt of application, NABL appoints a Lead Assessor to examine the Quality Manual for its adequacy.
(ii) If the Quality Manual is not acceptable, NABL informs the laboratory for amending the Quality Manual.
(iii) If NABL feels that Quality manual has adequately addressed all the requirements of NABL Doc. 101, it informs the applicant laboratory and fixes preliminary visit to laboratory by the Lead Assessor.
(iv) The Lead Assessor makes a preliminary visit to the laboratory and collects information on size of the laboratory, nature of the testing, experties and number of Assessors required for assessment.
(v) A team of minimum two Assessors visits the laboratory to make an on the spot assessment of the compliance of the laboratory to the NABL Criteria (1994).
(vi) Lead Assessor submits his final assessment report to NABL which is being presented to relevant Committee (s).
(vii) The Committee examines the findings of the assessment team and determines whether recommendations in the report are consistent both with NABL's requirements and claims made by the laboratory in their application.
(viii) On recommendations of the Committee, the result of the accreditation is
(ix) Accreditation certificate is issued by the NABL which is valid for three years.
(x) A surveillance audit is carried out every year by NABL but prior intimation to the laboratory.
(xi) Request for renewal of accreditation is made to NABL in advance (six months).

9 WATER QUALITY DATA PROCESSING AND REPORTING UNDER HP

The prime objective of the HP is to develop a comprehensive, reliable, easily accessible, user friendly and sustainable Hydrological Information System (HIS) in the concerned agencies. A HIS comprises physical infrastructure and human resources to collect, process, store and disseminate water resources data. The overall objective of HIS under HP is to realise part of the Govt. of India's policies and strategies in the water sector. Article 2 of the National Water Policy (1987) of India, which is pertinent to HIS, stipulates: "*The prime requisite for resources planning is a well-developed information system. A standardised national information system should be established with a network of data banks and data bases, integrating and strengthening the existing Central and State level agencies and improving the quality of data and the processing capabilities. There should be free exchange of data among the various agencies and duplication of data collection should be avoided*".

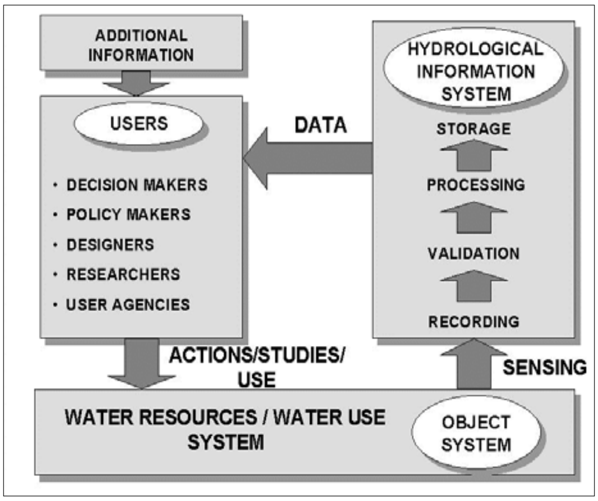

Figure 9.1 Role of HIS

The primary role of the HIS is to provide reliable data sets for long-term planning and design, and to frame rules for management of water resource systems. The system should provide the information to users in time and in proper form. The scope of HIS is not intended to provide data to users on a real-time basis for short-term forecasting or for operational use.

The first step is to obtain information on temporal and spatial characteristics of the object system through a network of observational stations. The basic data collected for different hydro-meteorological parameters in terms of quantity and quality are called observed or field data. Such observed data have to be processed to ensure their reliability. Both field and processed data sets have to be properly stored, i.e. processed data for dissemination and field data to permit inspection and revalidation in response to queries from users. This role of HIS is illustrated in Figure 9.1.

The HIS has the following characteristics:

- it is demand-driven, i.e. output is tuned to the user needs,
- it ensures use of standardised equipment and procedures for data collection,
- it employs computerised processed and validated databases for efficient dissemination, and
- it provides proper institutional support to ensure sustainability.

9.1 Assessing the Needs of Users

Under the Hydrology Project, Hydrological Data User Groups (HDUGs) have been constituted in each state and at the central level to ascertain and respond to the needs of users. A wide array of potential hydrological data users are represented in these groups, whose main aim is to review hydrological information needs, identify shortfalls in content and services provided, and make suggestions for improvements. This forum has given a unique opportunity to bring the HIS closer to the users and fulfil their aspirations. Such a system can be adopted for all the States.

9.2 Data collection

A comprehensive list of all monitoring equipment to be employed in the HIS has been elaborated. The equipment varies from a simple raingauge, a fully automated tipping bucket raingauge to digital water level recorders, Atomic Adsorption Spectrophotometer (AAS) and Gas Chromatograph (GC). Detailed specifications for all equipment have been drawn up and are being utilised by all agencies. This step will reduce variability in observations, at different locations and by different agencies.

9.3 Water Quality Analysis

A comprehensive water quality laboratory development programme has been completed by establishing or upgrading 290 laboratories under three categories: Level I, Level II and Level II^{+}, with varying levels of sophistication. Level I laboratories (215) cover six parameters (colour, temperature, pH, dissolved oxygen, conductivity and turbidity) for analysis at the site of sampling. The analysis of other parameters is done at Level II or Level II+ laboratories. There are about 50 Level II laboratories for the analysis of physico-chemical and microbiological parameters and 20 level II+ laboratories for the additional analysis of heavy metals and pesticides. Special instruments, like UV-visible spectrophotometer, Atomic absorption spectrophotometer (AAS) and Gas chromatograph (GC) have been provided in the Level II and level II+ laboratories for analysis of pollution related parameters including toxicants, like trace metals and pesticides.

The procedures for analyses of various parameters have been identified and documented as "*Guidelines on Standard Analytical Procedures for Water Analysis*" with illustrations / examples and sample calculations for the reference of the laboratory chemists. In view of the multiplicity of the water quality monitoring agencies and the large number of analytical laboratories participating in the process of sampling and analysis, it is imperative to conduct Analytical Quality Control (AQC) exercises for reliability and reproducibility of data. Two types of AQC exercises viz. "Within-laboratory AQC" and "Inter-laboratory AQC" have been formulated. While the first exercise is a routine exercise for individual laboratories, internally to be conducted regularly to gain confidence in analysis, the latter provides an opportunity to test the analytical skills of the chemists across various participating laboratories. The inter-laboratory AQC exercises are proposed to be conducted at least once a year. Two-rounds of "Within Laboratory AQC" and two annual rounds of "Inter-laboratory AQC" exercises conducted among the participating laboratories showed marked improvements in the generation of better quality data.

9.4 Data Processing, Analysis and Reporting

The existing system of manual or very limited computerised data processing is being replaced by fully computerised data processing using dedicated and user-friendly software. The raw data are in a variety of formats such as hand-written records, charts and digital records. Raw data as observed and recorded may contain many gaps and inconsistencies and are passed through a series of operations, typically: data entry, validation checks, in-filling of missing values, processing to estimate derived variables, compilation in different forms, and analysis for commonly required statistics etc. Of particular importance is assuring the quality and reliability of the data through a variety of validation procedures. Reports are prepared to bring out the salient characteristics of the hydrological regime of the region.

Both surface water and ground water agencies would employ dedicated hydrological data processing software. HYMOS, a hydrological data processing software and a product of Delft Hydraulics of The Netherlands is employed for all surface water quantity and quality and hydro-meteorological data processing activities. Similarly, a comprehensive groundwater data processing software is being prepared. Both surface and groundwater data processing software are modular in nature and are being implemented with varying levels of sophistication. The first module, also called the primary module, is dedicated to the purpose of entry of all types of data and for carrying out the preliminary data validation. The second module is oriented towards performing spatial consistency checks and having different types of data correction, data compilation and analyses procedures. The third or the highest level module will have the necessary options for hydrological validation and comprehensive reporting. The dedicated groundwater data processing software also includes GIS support, to visualise and analyse spatial data.

The primary modules of surface and groundwater data processing systems (including water quality) are called Surface Water Data Entry System (SWDES) and Ground Water Data Entry System (GWDES) respectively. These software have a Microsoft Access database structure at the back end and the front end has been built using Visual Basic for Application (VBA). These systems are customised to provide a user-friendly environment. The computer screens look alike the manuscripts used by observers for recording the observed data. Comprehensive and easy scrutiny of data is provided by graphical visualisation. Application of these data processing systems throughout the project area and at all the agencies has, for the first time, provided a unique scenario at a gigantic scale, in which all the hydrological data processers use standard and uniform tools.

9.5 Management of Historical Data

All the State and Central agencies have been maintaining their observational networks for many years and thus a huge volume of historical data is available. Most of this data is in manuscript or chart forms. Some of this data is even becoming physically inaccessible due to gradual decay of older manuscripts. Often these are of variable or “unknown” quality since in many cases the recorded data were seldom scrutinised. A comprehensive program of historical data entry is established in each agency holding such data, for organising this valuable information in the uniform databases of SWDES and GWDES. Subsequent to entry into the computer, the data will be scrutinised for obvious data entry mistakes and thereafter for desired hydrological consistency. Most of the available groundwater related data have already been organised and surface water data are also expected to be completed soon. Such a mammoth organisation of hydrological data are being accomplished for the first time for a substantial part of the country. It is expected that this would provide the water resources engineers and planners of the country with an excellent opportunity to easily access the required historical hydrological information and use it.

9.6 Data Storage and Dissemination

All historical and currently observed data sets are proposed to be stored and maintained in well-defined computerised databases, using industry standard relational database management systems like ORACLE. This is essential for long-term sustainability of the data sets and their efficient dissemination to the end users. Both, raw and processed data sets will be stored and archived with specified standards so that there is no loss of information. Necessary features of data administration and management like data security, protection from data corruption and provision of controlled accessibility would be part of the system design. An efficient and user-friendly query system aided with graphical visualisation on the maps for identifying the data required, also through Internet, is envisaged to be used for making data request.

9.7 Overall Structure of HIS

The structure of HIS at State/Regional level, as set up by various participating State and Central agencies respectively, emphasising the distributed approach to carry out data processing, data exchange and dissemination processes is illustrated in Fig. 3. Being a distributed data processing and management system, each data processing centre is provided with adequate communication links for exchange of data to and from other data processing centres.
HIS operates at different levels from measurement in the field to comprehensive validation and data processing at three levels of Data Processing Centres and storage at Data Storage Centres as follows:

- **Observation stations/wells:** Observations on different hydro-meteorological, hydrological and hydrogeological variables and collection of water quality samples is done at the surface water and groundwater observation networks. The field data are submitted to the Sub-divisional/District Data Processing Centres within the month of observation. The water samples are collected and send to designated water quality laboratories on a regular basis.

- **Water Quality Laboratories:** Samples arriving from observation stations are analysed within the prescribed time frame. The results are entered in the computer and subjected to primary validation. At regular intervals, the laboratory passes the information to the Divisional or Regional Data Processing Centre.

- **Sub-divisional/District Data Processing Centres (SDDPC/dDPC):** Here, all field data are entered in the computer and preliminary validation is carried out. Computerised data are passed on to the Divisional/Regional Data Processing Centre within 10 days after the month of observation.

- **Divisional/Regional Data Processing Centres (DDPC/rDPC):** Given their larger areal coverage, data is organised in basin/sub-basin wise databases and secondary data validation (spatial consistency checks) is carried out. Validation at Divisional Data Processing Centres is completed within 15 days of receipt of data and thereafter surface and groundwater data are transferred to the respective State Data Processing Centres.

- **State/Regional Data Processing Centres (SDPC/RDPC):** Their main activity is final data validation, completion, analysis, and reporting. Since these centres cover a whole river basin or a very large part thereof, it is appropriate to ensure hydrological consistency between inter-related variables like rainfall, runoff, recharge etc. The data arriving from various Divisional Data Processing Centres are organised in basin wise databases and hydrological validation is carried out. With the procedure, the need for exchange of data among different agencies, for the purpose of validation has been realised and a formal data exchange process has been established. The inter-agency data validation exercises are scheduled twice-a-year, in the months of February and August, for the data of monsoon and non-monsoon months respectively. After the data is thoroughly validated, the (authenticated) processed data are transferred to the respective Data Storage Centres.

- **State/National Data Storage Centres (SDSC/NDSC):** For six out of eight States there is a common Data Storage Centre for surface and groundwater data. Central agencies have separate Data Storage Centres for each of the regions. Each central agency also has one

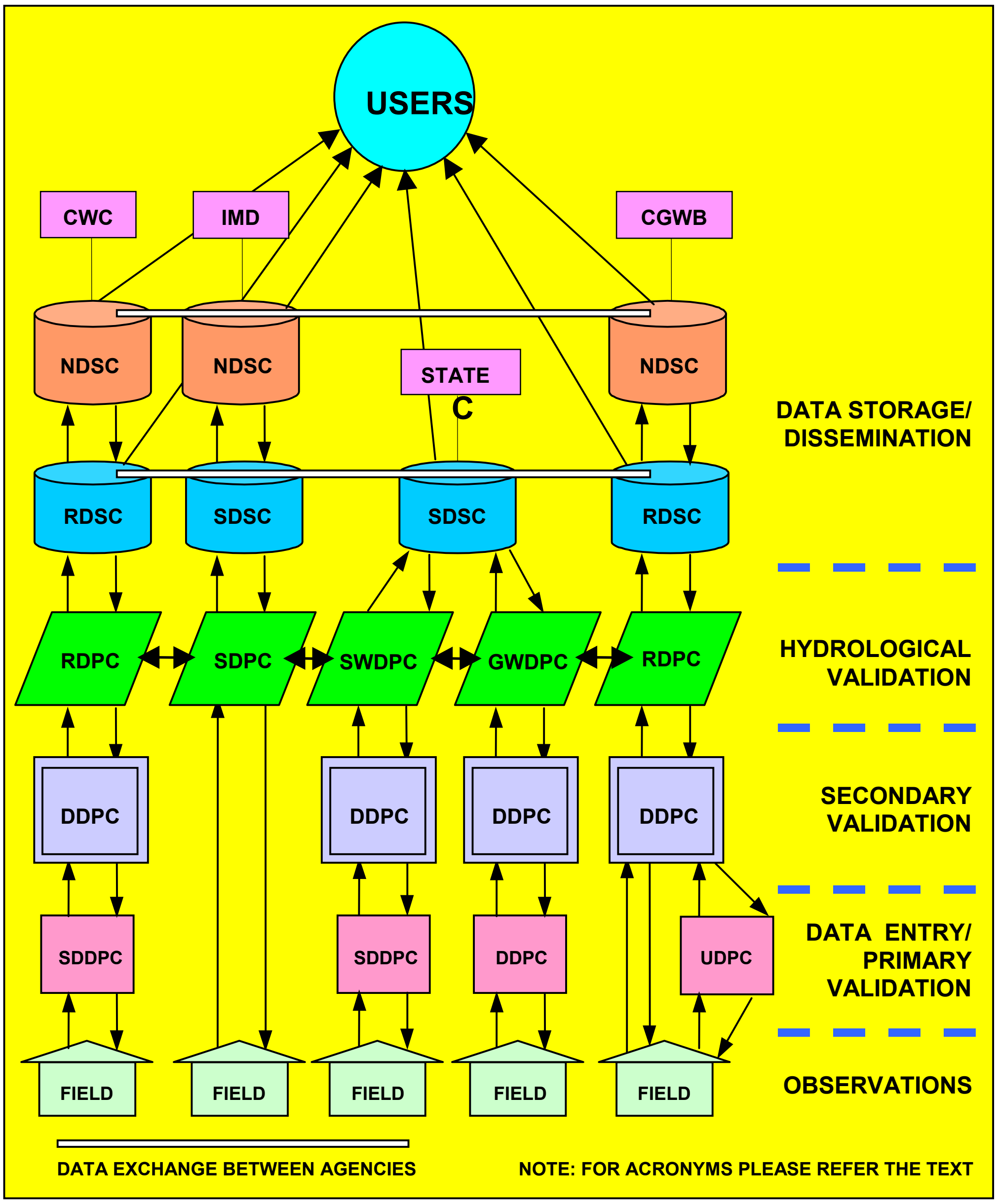

Figure 9.2 Structure of HIS at State/Regional levels

National Data Storage Centre for bringing desired information from various state and regional data centres to have an overall perspective of hydrological regime at the national level. All the State and Regional Data Storage Centres store and administer the storage of field (or raw) and processed (or authenticated) hydrological data and ensure smooth and efficient dissemination of data to the users. For an effective dissemination of available information, Data Storage Centres also maintain a catalogue of data stored in its own database and those stored in the databases of other agencies.

9.8 Sustainability of HIS

An extensive training program has been planned under HP and is being implemented throughout the project area. It is envisaged to ensure necessary skill building and provide training to all the personnel involved at different levels in various activities of HIS. A whole range of subjects, issues and activities are covered under the well-planned training program that includes training courses covering aspects such as:

- Observation practices on hydrological and allied data,
- Standard water quality sampling and analysis procedures,
- Basic know how for working on computers,
- Surface water, groundwater and water quality data entry procedures,
- Surface water, groundwater, and water quality data processing and interpretations using dedicated software,
- Geographical information system,
- Database management systems including aspects of latest information technology,
- Sophisticated equipment and installations like DWLRs, ADCPs, AASs and GCs etc.,
- Analyses of pollution related parameters,
- Procurement procedures for equipment and other infrastructural facilities,
- Installation and acceptance protocols for specialised equipment,
- Training and communication skills for in-house trainers.

Most of these training courses have been institutionalised through the services of a few designated research and academic institutions called the Central Training Institutes (CTIs). Courses are developed and refined by the in-house faculty members of such institutions and the consultants to the project. A three pronged approach is adopted for imparting training to a very large number (about 10,000) of trainees on a variety of issues as mentioned above. A concept called “training of trainers (ToT)” is employed by which a core group of a substantial number of motivated officers of each state and/or CTIs are trained. These are then expected to conduct further training courses for the actual trainees with or without the help of faculty members from the CTIs. After the formal training courses the trainees are further assisted at their own working place by what is called as hands-on coaching sessions. The CTI could be established at CPCB in Delhi with its extension counters at the SPCBs.

Comprehensive and well-laid out training documents have been prepared covering the contents of the course, the exercises and the presentation material so as to ensure uniformity and standardisation in transfer of knowledge and delivery of training courses. Scores of training courses have been conducted regularly by the CTIs and the HP-Consultants throughout the project period. It is also planned that these CTIs would continue to provide training facilities even after the project ends, specially to address the problem of frequent transfers of trained staff members out of the project area.

9.9 Institutional Strengthening

Information on hydrological processes would be required by the society on a continuous basis for a sufficiently long period of time in the future also. Since HIS is a vast system, institutional and human resource development aspects need to be paid adequate attention. This is particularly required in view of the absence of objective planning and maintenance of

HIS in the recent past, specially by most of the state agencies. Many water resources projects have been launched and successfully completed earlier, but there is always a fear that the created facilities would wither away, the trained staff will move elsewhere and the things would gradually return to pre-project stage. This has been experienced in case of many other projects funded by internal or external agencies and specially in developing countries. HIS is re-vitalised by way of the HP and it is, therefore, of utmost importance to ensure that the institutional strength required for HIS and created under the project is maintained and enhanced in the future.

There have been significant institutional problems in making the HIS efficient and objective. First of all, in a few states the HIS was not independent and was getting least attention for budgetary and personnel support. It required perusal at the highest level of governance, in some cases, to make the hydrological services independent, within the broad umbrella of the department. Secondly, in view of the tremendous water quality monitoring programme being introduced, there were serious problems of unavailability of suitable staff in the water quality laboratories. Similar is the case for database administration and information technology. Since application of emerging information technology tools is a recent phenomenon, not only in the water sector but in general also, it was expected to face such situation. Further, in this era of privatisation and shedding public funding by reducing staff, it was very difficult to deploy adequate number of observers and helpers on new and existing observation stations.

Though it is not to suggest that most of these obstacles have already been resolved to the desired level of satisfaction, the suggested solutions have been followed up in right earnest. The in-house capacity building by a strong training component would also go a long way in bridging the remaining gaps. Furthermore, a whole set of manuals, reports and guidelines prepared on various aspects of HIS has been made available to each office/location and would go a long way in institutionalising various HIS activities. Establishment of HDUGs and advisory role it would play would further make the system vivid and responsive.

9.10 HIS Implementation

Implementation of any wide spread project as the HP, involving participation of more than 20 independent government agencies, its bureaucratic way of functioning and variety of technical and institutional matters, would definitely not be an easy task. It is obvious that such projects must be meticulously planned and structurally implemented. As most of the activities are closely linked with each other, it becomes extremely important to rationally sequence and execute them within the stipulated time frame. When such a large existing HIS is being upgraded and standardised, it is very important that the required specifications, guidelines and training documents are prepared with utmost precision and clarity. Any shortcuts in these often lead to non-optimality, non-uniformity, inefficiency and wasteful use of resources in the long run. Also, the project must be phased such that activities are sequentially and/or concurrently initiated and completed as planned. Proper categorisation and sequencing of activities would ensure that due emphasis and efforts are given to various aspects.

The Hydrology Project has been implemented by most of the agencies to the satisfaction of all partners. However, it is apparent, retrospectively though, that there are certain factors which, if considered adequately, would have resulted in better implementation. Some of these factors are: (a) allowing adequate time period for preparation of standard specifications before initiation of procurement of sophisticated equipment, (b) accounting for longer time required for standard government procurement processes, (c) ensuring availability of infrastructural facilities before delivery of equipment, (d) synchronising training component with the availability of staff and computers in the offices and readiness of observation stations, (e) training existing staff for specialised jobs rather then expecting and waiting for recruitment of new staff in this era of slimming down government agencies.

The project has given a unique experience of standardising equipment specifications, setting uniform and standard data collection procedures, providing training in structured manner and implementing uniform and dedicated software for hydrological data processing and management at such a huge scale. However, rather than its successful implementation during the project period, it is more crucial to ensure continuance and sustenance of HIS activities, as prescribed under the project, in the future. Two major factors which may impede this continuity are the frequent transfers of government officials out of the project domain and lack of commitment from government side to continually provide adequate budgetary support.

9.11 Future Aspirations

In many countries, hydrological services receive inadequate funding to carry out even basic monitoring and assessment of national water resources. The situation is exacerbated by the existence of several monitoring networks with different purposes and standards; these are often independently operated. Computer archives are maintained on obsolete equipment or do not exist, and paper records are fast deteriorating, resulting in long gaps in records and unknown quality of data. This drastically reduces their value for planning, design, and management, restricting the ability of the nation to address the issues in the right perspective. Better (not necessarily more) information directly useful to data users in an open and participatory decision making process is urgently needed.

The expansion of water-development projects has slowed down in the recent past due to environmental and other considerations. The emphasis has shifted towards developments of management strategies that make optimal use of the existing infrastructure. The pre-requisite for any water resources developmental and management plan is the availability of a comprehensive, reliable and easily accessible hydrological information system. India has already established itself in the information technology area. There is no reason why this technology can’t be extensively applied in the water sector. There are great challenges in the water sector and unless these are faced head-on with the best tools, a similar opportunity may not come in the foreseeable future.

The Hydrology Project is a concerted effort for improving and developing computerised hydrological data processing and management systems. It has promoted interaction between different state and central agencies and different states. The procedures of observation, processing and dissemination of water resources data have been standardised. Special attention has been paid to the critical elements such as institutional capacity building and establishment of Data User Groups to enable sustainability of the system on a long-term basis. It would only be fitting to carry the experience gained in the Hydrology Project to the remaining areas in India and other countries, at least these in the SAARC region.

10 CONCLUSIONS

10.1 With the constitution of the Water Quality Assessment Authority at the Centre and the consequent formation of Water Quality Review Committees at the state level, protection of water quality of the national water resources is gaining a national concern. The appointment of the Expert Group by the Ministry of Environment and Forests, Ministry of Environment, Government of India, to streamline the water quality monitoring systems would, hopefully, lead to a further momentum to the resolve of the national government in protecting the quality of the national water resources for the sustainability of the designated-best-uses.

10.2 The Expert Group has reviewed the monitoring systems in vogue in various central and state agencies to arrive at a unified procedure, to promote integration of the monitoring programmes for better understanding of the factors influencing the deterioration of water quality and have a concerted effort in evolving Action Plans in restoring and/or maintaining the wholesomeness of the water bodies.

10.3 A 'Protocol for Water Quality Monitoring', as detailed in Chapter 7 of this report, has been recommended by the Expert Group for implementation in the water quality monitoring agencies, which deals with the various components of water quality monitoring as assigned by the Ministry of Environment and Forests (MoEF), from network design to quality assurance and quality control for reliable data generation. The Expert Group has also recognised the software developed under the Hydrology Project for data entry, data validation and analysis for promoting computerised data processing and storage to facilitate data user agencies in planning pollution control programmes.

10.4 The Expert Group has recommended (Chapter 8) various types of analytical quality control (AQC) tests viz. 'within laboratory' and 'inter-laboratory' AQC exercises, to be performed by the laboratories for reliability in data generation.

The Group also suggests (paragraph 8.3) that there is an urgent need for developing two 'Referral Laboratories' – one with the Central Water Commission and the other with the Central Ground Water Board – for providing expert guidance to the surface water and groundwater laboratories respectively and for conducting 'Inter-laboratory AQC' exercise once a year among the laboratories. The two Referral Laboratories should be equipped with state-of-the-art instruments and adequate qualified and trained scientists/chemists. The CPCB shall include these two laboratories in its 'Inter-laboratory AQC' exercise, which is conducted for the laboratories recognised under the provisions of the Environment (Protection) Act, 1986

10.5 It was observed, rather painfully, by the Group that the most vulnerable aspect in water quality monitoring programme is the lack of qualified and trained manpower. To estimate the manpower requirement, relationships (paragraph 7.5.3) could be established for surface water and groundwater laboratories based on the number of samples and the parameters to be analyzed, as stated in the concluding part of this report.

10.6 There is an imperative need for establishing a Central Training Institute for water quality monitoring, assessment and management (paragraph 8.4), preferably located in the CPCB Office Complex, for better co-ordination.

10.6 Incidentally, the scope of the report is restricted to the study of the monitoring systems for inland surface water and groundwater only as envisaged in its terms of reference. Monitoring systems for coastal water and lake ecosystem being of equal concern, the Group recommends that the same may be studied separately and at the earliest.

Arunoday Bhattacharjya
Chairman

R. H. Siddiqi Member	R. Dalwani Member	S. D. Makhijani Member
N. K. Verma Member	S. P. Chakrabarti Member	V. N. Wakpanjar Member Convener

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