RECORDING AND PROCESSING OF DATA

1.0 GENERAL

Water quality data may be stored manually on report forms and files or automatically on magnetic tapes through the use of computers. The rapid development of electronic devices for processing of data has provided a capability for handling large volume of data quickly and efficiently.

1.1 Water sample information

The recording and storage of data collected in any water quality survey programme must meet a minimum set of requirement. For each sample, the following is a minimum set of items which should be recorded:

- Location of the sampling point
- Date of collection
- Project/study for which the sample had been collected
- Laboratory number
- Field and laboratory results and the methods used.

The location of the sampling point should be recorded as geographical coordinates, i.e., latitude and longitude values. The station number is used to identify a given sampling point in a concise form. Because of this, the station number must be unique, i.e., no two different sampling locations can have the same number, and also no one sampling point can have two different numbers. The simplest station numbering system would be a table in which sequential numbers starting with 1 (one) are assigned to sampling points as they are established.

In addition to the geographic coordinates and the station numbering system, the location of the sampling point should be described in a narrative. The narrative description contain the name of the river, lake, etc., together with landmarks which will help identify the sampling point.

When a sample is collected, the following information should be recorded: day, month, year, hours, and minutes (if applicable).

The project for which the sample has been collected may also be identified by a number. Each project number should have a separate file with the associated information: project name, stations to be sampled under the project, frequency of sampling at each station, parameters to be measured, and other information pertinent to the project.

For identification purpose, each sample on receipt in the laboratory is assigned a laboratory number. Each number must have a unique number and the number should be recorded both on the bottle(s) containing the sample and sample card.

1.2 Field and laboratory results

The following items should be recorded for field and laboratory results:

- Parameters measured
- Analytical methods used
- Results obtained.

In most systems the parameters which is measured and the analytical method which is used is reflected in the parameter code number. A 3-digit subfield indicating the parameter measured followed by a

2-digit sequential number for the method used is usually sufficient to handle the analytical tests for water quality. The parameter code number thus have 5 digits.

Each parameter code number represents a specific analytical method for carrying out the measurement. This information is most important to water users of water quality data. A file of parameter code numbers in numerical order should be established.

There are various methods of recording results in a laboratory. The method described below is generally followed in most of the laboratories. The sample entering the laboratory for analysis is accompanied by a laboratory card. The card contains information about the sample such as sampling location, date of sampling, the sample number, and a list of parameters for which the sample is to be analysed.

The analyst performing a certain test might choose to record his results in a laboratory book, or in table which may have the following headings:

Sample Number	Parameter Code Number 1	Parameter Code Number 2
....	....	....
....	....	....
....	....	....

These results may then be transferred from the book to the laboratory card at the end of the day. Various sizes and formats of laboratory cards may be used.

Analytical results recorded on cards, magnetic tapes, discs, etc., must be filed in a systematic manner to allow easy rapid access of the results. The data file may be organized in the following manner:

- Station numbers in numerical sequence; and
- Samples under each station in chronological order.

Once the data are obtained, they must be filed in such a manner that they are easily retrievable in a format suitable for interpretation, report writing, plotting, etc.

1.3 Water quality data interpretation

Once water quality data have been assembled in data storage system, the next step is to interpret the data with respect to specific questions, environmental problems and water resource management requirements. The most commonly asked questions about water are:

- What is the water quality at any specific location
- What are the water quality trends in a particular region; is the quality improving or getting worse
- How do certain parameters relate with one another
- What are the total mass loadings of materials
- Is it possible to develop a water quality model based on the available data

Although general water quality conditions may be ascertained by scanning long column of tabulated data, the most reliable method and the most commonly used, is the statistical approach. A statistical analysis of the data provides a deeper understanding of the data and enables the water resource manager to arrive at better decisions in water quality management.

There are several well known statistical techniques for examining water quality data, some of which are:

- Mean values
- Standard deviation
- Cumulative frequency distribution
- Mass loadings
- Graphical display
- Least square fitting to straight lines or curves
- Comparison of average values
- Comparison of cumulative distribution
- Q-Q plots
- Frequency analysis
- Power spectrum analysis.

2.0 RIVER WATER QUALITY

2.1 Classification of rivers

The following rough classification of different ranges of annual average discharges is normally used for practical purposes:

Large rivers	> 1000 m^3/s
Rivers	150-1000 m^3/s
Streams	5-150 m^3/s
Small stream	< 5 m^3/s

However, these distinctions are arbitrary and no indication on annual variations of river flow is given. Particularly in sub-tropical and arid zones, rivers often range from zero discharge during the dry season to large during monsoon periods.

2.2 Water quality considerations

Knowledge of the natural water quality of a stream, its self-purification capacity and the effect of various wastes on its ecosystem is necessary for a planned development of its uses. While the ground water is protected by the overlying strata, a stream is highly vulnerable to activities of man in its basin. Of all the water sources, streams are one of the most extensively exploited water resources. The various beneficial uses to which streams are put include:

- Sources of water for municipal, industrial, cooling and agricultural purposes;
- Fisheries;
- Generation of hydropower;
- Recreation;
- Navigation; and
- Carrier and receptacle of waste waters.

It should be noted that to some extent the order of uses shown above requires water of decreasing quality. Although water does not exist in streams in its pure chemical form, it may be classified as unpolluted in view of its beneficial use.

2.3 Self purification of streams

With time, or as the water continues to flow its source, a polluted stream be able to regain its natural quality. Various physical, chemical and biological phenomena are responsible for this self-purification. It may be pointed out that some conservative pollutants may persist for a long time before they are diluted to insignificant level or are removed from the liquid phase due to physico-chemical reactions of precipitation and adsorption. Under a steady inflow of pollution at one point, the river stretch down stream may show a varying water quality.

2.4 Monitoring network design

The location of sampling stations largely depends on the purpose of study. In general the sampling stations may be divided into two categories, i) basic stations and ii) auxiliary stations.

Basic stations: Basic stations are usually located at the mouth of main streams and principal tributaries, downstream of river development projects, at or near hydrometric stations (discharge gauge site), at state boundaries, above and downstream of waste outfalls, industrial and urban centres, and at points of water use.

Auxiliary stations: Auxiliary stations are established to investigate the effect of pollutants discharged into a stream, determination of assimilation capacity of stream and similar studies with common objective. These stations are purposely related to each other and may be moved to another place or operated temporarily. Data collected at these stations is used to interpolate stream quality at other points, or predict the water quality described under a set of given conditions.

2.5 Sampling programme design

Sampling point location: Sample should be taken only where the composition is expected to be homogeneous over the cross-section. Usually there will be no difficulty in locating such points in effluents discharged from pipes or small open channels. Sampling points in rivers should be well away from any possible disturbing influence, such as pools, stagnant zones, heavy growth of weed or sewage fungus, or points where ground water enters (unless it is desired to study specifically their effects on water quality).

Sampling frequency: Sampling frequency depends largely on the purpose of the network, the relative importance of the station and the variability of the data. It is also influenced by the accessibility of the station. Lastly the work load involved and the financial commitment for a decided frequency of sampling must match the available resources. At newly started stations samples may be collected at a higher frequency so that within 2-3 years a sufficient number of observations are available for a statistical evaluation of variations, cycles and trains in the values of the parameters used in monitoring the water quality. The frequency of sampling may be increased or decreased after such an evaluation. For basic station networks operated for collection of baseline data, the sampling frequency may be from 3-4 times per year to monthly collection of samples. In any event, no less than one sample should be taken in each season. When stations are operated in relation to specific use, the frequency of sampling will be influenced by that use. The sampling of raw-water for water works may be carried out daily. While at a sampling station maintained downstream of a waste outfall in order to monitor the effectiveness of the waste water management programme and its effect on the stream, weakly or bi- monthly samples may be collected. Where the stream water is used for swimming and other recreational purposes, sampling may be confined only to the season of use.

Critical parameters: The choice of water quality characteristics that are to be measured must necessarily be determined by the local circumstances. It will, in general, be necessary to compromise between the number of parameters measured and the marginal difference that information on each parameter makes to subsequent management decisions. In principle, the number of organic constituents present could be very large but it would be hopelessly impractical to attempt measure them all on a routine basis. Instead, it wili be necessary to rely on non-specific tests such as COD or TOC to indicate the general level of organic pollution, together with a few specific tests for selected pollutants with particularly harmful properties.

It is suggested that subject to the findings of preliminary inquiries about a local situation, the characteristics to be measured may include the following parameters: total organic carbon, BOD, cyanide, pesticides, suspended solids, nitrogen, fluoride, cadmium, chromium, copper, lead, nickel, zinc, mercury, boron, dissolved oxygen, pH value and coliform bacteria.

If the intention is to develop a model which would permit the evaluation of the influence of pollution control measures on the cost of treatment of public water supply, additional information might be needed on total hardness, alkalinity, calcium hardness, sulphate, phosphate, sodium, potassium, etc.

While measurements should be made of coliform bacteria with complementary test at intervals for E.coli, no measurement of specific pathogens are suggested. It is doubtful whether additional information afforded by measurement of pathogens would add very much to the knowledge of the extent of faecal pollution. If there is serious concern about a prevalence of particular diseases of water borne origin, including those which might be transmitted, not as a result of human faecal contamination, but by other routes, such as contamination of the water by infected livestock, special studies might of course be required.

Automatic monitoring: The use of continuous water quality monitors in river water quality surveys need careful consideration. To be realistic, although good progress is being made with the difficult task of developing instruments which perform satisfactorily under the rigorous conditions encountered in the field, the number of relevant characteristics that can be measured with adequate accuracy is limited to the following: temperature, dissolved oxygen, organic matter, suspended matter, conductivity, chloride, hardness and pH value. Out of these, not all would necessary be relevant to any survey. Those, that seems most likely to be worth measuring are temperature, pH value, conductance and dissolved oxygen.

2.6 Reporting of results

Survey report: Depending upon the objectives, a stream survey programme may come to a definite conclusion after a period of time or it may be necessary to evaluate the collected data periodically to modify the procedures such as types of determinations, location of sampling stations, frequency of sampling, etc. The achievements and failure can be adjusted by writing a report. A guideline is suggested below which might be used as a example.

Introduction:

- Objectives and terms of reference.
- Description of stream and its basin; its present and prospective uses and sources of pollution.

Methodology:

- Description of sampling stations, outfalls and sampling procedure.
- Laboratory facilities and analytical techniques.
- Hydrological measurements.

Observations:
- Sources of pollution.
- Stream water quality.
- Stream discharge and other hydromorpholigcal measurements.

Evaluation of Results:
- Analysis of data.
- Formulation and evaluation of models describing the behaviour of pollutants.

Recommendations:
- Classification of stream.
- Necessity of pollution abatement measures.
- Future surveillance programme.

Water quality maps: One of the most efficient and attractive ways to present numerical results is through the use of graphs and maps. In addition to graphical data presentation, the visualisation of findings in the form of maps provides an easy and rapid comprehension of the situation. Such maps may in addition show the location of human settlements, industrial plants, major water outfalls and intakes, water purification plants, power plants, etc. The river course is represented by a band, the width of which indicates the mean low discharge. Colours indicate the quality of the water. Usually the following colour code is used.

Blue: Category I, no pollution to very slight pollution
Green: Category II, moderate pollution
Yellow: Category III, heavy pollution
Red: Category IV, excessive pollution
Black: Category V, zone of devastation.

Water quality modelling: Stream water quality forecasting in a basin has two components, 1) forecasting of the development of the basin and consequent effects on the water quality, 2) forecasting of the changes in concentration of the pollutants within the stream channel. It is simple to forecast the concentration of contaminants which are stable in nature, since there concentrations changes only due to dilution or evaporation. Concentrations of many biologically stable organic and inorganic substances changes due to precipitation, sedimentation, adsorption and chemical reactions with other substances. These reactions are influenced by several factors such as pH, ORP, temperature, bed characteristics, etc., and they are to be considered separately for respective mixtures of substances and local conditions. Therefore, it is practically impossible to draw general valid law for them.

Models have been developed and widely used to forecast changes in BOD of the stream water and its effect on oxygen resources of the stream. A number of approaches have been adopted for these formulations. Some have definite advantages under a given set of conditions. However, it is to be borne in mind that these approaches have limitations and can be used advantageously only if these limitations are kept in view.

3.0 LAKE WATER QUALITY

A lake may be defined as a partially enclosed inland body of fresh water surrounded by land. Lakes vary in size from many thousands of square kilometres in area and many metres in depth to only a few square kilometres and depths of less than 10 metres. Lakes are used for many purposes including municipal, industrial, cooling water sources, recreation, navigation, fishing, power generation, etc.

3.1 Types of lakes

Lakes are usually divided into three types, eutrophic, oligotrophic, and dystrophic. Eutrophic lakes are rich in nutritive materials and contain an abundance of plankton organisms, shore vegetation, and animal life. Oligotrophic lakes on the other hand, are poorer in nutrient materials and organic life, and are more nearly self contained. Dystrophic lakes contains excessive accumulations of humic type substances which slow down the process of the decomposition.

3.2 Stratification

Lakes are warmed up by the action of sun and wind on surface waters during warm weather seasons and are cooled thereafter by a net loss of heat to the atmosphere. Warm water, being lighter, floats on colder more dense waters. Because of these physical characteristics, lakes are usually divided into three zones of thermal stratification, epilimnion, hypolimnion, and metalimnion. The epilimnion zone is the upper layer of the lake consisting of the warmer, lighter water. The downward movement of this water requires displacement of the more dense and colder waters in the lower region of the lake and there is therefore, a thermal resistance to mixing. Warm waters in the epilimnion zone are circulated by winds and do not go far below the surface but move along the top of the cold water zone and then returns to the surface. The hypolimnion zone is comprised of the non-circulating cold mass of water in the bottom layers of the lake during the stagnant period. The hypolimnion zone has little or no opportunity to gain heat from the sun or oxygen from the atmosphere during the warm weather seasons. The metalimnion zone, known as thermocline, is the transition zone between the epilimnion and hypolimnion and is the area in which rapid temperature change occurs. Because of the difference in densities of epilimnion and hypolimnion waters, the thermocline act as a barrier to the downward movement of the lighter waters.

3.3 Sedimentation

Lakes receive a wide assortment of suspended materials from rivers, streams, precipitation, shoreline erosion, pollution sources and biological activities. These materials usually referred to as sediments are a very important factors in the life of lakes. Sediments, depending upon the climate and physical characteristics of the drainage basin, tend to fill lakes, thereby restricting there intended uses and eventually converting them into undesirable marsh lands and swamps.

Sedimentation in lakes usually begins with inorganic material from land sources. However, as biological production takes place, organic debris forms, settles and combines with the inorganic components of the bottom sediments. Coupled with this are the man-made materials which find thereway to the bottom sediments in lakes. Such materials may be pesticides, metals, trace elements and other constituents which are troublesome pollutants and cause ecological problems in lake systems.

3.4 Chemical considerations

Lakes contains a wide variety of physical and chemical substances. These range from floating debris, suspended materials, dissolved inorganic matter, nutrients, metals, organics and dissolved oxygen. Of these, dissolved matter, suspended solids, nutrients and dissolved oxygen are among the most important constituents in assessing the productivity of lakes. Dissolved matter or total dissolved solids is a measure of the total inorganic substances dissolved in water. These substances include the major chemical ions such as calcium, magnesium, sodium, potassium, carbonates, sulphates and chlorides as well as the dissolved metals. Suspended solids in lake water are, for the most part, finely suspended particles of insoluble material including sand, silt, clay, debris from vegetational growth, algae, chlorophyll and other substances. These materials originate from shore erosion through wind and wave action, turbidity inputs, biological activities and from pollution sources. Nutrients play a very significant role in the life of lakes. The degree of eutrophication in lakes is dependent largely on nutrient concentration in the lake waters. Considerable efforts has been made by water resource managers to control nutrient levels in lakes to reduce vegetational growth and thereby enhance the use of lakes. Nutrient in this context are usually considered to include phosphorous, nitrogen, carbon and silica in their various chemical forms. Dissolved oxygen is an important factor in the health of lakes. It is essential to the production and support of biological life in lake waters and necessary to the decomposition and decay of organic wastes and deceased organisms. Oxygen is consumed by the respiration of plants and animals, by bacterial decomposition of organic matter and by the chemical oxidation of waste substances. It plays an important role in the organic cycle of lakes.

3.5 Biological considerations

Biological substances in lakes consists of many different life groups of organisms including bacteria, fungi, phytoplankton, zooplankton, benthic fauna, aquatic plant life and fish. Of these, the phytoplankton and zooplankton, benthic fauna and fish are the most commonly studied. However, all of these organisms are essential parts of the biological community in lakes and each is critical to the overall balance and stability of lake environments.

3.6 Planning lake studies

Before designing a sampling network for lake studies, it is essential to identify the objectives of the study and to determine what information is required and for what purpose it is to be used. Vital information on the physical, chemical and/or biological characteristics of a lake may be required by a wide variety of users including municipal and industrial water supply agencies, water resource managers and research organisations. Water resource managers may wish to know material balance and pollution pathways in a lake, as well as input and output of nutrient loadings while researchers may wish to study production rates of lakes, exchange characteristics, behaviour of thermal bars, circulation patterns and other properties of lakes. Once the objectives of studies are known, criteria or guidelines may then be developed and followed in planning and sampling programmes for lakes.

Input-output sampling: In carrying out natural balance studies on lakes, it is important to sample all significant tributaries and outlets streams, precipitation, pollution point sources, sediments, etc. Knowing the lake volume and residence time, it is then possible to develop a simple lake input/output model and calculate the percentage of various constituents which originate from various sources in the lake system and to quantify those constituents which become lost in the lake cycle.

Spatial sampling: The design of a sampling network for a large body of water depends heavily on the capability of the organization. A grid type spacing of samples may be the best method of obtaining initial basic data.

Sampling in depth: Depth sampling must be related to the vertical thermal profile at any one surface station. Five depths are probably minimum, spaced as follows: (a) surface, (b) immediately above thermocline, (c) immediately below thermocline, (d) mid-hypolimnion and one meter or less above sediment water interface.

4.0 GROUND WATER QUALITY

4.1 Natural factors influencing ground water quality

Rocks and soils are the two main components which influence the ground water quality. The interaction of rocks and water is a complex process due to great variety of rocks and environmental conditions. Soil and rock basically can be distinguished from one another in that soil contain organic and inorganic constituents. Inorganic constituents in soil range from 90 to 95% while rock is almost completely inorganic. Soil is the result of total interaction of water, air, climate, plant and animal organisms upon the rock.

4.2 Man made factor

Ground water, though protected by the soil cover, are subject to quality changes as a result of activities of man on the overlying cover. The most important pollution sources include:

- Domestic waste water infiltrated into the aquifer through cesspools or septic tanks
- Municipal sewage (due to leaks in sewerage system) or percolation from waste ponds, etc.
- Leachates from garbage dumps and sanitary landfills
- Industrial wastes from mining, refineries and oil industries, metal processing, and other industries
- Cooling water infiltration through cooling water recharge wells
- Accidental discharges through petroleum products
- Irrigation-return flows
- Artificial recharge with treated sewage

4.3 Self purification of ground water

The self purification of ground water occurs due to a variety of physical, chemical and biological processes outlined below:

Physical process include dispersion and filtration. Dispersion causes dilution of wastes and filtration favours reduction in amounts of substances associated with colloidal or larger-sized particles. Geochemical processes include complexation, acid-base titrations, oxidation-reduction, precipitation-solution, adsorption-desorption. Biological processes include decay and respiration, cell synthesis etc.

4.4 Objectives of ground water quality monitoring

Quality aspects of ground water resources: Ground water has long been regarded as the best resource for any type of use. Although it is generally well protected from contaminating influences, excessive abstraction of ground water gas caused a number of serious pollution episodes and gradual degeneration of the quality of large ground water bodies. The need to conserve vitally important aquifers as raw water sources calls for deliberate management of ground waters with respect to their quantity and quality.

Major ground water uses: Ground water are used for different purposes, the major ones being community water supply, agriculture, and industrial processes. Each type of use requires certain water quality criteria which determine whether the ground water in question is suitable for the purpose.

The need for ground water quality monitoring: The vital importance of ground water resources in the use and re-use of available water supplies requires not only quantitative management of aquifer waters but also careful surveillance of their quality. To this end, ground water quality monitoring services are becoming an indispensable requisite.

4.5 Methods of ground water quality monitoring

Identification of pollution sources: Prior to the drilling of test holes, a careful survey of available information relevant to the pollution problem under investigation must be conducted.

Geohydrological investigations: The assessment of any ground water problem requires sound knowledge of the geological and hydrological conditions of the aquifer subject to pollution.

Ground water observation and sampling: The basic network of ground water observation points consists usually of production wells and water table observation pipes already in operation. In most cases, however, thee might be a need for additional monitoring points for ground water levels and selected quality parameters.

4.6 Ground water analysis

Sampling and analysis of ground water can be executed in two ways. (1) direct measurement of ground water quality in the test hole. For this purpose a probe is lowered or permanently installed in the observation well. Pollution indicators such as electrical conductivity and temperature can be easily measured this way. (2) Water samples are pumped from the observation well. If accurate measurement of pH, redox potential, and electrical conductivity are desired. it will be necessary to analyse these parameters at the site. For other parameters samples can be preserved by adding an appropriate preservatives and analysis can be carried out in the laboratory. The selection of analytical parameters has to be made according to the objectives of the monitoring programme.

4.7 Reporting of results

Investigations on ground water might be conducted either on a time limited basis by means of a survey or on a continuous basis through a monitoring system, with fixed observation sites being measured at regular intervals. In the first case a single report will be issued after the survey has terminated and the results have been evaluated. In the second case periodic reports (e.g., annual reports) are the usual way of data presentation.

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